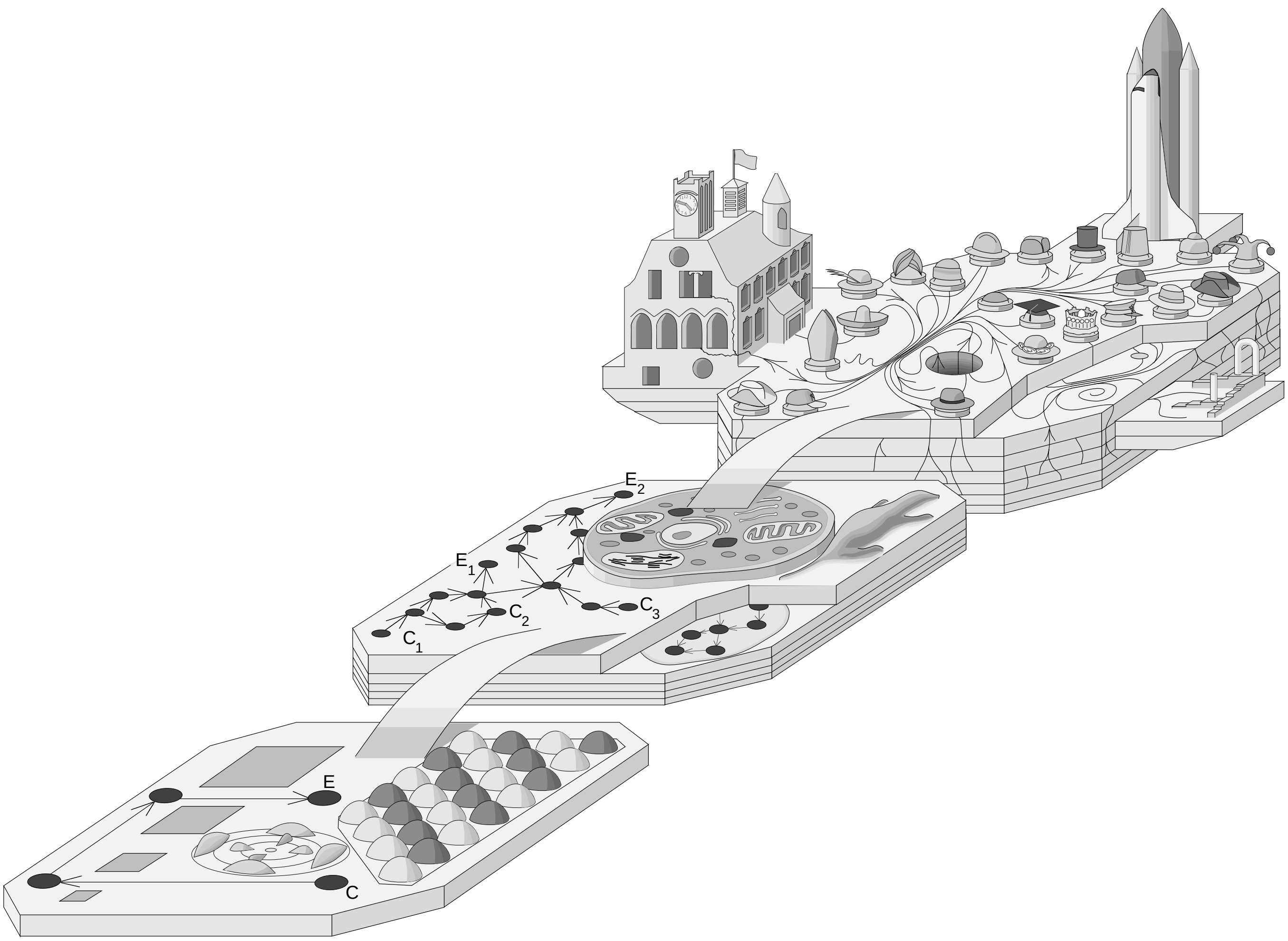
TRANSILIENCE

BRIDGING THE DIVERSITY OF KNOWLEDGE



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Transilience: How to Understand Everything
(Even Human Beings)

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How to Understand Everything (Even Human Beings): A Transilient Theory

Chapter 1: Introduction

"The greatest enterprise of the mind has always been and always will be
the attempted linkage of the sciences and humanities."[1]

E. O. Wilson

In the alpha quadrant of a spiral galaxy, nested in the alpha quadrant of the alpha universe, there once was a small-sized planet, well-constituted for the evolution of carbon-based life. In fact, the planet was so favorably constituted that after about 4 1/2 billion years, a bi-pedal, talking species with a moderately enlarged brain evolved. Across a hundred thousand years or so, that species became increasingly profligate with using symbols. Not only did its members assign dozens of over-lapping names to everything they encountered, but they invented multiple mathematical symbol systems, fluctuating vocabularies of visual icons, as well as print, telegraphic, audio and video systems of symbolic communication. Eventually, they created digital techniques to reduce, transmit, and reproduce all of the above, so that symbolic flows encircled the globe in an endless electronic web, inspiring endlessly new ensembles of behaviors.

Each of these flows of symbols made some members of the species very happy, or very wealthy, or both, for at least a portion of the time, and the flow of these symbols empowered that species to transform much of the planet. Some members of this "human" species, however, have found the flow of symbols overwhelming, and some have wanted to control the flow, perhaps even to understand it. They dream of a magic and all-powerful symbol to capture the flow and redirect it, to enable the control of all being. They dream of a theory of everything.

As a member of this species of symbolizing animal, you are probably well aware that for most of the species' history, competing religions have laid claim to such ultimate explanations. A few thousand years after the invention of the means to write down the species's symbolizations, however, scientists have made an alternate bid. Physics, rather than religion, these experts have claimed, offers the real "theory of everything" (to quote the title of a recent book by Stephen Hawking). They are near, promises Steven Weinberg, to a "final theory" that will be able to explain and compute everything in a single set of equations, unraveling the secrets of the universe and enabling fabulous control of it all.

The physicists' bid has some substantial plausibility, because physics has enabled human engineers to do so very much. Permitting everything from trips to the moon, to microwave-baked potatoes, to the placing of garage-band music on compact discs, the equations of physics have facilitated the radical re-constitution of the environments in which the human species conducts its existence. None-the-less, there are major problems with the physicists' bid for totality. There is enormous resistance to the idea that the control of "everything" permitted by physics might include human behavior. Most notably, the symbols of the physicist's equations and their pantheon of particles are so far removed from the social and symbolic activities of most of the members of the species that no one has ever been able to use, for example, the theory of quarks to explain a single human activity.

Into that crucial breach between quantum mechanics and human behavior have leaped a group of biologists who claim not only that their science can explain human beings, but also that their science is merely physics applied across the biological spectrum. This group of "socio-biologists" or "evolutionary psychologists" has been well-led by the brilliant biologist E.O. Wilson. Wilson has dubbed his version of the final theory "consilience." Wilson argues that the existing social sciences and humanities cannot provided real understanding of human beings, and that real progress in self-understanding lies just around the corner, as biologists begin to apply the physics-derived tools of science to serious study of human behavior. Wilson thus offers a form of explanation in which human behavior is determined by biology, and ultimately sufficiently accounted for by the laws of physics.

There is much to be said for this broadened, science-based bid for explanation, both as science and as public narrative. None-the-less, there remain major problems that this clever piece of patchwork does not resolve. We have written this book not only to show what those problems are (a task ably engaged in by many others),[2] but also to provide an alternative, and more powerful, theory. Indeed, we are not so naive as to try to take away the dream of wealth and happiness that might be provided by the magical tool constituted by the crucial type of symbols we call theories. We, too, are eager to promise that you really can understand everything! Instead of a single, unified theory of everything, however, we propose an open-ended but inter-connected network of theories, with clusters of explanatory nodes that correspond to what we believe are the three major modes of being—the physical, the biological, and the symbolic.[3] We propose that these nodes of explanation are indeed connected by the fact that all of being as we can know it is material. We argue, however, that the common substrate of matter is arranged differently and circulates differently to produce different modes of being and that these different arrangements of matter compel different tools for understanding and different theoretical systems. Instead of calling for a consilient theory that unifies all knowledge, we here present a transilient theory that shows both the continuities and the discontinuities in being and explains the character of our knowledge about it.[4]

Such an approach is made necessary if one wishes to understand the character of humans. Human beings are neither "just another animal" nor merely disembodied minds who wield "ideas" carried on or produced through symbolic systems such as language, mathematics, and systems of visual representation. While there are powerful theories that explain the animal inputs to our being, and equally powerful explanations of our symbolic activities, the way in which these two sets of theories have been formulated makes it impossible to understand the ways in which these two forces interact. Until we understand the interactions between these apparently different types of forces, we cannot understand the novel amalgam that is human behavior. But there are substantial barriers to bringing together these two sets of understandings. These include both a fundamental proclivity toward misunderstanding the nature of the symbol systems that make human beings so unique *and* a vision of the construction of knowledge that is well-entrenched and woefully insufficient. This book therefore addresses both of these barriers, offering a material theory of symbols and a symbolic theory of knowledge.

The novel power of this approach for re-envisioning human nature arises from combining two moves that are separately well-established but rarely thoroughly linked--taking symbols seriously *and* treating them as a material phenomenon, rather than as simply abstract ideals or conveyer belts for "ideas." The failure to take symbols seriously pervades the natural scientific study of humans. For example, although he is a rigorous materialist, E.O. Wilson dismissed human communication as "babble"[5]. Wilson confuses simple single signs (the word "red"), with the complex interactions that comprise a symbol system. It is the relationships among the signs in a symbol system—its structure and dynamics--that give it powerful and unique capacities, and it is therefore only by understanding the structure and processes of the system that one can understand both symbols and human beings. In contrast, most humanists take symbols quite seriously, but they do not treat them rigorously as material entities, but rather solely as ideas, structures, or forms. Because symbol use is what is most central to the distinctiveness of human being, it is only if one takes symbols seriously *as a form of material being* that one can bridge the gap between the natural sciences and the humanities.

Such an endeavor does not require radical change in how scientists study humans as animals, nor does it require radical change in how humanists study the symbolic activities of humans. It does require the invention of a set of bridging studies that interconnect and make mutually intelligible the results of each domain of study. That bridge does not yet exist, though there is a burgeoning crowd of workers bent to its construction.[6] To date, most of the bridging work has been done from the perspective of, and with the knowledge and vocabularies of, biological studies. In contrast, this book approaches the enterprise with an equal, and therefore greater attention to the perspectives, knowledge base, and vocabularies of the humanities and social sciences. The book thus provides a basic blueprint for a bridge across the different inputs to human behavior by rewriting our understanding of how material being might be understood, and in the later chapters it also cobbles together some preliminary planks to make a few initial crossings and to illustrate the traffic possible across such bridges in the future.

The Three Modes of Being

To introduce this theoretical conceptualization in a broadly accessible fashion, we will suggest that there are three basic clusters of modes of being—physical, biological, and symbolic (with artificial intelligence looming on the horizon as a potential fourth type). We will then show how what humans know about each kind of matter is a product not merely of the choice of methods and assumptions one uses in studying them, nor merely of the characteristics of the mode of being. Instead, our knowledge is a product of *the fit* between methodology and the characteristics of a particular mode of being.

The physical mode of being is constituted of all the energy/matter in spacetime. It features just four fundamental forces, which manifest themselves in a relatively few types of things, for which we will borrow the philosopher's label "natural kinds." The distinguishing quality of physical being is that it is *deterministic*: one factor influences another factor in exactly the same way always and forever and in every instance, as long as external variables are held constant. The interaction of billiard balls and the workings of clocks provide the mechanistic images of how physical being works. A mathematically based mode of investigation relying heavily on definitive experiments is well suited to such a constant and sparsely populated mode of being, although things change radically when aggregates of such being are studied, rather than tiny isolates.

Biological being is an aggregation of physical matter, the peculiar arrangement of which physically attracts other matter in a fashion that maintains and reproduces the arrangement of the original matter. A key feature of living things, as opposed to inanimate matter, is that they have quasi-stable forms or structures that they reproduce through different physical particles. The resultant "dynamism" appears as a kind of phantom or "ghost" in our current sensibilities (for a variety of reasons to be explored), but it is not a ghost or a mysterious force. It is simply an emergent effect of a particular kind of structure—one in which a network of feedback circuits function to maintain and reproduce a form in particular materials. Hence biological being, though its only substance is physical matter/energy, is something more than inanimate matter, solely because these collections of matter come in specific kinds of arrangements. In order to understand biology, one has to understand these specific arrangements (and their history). Because the laws of physics do not include these laws of arrangement and their consequences, biological being can't be fully explained through the laws generated by physics.[7] Instead, models and motifs, uncovered but not defined through mathematical tools, as well as rigorous observations paired with experiments form the most fitting and most productive mode of biological researches.

Biological being thus introduces a new kind of complexity into the universe and into the process of knowledge construction. People often intuitively describe biological being as more complex than physical being. This doesn't quite get the distinction right. Anyone who has struggled to understand physics immediately recognizes that calling physics a "simple" undertaking is just not a good description. Physical entities can vary dramatically with regard to their number of inputs. Some physical phenomena are enormously complex. Indeed, a quantitative characterization of most atoms remains, even with today's fantastic computers, too computationally complex to be calculated. Within physics, however, variations in complexity are variations in number of inputs. Biological systems are different because a single biological being will incorporate many different *types* of inputs, *and* these are coordinated in time-dependent arrangements. Not only do the many inputs that produce a biological being operate on different principles from each other at the level of their functionality, these differently structured inputs produce a particular functional (rheostatically maintained) outcome. We label this kind of complexity "transplexity" (see Table 1-1 and Figure 1-1), and it is not a kind of complexity that is directly reproducible from simple operators.[8] Transplexity can be defined as the characteristic of a system with multiple components of multiple types that interact via rheostatic feedbacks to produce characteristics beyond those of the individual components or their sum, with the potential to maintain functionality and to self-perpetuate. Intriguingly, as far as we know, such forms tend to produce novel forms through time. As a consequence of its pervasive transplexity, biological being has the distinctive characteristic of being both *systemic* and *opportunistic*. This is to say that biological systems are not adequately described as "mechanistic", even though they might be said to be materialistic, physical, or even deterministic. Causes and effects are not arrayed like clockwork in a simple series of interactions—a causing b, causing c, causing d.[9] Instead, the behavior of an organism is determined by sets of dynamic equilibria, by simultaneous interactions in different parts of the organism, and by the

Table 1-1: Complexity and Transplexity

	Complexity	Transplexity[1]
Inputs or components:	Similar inputs or components	Diverse inputs or components
Feedbacks:	No or unconstrained feedbacks	Rheostatic feedbacks
Observable results:	Pattern or organization	Organization *and* functionality
Long-term behavior:	Deterioration, homogenization, or randomization	Potentially self-perpetuating
Natural examples:	Aligned atoms (atoms are only components)	Life of organisms (multiple interacting subsystems – reactions, organelles. cells, organs, etc. – are components)
Technological examples:	Watches and clocks (mechanical components only)	"Manned" air- and space-craft (human, mechanical, and computer components)
Human examples:	Military squads (similar humans are components)	Civilizations (diverse humans, traditions, and technologies are components)

[1] *Transplexity:* the condition of a system with multiple components of multiple types that interact via rheostatic feedbacks to produce characteristics beyond those of the individual components or their sum, with the potential to maintain functionality and to self-perpetuate.

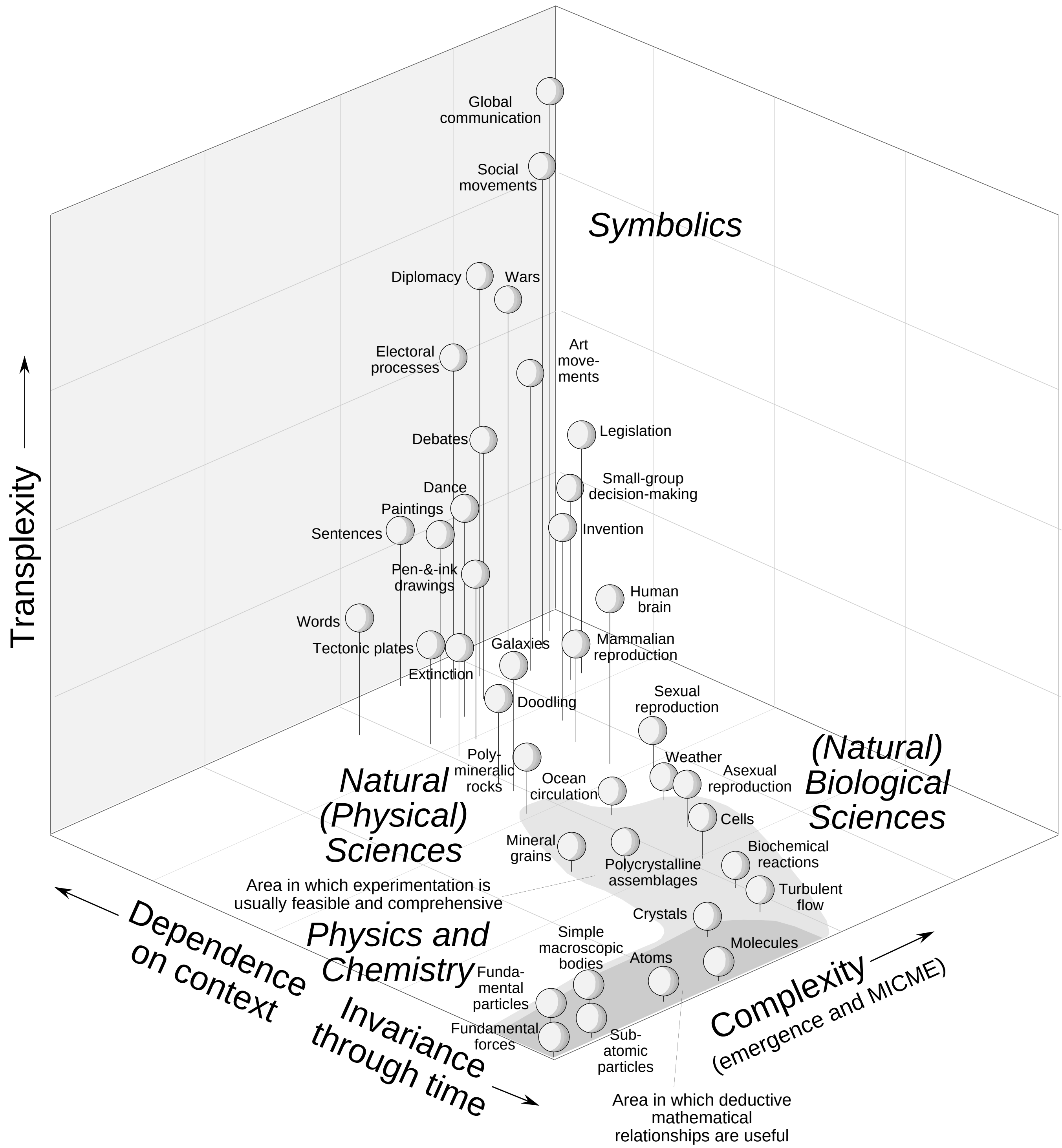

Figure 1-1: A three-dimensional plot showing the contextuality, complexity, and transplexity of phenomena studied by physics and chemistry, by the natural sciences and biological sciences, and by human studies, which hinges on interactions using symbols. See text for definitions of terms. Placement of entities is subjective but constrained by relative position: for example, atoms are more complex than the subatomic particles of which they consist, molecules and crystals are more complex than the atoms of which they consist; mineral grains with geologic histories have more contextuality than synthesized crystals, polymineralic rocks have both greater complexity and greater contextuality than the mineral grains of which they consist, and tectonic plates that have moved across Earth's surface have both greater complexity and greater contextuality than the rocks of which they consist. "MICME" refers to "multiple cause - multiple effect" systems.

organism's history. Further unlike clockwork, the same interactions among organisms do not occur in exactly the same way always and forever and in every instance. Every organism is different from its predecessors in at least some small way and so any organism may behave differently in a substantially similar environment.

Living organisms thus appear as *opportunistic* rather than mechanistic. They not only react to environments, but act to change their environments in accord with their own functional needs. We do not expect clocks or billiard balls to behave in such a fashion. While one can explain parts of an organism on a billiard ball model, one must eventually revert to the organismal level, and beyond, to fully understand the organism. Although the behavior of biological systems is determined by their physical components, a research logic that describes only the way one single factor influences another factor is thus doomed to be constantly perplexed. As we will show, this is not just a practical limit, but a theoretically based one dictated by the characteristics of organisms.[10]

The third mode of being is the symbolic: the world of words and numbers, language and icons, theories and theologies, fashions and fantasies. Just as biology emerges from physical being, utilizing nothing but physical matter, but producing different characteristics because of the unique arrangement of that matter, so too symbolic being arises from biological being, using nothing but physical and biological matter, but producing distinctive characteristics because of its unique, dynamic arrangements.

Thinking about language as a material entity is difficult. Humans have been misunderstanding the character of language for thousands of years.[11] The ancient Greeks described language as a form of magic.[12] After all, what is one to think when invisible words flow from the mouth of a speaker over a crowd and redirect their behavior to building walls or committing genocide? But language is not unlike other material entities in this regard. Compare language usage, for example, to a wave. A non-physicist might naively argue that waves don't exist – that they are not material. For example, a wave passing across the surface of a body of water diminishes into flatness, just as a word disappears into silence. A wave passing across a body of water can't be picked up or isolated from that through which it passes, just as a word can't be meaningfully isolated from the context through which it travels. We nonetheless concede that waves exist, because we can see or hear them, we can measure their characteristics, and we can observe their effects on other matter. Words likewise can be seen and/or heard, we can characterize them by type, and we can see their effects: we can see workers respond to instructions, we can see voters and shoppers influenced by messages, we can see readers excited by squiggles of ink on a page.

Furthermore, symbol use is characterized by transformations like that known from the behavior of waves. Just as waves can be reflected, refracted, diffracted, and dispersed, and thus transformed, the progress of symbols can be manipulated in many ways and can exert different effects in different contexts. A wave may undergo refraction that changes its direction and wavelength, but it survives as a wave with effectivity to rock a floating ship. A symbol likewise survives the transformation imparted by a new communicator and retains effectivity to motivate and inform, albeit in subtly shifting directions. As with waves, the seemingly ephemeral nature of symbols does not disprove their materiality or deny their effectivity. The parallel simply drives home the need to take seriously "arrangement" as an essential and determinative dimension of materiality.

This is not to say that waves and symbols achieve the same kind of effects or achieve those effects in the same way. Waves and symbols belong to different modes of material being and thus have different characteristics. Understanding their effects thus requires a different mélange of techniques from what may be a common repertoire. The example illustrates, however, that what distinguishes a mountain from a wave, and each of these in turn from a sentence, is not a difference in their materiality: one is not "material" and the other merely an in-substantial "ideal," rather, all three forms share a material base, but they differ in their arrangements. It is thus useful to understand "everything" as composed of matter, but to acknowledge that there are fundamentally different modes of arrangement of matter that give rise to fundamentally different properties of different kinds of material entities.

As we will show, human symbolic systems are arranged in highly mobile, convergent flows. The power of these flows derives not from a simple aggregation of signs, each of which carries its own fixed meaning, independent of other signs. Instead, the incredible power and capacities of symbolic processes derive from the way in which every sign carries a flexible range of "meanings" or influences, the specifics of which are determined by the other signs with which it is traveling as well as by "contextual" factors that chain out through time and space. The pre-material way of saying this would have been to say that the meanings of words derive from interaction with the other words in the sentences and paragraph of which they are a part, and from the specifics of the contexts in which they are embedded.

These flows of symbols are channeled through human bodies and brains, but also through airwaves and parchments and videotape and computer circuits. They can be shaped into amplificatory or rheostatic circuits by markets, institutions, and governments. Where we described physics as deterministic and biology as systemic and opportunistic, we describe symbolic being as having "*fantastic*" qualities, which include an arbitrary or historically based physical materialism, the consequent ability to bind time and space, and the ability to create moral codes .Because of these qualities, symbolic being is not only transplex, but its transplexity is more pliant and mobile than that of biological being. By further exploring the common basis, but divergent characteristics, of symbols and organisms and billiard balls, we may take a key step toward understanding ourselves.

Why "Transilience"?

To echo Wilson's goal of consilience, but to transcend it, the label transilience seems an appropriate one for this meta-theoretical enterprise. Transilience is an old word, not much used today. Webster's defined it in 1913 as "A leap across or from one thing to another."[13] More recently, in genetics, Alan Templeton has appropriated the word to designate a mode of speciation featuring intermediate stages that are unstable. Notably, for present purposes, such modes require mechanisms in addition to natural selection.[14] To apply the word as a technical term requires emphasizing that the "things" one leaps—like leaps over brooks and fissures—may be isolated at one level, but they are connected at others. A fissure is a gap, but under the gap the two sides of the canyon are connected by the earth, as are the two sides of a brook. Thus, species that have arisen from transilience, in Templeton's sense, are both reproductively isolated from other species and also connected to them historically and by many continuing similarities. In the same way, the three fundamental modes of being—physical, biological, and symbolic--are connected with each other through their sharing of a common physical basis, but they are also separated from one another through their additional distinctive properties. One might deal with the modes of being by attending only to their shared basis, or one might deal with the modes of being by attending only to their differences. Transilience can provide a term for bridging differences, while remaining cognizant of both differences and similarities. A transilient research agenda would use the method of synthesis, recognizing component parts but keeping a focused eye on how these parts come together. This book seeks to outline a research agenda for transilience, providing foundations for bridges that will allow human self-understanding to leap across the chasms between human biology and human symbol use.

Outline of the Argument

Because this is a very large argument, we anticipate that not every reader will want to explore in detail each of the components of the theoretical edifice. We therefore here supply an outline of the argument, which both shows how the pieces fit together, and may provide a guide to focus one's reading.

To develop this theoretical perspective, Chapter 2 describes the idealized model of physics from which much misunderstanding of the nature of science arises. The chapter does not provide a description of physics as an academic discipline, or even of all of the achievements that people might identify as physics. It is neither précis nor textbook. Rather, it addresses the idealization of physics that serves as the model that most people are using when they think they are admiring or emulating the "model provided by physics." This model excludes most of the work of astronomy and most instances in which aggregates of physical being, such as rocks, oceans, and clouds, are studied. Instead, it is a model that arises from the decomposition of physical aggregates into component parts. Except in the instances of the simplest atom (Hydrogen), the idealized model of physics has not arisen from studies of the synthesis of physical components into complex aggregates, and physical matter almost never manifests itself in this form outside of the laboratory. This process of idealization is what we think Richard Feynman was referring to when he said, "Physicists always have a habit of taking the simplest example of any phenomenon and calling it `physics,' leaving the more complicated examples to become the concern of other fields."[15] Physicists, of course, understand the difference between this idealization and what actually goes on in the broader discipline of "physics," though they may not always keep clear the idealization from the practice.

Critical to the idealized study of physical being is use of the hypothetico-deductive experimental method to produce universal laws in the form of an inter-locking set of mathematical equations (see Table 1-2). We then show how the fabulous productivity of physics has resulted from the well-tailored match between these methods and the distinctive features of physical being.

The most distinctive feature of physical being is the lack of variation through time and space, a feature which is absolutely necessary to produce laws that are universal. Physical being also appears to come in a relatively few types (or "natural kinds'"), which are ordered in a constrained pyramidal structure. This universality of a few kinds of

Table 1-2: A Summary of the Key Features of the Major Modes of Being

Mode of Being and Catch-phrase	Academic Field of Study	Characteristics of Being	Mode of Causality	Major Methods of Study	Extent of Prediction and Control
Essentialized Physical Being: Mechanistic Ch. 2	-Physics -Chemistry Ch. 2	-Time/space invariant -Constrained pyramid of types -Variation by degree -Low overlap in range of forces Ch. 2	-One Cause, One Effect (OCOE) Ch. 2	-Laws (L) -Mathematical equations (ME) Ch. 2	Strong prediction. strong control Ch. 2
Aggregate Physical Being: Historic Ch. 3	Natural Sciences: -Geology -Oceanography -Ecology -Astronomy -Atmospheric science Ch. 3	-Time/space specific -Diffuse types -Variation by degree, type, and context -High overlap in range of forces Ch. 3	-Multiple Causes, Multiple Effects (MICME) Ch. 3	-ME -Context-specific equations/laws -Inductively based mathematical models -Rigorous observation -Interpretation Ch. 3	Variable prediction; little control Ch. 3
Biological Being: Opportunistic Ch. 4	Biological Sciences: -Biochemistry -Genetics -Microbiology -Botany -Zoology Ch. 4 and 5	-Time/space specific -Enormous range of populations in "shrub-like" relations -Forces arranged in rheostatic circuits Ch. 4	-Rheostatic MICME (functionality) Ch. 4	-ME -Rigorous observation -Model organisms -Motif-like generalizations -Causal Chronicles Ch. 5	Variable prediction; some control Ch. 5
Symbolic Being: Fantastic Ch. 6 and 7	-Humanities Ch. 8 -Social Sciences Ch. 9	-Categorization -Converging flows -Historical materialism -Binarism -Valuation -Narrative Ch. 6 -Time-space binding -Novelty of kinds -Morality Ch. 7	-Effectivity Ch. 7	-Path modeling -Correlation -Memory -Innovation -Interpretation -Evaluation -Descriptive explanation Ch. 8 and 9	Prediction usually accounts for little of the variance; restricted control Ch. 9

things allows manageably small sets of laws about different phenomena to interlock productively. Thus, a light bulb, a magnet, and the aurora borealis can all be explained by an overlapping set of theories and equations.

The different kinds of physical things vary more by degree than by type, which means that the interlocking laws can take the form of mathematical equations, in which parameters vary continuously ($E=mc^2$!!!). Additionally, the physicists's research enterprise has been facilitated by the handy fact that the four basic physical forces do not overlap excessively in their scale, making it feasible to sort out their impact in a relatively straight-forward manner. Because physical being has these properties,[16] physicists think of it as operating on a "deterministic" causal framework, where a single cause reliably produces a single identifiable effect. This form of causality gives a tremendous amount of highly leveragable control, of the sort that scholars, administrators, and entrepeneurs desire to emulate in other areas.

Chapter 3 shows that this idealized model of physics is exceeded when natural scientists turn their attention to studying aggregates of physical being such as geological landscapes, meteorological systems, or ocean circulation. Because aggregate physical being features time-space specificity, the knowledge accumulated in disciplines such as geology, oceanography, and meteorology consists both of some universals and of many specific descriptive and historical accounts of more particular phenomena. As physical being aggregates, it forms more types, which are also more diffuse rather than coherent and self-identical. The properties exhibited by these types also may vary by context. In addition, the causal influences that shape aggregates exhibit many overlaps in their scale of interaction, and this makes it difficult to identify and apportion influences. Hence, the difficulty in determining what exactly will occur as global warming accelerates. Furthermore, because of issues of scale and time, not all of these phenomena and influences are amenable to direct and comprehensive experimental manipulation. (You just can't run a series of global warming experiments!). Consequently, observation and *post hoc* modeling play a much larger role than experimentation in assembling knowledge of aggregates, and synthesis is as important as reduction. The signature feature of causality among aggregates is therefore best captured by a multiple-causes/multiple-effects model.

In spite of the fact that aggregate being is nothing but physical being, the level of prediction and control in the natural sciences routinely falls short of that modeled by idealized physics. Because of the complexity and sometimes size of natural aggregates, we may not be able to accurately predict their behavior. Volcanoes, earthquakes, and hurricanes all escape our predictive grasp. Further, because some natural systems manifest time-space specificity, many generalizations are also not universally applicable. Finally, because of the scale of many natural aggregates, even if we were able to more accurately predict their behavior, we would have difficulties with controlling them. Archimedes' lever just costs too much to be of use. In all of these regards, the study of symbol use will prove to have more in common with aggregate natural sciences than the idealized model of physics.

Chapter 3 thus provides an important lesson about the inherent limitations of the scope of the idealized model of physics. The specific properties of the objects one would study provide important constraints on the methods one can use to study them (see Figure 1-2). Because aggregate being is more than isolated physical components, natural

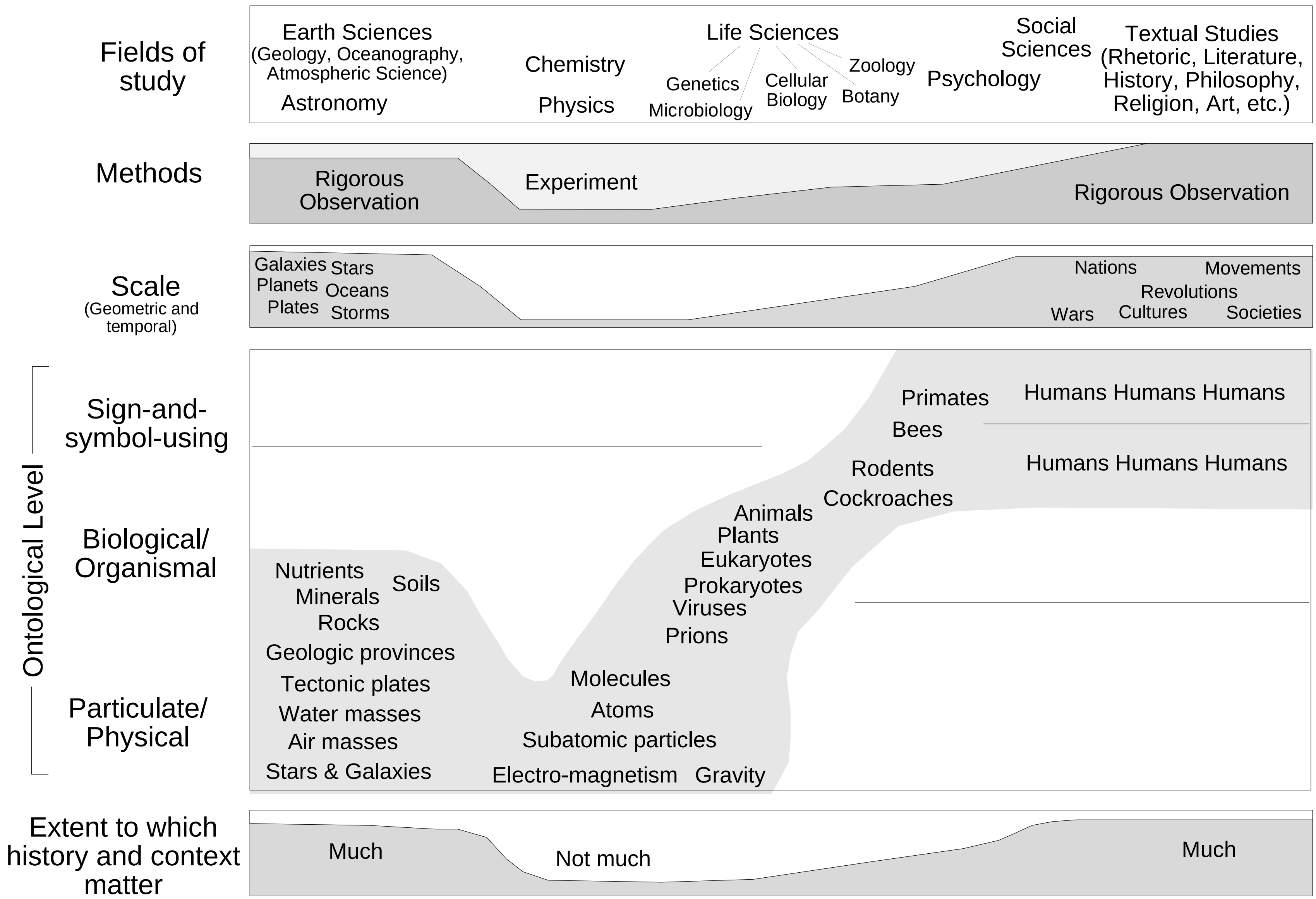

Figure 1-2: A graphic comparison of the nature and methods of physics and chemistry, the natural sciences, and human studies.

scientists must incorporate the idealized methods of physics into a much larger methodological toolkit and also into a broader sense of what must count as knowledge. Similarly, we will suggest that it is not simply the biologist's or social scientist's failure to copy physicists well enough that has limited the success of attempts to apply the model of physics generally. It is instead the specific properties of biological and symbolic being that shape what it can mean to "know" about them.

The distinctive features of biological being are described in Chapter 4. Over-simply stated, we argue that biological being is an emergent form of matter that is distinguished by an arrangement of inter-acting parts that function to maintain that arrangement through time and to reproduce that arrangement in the same types of materials. Because reproduction of these forms is necessarily faulty, biological being features an enormous number of types that are constantly changing, and the members of these types are never identical. The forces shaping these diverse organisms operate through a network of rheostatic circuits, rather than through convergence or linear cause-effect. That is, the circuits—such as those which stabilize the oxygen level in human blood--maintain a range of values that are responsive to a function that has been historically generated. Consequently, biological beings must inherently be understood as part of lineages, and this means that they are time and space specific. It is not true that if you know one animal, you know them all.

Biological being also manifests a different causative logic than those ascribed in idealized physics and the natural sciences. Because the characteristics of an organism are a product of both the physical interactions existing at a specific time and place and also of an evolutionary process, biological being is most fully understood as the product of dual sets of causal forces. This is a "multiple cause, multiple effect" system, as in the aggregated physical sciences, but there are two different planes of multiple causes. One is the historical lineage that caused the organism to have the self-maintaining circuits that it exhibits; the other is the interaction among the parts of the organism and the environment at any particular range of times. Both of these must be accounted for to "explain" an organism. In contrast, the physicist assumes, a quark is a quark is a quark.[17]

Chapter 5 fleshes out the ways in which these unique properties of biological being require distinctive methods of study. Like geologists, biologists rely heavily on rigorous observation and must synthesize reductionist observations with higher-order analyses of the interactions and functions of larger aggregates. Similarly, while biologists use mathematics as a tool of discovery and sometimes description, there are relatively few equations in biology, not because biology is immature (as Wilson suggested), but because biological being varies as much by kind as by degree. With thousands of species of bacteria and viruses at hand, one prescription medicine just won't fit all. Furthermore, because of the variability of their objects of study, biological generalizations are "motif-like" rather than law-like. That is, generalizations identify levels of commonality and overlapping shared properties rather than uniform and universal laws. The extent and character of these commonalities are explored through an array of "model organisms" which stand in contrast to the physicist's very justifiable assumption that every carbon atom is just like every other one. Finally, a distinctive feature of biological methods arises because of its dual causality and because evolutionary theory constitutes biology's "unified theory." The structure of this theory means that a narratively based form of reasoning, the causal chronicle, is an important component of biological method, whereas narrative has no recognized significance in physics.[18]

The character of prediction and control in biological studies also arises from the unique features of biological being. In classical physics, the behavior of individual objects is relatively predictable, but in biology, individual variability means that it is only in some instances that individual behaviors are usefully predicted by population averages. Biological beings also resist the simple models of control we continually seek to borrow from physics. In part this is simply because biological entities change through time. If biology took into account only life that had evolved before 100 million years ago, it would be different from the way in which it is studied today. This is to point out that Archimedes just wouldn't be able to use all the same biological levers across the eons. More importantly, biological beings resist control because they have their own complex, inter-connected, programmed functions. For example, antibiotic resistance, pesticide resistance, and side-effects from medicines are not exceptional, and they cannot be eliminated by better physical methods. They are paradigmatic of the responsive characteristics of biological systems in the face of human efforts to use biological materials to our own motivated advantage.

The question of distinctively human motivations is opened through Chapter 6's description of a material theory of symbolizing, which we take to be the most (though not necessarily the only) distinguishing feature of human beings. We provide a material theory that describes symbolization as an evolved capacity continuous with indexical and sign systems such as the sense of smell, or co-operative evolution of pheromones, or alarm calls, all of which exist among other animals. Symbol use, however, involves the interactions among a series of signs, and as such, it exhibits emergent properties that are so dramatic in nature that human beings have historically tended to identify them, errantly, as an opposite to material or physical realities.

We argue that the physically material character of symbols explains how it can be that symbolizing exerts its own distinctive tendencies upon symbol users. These tendencies add on to other biologically evolved cognitive capacities. Thus, for example, people and other beings that lack serial numbering systems cannot do things that people and other beings who have serial numbering systems can do, even if all of the people and beings share a basic capacity for estimating magnitude. Symbol systems are inherently categorical, so that they change a biological predisposition for recognizing relative magnitude into a discrete capacity for precise enumeration. Biological beings that have numeric symbol systems can match up in a very precise way hundreds of widgets, whereas biological beings that do not have that capacity can match only a few (1 to 4) widgets precisely, and they cannot do tensor calculus. Specific symbol systems thus enable particular, symbolically bound behaviors, and such behaviors spin off into wild new permutations (like non-Euclidean geometry!).

We show how this material theory of symbols rewrites the current debate over whether categories are inborn in people or not. Instead of the now-stale two-sided debate that alleges that categories are either "inborn" to brains or "created" by symbols, we provide a "value added" model of language (or perhaps a functionality-added model), which portrays categories as a product of the particular functionality added to brains by symbols combining with other cognitive capacities. Thus one notes that there is a difference between a capacity to notice something and the combined effect of that capacity and a symbolization that reformulates the capacity as a categorization. Both the inborn capacity and the symbolic category contribute unique components to the symbolizer's cognitive behavior. An inborn ability to conceptualize a relative difference in a quality is not equivalent to a category that instantiates the conceptualization in a particular way. We close the chapter by linking these theoretical accounts to recent research on how the brain processes language.

In Chapter 7 we describe the basic characteristics of symbols and symbol use. We show how categorization processes entail abstraction, differentiation, nested hierarchies, and reification, and suggest what this means for human behavioral tendencies. The chapter also shows what it means to say that symbolic being inherently includes valuative components, rather than merely referential components. We further highlight the way in which the human language system tends toward binary or polarized representations and operates through a grammatical structure that promotes narrative thought. We particularly explore the unique "arbitrary" quality of the material nature of symbols.

Symbols have been called "arbitrary" to indicate that they lack a particular physical bond between their sound or script and the things to which they refer. This does not mean, however, that the linkages between sounds and the uses to which those sounds are put are immaterial or non-physical. Instead, these references are historically material—formed through histories of usages. While historical materiality opens up unique possibilities, it ultimately relies on the same physical relationships as other biological processes. These are simply displaced through temporal chains.

These unique fundamental features of symbols give rise to some truly fantastic qualities of symbolizing, which are described in Chapter 8. First, symbolic being is time-space binding. Because the form of materiality is historical, symbols can forge direct relationships between phenomena that are not otherwise directly in physical or temporal contact. This enables human beings to be enormously creative both in the construction of new symbols and in the recomposition of the non-symbolic material world around them.

Second, because of this creativity and the arbitrary nature of the physical linkages involved in symbolizing, human beings do not operate solely within a stable set of pre-given natural kinds. Instead, human beings are constantly inventing novel kinds that come and go—radios, hot tubs, scientific journal articles, voodoo dolls, yurts, playpens, type-writers, clipboards, and on, and (hopefully) on. While human tool-making capacities have other roots as well, these symbolic capacities contribute enormously to our success as tool-makers.

Finally, and most controversially, symbols create morality. The valuative properties of symbolizing are essential to what we understand of moral codes. The character of moral codes is enormously consequential. They are what create the possibility (though not the guarantee) that human behavior can be different from the animalistic propensities that are programmed into our bodies. We can only envision a "better" way of living because of our symbolic capacities, and we simultaneously may also gain the tools to increase the frequency with which we might act in accordance with those better codes. Indeed, the flip side of the creation of this distinctive capacity is that once we are engaged in symbolizing, it is difficult if not impossible to escape either moralizing or our moral codes.

Given these unique emergent properties, it is not surprising that causality is a challenging concept within symbol systems. We describe symbolic causality as "effectivity," to highlight the ways in which any designated effect is a product of imprecisely-specifiable contextual factors as well as an imprecisely specifiable part of a continuous flow of symbols. Chapters 9 and 10 explore the ways in which scholars have studied the complex and challenging phenomenon of human symbolization. Chapter 9 focuses on the humanities, describing five common modes of research—cultural memory, innovation, interpretation, descriptive explanation, and evaluation. It indicates why those basic modes are responsive to the particular characteristics of symbolizing.

Due to the plethora of novel kinds, humanists must spend a substantial amount of time constructing, and selecting for retention, particular histories or cultural memories. This is the conservative branch of humanism. On the other hand, because symbolic novelty is a central resource, other members of the humanities spend their time generating innovations. Not surprisingly, there is always some tension between these groups. The innovations of today may become the conserved memories of tomorrow, but they often they serve as indigestible catalysts or even unproductive annoyances. The process of novelty generation is also always in tension with empirical studies. Empirical studies describe what is and has been. Novelty generation is responsible for exploring what might exceed the material constellations that have existed in the past, and thus challenge the closed causal explanations of "science" in a fundamental way. Nonetheless, the best of innovative studies are not merely about what might be imagined, but also about what might actually be made to come to be, and to that extent innovationist humanities, like innovative engineering studies, are not simply opposed to empiricism but part of an intellectual project with common grounds.

As in the natural sciences such as geology, humanists also use interpretation as a central mode of understanding. The complexities and convergent qualities of symbolic flows often make this the most parsimonious approach, and sometimes the only possible route, to understanding. Many humanists, however, have also engaged in descriptive explanation, akin to the natural sciences. Some of this work builds theories only about particulars, but other research streams build more general theories, as in genre studies and rule-based studies of conversation. Distinctive to the humanities is the method of touchstones, which utilizes intensively studied singular instances as bases for comparison and contrast. One comes to understand the possibilities of inaugural addresses, for example, by studying exemplary inaugurals such as Lincoln's second. Finally, the humanities alone come to grips with the evaluative characteristics of symbolizing, having developed methods for producing knowledge-based judgments.

The rather differently framed approaches to human beings offered by the social sciences are the subject of Chapter 10. E.O. Wilson's faith in the scientific method was adopted by scholars studying human beings well over a hundred years ago, and the social sciences are the increasingly mature result. Wilson and others argue that the social sciences lack unity and are banal and unproductive. We argue that the lack of unity is a product of the multiple inputs to human behavior and cannot be overcome by physical or biological methods, although we suggest that social science might profit from more direct engagement with both symbolization and biological studies such as neuro-imaging. None-the-less, the chapter illustrates the productivity of the social sciences, and argues that banality is both in the eye of the scholar and a strange complaint from those who find dirt, worms, and bugs to be fascinating.

Most importantly, we show that linking the social sciences to evolutionary theory and other biological components is unlikely to overcome the perceived difficulties of the social sciences, because the limitations lie in the characteristics of symbolizing, not in the methods of approach (which are, in this case, precisely the same as what Wilson advocates). We illustrate with a comparison of social scientific research on "cheater detection" to that of evolutionary psychology, which shows the superiority of the former over the latter.

This tenth chapter concludes by examining the inherent limitations on prediction and control in studies of symbolizing. Because there are so many inputs to human behaviors, the variance of any one element is relatively small. This makes models of human behavior complex, and limits predictability for individuals. Even when one can control human behavior, it is very expensive to do so. Most crucially, most thoughtful people are generally uncomfortable with the idea that others might control the behavior of other humans at all. Incorporating biological accounts of human behavior may well improve predictions by adding additional components, but it will not take away the dis-ease with the idea of humans exerting control over other humans.

These first ten chapters, while making independent arguments of their own interest, are necessary background. Chapter 11 synthesizes these previous chapters by elaborating a model of the integration of biology and symbolics. It describes three mechanisms that illustrate the ways in which biology and symbolics interact at the social level to shape human behavior. These are amplification of biological predispositions, the channeling of these predispositions to produce new patterns of behavior, and fictionalization. The chapter's implications are amplified in Appendix 2, which explores the implications of the interaction of symbolics and biology for evolutionary theory, including a suggestion that humans are not currently operating with an evolutionarily stable strategy and an example of the ways in which the evolution of co-operation would be modeled differently, and more successfully, if symbolic capacities were incorporated in the research designs. The offerings of the chapter are preliminary, but they chart some possible directions for a research program in bio-symbolic interaction.

The final chapter offers three radical syntheses, suggesting implications of a bio-symbolic perspective for a theory of knowledge, for reshaping our educational process, and for approaching social problems in new ways. In contrast to the equally unattractive alternatives of ideological relativism and the Popperian straight-jacket, we offer a vision of knowledge as a structured aggregation in which multiple inputs shape what we can count as knowledge. Critical experiments play an important role in falsification and description, but field-based observations are equally essential to our descriptions and even to testing our models, as is the degree of coherence of the relationships among components of a theoretical structure. The argument in that chapter is expanded upon in Appendix 1, which argues that knowledge, including scientific knowledge, should be understood as the best justified of well-justified beliefs.

An additional synthesis will be required with regard to our educational system. In the short term, we need simply to overcome major disciplinary barriers—our "institutionalized incapacities"--to allow the growth of a transilient research program. In the long term, we will need to rethink the divisions of our childhood education, which separates the natural sciences from social sciences, and which views history and writing skills as important to everyone, but natural science as the province of an elite. We will also need to become better at teaching young people to reflect upon the way their own behavior is an interactive product of the historical structures they embed in their brains through habit and selective exposure and the biological and socio-symbolic structures which they must inhabit. The transilient approach also suggests the need to rethink how institutions of higher education are becoming funded and organized.

Finally, and most importantly, Chapter 12 indicates how such a "transilient" orientation can enable humans to improve our shared future prospects. Previous efforts to link biology and human qualities to social policies have focused on the differences between people, and have therefore had a conservative cast. Instead, we focus on our shared, human, biological and symbolic heritage. As an example, we trace the insufficiency of current responses to the intertwined problems of environmental degradation and gross economic disparity to one-sided orientations that address either human symbolic capacities or human biological tendencies, but not both. We show how the symbolic capacities of amplification create these problems and suggest that strategic efforts at amplifying some biological predispositions, de-amplifying others, and re-channeling might contribute to ameliorating these tendencies. We thereby indicate that if we take seriously human biological predispositions and also take seriously the capacity of symbol systems to re-cue and re-channel those predispositions, we have at least some hope of redirecting our energies into more sustainable and more just behavior patterns.

<u>"A Vision for a Better Future"?</u>

To date humans have not been able to avoid using our symbolic capacities primarily to amplify the common disasters of our animal cousins. Plagues, deadly fighting over resources, and carelessness toward the world and other beings around us typify our past, our present and our likely futures. Perhaps these biological programs are inescapable. If they are escapable, however, it is our symbolic capacities that provide the means for discovering and implementing alternatives. Humans are unlikely to succeed at charting alternative routes, without clearly understanding what leads us to act as we do. There is now sufficient evidence to suggest that human actions are guided both by our biological proclivities and by our symbolic characteristics. If that is the case, each person with the means has an obligation to explore whether and how understanding these interactions will offer a better set of possibilities, better enabling human beings to use our rich symbolic capacities to produce a more humane future.

Chapter 2: The Model of "Physics"

Summary: Physics, as traditionally understood, uses controlled experiments and mathematical deduction as two of its most important methods. These methods have worked so well in physics because physical being is characterized by relatively few types, by types that vary by degree and are thus quantifiable and measurable, by types that vary little through space and time, and by forces that operate at different scales and thus are separable. The experimental method has also worked well and produced mechanistic models in part because causality in physical being can usually be readily resolved into single causes of single effects. These characteristics of physical being have allowed physics to produce remarkable knowledge, both of a pure sort and of a leveraged usable sort that allows non-physicists to use powerful technologies. The methods of physics have thus been tremendously effective in studying physical being, because of the excellent match between material and method. However, the remarkable success of physics does not necessarily mean that those methods can be applied so successfully in other areas of study, as we'll see in later chapters.

Everyday life constantly presents us with puzzles like "Why does a straight stick look bent when you stick it into water?" or "What makes rainbows?" More pragmatically, we need to know "How do you convert the energy of coal into electricity and transmit it across six states?" In just the past few centuries, the formal study of physical being has produced a set of answers to such questions that includes a sturdy tapestry of explanation, a highly accurate set of predictions, and relatively inexpensive and direct control over a broad range of physical phenomena. The ability of physics to generate this vast body of highly functional knowledge has induced the broader community of the sciences, and to some degree the broader society, to adopt what is taken to be the practice of physics as a model for what all knowledge should be like and as a methodological template.

In this chapter we will begin by briefly describing the two core ingredients of this idealized model: the use of 1) the hypothetico-deductive method employing controlled experimentation to 2) produce universal laws in the form of a network of mathematical equations. Our account describes an idealization. Physics has always been more complicated than this description allows, and today working physicists do far more than this model encompasses. Moreover, this model applies only to the reduction of physical being to constituent elements. As Chapter 3 demonstrates, the idealized model of physics does not describe the ways in which physical being actually manifests itself in the natural world—in aggregates of these constituent elements.[19] Nonetheless, we must attend to the idealization because it is this idealized model, not the real and full practice of physics, that continues to dominate the contemporary scientific consciousness.[20]

If the idealized model of physics were merely a false consciousness, our project would amount to nothing more than debunking. However, this idealized model highlights large and important grains of truth. The use of experiment within the hypothetico-deductive model and the production of law-like equations were crucial to the development of what is often called "classical" physics. They remain ideals operative in modern physics, even when the practice of modern physics far exceeds their bounds. Understanding the basic model is, therefore, important to understanding the success of physics, even if the model is an idealization.

We contend, however, that the success generated in physics by use of this model does not arise from the model's universal appropriateness and power. Rather, the successes identified with the model of physics are the result of the *match* between the approach used in physics and the nature of physical phenomena themselves. In the second part of the chapter, therefore, we will identify the factors that make the idealized model an appropriate fit for studying physical being. First, the match arises because all physical being, whatever its size or shape, can be effectively understood as resulting from just a very few fundamental forces and particles. Furthermore, the characteristics of these forces and objects are, for all practical purposes, universal—that is, they do not vary through time and space. Third, the forces involved operate at different scales, enhancing disaggregation of their contributions and characteristics. Finally, the types themselves vary by degrees. If physical being did not have characteristics approximating these features, it would not have been describable or manipulable using the approaches prescribed by the model of physics. As we will suggest at the end of the chapter, these fortunate characteristics have enabled us to utilize the findings of model physics to produce a particular kind of leveraged control over the physical universe.

<u>The Methods of Physics</u>

The total set of practices that are needed to produce the knowledge we call "physics" includes the full range of human behaviors and social institutions. When physical scientists began to use hypothesis testing, they did not eliminate logic (especially deductive thinking from fundamental principles) and rhetoric (especially analogical thinking from models)[21] from their practices. Instead, they *added* experiment as a way of testing the mathematical equations suggested by their models and as a way of working toward and from the major premises of their logics. Likewise, physics did not dispense with rigorous observation in favor of experiment, but added a layer of rigor to some kinds of observations by using manipulations to produce controls (more on the distinction in Chapters 3 and 5). These additions created a powerful new approach to understanding the world. A rich body of literature exists that describes the role of everything from funding agencies to individual creativity to ideology in the production of physics.[22] There is also continuous debate over the relative importance of these different factors, and the best way of describing those factors. We focus on only two components--controlled experimentation and the expression of fundamental laws in mathematical terms--not because these other components are inessential, but because these two components are widely (but not universally) believed to be *distinctive* features of the methods of physics and its success.[23] Physics has always shared the use of logic, rhetoric, creativity, ideology, and funding with all other human practices, but controlled experimentation and mathematically expressed laws were new additions and therefore uniquely responsible for whatever unique advantages the practices of physics offered.

Controlled Experiments

The method of physics is often identified as "the experimental method" or more broadly "the hypothetico-deductive method."[24] Richard Feynman, a physicist noted both for his excellence as a physicist and for his skills with communicating about physics to general audiences, wrote that “'The principle of science, the definition, almost, is the following: The test of all knowledge is experiment. Experiment is the sole judge of scientific ‘truth’.”[25] The procedure usually identified with this dictum is that physicists offer a prediction (hypothesis) that is based in a theoretical rationale, and they then test the hypothesis in a controlled experiment.[26] If the results of the experiment are in accord with prediction, then the hypothesis receives support, and if the results are not as predicted, the hypothesis is rejected. A key aspect of an experiment is the notion of “control.”[27] A viable experiment has to allow the bracketing of all possible factors that could influence the outcome of the study. It has to allow only one factor to vary; otherwise the experiment cannot tell us how two factors are causally related (for example, whether gravity bends light). Without “control” an apparent relationship between two factors may be caused by some third factor that is related to each. Implicit in this model is the idea that at least some experiments are “critical.” That is, a single experiment may provide a definitive piece of information about the status of a hypothesis.[28]

Both scientists and those who study science have long recognized that the relationships between hypotheses and experiments is rarely as neat and clean as one might wish.[29] Unexpected results from experiments are as likely to generate new hypothesis as the other way around. It is sometimes hard to analyze the results of an experiment accurately. It is also often hard to tell whether an experiment has produced a disconfirmation or has just been bungled. One might also unintentionally rig the experiments one performs to give favorable results. Indeed, the need for experiments to include rigorous controls on all extraneous variables invites the exclusion of variables that might make a difference in the real world outside the laboratory. Limits on the hypotheses that get tested also constrain what answers can be obtained from experimentation. Sometimes one might even get the right results for the wrong reason. Nonetheless, the experimental method is identified with physics, and with science generally, because it provides a strong means for falsifying one's beliefs. When done self-reflectively, with an eye to putting one's biases to the test, experiments are ways in which the world can talk back to our belief systems and tell us, "No, you haven't got it right." The history of science is full of examples of the world talking back in this way: the existence of elliptical orbits of the planets around the sun is the most familiar example to lay audiences; the rise of quantum mechanics is probably the example most familiar to experts.

The distinctive success of physics is, indeed, due in part to its rigorous use of the experimental method. Yet, as has become a virtual mantra in science studies, experimentation is not all there is to physics. If physics were nothing but a bunch of isolated experiments, then we wouldn't know anything about physical being except isolated numbers that were the results of these experiments. An equally important part of physics is an interconnecting lattice of "laws," most of which consist of mathematical equations.[30]

An Interdependent Lattice of Laws as Equations

A law is a statement of the relationship between two things that is assumed to be absolutely invariant at a specified scale. To say that something is a "law" of nature in this sense is to say that there has never been a known case, and there are no known situations, where the specified relationships do not hold. Some such universal laws state things that seem relatively obvious. For example, the 2nd law of thermodynamics says that heat is always transferred from a higher temperature object to the lower temperature object and never the reverse (unless work is done by some outside agency). This matches our common perception pretty well, as we expect a burner to melt an ice cube rather than an ice cube to warm up the burner. Other laws state relationships that are alien to common sense. The third law of thermodynamics describes the condition of matter as its temperature approaches absolute zero, and for the most part, we don't even think about the idea of an absolute zero in our common sense reckoning, because absolute zero is so much colder than any temperature we would naturally encounter.

Other laws from physics counter our common sense. One highly familiar example is Newton's statement that a body in motion remains in (the same) motion unless an outside force acts upon it. In the *Principia*, Book I: Law I, Newton wrote:

> Every body perseveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by forces impressed upon it.[31]

This law is interesting because it states something that today one might consider obvious to the point of banality: that things do what they do until something else makes them do otherwise. But the law was a breakthrough because it constituted a reconsideration of what, until then, was widely taken to be "common sense" intuition about movement and physical being.[32]

The common sense notion is that things naturally come to rest. If you live on a planet with a substantial gravitational force, it pretty much appears that the natural state of things is stasis, not movement. Because gravity and friction exert strong forces on any moving object, it appears to common sense as though the natural law of motion ought to be something like "things in motion come to rest unless some force continually acts on them to keep them in motion." Newton's so-called "First Law of Motion" formalizes the fact that this intuition is wrong. It lifts us out of our local range of experiences and into a broader range of experiences, where we discover that gravity is a force acting on things in all of our standard experiences, and that if something is not acted upon by such a force, it will continue in motion. Newton's world is a world of constant motion, where every change in motion requires explanation, rather than a world where a trend toward immobility is taken as natural.

Many other laws of physics are definitions. The idea that force equals mass times acceleration specifies what we mean by "force." Although force is a common sense notion, tying it specifically to the ability to increase the speed of a body narrows the definition. It makes uses of the term "force" such as "he forced his grandfather to give him the candy by batting his baby blue eyes" into a metaphor. While our common sense vocabulary understands why the "force" exerted by a bat on a ball and the "force" experienced by the grandfather are similar—both cause particular kinds of movements—the former force is described directly by Newton's laws, and the latter requires substantial translation to be explicable in Newtonian terms. Thus, the term "force" within the vocabulary of physics has been given a technical definition; the law that specifies its quantitative relationship to other physical variables thus defines it .

These facets of physical laws, however, do not capture their most distinctive feature: the laws of physics are equations.[33] This is an enormously difficult fact for non-physicists to accept. It is not just that physicists do a lot of math to support their theorizing. It is that physicists take the mathematics as being the very core of physics. Richard Feynman writes that, "Every one of our laws is a purely mathematical statement in rather complex and abstruse mathematics."[34] Steven Weinberg suggests that the central factor that distinguished ancient scholarship from modern science was the recognition that "successful scientific explanation" required "the *quantitative* understanding of phenomena."[35] Freeman Dyson further indicates that the importance of mathematics lies not only in the utility of the final version of the laws themselves, but in its role as a primary inventional resource. He claims that, "For a physicist mathematics is not just a tool by means of which phenomena can be calculated; it is the main source of concepts and principles by means of which new theories can be created."[36] If you can´t do the equations, you can´t really understand the physics. This barrier makes it extremely difficult to talk about physics with a general audience, but because we want to highlight the differences between physics and other sciences with regard to the use of mathematical equations, it's necessary to struggle through some examples: first, an equation from classical physics and then an equation from modern physics.

Though it does not capture everything about mathematics and classical physics, let's consider the work energy theorem and its use in calculations related to the speed of objects and gravity. The "work energy theorem" relates how much the speed of something is going to change for a given amount of "work" done on it. Specifically, it holds that the work done on an object is the change in its kinetic energy. Since kinetic energy is a product of the mass and velocity of an object,

$$\Delta K = 1/2mv_f^2 - 1/2mv_i^2$$

(where v_f refers to the final velocity and v_i is its initial velocity). This is called a "fundamental" equation for mechanical physics. It may seem odd from a lay perspective because "kinetic energy" is something like a made-up concept. That is, it is an abstraction that treats different kinds of effort (the gravitational effect on a falling rock and the Brownian motion among gas atoms) as though they were the same thing. But it becomes a very useful abstraction because it fits into a network of equations that can be substituted in part for each other, and together these allow all kinds of other calculations to be made that are very concrete. For example, imagine that an aid agency wants to assess how fast a relief package would be traveling when it hits the ground if it were dropped from a helicopter at a particular height, because they want to know if it would survive intact. The principle of the conservation of energy means that the mechanical energy E= U(potential energy) + K (kinetic energy) is constant, so that the energy of the package before one drops it is the same as the energy when it hits the ground; in equation form this is $Ui+Ki=U_f+K_f$. If the package is released from rest (no downward push), then this means that $Ui + 0 = U_f+K_f$. And, just as it hits the ground, all the energy is kinetic, so $Ui+0=0+K_f$. Now you can substitute $1/2mv^2$ for K_f (from the root of the work energy theorem), and you can substitute mgh for Ui. So this gives you $mgh +0 = 0+ mv^2$. Now just solve for v to get $v = \sqrt{}2gh$. Since you know g (earth's gravity) and h (the height you drop the package at), you can calculate how fast the package is going when it hits. Using similar relationships among relatively simple equations (and adding in coefficients for friction or air resistance and such) you can calculate with how much energy the package will hit its target. One can, of course, use the same equations and related equations to calculate more controversial applications, such as the physical energy of a bomb hitting a target.

The utility of such equations in classical physics results from the fact that they form a set of inter-locking pairs. You can substitute the equation for gravitational force in one component of the equation, or you can instead substitute the formula for electric potential for the potential energy component. This creates an interlocking grid that allows you to calculate (or predict) one feature of the system from some other set of features, or to move among apparently different systems (electrical circuits and pulleys and levers) making similar assumptions and developing appropriate calculations with some ease.

In such a network, each discovery suggests other relationships. Experiments are used to test whether these relationships hold in the new system. The equations suggest what the proper quantitative result of a given experiment should be if a specific equation is correct. When the result of the experiment is in agreement with experiments over a fairly broad range of trials, the equation is taken to be a proper description of the behavior of the phenomenon in question, and hence is said to describe the "law of nature" with regard to that phenomenon. If there is a tight relationship among the variables in the equations across a broad range of phenomena, then the network of equations (or laws) builds upon itself with relative rapidity and this allows the development of a science that is quite broad and powerful.

As it happens, *because there are so few basic variables in the physical universe*, this method has been able to produce just such a powerful body of knowledge. The equations of classical physics are the basis of all of the complex engineering that makes modern society what it is. Such equations allow us to imagine what is necessary to build a 35 story sky-scraper before one is ever built. They allow us to design electrical circuits that can run lights and toasters and can openers. Without the insights provided by these equations, most of the physical tools and toys we take for granted in our daily life would not exist (though a lot of good old fashioned tinkering is essential, too).

Thus have the dozens of basic equations of classical physics been established through an interlocking set of measurements (that test them) and mathematical calculations (using algebra, trigonometry, and calculus) that provide conversions among sets of equations and a kind of explanation. We call this kind of physics "idealized" in part because the measurements are never pure or exact. Every measurement is only an approximation. Even the best measuring device in the world only can measure something to a limited degree, and no two measurements will ever arrive at the same measure to an infinite degree of precision. In addition, the equations themselves are idealizations because they do not usually apply directly to the real world. Almost all of the equations specify very limited conditions that are rarely if ever found in the real world. For example, the basic equations of mechanics specify that one is operating in a frictionless system, but in the real world friction is always a part of a mechanical system. Similarly, the basic equations used in electrical circuits specify an idealized circuit with no resistance, or specifically programmed resistances and no extraneous dissipation. In practice, various kinds of "fudge factors" devised from experience have to be used to correct the equations when we move from abstract physics to applied physics. However, as long as the fudge factors are relatively small compared to the quantities specified by the relationships in the equations, the equations remain useful; the other factors can be treated as "noise" rather than as something intrinsic to the underlying relationship.[37]

The equations of classical physics can be understood and used by anyone with basic algebra and trigonometry skills, even if their proofs cannot. Many of the proofs can be understood by anyone with basic calculus skills. This is not true of the equations of modern physics, and indeed, the mathematics is different, and plays a different role in modern physics, although it is even more idealized. Schrödinger's equation is the fundamental equation of quantum mechanics. Its time-dependent form can be written for three dimensions as:[38]

$$i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m}\left(\frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial y^2} + \frac{\partial^2 \Psi}{\partial z^2} \right) + U\Psi$$

Understanding and using such equations requires not only powerful computers but knowledge of forms of calculus and matrix theory that are specialized.

The equations, moreover, present difficulties even for those with the most advanced mathematics, and their use must be idealized. The wave function (the equation above) involves imaginary numbers, which are simply lopped off because they are presumed to be inapplicable to reality (at least in our universe/dimension), and possible mathematical solutions of the equations are ruled out as "not well behaved" as the wave function is restricted to values that are continuous and single-valued as well as normalizable. Thus, in quantum physics there is more than a little bit of tension between the way the pure mathematics would run, and the way the equations must be treated if they are to apply to physical reality. Nonetheless, though the equations must be carefully massaged, they are enormously powerful because they specify a broad network of relationships well enough; they explain for example, how electrons fit with protons and neutrons to constitute atoms and how atoms fit together to make molecules with distinctly different kinds of properties.

It is not, however, just the difficulty of the mathematics that makes the equations of modern physics different from classical physics. They are also different because classical physics gives absolute values for individual objects and modern physics gives probabilities, usually for sets of objects. In classical physics an equation gives a good idea of what an individual object will do: if you run a car of X mass down a ramp at Y speed, it will hit the brick wall at the bottom with Z force, and this will have A impact on the bumper made of B material. Until only the last few years, in modern physics this attention to individual objects has not been the case.[39] The equations of quantum physics indicate probabilities, and thus predict on average what will happen in a group of atoms, but they can't tell you what any given sub-atomic particle will be doing at a given time. Thus, for example, modern physics can tell us that a certain number of atoms in a given pile of uranium will decay and emit radioactive particles in a certain amount of time, but it can't tell us which of the atoms will decay during that time. The equations can tell us how the probability cloud of an electron around a hydrogen atom is distributed, but it can't tell us "where" the electron is at any particular instant.

This is often called the "non-determinism" of modern physics, and it has generated angst and confusion, especially by popularizers of modern physics, some of whom have seen it as confirmation that materialism is wrong after all, and variously that either spiritualism or free will triumph. Even without making such leaps of implication, it is clear that this is a different kind of use of mathematics and equations than occurs in classical physics. Quantum physics predicts probabilistically and usually deals with collections, rather than providing singular values for specific individuals. No longer is there even an imperfect one-to-one link between a measured object and the equation that purports to describe it.

For the most part this theoretical difference doesn't make a practical difference. In most applications, there are so many individuals of a given type of quantum object that the average behavior is all one is ever likely to encounter (or measure). With 10^{20} atoms in a square centimeter, it doesn't matter if a few atoms are out at the tails of a distribution. If you can only measure 10^{10} atoms at a stroke, the probability is vast that you are going to get a measurement of atoms that are in the middle of the distribution. When your "N" (number of objects) is this large, you never have to worry about statistical problems of sufficient power.[41]

Although there are differences between classical and quantum physics, these do not vitiate the central fact that when we say that physics produces knowledge about physical being, in overwhelming measure, we are saying that physics provides us equations that tell us what the expectable values of energy, mass, and space-time will be in any interaction. Very little knowledge in some sense, but it produces a tremendous amount of output.

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<u>The physics-worthy character of physical being</u>

From the set of knowledge frameworks accumulated by physics, we have come to have a well-justified belief that all relationships, all objects, and all forces are the product of just a few basic things: especially four basic forces (gravity, electromagnetic energy, the weak force, and the strong force) and three families constituting 12 fundamental particles (though over 300 measurable energy effects have been named as "particles"). In terms of study, it can reasonably be said that physicists do research on just three things: energy, mass, and space/time. Though there are hundreds of concepts in physics, all of these concepts are versions or combinations of just these three phenomena. Energy, for example, is studied in different forms: heat, light, electrical conductivity, etc. It is combinations of these three basic phenomena that produce anything as a material entity. An atom, for example, has its characteristics as a product of the energy interactions among accumulations of mass and energy at particular distances one from another. These combinations are also invoked to explain the physical behavior of what we see on the normal scale of human interaction: velocity, acceleration and momentum, all address the way that mass and energy are related through space-time.

In focusing on energy, mass, and space-time, physicists found themselves with a field of study that had a limited number of stable types operating at scales that were suitable for manipulation and measurement. As Frank Wilczek put it in *Nature*,

> First is the very basic fact that matter is built up from vast numbers of copies of a few fundamental components (such as electrons, quarks, photons, and gluons). The properties of these elementary building blocks are always and everywhere the same--universal.[42]

This set of assumptions is sometimes short-handed as "reductionism," and although much maligned for its failure to attend to the holistic synergies of things, it is a set of assumptions that can—when directed at the right kinds of objects--produce functional knowledge.[43] Had physical being not had a kind of character that was amenable to such methods, physics would have floundered early, but had not physicists been looking for such a set of characteristics, they wouldn't have found them. It was the *fit* that made the physicists' study of physical being so successful. It is not merely that physics is less complex than other types of being. For anyone who has struggled with understanding the fine structure of atomic spectra or the nature of the wave function, portraying physical being as "simple" in any regard seems grossly inaccurate. Instead of chocking up the differences to something as uni-dimensional as level of complexity, the distinctive qualities of the physical level of being that make it more readily amenable to the equation and experiment-heavy approach of physics include four important happenstances: *physical being can be functionally distilled to a relatively constrained pyramidal structure of types, the types themselves have relative stability, the forces involved operate at different scales, and the types feature variability of degrees.*

A constrained pyramidal structure of types

Physical being appears to have a relatively constrained inverted pyramidal structure to the types or kinds of things that exist as physical being (see Figure 2.1).[44] There are only four fundamental forces, and there are only12 so-called "fundamental" or "mass-bearing" particles that participate in making up matter and the basic and common interactions that hold matter together (or break it down again). It may be that all of this is further reducible to a single phenomenon—tiny vibrating strings. Whether or not string theory is a good theory, the apex of the pyramid of physical being is relatively small. Even if you include the various kinds of "particles" that can be produced with sophisticated experimental apparatus, and you assume that they all play substantive roles

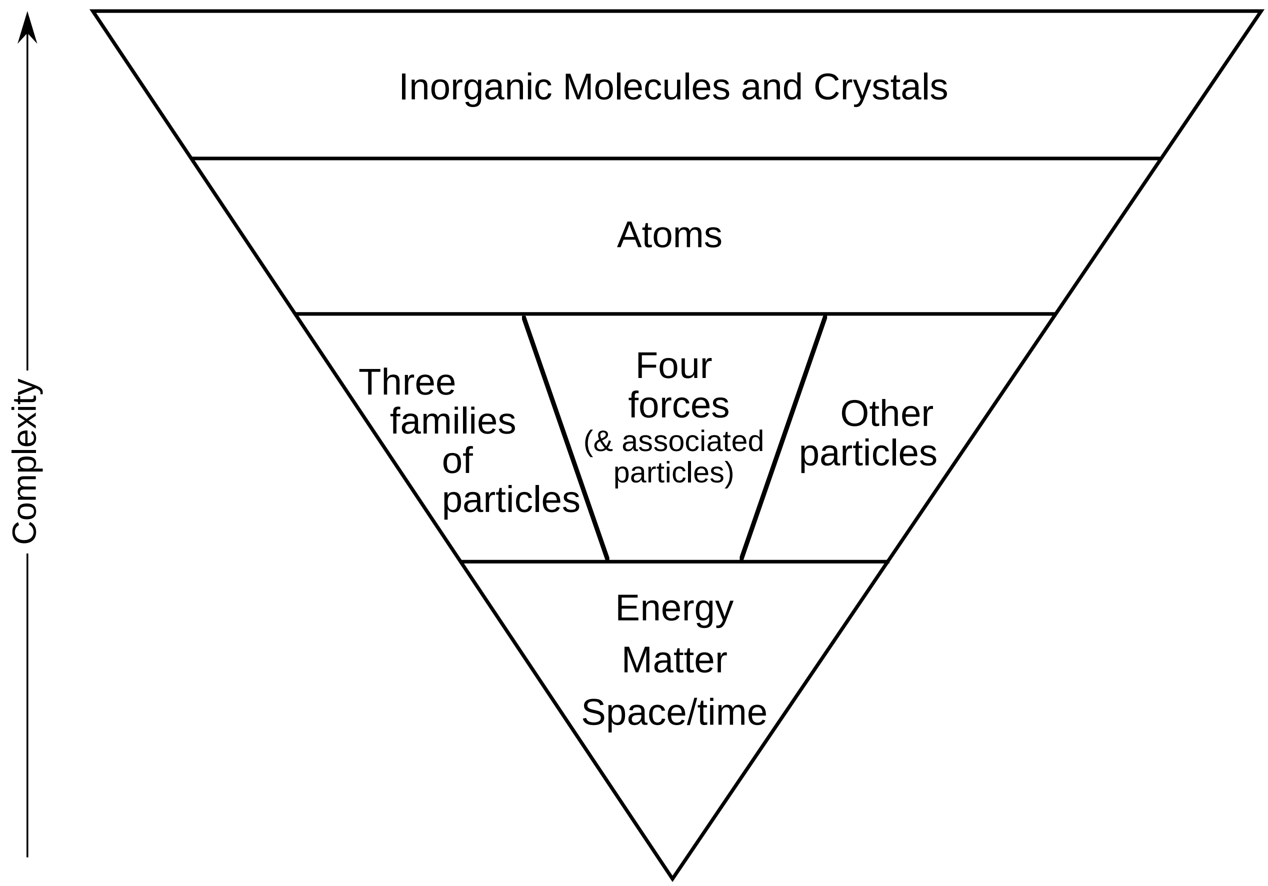

Figure 2-1: The (inverted) pyramid of types in physical being.

in constituting being as it is, you don't get up to even four hundred basic things to study. These different particles are themselves grouped into families, so one can further simplify the apex of the pyramid. And, for the most part, attention can be concentrated on the few players central to making up atoms. Quarks and gluons go together to make up nucleons. Nucleons and electrons go together to make up atoms. The atomic level of the pyramid is larger, as there are a hundred plus types of atoms ("elements": only 92 of which are known to be naturally occurring), but that is still a relatively small number of types compared to biological being (where the types are less stable and are easily numbered in the tens of millions, at least). These physical elements can, indeed, be combined into a very large number of inorganic molecules that can be compared, so the next level of the pyramid expands in size again, but even then it remains vastly smaller than the number of types in biology.

Not only does this pyramid feature a very few types of things to study, it also features stunning similarity in the way that different types of things are put together. The 100-plus types of elements don't differ in terms of what *kind* of particles make them up, just in the *numbers* of these particles that make them up. The only difference between one atom and the next is how many electrons, neutrons, and protons each one has.[45] This means that there is a common set of rules that govern all of the different elements, so that when you assemble them into a table based solely on the number of protons they have, they end up exhibiting orderly behaviors in what are called groups and periods. In other words, the constrained pyramidal structure of physical being means that you get a lot out of a very little information. You don't have unique rules to learn for every type of element. When you learn a basic set of rules, you know about *all* of physical being.

Remarkably this extends even to the molecular level. So, though there are thousands of types of molecules, they are all governed by the same rules: there are only a few basic types of bonds possible between different atoms, and a few basic types of shapes. There is sufficient complexity to keep one occupied here—for example, things change at different temperatures and different types of matter obey one of three different sets of basic equations for energy states, depending on their distinguishability and spin type—but the available array is still highly manageable. In spite of some messiness, there is an excellent ratio of reward to research input because most discoveries apply across a huge range of physical being. The "types" of both biology and symbolics lack this constrained character, so that in these realms, the ratio between variation and generality is quite different.

Stability in Time and Space

This discussion has so far taken for granted another important and basic property of the types of physical being—their invariance through time and space. Physicists sometimes label time and space invarianceas fundamental laws of physics. These "laws" point up the fact that, as far as we know, physical being is the same everywhere in the universe. In the words of Nobel Laureate Steven Weinberg: "We think that such statements are true everywhere in the universe and throughout all time."[46] Of course, the accumulated human data set bearing on this claim is a bit constrained, but astronomical measurements and associated calculations and deductions suggest that basic components like light and gravity function in distant stars and galaxies pretty much the same as here in our own little solar system. This makes physics ever so much easier than it would be if types of things changed through time and space. Imagine if atoms of gold were constituted one way in 1850, but by 2000 they had changed their composition. Imagine if gold atoms purified from ore in South Africa were different in substantial ways from gold atoms purified from Siberia! Physics would be facing, as the saying goes, "a whole 'nother ball game." As we will see, it would be much more like the ball game facing biologists and symbologists. Of course, there is some recent debate over whether basic forces like the speed of light or the gravitational constant have changed over time. But even if the challenges to orthodoxy in these areas prove true, the changes are so small and slow compared to the scale of their operation that they can be neglected for at least the next few tens of thousands of years. Unfortunately for biologists and symbologists, both biological systems and symbolic systems have major components of uniqueness in time and space, which make the physicists' easy reliance on universals lessavailable or powerful in biology and symbolics.

Different Scales of Forces

Remarkably, most of the different types of forces in the physical universe operate at different scales, one from another. Gravity is a relatively weak force, and it operates over very long distances. The so-called "strong force," on the other hand, is powerful enough to hold protons together to make up nuclei, even over and against the powerful repulsions of their positive charges (with the help of neutrons). The strong force, however, operates at very small distances. Electro-magnetic forces are intermediate in the distances and strength at which they operate.[47] The substantial difference in scale of different forces means that one can easily isolate and focus on the character of one force at a time. This means that one can do highly *controlled* experiments with relative ease. A physicist can manipulate something and know that almost all of the change observed comes from the input of one factor (or in the worst case scenario, two or three factors).

The same fortunate scaling of inputs occurs throughout reduced physical being. For example, although angular momentum and magnetic moments of both nuclei and electrons contribute to the total atomic angular momenta and magnetic moments, the contributions of the forces of the nuclei are a hundred times smaller than those of the electrons, so they can be either ignored or easily distinguished. Thus, in many kinds of experiments in physics, it is possible to pick and choose the factors and the levels on which one wishes to focus. *If the scale of forces overlapped, this kind of careful separate analysis would be much more difficult, as it would not be possible to eliminate the operation of one basic force in order to study the other, without decomposing the matter.* In some arenas of biology and throughout most of symbolics, this handy separation of the scale of different inputs is not available.

Variability of Degrees Not Types (Measurability)

The final factor that makes physical being so amenable to the application of controlled experimentation and mathematical equations is its easy measurability.[48] An aspect of this measurability is the fact that the components of the universe—energy, mass, space-time--vary by degrees. Each item has more or less energy, more or less mass, and exists here or a little over there, in space (or time). Although at the quantum level these degrees manifest themselves only in discrete packets, the packets can still be arrayed like stair steps up a continuous slope. This is not true in areas of study where the objects of study differ more by kind than by degree. If instead of three or four ways in which energy could be manifested at different scales to different degrees there were 100 types of energy exerting roughly similar amounts of influence to produce each different type of atom, physics would have found itself in serious trouble. Mathematics is designed to distinguish amounts, not types. If the physical universe had featured this very different character, the experimental method could not have been used to isolate and control particular variables with such relative ease and mathematics would have been powerless to provide descriptions that also stood as predictions of physical behavior. As we will see, much to the misfortune of biologists, life is as much a kind-making machine, as a degree-varying machine.

There are, however, problems of measurement that arise for quantum mechanics that do not arise in classical mechanics. Classical physics measures and describes things on what we would call the "daily-life human perceptual scale" or the "human scale"—boxes and the speed of bicycles and cars, and visible shafts of light entering eyeglass lenses. Classical physicists could easily find measuring tools that are smaller in scale (but not too much smaller) than the things they needed to measure. It was relatively easy to get the numbers needed to plug into equations. So, while still somewhat idealized, classical physics could deal with the individual object and readily describe the major forces acting on the object through simple equations.

Modern physics operates at scales where the factors that make measurement practicable in classical physics are not so ready at hand. How do you find something that is smaller than a quark to use in measuring quarks? The scale of the nuclear strong and nuclear weak forces is likewise vexing. These forces are strong, but only at a tiny distance. This is equally true for the short times (or in the case of the speed of light, very fast speed) that need to be measured in modern physics. Heisenberg's uncertainty principle captures part of this when it is interpreted to mean that you can measure the location or the momentum of a particle, but not both simultaneously. The lay explanation is that any effort to measure the location impacts the measured particle so substantially that it changes the momentum (and vice versa).[49] This problem doesn't tend to arise in classical physics because measurement devices can be found that impart so much less force or velocity to what is being measured compared to the size of the force that is being measured. Therefore, the effect of the measurement process itself is small enough to be ignored. But this is not the case in much of modern physics, and indeed physics as a field of study comes close to being paralyzed in certain areas today. Einstein's work predicted the existence of gravity waves, and their existence has received indirect support. But the ability to measure gravity waves directly remains at the limits of our measurement capacities. Current instrumentation set up to try to find such waves has so far not succeeded, and the sensitivity of the equipment is tenuous enough that even results that claim to detect such waves will be subject to serious argument. Likewise, the ability of physics to produce its longed-for "ultimate theory" or "Theory of Everything" (T.O.E.) is already put into doubt by measurement issues. String theory posits that entities that are 10^{-33} centimeters constitute the ultimate stuff of the universe. But no one has the faintest idea how to come up with a measuring device on that tiny scale. As long as that remains true, then string theory can't be tested through direct experiments. Theoretically, the limitation may be permanent, since by definition one can't find anything smaller than strings to use in measuring strings. Physicists face the awkward situation of having a theory that is mathematically tenable, but can't be tested. String theory may be stuck being more than a guess but far less than a theory with the level of support that it can ever be treated as taken for granted. It may be true, but according to the methodological standards of physics, one may never know whether it provides an acceptable account.[50]

The ability to measure relevant quantities is thus essential to the successful use of the method of physics. *When physicists say they "understand" something, what they are saying in large part is that they can accurately predict how much of some measurable characteristic will manifest itself in what setting*. How fast will a rock fall? How much current will flow through a given wire? What kind of light will be emitted when a given molecule is bombarded with photons? Indeed, the origins of the scientific revolution, which started with physics, are often traced to the ability of Tycho Brahe to make reliable and precise astronomical measurements. For a neophyte in physics it is stunning—even frustrating--how many units of measurements physicists have invented. These include, among others: the meter, the gram, the second, the Newton, the joule, the watt, the ampere, the volt, the coulomb, the farad, the ohm, the tesla, the curie, the degree, the radian, the Kelvin, the mole, the candela, the hertz, the pascal, the henry, the calorie, the erg, the dyne, the atmosphere, the bar, and the weber. In each case, the process of measurement entails using a counting device to convert a property that comes in continuous quantities into some external (symbolic) scale.[51] With a yardstick one records the height of the box by placing a thumb on the proper notch. With a voltmeter one bleeds off a tiny amount of the current to move a dial that is scaled in such a way that it moves a greater distance with more current and a shorter distance with less, and one calibrates the less and more with a numbered scale and reads that scale. Physical being is only knowable as physics to the extent that it comes in reliable doses of which the relationships are always the same. To the extent that biological being and symbolic being do not come in such measurable, repeated doses, but rather in kinds and convergences, the approaches of physics will not produce knowledge about them.

How Causality is Understood in Physical Being

Because one can numerically measure the readily distinguishable forces and particulates of physical being and represent them through equations that are universally applicable, one can understand causation in physical being in a particular way. This is a key aspect of what is referred to as a "mechanistic" model, and the workings of a clock are often used to illustrate it. As a mode of causal thinking, it is most clearly described as the "one cause, one effect" (OCOE) approach. This approach does not really assume that there is only one cause acting at any given time on any given outcome (see Figure 2.2). What it does assume, is that one can decompose the various factors acting on a given object and treat them one at a time. A watch is a fairly complex entity, but each piece of it can be studied by being broken down into simple parts that exert only one effect at a time. The effects accumulate in a series or in an additive way. At its most complex, theOCOE model recognizes that a chain reaction can be produced, as a series of additive effects is multiplied by the ability of one cause to produce more than one instance of the same type.

The classic insight that enabled the OCOE approach to function across realms in physics is the understanding of forces as vectors on a grid. Thus, if you have a force (a

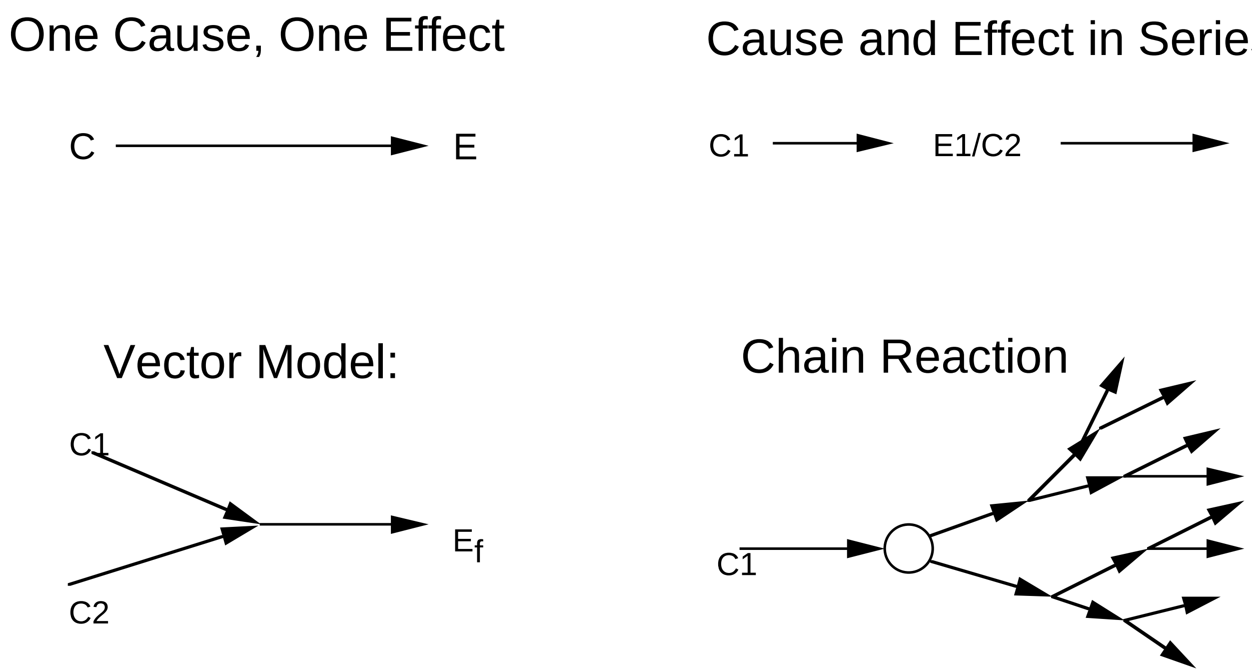

Figure 2-2: OCOE (one cause - ene effect) models of causality

Northeast wind at ten miles per hour, for example) that is acting diagonally on an object (an airplane for example), you can most readily tell where the airplane will get pushed by the wind by pretending that the wind is really a 5 mph wind from the North and a 5 mph wind from the East. Such an approach only works to the extent that forces in physical nature do not include what statisticians call "interaction effects," or at least where the interaction effects are trivial compared to the "main effects." In inorganic physical being at the classical scale this seems to be the general case, and this makes OCOE a reasonable way to understand causality in macroscopic inorganic physical being.

The situation is more complicated at quantum scales, as measurements of quantum behavior generally focus on aggregates and quantum behavior features discontinuities. The aggregate character of quantum formulations means that technically, one can't know the full behavior of a single quark or electron, one can only describe the behavior of a collection of them. That, however, is good enough for most purposes, so the probabilistic formulations of quantum mechanics can be subsumed within the OCOE model. The discontinuities of quantum behavior also are often subsumable within the OCOE model. Although in quantum phenomena causation does not act to produce continuous distributions, the inputs on the causal side are nonetheless related in a direct, serially ordered assembly to outputs on the "effects" side. The non-linearity is conceivable as a set of "gaps" in an underlying continuous series, and thus it is roughly approximated to OCOE logic.

When quantum physicists begin to look at a small number of cases or singular cases, and the scale of the different effects become roughly comparable, then interaction effects do arise and the models of causation become more complex.[52] However, so few people actually understand quantum physics that any perturbations its formulations create in the OCOE logic have not dislodged the general perception that the OCOE model is the "correct" model for understanding causation as modeled by physics.[53] This model probably gains as much currency from the fact that it matches "common sense" notions of causation as from the fact that it is taken to be the guiding model of physics and a factor in the success of the approach of physics.[54]

As we will see in analyzing biology and symbolics, the non-interaction assumption isroutinely violated in both these realms, and hence the OCOE approach, though it remains a useful tool for looking at some aspects of such phenomena, provides a fundamentally insufficient understanding of causality in organic and symbolic being. This is a serious problem for biological and symbolic research, because the OCOE model makes for extremely good prediction and control.

The Predictions of Physics

Physical laws and equations are intellectually impressive and even beautiful, but they matter to society because they enable prediction and vast control. Physics allows predictions of two kinds: the prediction of new phenomena and the prediction of quantities. The prediction of quantities is the bread and butter of physics, both as a basic and an applied science. This is because physics' major form of explanation is the equation and the major explanation is how things vary quantitatively with regard to energy, mass, and directionality. The equations of physics tell us, for example, that if we use a particular wire with a particular resistivity, we will get a particular amount of current in an electric circuit, as opposed to the use of a wire made of a different substance, which will be more useful if we need a different current flow.

In the discovery process, physics often works by “reverse prediction.” Physicists have a set of measures (e.g., frequencies of light emitted when atoms are excited, or binding energies of nuclei), and the game is to produce an equation that would predict those numbers. Once such an equation is generated, then its ability to predict new output values from new input values is tested. When this proves satisfactory, then the equation is available to anyone who wants to know which input is needed to gain a particular output in a particular situation. This is the applied phase.

Sometimes physics has also worked by “forward prediction”--predicting new objects and phenomena. One of the most historically significant examples was the prediction of the existence of Neptune on the basis of slight numeric discrepancies in the orbits of the other planets. Early in the development of physics, this discovery demonstrated the power of the method of physics to reveal new things to human experience. Later, Einstein was able to predict, on the basis of his theories, that gravity would bend light, although this was at the time an un-testable prediction. Later still, physicists were able to predict that something as large as a Buckyball would demonstrate detectable quantum behavior (in a double slit experiment)—a trick that still retains something of the “wild and weird” in the popularizations of science. Similarly, the particular energy features of nuclei allow the prediction of the relative stability of some atoms rather than others, and even of atoms that had never been found or created, on the basis of “magic” numbers (literally, 2, 8, 20, 28, 40, 82, and 126).

It is not merely the numbers of physics that allow prediction; it is also the underlying order that those numbers sometimes represent. Unknown particles have been discovered based on the idea that a presumed underlying order of nature had a "hole" in it that should be filled by a particle of a particular type. For example, the Omega minus particle was predicted on the basis of the orderly array called "supermultiplets" (see Figure 2.3).

As many observers have noted, applications and theory form a circuit in physics, rather than a one-way street, as the example of the exploration of superconductivity illustrates. The discovery of superconductivity was not a neat product of a set of mathematical predictions. Rather it was more on the model of "what you find when you are digging around." But developing an explanation for what was found, through a series of phases of discovery, tinkering, and explanation, led to superconductors with more desirable properties for human use (e.g. the ability to function at higher temperatures), as well as a fuller understanding of why the unexpected phenomenon of superconductivity might exist.

It is also not merely successes in prediction that are useful in physics. The so-called "ultra-violet catastrophe" was the failure of classical equations to account correctly (or even plausibly) for the behavior of black-body radiation. This anomaly was a major prompt for the move to quantum physical understandings. Not all difficulties of prediction appear to be so useful. There remain rough spots in physics--places where predictions are only post hoc or "empirical"—where the basis for the equation is not well understood, or where the equations come close to predicting the associated outputs in the real world, but are not exactly right (e.g. the binding energy of a nucleus). There also

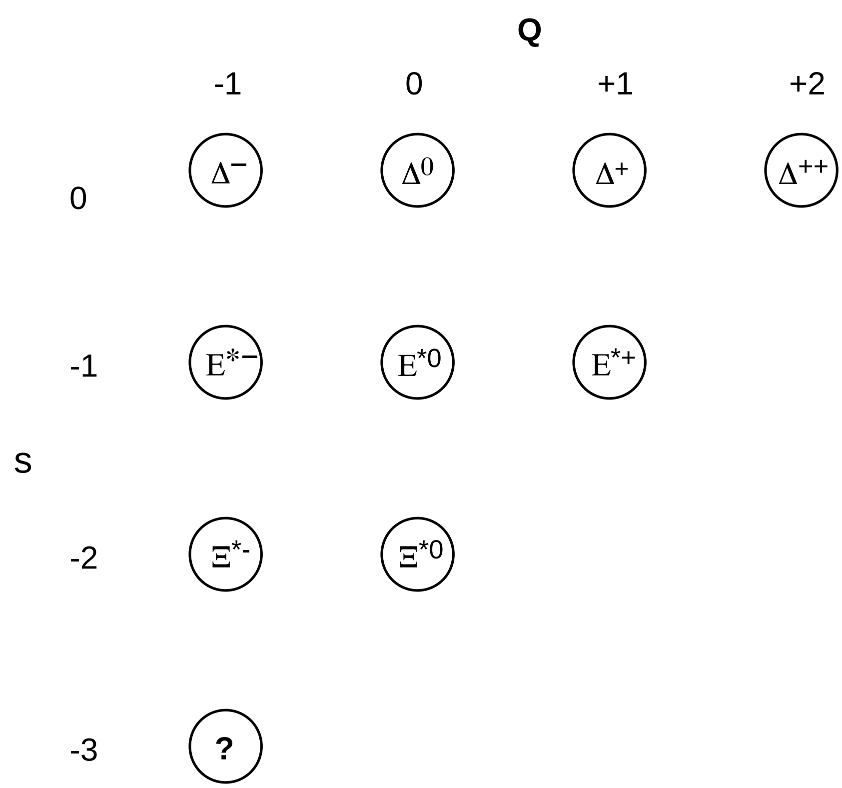

Figure 2-3: The Ω^- particle at the question mark on this diagram was predicted from the set of ordered relationships illustrated by this grid. After Beiser (2003, p. 489). S= strangenes; Q= Charge

remain many places where the physical equations exist in principle, but are computationally intractable. For example, although they work well enough for the hydrogen atom, physicists can't really use their abstract, basic explanations/equations to account for all of the forces due to the electrons in as simple and important an atom as carbon. As Chapter 3 will emphasize, the method of physics also doesn't fare well at predicting any large-scale phenomenon with any history underlying its characteristics, especially things like earthquakes and weather. Although the methods of physics are not all-powerful, they certainly have proven powerful enough to generate enormous control over physical being.

Controlling Physical Being

The kind of control that emerges from physics derives from the kind of predictions it allows and ultimately from the nature of physical being. A key and obvious feature of this type of control is that it allows one to arrange a given set of forces and objects to produce a given set of effects in a highly reliable manner. We would describe this control as reliable, tuneable, leveraged second-hand control. It is what allows control over physical being to be inserted into the "manufacturing" economy.

The time and space invariance of physical laws provides the essential ground for reliability of control. If the equations of physics only worked sometimes and in some places, the products of applied physics would be much less desirable. Even with such laws, the introduction of the practical and human limitations in production processes makes today's consumer goods and Mars Landers unreliable enough to cause some consternation!

The distinctive character of the statistical relationships in physical being at the classical scale is also important to the reliability of applied physics. As described above, on the scale at which most physical applications are made today, the fact that the behaviors of electrons and protons and such are only probabilistic rather than deterministic or absolute doesn't make any effective difference. Because the number of electrons involved in any classical-scale phenomenon is so large, you always get the average behavior. You can, literally, bank on it. If this were not true, if there were only fifty or a hundred electrons or photons manifesting their probabilistic behavior in any useful chunk of matter (a laser scalpel, a high-yield bomb), the utility of applied physics would be drastically modified, because the variability in the products would be dangerously variable.[55]

Another consequence of the frequency patterns of physics at the scale of classical physics is that the control allowed by the knowledge of physics is tuneable. Energy, matter and direction can be partitioned in almost any amount desired. In deploying electricity one can set the wattage, the voltage, the resistance to virtually any level needed. If that were not true, if there were only a few discrete options open to us, then we would surely have some useful applications for the knowledge of physics, but there certainly would not be a single grid of wires connecting up thousands of different home and industrial applications. In contrast, quantized behavior is fascinating, and may indirectly account for behavior on the macro scale, but if objects on the human scale manifested such behavior it would be far less easy to produce the thousands of conveniences engineering physics brings us every day.

A final important aspect of the control of physical being is its leverageability. Because all of physical being is governed by the same basic forces and elements, we can use intermediary tools to bring about desired end effects of a completely different physical nature than the intermediary tools themselves. For example, to tune a radio, one can turn a plastic handle. Tuning the radio means changing the frequency of radio waves it can receive. Plastic handles are not composed of radio waves or even of their receptors, and turning a knob in a clockwise motion has nothing directly to do with the amplitude of radio waves. Nonetheless, an action as simple as turning a knob can be programmed to produce a change in the frequency of waves a radio receives. This amazing sleight of hand is made possible by the relatively tight inter-relationships of all matter and energy in a constrained pyramidal structure of types. This commonality allows one physical entity (a plastic handle) to interface with another very different physical entity (a radio wave) in a tuneable fashion. This, in turn, allows people who know nothing of the underlying forces of physics, and nothing of the physical equations involved in setting up the tuning of a radio, but know only how to turn a plastic knob, to utilize on a daily basis the massive quantity of physical knowledge that has been so carefully, thoughtfully, masterfully put together over the past three centuries.

Physics thus provides an incredible and socially useful range of control over physical being, both because of the leveraging nature of the equations of physics and the leverageable nature of physical beings. There are nonetheless limits on this control. Some limits consist of relationships that the knowledge of physics tells us are impossible or close to impossible (e.g. heavy odd-odd number elements aren't stable so they will be hard to get and probably not very useful, so why bother?). Other limits are not absolute, but pose rather high level constraints. Even though physicists know that there might be gravity waves, they also know that their properties are such that it is extremely difficult to measure them. Even though physicists suspect that there is a Higgs boson, because it may be a thousand times the mass of a proton, it would take an enormously powerful particle accelerator to have a reasonable chance of identifying one.

Sometimes the difficulties involved exceed expectations, and expected control over a given physical entity eludes us. Producing power through nuclear fusion is one such instance. In the 1960's, scientists were predicting that unlimited cheap power from fusion reactors would be achieved within 30 years. Today, when they hazard any guess at all, they are predicting that it might be achieved in something like forty years.[56] Although physicists understand nuclear fusion itself fairly well, the forces involved are so large that controlling the reaction to produce useable power has proved infeasible in spite of considerable ingenuity and funding expended on the effort.

The ability to control physical being in the many ways physicists and engineers have developed thus is dependent on key features of physical being itself—its time and space invariance, the fact that very large numbers of particles aggregate to produce statistically average behavior, and the leverageability that arises from the interlocking character of the relatively small number of parts and levels. The ability to capitalize on these features of physical being, in order to control them, depends equally on physicists' having hit on a means of studying physical being appropriate to those features. The mathematical approaches that dominate physics elegantly interface with the statistical behavior of the components of physical being to create the concept of tuneability and enable us to exercise it. The assumption of time and space invariance—even if it is not strictly true--is true enough for enough purposes to enable mass production and marketing of conveniences designed to take advantage of physicists' formulations of nature's physical laws.

Whatever the limits prescribed by the nature of physical being and by our knowledge of it, it is crucial to integrate recognition that the control actually exercised over physical objects is also a product of human social factors that extend beyond physics. Human social factors not only encourage some applications rather than others, they also create limits on applications that might otherwise seem desirable. The generation of power from nuclear reactors is the poster child for this issue. Because nuclear reactions involve generating enormous, concentrated power, there is inherently some danger to nuclear reactors. This danger is exacerbated by the fact that nuclear radiation is harmful to people and other living things.

In principle, these problems are surmountable. As far as we know, the U.S. nuclear navy has managed to run dozens of submarines around the world for decades with no major casualties due to the use of nuclear power. In contrast, there have been major accidents or incidents involving commercial power generation in the U.S., the U.S.S.R., Britain, and Japan. The difference lies in part in the scale of the reactors. However, most of the difference arises from the social structure into which the technologies are inserted. At least while Admiral Rickover was in charge, the nuclear navy was relatively well trained and well disciplined.[57] In contrast, commercial nuclear reactors are sometimes shockingly poorly run. As the details of the Three Mile Island incident make clear, the staff may not be well trained, and modifications to key control areas can be made with no systematic thought to their safety implications. Commercial operations are designed to make money. In the contemporary business spirit, one advances one's career in a commercial operation by cutting costs this quarter and next. One hopes to move up the ladder and out of the local situation before the consequences of cost cutting hit home. This is no way to run nuclear reactors. Even when inherently safer technologies are available, issues of patent law, nationalism, and previous investment have precluded their use.[58] The problems of this type of social structure have provided fertile resources for those who object to nuclear power, enabling paralysis of its application.

Unfortunately, governmental bureaucracies have their own problems, as the Chernobyl incident demonstrated, and so government-run nuclear power plants have not appealed to many societies as an alternative. In spite of the relatively good prediction and control that understanding of physical principles offers over nuclear fission processes, there is not a very good match between nuclear power generation and human social foibles. Nuclear power may well be too powerful, too dangerous to living bodies, and too complex for a species like ours to control with comfort in our current state of social/intellectual development. Nuclear power generation thus provides an example of a crucial place at which a more materialistic approach to understanding humans and a better bridging of the separate cultures of "science" and "the humanities" is needed. We can't expect to operate nuclear power plants safely at a large scale unless our plans take into account both the nature of nuclear fission and the nature of the human beings running those plants. We can't generate an over-arching approach for doing so without at least a minimal shared perspective on what it is to know and to apply knowledge.

Conclusions

The implications of this chapter might, we fear, be misread. In showing that physics has succeeded so well only because the material on which it was focused was so well suited for such success, one might conclude that physics is not so impressive an achievement after all. That would be an erroneous conclusion. Physics is, indeed, one of the stunning intellectual achievements of humanity. The method of reductive idealizations from particular reality, which enables physics, constitutes the development of a major intellectual tool. To study the laws, equations, and analogies that physicists of the past hundred years have produced is a fabulous experience. Physics is beautiful, and understanding what it has created can bring one into a fascinating new relationship with the physical world.

The brilliance of physics, however, should be understood not as the discovery of a single machine that is suitable and sufficient for understanding everything and every kind of being. Rather, the brilliance of physics lies in its production of exactly the right kind of machine for understanding its object—the basic forces of the physical universe. It is the appropriateness of physics to its object, the beauty of the match between the physicists' methods and the physical universe, that should impress.

When we turnour attention to the aggregation of physical being and to the two other major realms of being—the biological and the symbolic—we will find that they are constituted somewhat differently, and so demand additional tools and sometimes different assumptions for their study. This is not to say that the two signature tools associated with physics—controlled experimentation and mathematical equations—lack all utility in other realms of study. Hypothesis testing, controlled experimentation, and mathematics can produce useful, even necessary, information in any realm of study. However, the characteristics of other forms of being are not constituted in a way that allows the methods of controlled experimentation and law-like equations to describe the bulk of the knowable material about aggregate physical being, biological being, or symbolic being. In these other realms, other tools become relatively more important. Knowledge in these other realms takes on different characteristics as well. Instead of universal laws in the form of equations, one has knowledge about specific instances and knowledge in the form of verbalized generalizations that feature various kinds of internal plasticity and ranges of external applicability. To use the idealized model provided by physics in these instances is therefore to employ an insufficient model, one that does not allow us to know all that there is to know.

There is, however, something given up when we are forced to leave the model of physics behind. The enduring attractiveness of the model of physics rests in the feel of absolute, comprehensive certainty that it provides. When one deals with universal laws and critical experiments, one has a sense that one's well-justified beliefs are not simply well-justified, but true and reliable for all time (even though that "sense" may well be misguided). Generalizations and verbalizations are inherently more ambiguous than laws and numbers. With such tools of knowledge, it is more difficult to maintain that rewarding feeling of certainty. Giving up the feeling of certainty and universality is nonetheless necessary. Landforms, life forms and symbolic forms change through time, and accounts of them must be able to incorporate descriptions of the differences at different times and places. The fuzzy boundaries and multiple inputs of physical aggregates along with the multiplication of kinds and the functionality of living entities necessitate heavy reliance on verbal descriptions. These generalizations and their variations make impossible the cool, elegant certainty of physics. To try, however, to maintain a false sense of certainty and universality in these realms is to endorse distortion in the name of truth. There may, however, be something gained for what is lost. We turn now to the other realms of being to see where those gains might lie.

Chapter 3: The Natural Sciences

Summary: The natural sciences, which deal with aggregations of physical being and include geology, oceanography, ecology, astronomy, and atmospheric science, differ significantly from physics and chemistry. For example, the natural sciences span great spatial and temporal scales, have numerous and diffuse types, deal with overlapping scales of forces, have great contextuality in time and space, and have complex patterns of causality. As a result, experimentation cannot be as singularly important to the natural sciences as it is to physics and chemistry, and instead rigorous observation and interpretation must be used as well. Likewise, multiple working hypotheses, rather than single hypotheses, must often be tested. Mathematics commonly takes a different role in the natural sciences from that in physics and chemistry, in that deduction of mathematical laws is rare, mathematical induction is more common, and mathematical modeling assumes a greater role. The knowledge generated is also different, in that *post-hoc* analysis can be, and often is, the desired and acceptable product. These differences set the natural sciences apart from physics and chemistry, and the natural sciences emerge as better methodological analogues of the social sciences and humanities.

As waves generated by a distant storm spread across a deep ocean, they finally come to that ocean's edge and crash on a rocky shoreline, slowly eroding headlands and cliffs of ancient sandstone. The sand grains of those sandstones, eroded millions of years ago from mountains long since vanished, are washed amidst the breakers. Finally they settle to leave a sandy beach amidst rounded remnants of bedrock. The waves meanwhile refresh the water of shoreline pools in which barnacles and anemones open their limbs and tentacles to feed on bits of sea life washed in from offshore. The line along which the waves crash moves up and down the shore twice each day, as the moon and sun tug at the entire ocean and, more subtly, at the land below. Out at sea, tiny planktic organisms take nutrients from the water and grow and reproduce, never reaching a size visible to the unaided human eye but feeding the entire ocean. The nutrients they use include nitrogen and phosphorous that may have been brought from the ocean's dark depths by waters rising to the sea surface after a journey of a thousand years. The plankton are ultimately eaten by small sea creatures who are in turn eaten by fish, or perhaps they die and sink to the seafloor, there to decay and release their nutrients or, less commonly, to be buried in the muds of the sea. Meanwhile, sea birds dive from the sky and pluck out the fish, carrying the nutrients once sequestered by plankton to nests ashore to feed their demanding hungry young. During the year in which those young mature, the land on which they live and the seafloor above which they feed will move together perhaps an inch in a slow dance that will, in two hundred million years, see all the present oceanic crust sink into the depths of the Earth.

All this action involves atoms, and their constituent subatomic particles, that would be the subject of physics, but now we see them as larger aggregate physical being treated by other sciences. In that spirit, having examined the character and methods of the idealization of physics in Chapter 2, we now turn to the natural sciences, which include geology, oceanography, atmospheric science, ecology, and astronomy. We refer to these as the "natural sciences" because they study phenomena found in natural settings like our shoreline, whereas physics and chemistry typically do their work in the lab and disaggregate, or even create *de novo* the items they are studying.[59] The contrast we are drawing is not between the natural sciences and the broad and rich academic discipline of physics. The contrast we are drawing is with the idealization of physics. That idealization focuses on the simplest endeavors physicists have undertaken, specifically the decompositional facets of the discipline. That idealization sacralizes experiment and mathematical equations as the only "scientific" components of research endeavors. As soon as physicists turn their attention to complex aggregations of matter, they face the same challenges as other natural sciences, and they may import the other research techniques common to the natural sciences. The contrast is drawn most clearly, however, not by ferreting out the "exceptional cases" in the real practice of physics, but rather by looking at the other natural sciences, which have as their core the study of the complex aggregations of physical being that appear in nature.

The objects of the natural sciences, in contrast to those idealized in the physics model, feature variation in scale, numerous and diffuse types that are related through overlapping forces, and space- and time-specificity. Consequently, methods of study in the natural sciences include more than mathematical equations and controlled critical experiments. Natural scientists may use multiple working hypotheses, interpretative methods, and post-hoc modeling. Instead of producing a set of universal mathematical laws that serve to predict the behavior of isolated components, they produce verbal, visual and mathematical models that account for the components of a complex system and explain how and why it came to take a given form.

The Character Of Aggregate Being In The Natural Sciences

Scale

One of the defining characteristics of the natural sciences is scale, in terms of both space and time. The level of physical being studied by modern physics is typically at the atomic or subatomic spatial scale and at the nanosecond to picosecond temporal scale. Classical physics characterized the behavior of larger bodies, famously up to the scale of planets, but viewed such large bodies as internally uniform and thus scale-invariant. The natural sciences, on the other hand, study phenomena ranging in scale from atoms to galaxies and in doing so take into account internal structure of great complexity. A geologist sees Earth at scales from that of microscopic crystals to tectonic plates, but must consider those plates in terms of kinds of crust and unique geological provinces that in turn consist of a wide variety of rock types, which in turn consist of differing proportions of various minerals. An oceanographer likewise works at scales from water droplets to oceans, and must consider each ocean (actually the entire world ocean) in terms of individual currents and water masses, and in terms of nutrient-cycling organisms in each. Even these scales pale in comparison to that of astronomy, where humans are just beginning to recognize planets in solar systems beyond our own and instead think in terms of stars whirling in galaxies in turn grouped in galactic clusters. The relevant temporal scales range from months to billions of years.

As we'll discuss below, one major implication of scale in the natural sciences is that experimentation is in many important cases impossible. Another result of large scale has been inaccessibility to even legions of researchers. The deep ocean remains a largely unexplored terrain, long after researchers have mapped the surface of the moon and Mars in far greater detail. Even more striking is the inability to sample the Earth's interior. The deepest wells penetrate about ten kilometers into a planet with a radius of 6378 kilometers; caves and mines don't even go that far. Geophysicists have cleverly made inferences about variation in properties within Earth's mantle by examining the speed at which seismic waves pass through. However, the lower limit of resolution of distinct bodies on their cross-sections remains on the order of hundreds of kilometers. Similarly, oceanographers now have maps of the seafloor generated from satellite measurements of the height of the sea surface, but the resolution of those maps remains remarkably low. These problems of inaccessibility, scale, and low resolution commonly lead to treatment of the mantle or the sea floor as if it were uniform, but it's more likely that "uniformity" is just the condition of things that haven't been closely examined.

Numerous and diffuse types

If physics enjoys the advantage of examining a few discrete types, the natural sciences instead treat multiple types, often with diffuse boundaries. For example, geologists have formally recognized more than 5000 minerals, and even attempts to resolve those types into discrete groups (.e.g, silicates, carbonates, and sulfates) fails when one encounters minerals like Tatarskite with its chemical formula $Ca_6Mg_2(SO_4)_2(CO_3)_2Cl_4(OH)_4.7H_2O$.[60] At a higher level of organization, geologists have recognized hundreds of different named rock types, many of which have gradational or arbitrary boundaries (e.g., between sandstone and conglomerate, or between granite and granodiorite). Undergraduates who have fled from the protons and electrons of physics sometimes come to realize that the discrete nature of those particles, elusive as they might be, at least provides enviably clear distinctions compared to the uncertainty of telling mudstone from shale from slate from phyllite from schist.

More importantly, things within types are commonly diffuse in the natural sciences. In geology, one describes a landscape in terms of landforms such as mountains, dunes, moraines, and valleys, but where a mountain ends and valley begins, or where one mountain ends and another begins, is an ill-defined thing. One might argue that this diffuse character is inconsequential, but it commonly frustrates attempts to test quantitative hypotheses about the size or spacing of such features.[61] Even at much finer scale, things one thinks are discrete become diffuse. For example, crystals that seem distinct have chemically altered margins where the surrounding groundwater has removed particular ions, and the surrounding groundwater, defined as a liquid and therefore structureless, takes on structure near the mineral surface. In this case, the seemingly uniform and distinct character of both crystal and solution are blurred, so that the aggregate physical being studied by the natural sciences loses the discreteness of abstract physical being or the uniform essence studied by physics.[62]

Overlapping Scale of Forces

In our discussion of physics, we argued that attribution of specific effects to specific forces has resulted from the discrete range of physical forces. In the natural sciences, forces are more prone to overlap, and researchers are more challenged to infer what has caused what. One example arises in examining the interpenetration of crystals and sedimentary grains in sediments rocks, as illustrated in Figure 3-1. Anyone familiar with plate tectonics and the deformation that occurs in rocks as continents collide might reasonably conclude that the interpenetration of a quartz crystal and an ooid captured in that sketch resulted from compression, and they might use the observed direction of interpenetration to infer directions of compression and ultimately of plate motion. If the compressional stress of plate-tectonic collisions can generate the Himalayas and Alps, surely it can press two grains of sediment together. However, a sedimentary petrologist familiar with compaction of sediments by the weight of overlying layers of sediments might instead reasonably conclude that the overlying weight had caused the observed interpenetration and might use that interpenetration to calculate a minimum depth of burial (with implications for the maturation of sedimentary organic matter and the formation of petroleum in surrounding rocks). A third geologist might focus on a third phenomenon, called "force of crystallization," wherein chemical precipitation at the surface of a growing crystal can impart sufficient force to physically displace surrounding mineral material.[63] All three interpretations are reasonable. Each of these potential accounts identifies a force of sufficient magnitude to cause the interpenetration of the quartz crystal into the ooid. The three combined illustrate the problems of isolating causes when forces act at overlapping scales.

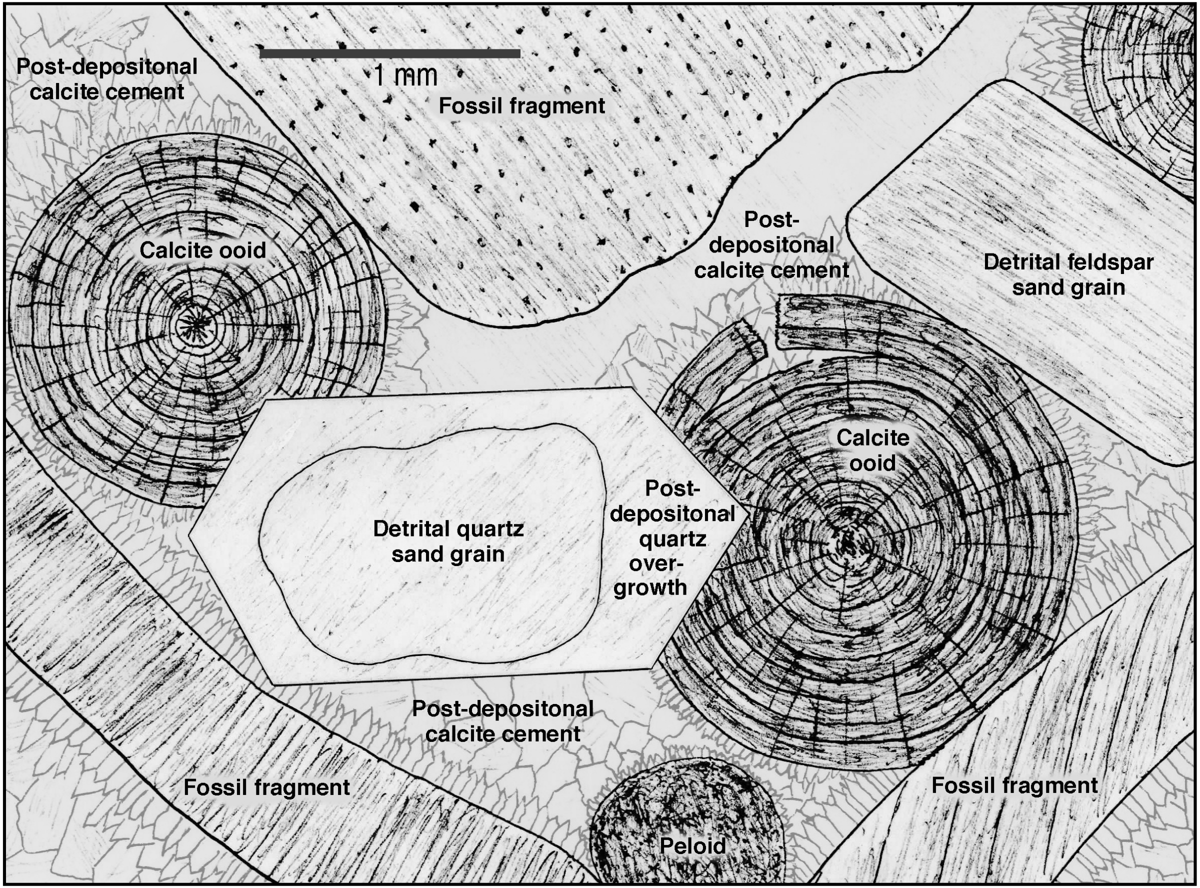

Figure 3-1: Sketch of a thin section of a hypothetical sandy limestone, the lithifed product of sediment deposited on a shallow sea floor. “Sand grains” here are derived from erosion of rocks on land, ooids are concretions of $CaCO_3$ that form as they roll about on the sea floor, and the fossil fragments are pieces of shells of organisms (clockwise from top, an echinoderm, a brachiopod, and a trilobite). Calcite cement and quartz overgrowth are material chemically precipitated onto edges of grains by water circulating through the sediment after its deposition. Possible causes of overlap of post-depositional quartz overgrowth with ooids are discussed in text.

<u>Space/Time Specificity</u>

As we noted earlier, the idealized model of physics (and chemistry like it) studies phenomena that are invariant through space: a hydrogen atom at one location is believed to be no different than a hydrogen atom elsewhere. This spatial invariance does not extend to the aggregations studied by the natural sciences, where spatial variation can exist across millimeters. For an example, we can return to Figure 3-1. The quartz within the area labeled “detrital quartz grain” consists of silicon and oxygen atoms in the same proportions and geometric arrangement as the silicon and oxygen atoms of the quartz labeled “quartz overgrowth cement.” From the standpoint of physics and chemistry, the two are effectively identical. However, in their geological context, they represent very different things. The detrital grain is a grain of sand eroded from some ancient rock, rolled and bounced along streams and rivers, wafted about on the sea floor, and finally deposited millions of years ago amidst the ooids and shell fragments that are the other grains of the sedimentary rock in which we find it today. In the space between those grains, groundwater has slowly precipitated minerals that presently hold the grains together as a rock. The “quartz overgrowth cement” is silicon and oxygen among this newer post-sedimentary mineral material, and the word “overgrowth” is used to indicate that the new chemically precipitated material has grown over the ancient sand grain with exactly the same crystallographic orientation. Thus there are volumes of quartz identical in all visible respects, but indicating two very different things: one about the erosion of quartz sand from some ancient outcropping inland and the journey of that sand grain down to the sea, and the other about the slow seepage of groundwater thorough the newly-deposited sediment, imperceptibly leaving behind quartz on the grain’s surface until finally a new sharp-edged crystal has formed. The two are contiguous in a tiny volume, the physical and chemical nature of the two are the same, and they follow the same physical and chemical rules of compressibility, thermal expansion, solubility, melting point, and the like, but they are utterly different in their significance to geology.

Context is of course also tremendously important in ecology. In a striking example recently discovered, three species of the fungal genus *Stictis* will grow saprotrophically as typical fungi on the bare wood of aspen trees, but the same species will join symbiotically with green algae to form lichens on the bark of the same trees.[64] The difference in mode of life is so great that the free-living and lichen-forming individuals had traditionally been placed in different genera, but molecular studies have shown them to be the same species. This ability of one species of organism to take two very different modes of life on the same tree exemplifies the contextual variance, or more generally the time/space variance, typical of the natural sciences.

In parallel with its assumption of invariance through space, physics studies phenomena that are invariant through time: a hydrogen atom today is believed to be no different than a hydrogen atom eight billion years ago. This time invariance does not extend to the aggregations studied by the natural sciences. Earth's crust four billion years ago was very different from the modern crust, and the position of pieces of continental crust has changed continuously, making Earth's present geography merely a snapshot in a long progression. Ocean circulation has changed significantly over the last few thousands of years and at longer time scales as well, largely in response to changing climatic conditions and plate-tectonic configurations. Earth's atmosphere has progressed from an early anoxic composition to its present oxidizing condition, largely as the result of photosynthesis, with resulting changes in soils and sediments covering Earth's surface. These changes make time a critical variable in the natural sciences, and few phenomena can be studied without consideration of their historical context, whether it be the hour-by-hour context of a storm system or the eon-by-eon context of a continent.

Study of evolving systems has made history a major facet of the natural sciences. Astronomy, as opposed to physics itself, devotes much of its attention to the history and evolution of stars, galaxies, and even the entire cosmos.[65] In geology, this focus on explaining the past is so great that the field is commonly defined simply as the study of "the history of the earth and its life." Oceanography as a whole devotes less attention to the past, but within it the field of paleoceanography has emerged to elucidate the history of the oceans. For these reasons, we would argue that, if the field of physics can be labeled "mechanistic" or "deterministic", the natural sciences instead are "historic" in their effort to explain not only the process but also the temporal evolution of natural systems.

Causality in the natural sciences

In Chapter 2, we argued that systems in abstract physics can be treated as though one cause leads to one effect. When causes are more complex, they can be decomposed by the method of vectors so that they can be dealt with, in effect, "one cause at a time." In the natural sciences, on the other hand, many phenomena are observed to be the result of multiple causes. Moreover, because the contributing causes are themselves the result of complex aggregates of causation, rather than a few simple underlying forces, they cannot be decomposed by a vector approach. The vector approach works only when the different causes can be measured on the same scale because they are essentially the same type of force.[66] For example, one of the fundamental generalizations of oceanography is that most of the world's deep water sinks in the Atlantic and ultimately flows at depth to the Indian and Pacific, where little deep water sinks.[67] The causes of this difference are manifold: the average surface salinity of the Atlantic is greater, which is in turn caused by the presence of enclosed low-latitude seas like the Mediterranean and Caribbean and by the narrowness of the Central American isthmus; the broad connection of the Atlantic to the Arctic, which allows a huge flux of cold water from the north; and the presence of an embayment in which sea ice freezes, the Weddell Sea, in the Atlantic coastline of Antarctica. In contrast, the lower surface salinity of the Pacific, its narrow connection to the Arctic through the Bering Straits, and the absence of an Antarctic embayment analogous to the Weddell Sea fail to promote formation of deep water in the Pacific. This difference between the Atlantic and Pacific goes on to contribute to differences in biological productivity, storage of carbon dioxide, distribution of deep-sea sediments, and coastal weather that have major implications for global ecology and human societal phenomena.

If the circulation of deep waters provides a specific example of a multiple-cause-and-multiple-effect (MCME) phenomenon, oceanography as an entire field provides a more general example. Three driving forces – solar energy, the Earth's internal heat, and the gravity of the moon and sun – interact to cause and control a plethora of oceanographic phenomena (Figure 3-2). Furthermore, these phenomena interact, so that almost every subject within oceanography, whether it be currents, waves, tides, sediments, organisms, or seawater chemistry, is controlled by multiple causes and in turn has multiple effects.

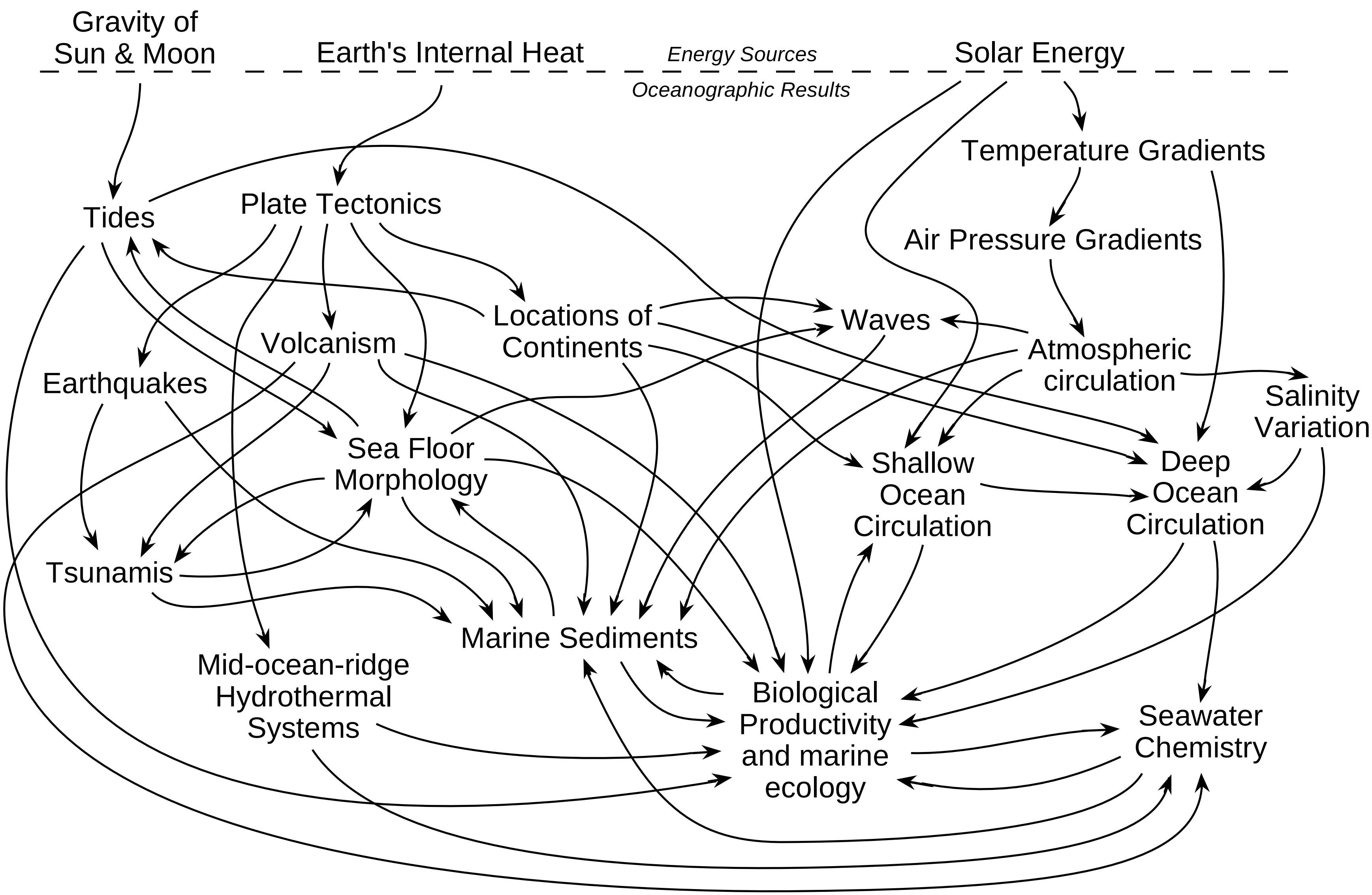

Figure 3-2: Patterns of causality in oceanography.

Diagrams like Figure 3-2 can be drawn for other natural sciences, and perhaps most notably in ecology. In ecology, several non-biological phenomena – for example, bedrock geology, temperature, rainfall, humidity, sunlight, slope, and soil – influence the diversity and abundance of multiple photosynthesizers, who affect each other's presence and abundance too. Those photosynthesizers in turn partly control the diversity and abundance of herbivores, who may affect each other's presence and abundance, and who in return partly control the abundance and diversity of photosynthesizers. The same multiple directions of causality exist between herbivores and primary carnivores, and between primary carnivores and secondary carnivores. The result is a system in which the question "what controls the abundance of this particular organism?" requires an answer involving a large number of causes, and the question "What other organisms does this same organism affect" likewise has a large number of effects as its answers.

Methods in the natural sciences

Experiments and Rigorous Observation

In Chapter 2, we observed that the study of physics is idealized as dependent solely upon the experimental method, in which one generates a hypothesis that is based in a theoretical rationale and then tests that hypothesis in a controlled and replicated experiment. "Control" requires that only one factor or parameter varies at the discretion of the experimenter while all others are held constant. Replication requires that the experiment be conducted multiple times to assure that the first result was not a fluke. This method has been famously successful in physics and is described in science books of all sorts as "The Scientific Method".

The strict adherence to controlled and replicated experimentation reported in physics has found application in the natural sciences only at small spatial and temporal scales. This is not to deny that the natural sciences have profited greatly from experimentation. Mineralogists determine the stability fields and solubility of minerals at various temperatures and pressures in controlled experiments, and sedimentologists conduct experiments in flumes to determine the styles of lamination and sorting resulting from different flow regimes. Ecologists conduct "bottle experiments" in which small numbers of small organisms are subjected to various artificial conditions in laboratory containers or greenhouses. Oceanographers have gone so far as to seed areas of the ocean with possible nutrients to study the response of marine ecosystems to those chemicals, and atmospheric scientists have seeded clouds to study resulting nucleation of droplets of water. However, these experiments only simulate short-term behavior at small scales, from which extrapolation must be made to the true scale of interest. Such extrapolations are rarely simply a process of magnification or multiplication, because scale matters. For example, the response of the entire ocean to a global and/or long-term forcing may very different than its response to a local and/or transient perturbation to which the larger system readily adjusts. Thus experimentation, the defining behavior of science in light of the idealized model from physics, provides at best small-scale and/or short-term clues to the questions pursued in the natural sciences.

As an example of the limits of experimentation, consider that all the world's geologists (even with massive increases in their currently meager funding) cannot induce two continents to collide, cannot observe the resulting behavior over millions of years, and cannot repeat the experiment to confirm that the results are replicable. The most useful experiments have been to construct layered masses of materials like plasticine, or of silicone and packed sand, to compress these models from the side until the layers fold and/or break, and determine the extent to which the resulting deformation in a few centimeters of plasticine or silicone resembles the observed deformation of an entire mountain range. Experiments of this sort have been performed to model the building of the Himalayas and the Alps, and they have been published in prestigious journals and even featured on the cover of the Geological Society of America's journal *Geology,* because this is the only means of getting "experimental" data.[68] To be meaningful, however, such experiments must be compared back to observed qualities of the natural scale items about which they presume to offer information. The scaled-down mock-up "experiments" have some uses, but they always require the questionable assumption that things at large scales can be accurately modeled in all relevant respects at small scale using more uniform, and often substantively different, materials.

At larger scales, experiment becomes impossible. A geologist cannot generate a planet 12,000 kilometers in diameter and weight 6×10^{24} kilograms, spike its interior with radioactive nuclides that warm it from the inside out, and observe its behavior for 4 billion years – and then replicate that experiment thirty times. A oceanographer likewise cannot put 1.4×10^{21} liters of water in interconnected tanks 6000 meters deep that rotate in a spherical coordinate system, heat that water differentially for two thousand years, and observe the results. Universities and funding agencies simply won't provide the facilities, and it's hard to keep graduate students around that long.

The alternative to controlled experimentation that has provided insight at meaningful spatial and temporal scales in the natural sciences is rigorous observation. As

Hartmut Grassl of the Max-Planck-Institut für Meterologie wrote, "The preferred scientific approach to complex systems is via experiments under controlled conditions . . . . In the geosciences, however, where deliberate experiments are impossible, the approach is via long-term, nearly global observations . . .".[69] For example, physical oceanography has profited immensely from a series of major regional and global surveys in which data were collected systematically. These have included MODE (the Mid-Ocean Dynamics Experiment), GATE (the Global atmosphere research program's Atlantic Tropical Experiment), SAVE (the South Atlantic Ventilation Experiment), SAFDE (the Subantarctic Flux and Dynamics Experiment), NABE (the North Atlantic Bloom Experiment), and most recently WOCE (the World Ocean Circulation Experiment). One may see in these names and E-terminated acronyms the desire of oceanographers to perform experimental science and be like physicists, but in fact none of these very profitable projects was an experiment – all were coordinated efforts to collect vast sets of naturally occurring data in uncontrolled settings, and thus were observational rather than experimental.

In another wing of oceanography, at least some scientists have been more than willing to cast off the appearance of experimental science. Alfred C. Redfield, after whom biological oceanography's Redfield Ratio of nutrients is named, wrote that, "in the United States the progress of marine biology was retarded for fifty years by the introduction of experimental studies."[70] Redfield went on in his essay, presented at a symposium in 1956, to stress the role of observation in biological oceanography. Experiments, he pointed out, were critical to developing the technologies used in observation, but it was observation that elucidated what went on in nature. When vociferously attacked by other participants in the symposium, he would only concede in response that biological oceanography would advance only if it used "all means of discovery at its disposal: observation, comparison, correlation, and experiment."

Unlike Redfield, ecologists have striven to maintain the appearance of experimentalism, despite the demands of multiple causality and large spatial and temporal scales of ecological phenomena – but much of their effort would be better categorized as rigorous observation. For example, Jared Diamond wrote in 1986 that ecology involves three kinds of experiments: laboratory experiments, field experiments, and natural experiments. Laboratory experiments involve setting up bottles, cages, or greenhouses with one or two species and observing responses to change in environment or monitoring competition between the two species. Laboratory experiments are indeed controlled and replicable experiments, but in Diamond's words they are characterized by "extreme unrealism and extremely limited scope," because real ecology involves communities of many species living in variable environments.

In contrast, according to Diamond, field experiments are performed in nature, and the experimenter manipulates one ecological variable, perhaps by removing or adding one species, while observing the response of the community. In the most simple case, two plots are used, one altered and one unaltered as a control; more meaningful experiments involve more plots. Field experiments thus have more realism than laboratory experiments, but lack of control on all variables and possible unappreciated variation between natural plots means that these are hardly controlled experiments by the definition from the idealization of physics.

Finally, in Diamond's so-called "natural experiments", the researcher observes ecosystems that have been perturbed by some natural or anthropogenic event, but the researcher does nothing to perturb or modify the environment. A site matching the perturbed site as nearly as possible in all other respects is selected as a control. Natural experiments maximize realism, but they are clearly not experiments in the classical definition: there is no control on variables, and no one variable is manipulated to observe dependent results. Instead, the format is rigorous observation. Geologists doing the same thing as Diamond's "natural experiments" – observing a natural system in the field – would likewise appreciate the value of data carefully collected from nature. However, they are much less likely to refer to their work as "an experiment" of any sort.

In summary, natural scientists of all sorts perform small-scale experiments as analogs to larger and more complex natural systems, but much of their research is, by necessity, rigorous observation of nature. Some branches of the natural science use the word "experiment" to characterize their large-scale observations, which provide their fields with great advances, but such work is far removed from the controlled experiments characterizing the idealized model of physics.

Multiple Working Hypotheses

The insufficiency of experimentation to meet the needs of the natural sciences has also led to a different view of hypotheses. The model used in physics and chemistry posits that all research uses experiments to test single hypotheses that, if not disproven, can be tentatively accepted as reasonable accounts of how the world operates. Work in the natural sciences, where testing of isolated hypotheses in controlled experiments is commonly not possible, has instead led to greater dependence on the concept of Multiple Working Hypotheses.[71] This method acknowledges multiple hypotheses and thus simultaneously seeks evidence supporting or disproving those hypotheses. As an example, a geologist might investigate the origin of a breccia, a body of rock consisting of large angular chunks of pre-existing rocks. Geologists have recognized several origins of breccias, including deposition on the earth surface as landslides, fragmentation of bedrock in fault zones, collapse of overlying strata where dissolution has produced caverns, and shattering where meteorites have impacted Earth's surface. If one undertook to study the formation of the breccia using the single-hypothesis method, one might test the fault-zone origin and find that the breccia is indeed located on a fault and that some clasts are internally deformed parallel to the orientation of the fault. This study, finding evidence to support its sole hypothesis and no evidence to disprove that hypothesis, would conclude that the breccia was caused by deformation in the fault zone. On the other hand, study using the method of multiple working hypotheses would instead seek evidence supporting or disproving all four hypotheses. Such an investigation might find that indeed a fault cuts the breccia, but that the breccia contains shatter cones, which are distinctive macroscopic structures caused by high-pressure near-instantaneous deformation, and that quartz within the breccia has microscopic lamellae likewise only known to originate in high-pressure high-strain-rate conditions. This investigation would conclude that the entire body of breccia was caused by an impact, and that a fault subsequently cut through the breccia. Temporal correlation of the impact with tsunamis or regional biological extinction might ultimately show that the impact had major implications for regional if not global history – but the impact would have gone unnoticed without application of multiple working hypotheses.

Interpretation

One method in the natural sciences not found at all in the traditional model of physics is interpretation. Interpretation, in this sense, is the process of inferring present reality from limited data regarding a diffusely bounded phenomenon that is not directly observable. The best example is probably that of field mapping in geology, a method first used famously by William Smith in the early 1800s and still the basis of much geological insight today.

A geological map aims to identify the kinds of rock or earth material present at all the locations within a map area. The area mapped by one geologist may be as small as a few square meters or, with sufficient time and effort, as large as several kilometers, whereas maps compiled from the work of multiple geologists may represent states, nations, continents, or the entire world. The individual geologist faces several challenges in mapping his or her chosen area, the most fundamental of which is that much of the bedrock is covered with vegetation, soil, or sediment. Any reader familiar with their local environment should reflect on how little of the land nearby consists of exposed bedrock (readers in Moab-like environments excepted!) but consider that at least one geologist, if not several, has probably produced a map purporting to identify the various kinds of bedrock underlying every inch of the landscape. One immediately has to ask how a geologist can make a scientifically reasonable statement as to the identity of materials that cannot be accessed by any practical means.

The answer is that geologists interpret the distribution of types of bedrock in an area using all available data, extrapolating from that data, extrapolating from trends known from the surrounding region, and using experienced judgment of subtle clues. For example, a geologist might be asked to produce a geologic map of the area from which the cross-section in Figure 3-3 was made. Bedrock is directly observable along 23% of the transect in the cross section, a proportion higher than that typical in nature, but that is all of the available data. Next, the geologist can extrapolate from that data. However, multiple extrapolations are possible, as the highly varied cross-sections in parts B to L of Figure 3-3 show, and these extrapolations imply different distribution of bedrock across the landscape. These extrapolations can be viewed as multiple working hypotheses, and our geologist may test Hypotheses E, F, H, and J by backtracking to look specifically for fault breccias in the valleys, or she may return to the western outcrop to test Hypothesis D by looking for evidence that beds are overturned. The geologist can also draw on her knowledge of the regional geology, favoring Hypotheses B to E and K if the region has been subjected to tectonic compression or Hypotheses F, H, or J if the region has undergone extension. Subtle clues matter too: if the geologist is convinced that the layers in the eastern outcrop are identical to those in the west, she will favor Hypotheses C, E. F, H, and J, or if she thinks the western valley is straighter than average but the eastern is not, she will favor Hypotheses F and H. Through all these considerations, the geologist must arrive at one conclusion that will dictate what rock types are shown in the areas with no outcrop. This is interpretation, not of history, and not of process, but of the present reality, and three different geologists mapping the same area may reach three different reasonable interpretations that will be mapped as the present reality.[72] This is not

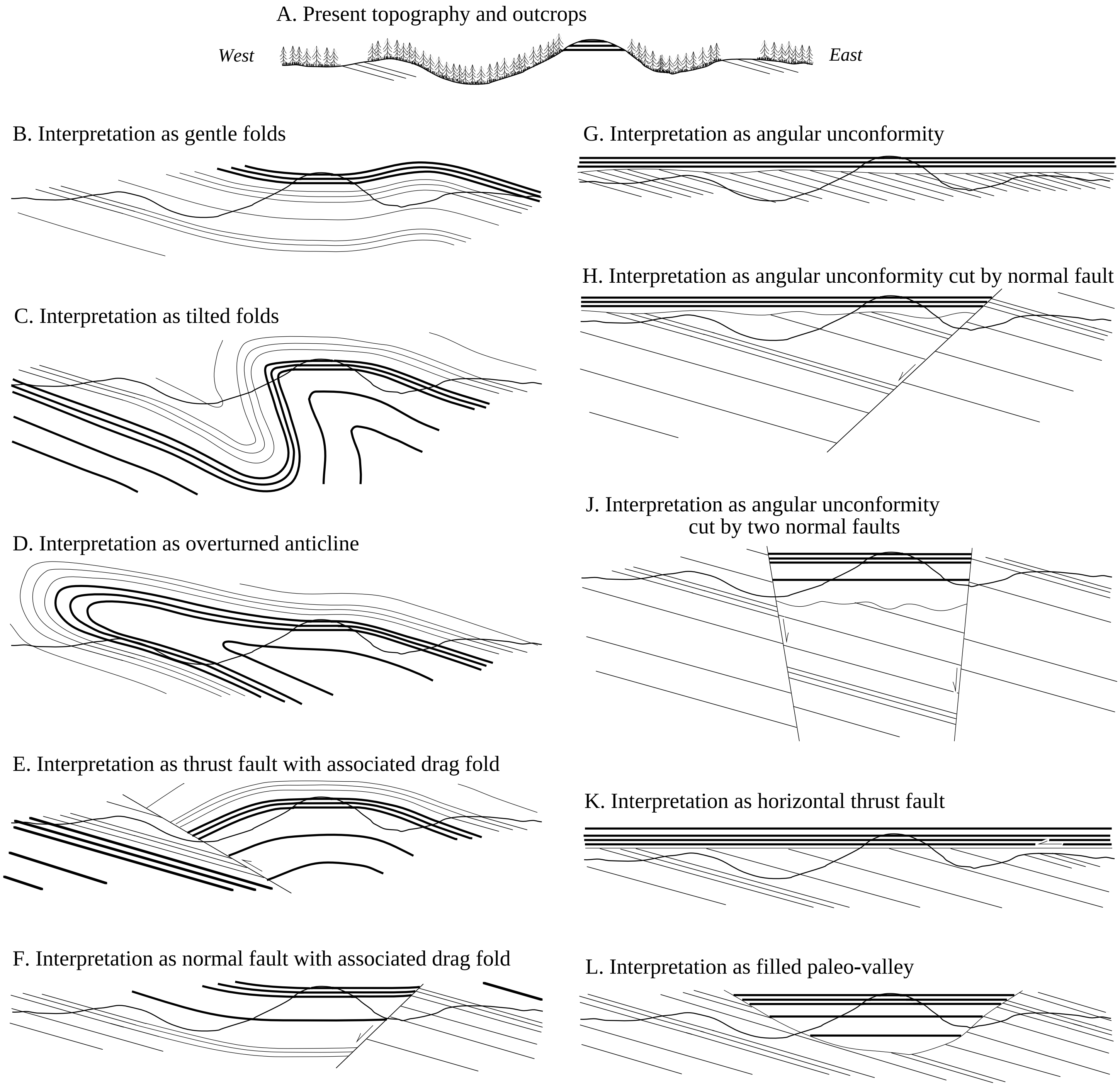

Figure 3-3: A: Cross-section (i.e., view from the side of a vertical cut) of the observed topography and outcrops along a hypothetical transect through forested hills and valleys. Interval of dark lines can be envisioned as slate and intervals of thin lines as schist. The proportion of landscape consisting of exposed rock (i.e., of outcrop) is considerably higher than that typically found in nature. B to L: Ten plausible interpretations of the underlying geology, and of now-eroded geology above present land surface. Note that these are interpretations of the present geological reality, not of history: different interpretations imply different rock types and orientations of layers in the areas below the tree-covered land. Faults are shown only as cropping out in valleys, a reasonable configuration because valleys commonly form along faults. Examination of relationships in three dimensions, rather than in the two shown here, would likely help eliminate some of the possible interpretations.

because any of the interpreters has made an error, but rather because they have emphasized different boundaries or relationships or evidence. Physicists and chemists may actually practice such interpretation, but it has no explicit role in the idealization of science that has arisen from popular conceptions of physics. Later we'll see that nearer methodological analogs may be interpretation in the humanities, where historians and rhetoricians likewise interpret events and motives where boundaries are indistinct and evidence is indirect.

Mathematics

As we observed in Chapter 2, mathematical equations are an important method, if not the entire goal, of physics. As John Gribben wrote in his book Schrodinger's Kittens and the Search for Reality (p. 66), "The reality resides in the mathematical equations themselves." Furthermore, as we saw in Chapter 2, physics derives great power from its ability to derive mathematical relationships from pre-existing mathematically stated physical laws. Mathematics commonly takes a different role in the natural sciences. For example, the only mathematically derive-able relationships in geology, such as Bragg's Law, the Van't Hoff equation, and equations for radioactive decay, come directly from physics and chemistry and provide solutions to small-scale problems.

Derivational or deductive mathematics applying the "laws" of physics to larger-scale geological problems have been less successful. The most famous example is Lord Kelvin's mathematically rigorous derivation of the age of the Earth. Kelvin's principal calculation used Earth's present surface temperature and rates of heat conductance to determine how long the planet had taken to cool from an initially molten state. Other calculations involved how long the sun could have been producing heat to warm the Earth. Kelvin used these calculations in the 1860s to reach the mathematically inescapable conclusion that the Earth was no more than 400 million years old; by the 1890s his improved calculations showed than the Earth was only 20 to 40 million years old, and closer to the former.[73] These mathematical derivations were assumed to invalidate decades of field work and more qualitative deduction by geologists beginning with James Hutton and Charles Lyell, who had estimated the Earth to have an age of billions of years, if not an effectively infinite one. The problem with Kelvin's derivation was that it ignored the contribution of radioactivity to Earth's internal heat, because of course heat from radioactivity wasn't understood until the early 1900s.[74] Ultimately a great many radiometric age determinations using diverse geological materials would lead to the conclusion that the Earth is 4.6 billion years old. Those individual age determinations would use derivational mathematics of radioactive decay, and thus use the mathematical model of physics individually, but the conclusion regarding Earth's age would be drawn by inference from such measurements on hundreds of samples, the context of each of which had to be evaluated by careful field work and detailed sampling.

This example regarding the age of the Earth illustrates a major difference in the role of mathematics in the natural sciences relative to that in idealized physics. Geologists and other natural scientists are not innumerate, but the mathematics they use is typically inductive, rather than deductive. Data are collected, and statistical analyses are then used to find trends, differences, and clusters within that data. The results are most commonly generalizations about the data, and hopefully they provide probabilistic predictions about systems as yet unstudied, but rarely do the results include mathematical laws that all systems are expected to follow.

As an example, we can consider one of the foremost mathematical generalizations in Ecology. Ecologists argue that ecology has a "general law"[75] called the species-area relationship, which is stated mathematically as

$$S = cA^z \qquad \text{or equivalently} \qquad \log S = \log c + z \log A$$

where S is the number of species found in an area A. In this law, c and z are numbers that vary with spatial and temporal scale, with type of taxa, and with ecological setting.[76] For example, z is typically smaller for studies within geographic provinces and greater for studies across provinces, and smaller for plants and larger for animals. z is also smaller for parts of one large landmass than for a group of islands. c is typically smaller for animals and greater for plants, and greater at low latitudes and less at high latitudes. In short, these parameters vary a lot, but in somewhat predictable ways. One should also appreciate there has been debate as to whether better forms of the law might actually be

$$S = zA + c$$

or perhaps

$$\log S = zA + c$$

for some data sets.[77] One should also bear in mind that these mathematical relationships only generalize sets of data in which individual data deviate considerably from the general trend, as the data on Antillean reptiles in Figure 3-4 show. Despite all the mathematical variation, this kind of quantitative generalization across data sets remains for many the Holy Grail of the natural sciences. Imagine, in contrast, the consternation of physicists if they were forced to concede that $E = mc^2$, the invariant relationship between

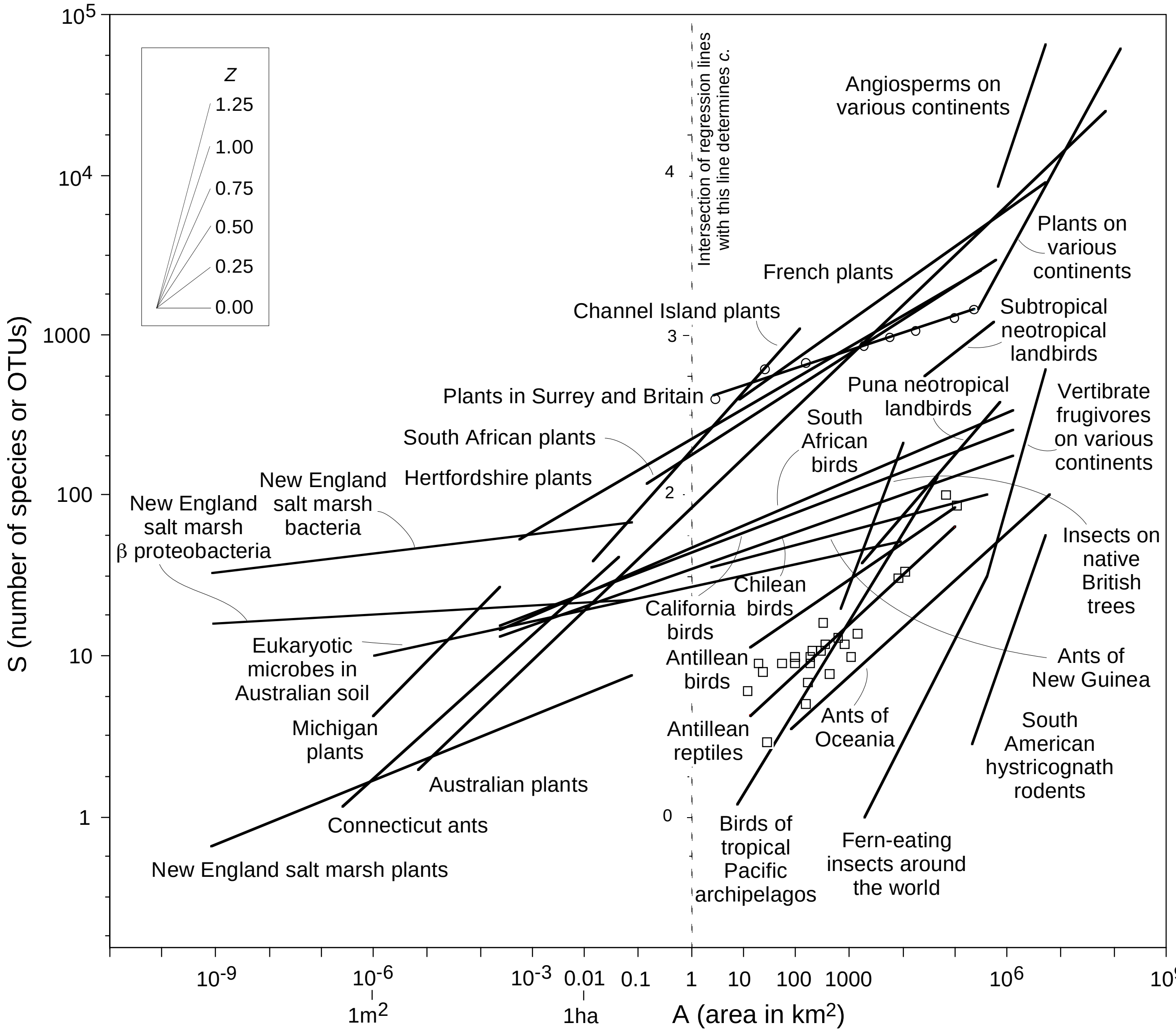

Figure 3-4: Regression lines for sets of data illustrating the species-area law in ecology, whereby $S=cA^{z}$. Inset at upper left shows values of z for representative slopes of regession lines. Intersection of regression lines with dotted vertical line at A = 1 yield c (for example, c = 0.3 for Antillean reptiles and 2.6 for Surrey plants). Individual data are shown for plants in Surrey and Britain (circles) and Antillean Reptiles (squares) to show range of variance in individual sets of data. S is number of species for plants and animals and operational taxonimic units (OTUs) for microbes. Regression lines are from Rosenzweig, 1995; Green et al., 2004; and Horner-Devine et al., 2004.

energy, mass and the speed of light, were really $E = qmc^z$, where q and z were variables dependent on local conditions and thus varying through space and time – or maybe it's actually log $E = qmc^z$ sometimes.

Another characteristic of the natural sciences is that mathematics is often applied toward modeling. For example, the many acronymically designated oceanographic projects discussed above were designed in large part to provide constraints for modeling, and WOCE (the World Ocean Circulation Experiment) was directly linked to NEG (the Numerical Experimentation Group), whose "experiments" were tests of computer models to see how accurately those models could *reproduce* the observational data (rather than showing that they could produce new data on specification by using a particular theory or technique). Numerical modeling is also closely linked, if not almost synonymous with, hydrology, and many other areas within the geosciences, which likewise seek to explain their data, test their hypotheses, and produce new insights via numerical models. One example derived from seemingly esoteric data but ultimately of considerable significance to modern humankind is geochemical modeling that has estimated, among other things, how the carbon dioxide concentration in the atmosphere has varied through geologic time.

An Example: carbon dioxide in Earth's atmosphere through geologic time

Past atmospheres have left few traces of themselves, and that's especially true of a relatively minor component like carbon dioxide. Estimation of the carbon dioxide content of the atmosphere through geologic time has thus been a considerable challenge, but researchers now have quantitative estimates of variation in that parameter over the last 540 million years.

The story begins in the 1950s with Harold Urey, who at the relatively young age of 41 had won the 1934 Nobel Prize in Chemistry for his discovery of deuterium, one of the heavy isotopes of hydrogen. Urey's interests drifted toward geochemistry, and his lab at the University of Chicago went on to produce the first generation of isotope geochemists, people who attempt to unravel Earth's history and processes by measuring ratios of naturally occurring isotopes in natural materials (e.g., ^{12}C, ^{13}C, and ^{14}C in everything from diamonds to limestones to air to meteorites). Urey is also relevant to our story because he pointed out in his 1952 book on the origin of the planets that the carbon dioxide content of a planetary atmosphere should most fundamentally be dictated by chemical equilibrium in the weathering of silicate minerals,[78] a thought that will reappear below.

By the 1960s and 1970s, isotope geochemistry had progressed to the extent that geochemists and carbonate petrologists (students of limestones) such as Jan Veizer had measured the carbon isotope composition (the ratio of the stable isotopes ^{13}C and ^{12}C) of $CaCO_3$ in hundreds of samples of marine limestones of different ages and from different locations.[79] These data were widely accepted as representing the isotopic composition of carbon dissolved in the oceans, and thus the atmosphere, through geologic time. During the same period, other geochemists such as George Claypool measured the sulfur isotope composition (the ratio of the stable isotopes ^{36}S and ^{34}S) of hundreds of marine sulfate sediments from around the world and from strata of all ages. These data were likewise taken to be a record of the sulfur isotope composition of sulfur dissolved in seawater through time. Statistical analysis (i.e., observational mathematics) of these seemingly unrelated results revealed two interesting things: the C and S isotope composition of these carbonate and sulfate sediments varied through time, and through time those compositions varied inversely (the C isotope composition of carbonate in limestones increased as the S isotope composition of sulfate in evaporite rocks decreased, and vice versa). Two ostensibly unrelated temporal trends were thus shown to be related by some previously unknown process.

An explanation of this relationship was provided by Robert Garrels, Eugene Perry, and Abraham Lerman, who argued in papers published in 1974, 1981, and 1984 that the linkage of the carbon and sulfur earth-surface systems reflected the criticality of oxygen to both. Carbon can be removed from the atmosphere and ocean and buried as a sediment either in oxidized form as $CaCO_3$ or in reduced form as organic carbon (CH_2O). Sulfur can similarly be removed from the atmosphere and ocean (mostly the ocean) in oxidized form as $CaSO_4$ or in reduced form as pyrite (FeS_2). Garrels and Lerman proposed that these systems were stoichiometrically linked by the mass-balance equation

$$4FeS_2 + CaCO_3 + 7\,CaMg(CO_3)_2 + 7SiO_2 + 15H_2O \Longleftrightarrow$$
$$15CH_2O + 8CaSO_4 + 2Fe_2O_3 + 7MgSiO_3$$

which contained within it the reactions written by Harold Urey years before. In essence, Garrels and Lerman proposed that the oceans would favor deposition of organic carbon (CH_2O) and $CaSO_4$ when FeS_2 and $CaCO_3$ were disproportionately weathered from pre-existing rocks (i.e., from left to right in the equation above). On the other hand, the oceans would favor deposition of pyrite and $CaCO_3$ when organic carbon and $CaSO_4$ were disproportionately weathered from pre-existing rocks (i.e., from right to left). The result of this system would be that some oxygen remained in the earth-surface system and maintained the oxygenated atmosphere known to have supported animal life over the last 540 million years.

To test this hypothesis, Garrels and Lerman used a box model, a system involving conceptual (and computational) boxes into which C and S were put and out of which they were taken. Their model employed six boxes (more formally, "reservoirs") that held C and S in the combined seawater-atmosphere system, in reduced sediments, and in oxidized sediments. They assumed that the concentration of carbon dioxide and sulfate and seawater-atmosphere system had remained constant through time. Their computational model transferred C and S between boxes at million-year time steps, with fluxes between boxes determined by a system of simultaneous differential equations. These computations generated changing abundances of sedimentary sulfate compatible with other estimates and changing C isotope compositions for the ocean that agreed with the observed record generated by Veizer and the other carbonate workers. In short, *post hoc* modeling using the mass-balance equation appeared to present a valid understanding of the linked earth-surface carbon-sulfur system.

At this point our story can turn to the issue of carbon dioxide itself. Robert Berner, a geochemist at Yale, co-authored papers with Garrels and fellow Yale faculty member Tony Lasaga in which they used a computer model to estimate the carbon dioxide content of the atmosphere. Their model included changes through time in weathering of rocks on the continents and depositon of carbonate sediments from the oceans. From this work, it became apparent that the warmer climate of the Cretaceous period (roughly 100 million years ago) was coincident with higher atmospheric carbon dioxide concentrations. Berner went on to generate a new model, Geocarb1, involving eleven equations monitoring six fluxes of carbon. Those equations were not derived from physical laws but instead largely kept track of transfers from one reservoir to another. These equations were used to calculate fluxes and reservoir contents every million years in the 570 million years since the beginning of the Cambrian period.[80] Berner's model incorporated inputs from geologic controls on the carbon cycle, including variation in land area for weathering (in turn a function of sea level), variation in kinds of lands plants as the result of biological evolution, and variation in the rate of plate-tectonic formation of new sea floor, which modulates volcanic output of carbon dioxide from the earth's interior. Subsequent versions of the Geocarb model published in 1994 and 2001 went on to include inputs regarding tectonic uplift and its effect on weathering, changes in solar radiation, changes in location of the continents, and several other considerations. These inputs of course came from the published work of other earth scientists, most if not all of whom had little idea that their results would be brought to bear on the history of carbon dioxide.

The end products of these papers were plots of Berner's best estimate of how the carbon dioxide content of Earth's atmosphere had changed through time. These results indicated that the atmospheric concentration of carbon dioxide in the Cambrian, Ordovician, and Silurian periods was twelve to twenty-six times that of today, that it then decreased in the Devonian to Mississippian periods to levels like that of today in the Pennsylvanian to Permian periods, that it then increased in the Triassic to levels in the Jurassic about eight times those of today, and that it then slowly decreased through the Cretaceous and Tertiary to the present.[81] These large variations in the model's results invited skepticism, but analyses of minerals from ancient soils by other workers provided independent single-time estimates that largely confirmed those findings.

The significance of Berner's results is that the carbon dioxide concentrations suggested by his model generally coincide with great changes in global climate from the Cambrian to the present. The two times of low carbon dioxide concentration, the Pennsylvanian and the Quaternary, have been recognized from other evidence as the two times of most intense glaciation since the Precambrian. The high carbon dioxide concentrations of the Jurassic, Cretaceous, and early Tertiary coincide with warmer times, as fossil Cretaceous breadfruit leaves in Greenland and fossil early Tertiary palm fronds in Wyoming attest. In short, the results of Berner's model support the argument that carbon dioxide as a greenhouse gas is a major control on global climate, in this case at long-term geologic time scales.[82]

The significance of this story to our consideration of the natural sciences is the difference between this work and that of the idealized version of physics. A result important to science and society arose not through a critical experiment or set of experiments but through inference from hundreds of measurements and observations. The result was further confirmed by testing against other observational, rather than experimental, evidence from the studies of ancient soils. Deduction was involved to initiate the mathematical model – for example, the stoichiometry of the mass-balance equation is quantitatively inescapable – but generation of the model itself rested heavily on inductive insight, and the specific components were influenced by subjective experience. The mathematical model used became more powerful as it incorporated more external inputs, each of which varies through time. The result was a powerful concept, but not a hypothesis testable with an experiment. If the genius of physics is to isolate the essence of a system, perform an experiment, and make an invariant mathematical statement about that essence,[83] the genius of work in the natural sciences is instead to recognize all the influences on a system and to generate a mathematical model approximating the system and accounting for its change through time and space as the result of multiple causes.[84] In the natural sciences, simplicity is merely the condition ascribed to things that are not yet understood well.

Theories in the Natural Sciences

The goal of any science is to develop theories. However, the kinds of theories sought by idealized physics, if not all of actual physics, differ from those inevitably developed in the natural sciences. First, theories in physics are expected to be simple and even elegant. Richard Feynman wrote that, ”You can recognize truth by its beauty and simplicity,” and that “This is common to all our laws: they all turn out to be simple things.”[85] Bernd T. Matthias is widely quoted as having asserted that, “If you see a formula in the Physical Review that extends over a quarter of a page, forget it. It's wrong. Nature isn't that complicated.”[86] Perhaps most strikingly, Paul Dirac wrote, “A physical law must possess mathematical beauty” and “. . . it is more important to have beauty in one's equations than to have them fit experiment.”[87]

These assumptions in physics are counter to the experience of the natural sciences. In the example above, Robert Berner’s first Geocarb model was questioned because of its simplicity, and Geocarb2 and Geocarb3 went on to incorporate more inputs and processes. At a larger scale in geology, the nineteenth century’s simple theory of the earth, a static model, gave way to a model in which continents moved (continental drift), which was in turn supplanted by a plate tectonic theory involving movement of both continents and oceanic crust, which has since gone on to incorporate microplates, plumes, swells, and fertile blobs. The relatively simple and time-invariant models of ocean circulation developed in the late 1800s to early 1900s have likewise slowly given way to more complex and dynamic models.[88] Marine ecology's assumption that all life in the oceans ultimately depends on photosynthesis had to be modified in the 1970s with the discovery of chemosynthetic vent communities, and now multiple types of vent and seep communities are known. Throughout the natural sciences, any assumption that more study leads to simpler theories has instead found the opposite, as more inputs and more special cases are found.

A second assumption about theories held by many physicists is that the number of general theories will decrease through time.[89] The most extreme but common version of this view is that the number of general theories will decrease until a single unifying theory is developed. Albert Einstein devoted many of his later years to the search for such a theory, and the titles of Steven Weinberg's *Dreams of a Final Theory: The Scientist's Search for the Ultimate Laws of Nature* and Stephen Hawking's *The Theory of Everything: The Origin and Fate of the Universe* speak for themselves. Even Lee Smolin, who dislikes the expression "a theory of everything," believes that research will ultimately lead to "a deeper and more unified understanding" of the phenomena presently treated by a variety of unjoined theories.[90]

In contrast, the natural sciences have little expectation of a grand unifying theory or theories. Instead, diverse theories have linkages, in parallel with the patterns of causality discussed previously. For example, plate tectonics offers explanations of how barriers to ocean currents have risen and fallen, and it explains why bridges for migration and barriers for allopatric speciation have developed or disappeared. However, no one expects a single grand plate-tectonic-like theory to predict all phenomena in the natural sciences. In this respect, and with regard to the simplicity of theories, the natural sciences have very different expectations about theories than those enunciated by leading scholars of physics. This is because the goal of the idealized version of physics is to account for a very few, perhaps only one, underlying force, whereas the goal of all other branches of study is to explore the many different ways in which physical components can aggregate.

Prediction, Accommodation, and *Post-hoc* Analysis

One of the messages of this chapter has been that experimentation plays a lesser role in the natural sciences than one might expect based on the idealized model of science derived from a partial account of physics, and that *post-hoc* explanations play a greater role. As Peter Lipton, a philosopher of science, has shown in a recent essay, experimentation and prediction are commonly considered more convincing than *post-hoc* accommodations of data.[91] One might thus take a dismissive view of the natural sciences because they commonly produce *post-hoc* explanations. However, extension of an analogy used by Lipton shows why such a view is not justified.

In our recasting of Lipton's analogy, an experimentalist is out hunting when he sees a red filled circle, presumably a target, painted on a barn in the distance. Taking aim, he fires a bullet that hits near the center of the target. Approaching the barn to evaluate his marksmanship, he finds someone painting a red circle around a pre-existing bullet hole. He laughs at the latter, explaining that there is no pride to be taken in painting a target around a bullet hole, whereas his ability to hit the target proves his marksmanship. The painter then explains that she is a forensic scientist marking the location of a bullet hole in the investigation of a murder at this site, and that she is far more interested in the exact location of the hole as a historical object than in how close he has been able to come to hitting an arbitrary target. Her only ultimate interest, and the only interest of the state and society that pay her, is in developing a historical *post-hoc* explanation of the origin of the pre-existing non-experimental bullet hole that she was labeling when the experimentalist came along.

This is of course not to say that our forensic scientist is ignorant of the experimental method or of the concept of falsifiability. She is of course familiar with an extensive literature reporting experimentally generated data on the marksmanship of various categories of shooters using different weapons, and with the literature on shapes of hole made by bullets tumbling in various experiments. Furthermore, in this particular investigation, she can conduct experiments to test certain aspects of her hypotheses by having various shooters try to replicate the shot under various controlled conditions. Negative results of those experiments can falsify hypotheses she has formed. However, she cannot now perform and observe an experiment involving the actual murderer and victim under the exact same conditions as those at the time of the murder. In attempting to determine the nature of a single historical event, she inevitably works after the fact and must construct a *post-hoc* explanation. Her role is thus like that of natural scientists attempting to understand historical events that took place thousands or millions of years ago – but the post-hoc nature of her work does not lessen its necessity or significance. The moral of this story is that whether *post-hoc* modeling is more or less impressive than a single successful test of a hypothesis by an experiment depends on what one wants to know.

A Natural Mirror

The natural sciences show many differences in character and methods from those of the idealization of traditional physics, and causality in the natural sciences involves more causes, effects, and feedbacks than usually involved in such physics. In future chapters we'll show that the natural sciences may more nearly mirror the social sciences and humanities in these respects than they resemble physics (also see Fig. 1-2). First, however, we must turn to biological being and the biological sciences as the springboard from which we'll move on to the study of human affairs.

Chapter 4: The Character of Biological Being

Summary: Biological being differs from physical being, in part because arrangement of physical entities such as atoms and molecules give rise to functionality and ultimately to self-similar reproduction in biology. In addition, evolution means that biological being is characterized by time specificity, and response and adaptation to environment mean that biologic being is space-specific. Biological being also consists of many more types than in physics, and those types are arranged in shrub-like configurations of taxa rather than in a pyramidal hierarchy. Finally, causality in biological being differs from that of physics in featuring functional networks in which multiple causes lead to multiple effects, rather than single causes with single effects. Attempts to use physical models in biology have produced advances in understanding the micro-dynamics of organisms, but the integrated nature of organisms as self-sustaining self-reproducing entities means that understanding biological being also requires methods beyond those of physics, as Chapter 5 will show.

The physical universe is vast and beautiful. Stars shine, casting light across spinning planets. Deep black holes circle furiously, birthing great galaxies. Tiny quarks bounce randomly, while fields of electrons play. Matter and energy, all that there is, simply Being. Yet if there is no life in this universe, if it is merely inanimate matter and mindless energy, our word for all this beauty is "sterile." We feel that a great and lovely universe, without life, is empty. What is this difference that life makes?

Both a living object and a non-living object are just made up of quarks and electrons and such, which are arranged into atoms of different types, which are then arranged into molecules of different kinds. Indeed, if we wanted to describe what was going on in any cell responding to its environment, we could, in theory, describe the cell's intake of nutrients or any other action simply in terms of chemical processes. It is also true, however, that such a description would miss the distinctive dimension of what was going on in that little piece of space-time. The cell is doing something that the lump of inert matter next to it is not doing, even if that inert matter has exactly the same numbers and types of molecules: the cell is actively maintaining a particular arrangement, that is a four-dimensional set of relationships among its physical components. Although it may maintain that set of relationships purely through physical means—the four forces of the universe and nothing more—an exclusive focus on the sub-microscopic interactions obscures the amazing things that happen to the arrangements on a larger scale.

Physical being also comes "arranged," and physical scientists often find the study of arrangements rewarding (e.g. the structure of atoms or outcrops). It is, however, unique qualities of arrangement that distinguish living beings as such.[92] Biological beings are constituted by forms that self-reproduce, and the fact of self-reproduction entails the fact of functionality. Consequently, biological being—understood at the organismal level and above--has features distinct from physical being: it is time- and space-specific, its functional circuitry produces a form of causation that is dynamic and systemic and thus opportunistic, and it therefore comes in an enormous range of populations rather than a few types. This chapter begins by describing the basic self-reproduction and functionality that distinguishes living and non-living beings and then addresses these unique characteristics.

What is Biological Being?

There have been numerous efforts to define what makes life different from inert being.[93] Textbooks in biology define life by assembling a list of characteristics that living beings often manifest: growth, metabolism, movement, reproduction, homeostasis, order, and responsiveness to the environment (see Table 1). These lists enumerate more precisely our underlying intuitions about what it means to be "animate." That is, they help specify what it is that we notice about most living beings that is different from non-living being. But they list common characteristics, rather than providing an essential definition. Efforts to define life in terms of essential characteristics have been subject to the lenses of those offering the definition. The physicist Erwin Shrödinger emphasized thermodynamics or entropy.[94] Philosophers emphasize autopoeisis, that is "self defining organization."[95] Computer scientists interested in artificial life and those biologists who have undertaken the task of definition have tended to emphasize self-replication: in the words of Maynard Smith, the "ability of like to beget like" (p. 9). Many people have offered insight-provoking discussions with these foci, and the definitional description we offer is quite close to several of these, which may recently have converged (see Table 4-2).

Table 4-1: Characteristics of Life

Characteristic	Sources	Characteristic	Sources
Reproduction	1,4,6,10,11,14,19,20	Homeostasis	3,11,20
Replication	3,5,7,13	Feedback	9,10,13,15
Evolutionary Adaptation	5,6,11,14,20	Response to Environment	1,3,10,11,19,20
Supple adaptation	2		
Genetic program	13	Open System	5,10
		Sense Organs	13
Growth	10,11,19	Movement	10,17,19,20,21
Development	3,5,20	Representationally guided movement devices	1
Differentiation	1,3		
Boundary Maintenance		Energy Utilization	3,4,5
Absorption/excretion	4	Negative entropy	6,18
Membranes (cell walls)	8	Metabolism	1,10,11,13,14,19,20
		Dissipative structure	10
Composed of cells	3,20		
Control	4,12	Function/purpose	1,12
Regulatory mechanisms	13	Teleonomic	13
Chemical Uniqueness	10l13	Vitality	16,21
Order	3,5,17,18,21	(Other)	
Nonrandom pattern	6	Uniqueness/variability	13
Highly complex	4,13	Dual level change	13
Functional organization	4	Life cycle/Historical	13
		Limited order of magnitude	13
Hierarchical	5,10,12		
	11	Quality not quantity	13
		Indeterminacy	13
		Self maintenance	19
		Repair	19
		Change	19

1 Agar (1997)
2 Bedau (1998)
3 Brum, McKane, Karp (1994)
4 Cambridge (1999)
5 Campbell, Reece & Mitchell (1999)
6 Chao (2000)
7 Dix (1983)
8 Hoffmeyer (2000)
9 Illich (1994)
10 Korzeniewski (2001)
11 Lange (1996)
12 Maynard Smith (1986)
13 Mayr (1982)
14 Purves & Orians (1983)
15 Rosenberg (1985)
16 Rowe (1992)
17 Schejter & Agassi (1994)
18 Schrödinger (1946)
19 Sherman and Sherman (1989)
20 Solomon & Berg (1995)
21 van der Steen (1997)

Table 4-2: Some Definitions of Life

Erwin Shrodinger (1946, p. 74 CK):

A living entity "goes on 'doing something: moving, exchanging matter with its environment, and so forth, and that for a much longer period than we would expect an inert piece of matter to 'keep going' under similar circumstances."

Maturana & Varela, (1980, p. 82):

"Autopoiesis is necessary and sufficient to characterize the organization of living systems"

Maynard Smith (1986, p. 9):

"The ability of like to beget like is the most fundamental characteristic of life."

Black's Legal Dictionary (1990, 6th ed., p. 923):

"The sum of the forces by which death is resisted"

Rowe (1992, p. 394):

"A creative animating process, life is an expression of the blue planet and its 4.6 billion years of evolution."

Scheiter & Agassi, (1994, p. 104, 105):

"The (entropically unfavorable) permanent transfer of matter against a gradient."
"The characteristic of living beings is that they are able to transform their ecological coordinates in the biosphere, so that they exist at all times in a viable ecosystem"

van der Steen (1997, p. 278):

"There are many candidate-units of life: individual organisms in evolutionary process, genes, species, the entire phylogenetic tree of organisms, ecosystems, indeed the earth itself (Lovelock, 1988 Schneider and Boston, 1991). Different contexts may require different **concepts** of life."

Korzeniewski (2001, p. 277):

"a living individual is …a system of inferior negative feedbacks subordinated to (being at service of) a superior positive feedback."

We suggest that the most useful approach to distinguishing living and non-living matter is to think about how life emerged from inert matter. The goal is not to provide a categorical definition, but instead to identify the key elements active in the transition from inorganic to organic being. Although relatively little is known about the origins of life, if one accepts the physicalist assumptions about those origins, then those assumptions specify a general idea of what the transition from inert to living must have been like. A set of molecules came together in such a way that they sustained a particular form, but they were also enabled to repeat that form by recruiting other molecules of the same type to establish another pair with the same form in the same type of molecules. Over time, some forms proved to be highly reproducible, and those increased in numbers. It turns out that an accumulation of particular structures proved to increase reproducibility. So those entities with such structures increased in numbers more rapidly than entities without such structuring. Over time, the variability of arrangements enabled more variability of arrangements that could replicate more readily, and a lush realm of biological being developed with new dimensions of complexity.

Given this way of thinking about how life emerged, living being appears distinguishable as a chain of forms that reproduce those same forms from their own locus. We call this type of arrangement self-locus reproducible forms. The duality of reproducibility and the self-locus are both important. It is not merely that a particular form is produced repeatedly: stars produce helium constantly, but neither the stars nor the helium are alive. The distinctiveness of living being lies in the way that the original form itself serves as the locus for producing another version of the same form, executed with a different set of molecules. Thus, a biological organism can be described as *a set of* *matter the arrangement of which can physically attract other matter in a fashion that maintains the form of the original matter (even in resistance to contrary local physical forces), and which is predisposed by that form to participate directly and materially in the reproduction of the same form/matter pairing*. The requirement for the form and matter to be paired distinguishes biological being from computer generated artificial life, which we suggest may prove eventually to constitute a fourth fundamental form of being.[96]

There is a distinctive and crucial tension at the core of this type of being. If the original molecules had only been able to self-maintain, then there would have been no evolution. There might have been an accumulation of these particles, based on the balance of the length of time they were able to self-maintain and the available molecules that could come together in that particular form. That would not look much like life as we know it; it would look more like the accumulation of sand on a sand bar or perhaps the growth of crystals. Thus, development of life with all of the characteristics we intuitively associate with life forms today (Table 4- I) required not only self-reproduction, but faulty self-reproduction. At its very core, therefore, life is self-similar, rather than self-identical. Life is the reproduction of a highly similar form, rather than exactly the same form. The variability of form was exacerbated when sexual reproduction developed.[97] To refine the definition, therefore, we need to say that a biological organism can be described as *a set of matter the arrangement of which can physically attract other matter in a fashion that maintains some basic forms of the original matter (even in resistance to contrary local physical forces), and which is* *predisposed to participate directly and materially in the generation of highly similar form/matter pairings.*[98]

The self-similar rather than self-identical quality of organisms pertains not only to reproduction but also to self-maintenance. An organism is not identical to itself from one moment to the next. In fact, over their lifetimes, organisms go through sometimes dramatic changes in form. Is it then simply a useful human categorization to call it "the same" organism? Is this much the same thing as when we call a river "the same" even though the water in it changes from moment to moment? At least in life as it has evolved on earth, living and inert beings differ in this regard. Living beings construct a semi-permeable boundary that constitutes a "self" that can admit resources and provide a screen from unfavorable environmental conditions, relocate to favorable environments, or even modify the local environment. Indeed, some biologists define the existence of a cell wall as a demarcator of living beings (see Table 4-1). The construction of a cell wall is not only a fabulous characteristic, it specifies that a living being is a "self" that has a kind of discrete autonomous identity unique to biological being.[99] Cell walls are indicators of the self-locus and were early enablers of the development of self-locus, but the existence of mostly coherent functional circuits enables the expansion of self-defining identity (autopoeises) beyond the cell walls and into the fourth dimension (time) of an organismal lifespan.

Function in Biology

Physical objects can be made to serve functions, but they do not have innate functions. In contrast, the distinguishing property of biological beings as self-maintaining forms inherently defines a functionality. Biologists such as Maynard Smith and Ernst Mayr have been cautious of the problems in function-talk, but they have recognized its necessity.[100] Indeed, Mayr argues that the requirement to attend to function distinguishes biology from physics, and we believe he is correct about this. Function-talk is confusing, however, because it is tied up in our daily language with notions of purpose and teleology. To separate the concept of function from purpose, we need to notice that there are two levels of "function" for a biological organism: one is the organismal level and the other that of sub-systems.

Talking about the functions of sub-systems is relatively unproblematic. When we say that "the function of a lung is to bring in oxygen and expel carbon dioxide" we aren't likely to assume that we are saying that a lung "wants" to do anything. We don't automatically anthropomorphize lungs. Instead, we understand that talking about the "function" of a lung is really just 1) to say what a lung does (which could be described in long-hand, purely in the vocabularies of physics, though it would be unproductively awkward to do so), but to do so 2) with an awareness that what the lung does fits into the larger organism in a way that is essential for the survival or reproduction of the organism. That second component cannot be accomplished purely with the concepts, methods, and vocabularies offered by physics. Because the organism is defined by its arrangement and the maintenance of that arrangement, a vocabulary and set of concepts about arrangements and maintenance (a function) is required. This new set of words and concepts are necessary not only to describe the organism's features, but also to *explain* why it has come to be as it has. Function-talk thus constitutes a new and necessary level of explanation, additional to the kinds of explanations used in physics.

As Mayr's analysis would indicate, such function talk is absolutely essential to understanding why the particular structures we call lungs exist in animals. If there were no beings that self-maintained and self-reproduced, the specific physical interaction sets that we call "lungs" would never exist. Lungs involve patterns of physical interaction that exist nowhere outside living organisms. Although these interactions do not violate physical laws,[101] an intricate series of interactions must have historically been generated and these must be precisely arranged to channel the forces identified in the laws of physics to the organism's self-maintenance. To explain the patterns of the organism thus requires an understanding of the history of the chain of organisms of which they are a part and a detailed understanding of the particular patterns of arrangements—which we will call networks of functional circuits—that make them possible. Physics, as we have noted, is ahistorical, and because it focuses on disaggregation, it lacks vocabulary, concepts, and tools for dealing with complex arrangements.

Although function talk on the component level is distinct from physics because it is focused on arrangements and must incorporate temporal relationships, it is still readily identified as a materialist enterprise. Things get more confusing in talk about function on the level of the organism. If one says that an organism functions to maintain itself and to reproduce itself, it is far easier to make the error of assuming that "function" here implies that the organism has some kind of choice about what it is going to do. Because an organism has a "self" (that is, a form or specified locus that is reproduced), it is easy to anthropomorphize function-talk and to presume that when we say an organism has a function we are attributing conscious intention to it. But the "self" of an organism is simply "that which gets reproduced" in contradistinction to that which does not. Thus functions obviously do not have to be understood as consciously intended. Perhaps it would be better to invent a technical terminology to talk about the fact that the structure of an organism takes the form it does because that structure has proven to be relatively self-maintainable and reproducible. Biologists often use “adaptation” as such a vocabulary, saying that an organism is “adapted” to its environment. Alternately, borrowing Mayr’s description of the biological mechanism as a “program,” one might invent a neologism such as “programmed goal” to describe the structuration of organisms as optimizing self-maintenance for reproducibility. Such labels, however, can also be misleading, for organisms are not little computers. What we call “their programs” are ordered interactions (generally involving DNA and proteins) that rheostatically channel external physical inputs, but more of that shortly.

Whether one invents new labels for organismal level “function” or not, this peculiar character of organisms—that they are organized in such a fashion that they have a series of sub-systems that *function to* maintain and reproduce the larger form of the organism—distinguishes living entities from non-living entities and produces unique characteristics of living entities. Without some vocabulary for describing these facets of the arrangement of living beings, at both the level of the organism and the sub-system, one cannot know much that is useful about them. In other words, because biological beings are defined by (and causally governed at) the level of their form, biological understanding requires vocabularies and methods distinct from those of physics. Talking about functions or programmed goals in biology is not just a convenience, or a merely pragmatic necessity,[102] but is the best way to describe sets of physical interactions, that are, in fact, historically determined as functions. These are functions from the perspective of the organism, not due to some conscious volition on its part, but merely due to the nature of its being an organism, which is to say it is a being that self maintains and replicates, as a part of a lineage of such self-similar reproduction. Thus, although function-talk in biology does introduce concepts that are not relevant to the inorganic world, function-talk is neither dispensable nor a reversion to defining life as a mysterious essence, but simply the best available description of what all living beings have in common in light of the way they have come to be arranged. It turns out that this functionality entails some distinctive characteristics of living beings.

<u>The Characteristics of Living Beings</u>

The laws of physical being happen to be such that relatively complex biological forms with many sub-systems are more successful at reproducing related forms over long stretches of time than are extremely simple forms.[103] This has interesting implications for other characteristics of life, especially the fact that the characteristics of living being vary across time and space. Difference multiplies at every point, as living being is manifested not in a neatly constrained pyramidal hierarchy but rather in a large sprawling number of non-discrete types and kinds called populations. Most crucially, because these forms include networked circuits with feedback loops, biological being displays causal relationships that are less serial and linear than mechanistic forces, instead including many interactive, dynamic and systemic patterns that appear opportunistic.

Time/space Specificity

Because organisms have "come to be" rather than existing through all time, it is not surprising that they are time- and space-variant. The same organisms are not found in all places and times. As far as we can tell, all life on earth (which is all humans currently know, perhaps will ever know) is part of a single lineage of organic being. That lineage is time-specific because you can't have a particular kind of organism without having previously had a series of different specific types of organisms.

Spaces are particular to lineage too. A species can only exist in a space with a relatively narrowly specified set of other species and non-living features. If these other features of the space change, the species either evolves to something different or it becomes extinct. Moreover, it seems reasonably likely that if life evolved in other solar systems, and if humans ever come in contact with it, it will not be an exact copy of life as it evolved on earth. Although there may be striking similarities because these organisms will also have to obey physical laws (i.e. convergent evolution writ large), the particularities of other spaces and the random vicissitudes of chance in time mean that any other lineages of life and the patterns of their relationships will also manifest differences from those on earth. The strongest form of this claim is that it would not be possible to reproduce the ecosystem of earth exactly on any other planet, even if that planet had exactly the same physical features as earth. The ecosystem on earth is a product of a long history of contingencies. If one tried to re-enact it in whole at any other place, one would be unable to capture the richness of all of those contingencies. The gaps and different balances would produce some differences from earth. Even if one could move it simultaneously in its entirety, over time new contingent differences would manifest themselves and the two ecosystems would soon evolve additional differences.

Time- and space-variance also manifest themselves in individual organisms. The same organism may behave differently in different environments. Moreover, the same organism may behave differently in the same environment at different times, depending on the order in which different environmental stimuli were introduced. Finally, the same organism may behave differently in the same environment with the same ordering if the state of its own internal clock is different. Organisms thus not only have different possible behaviors, but the particular behaviors that are demonstrated in any time-space are a product of an interaction between external conditions and internal ones, some of which are local and specific and all of which are at least partially due to the inherited lineage of the organism.

It is clear that the variability of the kinds of life across time and space is different from the invariance of the kinds of inorganic molecules, atoms, and quarks across time and space. While the distributions of physical kinds may vary across space, the very possibility of the coming-to-be of particular kinds of biological beings is time and space specific. Only at the beginning of the universe is this kind of fundamental variation taken as a possibility within the realm of physical being and this possibility is deliberately ignored in "model" physics. The enormous time/space variation of biological being has serious consequences for the nature of the generalizations that biological research can produce, and Chapter will detail the specific kinds of generalization that exist in biology, as well as the greater role for knowledge of specifics that exists in biological knowledge. However, time-space variance also means that kinds in biology swamp measurements of degrees in some ways, and the variability of kinds is also a distinctive characteristic of biology.

The Kinds of Biological Kinds

Physical being is arrayed in a relatively constrained pyramid of a relatively few types. Even in the aggregated forms of naturally occurring physical being on our planet, the number of natural kinds is relatively restrained. In contrast, biological being is arrayed as a lush tree of populations rather than as a constrained pyramid of types. The tree has the form of a relatively narrow base with wildly expanding branches. More recent characterizations describe the tree of life as more like a shrub or a spreading, mutating rhizome, rather than a stately redwood.

The branches of these shrubs bear something more like fuzzy globs of cotton fibers than like discrete leaves. In this respect, biological being is like aggregated physical being, where the types are more diffusely defined than in idealized physics. Biologists denote the specific historically defined character of their diffuse groupings by calling them "populations." Mayr identifies population thinking in contrast to typological thinking as a fundamental difference between biology and physics.[104] This distinction is founded in the fact that every biological being is unique (even twins and clones are different from each other due to developmental inputs).[105] Members are grouped together based on similarities, but differences always exist. Whether or not the differences are important to a given purpose is always an empirical matter, not an *a priori* given. Instead of simply assuming similarity, in biology the charting of similarity and difference is always a substantial part of the process of knowing. Both similarity and difference, after all, are essential to the process of evolution. This is why, when biologists discover a new phenomenon (e.g. recent discoveries of programmed cell death), the next research question must always be "how general is each component of these mechanisms" rather than simply an assumption that they are universal.

Given the variability of organisms, it is not surprising that it is difficult to define a species, and that definitions of species change over time depending on what kinds of information is available for classification (fossils only? fully preserved bodies? living entities? full genomes?). At best, when one says that two things are a member of the same species, one is saying that these two things are immediately descended members of a community, the overwhelming majority of the members of which are capable of inter-breeding. This definition of a species as an interbreeding community obviously doesn't apply to species that reproduce asexually and also can't in practice be applied to the study of any species from the past. [106] The working definition does, however, point out the relatedness of individuals, and based on that relatedness one expects a high degree of similarity (but not identity). Sub-groupings of species are even more diffuse.

Definitions of such groupings tend to be based on either selected key morphological or functional differences or on statistical thresholds of accumulated numbers of differences among individuals within groups. Today, many biologists use numerical taxonomy to recognize "OTUs" (Operational Taxonomic Units). Such units define species by arbitrary cut-off points in variation in some feature, especially in DNA sequence similarity in recent work.[107] For example, instead of the traditional, and difficult to operationalize, criterion of an inter-breeding group, one might define an OTU as a group of bacteria that share 97% similarity in their 16S ribosomal DNA sequences.[108]

Thus, in contrast to physics, the classification of biological entities into kinds has a relatively high degree of variability and it is based on a shared reproductive lineage rather than on a specific closed set of characteristics that are universally shared among its members (though characteristics that are relatively widely shared may exist and are useful in pragmatic assignment to groups).

Not only are the categories of biology fuzzy and changeable, but they are enormous in number. Living being can be divided into two or three types at the top of the pyramid (prokaryotes, eukaryotes and a category for "neither" variously constituted by different authors at different times). These are further divisible into a relatively small number of "kingdoms," but then things branch outward wildly. There are something like 80-100 phyla just of single-celled unicellular eukaryotes and 50-80 phyla of animals. These produce on the order of *10 million* different species on the planet.[109] Difference in biological being is thus not a simple matter of measuring degrees of difference among a few types of things (as it is in physics). Instead, difference in biology is difference among vast numbers of kinds, each of which is fuzzily bounded in itself.

A major consequence of this kind and amount of diversity is that knowledge of variation, difference and specific features is at least as important to understanding biology as is universality. If we were to limit ourselves to studying the "universals" of biology, we would have a relatively small set of things to study, and we would fail to understand an enormous amount about life. Organic being is not merely distinctive for its variation, it is also distinctive with regard to the patterns of causality that it manifests.

<u>Networks of Functional Circuits/"MICME" Cause-effect</u>

As we have seen, the patterns of cause-effect formulated in "model physics" are relatively simple. Although producing a full explanation using the "One Cause, One Effect" (OCOE) script often requires decomposition of more complex forces into vectors and linear series, the mechanistic model can be understood as a series of causes and effects which neatly add, subtract, or occasionally multiply with each other. OCOE cause-effect has the feel of simple predictability and clear relationship between input and output because of the simplicity of these relationships. Because they change through time, naturally occurring physical aggregates are better described with a "multiple interacting causes, multiple effects" (MICME) model, as Chapter 3 indicated. Living entities add transplexity to that complexity. The MICME causality of living beings is functional, which is to say it is defined by networks of rheostatic circuits.[110] Such function-based causation is always multi-leveled, in that it must be described at the level of component interactions, at the level of the organism, and also at the historical level of the lineage in order to provide a full account of its causation.

We have selected the phrase "network of circuits" as a useful metaphoric label to describe the distinctive features of biological beings. These biological "circuits" are not really organized in the simple linear series we identify with transistor circuits or running circuits on an athletic field. Instead, the circuits of biological organisms are defined by the linearity of DNA or mRNA *along with* the densely packed and somewhat disordered components of the cell. While the linearity of the DNA or RNA molecule no doubt contributes to the possibility of the circuit-like quality of biological systems, it is also the case that interactions among components in a circuit can take place at various places in the cell. Physically, interactions within a circuit may just represent the bumping of one molecule into another. The circuit is governed in such cases by the probability distributions of the specific interactions (which have to do with the number of molecules of a particular type in a cell at a time as well as the energy properties of their interactions). On organismal scales, the circuits are constituted through the same mixing of relatively ordered systems (e.g., the ordered paths of the human body's circulatory system) with probabilistically governed interactions (the proportion of oxygen in the atmosphere). The term "circuit" thus refers conceptually to a temporal dimension—a set of interactions must happen in a series—rather than necessarily to the orderly physical contiguity of the steps of the reaction. Keeping that meaning of "circuit" in mind, such biological circuits are further organized into networks. This is to say that one set of relatively tightly coupled interactions may have further implications for (that is, interactions with) other sets of relatively tightly coupled interactions. Thus, what is going on in the heart can affect how well the liver is able to function.

As many observers have indicated, a crucial feature of biological circuits is their rheostatic quality. That is, in general biological circuits have evolved to produce particular ranges of outputs from a larger range of potential inputs. Figure 4.1 illustrates a standard network of biological circuits (we'll give specific, concrete examples below), and it can be used to illustrate the distinctive causal interactions in biology. Imagine that you perturb node #9 in the circuit, and treat that as a "cause," the effect of which you wish to determine. If biological systems featured simple OCOE models of causation (see Figure 2, chapter 2), then all you would have to do is follow the series of cause-effect relationships from 9 to 10, from 10 to 11, from 11 to 8 from 8 to 16 from 16 to 11, and so

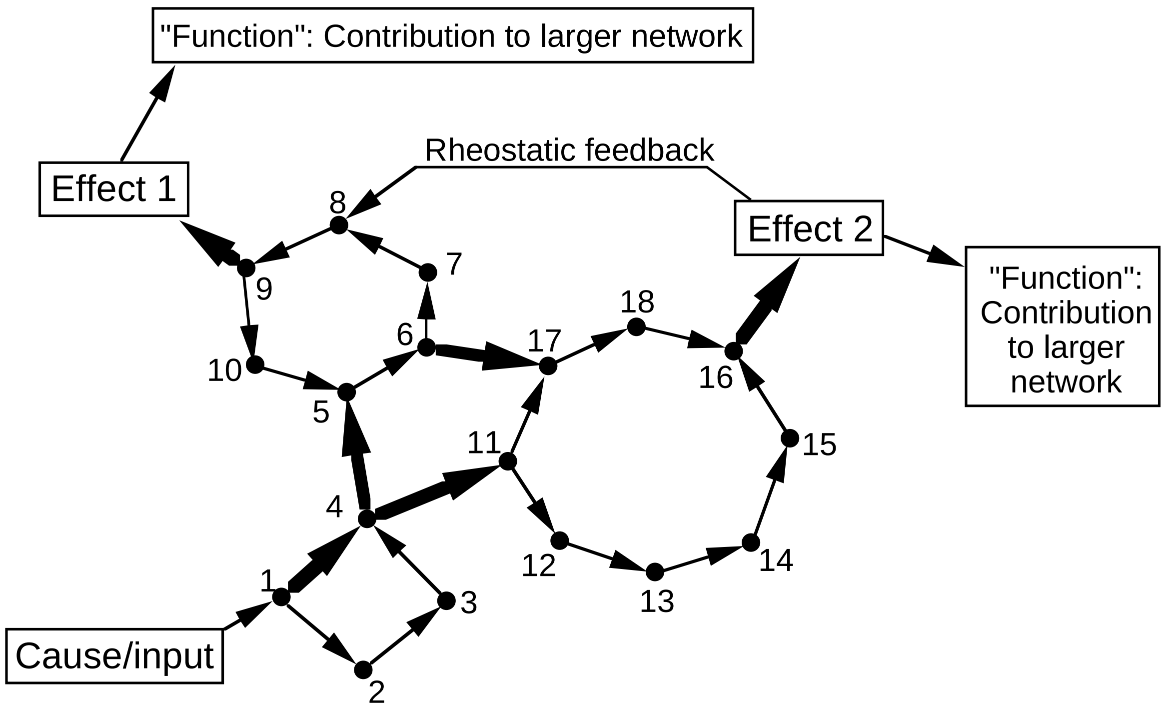

Figure 4-1: A MICME (multiple cause - multiple effect) circuit of causality.

on down the line. This might be difficult and tedious, perhaps even pragmatically impossible, but it would just be a long and tedious series that could theoretically be worked out in the same fashion as simpler problems in physics. However, you will notice that the biological system presents two additional dimensions to cause-effect. The first dimension is that inputs at node 9 chain out in two different ways: they affect the "A" circuit that then impacts on the "C" circuit, but they also impact the "B" circuit, which then impacts on the "C" circuit. This means that the effect "E" is determined by two simultaneously different inputs, both of which were instigated by the single input at 9. This dual input from a single cause is different from the model used in physics, and its differential effectivity is magnified by a second dimension--the fact that all of the nodes of the system may vary through time. This internal variability means that you may not get a stable value for the relationship between a causal input at 9 and an effect at E, because the effect may vary every time depending on the state of all of the nodes in the circuit.

Variations may be due to outside or "environmental" factors or they may due to developmental programs run sequentially within the organism itself, or due to sheer deterioration of circuits over time. This enormous potential for variability should make organisms wildly unstable. It certainly contributes to their enormous developmental plasticity and variability in behavioral responses. It is also what enables the coming into existence of an enormous number of different types of living beings from a small number of basic physical building blocks. However, the striking feature of biological systems is the way in which the potential variability in their circuits evolves in such a way as to produce a relatively stable range of outputs. Primarily through the use of various kinds of feedback loops, biological circuits tend to convert larger ranges of external inputs into a functionally advantageous range of internal "throughputs." Thus, for example, the human body's mechanisms for producing useable energy involve an enormously complex network of sugar utilization devices and sugar storage devices. Whether sugar inputs to the body are extremely low or extremely high, the network functions to produce a relatively stable blood sugar level. Of course, the complexity of the system also means there are many places for dysfunction, but in most cases the system functions effectively to drive an enormous range of sub-functions during the reproductive lifespan of the individual.

Biological beings thus harness the potential variability of networks of circuits to produce functional outcomes. To understand the outcomes requires not just a description of how each step in the series leads to the next step (though that relationship is very useful and represents the enormous contribution of biochemistry to biology in the past few decades). Understanding *also* requires, however, attention to the connections of functions within the organism and its lineages. As Chapter 11 will indicate, methodologies that address the circuit may be more successful than methodologies that seek only to identify its parts.

This account is consistent with the position that every interaction that is produced in biological beings is a product of nothing but physical interactions. The existence of rheostatically governed MICME patterns of causation at the level of the cell or organism is a product of the OCOE relationships at each node of the circuit. Thus, the existence of MICME patterns at the level of the organism does not mean that the circuit is overruling physical laws. The circuit uses and channels the physical laws, rather than denying them.

It employs the laws "opportunistically" to serve biological functions. A complete understanding of biological being thus requires both the micro-analysis of the physical interactions and the macro-analysis of the organism or larger phenomena. To further clarify, we'll explore the relationships between the human psychology of causation and the OCOE/MICME confusion below, and the mixed effects of that confusion in the next chapter. For now, however, it is important to provide examples of some of the efforts in biology to examine specific networked circuits, which will help bring home their transplexity.

A clear illustration of the nature of biological circuits comes from regulator molecules that interact with genes. Richard Young's lab group traced all of the different regulatory networks they could find in a specific type of yeast and located 6 different ways that the 106 regulator molecules can tune the organism's thousands of genes up or down.[111] As Figure 4-2 shows, these six different approaches include autoregulation, single inputs to multiple genes, chains of regulators, feed forward loops, multiple inputs from multiple regulators to multiple related genes, and multiple component loops. Each of these "circuits" channels internal and external inputs into different specific outcomes that depend upon the circuit structure as much as upon the nature of the input. They may amplify, dampen, or moderate effects. They thus serve as a causal locus. Imagine, for example, that molecule X is introduced to both Organism A and Organism B. In Organism A, molecule X interacts with a "single inputs to multiple genes" loop, so the insertion of molecule X results in numerous genes being "turned on" in Organism A, as a consequence of which organism X produces a series of proteins to convert molecule X to an energy source. Organism B, however, has evolved so that molecule X is part of a

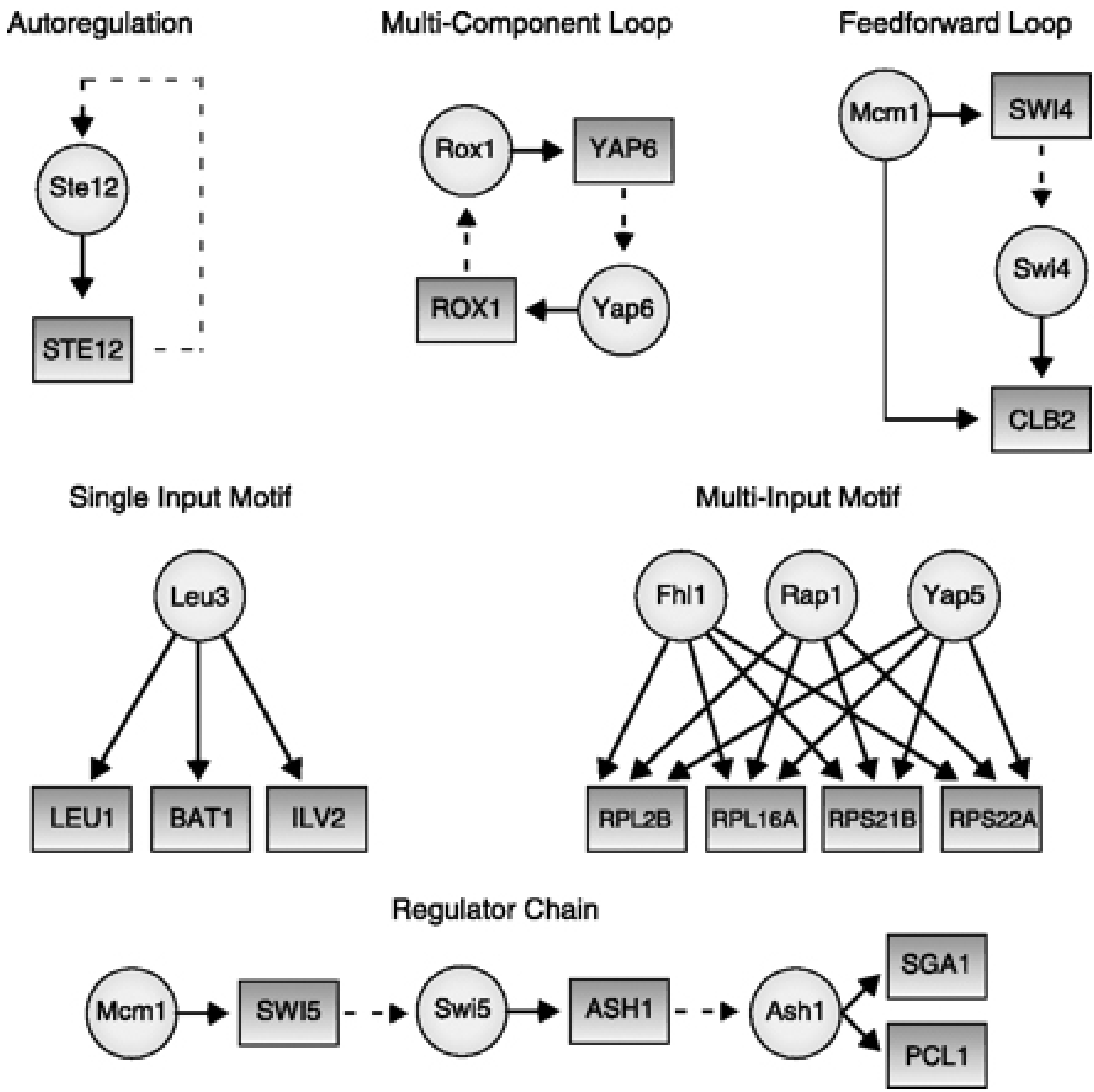

Fig. 4-2 Lee et al.

"multiple regulators to multiple related genes" circuit. If the other multiple regulators are available, then when molecule X arrives, Organism B will also produce the proteins to convert molecule X to an energy source, but if the other regulators are not available, then Organism B will just sit there with its undigested X, perhaps accumulating it even to toxic levels. Molecule X thus can have very different impacts on two organisms that might be quite similar, depending solely on the particular circuit structure of the organism (and its current state).

This example conflates differences of degree with differences of impact. Different biological circuits can produce both kinds of effects. Quantitatively, variations in circuit type can either massively escalate a response (through feedback cascades) or dampen it (through circuit breakers or other devices), or something in between. Consequently, biological responses to inputs can seem massively contrary to the scale of input. A tiny single base pair mutation in a 3 billion base pair genome can be fatal. On the other hand, recent research has discovered stretches of DNA as large as hundreds of thousands of bases long that may be absent in some healthy humans and present in others.[112] While these relatively large differences in DNA may have some effect that may be detected at some point in the future, the effects are certainly small compared to the major effects of single gene disorders such as Tay Sachs or sickle cell.[113]

Biological circuits are also stunning for their ability to produce different *kinds* of things with the same input. Put sugars into an organism and you can get out movement or new cells or heat or an electrical shock. The circuit determines the "effect" as much as do the external inputs. Again, this does not deny that each point of the circuit functions in accord with the laws of physical being. What it requires, however, is that if one is to understand the functioning of the organism and make predictions *about the organism*, one has to understand and attend to both the OCOE mechanisms of the circuit and to the characteristics of the circuit qua circuit.

An additional complexity is added to biological circuits by the fact that natural selection is extremely thrifty. It recruits the same genes, mRNA, proteins, or parts of the same genes, mRNA, or proteins for different functions in different systems. Network models of the interactions among components in biological systems thus become extremely complex (see Figure 4-3). This means that actions (or problems) in one functional circuit can produce effects in other organismal parts or circuits that are not necessarily functionally related. For example, a particular pathway or series of steps is responsible for metabolizing alcohol in humans. Some people have an inactive aldehyde dehydrogenase-2 gene in that pathway, and so acetylahyde builds up in the body. Because the body's systems are all inter-acting, however, the long-term consequences are manifested on very different parts of the body. Long term the constant high levels of blood acetaldehyde levels may affect the circulatory system by increasing the Mean Corpuscular Volume. This increase then may have several other effects, one of the better documented of which is an eventual case of cancer of the esophagus![114] A single, simple, pathway for processing a single chemical thus is inter-related through several levels and systems to different impacts on the functioning of several other systems in the body. This sticky interconnectedness makes it extremely difficult to trace out what causes what and even how different components are related.

There is yet one more level of complexity involved. Organisms have life cycles. They develop. Consequently, the effect of an input on a cell or organism at a given

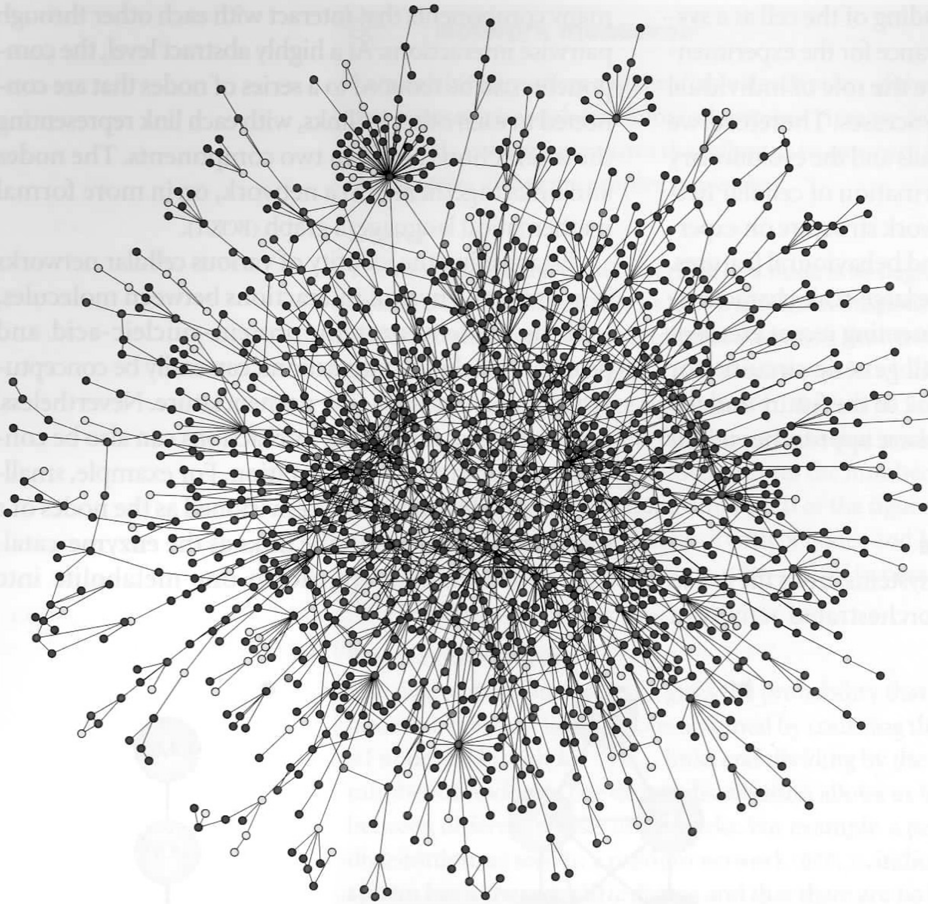

Figure 4-3: Map of a yeast-protein interaction network.
From Barabási & Oltvai, 2004.

developmental point may be enormously different from the effect of the input at a different point in the developmental cycle. Recent research on the causes of the increasing number of cases of asthma illustrates these complexities well.[115] For proper immune functioning, current research suggests that two types of molecules called TH1 and TH2 generally need to balance each other. When human infants are born, however, there appears to be an excess of TH1 over TH2. Exposure to substantial quantities of endotoxin appears to help rebalance the circulation of these two substances in the first years of life. However, recent research indicates that this effect appears almost exclusively in individuals who have a so-called “TT” genotype rather than “CT” or “CC” genotypes. This means that the input of endotoxin produces different effects depending on an individual’s genotype (see figure 4-4). People with the TT genotype who are not exposed to endotoxin will have a high likelihood of getting asthma, but if they are exposed to high levels of endotoxin, they will have a much lower likelihood of getting asthma. People with the other genotypes do not respond to endotoxin in the same way. This is called an “interaction effect” and the crossing lines of Figure 4.4 pop up everywhere in studies that investigate the relationships of genes and environment.[116]

Such interaction effects mean that it is not possible to specify a general rule about what effect endotoxin will have on a given species. Indeed, if you look at the species as a whole, it looks like endotoxin has no effect at all, because with an opposite-effect interaction, you have may have approximately the same mean for the population as a whole before and after exposure (as indicated in Figure 4-4).

Even knowing the genotype of an individual does not allow one to predict whether the individual will or won’t get a specific response from a specific input. The

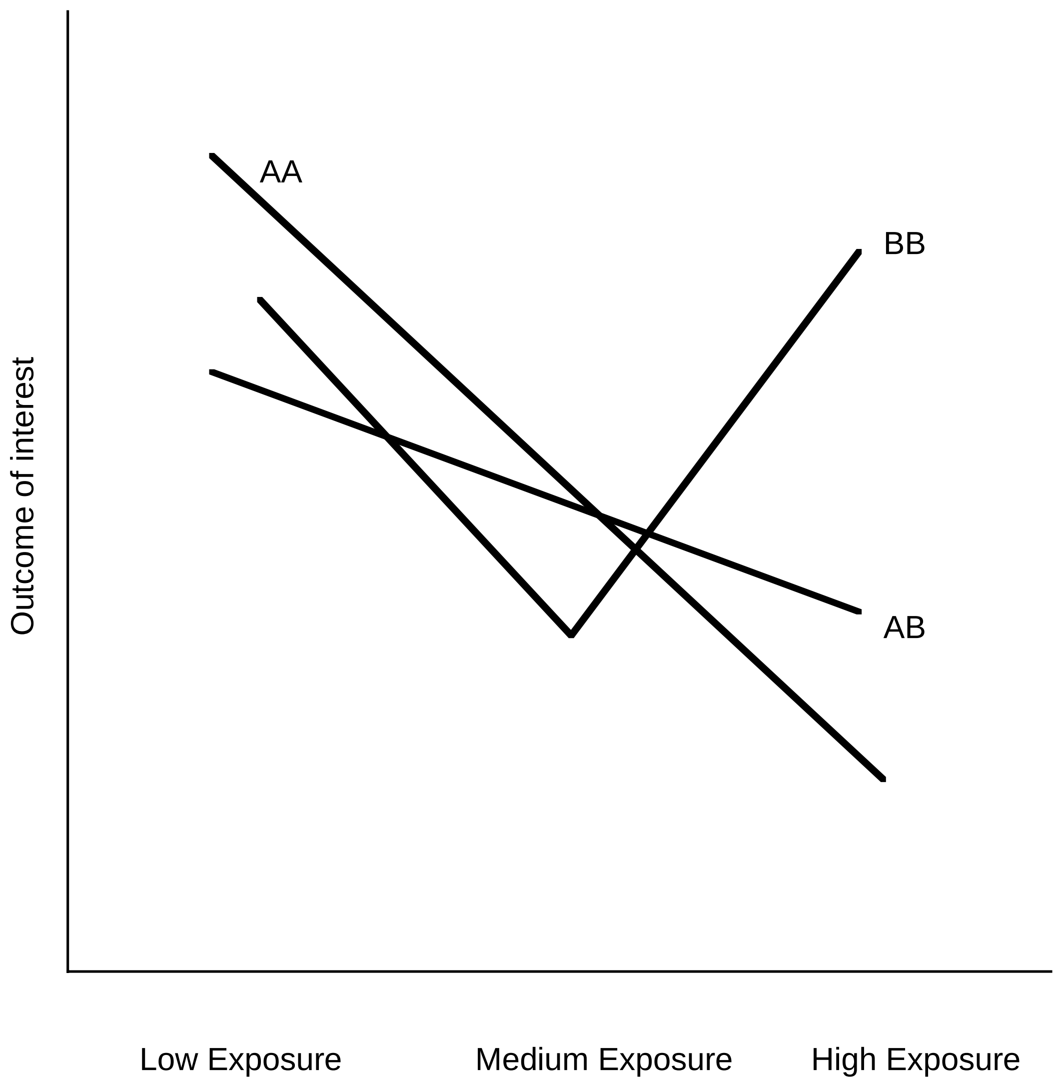

Figure 4-4: Gene-environment interactions. Y Axis represents outcome of interest; X axis represents environmental exposure; lines represent three different genotypes

effect is only probabilistic (a minority will get asthma). But to make the complexities even greater, the effect is time dependent. If the exposures do not occur in the first few years of life, then asthma develops and exposure to endotoxin won't at that point resolve the illness (regardless of the genotype). The case of asthma in humans thus re-emphasizes that causality in organisms is variable within kinds, probabilistic, and time (or even order) dependent.

The difficulties that such complexities present to research may be lessened when researchers deliberately look for circuits and interactions rather than expecting simple OCOE relationships. However, as we will see in the next chapter, even then the task of untangling the relationships to produce useful generalizations or "rules of thumb" are daunting. It is no wonder that given the much greater ease of analysis in OCOE systems, geneticists like to work with simple animals like *C. elegans*. In such cases, there are few enough genes and developmental inputs to treat like cases as the basis for predicting other like cases. The neural system of C. *elegans* with only about 300 neurons is indeed easier to work with, but precisely because of that there is a limit to what it can tell us about human nervous systems. The interactions among circuit components and within networks vitiate the assumption that one can use the simple case to predict fully and accurately the complex case, though one can learn useful things toward understanding the complex case from the simple. The occasional striking success and the ability to fit many cases into Procrustean beds that are at least not painfully constraining fuel the temptation to seek simple explanations that will be sufficient ones.

There is also a psychological reason for the tendency to valorize the simplistic vision over the complex, and that is confusion of single outputs with physical determinism and causation. There is a predisposition to assume that only simple accounts can be scientific because only simple accounts produce single outputs, and only single outputs are "determined" and hence "caused." This confusion arises because our lay sense of something being "determined" is associated with the OCOE model, that is people imagine causation and determination as necessarily being something like two billiard balls hitting each other. These psychological expectations are routinely violated by organic beings, because high levels of response variability can exist in organic systems. If an animal has a dozen different possible "programs" to run in response to heat stress or salt concentration or water availability or UV radiation, it is always possible that those programs will run in novel combinations that produce what appears to any observer, even an experienced one, as a novel behavior. This is especially true in new conditions. If one is operating on a billiard-ball model of causation, this variability and novelty will appear as "non-determinism"—the usual inputs did not produce the usual outputs. Hence, the inputs do not appear to "determine" them, and the system appears to be "non-deterministic". Moreover, in especially complicated organisms, the existence of the multiple possible programs really does create looser connections in terms of time or degrees of response between the environmental conditions and the organism, so that, depending on the organism's internal state, it may be more or less responsive to exactly the same environment at time one than at time two. The availability of multiple programs thus creates variability in response between and across individuals that seems to challenge the sense of determinism inherited from classical physics (which in turn may be inherited from common sense attributions, which tend to focus on especially crucial behaviors in a limited range of environments). [117]

Too many scientists respond by insisting that such variability is an illusion and that "really" the organic system, because it is nothing but physical matter, must be operating on the simple non-variable version of determinism represented in OCOE models of physics. They will thus insist that organic systems are just "mechanistic" systems too, and they assume that any other conclusion is tantamount to vitalism. Such a response, however, confuses variability of output with non-determinism every bit as much as do anti-materialist stances.[118] A better approach is to recognize that materialistic, deterministic systems that use networked circuits will produce variable response values. This avoids the mistake of assuming that "physically caused" means "produces only one possible output." It thus helps avoid the error of trying to understand biological causation without understanding the structures of biology. Instead of repeatedly insisting on the "mechanistic" metaphor for biology (which calls up images of clocks with responses that are non-variable, at least with regard to functional or consequential aspects), it is more appropriate to use the "systems" metaphor for biology, as an increasing number of biologists have done in the past decade. We suggest that statements that biological beings are "mechanistic" constitute inaccurate descriptions because they are *insufficient* descriptions of consequential aspects, and they are therefore bad descriptions.

Biological systems are fully material, fully physical, but they are systemic, not mechanistic. The systemic label allows for determinism (and even micro-mechanism) at the level of nodes, but preserves the appropriate description of the fact that the outputs determined by the system may be variable and that this variability is functionally driven. This shift in mentality aids in understanding biology better. Those operating on the mechanistic model are doomed to be surprised when cloned cows don't look alike, or identical twins are only 60% concordant on psychological measures, or knocking out supposedly essential genes proves to be non-fatal to a mouse or a fly. Operating on the systemic model enables one to expect variability in circuits and, as chapter 5 will suggest, to ask questions in ways that allow one to locate and identify the circuits and their functions.

Evolution

To this point, our discussion has focused primarily on the organismal level. This has appropriately noted that causation drives not only from simple physical processes such as molecule-molecule interactions, but also derives from arrangements at the organismal level. But the discussion has ignored the third level of biological causation, which derives from the lineage of the biological beings. In this third mode of biological causation, a historical chain of events and forces has produced the particular functional structuration of the organism.[119] That lineage is not a system (though perhaps an ecology as a whole might be). Instead, the lineage is a chain of events. The events are one part a product of the physical dynamics that enable organisms to take particular forms, one part a product of specific and constantly changing physical environments, one part a consequence of previous lineages, and one part chance.

Chance means simply that something happened at one time, when one set of conditions pertained, rather than at another time, when a different set of conditions pertained. For example, let us assume that indeed the Cretacean extinction was caused by a large meteorite hitting the earth. The existence of humans today is a result of that chance event. If the meteor had traveled on a path just a little to the left, then the dinosaurs might not have gone extinct or at least not at 65 million years ago, and small mammals would not have had the abundant newly-available ecological niches in which to thrive. Chance here does not mean "uncaused". It just means that the two factors—the arrival of a meteorite and the susceptibility of the dinosaurs—were not related by a prior necessarily coordinated cause. If either one of the two factors had not happened—and neither was necessary to the other—then the subsequent course of life would have been different.

In this sense, the particular course that life has taken—the particular forms and organisms that exist on planet earth at this moment—are all caused by nothing but physical and biological events, but they were also not determined solely by specific properties of physical being, because they also are the product of thousands of chance events. These events include things like which particular collections of alleles became part of founder populations when continents merged or split, which particular paths of genetic drift occurred, which particular birds dropped which particular seeds on which particular islands, which particular animals were in which particular caves during which particular devastating winter storms, and etc.

It may be useful to think of the intersection between such chance events and the programmed responses that produce lineages as "opportunism." The incredible variety of life speaks to the uniquely opportunistic nature of life. The ability of living chains of beings to produce forms that are capable of self-maintenance and self-similar reproduction in an enormous variety of environmental niches is surely stunning. Living beings can get their energy from photosynthesis, from eating photosynthesizers, from eating those who eat photosynthesizers or from parasitic habitation. Living forms can "breathe" oxygen or metals. Living beings can reproduce sexually or asexually. The capability of life to adapt—to be opportunistic—is a product of the nature of functional circuits and their MICME characteristics. A circuit can be tuned and the variability of response possible from a series of inter-networked circuits is what is necessary to allow such adaptation. It is in this way, that life is *fundamentally* different from non-living being.

Conclusions

Common sense tells us that living beings are not like inorganic beings. More rigorous observation indicates that biological being features millions of fuzzily bounded kinds that change through time and space and that respond to physical forces through the constraints constructed by their own evolved forms. Some scientists have, however, spent an enormous amount of effort denying both common sense and their own more rigorous observations. These denials have been both necessary and productive. At some points in time, the denials have been necessary to counter idealist or animistic accounts of living beings that would remove living beings from the materialist world and make them mysterious, magical, and unamenable to our understanding. The denials of the differences between living and non-living beings have also been productive in allowing us to learn an enormous amount about the micro-dynamics of organisms. The stubborn insistence that one could explain everything about biological beings by focusing on the molecular level, bracketing the organism and evolutionary levels, may even have been necessary to allow us to understand the functional and evolutionary levels.

In spite of these utilities, if one does not return to integrate the biochemical accounts with the functional and evolutionary accounts, one runs into inevitable roadblocks. The toolbox of biochemistry, inherited from physics, is insufficient to understand living beings. As the next chapter will indicate, the dogged insistence that such approaches offer the only "scientific" approaches sometimes interferes with the ability to find out some important kinds of things about biology. It also leads to constantly failed expectations about what kinds of control our explanations about biology can bring.

The successes of molecular approaches have also created a false mythology about how biology is actually studied. The recency of these successes allows the misrepresentation of these breakthroughs as though they were the sole source of the understandings of biology. Consequently, in spite of the economic and social power of biology today, there remain the wisps of physics envy, so evident in Wilson's view of consilience. Understanding the character of biology more fully eliminates that envy, because it shows how the tools of physics are just one component of the toolbox of biology, and biology has its own quite impressive and appropriate tools.

Chapter 5: How Biologists Come to Understand Biological Being

Summary: The differences between biological being and physical being discussed in Chapter 4 mean that the methods of the biological sciences must differ from those of physics. For example, mathematics is used inductively rather than deductively, with statistical inference as one of the main, if often elusive, goals in the biological sciences. Controlled experimentation plays a less exclusive role than prescribed by the idealization of physics, and rigorous observation is more central. In answering questions of physiological function, the generalizations reached in biology are commonly not universal, and instead selected species are studied as models that hopefully exemplify, but cannot be identical to, other taxonomic groups. At the sub-organismal level, motifs are likewise generalized forms that achieve generalized function, but specifics vary across and within types far more than in the model of physics. In addressing questions of evolutionary history, the explanations developed by biology are commonly causal chronicles, rather than quantitative laws like those of physics. From a more practical standpoint, predictions developed by biology are less certain than those of physics, and thus while biology has produced marvelous knowledge, the type of human control exerted over the biological realm is different and often lower than that produced in physics.

The most famous discovery of twentieth century biology was the elucidation of the double helical structure of DNA, the molecule that provides most of the codes for protein-building in living beings. This discovery is emblematic of the nature of methodology in contemporary biology. Watson and Crick did no experiments to make this discovery. Instead, they took physical data from Maurice Wilkins and Rosalind Franklin and others, and they tinkered with it until an appropriate inspiration allowed the proper assembly of all the data into a structure that successfully accounted both for that physical data, and for the functional characteristics required for DNA's roles in living beings. The data provided by Wilkins and Franklin also did not arise from experiments. Instead, their data came from new ways of observing organic matter on a very small scale. Though it used physical data, the discovery of the structure of DNA did not utilize the idealized model of physics, but rather employed long-standing methodological assumptions of the biological paradigm of science.

The work of intellectual synthesis that created an understanding of the structure of DNA was a part of a broader scientific movement--the "molecular" paradigm--which advanced biology significantly during the century. This movement linked the macro-structures of living beings to the micro-structures of physical or chemical being. The productivity of this linkage has led most casual observers to assume that the tremendous progress of biology in the century was due to an imitation of the approaches and assumptions of physics. Although this conclusion lands on the target, it misses the bulls-eye. While it is true that adding physico-chemico knowledge and methods to biological study promoted enormously valuable understandings that have chained out throughout biology, it is not true that the resultant understandings were achieved by replacing biological questions, methods, or assumptions with those of physics. Instead, the methods and assumptions of physics were adapted and gerri-mandered to fit the broader requirements of understanding biological being. They were modified and added to an older biological repertoire, rather than simply substituted for them. The progress in biology in the 20th century was indeed due to the study of the interfaces of biological and physical being, but this study was undertaken by combining the older biological and physical paradigms, not by replacing biological methods with those of idealized physics. We even suggest that where the physicalist paradigm becomes the exclusive frame of reference, it actually impedes the ability of biologists to make progress.

This chapter will overview the questions and methods of biological study, and then link those questions and methods to the particular form that prediction and control may take with regard to biological being. Through these analyses, it should become clear both how the study of biological being differs from physics and why those differences in approach are in major part a product of the nature of biological being.

The Questions of Biology

Unlike physics, biology has long had its unified theory—evolution. Charles Darwin formulated the theory of evolution using a variety of tools, including close observation, careful comparison, thoughtful inference, experimentation, the piecing together of historical narratives, and rhetorical invention.[120] The theory itself has become more precisely specified through time, but today it undergirds all of biology, even the most microscopic and physicalist experiments.[121] Although functional biologists describing how biological systems operate at the microscopic level may use more of the tools of the chemist than Darwin did, when taken in isolation, bio-chemical explanations offer only isolated facts about how particular operations in life occur. Because biology is defined by arrangements of circuits and networks, it requires syntheses that link up the physical parts in functional networks to understand biological beings. This is true both on the organismic scale and on the larger scale of population history. Without the theory of evolution one does not understand how life comes to be as it is.[122] It is this grand theory that unifies the explanations of biology at all levels, from the kingdom of life, to varieties of species, to development of organismal forms, to microscopic forces holding organic molecules together.

In answering the central question "why is this living being like this?" biologists therefore must answer questions of two different classes**:** #1: How does a given survivable and reproducible form function? and #2: What series of conditions and interactions have occurred that generated this form? This second set of questions addresses the lineage of the organism and how it fits into broader lineages. While this kind of understanding may not always be immediately useful for exercising immediate control over an organism or its parts, it is certainly a key part of what it means to understand biological being. While more "practical," the first set of questions can only be answered by combining two different kinds of analysis: descriptions of the physio-chemical interactions occurring in a fragment of a biological entity and their integration to constitute the functions of the organism. Describing the physio-chemical interactions without explaining how they fit into the organism's functioning is incomplete if not completely incomprehensible biological explanation.

The distinctive character of these biological questions has consequences for the methods that can be fruitfully employed in biological studies. In contrast to the model offered by idealized versions of physics, we will find that the answers to these biological questions do not usually come in the form of equations. Consequently, the nature of synthesis in biology is quite different from physics. In biology, synthesis takes the form of causal chronicles, either of a quasi-narrative form (in evolutionary accounts) or of a complex series of if-then formulations. Experiment plays a role in this research, but the research is also heavily dependent on rigorous observation, and the line between the two is blurred. Biologists are also notorious for spending enormous energy and time in generating classes, concepts and categories, as they must, due to the dispersed characteristics of the kinds of biological being. These categorizations are understood through careful investigation of "model" organisms and they are explained through motif-like generalizations. These inter-related features make biology, even in the so-called molecular era, a rich and varied enterprise.

Mathematics in Biology

As chapter 2 indicated, mathematical equations constitute the laws of physics, and mathematical proofs and predictions are therefore the core of that discipline. Mathematics does not play this central role in biology, and it will never do so. Biology will never be primarily constituted through a small set of interlocking equations. To see the difference between how biology and physics are currently done, simply pick some introductory physics textbooks and some introductory biology textbooks. When we did this exercise, we found an average of 2.68 equations per page in the physics textbooks and an average of .09 equations per page in the biology textbooks. Well over half of the pages in the physics textbooks (64%) had equations, whereas only 3% of the pages in the biology textbooks had equations.[123]

Physical scientists are prone to dismiss such differences on the grounds that biology is an "underdeveloped" or "immature" field. Indeed, a biochemist we know discounted genetics as an immature science because its relationships are not "quantified." Similarly, in a recent essay, the physicist John Maddox complained "biologists in general have paid too little attention to the quantitative aspects of their work."[124] The biochemist and the physicist, however, are wrong. They are operating on assumptions derived from the physical model of being, rather than the biological one. Genetics and biology will certainly continue to add additional work to their quantitative repertoire to allow better manipulation. Improved mathematics will continue to be important because some kinds of relationships can be effectively teased out by large-scale comparisons using statistical methods. However, such additional quantification is not itself *the explanation* in a biological sense.

In physics, mathematical equations are the core of the explanations, both because physics often deals with invisible phenomena and also because physical being varies more by degree than kind. Mathematics in physics thus provides a deductive framework. In biology, mathematical equations are refinements or tools of discovery and sometimes confirmation, not the core of an explanation itself. A clear indicator of this is the single piece of mathematics generally taught to students in introductory genetics courses—the chi square test.[125] This test assesses the extent to which an observed frequency of a phenomenon exceeds an expected frequency. This particular mathematical tool has played a central role in genetics because it allows researchers to assess whether a particular characteristic is associated with a particular gene (or inheritance pattern) as opposed to chance distributions. Its logic underlies Mendel's discoveries. Today, the mathematical tests that biologists use for such explorations are far more sophisticated, but the goals are similar. Researchers use statistical tests of correlation to assess which genes, among many candidates, might be associated with common diseases. Such tests identify, but they do not explain. The most prominent equation of population genetics—the Hardy-Weinberg principle—similarly provides a template of expectations for comparison rather than a universal law of behavior. The Hardy-Weinberg equation specifies what the mathematical equilibrium would be for neutral conditions. It is useful not because genetic frequencies always follow its distributions, but because when they do not follow them, that indicates various alternative conditions, especially selection pressures, at work.

Mathematics in biology is thus more often an inductive tool rather than a deductive predictor. Mathematical formula may quantify (that is numerically specify) the relationships among parts of a biological circuit or network, but it is the description of the components and series of interactions in the circuit that constitute the core of the explanation. Even in those cases where quantitative models can improve the efficiency of prediction (as in recent work in population biology), the precise quantitative aspects of the relationship specify the relationship, even help discover and verify which components matter, but they do not identify an essential, stable character. The complexity and messiness of biological being mean that there will be few if any laws as elegant as $E=mc^2$. Equations are elusive in part because the quantitative relationships are discontinuous. Biological outputs in a circuit vary within a range, but that range may shift in a discontinuous fashion as conditions change. For example, a set of chemical interactions in a glucose-utilizing circuit may drop precipitously from a relatively constricted "normal" range when glucose disappears from the environment and an alternative energy processing circuit goes into effect. Unlike the quantitative stair-step discontinuities of quantum physics, in biology the discontinuities are shifts from one *type* of circuit to another.

Quantitative analyses in biology are powerful simply because they indicate when a model has successfully incorporated all of the key inputs into the explanation in roughly the correct relationship. Equations help us to know when we have correctly identified the key components of the circuit or specified factors in a gene-environment interaction. They are a research tool, rather than the core of explanation. Because of the variable nature of biological being, the mathematical component of such explanations will inevitably be less than 100% precise, and it will vary through time and space, at least to some degree.[126]

In addition to the variability in types or kinds, biological systems manifest specific difficulties in measureability. Life appears in distributions rather than in simple discrete types, and therefore the mathematics for apprehending life must be that of probabilities. Physics, of course, often uses probabilities, especially at the quantum level, but in physical being the very large number of the objects in any application or measurement means that a mean can usually be treated as the singular value for the population. In biology, the variability is much greater and the number of instances is much smaller. This means that tools such as correlations, clusters, and confidence intervals are needed to capture the relationships among the entities being studied. It also means that projections about a population such as a mean cannot be taken to describe individuals, and in many instances, individuals or relatively small groups of individuals are of far more interest than in physics, especially when humans are the biological being at issue.

<u>An example of the mathematical challenges</u>

An example will help clarify the power, challenges, and limitations of the uses of statistics in biology. Because alcoholism seems to be more common in some families than in others, researchers have long believed there is a biological, hereditary component to the causation of alcoholism. In 1990 Blum et al. published an article in the *Journal of the American Medical Association* that claimed a gene responsible for this hereditary component had been identified. The gene was the dopamine D2 receptor. In their study, 69% of the 35 diagnosed alcoholics had the A1 "allele" (version) of the gene, whereas only 20% of the controls had it.

From a simple mechanistic perspective, these results provided highly problematic evidence. If the A1 allele "caused" alcoholism, why didn't the other 31% of alcoholics have it as well? And why did 20% of the population who had the allele not have alcoholism?[127] Clearly, this was not a law-like relationship, but a different kind of relationship or "causality".

Even the idea that the allele contributed to the disease at all was shaken by a study published in the same journal eight months later. Bolos et al. reported that there was no apparent association between the allele and alcoholism in two different kinds of studies:

one with 40 white alcoholics and 127 matched controls, and another that used two pedigree studies that actually traced family members with and without the gene and with and without alcoholism.[128] This double-barreled non-replication suggested that in addition to being non-lawlike, the association might not exist at all, in spite of the previous, carefully gathered empirical evidence that it did exist!

Two further efforts to replicate only confused the issue further. In October of 1991, not even a year later, *JAMA* published two more research reports, one claiming that the relationship did not exist and one claiming a modified confirmation of the existence of the relationship. Research by Gelertner et al. did not support the relationship, showing statistically indistinguishable levels of the appearance of the A1 allele in alcoholic and non-alcoholic white individuals (.20 for controls and .23 for alcoholics).[129] In contrast, the research by Comings et al. situated alcoholism as only one of several mental conditions, including Tourette's syndrome, autism, and attention deficit hyperactivity disorders. This broader framework responded to the replication problems and the doubt that they cast upon the direct causal relationship between alcoholism and the DRD2 allele.[130] Comings et al. suggested that the allele was a "modifying gene," that led to an underlying tendency, of which alcoholism was merely one manifestation. 42.3% of their 104 alcoholics manifested the Al allele, while only 14.5% of the 69 controls known to be non-alcoholics, and 24.5% of all of their 314 controls had the A1 allele. The gap between the two studies led the journal to editorialize that the D2DR allele was "associated but not linked" with alcoholism.[131] This statement evidenced the difficulty of biologists to come to terms with the non-lawlike nature of their object of study. The wording of the editiorial essay still implied that, out there somewhere, was a proper alcoholism-causing allele, but the *DRD2* allele just modified that one. Most members of the field did not yet understand and lacked a vocabulary to express what many accept today—that all alleles implicated in particular outcomes are merely contributing factors. Functional outcomes are the products of complex networks of circuits, not of single genes operating in a billiard-ball-like causal frame. Therefore, every variation in every gene in the circuit has implications for the functional outcome. There is no "prime mover" gene that "causes" an outcome and therefore constitutes the sole cause of a disease (dysfunction) in its absence. (Though this does not deny that some variations in some genes may have larger effects on functional outcomes because they exist in circuits that do or do not have "back-ups" in other circuits or because they serve as "bottle-necks" in the bio-chemical interactions, or because they code for proteins that exist at particularly dense nodes of networks (recall Figure 2 from Chapter 4).) So, of course, the receptor did not have a law-like relationship with alcoholism. At most it was a predisposing factor. It set up conditions that were more likely to aggregate with other factors to produce alcoholism. Or was it?

Given that two studies showed no relationship at all, it was still not even certain that the A1 allele played any role in alcoholism at all. It might well be that the weak relationship was actually a spurious one. None of the sample sizes were large enough to be definitive. The statistical likelihood of a relationship exceeded 95% in the confirming studies, but that still left a 5% chance that they were in error. Perhaps the two confirming studies simply fell in that 5% of the error distribution. In a non-law like world governed by multiple relatively weak inputs, a large part of the problem for science arises from the fact that establishing generalizations that have influence rather than absolute causal force is extremely difficult. The mathematical tools are good, and have been getting better. Geneticists are somewhat more careful (though often, they lack the resources to be careful enough) about issues of sample size and statistical power. There is, however, a separate problem, and that deals with a second kind of generality, the boundaries over which the generalization applies. One crucial study suggested that the positive findings were either a result of poorly controlled population sub-structure or pointed to differences within different population groups in the impact of the *DRD2* alleles.

In April of 1993, in the less visible journal *Alcoholism: Clinical and Experimental Research*, David Goldman and his colleagues published their research on the distribution of the A1 allele in different ethnic groups. They found that different groups had much different frequencies of the gene within their populations.[132] In Caucasians it was .19, in American Blacks it was .38, in Jemez Pueblo Indians it was .63, and in Cheyenne Indians it was .80. Moreover, the linkage disequilibrium (a measure of how closely surrounding genes are tied to each other) among different groups also varied widely, suggesting that the ability to use the *DRD2* alleles as markers varied in reliability among different groups.

The implications of this additional research were profound, but there remained different possible interpretations. One interpretation is that the *DRD2* allele indeed caused alcoholism, since the higher rate of alcoholism among many Native American Indian groups was well known. The problem with that conclusion was that studies within the Indian groups showed no difference in alcoholism rates between those who had the allele and those who did not. That pointed to the second interpretation: that the *DRD2* allele's association with alcoholism in some studies was an artifact of population structure—more people who were alcoholic had the A1 allele but this was simply an accident resulting from differences in the ancestry of those who were in the control group versus alcoholic groups due to different modes of recruitment.[133] The likelihood of this possibility was enhanced because the studies that more tightly controlled ethnicity of their participants were more likely to find no association between the allele and alcoholism.

Even that case, however, was not itself iron-clad, because the levels of the allele and the appearance of alcoholism in the communities where the allele was prevalent were so high that there might have been a ceiling effect that masked the role of the gene within the community. The ability of the statistical methods at this point foundered. As the Goldman et al. article concluded, the question would have to wait for molecular methods to locate a particular mechanism by which different versions of the gene might contribute to alcoholism, because the statistical methods could not answer the question definitively.[134] The mathematical tools could point to potential or "candidate" genes, but they could not overcome issues of sample size, population structure, and even cultural difference to provide definitive proof.

In the longer term, both of these paradigms have been adopted. The need to control for "population structure" has become a widely recognized issue among the research community. Simultaneously, rightly or not, the medical research community has come to believe that DRD2 is associated with various kinds of human behavioral patterns, such as alcoholism and drug abuse.

Measurement challenges

The problems that manifested themselves early in these alcoholism studies have recurred continuously throughout research into human disease and its relationship to specific genes. In many cases, the limits of statistical power mean that one can't use these kinds of tools to definitively answer questions. Sometimes, it turns out, the number of cases one would need in order to ascertain a statistically sound relationship between a disease and a gene is greater than the number of cases of the disease.[135] Most of the time, it is simply a matter of the availability of cases and the costs of ascertainment. These costs can be quite high. Francis Collins, the Director of the Human Genome Project in the U.S., has recently argued for the need for a longitudinal study of 500,000 people in order to disentangle gene-gene and gene-environment interactions in common diseases.[136] To mitigate these challenges, more statistical methods are invoked, as efforts to use haplotype maps or population-controlled samples are used to try to increase power, decrease costs, and encourage the prospects of additional results.[137] As an alternative, less mathematically intense methods are used. Animal models are employed to chart the susceptibility in tightly controlled studies that require only the simplest of arithmetical and statistical calculations. Chemical reactions are studied that also require relatively basic numerical tools. These approaches, however, run into their own biologically based difficulties.

The ability to measure the physical attributes of animal models suffers from the issues of uniqueness and access. When one uses animal models, one immediately runs into the problem of generalizing from one unique organism to other kinds of organisms. While one might be able to learn whether DRD2 contributes to high levels of alcohol consumption in rats, the negative effects of alcohol in rats are different from the negative effects in humans. Rats don't lose their jobs and alienate their friends, thereby triggering depression with high alcohol consumption. If DRD2 functions differently in two different backgrounds of population history among humans, why would we expect it to function in exactly the same fashion among humans and rats? In some cases, these problems can be overcome in a satisfactory if not definitive fashion by comparisons of various aspects of other biological byproducts from the two organisms in question. But many times, for example in the extensive history of experience in drug development, animal models have often proven not to be sufficient models of human beings. This is why clinical trials in humans are mandatory in all cases, even though they are expensive. Types of organisms are different enough that one cannot presume that what is true of one group of organisms is true of others. *Similarity is always an empirical question in biology* (which contrasts dramatically with the taken-for-granted universality of types in physics).

The pervasiveness of variation in biology thus shapes issues of measurement in biological research. The second factor influencing measurement in biology consists of issues of practicality. To measure the relationships among hierarchically nested circuits buried deep inside a well-defended body is not like measuring the weight and speed of a spaceship. It is even more difficult than measuring the energy in particles produced by smashing things together in an accelerator. What is sometimes called the Heisenberg problem occurs in biology not just at very small scale, but may occur at every scale: every attempt to measure produces differences in what is being measured. It is difficult to observe animals without affecting their behavior. A recent study compared the results of tests of mouse behavior gained in different laboratories using putatively identical methods. While some results, especially those of larger effect size, could be standardized across laboratories, many could not. The authors concluded, “Our results suggest that there may be advantages of test standardization, but laboratory environments probably can never be made sufficiently similar to guarantee identical results on a wide range of tests in a wide range of labs.”[138] This does not speak to any incompetence of the scientists, but rather addresses the innate instability and variability of the biological systems themselves.

These results point up the fact that no single measurement defines a value for many biological networks. Networks may operate at many values in many conditions, and what must be done is to specify all of those values. Biologists have done a fabulous job of inventing experimental, comparative, and mathematical methods to try to overcome these difficulties, but there is no single solution that applies to every situation. Some areas are particularly intractable, such as issues of development and deep time. As biologists assemble the mechanisms piece by laborious piece, mathematics is an essential tool in the effort, but the production of a mathematical equation is by no means a sufficient goal.

Experiment and observation

The problems faced in applying mathematical models or predictions to discovery and explanation in biology have obvious implications for the role of experimentation in studies of biological being. If the response of biological beings is sensitive to multiple inputs, then minor variations in genotypes, developmental sequences, or other epigenetic factors as well as minor variations in the environment may produce variations in responses. The inconstancy of experiments in a relatively tightly controlled laboratory setting further indicates that laboratory experiments are not likely to reproduce accurately the responses that a biological being may generate in a field context.

The field experiment is therefore the ideal for biology. Note that physicists don't worry whether the particles produced in their accelerators are the same or behave in the same way as particles produced in nature. Indeed, many of these particles are not produced in any detectable form in nature at all. But the principles of time and space invariance lead physicists to assume that the properties of a boson in an accelerator are the same as the properties of a boson everywhere (at least, close enough).[139] Biologists can't assume that the dynamics of a group of baboons in captivity are the same as the dynamics of baboons in the wild. It is sometimes possible to develop field experiments to aid in overcoming contextual limitations. However, the question always remains "which wild environment, when?" If one has only one set of experiments on one group of baboons in one context, one doesn't know whether those results apply to all baboons in all possible environments. Only further field experiment can answer those questions. This problem is greater for some kinds of study than others, but it is always the case that generalizations from one group and one environment to another are unwarranted until observation or experiment demonstrate them to be shared, as the entire premise of labeling different species is that these species do harbor differences, and the array of differences cannot be known *a priori*.

The ideal character of the field experiment does not mean that only field experiments are done in biology. In simpler organisms, and organisms that have been adapted to laboratory contexts, the concept of a "field" may not have a clear meaning.

Even where biologists are precisely interested in naturally occurring behavior, field experiments are not always feasible, and they tend to be expensive and difficult.

The expense and difficulty of field experiments combined with their limited generalizability means that many, if not most, areas of biological knowledge provide a relatively low pay-off (compared to physics). If a physicist is able to produce just one superpartner particle with the expected properties in the new larger accelerators scheduled to come online, that will be taken as proof of the huge theoretical edifice of supersymmetry. But it takes at least dozens, if not hundreds, of experiments to establish the generality of a given set of behaviors (e.g. forced copulation or heuristic vs. systematic cognitive processing) across the animal kingdom, and of course some questions that one would ask about animals would sound ridiculous if one even tried to apply them to plants. Few single experiments in biology can be definitive.[140]

Neither field nor laboratory experiments can address an additional problem unique to biology—one can't rerun the past. Because time-specificity dictates that biologists be interested in how things got to be the way that they are, biologists inquire into the history of the development of life. It isn't possible to re-run all of evolution in a test-tube. No field experiment can answer key questions about that history. For many reasons, therefore, biologists do not rely exclusively on either laboratory or field experiments. Instead, they also employ techniques of rigorous observation.

Biologists have a long history of making rigorous observations. Much of this history has been focused on describing lineages and drawing boundaries among different kinds—whether species or phyla or sub-species. One key element in rigorous observation is the use of a systematic approach that looks for specific, planned elements and then records results precisely, thoroughly, and in detail. In biology, comparison of two or more organisms provides the framework that stabilizes observation. Observations are more likely to be replicable when two items are compared in a systematic, literally "point by point," fashion than when an observer simply records what strikes her or him. The use of comparison functions implicitly to provide a template that anchors the observations, although the use of comparison rather than an *a priori* template helps ensure that the observations are relevant to the particular objects under study, rather than derived from some external and potentially misleading formula.

In the past, tens of thousands of person hours went into precise measurements of particular comparative features of thousands of fossils in order to establish taxa and the relationships among them. Today, thousands of hours go into using computers to trace the fossils for the same end, or into DNA sequencing to provide genetic comparisons when appropriate tissue is available. Developmental biologists have similarly used systematic observation to understand the unfolding of biological programs,[141] sometimes even in particular environmental contexts. The use of such rigorous comparative methods is surely a hallmark of biological method and an appropriate response to the variability of biological systems

In using observation for building theory two additional factors can distinguish a rigorous comparison from "just looking around." First, the researchers should not know the results of the observation in advance of formulating the theory. Second the researchers should not be able to collect the data in a way that (consciously or unconsciously) favors a hypothesis.[142] Rigorous observation, with safeguards similar to those of good experimentation, can thus contribute to generalized understandings in a fashion similar to good experiments. However, something is lost in observation as opposed to experiment, and that is the ability to control all the presumed inputs and therefore to focus on the causal relationship between one single variable and one single outcome. In biology this is not such a devastating loss, because, as Chapter 10 demonstrated, the circuit nature of biology means that one single variable rarely produces one single outcome. Indeed, as the example of the discovery that putatively "lethal" genes are often not lethal illustrates, focusing only on a single variable may prove misleading when the system has alternative routes for compensating for the loss of a single variable. T*his is not to say that controlled experiments are irrelevant for biology, but it is to say that both experiments and observations involve advantages and disadvantages: trade-offs between focus on a single variable and understanding of the functioning of the system as a whole in context*. Biologists are therefore required to use both approaches; neither is the singular key to their science.

The line between rigorous observation and controlled experiment in biology is also blurry, as an example will illustrate. The laboratory in which the first author did her training in genetics was interested in the function of various genes. As part of a large research strategy (and generously by the laboratory leader, to give her experience), she was assigned to assess whether a piece of DNA had been incorporated into the bacteria's DNA. If it had, then when the DNA was cut up by restriction enzymes, it would produce pieces of DNA of one length. If it had not, then it would produce pieces of DNA of another length. Was that an observation or an experiment? If the new organisms were then grown on Petri dishes and the colonies counted and described, is that an observation or an experiment?

In practice, biologists are quite loose with their use of the term “experiment.” They tend to use it to include any technologically mediated interaction with other organisms in a laboratory setting. This broadened vocabulary reflects the blurred lines between rigorous observation and experimentation. Both practices require systematic recording of results. Both require some staging of an interaction between the human and the organism. In contemporary settings both may involve testing hypotheses. Neither may produce extremely broad generalizations. Only the degree of control distinguishes them, but in biology it is degree of control rather than absolute distinctions about control vs. non-control, because one rarely knows all of the variables that might appropriately need to be controlled.

The case of running the DNA on the gel sits squarely on the boundary between observation and experiment. There is an informal hypothesis that is being tested here—that the new genetic material was incorporated into the lineage. The hypothesis addresses a specific case (this specific group of organisms), rather than a generalization about all organisms or even all organisms of this species, and thus might be understood as being closer to a description of a singular category rather than a general rule. There is also careful, even quantitative, recording of results (length of fragments). There is also manipulation of the organism, both to insert the new DNA and to extract that DNA from the organism, and to process that DNA in a way that asks the appropriate question. But there was no conscious effort given to the issue of control, and it is not clear what, if any controls would be useful.[143]

The counting and description of the colonies on the Petri plate takes a step over the boundary into the realm of observation. In that case, one may just be looking for the properties of these new organisms, though one will certainly have particular properties that one thinks might be more likely than others, and thus have some implicit, multiple working hypotheses. Ultimately, one is comparing these organisms with their unmodified progenitors.

The existence of these gradations between experiment and observation do not make biology less of a science than physics. They just constitute the scientific approach that is necessary for the time and space variant character of biology. What makes both physics and biology "scientific" is the use of procedures that allow the universe to talk back to us. I wanted to have incorporated the new DNA, but did I? Procedures for answering this question beyond my own wish-fulfillment may include hypothesis testing via sets of replicated and inter-related experiments or observations that enable triangulation of results in a fashion that produces understanding of all of the major dimensions of the phenomena under study.

To be sure that we are letting the universe "talk back" rather than just talking to ourselves requires safe-guards such as rigorous recording, double-blinding between hypothesis and results, and especially external replication. It also requires the entertainment of the richest range of plausible hypotheses. However, the unique configuration of biological beings means that if biology were to try to be more like physics, following the dictates of research laid down by Karl Popper based on the narrow model of physics alone, biology would actually explain biological being less well than it does. If biologists only did rigorous laboratory experiments and only counted as knowledge deductive equations whose results were universal, it would be a highly impoverished activity.

Generalizations: Populations, Models and Motifs

Knowledge of universals is widely perceived as the most desirable kind of knowledge, because it is so very efficient. If one has a universal law, one has to know very little in order to predict, control, or at least have a feeling of familiarity and comfort about very much. Biologists are thus as eager as physicists to find universals, and they reward such universals with their highest praise and awards. Nobel prizes go to discoveries with the greatest scope: the discovery of DNA's structure was important because almost all organisms employ that structure, the discovery of programmed cell death was deemed important because the programs are presumed to apply to a broad swathe of organisms. But because biological being has evolved into millions of kinds, there are very few true universals in biology. Studying things that vary a lot presents significant challenges for generalization.

In forming a biological generalization, there are always two questions at issue. The first is to how many organisms a generalization applies. In order to make that first question manageable, biologists have to identify an orderly array of types that indicates how organisms are related to each other. This requires an enormous investment in classification. Moreover, as we have already seen, the categories of these classifications are not discrete, bounded sets of identical items, but fuzzily bounded sets with overlapping sets of "family resemblances."[144] They are populations, rather than discrete categories. As we saw in chapter 4, they are often defined merely by arbitrary statistical cut-points in base-pair differences in DNA. Nonetheless, given a classification system that captures an adequate amount of the relative relationships among taxa, one does not need to test every organism, or every type of organism, to find out whether a generalization is likely to apply to any specific group of organisms. By strategically examining specific organisms in specific branches of the shrubby tree of life, one can make reasonable conclusions that generalizations apply in some branches of the shrub and not others. This makes the use of model organisms a unique and important feature of biology.

The second question that must be asked about any generalization is how precisely or how much a given generalization applies. Because of evolution, a group of organisms may feature part of a generalization, but in a different fashion or with notable modifications. In fact, as we will see, even knowing what counts as the general part of a generalization is a matter of comparison among organisms, rather than a fact deducible from the discovery of a particular feature in one organism. We call this "motif-like" generalization, and it is a standard form of generalization in biology. Examining the use of models and motifs as modes of generalization in biology will clarify what it means to develop generalizations or concepts that are not universal laws.

Model Organisms and Modeling Biological Phenomena

Biologists study life by studying model organisms. The Human Genome Project (HGP) did not sequence "the human genome"; it has sequenced and continues to sequence a series of model animal genomes, including a pastiche of chromosomes from different people intended to stand in for "the" human genome. Even before the HGP, however, biologists focused most of their attention on a few organisms—one kind of fly, a particular weed, yeast, some bacteria, mice, and a few others. What counts as a "model organism" is not determined by *a priori* representativeness. Rather, the selection of model organisms is driven by two factors—research utilities and applied utilities--which often conflict. Research utilities are driven in part by the unique features of some organisms. Yeast can be reproduced in two different ways, and this makes them very useful for tracing genetic pathways. Zebrafish are useful for a different reason; their early developmental forms are translucent and therefore can be watched in great detail, so they provide good research tools for developmental studies. In addition to an organism's ability to provide such unique features, research utilities include the ease of maintenance of large stocks of experimental animals, generation times, number of offspring, mode of reproduction, and ethical comfort with treatment of the type of animal. These factors often favor animals that are least human-like. On the other hand, the goal of much research funding is to generate practical utilities (e.g. food crops or organisms that can produce pharmaceuticals). Organisms related to these goals are not necessarily those that are most easy to manipulate in the laboratory. Most notably, medical interests drive much research and its funding. With human medical research, animals more like humans offer important advantages, yet these are the least easy to deal with in a laboratory context.

Physicists don't study model electrons. They just study any old electrons at hand, because all electrons are presumed to be essentially the same. But all organisms are not the same, and the only way in which we learn what is the same and what is different about organisms is by studying many model organisms and assessing their commonalities and differences. Biology lacks anything like a numerologically driven periodic table of the elements that predicts what elements exist and what properties they will have. What biologists find is what one might expect to find given the branching nature of life. Some components are widely shared and some are much more local. For example, gene sequences that control developmental cascades are more likely to be conserved across species than are genes that code for particular proteins involved in binding a molecule used in response to a particular environment. Mutations in developmental cascades produce massive changes that "screw up" too many different organs so that the mutated offspring are unlikely to survive. But changes in "downstream" proteins have at least some chance of being useful in some environment the organism is likely to encounter, without producing deleterious effects on other functions, and very tiny changes can sometimes produce significant effects. Thus, there are only 2 amino acids out of 715 that are different in the FoxP2 gene between humans and other primates. But this change may have facilitated speech by human beings, and speech turns out to be a very handy adaptation.[145]

Modeling the functional systems of biology is even more complicated than that, however. The duality of genotype/phenotype, form/function that is inherent to life means that a function can be preserved with many changes in the genotypic sequence and sometimes even with a change of form. Consider just one aspect of an effort to "model" how organisms use energy. Hemoglobin is an amazing molecule.[146] It picks up oxygen in the lungs and transports it throughout the body to all the cells. It changes its form in response to concentrations of $C0_2$ and relative acidity, and this influences its ability to bind oxygen in the lungs and release it in cells throughout the body. In spite of the fact that this function is enormously similar, perhaps "identical", among those species that have hemoglobin-like oxygen transporters, there are only 9 amino acids out of 140 that are common among all these species. Those 9 conserved bases, however, are at the critical points for producing the particular form that is hemoglobin. So there can be a huge amount of variation within the amino acids that achieve a particular function, but as long as there is critical similarity, the function can be basically the same. One cannot get to the core common components of hemoglobin by studying one model organism. Instead, researchers have to compare across many model organisms. The common components, however, do not provide the complete model of hemoglobin's transport of oxygen.

The molecule's function depends not solely on the "identity" of critical, conserved bases, but also on "good enough" similarity among the other 131 bases (or a close-enough number of such bases). Some substitutions, because they maintain the same charge, size, or hydrophilic qualities, are allowable; they don't disturb the form or function of the molecule. Other substitutions are less likely to occur, because they do disturb form and or function. Thus, the story is of some strongly conserved elements (sometimes called "canonical"), with some elements that are preserved-among-a-set ("synonomous"), and some elements that aren't preserved at all. A "model" of a system is generated by comparing systems in related model organisms, and identifying both the elements that are identical and also the elements that must exist in some degree of similarity. Every "model" organism thus provides only one version or set of characteristics that are taken to represent an imprecise range of other similar organisms.

No generalization has been tested in all of the millions of types of organisms that exist. For some biological generalizations (that DNA forms the common code of life), researchers have nonetheless fair confidence in the belief that this has been examined in enough organisms to know the range of its generalizability (to almost all organisms, with exceptions only for such organisms on the boundaries of biological being such as RNA-viruses or prions). For other biological generalizations (e.g. the particular forms of circuits used in control of DNA expression), there is not yet a clear picture of the generality of all of the mechanisms. Whether scientists know the extent of generalization very well or not, however, the manner and degree of similarities within the execution or character of the generalization also varies across species. That is, whatever the extent of their pervasiveness among biological organisms, the mechanisms of a generalization tend to be motif-like.

Motifs

Biologists have increasingly come to use the term "motif" to describe patterns of generality. A motif is a general form that achieves a general function, but with degrees of variation within components of the form and some latitude of variations within the parameters of how the function is executed. For example, the "zinc finger motif" is a particular molecular configuration that can bind a molecule onto DNA. Zinc fingers are formed by the binding of a zinc ion in the center of (for example), a foursome of 2 cysteine and 2 histidine molecules, with a protrusion of other amino acids at the end (see Figure 5.1). The protrusion has chemical bases that are specific for particular sequences of DNA. The common finger structure has "fingertips" that recognize particular sections of DNA and thus function as a transcription factor to allow the DNA to be "read". Thus, zinc fingers for different parts of the DNA molecule have different sequences of proteins, but they also have shared molecules or molecule types in some places that give them

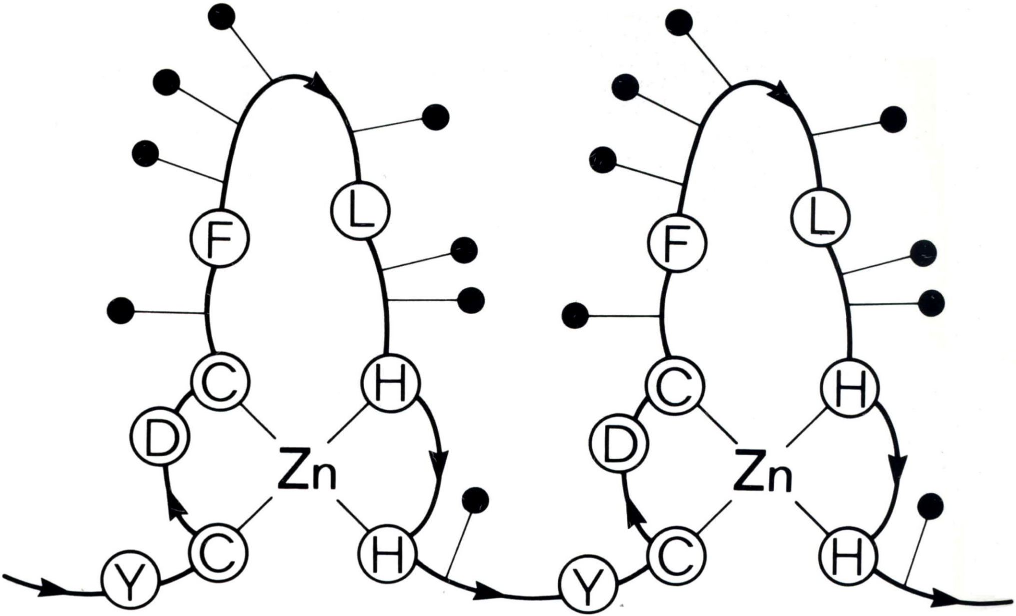

Fig. 5-1.

common structure. Additionally, in different organisms, the fingers might have slightly different parts for homologous DNA sections. Indeed, as Table 5.1 indicates, the amino acid sequences that make up these fingers are identified by a relatively few "consensus" sequences among a much larger series of sequences that have a much lower degree of similarity to each other. Identification of the key sequences that make up a zinc finger motif is not a matter of identifying a specific entity (a precise sequence of DNA), and thus does not come from looking at a single model organism. Rather, discovering a motif-like concept is achieved by comparing different organisms and charting the degrees of similarity in different components. In summary, there is an enormous amount of variation within the precise forms and functions of a "zinc finger motif," but it constitutes a single general concept because, when one sees enough components of this particular pattern in a DNA sequence, one can reasonably predict that the protein has a DNA binding domain, and so part of its function is one that requires interaction with DNA in a direct fashion.

Geneticists have been productively assembling data-banks of motifs in DNA. There are leucine-zippers and helix-turn-helix motifs, as well as "acid blobs." The term "motif" began its usage in DNA studies, but has now spread to protein studies. Even when the term "motif" is not used, however, *most* of the knowledge that biologists gather is about motifs. The various subfunctional systems in microbes—such as the lac operon or RNA splicing mechanisms, or DNA repair or photosynthesis--are functional motifs with semi-conserved forms. The rush to create haplotype maps of human variation reflects motif thinking. Even large scale capacities of organisms are distributed as motifs rather than specific classes that behave in a law-like fashion. Flight, according to

Table 5-1: Peroxin 7 Orthologues in Four Species

Organism																				
Humans	V	C	G	G	A	A	R	M	L	R	T	P	G	R	H	G	Y	A	A	E
Fly	-	-	-	M	Q	T	Q	T	H	T	T	T	D	R	H	G	Y	S	L	R
Plant	-	-	-	-	-	-	M	P	V	F	K	A	P	F	N	G	Y	S	V	K
Yeast	-	-	-	-	-	M	L	R	Y	H	M	Q	G	F	S	G	Y	G	V	Q
Conserved?											2		2	2^2	2	4	4	2	2	

Organism																					
Humans	F	S	P	Y	L	P	G	R	L	A	C	A	T	A	Q	H	Y	G	L	A	G
Fly	F	S	P	F	E	A	N	Y	L	L	L	A	T	S	Q	L	Y	G	L	A	G
Plant	F	S	P	F	Y	E	S	R	L	A	V	A	T	A	Q	N	F	G	L	L	G
Yeast	Y	S	P	F	F	D	N	R	L	A	V	A	A	G	S	N	F	G	L	V	G
Conserved?	3	4	4	3				3	4	3	2	4	3	2	3	2	2^2	4	4	2	4

This charts the order of amino acids in a short segment of Peroxin 7 orthologues in four species, with the bottom row indicating the number of organisms across which the same amino acids occur at the same place. Subsections of the order repeat across the protein. Data from A. M. Motley et al. (2002). Mutational spectrum in the PEX7 Gene and Functional Analysis of Mutat Aleles in78 Patients with Rhizomelic Chondrodysplasia Punctata Type 1, American Journal of Human Genetics, 70: 612-624: Figure 1.

Maynard Smith, has evolved four times. Each type of flying organism, bats, birds, insects and pterosaurs, has used different mechanisms for flying. Yet there is a commonality as well—each has used "thin movable extensions of the side of the body."[147] To illustrate the boundaries of that particular motif, consider that no organic life evolved jet propulsion through the air, though it did so in the water. The commonalities of plans for flight are greater among the vertebrates, which have in common a close historical relationship, and all modified the pentadactyl limb, but they are still quite different from one another. Thus, flight is a functional motif with some very basic structural similarities, which are closer to each other the more close the historical relationship of the species.

An example of the power available from motif-like conceptualization lies in the work on transcriptional regulatory networks developed in Richard Young's lab discussed in the previous chapter. Young et al. explicitly label their work the identification of motifs.[148] They traced all of the different regulatory networks they could find in a specific type of yeast and located 6 different ways that the molecules could tune the organism's thousands of genes. These six networks are motifs because they constitute available mechanisms that the organism can use for similar functions, but which are selectively used for some functions and not others, and which vary in their particular manifestations (see Figure 2 of Chapter 4). The description of these networks provides a kind of general knowledge, even though no one motif is universally used, and even though we await the additional knowledge of the "genrelationality" of the motifs (that is, how many have been used in what organisms). As the work by Milo et al. has pointed out, this is not merely a catalogue of all of the physically possible networks, because different systems, such as food webs, electronic circuits, and genetic regulators, use different sets of regulator motifs.[149]

The wealth of motifs assembled by biologists illustrates that although biology can assemble relatively few universal laws, this does not mean that it is impoverished in its ability to develop useful generalizations (with a motif-like form) and genrelations (placing those generalizations in a history of relationships to each other). *Such motif-like generalizations may be more difficult to describe and less efficient to work with, but they are the most efficient type of generalizations that can be developed for biological beings, because biological beings are not all universally the same*. Biologists therefore may strive for the most general possible explanations, but they impoverish their practice if they believe that only universals count as science, or that particularities are insignificant.

Fitting Evidence to Causal Chronicles

Biological knowledge looks different from physical knowledge in one additional, crucial respect. Because biological beings exist as lineages, historical accounts are a key part of biological knowledge. In his analysis of the distinctiveness of biology, the influential biologist Ernst Mayr emphasized that historical narratives play a key role in biological research. In fact, something like what Mayr is thinking of as an "historical narrative" plays a central role both in explanations of material, functional circuits in biology and in the broader evolutionary account. However, as the description of narrative as a basic symbolic form in Chapter 7's discussion of narrative indicates, the term "historical narrative" is not precisely correct, and we will suggest the label "causal chronicle" for this important type of biological knowledge.

The basic form of a narrative for human symbol users entails, as Kenneth Burke described it, an agent doing an act in a scene for a purpose with an agency. Biological narratives do not have "agents" who are conscious actors making choices.[150] Instead, biological "agents" are nodes in networks of causes and effects. Another way of saying this is that biological being does not feature *purpose* terms (defined as symbolically mediated choices), but rather they employ the assumption that the *functions* of self-maintenance and reproducibility drive any biological system. Thus what Mayr calls historical narratives are really a time series of interconnected cause-effect chains in which relatively stable functions stand as "agents" in the narrative in the place of individuals-with- purposes. The importance of the distinction (and the difficulty of maintaining it) is illustrated by the human proclivity to impose true narrative form on the chronicle of evolution, a tendency that has continually caused trouble for biologists and popularizers of selectionist theories.

The basic form of the causal chronicle in biology provides a means for evaluating a research program that seeks to establish a particular chronicle as an explanation. At the physiological or functional level, the causal chronicle includes a series of linked stories that indicate that physical agent "A" (e.g. a protein complex) interacts with agent "B" (a strip of DNA) in some fashion ("agency") to produce a particular result or output ("effect" or "function" rather than "purpose'), in particular scenes (under what constraining conditions). The chronicle is a series of linked stories because the phenomenon of interest is usually in a network or circuit, so that the interaction at each node of the circuit constitutes its own sub-story, but the account of the circuit as a whole depends on both the sub-stories and the way those sub-stories go together. It is often expressed as a series of "if-then" relationships. "If condition is x, then agent A and B will produce product 2, which will interact with C (which constitutes condition y), for the interaction of agent C, etc."

The failure to recognize the centrality of this form of explanation in biological accounts has repeatedly delayed progress in biological research. For at least three decades, biologists employed a physics-like linear model, "the central dogma", which held that "DNA" directed the output of an RNA, and this would produce a protein. Operating from this linear, one-cause produces one-effect model, medical geneticists spent their time looking for the single genes that caused diseases, and whose repair would produce a cure. Outside of identifying a few rare so-called "single-gene disorders," most of which have not been cured, this paradigm has proven to be a side-trip of only supplemental and instructive value. Research conducted on this model has constantly turned up low associations between diseases such as schizophrenia or diabetes or heart disease or osteoporosis and several genes on several different chromosomes, and these results have often been irregularly replicated. As in the story of the search for the "alcoholism gene" and the DRD2 receptor told above, when ambivalent results were found, the gene was declared a "modifier" that affected some other yet-to-be-discovered gene that was the putative causal gene.

Only recently have researchers begun to accept that the general pattern may not be a single causative gene with modifiers, but rather, because the processes in bodies consist of multiple staged and interlinked networks and circuits, that many genes may exert some level of influence and thus disease is not a product of one gene gone awry, but of how the inputs of several genes combine. Very recent research suggests that if one does one's research by testing simultaneously for a *set* of genes thought to be involved in creating a circuit, one gets clearer statistical signals.[151] The lesson was long in coming, but by now should be quite clear: because the functions of biology arise from MICME, one needs research methods that focus on circuits, in addition to the single node (OCOE).

One could not have known any of this in advance. The project in biology has in some measure precisely been the project of discovering *how* biological being was differently organized than physical being. However, now that these organizational frameworks are relatively clear, it is reasonable to expect biologists to be more consistent in deploying the methods appropriate to the qualities of the nature of the beings they study, and a theory of biology that reflects these distinctive characteristics is superior to a theory that tries to model biology on physics. The primary resistance to these alternatives comes from the fact that biological approaches seem generally to be more difficult than those employed by physicists. This is especially true of the proofs required for establishing causal chronicles.

At the macroscopic level, the basic form of the causal chronicle of biology is laid down by the theory of natural selection. This theory holds that in every location in space-time some forms are more capable of reproducing themselves than others, and the forms that exist at any given time are a product of the history of the forms that were able to reproduce at a previous time (and of immediate local conditions). Two over-arching and related mechanisms account for which forms persist: 1) the ability to survive given, and constantly changing, environmental conditions long enough to reproduce, and 2) the ability to reproduce (which may include such factors as the ability to attract mates with whom one can reproduce, have a sufficient number of offspring with those mate(s), or perhaps to provide care to those offspring so that they can survive to reproduce).

An example: Wilson's learned aversion to snakes

One need only peruse E.O. Wilson's book, *Consilience,* to recognize how central these chronicles are to biological explanation. Although Wilson's book is a lyrical hymn to the "Ionian Enchantment" that emphasizes what he takes to be a physics-based model of research, Wilson constantly resorts to causal chronicles. It is worth examining one of his chronicles in some detail to understand what is required and what can and cannot be achieved with such causal accounts.

Wilson explains that humans have evolved an inborn "prepared learning" for aversion to snakes because, on every continent where humans have taken up permanent residence, there have been deadly snakes (esp. pp. 79-80). Such an aversion thus has survival value. The structure of the explanation is simply the structure of the theory of evolution. A particular form—aversion to snakes—has had survival value through time (because there have been deadly snakes everywhere). Therefore organisms with forms that are predisposed to avoid snakes have successfully reproduced, and those that do not have such a predisposition have not. The forms taken by humans today are therefore those that have such an aversion.

How does one prove such an explanation? By comparison, proof of a physical equation is simply proof that the results of experiments produce the measured quantities predicted by the equation. Obviously, that doesn't work for causal chronicles. Ideally, causal chronicles require proof at the two levels of what Mayr calls dual causation. At the functional level, one would trace how "prepared learning" of snake aversion happens in the body. That isn't possible for human behaviors given our current knowledge and tools. This is a serious gap in the case of claims to "prepared learning" because such a mechanism is even more difficult to imagine than an instinctive aversion. But even if we were able to describe a biochemical pathway for such highly selective prepared learning, merely describing physiological mechanisms would not establish the selective history for the pathway. That would require the ability to trace the development of the mechanism back through the branches of the tree of life. Given the inevitability of the gaps in this record, there will probably never be a complete description of the evolution of any particular mechanism. Even in the relatively easy cases such as evolution from swimming to walking or from small to larger horses, there are enormous gaps in the biological record and hence in any description of the historical pattern of the evolution of a function. This is likely to be even more the case with regard to human behavior. Consequently, in practice, the burden of proof in establishing a causal chronicle falls heavily on the account of the value of the function itself for survival or reproductive value for a particular organism, in comparison to other organisms that are differently situated.

What kind of proofs can be employed to this end? Wilson cites evidence of the breadth of geographical distribution of snakes and mortality figures from snake bites. These indicate the potential survival value of the behavior. To establish the generality of the behavior of prepared learned aversion in human beings he gives anthropological accounts from different cultures, personal experience, and observations of children's response to snakes at different developmental stages. Although he is giving a popular treatment, and therefore does not cite his evidence carefully, he also seems to be including evidence from experiments about how easy it is to teach favorable responses to snakes vs. non-favorable responses. Wilson's proof thus consists of observational and experimental evidence that snakes are deadly and evidence that people readily learn to fear snakes.

All of the work of linking these two types of evidence to the broader evolutionary narrative that holds such prepared learned aversion to be inborn and evolved *due to* survival value comes from one's belief in the "warrant" provided by evolutionary theory. A warrant is the underlying logic that connects evidence with a claim.[152] If one believes the warrant of evolutionary theory, then, if the evidence has sufficient weight, one should believe the claim. Belief in the warrant provided by evolutionary theory is a product of a larger set of arguments, but also the product of a very large induction—the pervasiveness of types of forms that can be explained in terms of survival or reproductive value and a comparative scarcity of forms for which other available explanations are superior.

One either accepts that evolutionary theory is a sound warrant for explanations of existing forms or one does not. If one does not accept evolutionary theory as a warrant, then no argument of this form will be convincing. Polls suggest that a majority of people in the U.S. accept the theory of evolution as a warrant for arguments about the form of plants and animals except that the majority do not accept that the warrant applies to human beings.[153] There is also a greater tendency to accept this warrant for physical aspects of human beings than for behavioral aspects.[154] This does not mean that arguments of the type that Wilson advances (evolution of behavior in humans) have zero probative force for the majority of US residents. Indeed, these particular arguments are part of the effort to extend the arena over which evolutionary theory is taken to provide a sound warrant. Clearly, however, this is not the kind of tight, deductive reasoning to which mathematicians and even physicists aspire. Instead, because it is inductive reasoning, it uses a booststrap approach: each claim-evidence association makes the others appear more convincing. This type of argument builds on accretion rather than a single definitive test. This is only different in degree from physics, where the structure of argument similarly depends upon the lattice of relationships holding each part together. It is simply that the lattice in biology is more open to public inspection and also perhaps somewhat spongier.

For those who accept the warrant provided by evolutionary theory, there remains the question of what counts as sufficient evidence in a particular instance.[155] Many people accept the theory of evolution but reject particular claims made using the theory as a warrant due to the belief that there is insufficient evidence for the particular instance: liberals reject sociobiologists' claims that forced copulation in scorpion flies demonstrates an inherent predisposition toward rape in humans; conservatives reject claims that religion constitutes a mechanism for group evolution or that cooperation can have evolved as an innate predisposition in humans. As the role of political propensities in these responses indicate, the appropriate standard for accepting a claim can be frustratingly vague.

The appropriate standard is simply the best-justified, well-justified belief (see Appendix 1). The standard is implicitly comparative, contrasting all of the conceivable accounts against each other. The story offered by a given explanation should not merely be plausible, but it should have more explanatory consistency than any other story that is on offer. The standard also requires a substantial level of exploration of the possible relevant evidence. Just because one has the only story with any plausibility doesn't mean that it is a sufficient story to be believed. It is easier to get evidence in some organisms than in others (humans are usually difficult). It is easier to get evidence for some characteristics rather than others (it is harder to get evidence about sperm storage or annual nutrition component intake than about tree climbing height).

The basic format of the causal chronicle provides the template for indicating the places at which each story must be judged. The putative agent must be convincingly identified, the agent must be consistently linked to the effect, potential agencies must be of appropriate magnitude and scope to produce the effect, and the scene must be consistent with agent, agency, and effect.

The evidence that is relevant to identifying each of these components of the chronicle will be gathered through multiple methodologies. Controlled experiment provides a particularly valuable input. If controlled experiments are conducted and they do not show that it is easier to teach children snake aversion than snake adoration (i.e. establishing the linkage of agent and effect), and also that this is more the case for snakes than for other aversions, then the claim that there is a predisposition toward learned aversion of snakes would be placed into doubt. This might increase the likelihood of the counter-explanation that so many people fear snakes simply because they are taught to fear snakes. Even if the experiments supported the "learned aversion" account it would be best if this included multiple experiments from many geographically dispersed cultures (establishing that the scope of the scene matches the claimed scope of relevant agents). However, even such a set of experiments would not, on their own, be sufficient.

It might be possible that the image of snakes stands in for some other related image, and is only accidentally easier to learn (because aversion to long forms is easier to learn than aversion to round forms, for example). Other forms of evidence are inevitably important.

The numerical and geographical tally of poisonous stakes is not an experiment, but rather a quantitative observation. It too, is an important part of the required evidence. If deadly snakes existed only in Australia, but people all over the world had this aversion, then the survival value account would not seem to fit (in other words there would be a mismatch between scene and agent). In that case, one would need to go looking for other reasons why it might be easy for children to learn aversion to snake forms. The listing of death rate is also quantitative observational data, and it adds probative value to the argument as well (by establishing effects). Wilson also uses comparative data. He compares the behavior of humans to their nearest kin, who also share this aversion (which further supports the generality of the agent description). The comparative argument would be even stronger if he also made a comparison to less closely related organisms, demonstrating that the less susceptible an organism was to snake-induced mortality, the less likely it was to have such an in-built predisposition to learned aversion (thus using statistical correlation to give more precision to the agent description). It would also be a stronger argument if comparisons were made between the level of deadliness of snake bites and other phenomena that had or lacked prepared learning for aversion or direct aversion (alternate agency-effect relationships).

As this relatively simple example illustrates, it requires a large amount of evidence to establish a causal chronicle that inter-links function and physiology. Many kinds of evidence can be brought to bear, and must be brought to bear to establish the claim. In the background is always a comparison to alternative explanations: chance occurrence of a feature, design by a creator, alternative functions (e.g. snake aversion is a group affiliation sign). One is testing not only how much evidence supports the account, but what evidence supports alternative accounts. Because of this complexity, claims about a causal chronicle typically have been supported to highly varying degrees of probity. They are never certain, and they are often much less certain than accounts in the physical sciences.[156] But this does not mean they cannot achieve status as knowledge, as long as one recognizes a definition of knowledge that is broader than that of the predictive equations of physics. Each case must simply generate its own probative force, using the full arsenal of tools available for probing at the living beings of the universe and allowing them to talk back to us.

Biological knowledge therefore appropriately consists of three types of knowledge. First, there are specific descriptions of particular organismal types. Second, there will be a catalogue of the repertoire of structural and functional motifs that are available, that is, which have actually been used in living beings on earth.[157] Finally, there are statements of the historical relationships among these types based on similarities of structural and functional characteristics that establish a shared lineage (genrelations). Biological understanding is not complete without all three of these types of knowledge. Unlike physics, where universality is the knowledge coin of the realm, in biology the particularities, the motifs and models, and the genrelations are all equally important parts of the science. The character of these explanations is a product of the nature of biological beings and the tools that have been created to study it. These all coincide with the limitations upon prediction in biology.

Biological Predictions

The ability to make predictions in biology varies according to how specific one's prediction might be. If one is interested in very immediate predictions, biologists have good tools for prediction in many cases. For example, one can predict the probability that children will manifest a high-penetrance, dominantly inherited disease if one knows whether the parents have the disease. This kind of use of prediction is very similar to the power and utility of prediction in physics, though it has more constrained applications.

More broadly, biologists also can now predict that animals or plants of a particular category will draw from a repertoire of motifs to execute a particular set of functions. For example, energy has to be captured and stored in some way, and there are a set of options known for accomplishing that (photosynthesis, scavenging, killing and eating other organisms, parasitism, etc.). To take another example, most complex organisms have mechanisms for programmed cell death that are apparently related. Another, more narrow but still important predictions is that sexually reproducing species have some subset of a suite of mechanisms for DNA exchange. When encountering a novel organism, one can predict that a particular range of functions will be accomplished and they will probably be accomplished with a set of variations on known procedures. One can even expect that the particular variations employed will generally be most like the ones used by other organisms closest in relationship historically to the target organism. However, one can't know exactly how the variation is implemented without looking in detail at the particular organism. Particularities of mechanisms are unpredictable.

Population genetics also offers some limited predictions. The Hardy-Weinberg equation provides a useful prediction about the levels of genetic variation in a population, although deviations are hardly surprising. More predictions from population genetics and evolutionary modeling may well be forthcoming as the methods of DNA analysis make available much larger and more detailed data sets. Indeed, because population genetics is the branch of biology most amenable to measurement and most focused on numerical variation, it should produce more predictive guidelines, even if these do not manifest a rigid law-like character.

Biology is also relatively poor at predicting the future course of organisms. As Roderick and Navajas recently noted, "Purposeful introductions of pathogens, parasites, predators and herbivores, when considered as replicated semi-natural field experiments, show the unpredictable nature of biological colonization."[158] Because organisms have a fair amount of variability of response, gained by channeling external inputs through robust circuits, prediction in biology can in many cases at best specify ranges rather than exact values, and predictions will often simply be wrong. As has been frequently noted, biologists lack the power to predict how a particular mutation will affect an organism, let alone the viability of the organism in a particular niche.[159] Until recently, they haven't even had a very good ability to predict what sequences of DNA constitute genes or how proteins will fold up, given their sequence. Much of this limitation is due to the complexity and number of variables involved and the fact that there haven't been many models to work with. As more models are made available, biologists will get better at prediction. That, however, is pretty close to saying that the more they have charted the specifics of all the individual particular organisms, the less they need prediction as a tool at all; they'll just know about the ranges that exist within individual cases.

That is an overstatement, of course, because one can expect some improvements. All the same, there are built-in limitations to prediction in biology. For example, there are more false signals in gene expression profiles than indicative ones, and that is a consequence of the nature of gene expression and the statistical tools one can use. While researchers are getting smarter about sorting through the signals, they are still going to face the same highly variable patterns to sort through. Moreover, even with a wealth of available models noone will not able to predict every turn that a new species will take, because life is opportunistic and can therefore invent new models.[160] These limitations on prediction have serious implications for issues of control.

"Controlling" Biology

The differences in the predictability of biological vs. physical forms have led to serious disappointments in the realm of biological control. For example, there is less than a 20% success rate in efforts to use biological methods for controlling either arthropods or weeds.[161] It turns out that the model of control based on the physical paradigm—hit the billiard ball with the cue and it will move!—is grossly inadequate for biological systems. Organisms are 1) constituted of dense networks of circuits that maintain a range of values, and 2) opportunistic entities with their own goals; they are not passive, static being. Consequently, efforts to use the explanations and predictions derived from biological research in order to control organisms face at least two major barriers:

difficulties in intervening in robust and highly interactive networks and difficulties in dealing with the fact that biological systems change, and hence "fight back."

Nothing more clearly indicates the difficulties in intervening in the robust and highly interactive networks of living systems than the story of gene therapy. When originally conceived in the late 1980s, many of the researchers in gene therapy earnestly believed that the technique of inserting functional genes to replace dysfunctional ones would provide a widely applicable set of cures to serious diseases, and would do so within the space of five or ten years time. That was a hopeful time, when medical researchers believed that understanding genes would mean an immediate health benefit to their suffering patients. Today the roll call of successful gene therapies is slim indeed. Even those few instances that might not be called absolute failures have provided partial rather than full cures. In 2005, a moratorium on the most successful gene therapy—for ADA—was instituted because of spontaneous leukemia among the therapy's recipients.

The interconnected architecture of organisms is the cause of these failures. In the first place, organisms have mechanisms for keeping out foreign matter (including DNA). Finding safe vectors that can transmit large enough chunks of DNA into cells constitutes a first problem. More seriously, the DNA itself is highly ordered in time/space specific circuits, and the order matters to its function. Therefore, even when the DNA can be successfully inserted into the cell (without killing the organism), getting the DNA into the right place is extremely difficult. The organisms' internal systems are so finely tuned that if insertions are successful, they are far more likely to produce mis-function or non-function than correction of function. Inserting the DNA in the right place doesn't preclude also inserting it in some wrong places (which has turned out to include inserting them into tumor suppressor genes, which leads to cancer). Then, keeping the DNA functioning in the organism proves to be another problem. Organisms are constantly changing out their cells, and so putting DNA into some cells doesn't provide a permanent fix.

The disappointing limits of gene therapy to date are also related to the facts of development. Genes work in part by laying down developmental pathways, and once development is over and the pathway is turned off, it is hard to modify those "finished" characteristics of the organism. One can't cure Downs syndrome through gene therapy (or RNA-Interference), because some of the structural problems caused by the third copy of chromosome 21 occur as the fetus develops. De-activating the problematic genes after birth can't undo those structural problems. Similar limitations may exist for many other diseases including autism, depression, ADD, and some versions of heart disease. Even if one were to understand everything about genes and organisms, the possibilities for gene therapy would be limited, and even in the feasible cases, it would be difficult. Knowledge doesn't guarantee control when the system itself is delicate and structured into highly ordered, time sensitive, robust circuits. This dynamic internally circumscribed functionality does not mean that gene therapy will forever be unsuccessful, but it does mean that to exert control over biological organisms requires a different logic than to exert control over most inert matter.

Drug development is likewise seriously affected by the interconnected nature of the functional circuits that constitute biological beings. The greater understanding of biological systems enabled by the tools of DNA-based research have led the pharmaceutical research establishment to hope for "designer drugs" that would target particular parts of biological systems. This, however, is a misapplication of the model of control from physics to the biological systems, in which single drug targets, such as transcription factors or phosphorelators (review Figures 2 and 3 of Chapter 4), have multiple interactions and exist in circuits that are rheostatically balanced by the multiple components of the interacting circuits.

The recall of the anti-arthritis pain medicine Vioxx illustrates this clearly. Vioxx was a fine example of "targeted" drug therapy. It was supposed to be desirable because it targeted only Cox-2 inhibitors. Early treatments for arthritis had impacted both Cox-1 and Cox-2 inhibitors, and had therefore harmed digestive systems. Vioxx was thus expected to treat arthritis pain without the damaging side effects of less "targeted" medications. As it turned out, however, Cox-1 and Cox-2 interact in several biological circuits, and Vioxx's ability to target Cox-2 led to an imbalance in Cox-1, which then, it appears, produced blood clotting disorders.[162] The Vioxx experience will be typical rather than anomalous, because biological organisms are built of networked circuits that reuse many elements in many different ways. With medicine, therefore, one should expect that the question will always remain, "what are the unwanted or 'side' effects on the components of the network that are not targeted?" This might mean that instead of searching for perfect drugs—something that has no serious side effects for anyone--it would make more sense to develop a procedure that seeks to understand all of the side effects on all possible patients, and then to use a pharmaceutical when a well-informed patient decides that the benefits are substantially greater than the costs. Whatever the eventual medical delivery logic, seeking for perfectly targeted drugs operates on the wrong logic of control.

The changeable, dynamic and even responsive character of living beings provides a second major barrier to physics-like control over biological being. Organisms have developed mechanisms that respond to their environment. Species have developed mechanisms to evolve in their environments. Efforts to control living organisms thus face a kind of problem that does not exist in physical control. The organism and the species fight back. Insert a heart to try to cure a body and the organism rejects the tissue as foreign. Operating on a mechanistic analogy between cardiac patients and automobiles needing new engines just doesn't work. Biological beings are more than passive physical structures. Spray a pesticide on a crop, and you may kill a lot of bugs. But in a few years the bugs are back, resistant to your chemical. Use an antibiotic to keep cattle healthy, and soon the antibiotic is worthless for keeping people healthy.

The logic of "control" in biology requires looking beyond the immediate target and the immediate sub-system. It requires understanding the biological organism, its life cycle, and the interconnections among biological organisms through time; otherwise one is as likely to kill the organism or enhance its virulence as to get it to take the form or behave in the way you desire. The work of Rich Meagher's laboratory on phyto-remediation of mercury and arsenic in toxic waste sites provides an example of the broadening of perspective that is needed.[163] Meagher analyzes the interactions of the various systems of plants to imagine how uptake of various forms of mercury and arsenic can be increased from naturally occurring plants and by genetically modifying plants to get them to process the toxic chemicals through the various pathways in the organism from root to stem to leaf. Although each step of the process uses reductionistic, controlled approaches, the steps are imagined within the series of processes through which the plants live: what causes the root to take up the toxic element? how and where does it reprocess the element to detoxify it? how do different forms of the element then move up the stem of the plant to the leaves? at what stage does reprocessing function best for storing or expiring the chemical? Additionally, Meagher looks beyond the issue of simply moving the toxic chemical from the ground to the leaf. He looks ahead to the eco-system toexamine ways to make the plants infertile so that they do not cross with other plants and upset the ecological balance in other ways. He thinks about how well humans will do in monitoring the plants that they put out over the long term, and chooses species and plans in line with those expectations.

Given the nature of biological being, Meagher's word "remediation" provides a better description than "control." There is no perfect cure for the toxic waste sites that humans have already created, but we can remediate them: that is, "counteract an evil."[164] These efforts will never be complete, never foolproof (the infertilized plants might mutate to fertility, depending on the means of infertilization used; mercury vapor may prove to be a more pervasive and serious hazard over the long term than it appears now). But remediation, taking a moderately long term and moderately comprehensive perspective may be the best we can hope for.[165] It is not the case that we can simply avoid interacting with the rest of the biological world.

The word "control" is problematic for biology because it seems almost to have embedded in it the adjective "absolute." Whether the term "control" continues to be the dominant term, or it is modified to "mediate," "reshape", "interact," "negotiate" or something else, however, more attention and deeper analysis is needed of the kinds of interaction with the biological world that will produce the kind of equilibria that humans desire. While we've suggested that attending to interconnection and responsive dynamism are two parts to such a reframing, clearly there is much more work to be done. The state of knowledge is now, however, far enough away from the model of physics and deep enough into the frame of biology that our species can begin to make substantive moves in that direction.

Conclusions

Biological being is different from physical being. It features a roiling diversity built from nested circuits that function to reproduce self-similar forms that change through time and space. To study these forms and their formation, biologists use all of the tools of physics, but embed these with other tools and in different configurations. They deploy these tools not toward the generation of mathematical laws, but rather toward causal chronicles and functional accounts that consist of models and motifs. These explanations allow some kinds of prediction, but not others, but they rarely produce firm, permanent "control" of any biological phenomenon. Instead, they show us how to interact with other biological organisms in ways that might temporarily serve our own self-interests, though we cannot completely neglect the organisms' program of self-replication. One is surely correct to claim that this amalgamated program of research has produced a wealth of knowledge, even if that knowledge is more a knowledge of motifs, options and particulars than it is knowledge of universal mathematical laws, and even though it will always need to be adapted to the changes life itself undergoes.

There is, however, one animal that is particularly troublesome for biologists to study. Humans are symbolizing animals. Just as biological being requires its own methods of study because biology is supervenient on physics, so also does symbol-use produce unique properties, and these too require appropriate methods of study and produce unique types of knowledge.

Chapter 6: The Material Character of Symbolic Being

Summary: Symbolic being--the world of interacting signs, numbers, and words--has many features distinct from those of physical and biological being. Symbols are material entities like those of physical and biological being, and symbol systems build onto biologically coded predispositions, but those systems give rise to new capacities beyond the purely biological. This "value added" model of symbol use is supported by recent research on human use of number systems and comparative language studies, which show that symbols may be linked to other cognitive capacities such as set construction and reasoning, but that human tendencies to access those capacities through language produce new capabilities. Through those capabilities, symbols produce different behaviors, thereby exerting unique material impacts on the world. Recent neuro-imaging research further supports that view by showing that language is a neuronal web involving linkages among language specific areas and a diverse array of content specific areas in the brain.

Kenneth Burke, who was perhaps the most influential rhetorical theorist of the 20th century, dubbed humans the "symbol-using animal." E.O. Wilson, the progenitor of socio-biology, called us the "babbling ape." The difference in labels is indicative of the considerable gap between two major conceptualizations of human beings. Scholars studying human communication perceive incessant symbol-use as the central feature that distinguishes humans from other animals, and they have invested substantial effort to understand symbolizing. As a rule, bioscientists do not understand the character of symbols, and so they interpret them as little more than the “babble” of apes.

There are historical and disciplinary reasons for the tendency of natural scientists not to take symbol use seriously. The current battle between “cultural” accounts of human behavior (to which language is generally assigned) and “socio-biological” accounts of human behavior have exacerbated that history. Many biologists and evolutionary psychologists implicitly assume that to assign a causative role to language is to “take the side” of what they perceive to be a discredited approach that portrays human beings in an imprecise fashion as infinitely “plastic,” and hence not at all a product of our biological characteristics.

To see how it will be profitable to set aside that disciplinary history and its resulting duel, turn the page and look at the diagram on the next page. What do you see there? What do you think about it?

Can’t answer those questions, can you? The point of those sentences was to compel you to do something through words alone. There isn’t a diagram on the next page for you to see. The example illustrates a simple case where language generates a specific behavior. Not only that, but the example shows that it is possible to predict the behavior of the population receiving that particular stream of words (not everyone would have turned the page before reading the text that admitted that there was no diagram to see, but the overwhelming majority would have done so). Furthermore, by using those words, we generated (and could predict) the emotional responses associated with the behavior—low levels of confusion or uncertainty and annoyance. (For some readers, this would be followed by a wry smile of pleasure at the deceit and at the success of the example).

This manipulative little example does not, of course, deal with all of the complexities of the inter-relationships of biology and symbols. It doesn't address the status drives, visual capacities, developmental proceses, etc., that also went into the turning of pages in response to a sentence. It doesn't address far more complex symbolically shaped behaviors such as war or marriage or university life. But the example demonstrates that specific sequences of symbols have the power to direct specific sequences of behaviors. Without that sentence, the page would not have been turned at that time it was turned by its readers, and the readers would not have experienced the range of emotions that they experienced. The admission that language and other symbol systems have material effects enables one to move on to the harder and more precise (and interesting questions) about the material processes involved in the interactions of biological and symbolic processes.

The materially based understanding of language that we are developing can be described as a replacement for the "expressive" theory of language. The expressive theory of language has great intuitive appeal, and its academic legitimation stretches at least to Plato's theory of "ideas." The expressive theory holds that there are things and ideas out there in the world, and all language does is "express" or "convey" them. That theory is today a mainstay of sociobiological conceptions of language, as is illustrated in Stephen Pinker's statement that "knowing a language, then, is knowing how to translate mentalese into a string of words and vice versa "[166] (for more detail on language and evolutionary psychology, see Chapter 10).

The wide-spread appeal of the conveyer belt metaphor is a testimony to the power our language systems exert on our perceptions of the world, and it will take both this chapter and the next to provide a thorough discrediting of that common sense perception. There is no reasonable doubt, however, that the expressive theory is wrong. Language and other symbol systems are not simply passive conveyers of material being. Because symbol systems are themselves material, engaging them generates a series of specific effects that are not just a product of the reality outside the symbol systems, nor of the other cognitive processes that are involved in addition to the symbolic system per se, but also of systematic biasing properties of the symbol system itself. Instead of a passive conveyer belt, symbolic systems are more like assembly lines, in which raw materials with specific qualities are formed and shaped into new objects with novel capacities and properties by the machinery of the assembly line. The products of the assembly line are certainly shaped and constrained by the characteristics of the original raw materials, but they are likewise shaped and constrained by the material qualities of the processes that take place on the assembly line, which in this case is the symbolic structure. Chapter 7 will introduce these characteristic tendencies of language as particular effects of categorization, the convergence of flows, historically based materialism, binarism, and narrative, and Chapter 8 will discuss the truly fantastic emergent properties that build on these basic characteristics, including time-space binding, novelty of kinds, and a kind of causality we will label effectivity. The present chapter, however, will build a base for the elaboration of the characteristics of language through three sections. First, we will show how human language is continuous with the material communication processes of other species, but also distinctive due to its symbolic rather than sign-based form. Second, we will review two crucial experiments on numbers and natural language that illustrate at the most micro-analytic level exactly what it means to say that language does something material to create novel capabilities in a symbol-using animal. Finally, we will tentatively link these material properties to recent research on how the brain handles language, to show the ways in which the distinctive properties of language none-the-less can be linked materially to the brains that process those symbols.

The Physical Character of Symbolizing

Biologists have recently gained a great appreciation for the role of communication in biological systems. Whether exploring the coordination of cellular or organismal components, watching interactions within ant colonies or among bees in hives, or studying the mating rituals of larger animals, biologists have accepted that physical elements such as pheromones wafting in the air serve to coordinate the behaviors of different biologically based entities. A pheromone is just a complex molecule or set of molecules. To the receiving organism, it indicates a particular "environmental" or external condition, just as stepping out of a den into a rainstorm indicates a meteorological condition. Pheromones, however, operate at a step removed. The rain drops *are* the storm, rather than being a *sign* of the storm. The pheromone, as a sign, is a detachable stimulus that is reliably associated with some other physical phenomenon external to the organism for which it stands as a sign. In this way, pheromones or hive dances are like the smell of prey or of a watering hole, which indicate the availability of resources. But pheromones or hive dances are also different from the smell of prey or a water hole, because the latter have not evolved *to communicate* to the prey-seeker or the thirsty animal.

Pheromones and hive dances have evolved as emissions from one biological being to communicate with another biological being, and such evolutions have occurred because they *coordinate the behavior* of the biological entities involved, in a fashion that is relatively and mutually advantageous for the survival or reproduction of those beings. The label "signs" designates physical phenomena like pheromones, honey-locating dances, or courtship displays that constitute stimuli that are associated with, but detachable from or additional to, states or characteristics or resources about which it is mutually advantageous to coordinate behavior, and therefore have evolved as such.

Human beings use signs too, but most human signs are embedded in sets of signs.[167] Sign sets have properties that arise from their characteristics as a system, and we therefore designate human sign usage as symbolization (though there may be other animals that have at least basic symbol systems).[168] Because the symbol systems used by humans are composed of nothing but flows of signs, they are fully based in physical being. Setting aside the unlikely possibility of telepathy, there is never any symbolic communication without inscription in physical substances. Oral communication occurs via the passage of compressional waves through air, and visual communication occurs through light waves—reflections and projections of body movements, marks on paper, or video and photographic images. Braille utilizes differential heights of surfaces. These variations in light or sound waves or touch are sent along nerves to the brain, where they are processed in distinctive parts of the brain, inducing humans to act in various ways.

There is every reason, therefore, to try to understand symbol systems as carefully as we understand other physical phenomena, rather than dismissing them as "babble".

The distinctiveness of symbol systems from signs is both qualitative and quantitative. Putting two or more signs together changes the potentials of signs to what we call symbols, because the signs act on each other. A sign gets its meaning (or what we will define more carefully as "effectivity" in Chapter 8) solely from its association with a particular valued or disvalued stimulus. In contrast, the effectivity of a set of symbols derives both from its historical relationship to the stimuli with which they have been associated *and also* from the surrounding symbols (and even contexts). The more elaborate the symbol system becomes, the more distinctive its features become. Thus, a sign generates only one response.[169] When a vervet emits the troop's sign for "leopard", all the vervets within hearing run up trees to safety. This happens even when a vervet uses the sign deceitfully—when there is no leopard present. A vervet may emit the call for leopard when engaged in a losing battle with another troop of leopards. The vervets run up trees, postponing the battle. In contrast, two symbol-users not only can tell each other "leopard", but they can also tell each other "that's not a leopard, it's a plastic replica." The symbol "not" has no specific association within any phenomenon in the world.[170] It has meaning only in relation to the other signs with which it is associated, and indeed human language is a symbol system that is full of symbols that are not linked to particular external stimuli, but rather are generated by the utility of establishing relationships among the flow of symbols itself.

More complex series of symbols magnify the interactions among the symbols. For example, "it is raining too hard today, let's not go hunting" gains its effectivity not simply from the relationship of "raining" to falling water and the temporal marker, but also from the relationship with "hunting" as a purpose-driven activity, and the relational marker "we." Each of these signs taken alone does not specify a recommendation about a proposed coordinated activity, but taken as an ensemble in some contexts they may have that specific effectivity. These processes are magnified to produce massively complex coordination of behavior, as when the leader of a multi-national power declares, "Someone has attacked us! Let's go kill people half way around the globe!"

The Material Impacts of Symbols

Once one begins to think of symbolizing as a material phenomenon, one should expect that the movement of symbols will have a physical or material impact on the other physical and material entities with which they interact. The kinds of impacts that symbols have are determined not only by the properties of each individual symbol but by the properties of the symbolic system, much in the way that the outputs of biological systems are determined by the system rather than by a single node (see Chapter 4). The outputs of the interactions among signs in a symbol system are guided by their serial order. They may also be guided by additional components of the system: symbol systems may evolve an internal logic and the signs in the symbol system may develop in specific types or categories. These internal logics and categories impart particular potentials to the symbol system.

If symbol systems have material effects of their own, then this means that the brain processes involved in using symbols must be different from the brain processes that occur without symbols. If their effects were not also different, such modifications in the brain would have had no impetus to evolve. This is to say that neither the strong form of the so-called "Sapir-Worf" hypothesis nor the uniformitarian view of evolutionary psychology are accurate.[171]

The Sapir-Worf hypothesis is taken to hold in its strongest form that human perceptions and beliefs are a product of the language to which people are exposed. This linguistically exclusive hypothesis has been strongly discredited. Animals that lack the brain structures associated with human language none-the-less reason in ways that are often strikingly similar to human reasoning. They have been shown through relatively recent rigorous scientific testing (not to mention common-sense observation) to be capable of at least basic problem-solving, quantity estimation, and set construction, along with other "conceptual" tasks that have historically been associated with the realm of "ideas," and hence assumed to be the product of language.[172] Language thus, if it does anything, does something other than create the ability for all cognitive capacities or "ideation."[173]

On the other hand, this evidence does not mean, as some evolutionary psychologists have maintained, that "thought precedes language: language is a tool with which to express one's ideas."[174] Instead of "language does it all" or "language is only an a-conceptual conveyer belt," the increasingly obvious alternative is to suggest that language adds additional cognitive capacities to other brain processes. This produces a tri-partite "value added" model with the following components: an ESSR (evolved sensitive to specific relationships), a symbol system, and a CS (categorical specification). Non-linguistic brain modules produce certain mental predispositions (ESSR, usually thought of as conceptual capacities), which language processing then modifies in systematic ways to produce Categorical Specifications (Chapter 7 will elaborate on what exactly the process of categorization entails, and Chapters 7 and 8 will expand beyond the basic foundation of categorical specification to indicate additional symbolic capacities). The tri-partite model thus holds that ESSR plus symbols produce CS, where ESSR is different from CS both as a physiological process and in terms of potential behavioral outputs. To illustrate and to link this model to the existing evidence we begin with the simpler system of mathematical symbols and then move to the more complex system of so-called "natural" human language.

Impacts of Numeric Symbol Systems

A recent pair of experiments has illuminated the precise capacities that are created when a numeric symbol system is added to brains that lack them. Without number systems, many animal brains (including those of humans) are capable of estimating relative quantities. In addition, in the absence of access to number systems, human brains (and perhaps some other animals) are also capable of counting out precisely three or four items. However, without number systems, humans do not count out precise quantities of larger numbers of items, and do not match precise quantities in sets of five or more. The fact that numeric symbol systems add this capacity has been demonstrated expirementally. Peter Gordon gave members of the Pirãha peoples of Brazil an image of five wavy lines, and asked them to copy them. They reproduced many qualities of the lines they had been asked to copy, but they did not reproduce their exact number—they might, for example, produce four wavy lines.[175] Other tasks produced the sample result. In the absence of a numeric system, people do not match large quantities of items precisely, but when given such a system, they do so. This finding indicates clearly that symbolic processing adds a specific and powerful behavioral capacity to human brains. It does not, however, mean that language creates the capacity for quantitative assessment. For indeed, in another experiment with an Amazonian group, Gelman and Gallistel have shown that another group of people who also lacked serial numeric systems were able to assess approximate quantities, even relatively large amounts, successfully.[176] What this pair of experiments, taken together, exactly indicates is that human brains (like those of many other animals) come equipped with algorithms that can keep precise track of quantities of four or less, and additional neural processes for recognizing approximate magnitude, but that a specific kind of symbol system—one based in serial enumeration--adds to that neurological equipment the additional ability to define precise quantities in large numbers.

The results of this pair of experiments are indicative of the way in which symbol systems build onto biologically coded predispositions in ways dictated by the character of the symbol system itself. Discrete, serial number systems categorize phenomena by exact quantity because the symbol system itself is composed of discrete signs (uno, dos, tres, quatro or eins, zwei, drei, vier….) and these signs are ordered by a relationship of the repetition of an exact quantity (un et un fait deux, un et un et un fait trois, un et un et un et un fait quatre). The logic of the numeric symbol system thus enables the matching of exact quantities of things because it enables the articulation of an abstraction of precise or individuated quantity out of all of the different features that might be represented in a group of squiggly lines. In other words, by creating a category for "exact quantity" (understood as the repetition of a unit amount/symbol), a user of such a symbol system has a focus or reference point for considering a group of squiggly lines in a particular way—as a set of things related by a particular quantity (rather than by, for example, the similarity of their form to each other or their location on a table). The pointing-out-of-precise-quantity that the numeric symbol produces enables or even tacitly encourages the symbolizer to reproduce the exact quantity, whereas someone without such a symbol system does not have such a frame or tool available.

A symbol system thus can create a specific capacity that is absent without the symbol system. This capacity materially participates in the production of new sets of behaviors (e.g. exact matching of large numbers). The fact that the new capacity is also dependent on other capacities (such as for small number numeration and large quantity estimation) does not relegate the unique contribution to insignificance. It cannot be said that the new capacity merely "expresses" old capacities, even if it functions by creating the ability to combine those capacities.

Because our agenda is to encourage researchers and policy makers to take symbols seriously as substantive contributors to human capacities, it is worth attending at this point to the ways in which such an approach is deflected by the standard scientific assumption that language is just a conveyer belt or an immaterial medium that relates other cognitive capacities. This is evident in the work of Spelke and Tsivkin (2001), who three years before the publications about number-use in the Amazon had published a formulation of the research on numeric cognition that already encompassed the basic principles presented by the authors of the new research, only more fully. Spelke and Tsivkin summarized work that already showed that humans, like other animals, had brain processes for 1) precise enumeration of small quantities (less than 4), and for 2) approximate estimation of large quantities, but that 3) only people with language could perform precise enumeration of middle and larger quantities. They further validated the role of language in mathematics in experiments with bilingual speakers. These experiments showed that people are better at doing mathematical tasks in the language in which they are trained on those tasks and also that this is not just a matter of speed of encoding or decoding. Their own novel research showed additionally that multiplication required language (i.e. mathematical symbols) even though addition of small quantities was possible without such symbols. However, these two excellent researchers did not conclude therefore that the symbol system was a substantive factor in the constitution of the capacity for precise enumeration of large quantities, multiplication, and advanced language. Instead, like almost all scientists, they persisted in perceiving language as epiphenomenal. So they described language as a "medium" that merely "conjoins" the large-number-estimating system with the small-number-enumeration cognitive structures (p. 90). They admitted the difficulty of explaining how such a conjoining could occur, but because they would not look in detail at how symbol systems function, they could not resolve that problem in the simple fashion we have described above.

On the standard account, the human capacity for counting large numbers is a "universal" because all ("normal") people have a non-symbolic capacity for both counting small numbers and estimating large quantities. However, all people do not, in fact, have the capacity to count large quantities, and this is true even though all people have symbolic capacities. Thus, enumeration of large quantities may be a *potential* that is accessible to all humans (at least all those with normal symbolizing capacities), but it is not an *actual capability* that they have in the absence of a specific type of symbol system—one for serial enumeration of quantities. Adding the numbers (a symbolic set) adds specific capacities.

Our recurring point will be that the specific capability created by a specific type of symbol does not have to be evolved as a special unit or program in the brain, but merely constituted ad hoc through programs that were already evolved (e.g. like the general ability for sign usage and approximation of quantity). Nonetheless, the application of symbolizing capacities to specific existing non-symbolic brain functions creates new "cognitive" capabilities and behaviors that do not exist without the symbolizing. It is a mistake to overlook the role of language in the process of the production of human behavior and to assume that all of the causation happens in some other units of the brain. This point is underscored by considering higher mathematics. In some sense the human brain has the biologically based ability for tensor calculus, or no humans could do it. But humans can only do tensor calculus after adding complex mathematical symbol systems to their brains.[177] Tensor calculus did not evolve as a biologically embedded program in the brains of our Pleistocene ancestors. Mathematics is a symbolic evolution of categories of numeric symbols (e.g. real numbers, imaginary numbers, matrices). Symbol systems with particular characteristics thus enable particular outcomes, and these outcomes are in-addition-to other biologically embedded programs, even though they are also obviously consonant with or enabled only because of the character of the biologically embedded programs.

To generalize from the example provided by numbers, we would say that animals have biologically evolved to be sensitive to specific relationships such as relative quantity, the closeness of things to each other, movement, coloration, three-dimensional form, etc. At the very least, symbols add to such evolved sensitivities to specific relationships (ESSR) the material property of categorical specification (CS).

Impacts of Natural Human Languages

The logic of numeric systems adds certain kinds of capacities to human brains. Similarly, natural languages employ a particular structural logic (usually called "grammars") and specify specific categories of symbols, which add new capabilities to human brains. Probably the most central feature that natural languages add to human capabilities is the creation of categorized objects. Chapter 7 will help make this argument meaningful, but here we will merely provide the empirical evidence that this is so.

The central experimental example of the ability of language to constitute categorical objects is the Korean term "kkita." Many years ago, research demonstrated that native Korean speakers tended predispositionally to classify objects as to whether they were "tight fitting" or "loose fitting." Speakers of other languages, which generally do not have an equivalent of the Korean word "kkita," do not predispositionally make this categorization. This indicates that specific language systems shape the cognitive behavior of people. People with one symbolic set notice certain things about physical objects in the world, and people with other symbolic sets notice other things. They subsequently classify the world into different sets of objects with different category boundaries.

The clarity of the evidence on this point was, of course, problematic for those who want to defend the conveyer belt notion of language. Recently, therefore, they set about trying to show that human brains come pre-wired to notice “kkita” relationships, but it is simply that people with languages that lack a term for “kkita” lose this ability to notice such relationships. Two researchers, Hespos and Spelke, did this by showing that babies who do not yet know languages notice “kkita” relationships. Of course, even if this conclusion is correct, language still makes a large difference, and is not merely a conveyer belt. It is, at the very least, a sieving conveyer belt. But it turns out that their research does not even establish that human babies have the ability to notice “kkita” relationships, as a more careful analysis will indicate.

Hespos & Spelke framed their experiment on babies as a test of two hypothetical possibilities, 1) that “language learning creates new conceptual categories” (p. 435) or 2) that “sensitivity to conceptual distinctions that are central to the semantics of any human language may emerge before language experience and then be enhanced or diminished by subsequent experience” (p. 435).[178] To test these two alternative possibilities, in their experiment they assessed whether infants noticed a shift from tight-fighting to loose-fitting items. The infants did notice such shifts, even though they did not have any language, and this was offered as proof that the category tight-fighting/loose-fitting was embedded in the brains of all humans, although only Koreans happened to have words for it. In the experimenters’ words, “infants therefore divided this continuum of events into the *categories* of tight-fitting and loose-fitting relationships” (our emphasis, p. 435) and that “language experience reduces sensitivity to conceptual distinctions not marked by the native language, but it does not produce the relevant concepts” (p. 456). In other words, they claimed that the experiment support hypothesis 2 and discredited hypothesis 1. We will suggest that, instead, a third hypothesis should be considered most consonant with the available data—that the word "kkita" combines at least two underlying cognitive capacities to produce a novel category with relatively high salience for its users.

The conceptual or perceptual capacity that the researchers interpreted as the "category" of tight-fit/loose-fit was the tendency of human infants (and other animals) to understand basic object mechanics—that objects that are in contact with each other will tend to produce corresponding motions when one of them moves. The authors of the study write, "For infants, the categorical distinction between tight- and loose-fitting relationships may be a product of a more general, language-independent system for representing object mechanics" (Hespos & Spelke, 2004, p. 454). Let us call this conceptual capacity "contact produces co-motion."

Hespose and Speke tested the existence of this capacity in an associated experiment and showed that infants do indeed have the perceptual capacity for noticing this relationship. However, Hespose & Spelke's conclusion about what the existence of this capacity means rests on the faulty assumption that the category designated by the Korean word "tight-fit/loose-fit" is identical to the perceptual capacity to notice that contact produces co-motion. This is not true, even though "contact produces co-motion" may be one of the principles upon which the symbol tight-fit/loose-fit is based. Other conceptual principles are also required for the "category" as demarcated by the word. As Bowerman and Choi (2001) describe it, the Korean term "kkita" is translated as "interlock, fight tightly," and it includes only things that not only fit tightly together, but also that interlock. Two items that fit tightly against each other would show the "contact produces co-motion" principle, but they would not fit the "kkita" category unless they also fit the "interlock" criterion.

The difference between the concept “contact produces co-motion” and the verbalized category “kkita” is emphasized by the systematic errors made by children learning Korean. They tend to over-apply the term; Bowerman and Choi show how differences in the types of systematic errors among children learning different languages reveal the differences in structures of these languages. For example, children identified both sticking a fork into an apple and a magnet attached to a surface as “kkita”, but adult speakers of Korean do not accept that labeling. Although in both cases the “contact produces co-motion” principle is observed, in the first case the contact occurs after the initial movement and in the second case there is close-fit but not interlocking fit (p. 489). The conceptual territory that the linguistic term takes in is not self-evident to children because it is not identical to a single under-lying concept (or ESSR).

The Korean term “kkita”, like most symbols, is not simply an expressive device for a pre-existing concept (the ESSR of contact produces co-motion). The word *constitutes* a category that is a particular blend of principles that are demarcated in particular ways according to the structure of the entire linguistic system in use. Bowerman and Choi suggest that instead of identifying words with discrete concepts, a more useful approach is to think about language as demarcating territories along conceptual “gradients of perceived similarity between situations of different types” (p. 503). This approach usefully captures the way in which language creates discrete boundaries out of capacities that may be more continuous. However, instead of imagining single gradients, one must use a model that envisions twisting and folding multi-dimensional interfaces among several different gradients. Moreover, such pre-linguistic conceptual grids are not the sole input.

The case is analagous to that of the numeric symbols, which changed the embedded ability for a rough specification of magnitude (an ESSR or, more colloquially, an ability to "conceptualize") to a new capability for precise quantification of all degrees (a categorical specification, or CS). The human infants, like many other animals, probably have a conceptual capacity (an ESSR) to notice whether two things are in contact with each other, and therefore whether movement of one will result in movement in the other. This ESSR, however, is different from a category (CS) that specifies this relationship in the binary form "tight fitting, interlocking" vs. "loose fitting." Indeed, the questions an English speaker naturally has about this unfamiliar categorization indicate the difference between the binary category and the pre-linguistic conceptualization: Why is the category translated "tight fit" vs. "loose fit", when what is tested in the experiment is "contained within and touching" vs. "contained within and not touching"? How close do two items have to be before they are placed in the "tight fit" category? Does infant attention shift vary discretely at some break point of "closeness" or is there a gradual falling off in attention? Does this vary by size or some other qualities of the items assessed? In what ways does the tight fit/loose fit binary category differ from a potential gradient in the contact/no-contact conceptualization? All of these questions point to the gap between the ESSR and the CS.

To summarize, *an inborn ability to conceptualize a relative difference in a quality is not equivalent to a category that instantiates conceptualizations in particular ways*. The category is not simply a faithful reproduction of a conceptual capacity. The symbolic category involves the concept, but more than the concept. Consequently, it is misleading to imply that because the conceptual capacity is "prior to" the linguistically enabled capacity that it is the "source" and therefore more important (the assumption made by Bloom, and Hespos & Spelke). The sensitivity to a particular type of relationship (ESSR) may exist without the linguistic category, but the linguistically enabled capacity can only exist when the language is invented that *merges* the symbolic proclivities with the target conceptual sensitivity to produce a categorization and thus a distinctive capacity. The bare conceptual capacity (ESSR) is *different from* and commonly *more simple than* the linguistically enabled capacity (CS). Symbol systems produce complex cognitive capacities by 1) linking other cognitive domains, 2) repackaging perceptual gradients into discretely bounded entities, as well as many more elaborate tendencies such as the production of narrative forms.

The two alternative hypotheses that Hespos and Spelke list are thus both incorrect. Language does not merely create "conceptual categories" that are unrelated to other brain functions, nor does it merely "express" a pre-existing category. Language makes ESSRs into specific categories. The repeated use of these categories then modifies the predispositions of their users. The research of both Bowerman and Choi and of Hespos and Spelke shows that adult speakers of Korean mark the tight/fit-loose-fit distinction more readily than do adult speakers of English. Choi shows this effect exists as early as 18-24 months, even before children have started to speak the language that they have already begun to comprehend. As these differences between Korean speakers and English speakers demonstrate, once it has come into existence, the symbolic system can even override or suppress the conceptual capacities that it has reformulated to some substantial degree. Different behavioral responses are emitted by brain/bodies that have the category "kkita" than by those bodies that have different category systems. There is thus a material impact of the specific symbol system. The existence of such material impacts from symbolization means that understanding human capacities requires attention to symbolic characteristics, not merely to pre-linguistic sensitivities. To further develop an understanding of how symbols function materially, we will now explore how symbol systems are instantiated in the human brain.

Neuroscientific Research, the Brain, and Language

E. O. Wilson says "first we see red and then say 'red'."[179] Recent research in neurolingistics, however, indicates that this widely shared piece of common sense is simply wrong. Most people have experienced the feeling of searching mentally for a word. But the assumption that this experience means that ideas get formed and then words get located to express those pre-formed ideas is not only wrong, but may well be the single most important barrier to understanding exactly how language is related to other biological structures. To show why, we'll quickly overview neurolingistic research and then talk through some examples, concluding with an analysis of when and how we produce the word "red".

Research on how human brains process language has been accumulating for at least two decades. If the "conveyer-belt" account of language were true, that research would have shown activation of the brain in conceptualization areas as a person "thinks" followed by a singular pulse down a neuron or neural pathway as the "concept" is sent to the language areas, followed by localized activation in the language areas. If, on the other hand, the pure linguistic constructivist account of language were true, then all conceptualization would take place merely in the language areas, and there would be no activation of any of the rest of the parts of the brain when people were thinking-through-language. Neuro-imaging research has shown neither of these two accounts to be accurate.

The best model of the research results to date has been provided by Friedemann Pulvermüller.[180] Pulvermüller's synthesis indicates that language is instantiated in human brains as neuronal webs that include not only the regions of the brain along the perisylvian areas that have classically been identified as distinctive to language use, but also the parts of the brain that are linked to a particular semantic component of any given word. Thus, for example, neural imaging indicates that words for moving one's hands consist of webs of neurons that incorporate not only perisylvian areas for *both* speech production *and* speech reception but also the part of the brain classically identified with controlling movement of the hands. Likewise, other action words are processed within webs including the parts of the brain linked to their appropriate physical actions (e.g. a web linking "walking" to the part of the brain that involves motor control of the legs). In other words, the phrase "wave your hand" is not produced by first generating a non-linguistic conception of waving one's hand in one part of the brain, and then putting that conception into the necessary words ("I will wave my hand"). Instead, the meaning is generated by the activation of a neuronal web, which includes both the word form and the motor control centers. Complex patterns of excitation race back and forth between the "word" centers and other parts of the brain (not only "content" related areas, but also associated "emotional" centers and social relational centers as well). Because the word centers are networks of meaning rather than just isolated words, the patterns race around within the neural centers as well. *The word-dedicated cluster of neurons serves as a* *selection and coordination area for diffuse other brain clusters*, rather than simply as a translation center for pre-cast thoughts. For symbol-using animals, in symbolic contexts, the verbal center of the brain becomes something like a half-awake manager.

Key to understanding this process of language generation is understanding that humans do not talk using single words. They produce phrases or sentences, and the production of a sentence involves moving back and forth between several parts of a neural network. The selection of a particular word increases the likelihood that some words, rather than others, will be selected. The selection of a given word primes some parts of the neural net (both those within the language center and those without), and it makes semantically implausible others. Consequently, it is rare that one “has an idea” and then puts it into words. Instead, one gradually congeals a set of relationships from a neural network into a specific series of words. What pre-exists in the neural network is multi-dimensional and multi-potential (though not infinitely so…an idea is a set or a region of potential relationships). What comes out as a verbalization is a highly truncated, highly limited selection from what could be said from the complex pattern of neural action that is “thinking”. Indeed, anyone who has spent much time writing at all realizes how very much it is the case that the process of discussing and writing forms and reforms the potential set of relationships involved in a diffuse cloud of neuronal potential.

This view is further supported by neurolinguistic research into the way in which words are distributed in neural networks with various levels of abstraction. A variety of neuro-linguistic studies have shown how a word like “dog” is an abstraction that is linked with webs including both a variety of more concrete words (Doberman, poodle, Spot), but also more general words (animals, threatening creatures, friends, enemies-of-cats).

Although some levels of generality have stronger predispositions to be articulated, nonetheless, when deciding to speak about something one sees, one must decide whether to choose several of a number of equally plausible words—poodle, Spot, animal, friend. This selection is made in relationship to the person(s) with whom one is communicating and the other words that one is selecting. One doesn't "see Spot" or have an idea that is precisely "Spot". One has a brain-network that primes or sends pulses through a variety of neurons, some of which include visual images of particular dogs or general dogs as well as a range of particular dog-words. One selects "Spot" as one reasonably appropriate word choice (though others could have been selected as well), and thus begins to materialize a particular range of possible articulations into a specific one. For example, having selected "Spot" one does not need to add that Spot is a poodle, for any audience that already knows that Spot is a poodle, whereas if one had first selected "dog," one might later have needed to add the poodle designation.

Results of research on the timing of speech processing in the brain indicate that this kind of back-and-forth movement is enabled by the tremendous speed at which the brain operates. The earliest detection of differences in the activation of the different parts of the brain related to different semantic contents is 100-200 ms after stimulus. This is the same time period where differences between brain processing of words and pseudo-words are found. As Pulvermüller indicated, "Thus, the earliest latencies at which the lexical status and the semantic category of word stimuli were reflected in the neurophysiological response coincided with each other. These neurophysiological data support psycholinguistic models postulating that information about a word's meaning can be accessed near-simultaneously with information about its form, a proposal motivated by behavior studies" (p. 64).[181] Thinking that is verbal thus can be accomplished by the co-activation of neural nets that include word forms and other related cognitive structures.

In contrast to older models that separated speech production and speech processing into separate brain "modules", Pulvermüller's model of the neuronal webs shows instead that sets of neurons with similar functions are connected to each other through relatively short paths and connected to neurons with different functions with relatively longer paths. But there is no tight box-like separation between neurons of different types. Nor are clusters of different neuronal types connected only by a few connecting lines. Instead many neurons for the word-dedicated brain clusters reach out to contact differently-dedicated neurons in many different parts of the brain.

As a consequence of this non-hierarchical, networked structure, brain clusters do not do what they do internally and then communicate with other clusters of neurons. Instead, they communicate simultaneously with different, more distant clusters even as they communicate within the closer-cluster. They also communicate along multiple lines from multiple members of the cluster, not just from one specialized "communication" neuron. Verbal webs are not completely unstructured. Like the rest of the brain, they are given specific structures through synfire chains, general and specific inhibition mechanisms, and sequencers. *The brain is thus neither modular nor homogeneous, but a dense network of interconnecting clusters of specialized neurons. Speech processes are determined by that structure.*

As Pulvermüller details, the neuronal web model accounts for three different kinds of research results. First, it accords with the results of neural imaging data.

Second, it accounts for the particular patterns of speech aphasia. Finally, it also produces simulations that can reproduce outputs matching brain outputs in areas where existing methods of in vivo research are impossible. The model also avoids the unreasonable tenets of both the "modular" and "linguistic constructivist" positions. On the one hand, it does not require that the human brain have evolved a relatively large, complex, and virtually independent module in the relatively short time period between the shared ancestry with primates and the onset of human culture. It is much more plausible to imagine an evolutionary pathway that utilized existing brain architecture and developed specialized portions of the neuronal webs rather than to assume that a novel, independent area arose to be fed by a neural pathway. The fact that other primates and animals can learn some symbolization without detectable language regions further supports the web-based rather than modular evolutionary pathway.

On the other hand, the neuronal web model does not require, as do linguistic constructivist positions, that humans be unable to "think" without producing subvocal speech. For humans (as with all higher animals) it is possible for parts of the brain to be active—solving problems, navigating, estimating quantities, and doing at least many of the tasks we associated with "thinking"--without verbal articulation, and this is true even of parts of the brain that are connected through neuronal webs to verbal centers. The complex series of cross-cutting "synfire chains", inhibiters, and sequencers permit activation of parts of a connected web rather than all connected neurons (and this is also necessary to language use itself, as in metaphor, when one potential set of connotations for a word are selected instead of others).[182] Without such cut-outs and patterns, the density of the connections among the neurons would lead to chaos in the brain (neurons have as many as 5 X 10^4 dendritic and axon connections each). Indeed, the linear nature of speech production permits only one stream of language to be generated at a time, even if multiple competing neuronal webs are active. So, whenever there are multiple competing active areas in the brain (which happens constantly due to multiple external and internal stimuli), some of these activated areas are "articulated" and others are not (which gives rise to a theory of what the "sub-conscious" and the "self" really are; see Appendix 3). However, as Pulvermüller indicates, "areas that fire together, wire together." This means that areas of the brain that have built strong connections to the articulatory regions of the brain are predisposed toward articulation.

How Do *You* Decide What to Say?

The common experience of "knowing the answer" but not being able to articulate it is actually an emotional state that results from activation of some kind of physiologically coherent pattern in non-verbal parts of the brain, accompanied by the effort to prune and specify this diffuse activated network into a linear form that is the only type of form that can be articulated by verbal languages. But, as the language experiments described above highlighted, language cannot simply express what is in the brain. Instead, linking these verbal neural networks produces an expanded "thinking" process. Thus, one cannot think that the pile of 65 feathers and 27 feathers is 92 feathers without having created symbolic centers in the brain that do direct counting of large numbers. The neural structures for larger numbers created in the brain by counting symbols link up the neural structures that enable quantity-estimating and exact matching to produce capacities not only for exact matching, but also for an incredible array of mathematical manipulations.

Moreover, because verbal systems have particular biases, the participation of verbal centers will bias the process in particular ways that are dependent on the inherent structure and historical learning of the brain. What one thinks, therefore, cannot be independent of the effort to say it. What one says also cannot be all that one has thought. What in particular gets selected from other parts of the brain (other components of "thinking") and especially how those get put together into sentences and paragraphs, is a product at least as much of the nature of the verbal centers as of the activities in other parts of the brain (although relative influences probably vary depending on specific tasks). This is the physiological basis of the distinction between non-symbolic cognitive activities and capacities (described above as ESSR) and the categorical specification (CS) that is the novel output of symbolizing processes.

A way to tie this insight to one's own experiences is to imagine an experiment in which the experimenter asks you to make a novel statement, one that you don't think anyone else would make. *Watch carefully* what your mind does as you perform this requested activity. (No, really, take the time to do it before you read on). When I, the first author, tried this thought experiment, the first thing that came into my mind was the word "PONNIES." I have no idea why (some people will find that what they produce first is a visual image). However, almost immediately, I said to myself, subvocally, but in a sentence, "Ponnies is too common, so you need to come up with something that is unique to me." At that point a vague memory of a particular experience as a pilot volunteered itself. It consisted of a non-verbalized sense of the experience, along with a visual image of a small plane (probably a Cessna 172) smashed upon a very large volcanic rock (about the same size as the plane). I struggled to articulate some specific aspect of the stored gestalt of the experience, and the sentence that assembled itself (not linearly, but with some editing as I "thought/subvocally-spoke") was "It is particularly hard to make an emergency landing in a lava field." The visual image that arose in my head was not a "picture" of anything that had actually happened (as a matter of historical accuracy, I actually succeeded in NOT crash landing in the lava field, and the lava rock in the image was far larger than any of the protrusions I had been flying over). The sentence I assembled thus by no means captured the experience, and it didn't even express particularly well a unique aspect of my experience. The sentence I generated *articulates something out of the* experience, rather than *expressing the experience* itself. Thus, the creation of a verbal answer is a particular thing in its own right; it is not simply the "expression" of what is stored, in a different form, in my head. This is true even though I "felt" like I had an answer to the task, and I felt myself "searching" for the answer that I already new I had. My feelings were somewhat delusional, and this is the standard state of our feelings about our language. When we think that we "know an answer" and are simply struggling to "express it," what we are actually doing is trying to assemble a particular formulation out of a diffuse neural network that contains far more than could actually be expressed. We are trying to generate a discrete, linear statement from a neural network that is not discrete or linear. The symbols that we generate therefore can never be a mere "expression" of "an idea" in the network. They are both a selection and a particular construction. They are an assemblage.

Seeing More Than "Red"/Saying Red

So, we do not "see 'red'" and then "say 'Red." Instead, we say things like, "The señor wearing a bright-red cap perched on the rusty red bench behind the redwoods and read the gringo newspaper." Okay, maybe it is generally more like "look at the dude in the red hat." In any case, what happens is that our eyes process a complex set of light waves of different frequencies, and this, in combination with other stimuli and pre-existing states of our neural webs potentiates a range of different neurons, including many red-related neurons. If circumstances are such that it is appropriate to articulate something out of this gestalt, the brain sends electrical impulses bouncing back and forth among different parts of the brain, and back and forth across different potential words. One gradually assembles a sentence, using the architecture for sentences that is partially programmed into the brain and partially learned. That sentence doesn't express what one has seen. Language is both too impoverished and too active for that to be true. We never see just a "señor wearing a bright red cap…." and we only see it *as* a señor for reasons that have to do with the dense web of partially-symbolic and partially non-symbolic contexts. We see much, and if we the neurons involved in language are activated, they participate in "characterizing" what we are seeing, and then composing a statement that is about what we are seeing, but which does not really express it.

One can define "idea" either as what gets articulated at the end product of a sentence or as the diffuse gestalt that precedes articulation, but in either case, language doesn't just express a pre-existing idea or "thought" that is tightly and narrowly constructed in the absence of the symbolic network and its activities. The articulation—i.e. the linear symbolic form that is a sentence or paragraph—shapes a diffuse set of phenomena and then places it into a specific set of verbal categories, organized in historically specific ways, and related in a temporally fluid fashion.

It's True for Science and Mathematics Too

Many scientists and mathematicians are particularly prone to resist this understanding of language. Because they struggle so hard for words, and do not perceive themselves as word-smiths, they are particularly prone to assume they have an idea before they can make a statement. They see the struggle not as one of formulation, but as one of expression. Having watched biologists work first-hand, and having read how Watson and Crick assembled their double helix and Einstein generated his equations, however, it is quite clear that scientists and mathematicians shape their ideas and even "discover" what works through the process of drafting and redrafting that is articulation. Watson and Crick did not have the idea of a double helix, and then spend months trying to articulate it. Instead, they talked constantly as they tried out different patterns, employing visual, tactile, numeric, and verbal cues in series and parallel.

This is even more obvious in theory-driven research. A hypothesis is centered as a verbal statement. That statement is used as a heuristic device for thinking of all of the connections that would exist if the hypothesis were a reasonable characterization of the non-verbal universe. In the *e. coli* laboratory where the first author "worked" (really muddled and observed), Sydney Kushner and Rich Meagher did not observe the patterns of experiments and then translate them into the phrase "e. coli mRNA have poly-adenelated tails too." Instead, they worked back and forth between hints in the experiments and the phrase "mRNA have poly-adenalated tails" from other classes of living beings to create more experiments and to assess any revisions in the model needed for this particular life form.

Even in science and mathematics, verbal formulations like theories and equations are not simply the expression of a non-verbal thinking process. There is always a working back and forth to "characterize" something in a specific symbolic series. The symbolic series hopefully captures something that one might well call fundamental truths or relationships in the universe, but it does not simply "express" that universe. It selects and orders some facets of the universe and not others. As Chapter 2 noted, physicists are particularly prone to rhapsodize over how well mathematics "expresses" the laws of the universe. But that is only true if one ignores all of the ways in which something like Shrödinger's equation is chopped and hacked and confined to produce results that actually fit the outputs of observations and experiments and other equations. It is, indeed, amazing that humans can produce streams of symbols—mathematical or natural language—that can share aspects of the universe with one another and steadily reproduce them, but that amazing power is not simply "expression," it is composition, or if that word raises one's disciplinary hackles, then "characterization".

Pulvermüller's neural network theory is the best available account because it neither over-plays nor under-plays the flexibility of language-based human activity. The theory neatly combines facets of both the genetics-based and learning-based accounts of language use. His formulation indicates that there are basic principles underlying syntactic patterns that result from genetic programming of the brain, and these include "the specialization of neuron ensembles as sequence sets and word webs, the distinct types of activity states of neuronal sets and their 'push down' dynamics' along with basic principles of threshold regulation, inhibition, and activation" (e.g p. 247). Most other features of human language production are products of associative learning—specifically which neurons wire with which other neurons. Thus, while all people have the capacity to learn numbers, only those who actually do wire specific neurons together through symbols with an enumeration-specific logic will have the capacity to count and match exact large numbers of items by precise quantity. Similarly, all people have the ability to notice "contact produces co-motion" relationships, but only those with kkita-like symbols will predispositionally demarcate things that fit tightly and interlock from things that do not.

Summary and Forecast

This chapter has sought to show how it is possible to think of language and other symbol systems as material entities with material impacts on the non-symbolic parts of the universe. Human symbol systems are elaborations of sign systems that are shared with many other animals. Because symbolizing, including language use, is partially embedded in and processed by brains, it is a material phenomenon. Material phenomena tend to exert material influences on the world. We have indicated that this justifies a tripartite conceptualization of the relationship of symbol systems to other parts of the brain and the outputs of such brains to replace both the existing bipartite (idea/language) or univocal (it's all text) formulations. Putting things into language (or numbers, or other symbol systems) changes a response predisposition from other parts of the brain (ESSRs) to produce categorical specifications (CS's). Thus, learning a serial enumeration symbol system allows a brain that can otherwise estimate quantity and keep track of a small number of items individually to do something new--enumerate large quantities precisely (and potentially much more). Similarly, learning a word like kkita encourages a brain that has an ESSR for co-motion of physical masses to attend to a precise distinction between those masses that are contiguous and interlocked and those that are not. Thereafter, people with such a language pay more attention to such relationships than those who do not have a symbol that specifies and highlights such relationships.

Because the materiality of the process is largely (but not wholly) embedded in brains, the architecture of the brain heavily determines what the process of symbolization can be like. Because brains work by complex activations of complex networks of neurons through quick but extended time, whereas language production is relatively slow and linear, language processes cannot simply "express" ideas pre-formulated in the brain. The verbal centers shape the thinking process as it occurs and the linear production of symbols reduces or "characterizes" what has been thought. This then exerts a new set of influences upon the speaking partner (which will produce the phenomena discussed in Chapter 11).

This is the basic story about language as a material process. But it is not a full story about how language works and what it may do. In the next two chapters we will catalogue the characteristics of human symbolization as they have been described by humanistic scholars across the past century. Chapter 7 will describe the most basic tendencies of language, including its tendency to create dualistic, rigid, categories in nested hierarchies, as well as its tendency toward narrative form. Chapter 8 will build on that more mundane base to illustrate the truly fantastic qualities that arise from language. These include the ability of humans to transcend some limits of time and space, and our ability to create countless novel objects and concepts that have no previous material existence. Most crucially, that chapter also shows how language creates the human capacity for moral assessment, which may be our most remarkable feature. It is this feature that most confounds the dark predispositions of uniformitarian evolutionary psychology, and which offers our only hope for becoming something other than herds of animals driven by individually-based evolutionary drives.

Chapter 7: Basic Characteristics of Symbolic Action

Summary: Symbol use creates categories out of intersections of conceptual sets. This process requires and produces abstraction, differentiation, hierarchicalization, and reification. Symbol systems work via converging flow of symbols, and this flow through historical time entails arbitrariness and historical materiality. Symbol use also leads to binarism, to valuation, and most distinctively to narrative. Out of narrative emerges the symbological concept of purpose, as opposed to the biological concept of function, and out of all these characteristics of symbolic being come emergent properties considered further in Chapter 8.

One of the most stunning intellectual achievements of the twentieth century was the characterization of some of the primary features of human language systems. This was an enormously difficult achievement, because the tools of analysis for language systems are linguistic, and that creates confusion in separating analyzed from analysis. This may explain why these achievements have gone largely unsung—these analyses remain difficult for the non-expert to understand. Unlike calculus, whose unfamiliar signs warn its students that they are approaching unfamiliar territory, there is a persistent belief that language about language should be clear and transparent. But it is actually quite difficult to produce precise language about language, and outsiders who approach it are often not willing to accept that the same intellectual discipline necessary to learn calculus may also be necessary to understand theoretical formulations about symbols.[183]

This problem is exacerbated by the discovery of the same features in different theoretical and philosophical traditions, which operate from somewhat different assumptions or goals, and therefore are loathe to borrow concepts or labels from each other for fear of the accusation that they have distorted an original concept. Specialists will therefore find the following an oversimplified primer that does not accurately or fully represent the views of any of the theoretical lineages that have contributed to the discoveries we enumerate. None-the-less, for non-specialists we believe there is value in high-lighting the commonalities of concepts that span different theoretical traditions.

The characterizations of language that we will enumerate in this chapter are different from, but not necessarily inconsistent with, newer explorations going on in linguistics and cognitive studies. The newer studies are exploring the way in which language use influences particular conceptual proclivities in particular content domains. For example, the patterns by which people orient themselves in space seem related to their language capacities, as for instance, having a vocabulary for “left” seems to be associated with orienting the location of an object by remembering it was on the left side of a wall instead of by remembering the shape of the room (which is the typical approach for animals that lack the symbolic left-right code).[184] In contrast, what we focus on here are basic tendencies in language that extend across many, if not all, domains of language use.

Most of the insights about these general tendencies of language were generated by observations of similarities across many texts rather than through experimental testing with single texts. If there is a serious bias among these observations, it arises from the focus in most of the observations on written texts. As many theorists have observed, there are systematic differences among primary orality, writing, and secondary orality.[185] We are also not able to distinguish consistently between characteristics that pertain to symbol use in general, and to those that are specific to human language use. While we have made some effort in that direction, the research base does not yet exist to make such distinctions rigorously. Finally, it is not always clear what observations are bound to specific languages and what apply to language in general. With those cautions noted, the basic building-blocks of human language as a symbol system include categorization (which requires abstraction, specification/differentiation, and discreteness), converging contextual flows, which entails arbitrariness (or historicity), and binarism, valuation, and narrative. These basic features of language are tied to basic brain structures and create fundamental predispositions for human communication.

Categorization

The discussion above indicated that symbols specify humanly observable relationships by constituting categories. The process of categorization requires abstraction, which as we will see is simultaneously differentiation. The nature of human language is such that language categories are hierarchically nested and discrete rather than continuous in form.

Abstraction

When we say that the constitution of a symbolic category requires "abstraction" of particular aspects of reality, we are saying that words select out and gather together certain properties from phenomena that have many potential properties. This doesn't mean that the properties that are selected "don't really exist" or that there isn't some logic or principle to their assembly. Rather the specific properties *are assembled* or *pointed out* by the word in a way that distinguishes those properties as the facet of the potential properties of things that should be attended to. For example, to call the being on the rug in front of you a "cat on the mat" is to call attention to particular properties and to link the being to specific other beings—a range of four-footed, fur-bearing, animals that generally (but not always) have tails and the ability to purr. In contrast, calling the same being a "pet" emphasizes somewhat different features and links it to a different set of beings. This alternative categorization emphasizes the relationship with a human and includes dogs, gerbils and ferrets. Calling it a "vermin carrier" calls up still different associations. Calling it "Kelly" perhaps links it to fewer properties (the set of changing molecules but quasi-stable arrangements that mark it as a particular organic being rather than all felines or all small, domesticatible animals or animals-that-bring fleas and ticks into my home). Thus, every symbol abstracts a *particular* set of shared properties from a range of phenomena that share some qualities but not others. It links those shared properties into a specifically bounded category. Using the symbol thereby highlights (or "makes present') the shared properties.

To say that language creates categories is also not to deny that humans, and other animals, have pre-linguistic conceptual apparatuses that allow them to assemble sets of things and later in development even to group things based on shared characteristics. Careful research shows that such a capacity to group identical or physically similar items exists.[186] Indeed, this research indicates that many animals have the capacity to create a set, and that chimpanzees have the ability to create two different sets simultaneously.

This capacity is correlated with signaling ability (which we have characterized as a pre-symbolic mode of communication). Likewise, first and second order cognitions exist among humans prior to language, and are probably necessary to the formation of language. Only humans, however, create third order cognitions, and only after they have developed multi-word language use. Such third order cognitions are necessary to the construction of hierarchical categorization instead of merely linear categorization (see "Hierarchy" below).[187] Additionally, such hierarchies constitute relationships, which enable abstract thinking, and only humans appear to spontaneously create categories based on abstractions rather than concrete objects.

As the analysis of Chapter 6 suggested, therefore, when we say that symbolization uniquely enables the construction of categories, we are distinguishing categorization from the formation of sets based on similar physical characteristics, even sets that use a singular principle (such as color or abstract geometry) as a grouping rationale. True categorization, as opposed to such groupings, consists of the creation of sets by the constitution of boundaries on gradients of multiple intersecting principles. In a sense, a symbolically constructed category is thus a unique conceptual space that is bounded by the structure of the web of words, even though it is associated with a particular word or phrase.

In the case of concrete objects, we operate under the impression that the verbally constructed category maps neatly to a discrete set of objects. This impression is false. Consider the gradations from "saucer" to "plate" to "platter" to "bowl". The three terms denote something categorically different from each other (a platter holds food for several people, a plate holds food for one person, a saucer holds a cup, and a bowl holds either liquid for one person or low coherence foods for many), and we may only rarely make a mistake when classifying a particular concrete object into the category. Nonetheless, a visit to the local china store makes clear that the array of concrete objects in these categories overlap each other considerably and do not map themselves into the categories, but are mapped into them by their relationships within their own "sets." The plates in some very large "patterns of china" are as big as the platters in others, and the plates in some very flat sets are as curved as the bowls in yet others. Even cups and bowls form a continuum rather than a naturally occurring discrete set. This same kind of mapping of discrete linguistic category over a natural continuity is signaled by the contemporary resort to percentile differences in DNA to demarcate "species."

In these ways symbols do not simply "refer to" a self-evident object that is pre-designated outside of the symbols' calling the object to attention in a certain way, even though the properties that the symbol gathers together may be said to have some kind of material reality outside the symbol. Thus to say that language does more than "refer" to pre-constituted objects is not to contradict the research finding that humans (like other animals) have brain processes that treat some phenomena in the world as "objects" in the absence of symbols. To say that a "categorization" is different from recognition of a segment of matter as an object is instead to say at least three things.

First, symbolization enables treating as discrete objects even phenomena that do not appear as discrete objects, especially but not exclusive abstract nouns such as "love", "justice" and "tension", but also "foam", "surf", and "snow bank." Second even with phenomena that appear as discrete objects, symbolic categorization takes them "out of context". To illustrate this, think about a real and striking object that you have seen quite recently (for me it is a tall, black, old-fashioned lamppost standing in a backdrop of lush green trees and grass). Now contrast that mental imagery with the name for the object ("lamppost"). When I think about the image of the lamppost I saw, I don't see in my mental visual image-machine just the lamppost; I see it in the context of the trees surrounding it and the specific patterns of light and dark. In contrast, when I think about a word like "lamppost" or "cat", I see the object with no surrounding context. Because the *category* is based on many lampposts in many scenes, to maintain it as a category requires effacing all the conflicting contexts. In contrast, when I think about a specific *object*, I tend to retain its context. The existence of object perception may thus provide a foundation for the particular way in which we symbolize, but it is not the same as a symbolically formulated category of objects.

Finally, third, as implied by the discussion of selectivity above, categorization serves unique functions in the social process of communication by preferentially pointing out features of specific sets of objects for shared attention. If I tell you to look at the "cat", I draw our shared focus to something specific, and what I draw your attention to is not the object per se, but particular facets of or intersections of object qualities. The attention director that causes us to focus on a particular object set when language is involved is not directly and immediately a set of biological drivers (the sabre tooth tiger that is poised to jump us), but rather the set of words that I have shared with you. This shifting of immediate attention priorities certainly has links to biological priorities in the longer term, but as Chapters 8 and 11 will show, the capacity to shift among priorities in the short term turns out to be enormously consequential for the possibilities of living that humans can create.

Differentiation

A second key component of categorization is differentiation. Because languages are not isolated signs, but rather sets of symbols, categories are always related to each other within a logic of association that develops within the symbol set itself. This means that the specification of a category is always simultaneously *a differentiation from other categories* (and hence from other qualities). The basic insight of structuralism was that meaning in language systems is as much constituted by the relationship of differentiations/specifications in the language system per se (its "structure") as it is by the qualities of items being identified by the language system per se.[188]

An excellent example of the process of categorical specification as differentiation is provided by terms for color. Recent biological accounts of human color terms have noted the interesting fact that there is a somewhat standard series by which human languages add different color terms. Although some languages do not demarcate color, and some that demarcate it do not treat it as highly salient, if a language has symbols for only two colors, these are black and white. If the language includes a third color term, it is red. After this point, accounts differ, but green or yellow, blue and brown are highly common.[189] As the series grows, the order of colors added becomes less stable.[190] The commonalities among the simplest color systems appears to be due to biologically based dispositions arising from how the eye processes different frequencies of light. Biologists or psycho-biologists argue that this demonstrates that colors are biologically embedded, if not in human brains, then in human physiologies more generally.

The fact that brains or optical nerves are predisposed to chunk color categories at particular wavelengths does not mean, however, that symbolizing is irrelevant to color naming. Some cultures do name only two or three colors, while other cultures name dozens, if not thousands. If the biology of optical processing were determinative of symbol production, then all cultures would have exactly the same differentiations. They don't. Wilson claims that English uses only 11 "basic" colors,[191] but his fashion sense seems limited, for English also has color terms such as magenta, aqua, periwinkle, turquoise, burgundy, lime, and burnt umber**.** Contemporary U.S. English also has fairly standard specifications among "basic" colors such as "hunter green," "sky blue," "jet black," or "navy blue." English actually has hundreds of color terms, most of which are demarcated on color wheels at paint companies, but many of which are demarcated in other systems (for example, the Munsell system).[192]

The brain's capacity for building neuronal webs associated with specific inputs through associative learning allows the creation of symbols that parse colors into variable subsets among different language communities. Smaller subsets specify or *differentiate* colors from each other that are not otherwise specified (from one human to another) as different. The existence of biological predispositions toward some specifications rather than others obviously does not mandate which level of specificity will be adopted, nor can it function in communication among humans without the manifest existence of a particular symbol system. In a culture that does not have symbols that differentiate "sunny yellow" from "pale lemon yellow" via a color wheel that gives precise hues to each, the authors w*ould not* have differentiated the colors we painted the two rooms in our basement in the way we did. While the different hues of the two rooms might (or might not) literally have "existed,"[193] we would not have been enabled and moved to distinguish between colors of yellow so precisely. We would not have been shown these options (among dozens of others), and we could not have successfully ordered this particular color of yellow and that particular one.

Just as serial numeric systems allow the specification of exact quantity from general quantity, so a large vocabulary symbol system for color allows the regular application of more narrow differentiations among different wave length groupings and saturations, regardless of in-built tendencies that may produce a preferential order for the specification process as it is set in motion by cultural or geographical factors. The specific range of colors that are demarcated is a property thus of the *differences* among the symbols (a product of the symbolic structure) as much as it is of the biological predispositions. The process of abstraction in symbol systems always entails differentiation and specification in this way because to draw attention to a particular quality is simultaneously to distinguish it from other particular qualities.

All symbol systems necessarily differentiate, but specific symbol systems specify particular domains of differentiation and degree of differentiation within domains. In doing so, they enable the users of the particular symbol system to communicate about particular items with given levels of specificity. NASCAR drivers communicate about motors with far more specificity than most other people, and this enables them to make their cars travel faster. Microbiologists communicate about cells with far more specificity than most other people, and this enables them to manipulate living beings in ways the rest of the human population cannot. Cultures that lack vocabularies about motors or microbiology or colors lack the power of differentiations required to sustain the collective efforts necessary for developing and progressively modifying such complex and finely tuned tasks. This does not mean that a word must be invented before a new object can be invented. It does not mean that non-symbolizing species lack any capability for relatively complex coordinated activities. The power of differentiation that arises from symbols does mean that beings cannot create a culture of invention—that is, constant, rapid change in coordinated behavior and cultural outputs--unless they have the symbols to support differentiations that operate at multiple levels of specificity in a variety of different domains.

(Nested) Hierarchicalization

The categorizations constructed by human symbols also tend to have the additional quality of constituting hierarchies. The ability to abstract is applied not only to generate symbols for repetitions of what can be specified as "the same" form (snake 1, snake 2, snake 3), but it also includes nested categorizations of forms that have different levels of generality, as in the nested series snake, vertebrates, animals, biological beings. These hierarchies exist in brains as webs that encompass or overlap each other, with stronger connections among sub-parts of the larger web specifying sub-categories. These hierarchically based categories are detectable in the variable speeds at which different levels of names are called up by participants to describe pictures. Middle-to-low level categories are generally first activated. Highly abstract categories (e.g. "animal") are more slowly cued because there are not enough specific referents in the image to cue them. Extremely specific categories (e.g. "Mancune") are slowly cued because they are not strongly established through frequent repetition (except perhaps to cat breeders).

Middle level categories such as "cat" are most rapidly cued because they present sufficient cues and have high connection strength (see Pulvermuller pp. 87-90).

Symbolization extends the hierarchicalization process to categories that are defined not by material entities, but by series of actions among them (playing the flute is a subset of making music but putting chimes on your deck is not, shooting people who belong to a group defined as "aliens" is a subset of making war, but shooting people who are in your own group is not). Symbolization also hierarchicalizes presumed abstract states of being (political equality is a subset of equality; parental love is a subset of love). The nested hierarchicalizations created by symbol systems add dimensions to behavior even in those instances where they are based on "hierarchies" that have additional biological bases. For example, many animals, including other primates, live within status hierarchies. Such "hierarchies", however, are essentially degrees of status and a network of alliances. There are no differentiated subsets or sub-categories within levels of the hierarchy (see Figure 7.1). The singular exception is the subset by gender in many species, but even this differentiation does not produce the autonomous spans of control seen in the corporate hierarchy, because the alpha male usually has access to any female. The symbolically enabled hierarchy is distinctive for the large number of levels it can support, the autonomy of control, the differentiation of tasks, as well as the control over contact (violations of formal lines of communication occur in practice in all human hierarchies, but they are under the control of the supervisory personnel and punishable). These human status hierarchies are characterized by and maintained by unique symbolic processes that Kenneth Burke has described as mystification, guilt, purification and redemption.[194] While humans still obviously use means to mark and protect their hierarchies that exceed linguistic symbols—buying overly large vehicles or occupying overly large and disfunctionally decorated office spaces—they also rely heavily on more purely symbolic practices for maintaining the hierarchy and a favorable place within it. These symbolic tools then have their own side effects, as is frequently the case when mystification designed to protect status hierarchies in corporations has the undesirable side effect of shielding decision-makers from communication flows that would apprise them of problems in the organization.

Reification/Perfectionism

The final significant process involved in producing abstracted categories of symbol systems is known as reification or essentializing, a process that often manifests itself as perfectionism. Language tends to produce discrete types. Much of the inorganic physical being that meets our human eyes on a natural scale is non-discrete. Rocks, pebbles, crystals, and planets may constitute exceptions, but the boundaries between mountain and valley, day and night, sun and solar field, or shades of pink are not. While human and other animal minds may be capable of demarcating objects within these continua based on mechanisms of the brain that are not symbolically-dependent, the gestalt processes of the visual field tend to recognize these as objects-within-relations. Human symbolic systems, however, remake all of the entities with which they engage into discrete categories separated from specific relations—regardless of whether that discreteness and separation inheres in the properties being gathered together and identified by the symbol. This is not a product of the nature of the neuronal webs that instantiate words in human brains. Such webs feature indefinite boundaries and probabilistic activation of different parts of the webs.[195] Instead, the phenomenon occurs because of the physical nature of words. Human words are physically discrete—a fixed and relatively repeatable sound or set of sounds with a relatively precise beginning and end. This tendency is probably exacerbated by Western systems of writing that block words with spaces.[196]

Science fiction stories have imagined creatures that communicate instead by non-discrete means (e.g. a continuum of color variation on their hides), a system which would permit and even emphasize communication of continuous variation and relationship among phenomena. In such a symbol system perhaps there would be less of a tendency toward "reification"—the assignment of things and processes in the world to rigidly bounded groups that fit the discrete structure of a categorical "name". However, human symbol use as we know it often leans heavily towards reification.

Two recurrent problems are created by this aspect of categorization. The first is perfectionism. The combined hierarchical and reifying qualities of symbols produce a drive toward "ultimate terms." In the non-symbolic world, there is no perfect lion or perfect mate. Things may serve functional needs well or poorly, even better or worse, but there is no perfect meal, and especially no perfect meal in an absolute context-free sense. But by combining hierarchy and reification, language adds to "good, better, best" the concept of the perfect or the ideal. Symbols allow us to imagine a trans-contextual "top" to every hierarchy, and that is perfection, even though such perfection cannot actually exist in the non-symbolic realm (in part because the world of actual being is not context-free). As Kenneth Burke has noted, this feature of language means that whether or not a "God" actually existed, language would create this category. This ideal of perfect being drives humans to perpetual dissatisfaction, and worse. The species is, as Burke has further noted, "rotten with perfection."

Discrete categorization also hosts a second recurrent problem. Discrete symbols over-simplify the complexity of the world.[197] A useful way to say this is that words pretend to stand for discrete categories of things, but few things categorize discretely and most things can be categorized in many ways. This linguistic characteristic may thus account for a human tendency to approach efforts at knowledge with excessively simplistic assumptions. Humans are always looking for simple, discrete categories, perhaps in part because the non-symbolizing structural components of our brains are predispositionally programmed to that, but also because that is what our language system handles best.

Converging Flows of Symbols

Categorization processes are inherent to symbolizing, but they do not sum up all of the processes that go into the outputs of symbol systems, because individual symbols do not function in isolation. Indeed, as Chapter 6 suggested, what distinguishes sign usage from symbol usage is that signs have meaning that stands alone, whereas symbols gain their meaning from the relationships among the flow of words. "C.J. touched the dolphin" means something different from "The dolphin touched C.J." The meaning-sensitivity of symbols is not just grammatically driven, however. "C.J. touched the dolphin" means something different if it comes after "C.J. held the electrode over the dolphin" than if it comes after "C.J. was awed by the graceful mammal." In fully developed human languages, no word has a precise meaning on its own. Rather, each word has a range of different potential specifications that is instantiated in a neuronal net that has been built through multiple associations. The particular portions of the neuronal web that are activated in a speaker or a receiver are dependent upon the flow of symbols in which the given symbol is embedded at the moment. Thus, for example, research by Condit and colleagues has shown that when lay people are asked to say what a "blueprint" is, they mention a variety of meanings, many of which are explicitly non-deterministic and which include both visual analogies and abstract notions of "plans". However, when the context is specified as the manipulation of human genes, the meanings that research participants select for "blueprint" narrow dramatically. They almost uniformly describe blueprints using a visual analogue that was relatively closed and yet positive.[198]

The meaning of a particular flow of symbols is thus always a product of a particular convergence. More general factors contribute to the convergence (grammatical rules, ranges of prior associations, limitations on human symbol processing capacities, etc.), but each convergence is unique. To up-date Heraclitus, no word participates in the same speech act twice.

The convergence that specifies meaning consists not only of the flow of symbols, but also of the non-symbolic contexts in which the symbolic flow occurs. To yell "fire" on a gun range means something different than to yell "fire" in a crowded basketball arena.[199] Like the symbolic flow, the non-symbolic elements we summarize as "context" have indefinite boundaries that can be ascribed differently by different participants in a communicative flow or for different purposes.[200]

This account implies that there is no singular “meaning” of any symbol. This is not particularly annoying for a materialist, however, because the concept of “meaning” is either merely a lay conceptualization or arises from an idealist framework. From a materialist perspective, what is of interest is not “true meanings,” but the effects of the flow of symbols. The multi-layered character of symbolic flows nonetheless obviously implies some difficulties with regard to assessing the effects of the flow of symbols. We will hold off attending to those difficulties until the next chapter’s discussion of the character of causation in symbolization (which we call “effectivity”). The characterization of symbolic flows as imprecisely bounded nested abstractions that differentiate also leads one to wonder just how one can characterize this as a material or physical phenomenon. It is surely a quite different form of physicality than our normal sense of an “object”. This unique form of materiality is historically mediated, and it turns out to have some truly marvelous properties.

Historically Based Materialism (“Arbitrariness”)

Symbols are nothing but physical material, physically transmitted, and sometimes embedded in brains. But there is no necessary physical connection between a particular symbol and the range of referential properties to which it is related. The material thing scientists recognize as H_20 can be called water, agua, l’eau or even couch. The four major forces of the universe do not link “water” to the material thing we identify in a flowing stream in the same way that the physical properties of molecules link DNA and RNA. Since deSaussure, semioticians have described this lack of universal and physically necessary linkage by saying that words are “arbitrary.” That label is misleading, however, to the extent that it suggests that material forces are not at work producing effects from symbols. Instead, it is simply that the physical relationships are specified through a historical process. Although in some times and places one could call water "agua," one can't today just decide to call the block of ice on the doorstep "couch" and expect others to know what the heck one is saying when one says "put some salt on the front stoop to melt the couch." Though there is no trans-historical physically necessary linkage between specific words and the phenomena they categorize, there is a historically developed set of physical relationships. "Water" is encoded in your brain for flowing clear stuff and "couch" is not. One can't just "arbitrarily" decide to substitute "couch" for "water."

Although any sound set *could* be used to "gather up" the properties we call "water," in every culture a specific set of sounds (or gestures) *has, in fact*, been used to do so. This is accomplished by "learning"—a process by which the specific physical characteristics of the brain are reshaped so that they associate this sound (or symbol) with a particular range of other physical properties (either visually denoted phenomena such as a ball or associations with other symbols, as with the unicorn). Every word you know has been learned in this completely material fashion. You have engrafted a set of associations in your neurons. Once a particular association is physically engrafted, it operates in use (i.e. in communicating) operating through the four forces of the universe with as much specificity as any other physically material process. Because the process requires a specific linkage to have occurred in a prior time, we can describe it as historically material.

This kind of historical materiality (which is obviously quite different from what Marx and Engels defined as historical materiality) produces different properties from transhistorical material processes. This is because every symbol has a range of potential associations rather than a singular linkage to one discrete phenomenon. One's associations for the symbol "dog" are likely to be heavily influenced by the first dog one met (Burke calls this the "primal dog").[201] If this dog was a beagle and a family pet, one's associations for dog are likely to forever be different from those of someone for whom the first "dog" was a snarling, snapping Doberman in the neighbor's yard. Overlaid on that first engrafting of the symbol will come to be all of the dogs one has ever encountered. One's range of associations for the term will also be influenced by formal dictionary definitions of dogs (Burke wrote that his meaning for "dog" had changed when he learned that the lion at the zoo, though seemingly "doglike" in important ways, was not dictionarily-speaking, a dog at all). Associations are even influenced by apparently accidental features of symbols, such as their sound (Burke calls this the "jingle dog"). Thus a *poo*dle sounds nicer than a *Rot*tweiller and an ad-writer would have an easier time of making the "poo-sweet poodle" sound precious and the "rotten roaring Rottweiler" sound reprehensible than if the names had been assigned the other way around.

For all these reasons, one has to say that the symbol "dog" has a range of associations, rather than that the word dog has a single, precise meaning (even dictionaries usually give multiple definitions for the same word). This is true, even if, as some research suggests, we each develop an "archetypal" dog, that captures the "essence" of dogness for us. Such archetypes do not exclude our understanding of non-archetypal dogs as part of the set of "dog". Thus, though the linkage between symbols and their associations comes about solely through physical processes, they do not operate through one-to-one relationships but rather through a "logic of the range." That is, the symbol is linked to a range of other physical phenomena, rather than to a single, specific other object.[202]

The range of the symbol seems indeterminate because it is so complex. However, if symbol-use were an individual level phenomenon, we could in principle identify precise physical linkages between each neuron of the brain devoted to symbolization and each association (received in the brain, although brought in through visual, auditory, olfactory, etc. sensors). It would be a messy brain map, but it is at least a conceivable one. But communication is not an individual-level phenomenon. Signs coordinate behavior between animals. Among animals with complex symbol systems, the range of associations of a particular symbol are always in some ways different for two different users, even of the same language. Consequently, there are overlaps among the sets of associations of two symbolic communicators (or they could not communicate at all), but there are also always areas of non-overlap. This means that the material relationships between a symbol and the phenomena with which it is associated are not defined by the traces in one brain, but by the relationships among the traces in all the brains of all the language's users.

Actually, pinning down a theoretical account of what a word "means" gets even more difficult than that. In the first place, the effects of communication are determined not only by the areas of overlap in two speakers' sense of "dogness", but also by the areas of disjunction. Miscommunication is an effect of symbol use every bit as important (and frequent) as what we would call successful communication. Additionally, because language is a historically based phenomenon, each usage of a symbol changes the range of its associations (languages can have something like a 50% turnover in less than three centuries, and new languages can come into being in two generations). So the physical associations at time one are different from those at time two. Moreover, languages are also geographically variable. This means that there is really no tightly delimited set of speakers of “a language.” People in different geographical zones use different sets of associations. Today, even people who live next door to each other may ascribe different meanings to the same term if they are involved in different intellectual enterprises. Thus, medical geneticists tend to assume that the term “mutation” means a dysfunctional change in a gene, while classical molecular geneticists assumed that the term “mutation” applied to any change in a gene, whether deleterious or not.[203] All of these factors mean that one could not, in fact, draw a single map of the physical associations of a single symbol, let alone multiple symbols and their associations. This also means that the potential impacts of a specific set of symbols is difficult to specify, even though the symbols and their associations always operate according to the strict constraints of physical being.

The physicality of language thus rests in historically acquired physically-mediated dynamic relationships rather than in a set of inviolable physical interactions that are necessary in every time and place. The linkages among symbols occur both in the neuronal webs of individuals and in the accumulated archives of a culture—its books, videotapes, computer records, and even buildings (Stonehenge, cathedrals, and the pyramids clearly have symbolic aspects, but so does the architecture of the homes of

Pompeii and Ottowa, and the layout of modern corporations or judicial chambers contain symbolic dimensions). The historical acquisition of physical linkages in the neuronal webs of human minds is particularly significant, however, because these linkages are of a form that is relatively malleable. The properties of being learnable and based in variable associations means that new words can be invented and learned. If one stubbornly persisted in calling ice "couch", one's regular language partners would soon figure out what one meant. They might even begin calling it "couch" too. When someone invents a "computer", the whole culture picks up the term with relative ease, and forgets that "computers" were once young women who were paid to do calculations assigned to them using paper and pencil. Thus, it is enormously consequential that the quality of the material relationships among signs and the phenomena they categorize is historically material ("arbitrary") rather than grounded in physical necessities that are trans-historically necessary. This quality produces novelty as a defining feature of language, and the prevalence of novelty has major implications not only for the "kinds" of things that exist in language but also for the ways in which symbol systems can be studied (see Chapter 9). In spite of this contingent variability, there are three characteristics of human language as a symbol system that seem to constitute inherent predispositions: binarism, valuation, and narrative form.

Binarism

Human language has a persistent tendency to operate in binaries. This characteristic has been described by Kenneth Burke as the centrality of the negative, by Alfred Korzybski as the misleading quality of the copula "is" (also as Aristotelianism), and by Jacques Derrida as the metaphysics of presence.[204] In Burke's account, this is an innate feature of all languages, whereas Korzybski and Derrida suggest binarism is a tendency of Western-based languages. There is some evidence that the tendency may be more pronounced in Western systems, but it may also be that Western systems simply understand the binaries as "opposites" whereas other language systems understand the binaries as "complements."

The common manifestation of binarity in the West is our framing of terms in pairs of opposites: up/down, night/day, good/bad, peace/war, etc. Burke argues that this tendency is due to the existence of the negative as a foundational quality of human symbol use. Negatives do not exist in nature, he points out. Things simply are what they are. It is the creation of a symbol for a selected quality that permits negation. That is, in order to specify a precise quality—what something *is*--it is always necessary to differentiate something from what it *is not*. Thus, language is constituted by implicit negation.[205] Korzybski uses this fact to criticize Aristotelian logic, which holds that "A is either B or not B but not both." Korzybski points out that this is a fallacy that assumes that categories must always be fully encompassing and mutually exclusive. It may be that this binary tendency of language also has a foundation in the fact that neurons are activated in a digital fashion. Neurons do not appear to "turn on part way". They are either ignited by incoming signals or they are not. If the incoming signal is below a given threshold, then the neuron does not fire. The meaning of a word may be instantiated in a neuronal web with distributed qualities, but the actual activation of the word form itself may be governed by the more simple neural architecture. Future research will no doubt illuminate this issue.

Although the binary tendencies of language have indeed formed the foundation of formalized Western logics, and while binarism has proven in computers and elsewhere to have some powerful utilities, the binary tendencies of language also constitutes a recurring stumbling block. Humans tend to identify political and theoretical positions as opposing "sides" and to feel compelled to support one "side" of the dispute. This is often an incorrect choice, because debates usually persist precisely because both "sides" have facts to support their contentions. The availability of evidence on both "sides" of a controversy is usually a good sign that neither "side" sufficiently frames the theory or policy. For example, a debate raged in the nineteenth century as to whether earth history was better explained as a series of catastrophies (a notion inherited from attempts to explain geology in terms of the Noachian flood) or better explained by processes like those observed on earth every day, applied at uniform rates for billions of years. For most of the twentieth century, the uniformitarian view clearly prevailed, but late in that century it became apparent that occasional meteorite impacts had played a major role in earth history.[206] Geologists came to appreciate that rare "catastrophic" events would occur sufficiently frequently in the vastness of geologic time that such events could play a major role in the long term. As a result, the two seemingly opposite views merged into a modern synthesis in which events rare at human time scales are nonetheless recognized as common in geologic time. Likewise, the current tendency to understand "biology" and "symbology" as binary opposites precludes a synthesis that incorporates the contributions of both (hence our effort to use a trinary system in structuring the theory of knowledge in part two of this book to help loosen up that tendency).

Valuation

The binary quality of language—something either "is" a member of the category gathered by language or it is *not*--appears to be the basis for a broader characteristic of language--its inherent evaluative activity. As Richard Weaver put it "language is sermonic." In part, the inherent evaluative quality of language arises because human symbols are inseparably linked to human affective systems. The neuronal webs that instantiate words are not cut off from the parts of the brain that motivate humans but rather integrated with them. The sermonic quality of language is also, however, due to the structure of the symbol system itself.

As we have seen, symbol systems operate through categories that are binary and hierarchically structured. A symbol system thus prescribes a set of weightings among components existing at any one time, because categorization is a relational process.[207] The place of a word in a symbolic structure is not simply the putting of like things in a box, but it is a system of relationships—X is *not* in other boxes, and the X box is a sub-category within a larger category, each of which has particular associations. Every category is related to hundreds of other categories. For humans, these relationships are loaded or weighted with desirability and undesirability. Even simple descriptive words have relative weightings, at least within a given culture. We are predisposed to process "up" as better than "down", being "in" has come to be widely understood as being better than being "out", and being called a "garden" is better than being called a "garbage dump" (even though both of the latter have their uses). This relational net of meanings bleed over in all kinds of creative, unruly and often troubling ways. For example, the fact that in our culture "dark" is better than "light" leads to difficulties in ethnic descriptions.

There are a range of weightings for terms. Some of the weightings are fairly strong, what Richard Weaver calls "god and devil" terms: for example, wealth or death.[208] Most weightings of terms are mild: "chair" has a slightly positive loading as it tends to be perceived within a category of functionally useful devices. Remember that even a relatively neutral (i.e. balanced) weighting is still a weighting in a structure of relationships. Although these weightings can be over-turned in specific instances ("wealth is a burden to the mind"), and although these weightings are polysemic,[209] nonetheless, the available valuational resonances of the word must be overcome or worked against or used as a point of reversal. They cannot simply be ignored.

Having access to a symbol system that is evaluative also changes the possibilities for decision making from a relatively restricted scope to a vast scope. It does this not only because of the capacities of a symbol system to act as a place-holder for many goods, but also because a flexible symbol system enables the placing of many different types of goods within a single system, where they can be directly related and compared. Economists have marveled and critics have bemoaned the capacity of contemporary society to reduce all goods to one value system—the economic. But symbolic systems long ago reduced all perceptible phenomena to a single valuation system for humans, that of language, and created the linguistic "market" or space in which widely varied phenomena, which cannot otherwise be "placed" beside each other, can be easily placed in many different alternative configurations and compared. In fact, language not only allows their sharing of this common dimension, it makes it an unavoidable fact. The relationship they share in the symbolic realm comes to have a coercive force of its own, even if it is only a small force. Fortunately, symbolic systems are multi-valued, rather than reductive like economic markets.

As a symbolizing animal, therefore, one is inherently engaged in the process of evaluation every time one talks. Talking does not engage a separate "word" or "concept" part of the brain that can be "logical" and "disinterested." Neuronal webs link many parts of the brain, and all these parts, but especially the word webs, constitute the experientially deposited "values" of the symbolizer. However, because the symbolic network is social, it is not merely one's own interests and experiences that get weighed in this process. Each individual implicitly picks up the weightings that have been built into the symbolic structure as well (merely by having heard how others use the symbols). In Chapter 8 we will see how this creates morality for our species.

Narrative

Narrative constitutes a final distinctive feature of human language usage. Extended human monologues tend to come in narrative form, and the components of narrative powerfully shape the way humans converse and think. The influence of narrative form is so important in producing human behavior that some writers have called us "homo narrans."[210]

The brain architecture that gives rise to the possibility of narrative seems to be the fact that the brain processes nouns and verbs separately. There is disagreement about whether the available facts indicate that this syntactic difference is a product of structural differences in brain architecture for nouns and verbs or is merely a result of the different loci in which movement and non-moving objects are lodged, so that the neuronal webs for nouns and verbs extend into different parts of the brain outside the language centers. While the case for the latter account is currently more convincing, in either case, the difference between action and objects seems to ground not only our grammar, but also the existence of narrative as a fundamental feature of human language.

No other human language structure has gained more attention than narrative (though metaphor may have generated equivalent interest). Hundreds of explorations and definitions of narrative have been offered.[211] A distillation of these reveals two different traditions that highlight separate important facets of narratives. A sequentially oriented definition arises from studies of folklore and literature; this approach emphasizes a chain of events, describing narrative in its simplest form as a series of related events, especially with a complication.[212] Elsewhere, in the more sociologically and philosophically influenced dramatistic traditions, narrative has been treated by Kenneth Burke as the motivational set composed of an agent doing some act, using some tool, in some particular setting, for a particular purpose.[213]

Burke's dramatistic approach is broader, and subsumes more of human talk, because not all narratives involve a complication. Stories presented in monologues tend to involve complications, but narrative seems to be a broader mode of thought that goes on in our mind constantly and in our informal talk in a fragmentary fashion, and even in our formal non-narrative talk as fragments of stories. Complications don't always figure into these kinds of narratives, though a mode of causation does. In this sense, narrative involves simply the linking of agents, actions, purposes, scenes or tools. Burke's account, however, tends to ignore the sequential movement through time that is crucial to narrative thought, so the two different definitions of narrative are useful supplements to each other.

When we say that narrative form shapes human thought in important ways, we mean specifically that narrative form enables extended, linear thought and that it gives a particular set of emphases or a "logic" to that thought.

Extended linear conscious thought is made possible by having a symbol system to use. As a first-hand proof of this, try to tell yourself a story that you know well (for example, Cinderella), without using words. Now try telling the story in words. If you are like most people, what you get in the non-word version is surprisingly little—a few fragments of images, and it is almost impossible to tug yourself along from one part of the story to the next without falling back into words. When you start to tell the story verbally, however, it comes moderately easy, with plenty of detail. This is not because our brain stores narratives in words. For example, in each telling of the Cinderella story, one will use slightly different words. Sometimes it is the "wicked stepmother" and sometimes it is the "evil stepmother." So it isn't that words make narrative possible because they allow storage of narratives. *Rather, symbol sets allow, even require, the constitution of extended linear mental processes that can dominate other mental processes over a relatively long time span.*

For the most part, the brain is not built as a linear-processing device; it is a gestalt device.[214] At any one moment there are an enormous number of active brain cells sending and receiving messages to each other, to various parts of the body, and from the stimuli around the body through the sensory apparatus. There is, even in non-symbol using animals, a "directed consciousness device," that allows the brain to switch constantly among these inputs, attending more fully to some rather than others. This consciousness director is not a self-guided device, but rather it responds to external stimuli and internal bodily states with rapid shifting of attention. It is therefore not a linear process, but a kind of rapid switching among inputs based on their relative strength.

In contrast, in human symbol systems, it is the flow of the narrative superimposed on sentence structures that guides the selection of which component comes next. Verbs or actions require nouns or objects and these in turn imply scenes. Particular scenes are consonant with particular actors, so that "understanding" something seems, for humans, to predispositionally presume the five basic components Burke defined as the pentad. Thus, "Once upon a time" (scene) leads to "there was a pretty young girl" (agent) which leads us to "she was mistreated" (action), which leads us to "by her evil stepmother" (counter-agent; perhaps generated by the binary tendency as well), and etc. When telling a story, our attention is guided by the symbolic template, not by the moment-by-moment outcome among a competition of different brain sectors. Of course, this can only happen to the extent that the symbolic system is able routinely (but not always and inevitably) to subordinate other inputs to the flow of attention it directs. This probably could only evolve to the extent that the symbolic flow was capable of subsuming or incorporating this shifting flow, and that doing so had substantial survival advantages.[215] Nonetheless, this capability produces a highly distinctive form of mental process.

The logic of cause and effect is surely a part of brains that do not have symbol systems. But there is little reason to believe that this logic is narratively based. In non-symbolizing brains causal logic appears to be either simple "tiger…run" (a two step-flow) or it is complex, but gestalt (I simultaneously judge the tiger's distance, the nature of the terrain, my own physical condition, the placement of my young, etc.).[216] In the gestalt case, the judgment is made by the simultaneous input of multiple variables. In contrast, narrative logics guide a selection of particular elements from the gestalt flow and prescribe a particular way of linking up these components in a linear series. To understand what difference this logic makes requires a somewhat extended analysis.

First, the process of constituting a narrative requires a new kind of temporality. The stream of events that our bodies pass through consists of "real time" and in that bio-physical time stream any animal with a complex brain operates with multiple channels in the brain simultaneously active. The animal may have "consciousness" in the sense of directed awareness at different things at different times. The deer now focuses on the brush she is chewing, and now on the new smell that comes on the wind. However, a non-symbolizing being c*an't tell itself about the events it is experiencing out of the actual time of those event*s. By contrast, when symbolic capacities are overlaid on other capacities, this creates a time series that it is other-than the time series of external experience. Although this re-telling certainly goes on in a new real time as well, the time-series of experiences that are the narrated content of the cognition are from another time than the re-telling and may be compressed or expanded compared to the "real" time. As we will see, in the next chapter, this "time-binding" quality of symbol use forms a key dimension of the "fantastic" or "more than real" temporal features of symbol using. Symbol using allows the temporal movement of an event series in the brain, and, of course, the communication of this series to other people.

The narrative series that runs in this other-time is, of course, different than the original experience of the events. It is linearalized as a drama or narrative, rather than simply as a sensu-round montage replaying itself. Additionally, because it is symbolized, and linearalized, it is a selection from and re-arrangement of events and experiences. Moreover, it is moderated by the specific character of the specific symbol set that is available to re-constitute it. The narrative is thus not a "real" representation of the original experience or event but rather a modified selection from that original multi-dimensional sensory stream.

This incompleteness of reproduction should not be seen as a correctable deficiency, for it is precisely what gives narrative its power. The selection and correlation add cognitive power because they allow generalization and simplification. The narrative simplifies because the form tells one what to look for as relevant inputs: look for an agent, doing an action, for a particular purpose! What kind of tool are they using, and what is the scene? Narrative form thus simplifies from an infinite number of possible inputs. Simplification is powerful because one can get from 400 potential inputs to 5 or 6 relevant ones in the space of a sentence or two. Generalization is also made possible because the narrative has abstracted out the relevant features of the particular plot, and so one knows when the same story-line is likely to be made possible or probable again. This template also helps the telling of an extended story—you know what to look for next, and next, and next. You know when the story is "done." Narrative form thus supplies the basic logical template that humans employ to collectively form their judgments in the world.

Narrative as a predisposed foundation of human language may arise from the advantage communication among animals provides to them. A single animal can process all the elements of its sensory gestalt rapidly. But all of the elements of the gestalt cannot be put into signs or symbols and communicated rapidly. A selection must be made. Presumably, using a shared logical/grammatical template coordinates the selection by the sender with what the receiver is likely to find salient. A narrative logic is therefore an efficient logic for the coordination of action.

Presumably, some kind of evolutionary devices have favored the privileging of the particular elements that we recognize as the fundamental components of human narrative. It is certainly not the case that all symbol systems are narrative in their structure. Mathematics is not, and science spends an enormous amount of its effort trying not to be. Traffic systems and fashion are symbol systems that seem not to be narrative in their structure. A typical just-so evolutionary story would say that it likely was most critical or useful for humans to talk about agents (e.g. themselves or their predators) and their acts (e.g. being pounced upon or searching for berries) for various purposes (e.g. protection from predation and finding food) and to locate these in specific space/times, and eventually to identify the tools that were useful for accomplishing these goals.[217] The special importance of these factors led to a biasing of symbolic processing in these directions.

Whatever the truth of such a story, it is clear that narrative form exerts a powerful force upon our understandings. Humans find it difficult to give descriptions without imputing agent/purpose status to things that move or change, even when we consciously repudiate agent and purpose status for the entities about which we talk. Some of the best examples come from scientists. In general, scientific enterprises seek to replace narratively driven accounts of causation with accounts driven by other logics. Nonetheless, physicists routinely find themselves telling their students about balls "wanting" to get to lower energy states and biologists routinely talk about genes "acting selfishly". On the other hand, the human tendency to what we call "superstition" is not much more than our narrative/grammatical tendencies put into action without any material referents. Superstitions are usually stories in which particular narrative components assume inflated, perfected, or distorted characteristics.[218]

The driving force narrative form exerts upon us makes it important to attend explicitly to the ways in which the particular components of the basic narrative form—agents, acts, purposes, scenes, and agencies—influence human action. In purely biological beings, the programmed goals of survival and reproduction link ultimate causation (natural selection) and proximate causation (how a portion of an organisms responds to stimuli) and thus act as forces that shape the impacts that external inputs may have on an organism. In symbolic beings, an additional layer, usually called "purpose," must be factored into the understanding of causation.

Human beings, as symbolizing animals, typically do not explain their own actions and those of other symbolizers in terms of the functions that an action serves, but rather in terms of the purposes they serve. The narrow biological account of humans sees purposes as either simple products of function or as masks for functions that one does not wish revealed. On such a view, one can just ignore purpose statements, and look to biological functions in order to understand human behavior. But if symbolic being really does exhibit material effects, then such an approach would miss a crucial variable in explaining human behavior. We believe the evidence is sufficient to require serious investigation of that potential, and therefore a true program of consilience must understand how purpose differs from function, just as function differs from mechanistic causation. It must be transilient.

Chapter Summary

Understanding how purpose actually relates to biological functions (often called "drives") is no simple matter. Indeed, it might be said to be the challenge of the next level of human self-understanding. It is an endeavor we will try to make some small headway on in Chapter 8 as we talk about "effectivity" as the form of causation in symbolic being and in Chapter 11 as we propose some research programs for exploring the interactions between biological and symbolic dimensions of humans. As this chapter has indicated, however, we already know that symbol systems are material systems and well-grounded observations indicate that they produce identifiable patterns of material effects. We also know that human languages function using specific mechanisms: categorization through abstraction and differentiation operates through a convergent, contextualized flow of symbols, which instantiates a historicized set of material relationships. This system manifests binary, evaluative, and narrative proclivities.

Developing further understandings of symbol systems, and especially of how these systems interact with biological predispositions, will require the efforts of the best and brightest of a new generation of scholars, people who are capable of entertaining the possibility that symbolic forms are integrated with biological forms in guiding our thoughts and behavior, people capable of consciously integrating the material potential of symbols into their hypotheses, and people capable of imagining new more comprehensive models for describing symbolizing animals. Before taking steps explicitly toward that endeavor, however, we need to understand the amazing emergent characteristics that arise from symbolization.

Chapter 8: The Fantastic Properties of Symbolic Being

Summary: Powerful properties emerge from the fundamental characteristics of symbol use outlined in Chapter 7. First, use of symbols allows time-space binding, where events at one time and/or place, such as the writing of a constitution or the martyrdom of a leader, can have direct effects in other times and places. Symbol use also allows generation of new things and concepts, such as new technologies and new ideologies. Perhaps most crucially, the evaluative features of symbols are the key element in moral judgments, which impart qualities to phenomena not evident from their physical or biological characteristics. Finally, the causal form of symbol use is effectivity, which is exhibited in both individual and social behavior. All of these add up to provide symbol use with a "fantastic" quality, the ability to envision, plan, motivate, control and judge objects, beings, and events that may exist only in other times and places, or perhaps (in the literally "fantastic" sense) nowhere or never at all.

In Chapter 7, we summarized existing literatures that indicate some of the most fundamental features of the human symbol system usually identified as natural language. We perceive this as a description analogous to that physicists have used to explain how molecules and atoms and gravity and electromagnetism work. We now wish to suggest why and how the practice of symbolizing, when it becomes sufficiently complex and frequent, comes to constitute a particular realm of being, by which we mean that entities that have these features will exhibit major and different properties than entities that do not symbolize. We are here arguing that some of the most distinctive characteristics of human beings--our proliferation of cultural objects, our creativity, our intense participation in fictional realms and most crucially, our moralizing tendencies—are all emergent phenomena that arise from the interactions enabled by the fundamental features of symbolization.

We summarize the emergent properties of symbolic being by calling them “fantastic”, in contrast to the “mechanistic” and “systematic” qualities of physical and biological being respectively. The term “fantastic” captures both the amazing quality of the features of symbolizing and also the extent to which they seem to be, and some times are, involved in the realm of fantasy. The fantastic qualities of the realm of symbolic being include the ability for time and space binding, the proliferation of novel kinds, and the fusion of degrees and kinds to produce morality. These features mean that the cause/effect structure of symbolic being is best characterized as “effectivity” or influence.

Time/space Binding

As Chapter 2 noted, physical being is presumed to be either absolutely or dominantly time invariant. Physical beings are presumed to have followed the same laws and have come in the same types since sometime between one second and five minutes after the Big Bang.[219] In contrast, Chapter 4 described biological beings as having time/space specificity because they vary through time and space. They can exist only in specific times and spaces because they are dependent on their own lineages as well as those around them. Symbol systems are time and space specific, but their time/space relationships are even more distinctive than the biological realm, for symbolic systems are also said to be time and space binding.[220] Because symbols arise from past actions in dispersed bodies and other media, but are applied in a present, they link the past and present, binding past and present through a mechanism that steps outside of the immediate physical relationships in the phenomena to which the symbols refer, rechanneling these through the arbitrary physical relationships of the flow of symbols. A holocaust survivor's story about her experience in the 1940s in a German concentration camp, related on television in January of 2005, informs a news report that follows it about the treatment of prisoners by the U.S. at Guantanomo Bay prison camp in 2002. None of the parties involved may ever have directly communicated about the two different sets of events. Yet, transmitted side-by-side, the one affects the other.

This is not the time specificity of the organism. The organic form of today is linked in a physical chain of DNA and epigenetic substances to the organic form of its grandparents or great-grandparents through its parents. The link of the grandparent to the grandchild is indirect, but the chain of relationships can be traced through a set of physical relationships that is constituted by the interaction of the molecules *in the bodies* of the organic beings. Particular parts of the DNA code must have their order repeated and must dwell in one body and then in its offspring. In contrast, through writing (and even oral story-telling), the symbol forms a direct bridge between past and present that requires no personal lineage, no carry-over of any particular physical entity, no retention in any specific body. The set of symbols that binds the past to one's present need never have been uttered by one's parents or grandparents, and the exact words need not be used in a retelling. Indeed, they may have come from a papyrus, written a thousand years ago in a different language and stored in a vault unread in the centuries in between.[221] There must be a physical chain of symbols, and this chain is constrained by the prior uses of the set of symbols as a whole; it is therefore still a material process. Because of the arbitrary historical character of its constitution, however, the process can "skip generations" or even move across different cultures, jumping out of any biological lineage. The processes of symbolization can in this way bind different times and spaces rather than merely being specific to one space and time.

Spaces are bound by symbols in a similar fashion to time. The behavior of a religious group in the Middle East is tied to the behavior of opposing and adhering groups in Seattle, Washington. If a Tsunami sweeps Thailand and Indonesia, millions of people are saddened in all parts of the world. Only a stream of verbal and visual symbols connects the victims at the moment of their terror with the television viewers safely lounging around their screens thousands of miles away. But the tv viewers and the victims become bound in facing the awesome horror of nature's power.

The ability of symbolizing to bind time and space creates what are effectively new planes of temporality and spatiality. The story about one's day (the day ahead *or* yesterday) that runs through one's mind as one eats breakfast is a temporal narrative that does not run in the "real time" or "real space" of the day as it will unfold. Of course, this imaginary plane of time and space also runs in the real time of the biological processing that goes on in the mind of the symbolizer, but this merely points up the duality that is constituted by symbolizing, as the symbolic narrative selects and therefore re-runs and recasts events at high-speed. Anyone who has paid fifty dollars for a concert ticket only to find themselves thinking about their niece's wedding three years ago has experienced this duality. The narrative or narrative fragments that run in one's head need not even be things that one has personally experienced. They may be about battles or discoveries experienced by people or beings hundreds, even thousands, of miles away.

Because it creates such a "stepping out of real time," symbolic activity constitutes a powerful resource that allows several distinctive types of behavior that are not available to non-symbolizers. The first class of behavior is simply the extension of the information used in pragmatic calculations of costs and benefits. The time and space binding properties of symbols allow human beings to share information about spatially and temporally distant events. This allows one, for example, to plan ahead for a hurricane hundreds of miles away—either by evacuation or taking in their stock of beer for a risky "hurricane party." It significantly expands the scope of decision-making.

Finally, and quite notably, because symbolizers have the highly flexible alternative space/time of imagination in which to create, and because they have the time-binding capacity to share creations directly rather than through lineage, human beings create an endless stream of types of things, or kinds. The creative capacity is, of course, further enabled by the "arbitrary" (i.e. historically material) character of symbols, which contributes to the relative ease of their manipulation into alternative potentials. Together, however, these features enable the fabulous proliferation of things that constitute the most visible, distinguishing mark of humans as a species. The proliferation of novel kinds, then, constitutes the second fantastic quality of symbolization.

Novel Kinds

We have already shown how purely physical being occurs in a constrained pyramidal structure of kinds that are relatively few in number, and we have indicated that biological kinds are far more numerous and come in probabilistically distributed populations rather than discrete types. Variation within biological populations is great enough that one generally needs to remain cognizant of the ranges within the populations, and to remember the potentials for overlaps among the types. Moreover, the huge diversity of types means that in biology variation matters as much as similarity.

Human symbol systems create types that are even more prolific; symbolically constructed kinds are constantly invented and refashioned by both history and specific contexts. There is no constrained pyramidal structure of typologies, as in physics, or even a constant, historically grounded "tree" of relationships, as in biology. The symbolic categories that things are placed in are determined by the situated needs for coordinated action of the symbolizers. The same piece of wood can be a walking stick, firewood, a club, or a lever. It can be built into a "coffee table," a "bookcase" or a "chapel". The categories "coffee table," "bookcase" and "chapel", do not even exist in all human groups. Hundreds, perhaps thousands, of the categories that we use today did not exist a thousand years ago (weather satellite, refrigerator, United Nations, nanotech, blender, quark, mini-skirt, deconstruction, academic journal, sports car, impressionism, re-cycleable, anthropology, tight end, pollsters, game theory, situation comedy, etc.). This is not just a matter of having different words for these things at different times and places. In some cases, the associated phenomena or "concept" didn't exist. In others, analogues may have existed but the total social and symbolic space were arranged in such a way that the components were parsed into different categories.

The pliability of symbols means that symbol-users are capable of "moving" things created within one category into a variety of different categories at any time (the fender of a sports car becomes a chair or the object of a demolition derby or scrap metal). Because use is determinative of meanings, "kinds" for symbolizers are endlessly novel, even if there were a fixed set of "things." But, of course, the symbolic capacity also greatly enhances the ability to create novel physical objects as well.

The proliferation of readily re-shuffleable kinds in the symbolic realm is a product of the interaction of their physically arbitrary (i.e. historically material) quality and their time-space binding properties. These qualities enable symbol users to try out new relationships among parts of things without actually having to invest the struggle and effort necessary to build them. The widespread use of blueprints and computer models illustrates the currently most advanced version of this capacity.[222]

This inventiveness and variability of types among symbolizers does not deny some constancy or generality across human communities.[223] As we previously indicated, the human brain may well be predisposed to certain kind of processes and therefore toward certain kinds of conceptualizations. However, the specific forms and the reach of these conceptualizations generally manifests with substantial variation. Consider the example of the wheel. Given the structure of human beings and of many human environments, wheeled vehicles seem to provide a category toward which there is some human predisposition, and once the conceptualization was realized, it spread through many cultures with some rapidity. However, relatively few cultures seem to have invented the wheel, and not all cultures adopted the wheel. Peoples living on waterways were less likely to adopt it for obvious geographic reasons. However, on the whole Native Americans did not tend to integrate wheeled transportation into their lifestyles as long as their cultures were relatively intact. This contrasts sharply with their rapid adoption of both horses and guns. The generality of human predispositions is thus more similar to the motif-like generality of biology than to the universals of physics.

Symbolizing constitutes an effective mechanism for the powerful amplification of various relatively vague conceptual potentials into a proliferation of different types. Symbolic capabilities may rarely if ever stand alone. Instead, the general model is an interaction between verbalized categories, as a telephone is imagined in the context of a science fiction movie as a hand-held flip-top “communicator” which is then materialized as cell-phones, which are then imaginatively linked to computers in new science fiction that portrays us all walking around with microchips in our heads that allow us to “talk” with each other across distance in a telepathic like fashion, which is…… As one might well imagine, such a proliferation poses enormous challenges for knowing about the production and effects of such slippery types. Before we turn to the challenges of considering "cause and effect" in symbolic being, however, there is one additional fantastic emergent property of human symbolizing—the production of moral codes.

Morality

As we observed in the previous chapter, the potential meanings of any term are partially determined by its differentiation from other terms in the symbolic network. Consequently a system of evaluations is implicit in being a symbolic "kind." The obverse side of this coin is that abstract evaluative characteristics such as "good", "bad," "right," and "wrong" do not exist in nature.[224] They exist only in symbol systems. Consequently, the things we call "moral judgments" are a product of symbolization, both due to the constitution of such abstract judgments and also due to the time/space-binding qualities that allow consideration of alternate agents and futures.

To say that symbol systems create the potential for moral valuation requires two distinctions: first between (pre-)moral emotions and moral codes and second between moral and pragmatic decisions. The claim that symbol systems create the potential for moral valuation does not conflict with evidence suggesting that humans have so-called "moral emotions" including a righteous anger at perceived unfairness and guilt. Instead, although moral codes may gain force and some general form from whatever brain-and-body configurations give rise to such pre-moral emotions, moral codes give specific content and direction to those emotions. They distinguish just what counts as immoral lust ("adultery") as opposed to moral passion ("marital bliss") for a given social group.

Linguistically-grounded moral codes are different from pre-moral emotions not only due to their function in creating local specifications, but due to their fundamental character. The emotions that we linguistically describe as "moral" appear to both shape and give force to our moral codes, but they are not "moral" without the existence of a symbolic system that assigns a scale of good and bad that is independent of individual survival. Anger at someone's failure to fulfill a contract, or guilt about hurting someone are simply evolved responses that help one's genes survive. They are no different from the adrenaline drive involved in fighting an attacker or killing a less intelligent animal to survive. We think of anger and guilt as different only because they have been incorporated into a linguistic code that valorizes fulfilling obligations and cooperating with certain classes of other people.

Admittedly, humans tend to have a shared linguistic code that categorizes such behavioral tendencies in a single category (morality) because those drives exist and they share some features (being directed at successful social behavior), but the existence of emotions with such shared characteristics does not make them "moral" (i.e. to be advocated for their goodness per se rather than because they serve a particular function). Although these pre-moral emotions are probably causal components of moral systems (we likely would not have moral codes without them: a serious consideration in Artificial Life scenarios), they are not the sole causal components of moral systems. Without symbolic capabilities, there is no morality, only the bodily flows of chemicals we can—*post hoc*--symbolically identify as anger, remorse, hate, grief, or immoral lust.

The second distinction required by the claim that symbols create moral codes is that between pragmatic decisions and moral ones. The pragmatic calculation of pragmatic pay-offs occurs when the evolved functional circuits of a biological being operate to assess and choose a course of action that preserves immediate self interests such as survival or reproduction. In contrast, symbolically based moral decisions involve comparisons of the merit of goods in different time/space frames, goods for more than one person, and of goods that have only symbolic forms of existence. Only symbol systems create such different kinds of entities for comparison and make them immediately comparable.[225] We are here assuming that moral evaluation is defined as that part of symbolic evaluation that includes in a decision the needs and interests of non-kin others in extended time/space frames.

To illustrate the distinction between the two forms of calculation, consider that one might say that a leopard "values" a vervet as a meal. What is probably meant by that is the leopard needs food to survive, and perhaps that the leopard can make a calculation of whether, given its current state of hunger and the relative positions of the vervet and the leopard, and perhaps the likelihood of finding better positioned prey, the probability of the success of the chase is worth the energy to be expended. This is a complex calculation that entails costs and benefits, measured in degrees of risk and benefit, and that is why we see it as weighing or evaluation. It is, however, a completely self-focused and pragmatic calculation, and it is also extremely limited in its time horizon. Even though the illustration can be stretched to include a variable weighing of the relative safety or hunger of the leopard's kittens at the time, and thus introduce something slightly less tightly self-focused and immediate, evolutionary theorists would still make us recognize that the interests in passing on one's genes makes this a self-focused pragmatic process. The process of natural selection dictates that an animal's evolved calculative formulae include only its own reproductive success and survival to the end of reproductive advantage and the survival of its kin.

Symbolic systems expand the pragmatic decision-making process because they enable the introduction of more variables. Consequently, rather than merely deciding whether success is sufficiently likely in chasing a vervet, a symbol user can decide whether eating the last breeding vervet pair on the island is a good idea, or whether a delay or another meal might suffice. This expansion of the pragmatic scope of decisions enabled by symbolization is consequential. People can weigh a choice of actions in the present (go to the bar to party or do homework) against a future outcome ten years in advance (enjoying myself now instead of becoming a lawyer, or even anticipate a personal punishment of "going to hell" in an afterlife for particular behaviors). As Chapter 5 will indicate, this capacity to defer from the present enables the re-channeling of biological inputs in ways that may produce different and novel behavior patterns over the long term.

Inn addition to extending the time horizon of a personally-focused decision, however, a symbol user may also be induced to do something radically different, and that is to include the interests of others as part of the decision process (weighing my immediate gratifications against the possibility that as a public interest lawyer I'll be able to help the poor). The introduction of this specifically moral type of decision-making occurs through two processes. First, it occurs indirectly, without conscious or specific consideration because the symbolic net inherently contains a broad range of valuations. Decisions that are made with symbolic inputs inherently import all of the relationships in the symbolic web, at least to some degree. Second, it occurs through the symbolic process called "identification." As Burke describes it, in the process of identification one comes to see ones' self as "consubstantial" (literally sharing substance) with another person or beings. When the interests or identity of others is shared with one's self, others are necessarily being included in a deliberation in the same place as the "I".[226] The sliding quality of the associations that are grouped in different categories in the symbolization process make this diffusion of the agent position possible. Perhaps it is even inevitable. "I" becomes "we" and the particular associations for "we" are easily rearranged through symbolic devices such as metaphor. This broadened identification of "self" interest is probably evolutionarily supervenient on the "we" based in kin care, but the symbolic process can occur whether or not one "really" (i.e. independently of the symbolization) has a shared interest with the object of con-substantiality or not.

The process of identification encourages a symbolizing creature to make value judgments that benefit those who are not one's self (biologically) nor one's biological kin, and sometimes not even one's tribe or nation state. Thus, for example, symbolic capacities enable one to weigh one's own interests (to live safely in the home territory) against those of one's imagined tribe (to travel to the far side of the globe and participate in a war against communism, risking both life and reproductive potential). To take less extreme examples, it encourages some people to become vegans because they identify with non-human animals, and it encourages others to send money to starving children on other continents. Such choices are literally unimaginable for a creature that has no symbolic capacity.[227]

Although symbolic processes might indeed *enable* such inputs, there are two important lines of argument against the claim that human morality is created by symbol systems. The first arises from philosophers and theologians who argue that morality derives from a transcendent space outside the human and material realm. Since no one has direct access to such an a-material space, it is difficult to engage such theories on a material basis. One simply can't prove that there is such a space from which morality derives (or that there isn't). Given the indecidability of the issue on empirical grounds, the thrust of the argument against locating morality in human symbolic action usually rests on the pragmatic claim that accepting such a base for morality produces subjectivism, which in turn produces a-moral consequences. We believe these arguments have already been sufficiently answered elsewhere.[228]

The second line of challenge arises from evolutionary theory, the dominant version of which has held that natural selection favors individual self-advantage. Including the interests of others is always prone to be eradicated by evolutionary processes because individuals who include others will be taken advantage of by others who do not do so. Selfish individuals, on this dominant interpretation, will always outcompete nonselfish individuals. This perspective has recently begun to be softened. Various ways in which "mutualism" can be balanced evolutionarily have begun to be charted.[229] In Chapter 11, we will consider in more detail how symbolic capacities can be modeled in a way that accounts for the evolution of such mutualism, even collective action, and we will then be in a better position for examining the available ways in which one might reconcile evolutionary theory and the partial independence of symbolic processes (see Appendix 3). A preliminary treatment is nonetheless useful here.

There are at least three ways in which moral action could be accounted for without in general denying that humans are subject to evolutionary forces. The first is to suggest that human beings are not operating at an evolutionarily stable strategy because of the instability of their environments. Humans evolved symbolic capacities too recently, and symbolizing involves constant novelty, and these two factors mean that we are not at a stasis point. On this view, evolutionary processes may eventually weed out either morality or, if morality is inherent to symbolization, humans as a symbolizing species. However, morality could be a component for a relatively long period on a human historical scale, because evolutionary processes operate on even longer term time-scales.

A second way to account for moral discourse without denying the general existence of evolutionary processes is to suggest that cultural transmission of symbols itself operates on evolutionary principles, even if its substrate is not the biological substrate. On this view, the force of symbolic evolution has become at least as strong as biological evolution among humans, negating the evolutionary constraints of the latter on the former. In other words, as Susan Blackmore has suggested, it might be that among humans it is no longer biological lineages that are successfully reproduced but rather cultural "memes." On this view, just as "genes" created organisms to reproduce themselves, "memes" might now be creating genetically based organisms to reproduce themselves. To the extent that "memes" can skip from one human population to the next like a virus, this is a live possibility (a fuller discussion occurs in Chapter 6).[230] If this option is true, it highlights the importance of attending to the processes of memetic evolution in designing social action and policy.

The final alternative is to suggest that group competition has been a greater force in the constitution of the human gene pool than previously recognized. If this is true, then the evolution of symbolic moral codes would be consonant with evolutionary processes in precisely the same way that the evolution of moral emotions is consonant with those processes. Although group-based evolution is still heretical to some evolutionary theorists, all that is required for human group-based evolution to fit within the framework of evolutionary theory is that there have been stringent competition between relatively rigidly separated groups such that the likelihood of a particular genetic configuration surviving and reproducing was at least as strongly determined by which group one belonged to as by one's place within the group. In other words, in instances where the "tribe"/individual is an analogue of the organism/cell. Whether or not such conditions have been met historically for humans is currently being explored and debated.[231] We think that the complete genocide of the native Tasmanians, the nearly complete genocide of Native Americans, and the continuance of genocidal efforts in the 20th and 21st centuries answers the question definitively. There are clear instances in human history where the group one belongs to has been more important in determining reproductive outcomes than one's one place within the group.

If groups with more effective symbolic systems for group identification swamp the reproductive successes of groups with less effective systems (through direct genocidal campaigns or through other means), then evolution of such moral codes would be consistent with evolutionary processes in general. Note that to describe one symbolic system for identification as a moral code that is more effective than another, is not to say that one group's code is more "moral" than an others' in a global sense. All that might be needed for greater effectiveness, for example, would be the capability to ensure that more different people of more different professions identified more intensely with the group. A radio system might make that difference as well as the particular contents of the group's moral code. If the effective identification process is directed at genocide, one would not say that the genocidal group's moral system was globally better than the victim group's. It is simply more effective for a given purpose.[232]

We have shown how symbol systems enable, even encourage, specifically moral decision-making. There are many examples of such behavior. We have outlined at least three ways to account for the relationship between those moral processes and behaviors and the apparently opposite force of at least some components or models of evolutionary processes. Scholars are now in a better position to explore these alternatives carefully, because the material model of symbols enables more precise formulation of hypotheses and operational definitions. Such research should better specify the parameters of moral decision-making.

Symbol systems may enable us to become moral beings because they enable us to extend our sphere of consideration between self and kin. What most people mean by morality, however, is a more formalized system of explicit general statements about what is good and bad, acceptable behavior and unacceptable. Such rules or commandments are presumed to have prescriptive force in guiding conscious decision-making. We suggest that such explicit moral codes are simply evolved symbolic sets, and that they have expanded their scope as the expansion of human communication systems has enabled contact with peoples in broader space/times. Thus, there is some evidence that localized groups use as their moral framework a rule something like "don't act against the welfare of your family or tribe." As family and tribal boundaries become less discrete, moral codes may include "love thy neighbor as thyself," giving moral weight to the people around one, even if one does not identify those people as having shared organic or cultural lineage. Later, as international scale communication happens, "all persons are created equal," becomes an even more generalized formula. Such a formal moral code designates all humans as having a shared identity, calling individuals to act not in self interest, but in regard to a generalized set of norms that apportion what should be done based not on what is good for me, but rather one how I believe all people should be treated.

Symbolically evolved moral codes may have at its core a general mental disposition to divide people into in groups and out groups and to favor emotively treatment that is "just" within the in-group. However, by expanding what counts as in-groups from family to neighbor to nation to all humans, the symbolic system adds specific contents to moral possibilities, changing what behaviors are sanctioned.

There is, of course, an on-going struggle to implement such a general code in lived practice, because it is by no means the only force operative in human relations. We would emphasize therefore that such moral codes cannot be assumed to have anything like a presumption of dominant influence. Nonetheless, change in the codes seems to be observable; today even enemies engaged in deadly warfare tend to endorse such a broad code as an ideal. This has not been the case in all times and places. In classical Greece, pro-war speeches made direct arguments that a war should be undertaken because it would bring economic advantage to the nation.[233] Today, pro-war speeches make arguments based on maintenance of freedom or peace (regardless of what the mix of interests motivating different sub-groups might be). The expansion of moral codes also appears to be an on-going process, as more recently, a further expansion of the code is urged by those seeking to include non-human beings in the framework of moral judgment.[234]

Finally, the symbolic time/space in which moral decision processing takes place also creates a space for original invention, which enables moral problem solving. Because the symbolic realm has the property of allowing things to be moved around in ways that are “not real,” new ideas and options can be readily constructed. We usually imagine this process as the doodling of an inventor on a table-cloth, but it is also at work in the moral plane. This is what people often do when confronted with choices they think are morally or otherwise bad. For example, research into moral decision making often poses hard and fast dilemmas to which research participants are asked to respond. A standard scenario that is used describes a woman who needs a drug that her family can’t afford, or she will die. Participants are then asked whether the woman’s spouse should steal the drug or let her die. Many respondents come up with alternatives to either stealing the drug or letting the woman die, because they find both theft and avoidable death to be morally repugnant. This annoys the researchers (“no,” they respond, “the pharmacist can’t be persuaded to discount the drug,” or “no, it costs more than a fund raising campaign can secure in time; so are you going to steal it or let her die?”).[235] People’s persistent avoidance of the forced choice illustrates the creative moral power granted to us by symbol using. We can create new moral actions because we are able to incorporate many factors into moral judgments and move around the symbolic markers to find ways to accommodate these options. If there is hope for our species’ survival and even social improvement, it comes precisely from this capacity of the moral imagination.

In order to take symbol systems seriously, we will have to change how we think about research, knowledge, and understanding. Because it is inherent to human symbol systems, moral judgment should be understood as an inescapable component of knowledge generation about symbol usage. Because knowledge of human symbol use always takes place using at least some of the symbols in the object studied, it is not possible to escape from the valuational implications of the symbolic network, including the moral implications. However, this should not be taken to mean, as it is too often taken to mean, that we cannot produce knowledge about those symbolic systems. It is simply that the character of that knowledge, taken in total, will be different by degrees in some dimensions from the character of knowledge in physics or biology. As Part II will show, however, there are also differences in the character of knowledge between physics and biology, and no universal template or methodology can provide the exclusive ground of knowing and understanding of being, even though there are clear continuities across levels and some sharing of tools as well. The continuities and dissimilarities are evident in the way in which "cause and effect" functions within symbolic beings.

Effectivity

Rather than understanding symbols as having effects, Western cultures and academics have tended to characterize symbols as having "meanings." A meaning was vaguely assume to be something like a reference to a real world "referent" and it was presumed that rather than "effecting" things, it gave people information about the real world that they could then use to make decisions. The agency rested not with the symbol, but with the human decision-maker. This model has been attacked from many quarters, ranging from sociobiology to post-structuralism, and we hope that we have now provided a clear explication of its errors and the basis for an alternative. In a theoretical framework that understands symbols as material phenomenon, one expects to be able to account for the effects of the symbols in the world, but there are specific constraints on these accounts.

Experimental and observational evidence indicates clearly that symbols do have effects. The first author's research team exposed people to messages that linked genes, race, and health.[236] After receiving messages linking African Americans to health problems that were ascribed as genetically based, people expressed attitudes that were significantly (and substantially) more racist than people in the control condition who did not receive these messages. A specific set of symbols produced a specific change in behavior—at least the behavior of which circles one fills in on an attitude scale. Although achieving sustained behavior change of other sorts generally requires more than a single message, evaluations of many health campaigns have documented such results.[237]

Observations of more complex, social level phenomena, also indicate that symbols have effects. A Klan rally occurs, inflammatory speeches are given, and afterwards a cross is burned on a lawn. If those speeches had not occurred that night, then that cross would not have been burned on that lawn on that night. At the least, the sharing of symbols focused a set of forces onto a specific time/space. At the most, the sharing of the symbols caused an event that would not have occurred on any night absent such symbolic action.

Yet though we can provide reasonable evidence that symbol use has effects in some circumstances, it is much more difficult to prove the force and character of these effects in the many instances where it truly matters. This is represented by the difficulty of "testing" whether economic or other material factors as opposed to symbolic actions determine a particular historical outcome. For example, did Winston Churchill's speeches contribute to the success of the allies in World War II, or was it simply that the allies were stronger? One can make a fairly good case that Churchill's speeches spanned a particularly important historical gap, enabling Britain to resist appeasement until greater allied (U.S.) fire power could be brought to bear against the Axis. But those who do not believe in the effectivity of speeches are quick to point out that it is difficult to trace any specific effects of Churchill's addresses. And indeed, the senior author has argued that a key component of at least one critical speech was Churchill's ability to imply persuasively but subtly that the U.S. might was on its way. In that case, is it possible to separate out the actual might of the U.S. from the persusaive representation of its role in the conflict?[238]

The difficulty of identifying the effects of symbols can be traced to many sources. Several of these are shared with the study of aggregate physical and biological being as we will further rindicate in Part II. Like geology or meteorology, symbol sets feature an enormous number of variables and these variables operate at overlapping scales of force. In symbolic studies each variable tends to have a very small level of force, accounting for tiny parts of the variance, in part because each message has so many words, and in part because other factors than words are always also at play.

Symbolics is also like geology or meteorology in that there is usually no clear "starting" or "stopping" point. Because of time/space invariance, a physicist can presume that the effects of an experiment are the product only of what happens in the laboratory during the experiment. This isn't true for the geologist or the symbolist. The results of the experiment on linking symbols about race, genes, and health might have been influenced by a crime story about capturing an African-American rape suspect using DNA that played on the television that day. The use of an internal laboratory control would not adjust for that external variable if the race, genes, and health message only called up the racist sentiments because they were already activated.

This problem is exacerbated when one turns to the historical, large scale level. Like the aggregate natural sciences, scholars studying large-scale symbolic flows cannot run experiments to test results. It is impossible to set up the scale of forces and number of variables required. We can't and don't want to run the "slavery" experiment again.

In addition to these ways in which symbolic studies are like other studies of large aggregations, there are ways in which symbolic studies are analogous, but also somewhat different. Like biology, symbolic studies of causation have to be conducted on two levels. In this case the levels are the individual and the social. Studies of individuals manifest most of the difficulties already described. Individuals are not simple monods like alpha particles. Instead, they are themselves historical accretions. In spite of this, studying individuals is at least often feasible, and this is why psychology has been generally felt to be more "scientific" than the other social studies. However, the results of experiments on individuals do not tend to tell us anything definitive about large scale symbolic processes. In part this is because human individuals are even more variable than the individuals that make up biological populations. In greater measure, however, it is because the convergences that occur on the social level feature different interactions than the convergences that occur on the individual level. For example, in a set of experiments individuals may exhibit fear of snakes and retreat when faced with a snake, but when a social group gets together, processes such as status drives or the "risky shift" may become operative and the exact same individuals begin to outdo each other in demonstrating their dominance over the snake. This is a very simplified example of the differences between the convergences operative at the individual level and the convergences operative at the social level. These patterns, however, manifest themselves frequently in race relations, for example, when individuals with a specified level of racism and particular private and personal responses to persons they know of other races either act more or less racist in public venues where other factors are brought to bear.

The study of symbolic convergences is also similar to the study of other complex phenomena in that it is made more difficult by the existence of feedback circuits. Thus, for example, in the U.S. Southern states in the late nineteen forties, fifties and sixties white Southern politicians acted as feedback devices to enhance white Southern racism, at a time when other processes might have been acting to decrease it. In symbolic systems these feedback circuits can have multiple different forms and also multiple different causes that shift through time. The fluidity of symbolic circuits make them particularly difficult to identify.

Finally, the study of symbolic systems suffers from an exacerbated Heisenberg problem. In physics, the measurement process is limited by the nature of the relationships of the things being measured. This is usually translated as indicating that measurement changes the phenomenon itself. In symbolic beings this is true, and it is exacerbated by the capacity for self-reflexivity. Once many lay people know that researchers measure racism with survey instruments and that to appear racist is "socially undesirable" it becomes enormously difficult to measure peoples' attitudes about race.[239]

Symbolic studies thus face all of the problems that make describing “effect” in the earth sciences so difficult, and in some cases these problems are even more highly amplified. Symbolic studies adds to this the problem of novelty. There are no new geological kinds invented from day to day. Every day there are new symbolic kinds invented. The terms we use to designate race today and racial stereotypes are different from those of a hundred years ago. Different measurement tools have to be brought to bear and it is debated whether the “racism” of a hundred years ago should even be thought of as the same phenomenon as the “racism” of today.[240] Each event has the potential for subtly changing the effects of the symbolic net as a whole.

Taken together, these problems identify the character of cause-effect relationships in symbolic systems. There are always many salient causal inputs, most have small and overlapping influences, larger feedback circuits may influence which inputs get channeled into a particular flow, there is individual variation in response, and responses may change through time due to self-reflexivity (learning) and due to the introduction of novel kinds. We sum up this kind of cause-effect pattern by calling it “effectivity.” This label indicates that indeed, causal force is operating, but it also suggests the often small, always probabilistic, and interactive nature of each component’s influence on outcome. Symbols do have effectivity, even if effects are due not to an individual symbol but to the particular convergence of many symbols and their contexts. We know that the 113 word message about race, genes, and health from the study described above had an undesirable effect. But which words were crucial to this effect? Would linking race and health problems alone have the effect, or was the mention of genes crucial? Which of the other 113 words could be changed or deleted without changing the effect? Or rather, which words would change the effect in what ways? These kind of questions make it difficult to generalize from one instance to another. We know that symbols have effects, but describing their specific effectivity is theoretically difficult, and in many instances pragmatically impossible. At best, we can describe a range of probable effects in historically bounded circumstances.

For these reasons, people studying symbolic behavior have tended to eschew studies of effect. Humanists avoid making precise claims about causality.[241] Instead, they operate with the faith that they are describing some kind of important effects, even if those can't be precisely pinned down and documented. Social scientists make claims about effect but avoid making claims about specifically symbolic effects. The research community has, in other words, tended to operate with the assumption that symbol systems have effects without trying to pin down specific effectivities. It is an open question as to how far scholarship can get beyond such understandings.

In most cases of human action, the outcome achieved could not have been achieved without the symbols involved. If there hadn't been something like Winston Churchill's speeches, England probably would have capitulated to Hitler's overtures for a truce and perhaps eventually suffered the fate of France (some of the Lords were actively working to promote acceptance of the truce). This doesn't mean that Churchill's speeches were a fully independent cause, because, given the circumstances (existing feedback devices), something like Churchill's speeches were highly likely (though Churchill probably did it better than almost anyone else could have). It is, of course, difficult to identify with certainty which precise elements of Churchill's rhetoric made the difference, but his ability to demonize Hitler and undermine the Fuhrer's "reputation for veracity," to solidify the collective identity of Britons, and to imply through metaphor the eventual presence of the U.S. forces (without stating it explicitly) provide highly probable key components. How we think we know things of this character will be the subject of Chapter 9.

Summation: Symbols as Fantastic

To understand human symbol systems challenges us greatly. On the one hand, symbol systems are simply one more type of physical phenomena—just air waves and light waves interacting with human brains and other media. On the other hand, their particular constitution through physically arbitrary (though historically material) categorizations, their movement as convergent contextual flows, and their inherent tendencies toward binarity, valuation and narrativity, produce a phenomenon that is distinctly unlike physical or biological being that is non-symbolic. Symbolizing produces a phenomenon that is fantastic—full of perpetually novel kinds that exist in a realm of space/time that can bind vast distances and eras, and that manifests itself fundamentally as moral judgment and through a complex role in the cause-effect scenarios of the universe that might be called effectivity.

The symbolic realm is a "fantastic" realm not only because it is so distinctive and flamboyant, but also because it harbors "made up" beings. A unicorn has no existence outside of the realm of symbols. It is literally "made up" through symbolic processes. But it clearly has an existence due to that realm—most native speakers of English could pick out a picture of a unicorn from a book, with no hesitation. The ability to generate symbolically made beings that have no being outside the symbol system is a product of the time and space binding capabilities of symbolizing. It is also a product of their arbitrary physical character, which makes them relatively malleability. Their malleability enables people to move them around easily in infinite combinations to find which ones might work best for specific functions, might produce novel moral codes and solutions, and simply what is most aesthetically pleasing.

The symbolic realm is the realm of imagination, and that imaginative capacity is what enables humans to be so enormously inventive. The capacity for symbolic "making" is thus the source of our ability to travel to the moon, to produce antibiotics, and to have already provided many (if incomplete) cures for cancer. We are also, however, able to inhabit the symbolic realm in a unique way. Humans live rich fictional lives, now augmented through television, movies, novels, chat rooms, and video games. People in rich societies spend an enormous part of their lives in these activities. Though our survival instincts or academic elitism may lead us to disparage this realm of being, it is undeniably an important component of human behavior. To fail to take it seriously is to fail to understand one of the most characteristic qualities of humans.

Given the uniqueness of the phenomenon of symbol use, its complexity, and the fact that we must use our words to understand our words, it should not be surprising that, even after over two thousand years of study, our understandings of humans as a symbolizing species are fragmented, partial and contested. The wonder, indeed, is that we have managed to learn so much about human symbol users. In the next chapter we will attempt to integrate that knowledge with biological frameworks to produce a more accurate and more powerful understanding of human lives than either symbolic or biological doctrines alone have allowed.

Chapter 9: How Humanists Study Symbolic Being

Summary: The study of symbolic being focuses on texts, which are typically linguistic entities such as books, letters, speeches, novels and song but also include charts, paintings, sculptures, photographs, films, and dance. Methods to treat texts include memory, which involves the inevitably selective preservation and even canonization of some but not all texts. They also include descriptive explanation, in which specific cases are described and generalizations are made. They include interpretation, in which both the manifest and latent content of a text are brought to light. They further include evaluation of the relative quality of a text. Finally, they include innovation, or the creation of new modes of theoretical symbolization. These methods are important because among our symbolic strategies — our various communications, negotiations, legislations, inspirations, indoctrinations, educations, condemnations, and the like — they allow some to be forgotten, some to be censured or proscribed, and yet others to be validated for and incorporated into present and future cultural use.

Understanding human beings is a delightful challenge. Consider carefully the dimensions of the task. Start small, perhaps by exploring the tiny town of Arco, Idaho. Its economically depressed population of 1016 would give you plenty to explain. A sign over a basalt-walled gymnasium, once the seat of city government, boasts the town's status as the "first city in the world lighted by atomic power." A 60-ton submarine sail graces the entrance to the town. This "submarine in the desert" stands near the many finely executed mountain murals on the walls of the failing small businesses of the town. Look up 500 feet to "Number Hill" and you'll see the dozens of ten-foot tall white numbers daringly painted on the cliffs by successive graduating classes of the local high school. Until a week or two ago, you could also have seen an anti-gravity simulator sitting beside the runway at the local airport, but the locals had a fight and someone cut it up for scrap. You can stop for an excellent lunch at "Grandpa's BBQ", run by the only African American couple in town (she was elected to the city council). Or you can enjoy a juicy, king-sized "atomic burger" at Pickle's Place, where you could also buy an Elvis clock. Alternately you can grab a pizza at "booze and boards", the local lumberyard-videorenter-liquorstore-and-sometime-pizzaparlor. Afterwards, take a walk on the "greenway", 2 miles of asphalt pavement plunked down amongst the desert scrub. Of course, you would also need to account for a championship-quality girls' high school basketball team, the occasional excellent violin or piano concert performed by young people who will go on to prestigious musical academies, and the pride taken when a local youngster shoots their first deer, moose, or elk. All of this, moreover, doesn't even begin to mention the more quotidian facets of daily life in the small town.

This potpourri of behaviors can no doubt be partially described, and major features can even be "explained", in terms of general theories of one sort or another. But general theoretical explanations do not capture all of the qualities of the town. The local card-board cut-out archery "hunting" maze might indeed share basic causal mechanisms with the practice of Minnesotans who drive their snowmobiles into lakes in the summer to see whose will go farthest before sinking. But a generalization describing the behaviors as the product of domesticated male status competition does not capture the vibrant textures of the two different practices. It does not explain the *range* of human behaviors that may implement the same basic drive. Because of their unceasing capacity to produce novelty, to understand symbolizing animals requires both generalization and specification.

Symbolic being is like biological being in this respect. In both cases, one is fascinated as much by the lavish peculiarities of particular instantiations as by shared commonalities. In both cases, the particular instantiations are a product of complex convergences. In humans, however, the variations exist upon largely similar biological backgrounds. The human inhabitants of small town Minnesota at the dawn of the 21st century are not biologically much different from the Arconians of Idaho. To understand the particularities of humans thus requires understanding their symbolizing, and symbolizing itself features both general and particular facets.

Over the past several centuries, scholars in the humanities, and more recently in the social sciences, have developed a sophisticated set of methods for approaching the distinctive qualities of the generality and specificity of human symbolizing and its by-products. Natural scientists who have approached these studies have tended to view the diversity of methods as a deficiency. Wilson says of the social sciences, for example, that "they are snarled by disunity and a failure of vision."[242] It should be increasingly clear, however, that the existence of diverse methods is a product of the diversity of the subject matter rather than a failure of vision or unwillingness to act in unity. Wilson ignores most of the productions of the humanities—history, philosophy, rhetoric, comparative literature (as opposed to the production of literature per se), etc.—except in so far as they contribute to his version of religion and ethics. He glosses the humanities by creating a cardboard caricature of "postmodernism" and dismissing the humanities with it as mere Dionysian impulse, or "passionate abandonment."[243]

While there are, indeed, advocates of passionate abandonment in the humanities, Wilson's caricature over-represents that urge, and he fails to understand what symbolizing is, and what it can do. His theory is therefore incapable of understanding the structure of research about human productions. The first problem, of course, is that bio-humanists such as Wilson want only one type of explanation of human beings—generalization based on the theory of evolution. We've already shown that biology itself, in spite of having a unified theory, does not operate with just one type of explanation. Because symbolizing is even more transplex, it is hardly surprising to find that understanding it requires even more forms of explanation. This does not mean that we should eschew adding evolutionary explanations to the mix, or even that adding evolutionary explanations will not reconfigure the humanities and social sciences in important ways. It does mean, however, that evolutionary explanations cannot substitute for all of the other kinds of things that the humanities and social sciences accomplish.

In this chapter, we will summarize the most common methods employed by the humanities, indicating how they arise from the character of the symbolizing process being studied. In the next chapter we will examine how the scientific method has already been used to study human beings in the traditional social sciences. At that point we will be in position to consider the character of prediction and control that arise from the kinds of knowledge that can be gained from human studies, including those that are bio-symbolic in their focus.

Texts and Symbolic Study

Much of humanistic research involves the study of "texts." A text is a set of temporally and spatially related symbols that are in some way bounded (either by the producer's intention, the receiver's mode of reception, the textual structure, or intervening contextual factors). Texts using natural language include letters, books, speeches, novels and songs, but other symbol systems may be used in paintings, sculptures, photographs, or even dance. Some such texts have been believed to be influential, including John F. Kennedy's declaration that we would go to the moon, or Martin Luther King's proclamation that we should all share the dream of desegration, or Jesus's "Sermon on the Mount", Mohamed's *Koran*, or Charles Darwin's *Origin of Species*. To the extent that these texts have motivated human behavior and even influenced the course of human history, understanding them is as crucial to understanding humanity as is understanding the human endocrine system.

There are five major ways humanists explore symbolizing, in most cases by focusing on texts. These methods include memory, descriptive explanation, interpretation, evaluation, and innovation. Descriptive explanation and interpretation overlap with the natural sciences, but the other modes may be unique to symbolic studies. In considering each of these approaches, it is useful to think of the experiences of human beings as instantiating different possibilities for symbolization. The possibilities available are constrained, of course, by biological and physical factors distinctive to the particular time/space. They are further constrained by the history of previous symbolizations used by humans and by the distinctive constraints and enablements of symbolic structures per se. There is none-the-less a particular set of symbolic possibilities that have actually been developed out of all of the possible symbolic possibilities that could be developed. These materially developed experiences provide a set of options that are available for future use as well as providing bases for further creative inspiration for new symbolic possibilities. Humanistic study therefore has developed methods to retain a range of these symbolic options, to understand them, to evaluate them, and to create new options. We have learned a lot about our species using these methods.

Memory

Because symbolic systems are fundamentally time-binding systems, a substantial portion of humanistic research is devoted to the project of cultural memory.[244] Such memory-work is an enormous task. We have not recorded every flow of symbols that humans have produced, even all the socially important ones. Theoretically, we could videotape every moment of every life from this time forward, but of course, we cannot pragmatically do so. Even if this could be done, there would remain an enormous problem in retaining such vast records. All recording media are subject to degradation through time. Active renewal is expensive, too expensive to enable retention of all of the records that currently exist. Even if physical retention were possible, memory is not simply the existence of a physical record of a past. Remembering in biological creatures as well as in bio-symbolic creatures is a process of both selection and retrieval. A recording is not a memory if it is not accessible.

For all these reasons, even portions of the historical record of human symbolizing that are quite important are now being lost and will continue to be lost. Of what we have retained, much is effectively lost because we do not have people actively retrieving it. Huge library archives sit virtually untouched today. Existing societies do not choose to afford to pay the trained, skilled, people who would keep the memories of most of those experiences accessible. Consequently, the process of selecting those experiences that *will* be remembered is a crucial focal point of historical scholarship.[245]

The size of the corpus of human symbolizations is vast in part because in the study of humans we take not only the species as a whole or particular lineages as relevant to our memories, but also individuals. This may be because our theories are based on individual psychology or on specific convergences, or because our politics are based on the worth of each human individual, or because we believe pivotal individuals have made distinctive differences in the paths of human understanding (if no-one else, then Einstein), of artistic expression (Michelangelo, Monet, Matisse, Seurat, Van Gogh, etc.) and of human political organization (Pericles, Alexander, the Emperor Charles V, Lincoln, Hitler, Churchill, Lenin, Stalin, to provide what is admittedly an exclusively Western-centric list). Social lineages too are of interest because we recognize cultural differences as a productive source that expands our understanding of human symbolic options. Finally, the species level is of interest for the same reasons of generality or universality that are shared with biology; just as biologists wish to understand organic being as a whole, humanists seek to understand humans as a unique kind of being.[246]

A major challenge of making these diverse types of historical records useful arises because putting any of this history to constructive use requires that the individuals actually making decisions must have internalized at least the major outlines of the remembered experiences. A foreign policy analyst who doesn't know a deep range of relevant human history can't draw on that history, even if there is a historian somewhere who knows it. Thus, the process of selecting what is taught to the average person is even more draconian than the process of selecting what it is we keep as an active archive at the social level. Individual humans are not in the habit of taking on large quantities of the knowledge in the reservoir that we have amassed, and indeed their capacities for doing so are limited. We have not developed social systems for overcoming that limitation.

Due to the volume of knowledge, and the need to ensure something like a general circulation of it, a substantial part of the battles in the historical components of the humanistic disciplines today are therefore debates over what stories from past human experiences should be retained. Social-level analysts argue the merit of their case over individualists. Scholars of particular eras and regions (e.g. U.S. Southern civil war experts) debate the value of their records and stories over those of others (S.E. Asian studies). This is not unproductive sniping, but rather essential debate. Because no society can retain understanding of all that humans have done and been, each society must make judgments about what is crucial to retain, in the archive, in active social memory, and in the average individual. Any improved system for deploying the knowledge of the humanities would face the same problem.

Although the biological dictum might be something like "the victors write the histories," a better goal as semi-self-conscious symbol-users is to transcend that limitation. There is value in remembering the alternative approaches to situations and ways of living that humans have had as possible modes of experience, even if those approaches or modes of living lost out in particular times and places to modes of social organization that had greater military or even economic might. Such records continually enrich the contemporary arts, our sense of the breadth of potential human experiences, as well as our sense of commonality. Viewed more carefully, they provide guides to political judgment.

Humans cannot remember all of this in all its detail, and so debates occur about what is of adequate significance to retain, and individual scholars embody different parts of the record and keep those possibilities—those potentials and dimensions of human being—available. The vitriol of the debates and the clutter of the records makes the alternative of a few simple principles seem immensely attractive, but as the preceding and following should emphasize, such a yearning is an unsophisticated emotional desire for a simple world, one limited in its possibilities. Instead, the fundamental logic of the humanities must be to describe the *range* of symbolic actions that have to date occurred, rather than a mean or norm. The dominance of the *logic of ranges* arises in spite of the existence of some general principles operating within symbols (those elaborated in Chapters 3-5). Such general principles only create predispositions, and there are so many principles that are interacting in any one space/time to produce unique convergences that simply knowing the principles does not allow one to delineate the range of possibilities, which exceed human capacities for enumeration and all of which are not actually realizable. Consequently, a highly useful guide for both the actualizable possibilities and potential constraints on humans turns out to be the actual record of human experience.

Given this logic, one major goal of academic collective memory is and should be keeping active as wide a possible range of memories that are as different as possible. If a major utility of symbolic capacities is their ability to produce adaptive responses to changing environments, then having the widest possible range of human experiences at its disposal is clearly of value to a society. This emphasis on variation needs to be balanced with specialization in particular areas that may have special qualities (closeness to our own experience, particularly desirable qualities, or particularly undesirable qualities, for example), but retaining more dissimilar experiences provides a better catalogue to choose from than saving only very familiar cases, such as exclusive focus on a culture's own lineage.

Beyond such very general guidelines, arguments for what might be most worthy of our attention and retention enter into the other areas of humanistic inquiry, especially interpretation and evaluation. Before addressing these, however, it is essential to address the broader explanatory goals of the humanities.

Descriptive Explanation

The project of descriptive explanation in the humanities is the project that most closely matches the explanatory goals of biology and the other natural sciences. Description in the humanities, as in these other areas, comes in two forms: description of specific instances and generalizations across types. In both cases, a dominant mode of approach is through narrative because human symbolic systems are structured through narrative, although in symbolic studies the full form of narrative is usually employed, rather than the causal chronicle found in biology.

Describing Specific Cases

At one time, the description of specific cases dominated the humanities. Whether one focused on a specific war or political leader, a particular literary masterpiece or a philosophical work, a note-worthy speech or a great symphony, the humanities were defined by their focus on the exceptional, the truly excellent. Given limited resources for cultural memory, remembering the best seems like an appropriate means for enhancing future symbolic productions. The study of "the best" cases is still an important part of the humanities today, but the blending of social scientific and humanistic assumptions has expanded the study of singular instances to include a broader range of singularities, not only those that are most influential, but those that are representative of different classes, genders, cultures, ages, etc.

The study of single instances (texts, people, or events) is motivated by several factors. First, because such foci fit best in classical narrative formats, their logics come most readily to the mind of the researcher and are most entertaining to readers. Second, the study of individual instances is made necessary by the fact that every individual instance is the product of a unique convergence of symbolic and non-symbolic factors. Especially with regard to large-scale, highly transplex events such as international wars or space programs, explanations do not consist of the identification of a single guiding force (and hence the underlying principle that governs the force), but rather the teasing out of all of the major forces involved and an exploration of how they interact.[247] The best accounts of an event such as WWI do not assign singular causation, but rather note the interplay of specific configurations of economics, political histories, language/cultures, individual actions, etc. Likewise, the power of a Shakespearean play derives not from a single factor—the playwright's use of metaphor, his depiction of character, his choice of universal themes—but rather from the interplay of all of these. Consequently, if one wishes to understand the actual course of human history, one must include the study of specific convergences, especially the ones that seem to be most significant in their effects.

Finally, if one wishes to derive lessons from human history, to ascertain likely effects, the lessons learned must be about relationships or convergences, rather than solely about singular principles. Individuals who look at World War II and conclude "one should always participate in wars," are as ignorant and dangerous as individuals who look at the U.S. intervention in Vietnam in the 50s and 60s and conclude "one should never participate in wars." It is the specific convergences in each case that led to the signature outcomes of these two iconic events. One can only appropriately apply the lessons of history if one understands whether one's situation is more WWII-like or more Vietnam-like. At this point, however, the discussion has crossed over to the part of the scale where description of singular instances merges with generalizations.

Generalizations

Generalization, as a component of descriptive explanation, has always been one goal in the humanities. Aristotle, for example, tried to describe what made a literary work of tragedy into a tragedy, and he distinguished excellence in literary productions from lesser achievements by the standard of unity.[248] Two factors have shifted the balance in the humanities toward greater focus on generalization. The first is the influence of the scientific model. The second is the explosion of symbolic production and our access to these texts. Even as recently as 1910 it made some sense to focus on a single great speech, because the numbers of speeches that had been recorded and were accessible was manageable. In the mass mediated era, however, there are not only thousands of speeches recorded, but there are daily hundreds of mass mediated texts about a single subject. Consequently, one important, if relatively simple, form of generalization in the humanities has become basic description of the major properties of a set of texts. Thus, one may hear conference papers that describe the major contents of science fiction films about genetics, or that summarize the coverage of crime news on local television, or that enumerate major features of direct advertising for pharmaceuticals. Content themes form a major focus, but studies also summarize visual elements, ideographs, metaphors, as well as other features. As with taxonomic efforts in biology, such descriptive summaries are essential. The sheer volume of symbolic production on most topics is so large that some kind of reduction must be made in order to have even the most rudimentary comprehension of the symbolizing available on a topic. Each such description, however, rests on a variety of assumptions.

Efforts to produce explanatory generalizations in the humanities include four major approaches. First, using an analogue logic, one may build a landscape of guiding touchstones. In the other three approaches, a combination of inductive and deductive logics are used to build genres and "rules" as well as a set of highly abstract generalizations that look something like the non-mathematical generalizations of the natural sciences.

Touchstones

To the extent that individual instances are unique, or at least exemplary of only a limited class of possible convergences, this means that generalization about texts cannot consist merely of a set of rules that can be applied or understood as operative in all cases. Consequently, one major way that a level of generalization may be achieved is through the analogical method sometimes called the use of "touchstones."[249] The method is a qualitatively based version of the use of quantitative models in the natural sciences. It requires the assemblage of a large number of exemplary instances whose convergences are well understood. The act of generalization involves the selection of an appropriate touchstone to guide understanding of a new individual case. Elements from more than one touchstone may be combined to cover a "hybrid" case.

This kind of generalization is not deduction, but rather pattern recognition. The observer examines the available known patterns and selects the pattern that seems most like the specific instance. The observer then attempts to locate the key elements of the pattern in the new instances. In the case of using history to avoid repeating our mistakes, one might decide, for example, whether one thought a given instance was more "World War II like" or more "Vietnam-like." Having selected what one determined to be the closest historical analogue, one would then try to copy (or avoid) the relevant elements in the situation. Thus, President George Bush (senior), chose avoiding the quagmire of Vietnam as his touchstone for guiding engagement when Iraq invaded Kuwait, and limited his actions accordingly.[250] In contrast, the advisors of George W. Bush (junior) chose World War II (up through the fall of the Berlin wall) as their touchstone, and have tried to act more or less accordingly.[251]

The use of touchstones is a demanding form of reasoning and generalization.[252] It requires that the user know a huge number of exemplars in some depth. It remains the dominant method by which humanists teach. This is in part because it is the most empirically grounded method, in part because pursuit of the other methods requires basic competence in this method, and in part because engaging in texts of this complexity is both demanding and satisfying. However, greater levels of generalization have been developed through combinations of inductive and deductive logics.

Genres

A genre is a set of symbolizations that share characteristic goals, settings, stylistics, or contents. Examples of genres include funeral orations, sonnets, scientific papers, and probably tailgate-party talk. Some theorists have employed a very restrictive definition of genre, one that presumes a kind of essentialist dynamic that drives a unifying set of substance, situation, and style.[253] Such essentialist dynamics are rare, and so such a definition of genre is unhelpfully restrictive. Such approaches, however, highlight the deductive component of genre-building. That same deductive logic exists when the dynamics of a genre are understood as fuzzy, family-resemblance based sets.[254] These deductively based components are generally based on a conceptualization of recurring situations (what is an inaugural? what is a funeral oration?). However, the description of the genre is produced by coupling these deductively based conceptualizations with careful empirical observation of instances that might be expected to represent the genre. For example, one might expect that "speeches at death" will cohere as a specific genre because death is a major event that ruptures a set of relationships in a human network. One therefore looks for a range of examples of such speeches, examines their contents, and refines the description. From such means, a description of the genre of "funeral orations" has arisen that indicates they include praise of the person who has passed, claims that the dead live on in some fashion, and reassurance for those left behind.[255] In contrast, one might expect that inaugural addresses of U.S. Presidents also would form a relatively coherent genre, but inductive analysis has revealed a significant lack of repeated components among speeches given on the occasion of the inaugural.[256] Humanists have amassed a significant knowledge base about symbolic genres, though there remains substantial work to do in this arena.

If one knows what the typical components of a genre are, one has a useful kind of generalization. One can not only better understand why a speaker is selecting specific components, but one can better predict the likely components of an ensuing instance of the genre with a substantially higher degree of accuracy than if one does not know about the genre. One also has a general guide to constructing a member of that genre, and even an enhanced potential for constructing a more effective instance of the genre. Thus, for example, scholars who have examined many instances of political scandal have been able to identify the use of four key strategies in political "apologia" and to indicate the conditions under which each of these strategies seem to have been most effective.[257]

This is not to say that components of a genre are law-like. While it is almost impossible to imagine an apologia that does not employ at least one of the four strategies that have been identified by genre theorists, one can employ the strategy of "transcendence" in an apologia and either fail or succeed with it. Effectivity is always contingent upon the specifics of a convergence, and genre analysis cannot override that basic characteristic.[258] Thus, genres are both like and unlike biological motifs.

Both genres and motifs include sets of similarities that vary in degree across potential component parts. They are generalizations, but not generalizations that hold uniformly or homogeneously. The key difference between motifs and genres arises from the arbitrariness of the symbol-event relationship and the existence of the negative. Motifs are tied to function. If one has a given motif (a DNA binding domain), one will get DNA binding, and if one changes a motif past a critical point, the function changes, or more likely, disappears. In interesting contrast, function and structure are not inevitably linked in genres. A speech may clearly include all of the identified components of a genre and nonetheless fail. Alternatively, a speech might violate key elements of the genre, and succeed fabulously. Or, a speaker might hi-jack the purposes of the genre and the speech may succeed at a task other than the genre-specified functions, as, for example, when African American orators used praise of the founding ideal of "liberty" to give Fourth of July Addresses that utilized their own ironic position as an enslaved people to provide potent argument for anti-slavery.[259] This negation not only achieved its goal, but then inspired later speakers to use the negation of expected generic contents to achieve the ends of other genres.[260] Knowing about symbolic genres thus is a useful kind of knowledge, one that has some predictive power and constructive utility, but that utility comes from sensitivity to and familiarity with complex interrelationships and awareness of possibilities (pattern recognition), rather than from rote-like application of principles. This is, of course, similar in underlying principle to how scientists work, though the lack of quantitative form and formal hypotheses may mask the similarities.

Rules

Genre theory is probably just a particularly complex example of the broader category of generalization in the humanities that has traveled under various rubrics, but most generally as “rules.” The symbolically generated regularities of human symbolic behavior are probably best understood as more and less strategic reactions to a set of expected patterns for symbolic interactions. Some of these rules are “constitutive,” that is, without the rule the symbolic activity simply does not exist. Thus, a fundamental rule of conversation is that participants must take turns in speaking. If this rule is not in operation, one doesn’t have a conversation, one has a monologue. Other rules are normative. For example, in contemporary U.S. culture there are rules about how to end a conversation with someone with whom you have an ongoing relationship. Everyone, of course, knows how to end a conversation. Most of us do it many times a day. However, our knowledge is tacit, not explicit. When scholars carefully studied how people actually say good-bye, they learned some interesting things. The standard components of a parting sequence include signaling inaccessibility, summarizing, and reaffirmation of the relationship. The last feature is particularly interesting because it is not functionally necessary in order to end any given conversation. However, if one is involved in a “good-bye” sequence where both conversational partners fail to indicate openness to future communication, one is likely to feel uneasy, even if one does not realize why. This uneasiness indicates the extent to which conversations are embedded in a larger phenomenon—webs of human relationships. Ending a conversation is relationship-threatening, so ending a conversation requires an explicit signal that this ending of communication is temporary, not permanent. In fact, this generalization allows one to tell whether a conversation is between people with an on-going relationship or merely a business transaction where one does not expect to interact with the person on the phone again. The impersonal business transaction is far less likely to have the future-contact preserving sequence.

The example of "rules for good-bye" illustrates the nature and utility of making the underlying "rules" of human symbolic interaction into explicit knowledge. While everyone "knows" the rules for saying good-bye, when explicit study is brought to bear, one "knows" them in a different way. This explicit knowledge enables one to pin-point why a particular conversation went poorly and correct patterned defects (insert future-maintaining sequences to reassure partners). It also enables deeper explanations of the components of the behavior (the need for a future-maintaining component to a "good-bye" sequence arises from the threat to the relationship implied by ending the interaction), and to predict behavior (future-maintaining components will occur where a relationship exists, but not in impersonal transactions).

There are not only rules for how to say goodbye, there are rules for "repairing" a conversational breach, for who can talk to whom in an organization, rules for topics that can and cannot be broached in different circumstances, among dozens of other rules.[261] These rules have some commonalities across cultures, but because of time/space specificity and the potential for novelty, these rules are all also enacted in different ways in different societies, groups, families, etc. As with genre, then, these rules are motif-like, and functionally pliable. One can inadvertently break the rule, and indeed, people who strike us as "a bit odd" or "socially inept" are usually people who regularly fail to follow some of these rules. Alternatively, one can strategically break these rules to gain advantage. For example, someone with relatively low status might enact the conversational patterns of a higher status person (interrupting, longer talk turns, less eye contact) and therefore be perceived as having higher status (but also risk being perceived as socially inept if their performance does not succeed and they are perceived as acting inappropriately for their status). In spite of their strategic pliability, scholars have learned about these rules by close observation of the typical patterns of human symbolic interactions combined with deductively and analogically derived senses of function and purpose.

General relationships

The final class of generalizations in symbolic studies resembles theory in biology and the natural sciences, and it roughly corresponds to non-equation based versions of generalizations from foundational physics. Equivalents of "for every action there is an equal and opposite reaction" in humanistic studies include statements such as "narrative is a human universal," 'hierarchy encourages mystification," and various linguistic versions of the sociological maximum that "advantage accumulates advantage," such as "every identification is always already implicated in a network of relationships."[262] These are high order generalizations similar to biological generalizations about sexual selection. As such they require specific operationalizations to make them functional, but this is not really any different from the gap between theoretical statement and operationalization that exists in the natural sciences. There is a difference in methodological approach to the generalization, but this is a matter of degree rather than type.

To illustrate, consider Aristotle's claim that pathos (emotional appeals), ethos (reputation, credibility, character), and logos (reasoning and evidence) are the basic components of human persuasion.[263] This is a regularly taught, widely accepted, generalization in communication studies. The veracity of the generalization is not based on any critical test experiment, but rather on the interplay of deductive and inductive reasoning as it has been tested in argument and experience across 2000 years. The deductive components come from applying general understandings such as "humans are reasoning animals" to generate the conclusion that deductive evidence will persuade. Inductive observations come from close observations of what is actually contained in speeches. Veracity is further established by their applicability or utility in building pieces of persuasion.

The procedure of observation, application, argument, and continued observation is similar to the establishment of taxonomies in biology. Biological taxonomies have been built through careful observation of characteristics of different individual examples and classified into categories based on sets of similarities. While the new method of genetic analysis has challenged some of these previous categorizations, if there were not substantial agreement between the older observations and the genetic accounts this would represent a significant problem, not for the observations, but for the theory of evolution that claimed to link genes to the characteristics of related organisms. This does not mean that either evolutionary theory or symbolic theories lack the potential for falsifiability. It means instead that highly general theories formulated on a large base of empirical observation have a solidity to them that has substantial magnitude, akin to those of experimental methods.

It is therefore unlikely that Aristotle's formulation would be falsified by scientific experimentation, because it was based on observation and those original observations have been informally but intensively replicated. In fact, experiments about persuasion conducted in the late twentieth century have not falsified Aristotle's formulation. Like genetic revisions to earlier observation-based taxonomies, however, they have revised it or given it particular kinds of precision, including emphasizing that 1) it is much harder to get people to change their opinions and behaviors than Aristotle's formulation makes evident, and 2) that logic and evidence are a smaller factor in persuasion than Aristotle and the rest of us might have wished, though they are not absolutely ineffective.[264]

The resistance of Aristotle's formulation to experimental challenge also does not mean that his theory will forever form the core of our understandings of persuasion. Kenneth Burke's (1950) theory of "identification" has added a major alternative to Aristotle's concept of "ethos."[265] Stephen Toulmin's analysis of argumentation has added a significant alternative to Aristotle's bifurcation of reasoning into unrelated inductive and deductive forms. These developments haven't invalidated Aristotle's observations, but rather added major alternative lines of approach. An analogy from biology would be the addition of sexual selection to other theories of how natural selection processes occur.

As with rules and genres, the broad abstract generalizations of symbolic theories are not law-like. Aristotle's theoretical formulation does not tell us that *all* emotional appeals are persuasive, nor that one *must* make a logical appeal in order to be persuasive. Instead, Aristotle's formulation describes a set of resources that are available to be manipulated in order to produce persuasion. The logic of the range discussed above applies here. The specifics of the emotional appeal as they relate to a specific audience in a specific situation will always vary, and those specifics will influence where in the range a given symbolic production is located.

Abstract generalizations about symbolizing are motif-like, but even more variable than biological motifs, and they are strategically deployable. Consequently, in the humanities the descriptive aspects of a theory are often conflated with the prescriptive aspects. Aristotle's treatise on rhetoric admits that ethos is the most important of the persuasive modes, but Aristotle spends almost no space on it. Instead, he spends the bulk of his book dealing with reasoning. This is not a contradiction, because Aristotle believed that improving the reasoning abilities of humans was more key to their "humanness." Thus, more attention might be given to a component that was less important. Which is to say that the lines between theory and philosophy, morals and theory, tend to be unstable in human studies. However, as sociobiologists have found in facing substantial resistance to their work, the fact that one has an empirical method at hand does not erase that difficulty.

The way in which Aristotle's formulations of the primary persuasive factors in a speech were developed is exemplary of the issues regarding generalization in the humanities, although the challenges are amplified when theorizations address social practices rather than individual performances. Wilson has argued that what is true of the human individual is true of the human group.[266] One might wish that he was correct and that one would need only to study individuals to understand how a group of people will behave, because studying social formations experimentally is as impossible as studying geologic history experimentally.

Unfortunately for experimentalists, the example of mob behavior indicates vividly the falsity of this presumption, as does the example of an individual's behavior in the proximity of a snake as opposed to a group's behavior in the proximity of a snake. The few experiments that were done on social stigmatization processes before such experiments were ruled out as unethical also indicate clearly that people behave differently when driven by collective imperatives than when not so driven.[267] One cannot presume that because a human being exhibits a particular behavior when isolated in a laboratory that this behavior is indicative of how the society as a whole will act. The extent to which an individual behavior is indicative of social behavior is always an *empirical question*. It cannot be presumed *a priori*.

The only reason that some experimentalists are able to remain so obstinate in their insistence that individual behavior is tantamount to social behavior is because it is so difficult to test social behavior. The problems of convergence can be overwhelming on a social scale. You can't run an experiment to see if nation states with more centralized communication networks are more durable than nation states with decentralized communication networks. Knowing that individuals dislike responding to bureaucratic communication forms doesn't settle the issue because individuals also like identifying with powerful groups, and centralized communication networks enable greater coordination of more human and other resources.

Social scientists have long attempted to address such limitations on producing generalizations in the same ways that biologists studying ecosystems have addressed them. One generates a model and then looks for instances where post-prediction is possible. This is the best one can do on the experimental side. While some progress has been made in this fashion, the analogical and deductive methods of the traditional humanities remain prominent. Because of the complexity and political salience of such theories, there remains some substantial disagreement among different “camps.” However, such disagreements are frequently best understood not as opposing accounts but as accounts of different components of human behaviors. Economic theory, political theory, and sociological theory are different because each identifies an important component of the larger picture. Indeed, we believe that a more adequate explanatory structure of human beings is likely to be one that incorporates the distinctive contributions of biology, economic structures, political structures, and symbolic characteristics and circulation paths rather than one that identifies only a single factor.

In spite of the evident and sometimes vitriolic conflicts, there is a tremendous amount of agreement that has been generated in the humanities. Indeed, right wing conservatives bewail the uniformity of view that pervades the humanities (because that view endorses theoretical formulations that are not preferred by conservative politicians). There is even a great deal of agreement that has been developed using these methods that transcends all but the most extreme of partisan lines. Both right and left agree that economics are central to human political structures, for example. Both agree further with the sociological principle that “advantage accrues advantage,” though they disagree on the extent to which disadvantage inevitably accrues disadvantage. Both right and left also agree on the importance of symbols to human life (though the right tends to call these “family values” and the left “ideology”). Indeed, if one listens carefully enough to both natural scientists and humanists, one has grounds to wonder whether the level of agreement in the natural sciences is really any greater than that in the humanities. The appearance of a different level of agreement may be due exclusively to differences in discursive norms: natural scientists discourage overt disagreement in their printed publications while humanists do not.

Interpretation

Both natural scientists and humanists use the third method of knowledge generation—interpretation--though humanists may be more self-reflective about the importance of this practice to their knowledge production. As Chapter 2-4 indicated, symbols operate in contexts and in relationship to other symbols, so that a set of symbols does not have a single effectivity, nor a single cause. The process of interpreting texts is the process of exploring the different potential causes or effects of a circumscribed set of symbols. Such interpretive practices gained their hold in the Western academy through the practice of interpreting the Christian Bible. However, today interpretation or “criticism” has become thoroughly secularized and it dominates most humanities departments as well as much of the fine arts.

The Biblical versions of interpretation (or “hermeneutics”) assumed that the critic’s goal was to identify the single correct meaning of an opaque, sacred text. Secular versions of interpretation today do not generally presume that there is only one correct meaning of at text. Instead, interpreters presume that they are unveiling different possible implications of a text. In either case, however, the interpreter presumably has access to special keys for decoding a text that other readers of the text lack. This is to say that the practice of interpretation presumes that all of the possible meanings or effects of a text are not self-evident to all of the recipients of a text.

The meanings of a text might not be self-evident to a reader because a text has substantially changed its contexts. Late twentieth century “readings” of the speeches of Edmund Burke for example, tell us that, although Burke’s statement that an opponents’ effort is “like burning tapers at midday” seems creative and poetic to 21st century readers, it would have been common, even clichéd to Burke’s audience.[268] Likewise, scholarly interpretations of the Declaration of Independence are productive in part because they inform a late twentieth century reader of contextual factors that would have been evident to those who endorsed this founding document in the 18th century, but not to the average person in the 21st century.[269]

Changes in historical context are not the only reason that interpretations of texts created by scholars may provide additional knowledge. The 19th century giants—Darwin, Marx, and Freud—all demonstrated that human behavior was the product of hidden forces—biology, economics, or symbolically potent psychological developments. Although the insights of each of these giants have been modified, in some cases drastically truncated, their collective lesson is that receivers of texts do not naturally or routinely process messages in ways that make accessible all of their meanings or effects. A text can be said to have “latent” content, as well as “manifest” content. Manifest content is the component of the text that a recipient consciously processes. It can be thought of as what a recipient might describe a text as being “about” or what it “said.” Latent content is the component of the text that may affect the responses of recipients, but about which they are less aware. Literary scholars have long successfully shown us the way in which the latent aspects of texts—their tropes, recurrent sounds, or visual imagery, for example—influence our response to a good play, poem, or novel, even when we don't explicitly notice the pattern of tropes or sounds or images.[270] Likewise, in the past thirty years, ideological studies have emphasized the way in which texts such as situation comedies, country music, blockbuster movies, and others carry latent ideological lodes among their manifest narratives.

A good interpreter thus provides additional knowledge about the kinds of effects a text might produce. While a detailed description of the methods used in interpretation is beyond present purposes, the methods amount to purposive selection and description of textual elements and contexts and their combination through the modes of generalization described in the previous section. When a critic matches up textual elements and theories effectively, one may learn a great deal about one's self, about human beings, about symbolics, or about the text and its subject. Because symbolizing is so important to human beings and because symbolizing is polysemic, good interpreters are valuable contributors to our collective weal.

Evaluation

Criticism is usually a combination of interpretation and evaluation. As Chapter 3 indicated, symbolizing is inherently evaluative. Consequently, evaluation is integral to human knowledge practices. Because such evaluation is not a part of the overtly recognized knowledge producing practices of the traditional sciences,[271] this statement is an enormous challenge to a scientific understanding of "knowledge," which has pretended to a rigorous fact/value split throughout most of Western academic investigations.[272] If one is to understand human beings as symbolizers, however, the inherent valuational components of symbolizing cannot be swept under the carpet.

The status of evaluations as knowledge rests in the knowledge that experts have about specific sets of texts that allows them to produce more general, more robust, evaluations than non-experts. To illustrate, consider that your average 14-year old movie-goer can certainly make statements about their likes or dislikes with regard to a particular film. "Like, wow!" This is, indeed, an evaluation of a symbolic artefact. A knowledgeable film critic can provide, however, an evaluation that is simultaneously broader and more specific (or one or the other). The film critic has a broader basis for comparison than does the 14-year-old. The film critic will know the genre to which the film belongs and will know a wide variety of ways in which the genre has been mined in the past. The film critic will know the range of different types of interpretations that could be applied to the film and many of the likely conclusions of those different interpretive lenses. The film critic may also be familiar with audience reactions to this genre of film, as well as the range of other reactions possible from other genres or hybrids. Because the critic knows the range of prior executions of the genre of the film, the critic has a set of well-developed comparisons and criteria for evaluating the film.

To the extent that one is not a well schooled film critic, one's own response to the film may be more like that of the 14-year-old than the seasoned film critic. None-the-less, one should devote more interest to the analysis of the film critic rather than to the 14-year old. This is true whether one is judging solely based on ethos or on logos. With regard to a judgment from ethos, if you have to choose between the film recommended by your 14 year-old neighbor and the film recommended by the film critic down the block, you should choose the film recommended by the film critic, even if you don't get any reasons from either party for doing so. You might actually enjoy the film recommended by the 14-year-old more, but you will see a better film if you watch the one recommended by the film critic. "Better" dos not mean more enjoyable, but rather that your sense of the possibilities of human symbolizing, and hence of human being will be expanded by the film recommended by the expert critic and probably less so by the 14-year-old's recommendation.

The greater value of the film critic's contribution ultimately arises from their contribution to the logos—that is the reasons and criteria they will offer for seeing a particular movie. While a good 14-year-old's review might be someone instructive—a recitation of impressive special effects or plot twists—the film critic's evaluation should provide, at least a) explicit evaluative criteria, b) specific comparisons to exemplary alternatives, and c) a sense of the innovations (if any) contributed by the film being recommended. Such an analysis allows you to judge for yourself the potential merits of the film under discussion, even as it broadens your own understanding of human symbolic potentials.

The example of film criticism provides a clear example of how knowledge can be more than simply the recitation of facts and explanations, but rather can encompass evaluation as well. The expert film critic's evaluation of the film is simply a richer, deeper evaluation than that of the 14-year- old. It is a better evaluation, and it thereby constitutes *knowledge* about film. However, key to this assessment is the stipulation that one provide's explicit evaluative criteria. This meta-evaluation presumes that "immediate enjoyment of 14-year-olds" is not a good evaluative criterion and that "comparison to the corpus of human symbolic productions" is a good criterion. In practice, each critic (of film, painting, architecture, speeches, etc.) will not offer evaluations that are based on all possible aspects of all human symbolic productions, but rather on a narrower range of criteria. Some critics use an implicit norm of ideal gender roles as their litmus test, others use narrative coherence (or refusal thereof), others use integration of special effects and thematics or plot. The sticking point arises because the same film can be good on some of these criteria and bad on others. Evaluation then, is always evaluation with respect to a specific set of criteria. Evaluation as a form of knowledge is thus bounded by its criteria.

To the extent that people do not share criteria (and this is often the case), they will not share evaluations. To some extent people never share all of exactly the same criteria, and this means that to some extent, no evaluation is fully generalizable. This is the frustrating facet of the productions of the humanities, and the major reason that the humanities and the natural sciences look so different on the surface. The natural sciences have been able to minimize and standardize the criteria that they use. By de-contextualizing they have been able to reduce evaluation to standard templates that apply across situations. It is more difficult to do so in the humanities, but there is actually an enormous amount of evaluation shared among people; it is simply the case that such shared evaluations become taken-for-granted and unexpressed. For the most part, humanists put their efforts into arguing about those things about which they differ, rather than into cataloguing those things on which they agree.

There is no way to fiat the element of evaluation in the humanities. One can try to hold it to background levels for particular purposes, one can keep a clearer eye on the large ground of evaluations that are shared, but evaluation is intrinsic to symbol use. Humans not only can have knowledge with evaluational components, we need to do so. While that knowledge will be more explicitly contingent—on expressed criteria--than knowledge of other sorts, to make human progress requires taking seriously knowledge of this character.

Innovation

The last major activity of the humanities is the generation of innovation. Chapters 7 and 8 indicated the ways in which the arbitrariness and time-binding qualities of symbol systems enabled tremendous novelty of kinds, and this creative capacity is necessary for the enormous range of theories, products, and institutions humans have developed. Just as engineering new materials and medicines constitute major activities of the physical and biological sciences, knowledge practices that are focused on generating innovation are likewise desirable for the humanities. If the virtue of symbols is the supple way in which they allow us to imagine and therefore create new possibilities, then innovation generation is a central task of anyone who works with symbols. The importance of innovation is widely accepted in the fine arts. Even people who don't like contemporary art may recognize the principle of innovation that stands behind it, and U.S. culture is heavily influenced by a "what's new" mentality. At least since the Protestant reformation, Western theory has featured a constantly-renamed "vanguard" that promoted itself as novel and in opposition to established ways of thinking and doing, and this fervent dedication to novelty has produced new styles of art as well as new modes of artistry, as well as contributing to more pragmatic developments in political theory and policy.

The key difference between engineering new building materials and engineering new possible means for humans to organize their social relations is that people don't recognize the former as threatening their current social positions and self identities, whereas they do recognize the threat from the latter. Of course, both bio-physical technologies and alternative visions of government change human social relations. Human societies after the electronics revolution are organized in a drastically different fashion from the way human societies were organized before the electronics revolution. However, because those changes were not the goal and focus of the new electronics-based technologies, large numbers of people aren't troubled by them. They see what the new technology enables, not what it displaces. Only a few activists focus on the latter.

When humanists and social sciences envision novel approaches to human relations, however, almost everyone can see the threat to their current social position or identity. By definition, such visions threaten the basic beliefs with which each person has become enculturated. Innovations emanating from the humanities and social sciences are, therefore, generally more controversial than those from the physical sciences. Moreover, like every new idea generated in physical engineering, an idea about novel modes of organizing human relations is just an idea. Most ideas don't work out (because we have insufficient capacity in our conceptual models to capture all of the variations and linkages among all of the variables in a complex system).

Some ideas in both physical engineering and human engineering do work out, however. Replacing monarchy with representative government is generally understood to have been a good move. Eliminating slavery has generally been understood to be a good move. Equal voting rights for all persons and opening up most schools and categories of labor to both men and women is viewed by most people as an effective social change. Such successes highlight the extent to which the argument that "humans have always done X" or "Human societies across the globe always do Y" is not a sound argument against the possibility of humans doing something new. Just as the fact that a newly conceived chemical has never existed in nature does not mean that it cannot be made to exist, so too the fact that human beings do not presently organize their relationships in a given fashion does not mean that they cannot be induced to do so.

Some humanists and social scientists spend their time imagining alternative social relationships and exploring their implications, as well as the barriers to them. Humanity does not have very good tools for assessing the likely effectiveness and impacts of such social alternatives. Currently, the task is undertaken primarily through criticism of current arrangements and the construction of narratives to model alternatives. It is striking that there are virtually no efforts to model alternative human social arrangements outside of such verbal narratives (the few examples are narrow economic models). While the challenges to such alternative approaches to modeling are daunting, the approach would at least seem worth exploring.

Most of the social innovations generated in the humanities, like most of the innovations envisioned in bio-physical realms, will not pan out. Opposition to specific proposed innovations should not, however, obscure the potential value of such innovation-generating activities. Recent developments, however, have made such innovation generating activities a point of major conflict between some scientists and humanists, and understanding the reasons for this conflict may be productive.

Recent developments in the humanities have generated a type of theory that is rigorously anti-empirical, and therefore lends itself easily to an anti-science interpretation. While an interest in "new theories" has long been part of the academic economy of the humanities, a new level of novelty generation arrived with a group of scholars usually lumped into the broader trend of "post-structuralism"[273] Before the works of such scholars (sometimes labeled "anti-humanists"), innovation in scholarship was largely presumed to be based on some newly discovered or re-valued goal, such as class justice, gender equity, or cultural pluralism. Innovation was considered good because it served these values, whereas older humanistic scholarship was presumed not to have served such values. With the rise of thepost-structuralists, however, novelty in theoretical research is presumed to be valuable for its own sake, not because it serves some external, predetermined cause. Deleuze and Guattari's theoretical "experiments" sometimes read like word hash, as they explore what might be the implications of selecting different core metaphors (e.g. "rhizomes" or "bodies without organs") as our vehicles for understanding social processes. Jean Baudrillard's work can appear to be little more than an assemblage of bold statements aimed at merely being controversial. And scholars such as Arthur and Mary Louise Kroker meld artistic flourish with dense webs of theory in ways that are likely to put off all but the most adventuresome pendants.

The work of such theoretical innovationists is, perhaps inevitably, widely misunderstood. Natural scientists are not the only ones to interpret this line of academic work as a horribly failed (if not psychotically misguided!) effort to provide classical versions of explanatory generalizations. Instead of understanding post-structuralism as a bad effort to play the traditional game of theory building, however, one should understand it as a new theoretical "game." Innovationist theoretical efforts are best compared to early moves in alternative mathematics (such as non-Euclidean geometry). The goal is to see what can be done if one takes a new set of axioms (or, in the humanities, new key metaphors and principles) and employs them rigorously. The new axioms, metaphors or principles do not have to be accurate and complete descriptions of reality as we already know it in order to be fruitful and instructive.

The value of innovationist theories is best illustrated by Derrida's famous claim, usually translated as "there is nothing outside the text."[274] This statement is often interpreted to mean that there is nothing other than texts, and such a claim would be profoundly wrong because it is profoundly incomplete. The utility or fruitfulness of Derrida's statement—his willingness to play the innovationist "game"--however, shows up in the many things that were not generally realized about texts previous to its rigorous application. If post-structuralists hadn't ever asked the question "how far can one take the claim that texts shape everything" most theorists would have continued to assume that symbols were just Wilson's "ethereal agents" rather than materially real phenomena leaving "traces" and "tracks" (effectivities) on the world.[275] Thus, though Derrida's innovationist "theory" may be technically wrong (because it is so limited and partial), it helped to generate a material theory of symbols that is more accurate than previous conceptualizations of language. Similarly, the works of Deleuze and Guattari have indeed, pushed intellectual boundaries in some productive and interesting ways. Their experimentation has, for example, promoted a reconceptualization of social processes as "rhizomatic" in their nature, thereby helping to displace the old and problematic social metaphor of fundamental taproots and less important foliage.

Innovationists are thus like catalyzers that get reactions past energy barriers, even when their formulas aren't components of the final reaction products themselves. This interpretation of the function of innovationist theory also helps to explain why innovationism can be so absolutist—for example, why some people do blithely insist that "there is no outside of text" implies that "nothing but text matters." Or why ideological scholars may assume that "there is ideology in everything" means that science is *reducible* to ideology. Such absolutist statements are necessary to keep open the field of investigation. If one accepts what has proven to be the case as definitive, one has no room to consider alternative possibilities. The massive success of the scientific enterprise, and the rigorous logic of its approach to producing truths means that a "scientific" account may too easily be taken as a pre-determined winner to any other form of challenge. Innovationists set aside scientific presumption in order to move from the realm of "is" to the realm of what might be.

Instead of accepting "the world is an oblate spheroid" as an unproblematic truth, for example, such an approach issues invitations to explore what it means to think of the world in the established fashion and what kinds of factors are favored by such knowledges, and what it would mean to think of the world otherwise (as "flat" socially, as non-world, as fragmented surfaces, as shifting geological contours, or as multiple worlds). An absolutist insistence on focusing on texts or ideologies frees the innovationist from working through the details of the proofs that the world is indeed, an oblate spheroid. Such an exercise in the analysis of the data and the proofs would not be productive. The scientific evidence in such cases is overwhelming; moreover, it is not really to the point. The question is "what else might we think" and, where a given piece of knowledge is well grounded, *it is only by calling into question what is believed on other than empirical or knowledge-based grounds that one can ask "what else" rather than "what is"*?

Innovationism is not for the lover of order. The Dionysian impulses that Wilson disparagingly attributes to the humanities tend to be at their reddest hot in this quadrant. It takes time, moreover, to sort out the productive elements of such innovations from the heap of rubbish in which they are inevitably embedded. It is also not clear the extent to which innovationism is sustainable. Post-structuralism itself already threatens to become a conservative cemetery where disciples worship at the temples of dead academic heroes and protect their sacred texts with ardor.[276] There may be a limit to the productive rearrangements that can be generated in this fashion. That, however, remains to be seen.

Conclusion

The persistent reader will notice that novelty generation also might be likely to stand in tension with the function of collective memory. The historical group must at least partially embrace a conservative impulse that valorizes knowing about the past; the innovationists must be dominated by an impulse that prefers the novel. There is indeed sometimes considerable tension in the humanities between those who take as their goal the conservation of older experiences and those who work to create novel possibilities. There is also a tension between those who seek generalized explanations in either the natural or human sciences and those whose primary goal is innovation generation. These are very different activities, all conducted in an overlapping set of symbols. Too often, practitioners of one mode of knowledge generation are prone to interpret all other modes as failed examples of their own precepts. As we hope we have suggested, however, because of the multi-faceted nature of symbolizing, it is important to understand, respect, and maintain a variety of humanistic practices that achieve different functions: social memory, explanation, interpretation, evaluation, and innovation. Each of these practices contributes a crucial kind of knowledge that cannot be provided through other methods.

Each of the practices of the humanities also has analogues in the bio-physical sciences. Scientists select and preserve some of the knowledge of their past (an effort gaining substantially more time and attention as the various genome projects overwhelm the scientific community with data). Scientists explain and interpret particular phenomena like the dynamics of our solar system or the formation of the Rocky Mountains, and they build generalized explanations from observations of models, if not from singular touchstones. Scientists generate innovations, and value doing so in their own field, even when they (like other civilians) do not appreciate the innovations of the humanities and social sciences. Only with regard to evaluation and experimentation are there truly large distances between the sciences and the humanities. Scientists rarely evaluate the goodness of their creations and humanists rarely do experiments. But humanists have out-sourced experimentation to the social sciences, and as the technologies generated by science have become more complex and more powerful, scientists such as Rich Meagher have begun to incorporate evaluative criteria into their work, as described in Chapter 5. Although it is common in the academy to emphasize the differences between the humanities and the sciences, and although there are differences of objects of study and a concomitant difference in the balance of tools employed in each area, viewed from outside of Western civilization's internal divisions, there is more in common in the knowledge production enterprises of these areas than not.

One hears widely a call to bring the sciences to bear to ameliorate the problems faced by humanity. As human beings face the problems of the globalized era, more pervasive application of humanistic practice s may be even more vital to the generation of widely shared good qualities of life. This is not to hand over the formations of societies to experts. "Experts" in the humanities and social sciences can only generate possibilities and educate people about their existence and potentials. Actual social decision-making should be democratic, ensuring input from all perspectives, because persons from all perspectives may bring information, values, and interests not accessible or relevant to others. Nonetheless democracy should not be modeled as the enshrinement of the least common denominator (or in the current era, the largest market). If U.S. society continues to allow its aesthetic and political tastes to be guided by 14-year-olds, we will have eroded the possibility for civilized behavior.

Civilization is not a natural condition for human beings; it is a learned and worked-for achievement. Human beings may be born with the capacity to symbolize, but they are not born with a richly elaborated symbolic code structure—such are developed through time. To improve the current level of civilization will require knowledge of the predispositions of humans, and the general rules that guide our behaviors, but also of humanity's highest achievements, so that we know the possibilities of which we might be capable. To be civilized also requires the ability for sustained, rigorous evaluation, rather than satisfaction with immediate expressions of pleasure and pain.

To insist on the higher standards of symbolization is not anti-democratic, nor is it to discount "the masses." America's many nouveau rich have vividly demonstrated at the turn of the twenty-first century that wealth is not tied to knowledge, broad judgment, or rigorous evaluation. As a group they focus their attention on football and hockey, boxing and NASCAR, not on symphonies, histories, or political engagement, being no different in this regard from the workers they exploit. On the obverse side, the existence of public libraries and a true wealth of materials on the web make access to knowledge about a broad range of human symbolic experience, depth of interpretation, and even participation in rigorous evaluation accessible to the common person, even if not to the most oppressed members of the society. In America, access to the humanities is fairly generally available; it is the taste for and appreciation of humanistic disciplines that is generally lacking, at all socioeconomic levels.

This disinterest in, even disparagement of, the disciplines of humanism has arisen because U.S. society is dominated by the consumer marketplace, which panders so well to our immediate pleasures. This is a relatively new phenomenon, and there is at least some possibility for learning to re-balance the society, once the dynamics involved are better understood. We hope that this chapter has contributed to a more integrative understanding of what it is that the humanities contribute and how and why they do so. In the next chapter we will add to this repertoire the substantial efforts that have already been deployed to describe symbol use through explicitly "social" scientific approaches.

Chapter 10: The Social Scientific Study of Human Being

Summary: The social sciences seek to address many of the same issues of human interaction that the humanities address, but they employ a much heavier dose of experimental and quantitative methods, making them more akin to the natural sciences in that regard. Despite the rigor of these methods, many authors outside the social sciences have derided the latter for a lack of progress and for producing only banal results. If such critics were correct, their claims would indicate that E. O. Wilson's "consilience" would fail because experimental methods are of little use in explaining human behavior. However, across the century of its development, the social sciences have actually produced increasingly precise and predictive models of human behavior, and banality turns out to be largely in the eye of the beholder. Wilson's other alternative, linking up biology with humanities is more promising, but this is unlikely to overturn the existing knowledge generated by the social sciences, though it may add to and rearrange it to some extent. An example of the perils of such endeavors is provided through an exploration of "cheater detection modules" in human brains.

The humanities and social sciences taken together have produced substantial real knowledge about human behavior. This knowledge allows enhanced prediction and life satisfaction, although predictions are probabilistic and any given theory accounts for only a small portion of the variance because of the multiple inputs into human behaviors. The control enabled by such predictive

theories is used by advertisers and political campaigns, but it is largely off-limits to governments, at our current state of development.

Imagine that one did not believe that symbols made a distinctive difference in the character of human beings. Imagine that one believed that the method of physics was a powerful all-purpose tool that could be applied to human beings in just about the same way that it had been applied to light and heat and sound. In that case, one would be in the position of the social scientist at the close of the 19th century. Having seen the wonders of physics unfold, one might well conclude that the study of human beings using the hypothetico-deductive method with the goal of producing universal laws of human behavior would be a rewarding endeavor.

For well over a hundred years, social scientists have pursued this endeavor. Hypotheses have been formulated, controlled experiments have been conducted, and all of the most rigorous apparatus of the narrow classical physics-based version of "science" has been energetically pursued. Nonetheless, the pervasive view among physical and biological scientists seems to be that this research agenda has failed. Certainly the society at large has not chosen to fund, teach, and support the social sciences in the way they have funded and supported the natural sciences. E.O. Wilson is, to say the least, dismissive of the traditional social sciences, and his opinion is shared not only by other scientists, but also by prestigious philosophers of science.[277]

If the social sciences really have not succeeded, this creates a paradox for Wilson's argument. If they have failed when using the apparatus of "science," how could a program of consilience do anything more? If what is needed for consilience to be achieved is the reductionistic application of the hypothetico-deductive method to the study of humans, why have not the social scientists long ago ended up on the door-step of biology? To deal with this paradox we will first briefly describe the methods and objects of the social sciences. Then, we will demonstrate that the attacks upon the social sciences are mistaken, that social scientific studies have made reasonable progress and that their products are not accurately characterized as banal or un-useful. We will then suggest that Wilson's complaint comes down to the resistance of traditional social scientists to grounding their work in evolutionary theory. We will indicate why evolutionary theory would not rescue social scientific research from its public relations problems, and use the example of the "cheater detection" experiments of evolutionary psychologists to illustrate the problems of their approach. We will close by unifying our examination of the traditional humanistic and social scientific approaches by means of an examination of the issues of prediction and control in human studies.

The Objects and Methods of the Social Sciences

Major Objects of Social Scientific Study

Human beings are, of course, the objects of social scientific study. Because the theory advanced in this book holds that symbolizing is one of the most important material characteristics of human beings, it is striking that social scientists do not generally study human symbol use per se. In large part, this is because social scientists suffer the same misconception about language held by the natural scientists—that it is just a "conveyer belt" of hidden forces. In some part, it is also because the study of symbolics has until recently been forbiddingly complex. Instead of studying either biology or symbols, social scientists tend to study “constructs” that are unrecognized amalgams of biology and symbols. For example, when researchers study “communication apprehension,” they may use a combination of bio-monitoring and pen-and-pencil survey instruments to assess how much negative affect people experience when asked to give public speeches. The bio-monitoring measures levels of arousal and the survey instruments ask participants to assess how much they dislike, suffer from, fear, or avoid such situations by indicating their level of agreement with statements (e.g. “I avoid situations where I will have to give a speech”) by circling points on scales (e.g. 1=”strongly agree” through 7=”strongly disagree”). Bio-monitoring such as galvanic skin response is used as an effort to side-step the “subjective” statements of individuals, but it does not provide a direct measure of “communication apprehension.” The apprehension measured may be linked to having measuring devices attached to one’s body as much as to communication apprehension, individual differences in general excitability may be what is measured, rather than a specific fear, and arousal may be experienced as positive excitement about a speaking opportunity as well as negative anticipation or dread. This is to say that there is no biological state that is precisely “communication apprehension” absent the symbolic components embedded in the person as well.

Many, if not all, constructs generated by social scientists likewise feature this dual-aspect. Cognitive dissonance has both a symbolic content dimension and also a biological processing dimension. “Racism” clearly has complex symbolic dimensions (witness the multiplicity of scales and dimensions produced to study it), but also has been recently shown to have surprisingly strong biological responses (which is not to say that it is biologically programmed, but only that people can be shown to respond with strong differences in arousal to persons who are members of more oppressed racialized groupings as opposed to more dominant ones). For the most part, the study of such amalgamated constructs has served the social sciences well. While, arguably, there is more to be learned by separating and more self-consciously re-synthesizing biological and symbolic components, the use of amalgamated constructs has worked sufficiently well because in actual human behavior and interactions the biology and symbolics function together. It is impossible to do justice to the vast and complex repertoire of knowledge that social scientists have produced in this fashion, but it is worth attending to some of the broad themes. Our overview will give more attention to study of individual behavior than to social behavior, but this is not to suggest that individual studies are stronger or more important than social ones.

The kinds of individual behaviors that are studied by social scientists include the kinds of things one readily thinks of as "behavior": movements of the body, sexual exchanges, and even which lever on a voting machine one pushes. However, cognitive processes ranging from trends in visual perception to language production and reception to self esteem to persuasibility are also treated as individual behaviors. Individual attitudes and beliefs are also treated as behaviors in some lines of research, and these come close to being symbolically based studies.

Research at the social level tends to separate out one dimension of social forces and to try to analyze how the processes active in that dimension shape the behaviors of humans as well as the social structures they create. Economics explores the social forces of money and markets and exchanges of goods and labor. Political science explores governing institutions. Anthropology has explored cultural forces. Some participants in these disciplines have also joined more integrative disciplines such as sociology, communication studies, and geography to study the ways in which economic, political, and cultural forces interact. Because the narrow Popperian vision of "science" remains wide-spread, these integrative disciplines are widely viewed as less "scientific" or "rigorous" (and hence are less prestigious) than the more tunnel-visioned disciplines. This, of course, runs counter to the Wilsonian argument that favors integration.

Whether studying individual behaviors or social structures and process, social scientists generally work at up to five levels of analysis. The first level consists of the identification of the patterns that constitute a behavior or social structure, whether performed by an individual or consisting of the behaviors of many individuals or the artifacts produced from human interactions (e.g. patterns of streets and buildings or contracts or constitutions). Second, separately or simultaneously, distributions of behaviors or artifacts are identified (e.g. how many people avoid public speaking or how money is distributed). Third, social scientists explore associations between different components or levels of components in a behavioral repertoire and other forces, or at the social level, they explore the social structure and its many forces (e.g. is avoidance of public speaking more frequent among people who are wealthy or poor? or is money distributed through familial networks or by other merit-identified actions?). When possible they trace further trace out associations to identify causes. Sometimes they will seek ameliorative actions, such as prescribing ways to overcome fear of public speaking.

Major methods of social scientific study

Methods in the social sciences most commonly involve experiments involving individuals, observations of groups, and surveys sampling large populations. In the first of these, single subjects respond to a controlled stimulus or situation. In the second, large scale processes such as economic flows or political choices are examined through artifacts that trace the relevant components, such as tax records or vote counts. In the third, random samples of individuals form various societal divisions are queried.

Whatever the method of gathering the data, quantitative analyses are performed, using detailed statistical techniques, including especially correlation-based studies. Statistical analyses are used to identify patterns as well as to identify associations--what components appear most frequently with which other components. One of the increasingly common techniques in recent years consists of various modes of path analysis. This form of analysis seeks to chart not only a broad range of inputs into an outcome, but also to account for the order in which these inputs might be added (see Figure 10.1). Such models differ from the mathematical models of idealized physics both because of their focus on multiple inputs and outputs (MICME) and because of the attention to arrangement (through time). The knowledge provided is therefore not simply "yes, this factor causes that factor," or "no, this factor does not cause that factor." Instead, it is of the form "factor *a* affects factor *b* to this relative degree and this combined with factor *c* affects factor *d* at this relative level." The best path models incorporate interaction effects common in the kind of variables involved in human behavioral drivers.

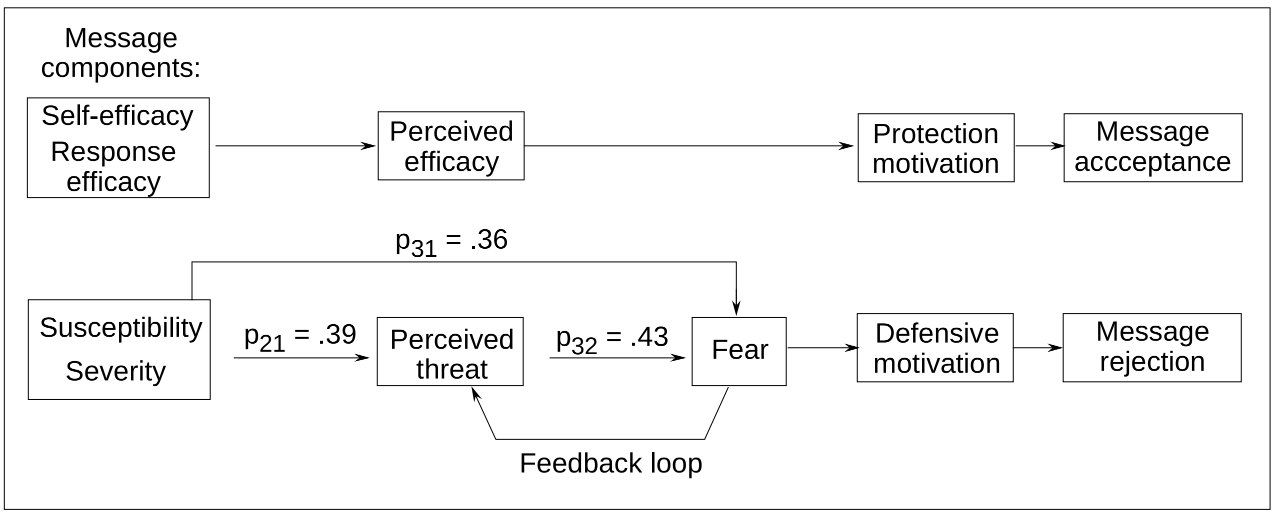

Figure 10-1: A path diagram of the extended parallel processing model showing results of a partial empirical test. After Witte (1994).

Depending on the questions involved, a variety of other statistical approaches may be utilized. Scales for measuring phenomena are developed using factor analysis techniques. Cluster analyses can be used to assess which kinds of behaviors tend to come in sets. As in much of biology, chi-squared or t-tests are used to identify deviations from neutral conditions or to identify different "populations" (as in different effects of different experimental exposures).

In experimental studies, carefully designed controls can also allow the same kind of ruling-out of hypotheses that is conducted in the natural sciences. These controls include a host of elements such as double-blind techniques, random assignment, inter-coder reliability assessment and manipulation checks that are not as common in the natural sciences. Such techniques adapt to the unique exigencies of objects-of-study that are aware of what the researcher is doing as well as the self-interests of the researchers. They also seek to adapt to the unique role that symbols are taken to play as mediators of various underlying "causes" and behavioral effects.

In an enormous variety of social scientific studies, including most obviously survey research, behaviors are measured and underlying "constructs" are accessed through participants' symbolic responses to symbolic stimuli. Although social scientists rarely assume that the symbols are the "real" cause of a behavior, or that the "symbol" itself is the behavior, in many cases the symbols are the only thing to which the researcher has access. Factor analyses are often used to assess whether a set of symbols (answers to questions on a survey) cohere into a "construct" (such as personality variables), but it is usually merely assumed that the construct has some material being other than merely being constituted by an intersection or association of symbols.

Likewise, it is assumed that the symbols produced on a survey have some relationship to some other sets of behaviors. The latter has been repeatedly shown to be a faulty assumption (people say on surveys that they recycle all their cans, but a check of their garbage shows they don't!). Social scientists have therefore struggled with the latter assumption. In some cases the assumption is used because surveying peoples' statements is easier than surveying their other behaviors (i.e. their garbage). Many behaviors are simply not directly observable (what tactics do men use to frustrate women's efforts to get them to use condoms?). Even behaviors that are directly observable are known to be modified by the presence of an observer. In other cases it is the "attitudes" of the participants that are of interest, and symbols appear to be the primary window to attitudes (or beliefs or values).

Social scientists have studied a wide variety of individual and social level phenomena. They have employed methods that utilize the experimental, observational, and statistical apparatus of the other sciences, though they have adapted these by developing even more rigorous constraints to account for the unique characteristics of humans as objects-of-study. The methods and approaches are not perfect, for humans are difficult to study. This limitation, however, does not arise from faulty theoretical models (i.e. lack of attention to evolutionary dynamics), but from the nature of an object of study that can talk back. With that background in mind, it is time to deal with the complaints against the achievements of the social scientists in some modest detail.

The Achievements of Traditional Social Sciences

Three major complaints dog the social sciences. First, is the concern that the social sciences aren't sufficiently "unified." By this point in the text it should be obvious that diversity in human studies is an inevitable product of the breadth and variety of human productions. This is therefore not a failure of vision, but exactly the opposite. Diversity of available frameworks is a product of a vision broad and deep enough to recognize that no single dimension accounts for human beings.[278] The social sciences should continue to rigorously address singular dimensions of human behavior in some disciplines, while rigorously integrating multiple dimensions in others. The other two major complaints are that the social sciences have not made any "progress" and that they are "banal."[279] These complaints seem to us to be made in ignorance or prejudice.

Progress in Social Science

The social sciences have made enormous progress across the past century. By this we mean that they have amassed an increasingly specific body of accounts of human behavior that have increasing predictive power and explanatory value. These accounts are as good at predicting human behavior as are the theories of the physical sciences for predicting similarly complex phenomena. Voting behavior and consumption patterns are at least as well understood and, on average, more predictable than weather, volcanic eruptions, or asteroid strikes. Moreover, there has been substantial progress in successfulness of prediction due to the existing social scientific work. Human behaviors are far better understood and far more predictable than they were a hundred years ago. Additionally, in areas where different disciplinary traditions approach the same issue, there has been substantial convergence in theoretical frameworks. Theories of health communication provide a simple example.

Health communication studies are one of the very few areas where social scientific study has had any substantial funding. Studies of the impact of messages designed to change health behavior have been undertaken with resources sufficient to generate at least some sustained effort and a modicum of rigor, and they have been undertaken from different disciplinary traditions (and hence vocabularies), including psychology, sociology, communication studies and health education. In spite of disciplinary barriers, the theoretical descriptions of what is necessary to improve the chances that a health message will persuade its recipients to act in accord with its prescriptions have converged on shared components and frameworks across these disciplines. A brief and highly selective history of one line of investigation will give a flavor of the progress.

In the nineteen-sixties, health communicators began to try to convince people to adopt healthier behaviors, such as to drive carefully or avoid cigarette smoking. A prominent line of research focused on the generation of appeals based on fear, because the common sense of health promoters suggested that showing the vivid and horrific effects of unhealthy behaviors would motivate people to abandon those behaviors. Not only did researchers discover that such messages had relatively low efficiency for generating behavior change, but it also appeared that there was an inverted "u-shaped" curve to their efficiency.[280] In other words, relatively low intensity messages *and* relatively high intensity messages were less effective than moderate intensity fear appeals. With high levels of fear, people seemed to "turn off" to the message.

This strand of research experienced the usual difficulties of social scientific study. How does one compare the level of "fear" generated across different messages and different subject matters? How does one measure effects that occur outside the laboratory and over long term using only one-shot laboratory methods? How can one sample a representative group of participants instead of just college students? Gradually, however, through many experiments and observations, conducted with differing stimuli and differing conditions, the picture became more clear. It was not that high intensity fear appeals were *per se* ineffective; instead it was the interaction between people's perception of their ability to alter the behavior and the level of fear generated that mattered.[281] If you generated a lot of fear in someone, you better also arouse a high level of confidence that they can solve the problem, or you get the "turn off" effect seen in earlier studies. When presented a message indicating that horrible things would happen to them, if people felt they could not do anything to preclude the horrible outcomes, they found ways to escape the message cognitively.

Gradually, these findings were related to and embedded in larger and more full descriptions of reactions to health messages. Today, the Extended Parallel Process Model (EPPM) is a theory that captures multiple components that are necessary to incorporate in a message that will produce the maximum change in health behavior.[282] While this model was developed by a scholar in the communication discipline, it is now used by scholars form multiple disciplines, and other versions of the model developed in other disciplines have converged on similar elements: self efficacy, fear level, response efficacy, goal relevance, etc. Though work on refining the model continues, there is a widely shared understanding of the dynamics involved by researchers in the different fields that approach the application.

This general model for health communication messages mirrors what the philosopher of science, Alexander Rosenberg calls the "folk psychology" model of human behavior. He describes it as the following:

"For any agent *x*, if

(1) *x* wants *d*,

(2) *x* believes that doing *a* is a means to bring about *d* under the circumstances,

(3) there is no action believed by *x* to be a way of bringing about *d* that under the circumstances is more preferred by *x*,

(4) *x* has no wants that override *d*,

(5) *x* knows how to do *a*,

(6) *x* is able to do *a*,

then

(7) *x* does *a*."[283]

Rosenberg argues that social scientific research is defective because it reproduces this folk psychology. As we saw in the previous chapter, however, it is not surprising that scientific research should end up reproducing non-scientifically generated models of human behavior. Aristotle's observations of human persuasion are unlikely to be overturned by scientific research because they are based in sustained observation. Likewise, the folk psychology model Rosenberg articulates is grounded in a wealth of observation of human behavior. The fact that a scientific research program validates some portion of lay observations cannot count against its status as science, or even against its value as knowledge, because rigorous validation is a core component of science. After all, sometimes common sense is wrong, and we only know the difference between accurate and inaccurate common sense through rigorous assessment.

The mainstay of Rosenberg's objection, however, is somewhat different; it is that research that reproduces the folk psychology model cannot improve our predictions that are based on that model.[284] This claim, however, is falsified in the example of the Extended Parallel Process Model (EPPM). While the general framework of the folk psychology model captures much of what the EPPM holds, the EPPM improves the level of prediction because it more closely specifies, and to some degree quantifies, the components in the model and their relationships (see Figure 10.2). As noted above, social scientists routinely use such "path models" to specify the relative strengths of various relationships among components of their models.

The various path models that have been developed to account for different human behaviors are not, however, simple replications of common sense beliefs. First, common sense usually does not attend to the full model. At least in the early days, most people really thought that intense fear appeals would be sufficient to motivate smokers to quit (and most non-experts today tend to make that assumption as well). Furthermore, the outlines of the folk psychology model are extremely vague, and unrealistically uni-dimensional and non-interactive. The folk intuition doesn't specify what happens when people face multiple conflicting wants, and some flexibility in circumstances, which is the typical case. The folk model also does not address the crucial issue of the way in which the circumstances can be shaped by social norms or public policy.

Much social scientific research is thus directed toward understanding what kinds of goals people are going focus on and what kinds of mechanisms for achieving those goals are likely to be preferred. Our common sense or folk psychology is often absent or even contradictory on such points (is it "out of sight, out of mind" or "absence makes the heart grow fonder"?). In health processes, for example, social support turns out to play a substantial role, even though this doesn't fit the mechanistic view of medicine. Habituation turns out to be very important too, though the folk psychology model certainly doesn't factor that in specifically. For all these reasons, an expert using the EPPM and other similar tools can predict the effectiveness of a health message far better than a naïve individual using only their common sense. Indeed, the history of research and applications in health communication message production has indicated that money spent on ad campaigns that are not theory-based are likely to be essentially wasteful of that money. Research-based campaigns know to balance fear with efficacy, to incorporate both response and self efficacy, to attend to identity triggers, to avoid stigmatization, and so forth. Unfortunately, because of the widespread lack of respect for social science, most money spent on health campaigns today continues to be spent without taking account of these knowledge frameworks.

There is every reason to believe that additional progress in the development and refinement of this model is possible. Most of the research to date has documented only the impact of message components on intentions to execute healthy behaviors, rather than on actual follow-through of healthy behaviors. Research that follows through to the level of behavior rather than learning or intention is enormously expensive to complete. Moreover, in general it appears that the health message approach is not sufficient to produce dramatic levels of change in behavior. Although campaigns based on the EPPM are likely to be more effective than those based on naive guess, the difference is modest. Only a few percentage points of behavior change can be expected as a result of even relatively good campaigns of health messages.

One of the major findings of health communication research has been that it is very hard to get people to change their behavior based on a single message (or even repetitions of the same or related messages, especially when conveyed by mass media). Either people are unwilling to change the values assigned to the component entries in the model identified by Rosenberg's "folk psychology," or factors not amenable to message manipulation, such as the "circumstances" or competing constraints (lines 3 and 4 of Rosenberg's model) are determinative (or both). This has led to the increasing recognition that social level, rather than merely individual level, approaches are critical.

The stand-out example is smoking behavior. In the U.S., people have been increasingly successful at quitting smoking across the past two decades.[285] There have been many individual message campaigns against smoking, but such campaigns to tell people what they already have heard—that smoking is bad for your health—are not particularly effective. Even today, most smokers know that they may be destroying their health by smoking, but smokers continue their habit and young people continue to start smoking, at record rates (among young women). Successful quitting among adults has increased for several reasons, including increasing prices and more effective anti-smoking campaigns, which included efficacy components and addressed additional motivators (group identification). Additionally, as passive smoking campaigns convinced the majority—who are non-smokers—to insist on their right to breathe clean air, non-smokers made legal and normative changes in access to smoking venues. When people around one are not routinely smoking, but instead one has to go to a designated (slightly uncomfortable possibly even stigmatized location) to smoke, social forces reinforcing smoking are substantially reduced. Combined with improved assistance in quitting smoking, these changes in access and norms allowed further attitude changes and enabled more actual behavioral change. Previous bans on smoking advertisements on television and radio reduced competitive messages and may have provided enabling conditions for later anti-smoking campaigns.

The lesson from the smoking behavior successes is that the predispositions of individuals—such as their attitudes about the healthiness of smoking—play only one role in a behavioral outcome. Social norms and socially constructed circumstances that enable some behaviors and disable others may often play at least as large a role. Knowledge of social norms and circumstances is thus a crucial element in producing positive changes in health behaviors. This provides knowledge that one could use, if the social group chose to do so. One can project, for example, that future health campaigns to prevent diabetes and heart disease through obesity reduction will have to provide the structural access to exercise venues and social norms that approve of physical recreation by adults if they are to allow messages about the negative health effects of obesity to gain any traction.

Social scientific research thus has made and continues to make refinements, modifications, and specifications of "folk models" that make a real difference in our predictive capacities and therefore meet Rosenberg's (and society's) test for the output of social scientific theory and research. This is not to say that social scientific study does not face distinctive challenges. The problems of developing measurement tools in social science are ever-present. Given that innovation and symbolic change are constants in human being, and given that measurements have to be made through symbol systems, there are no permanent yardsticks available. The survey questions that one could use to measure racist attitudes in 1950 are not the survey questions that one can use today. Developing appropriate measurement tools is a part of each experimental program anew. The lack of definitive experiments is also a major problem. The gap between theoretical conceptualization and operationalization is large in social scientific study. The specifics of test cases can make a major difference in outcomes. Therefore large numbers of experiments need to be conducted to triangulate the characteristics and boundaries of the phenomena being studied.[286] Good social science requires a continual struggle with these unique challenges, but they are not insurmountable. The progress social scientists have achieved to date suggests that if societies were to invest in social scientific research at the level and with the strategies it has invested in biological research over the past four decades, or in the broad range of ways industrial societies have invested in physics over the past century, the outcomes would probably be worth the investment. As we will discuss below, the outcomes would be different and perhaps more modest in their power, but given their importance to people's lives and to building sustainable, healthy societies, the effort seems well worth making. If fingers are to be pointed, a major source of remediable deficiency in the output of the social sciences lies in the failure of societies to support such work.

The Originality of Social Scientific Research

The second objection to social scientific results is the claim that these findings are "banal". *Webster's New Collegiate Dictionary* defines banal as "lacking originality, freshness, or novelty." Because social science deals with things we encounter every day—other human beings and human institutions--this is a charge to which social science is prone. Humanists and social scientists will have no pretty photomicrographs of unseen phenomena to display. But the objects of natural science—rocks, dirt, water or fruit flies—can also be portrayed as utterly banal and boring (as the average teacher of science well knows). Whether it is soil studies or self-esteem studies that one finds to be uninteresting, the charge of banality is the charge of the tone deaf. While the resonance between many social scientific theories and the folk psychology model gives many social scientific findings a ring of familiarity, those who are willing to engage the details find much that is fresh and original in social scientific research.

A quick example can be provided by the concept of the "approach-avoidance" conflict. The first author remembers this as one of the many interesting insights introduced in an introductory course in psychology. While the "approach-avoidance" conflict is familiar in folk concepts such as "buyer's remorse" or "cold feet" on wedding days, the more general construct of "approach-avoidance" conflict helps one to recognize and identify a pattern of behavior that people often exhibit: when costly goals are distant, one eagerly moves toward them. However, since the "fear" or "worry" gradient is steeper than the "reward" gradient, as one gets close to or actually arrives at a goal, the costs loom larger than the benefits. We are therefore continually driven toward goals and simultaneously repulsed from them. Recognition of this pattern was a novel and original theoretical contribution, and the explanation seems cogent and useful.[287] As a learner, having been taught the theory, I could recognize and understand my responses to particular situations in ways that I previously did not understand. This understanding has enabled me to cope far more comfortably with the conflict, even if it has not completely erased the conflict and its experience.

There are many other examples from introductory psychology or sociology textbooks that could be pointed to. Studies showing oddities of human perception have long been popular in the introductory communication classroom, and they continue to make the rounds in popular non-fiction. We suggest that natural scientists (many of whom routinely disparage such findings as "trivial") just have a different "taste" for knowledge. They tend not to be particularly self-reflective about their own behavior, nor are they particularly interested in the behavior of other people. Instead, they find quarks or forams more interesting. But the studies of many natural scientists seem incredibly trivial to most people. How many of us really care how many types of forams there are? Raise your hand if you think glycoproteins and their processing sound fascinating. The dreaded "Golden Fleece" awards for wasteful research could be handed out to natural scientists as much as to any other group. Interest value, in other words, lies heavily in the perceiver.

The examples of the Extended Parallel Processing Model from health behavior and the approach-avoidance conflict usefully illustrate the contributions of social scientific theory. As in any science, individual pieces may or may not be fascinating and of general interest. Progress rests on the slow, painful, gradual accumulation of specificity and sometimes of linkage among areas. Social science faces more challenges than other areas because people are more difficult to deal with than rats or crystals, but it is incorrect to deny its success in assembling these small bits into interesting and useful theories that can explain ourselves to ourselves as well as guide prediction and application.

What difference would evolutionary theory make?

Even were they to admit that progress had been made on interesting questions by social scientists, advocates of Wilson's narrow vision of consilience might argue that adding on the program of epigenesis would accelerate the progress and remove the perceptions of banality. There are good reasons to believe that the contributions of evolutionary theory to the social sciences would be interesting, but modest. For example, it is quite possible that one could add an evolutionary account to existing theories of the "approach-avoidance" conflict. Recent research has shown that other animals have two different mental processing algorithms for "approach" (seeking positive gains such as food) and for "avoidance" (avoiding negative outcomes such a capture by a predator). Animals do not just weigh the value of the advantages and disadvantages on a single scale, and decide whether to "approach" or "avoid" based on that scale. Instead, the "avoidance" directive operates on a separate biological pathway than the "approach" scale. This difference can be well explained by evolutionary factors that give higher priority to avoiding death by a predator than any one benefit of "approaching" a potentially positive stimulus.

Unfortunately, evolutionary accounts are generally too distant from human behaviors to provide a tremendous amount of predictive guidance. Although humans might do what they do because particular behaviors have survival and reproductive value, there are just too many different behavioral options that have survival and reproductive value for this fact to narrow the field much. The very different behavioral repertoires of bees and of scorpion flies, of chimpanzees and of bonobos all have proven to have survival value. One can't even assume that humans are in all ways genetically programmed to be like our nearest kin, since we don't spend our days picking vermin from each others' coats, we conceal our ovulation, and we do seem to watch a lot of television. Evolutionary theory might apply to humans, but it is too general, too distant from the relevant applications to provide strong guidance on many behaviors, much in the same way that quarks and gluons are too distant from insulin processing to prove particularly useful in accounting for the circuits of the glucose processing system in humans. This doesn't mean that the whole thing isn't made up of quarks and gluons; it is just that there are too many layers of interactions between the two to allow direct prediction from one to another.

A second basis of limitations on what evolutionary theory can add to social science is that so much research has already been accomplished. The situation is analogous to efforts to disprove Aristotelian accounts of persuasion. There has been so much good observation and correlation that evolutionary theories have a limited scope to discover new relationships. In many areas, they are confined to providing an additional (not replacement) layer of explanation. Given that almost any account can be plugged into "natural selection favored this, because it exists", this additional layer of explanation may not frequently provide much added power.

The distance from evolutionary theory to particular behaviors means that efforts to link evolutionary mechanisms directly to behaviors entails significant risk, and may even be a non-productive, misleading enterprise. An excellent example lies in the line of research claiming to support the idea that human minds have evolved with "cheater detection" modules. This line of research was heavily promoted in the popular press, but it has not born the weight of scientific analysis. Indeed it runs directly counter to a well developed body of social scientifically generated research that shows that people in general are terrible at detecting deception. We will tell this story at some length, and there are at least three important points to the story. First, we think the story suggests the need to level the field against any presumption for too-easy evolutionary tales (though we don't argue that evolution is irrelevant). Second, the story makes evident the importance of integrating such efforts with the large existing body of social scientific research, rather than ignoring or bull-dozing the same. Finally, the story suggests that a more productive way for integrating the natural sciences with existing knowledge of human social behavior is through the direct material mechanisms (such as brain structures).

Brain Modules or General Logics with Specifying Word Webs?

A key component of current versions of evolutionary psychology as promoted by scholars such as Steven Pinker, Leda Cosmides, and David Buss is the idea that human brains have evolved with functionally specific brain modules that bias how people process particular kinds of information. In its weakest, most general version, this claim is not problematic. Although the "modular" metaphor may be unhelpfully vague, human brains are, no doubt, on average biased toward behaviors such as breathing and toward eating, sleeping, and sexual activity, at least in particular times and places.

The controversy arises when this claim is extended from such general phenomena to the more specific claim that a presumed uniquely competitive and intense social experience in a homogeneous hunger-gatherer existence in the Pleistocene era produced strong human behavioral predispositions with regard to phenomena such as infanticide, deadbeat dads, differences in women's and men's mating strategies, sexual orientation, patterns of aggression, etc. (all topics in the popular textbook on evolutionary psychology by Buss (2004)). These extensions are at the heart of what we label the "uniformitarian" version of evolutionary psychology promoted by the authors listed above.[288]

There are several problems with this version of evolutionary psychology. First, no one knows what the range of environmental conditions during human evolution have been in sufficient detail to use them as a template for specifying advantageous behaviors. Indeed, it is more likely that humans were selected for adaptability rather than a narrowly constrained suite of behaviors, as the evidence clearly indicates an amazingly rapid expansion of human beings to virtually all of the ecological niches on the planet, with the species out-competing other large mammals in virtually every eco-system, causing the extinction of many of those animals.

It is hard to imagine how a species carrying only a rigid set of behavioral responses determined by its Pleistocene or pre-Pleistocene ancestors could have survived through the many and changing environmental conditions encountered by humans in the last few tens of thousands of years. Even among the surviving hunter-gatherer peoples today there is some substantial variation in environment and behavioral patterns, further indicating the difficulties in using a fixed environment as a template for causation if not also suggesting that human distinctiveness rests on something other than a rigid set of behavioral responses imparted to all present humans by their ancestors.

The problems involved in specifying a single and accurate template for describing the functional causes of human psychological adaptations is added on top of the usual difficulties evolutionary theories have in specifying the ways in which environmental conditions led to functions. At best, evolutionary psychologists can only point to uniformities in human behaviors and then try to construct "just so stories" about why a hunter-gatherer existence might have caused such a regularity. An enormous range of potential behaviors can be rationalized in this fashion with a moderately creative mind. Nonetheless, the search has proven to have some heuristic value and opened up new possibilities for consideration.

We have no objections to applying evolutionary theory to human behavior. Indeed, we think that a general calculus of survival and reproduction has selected human beings to have certain proclivities. The problem, as we see it, is the presumption that conditions in human environments are static enough to have generated specific brain modules to calculate each specific function, instead of generating more general brain architectures that are capable of assessing individual situations to achieve evolutionarily predisposed goals (but also, as we will show, re-directions of goals overlaid on evolutionary architectures by language experiences).

Tooby and Cosmides frame the issue in this way: "Does the mind consist of a few, general-purpose mechanisms, like operant conditioning, social learning, and trial-and-error induction, or does it also include a large number of specialized mechanisms, such as a language acquisition device, mate preference mechanisms, mother-infant emotion communication signals, social contract algorithms, and so on?" (citations edited out of this quotation, p. 39). Although this statement phrases the two alternatives in "and" terms, Tooby and Cosmides go on to assert that "Our ability to perform *most* of the environmentally engaged, richly contingent activities that we do depends on the guiding presence of a *large number of highly specialized* psychological mechanisms" (our emphasis, p. 39). In other words, uniformitarian evolutionary psychologists claim that most human behavior is the product of discrete inherited brain modules particular to activities such as social exchange, mathematics, and parenting activities. As in the instances of language and numbers discussed above, we will suggest a third alternative: general brain processes can be "tuned" to specific outcomes for particular domains, at least in part by symbolic activities.

A thoughtful person will immediately recognize that determining whether a widely-shared human behavior is the product of a general mechanism operating in shared environments or is the product of a specific mechanism operating as the consequence of a specific (guessed-at Pleistocene hunter-gatherer) environment is not generally going to be a simple one. It is not in doubt that there are some general brain mechanisms (the uniformitarian evolutionary psychologists agree on this, as the quotation above indicates). We will also not be surprised if there are some more specific mechanisms. However, it seems that the environmental variation within which humans have demonstrated themselves capable of operating requires mechanisms that can respond to cues *by selecting among different behaviors* to achieve specific ends. This contrasts to a modular logic, which specifies a mechanism that produces a *singular response to a singular* *environmental cue*. The neuronal web model of language provides a flexible mechanism that might provide varying behaviors in response to different environmental cues, while still aligning those behaviors, at least in the short term, with ends that might be evolutionarily predisposed. The "cheater detection" modules provide the key test case because this research has played a major role in giving the uniformitarian version of evolutionary psychology an academic hearing and it has received wide play in the popular literature. We seek to show not only how language might play a key role in the phenomena identified as "cheater detection" but also why researchers must attend carefully to the material impacts of language in order to sort out other potential variables in human behavior.

Cheater Detection Experiments

Leda Cosmides and John Tooby illustrated the claim that humans have specialized brain modules primarily through research purporting to show that humans come equipped with specialized "cheater detector" modules in their heads. They argue that humans respond to reasoning tasks in systematic ways when the context is represented as one of social exchange (and hence when detecting cheaters would be valuable), and these response patterns are different from responses to contexts that are not understood as social exchanges.[289] The "Wason four-card selection task" is the basic vehicle of this line of research. In its simplest form it asks people to select which cards one would need to turn over in order to detect violations of a conditional logic (e.g. "Which cards would you need to turn over to determine if the following rule was observed: if a card has a vowel on one side, then it has an even number on the other side," with the visible side of the cards marked D, 4, A, 9).

Cosmides & Tooby use several variations of the Wason task, but their basic design provides fairly elaborate stories of five or more paragraphs to frame the choice situation in different contexts. Their primary "cheater detection" scenario reframes the "cards" as hungry people who have stumbled into the camp of a "ruthless" Polynesian King who promises them food in the morning if they get a tattoo tonight signifying that they belong to his tribe. The research participants (mostly undergraduate college students in the U.S.) are warned that the King might cheat, and their task is to turn over only those cards that will determine whether the King has cheated. Typically, players do far better at parsing the conditional logic involved when the task is framed in this fashion than in an "abstract" condition or in other contexts, such as the "descriptive" condition in which the participant is situated as a researcher whose goal is to find out whether particular foods are associated with getting a tattoo or not (see Table 10.1). Hence, Cosmides & Tooby argue that "social exchange" situations "turn on" cheater detection modules in the brain, which have evolved to deal with the presumed fact that cheating was a common condition humans had to deal with in our evolutionary history.

<u>A Response to the Cheater Detector Experiments</u>

This "social –contract/cheater-detection module" interpretation of the experiments described above has been ably dissected on logical grounds by David Buller 2005). We will not replay the details of Buller's arguments, but Buller shows that the various versions of the tasks that Cosmides et al. employ vary systematically with regard to the

Table 10.1 Results of Experiments Testing the "Cheater Detection Module" Hypothesis

Scenario	Rule	P Card	Not-P Card	Q Card	Not-Q Card
Abstract*/**	If a person has a 'D' rating, then his documents must be marked code '3'.	D (<10%) **? $**	F	3 (<10%) **? $**	7
Drinking**	If a person is drinking beer, then he must be over 20 years old.	Drinking beer (91%) **$**	Drinking coke	25 years old	16 years old (91%) **$**
Unfamiliar Social Exchange*/***	If you get a tattoo on your face, then I'll give you cassava root.	Got the tattoo (75%/39%) **$**	No tattoo	Big Kiku gave him cassava root	Big Kiku gave him nothing (75%/39%)**$**
Unfamiliar Descriptive	If a man eats cassava root, then he must have a tattoo on his face.	Tattoo (21%) **$**	No tattoo	Eats cassava root	Eats molo nuts (21%) **$**
Card Cheater**	If anyone happens to end up with a card that has a vowel on one side and an odd number on the other side, then they have cheated.	E (86%) **? $**	K	4	7 (86%) **? $**
Card Winner	If you happen to end up with a card that has a vowel on one side and an odd number on the other side, then you win.	E (90%) **? &**	K	4 **$**	7 (90%) **?**
Switched ***	If I give you cassava root, then you get a tattoo on your face.	Big Kiku gave him cassava root	Big Kiku gave him nothing (36%)**$**	Got the tattoo (36%) **$**	No tattoo

*Cosmides (1989).
** Lawson (2002)
*** Cosmides & Tooby (1992)

Percentages indicate actual percent of individuals giving pairs of answers in accord with particular predictions. In all cases selecting both the "P" and "Q" card is the answer in accord with the definitions of formal Western logic. Comparisons of percentages across tasks should be cautiously undertaken, as different runs of the experiments and different wordings produce different results.

$ = Level of response accords with explanations of the "Cheater Detection Module" Hypothesis.
?= Level of response accords with explanations of the "Misunderstandings" Hypothesis.

underlying conditional logics and context-specificity of the cases used, and that these variations account for the experimental results that Cosmides et al. mistakenly attribute to the existence of a "cheater detection" module in the brain.

As a philosophically precise analysis, Buller's treatment is definitive. It has also been supported by the results of five experiments conducted by Anton Lawson.[290] Lawson argued that the biasing factor in the Wason task experiments was not the social context, but rather the kinds and amounts of information offered in the "set up" of such experiments. Like Buller and other previous researchers, Lawson suggested that the reason humans generally do so poorly on the basic version of the Wason task is that research participants make different assumptions about the meaning of the phrases in the task than do researchers. For example, lay people often assume that a statement framed as a conditional possibility is reflexive (if p then q is taken to entail if q then p), but that is not the presumption of logicians. The system developed by Western formal logic defines propositions of the form "If p, then q" to mean p requires q, but not that q requires p. Answers that do not accord with the definitions of formal logic are scored as incorrect. Lawson proceeded to use a series of experiments to pit this "misunderstanding" account of the differences in results against the "social – context/cheater-detection module" account.

Lawson's experiments showed that participant responses were indeed highly responsive to the framing of the rules. When the rule statement was framed by a direct statement using reflexive logic ("If anyone happens to end up with a card that has a vowel on one side and an odd number on the other side, then they have cheated") rather than using the conditional statement that Cosmides and Toobes had used (e.g. "If one has a vowel on one side, then one must have an even number on the other side"), there were no differences between participants who were told to look for cheaters and participants who were told to look for other things (either for altruists or for winners of a contest). For example, in one experiment, the "logically correct" response was given by 86% of those in the "cheater" condition and 89% of those in the "winner" condition.[291] This result accords with the misunderstanding hypothesis and falsifies the "cheater detection" hypothesis. When misunderstandings are cleared up by clear articulation of what the stated rules imply, performance improves in its accord with formal logics. Crucially, that performance is no different when cheater detection is the stated task than with a different task. Lawson further verified these results in an additional experiment with open-ended or "qualitative" results that asked participants to explain their reasoning, as well as in modified "altruist" detection tasks.

This refutation was particularly pertinent because Cosmides and Tooby's analysis did rest heavily on the assumption that social contract logic is conditional, not reflexive. This is evident in what they called the "switched" experiments. In these experiments, they gave participants the same scenarios used for other experiments, except that they reversed the proposition and consequent clauses in their rule statements. Thus "If a man eats cassava, then he must get a tattoo" becomes "If a man gets a tattoo, then he eats cassava." They argued that in the standard version of the experiments, the same responses are predicted by both the social-contract-brain-module and by a theory that a general logical processor guides the choice (where they assume that the general logical process is defined by the rules of formal logic formulated by Western philosophy). In contrast, in the switched version of the experiments, the two accounts predict different choices. The social-contract-brain-module should produce the same card selections as the standard condition, but an all-purpose brain logic (presumed to be that of Western formal logic) would produce a different result (because switching the order of the sentences changes which element is the proposition and which is the consequent, and since formal logic specifies non-reflexivity in conditional statements this changes the dependency relations).

As Lawson's analysis and results reveal, the flaw in Cosmides' and Tooby's argument is the assumption that the general brain logic interprets sentences in a fashion that is identical to the specifications of formal Western logic. Because people's answers in these tasks don't match formal logic, Cosmides et al. presume that people are not reasoning or are reasoning poorly in these tasks because they don't have an appropriate brain module for the task, whereas for social contract situations, they do have such a module. Instead, all this shows is that lay people's general logical mechanism (if such there is) does not adhere to the definition of a conditional sentence specified by the system of Western formal logic. Instead, consensus answers are determined by the particular meanings participants impute to the sentences that state the rules for the task.

Lawson's results convincingly demonstrate that people do not lack the ability to reason logically in the absence of a social contract situation, they just interpret the "rule" as reflexive rather than conditional. When they are explicitly told to interpret two situations—social contract and non-social contract (or cheater and non-cheater) as operating on a reflexive rule--then they give the same responses to those situations (using the same logic to do so). Unfortunately, this does not explain everything. For the question remains as to why, if as Lawson's results indicate, there is no "cheater detection" module, the subjects in the cheater detection task give different answers from those in the non-cheater detection tasks *when there is no explicit statement of the logi*c. In other words, when ambiguous instructions are given, why do people tend to interpret the social contract situation in a relatively uniform fashion but interpret the "descriptive" conditions in less uniform ways?

We suggest the following explanation. The original cheater detector scenarios cue systematic processing by arousing suspicion, and when participants search their neural webs, they activate densely wired neuronal webs that effectively provide rich analogies for analyzing the case, because all participants have extensive experience in the dynamics of social exchanges. Experience in exchange situations does not merely make the problem familiar, it provides tested effective means for coping with such situations (Pulvermüller explains the way categories of experience might work in neuronal webs, pp. 88-90). In contrast, the descriptive scenario is ambiguous in its arousal of suspicion, so that it may cue systematic processing in some individuals and not in others. Even when systematic cueing is aroused, the task at hand (anthropological investigation) is not a task for which the participants would have a densely wired web of experience, so they would not find a strong template that could produce a reliable result. Results across participants are *less consistent* both because of differential cueing *and* because of a lack of common grounds of experience in analogous tasks. In further contrast, we will suggest that Lawson's revised scenarios (as well as earlier versions of the Wason task) produce relatively uniform responses because they provide verbal cues that permit "verbally based heuristic processing" or readily accessible substitutes for the verbal markers when the verbal heuristic fails them. To support this claim we will first summarize the existing social scientific research on deception detection and then the research on systematic vs. heuristic mental processing. Then we will show how the data generated by Lawson and by Cosmides and Tooby can be fit into these frameworks.

Deception Detection

The well-established research corpus on "deception detection" has shown that human beings are very poor at detecting lies. As Levine, Park and McCornack recently put it, "Many studies have examined human accuracy in detecting deception, and there is strong general agreement among researchers about human's relative inability to detect deception in others."[292] These robust findings contradict the "cheater detection" analysis, which holds that social exchange is rife with the possibility for deception, and therefore humans have evolved to be good at detecting it. Instead, Levine et al. and others have indicated that human social exchange in tribal conditions was such that lying was infrequent and therefore development of advanced skills in the detection of lies as they were being told was not needed. This may have been true because in communities where people continually interacted closely lying would be easier to detect by the failure of match between the lie and the subsequent behavior or conditions than by the manner in which the lies were told. It may also have been true that people didn't lie much because the consequences of lying were so great: isolation from the tribal unit that was requisite for survival.

Further in support of this alternative evolutionary scenario, the literature on deception detection shows that the average current level of human deception detection skills has not been maximized by evolutionary processes, and thus is unlikely to have been the product of substantial evolutionary pressures. As Levine et al. note, the weakness in naïve human skills in detecting deception is not a product of a ceiling effect produced by a competitive evolution of lying skills that might make lying simply undetectable. Indeed, research has identified several speech production cues that correlate with deception, and individuals who are taught to detect these cues can improve their skill at deception detection.

In striking contrast to the dark view of human relations offered by the evolutionary psychologists, Levine et al. provide clear evidence for a "truth bias" among humans. The evidence indicates that, contrary to being continually suspicious in social exchange situations, humans tend to presume that what others are telling them is accurate. This bias makes them far more successful at detecting truths accurately than at detecting lies. In the research by Levine et al, people identified true statements as true accurately about 80% of the time, but detected lies as such correctly only about 34% of the time. Most relevant to the results of the evolutionary psychologists's experiments with Chief Kiku is the fact that people were much more effective at detecting lies in high suspicion conditions than they were at detecting lies in low suspicion conditions. This demonstrated flexibility of processing *within social situations* further casts doubt on a general brain mechanism specific to social exchange (at least one that is equivalent to "cheater detection"). Instead, specific cues within some, but not all, social exchange situations seem to lead people to attend more carefully to the possibility of deception, and they therefore more actively process information to which they would not otherwise attend.[293] In the cheater detection experiments, the "cheater" conditions specifically tell the participants to be suspicious, and this makes them more successful at reasoning about the logical relations. But how plausible is it that the brain routinely shifts from "normal" processing to more extended processing?

Systematic vs. Heuristic Processing

The body of research on systematic vs. heuristic processing establishes that people do have general-purpose variations in cognitive processing, labeled "heuristic" and "systematic" processing. Systematic processing is rigorous and thorough. As Maheswaran and Chaiken describe it, systematic processing is "a comprehensive, analytic orientation to information processing in which perceivers access and scrutinize all informational input for its relevance to their judgment task." This mode of processing input is high cost, and requires both capacity and motivation. Not surprisingly, it is not a default condition for most people in most situations. In contrast, heuristic processing is low cost and depends on available heuristic cues. In this mode of processing people formulate quick judgments based on heuristics or decision rules such as "consensus implies correctness" or "agree with people you like." [294] (Note that heuristic processing is not the same as the "availability heuristic", which Cosmides and Tooby's research accurately refutes, although the latter can be understood as a subset of conditions that facilitate heuristic processing).

Processing and Suspicion in Cheater Detection

The results of the whole suite of experiments on "cheater detection" (by both Lawson and Cosmides & Tooby) are consonant with an interpretation based on the character of heuristic and systematic processing depending on the particular formulations of the tasks. The participants in the "social exchange" conditions of the original "Chief Kiku" experiments of Cosmides and Tooby are being cued by the frame to engage systematic rather than heuristic processing. Asking someone to look for cheaters (or rule violaters in their more general scenarios) creates the motivation for using systematic processing modes (as opposed to constituting a unique brain module). Lawson's ability to make the results of cheater and non-cheater tasks equivalent results from providing additional information. The scenario does not require such extended processing because the necessary information is made ready at hand, and the availability of that information to all participants standardizes the responses.[295]

It is worth questioning, however (as Cosmides does with regard to Lawson's modified Altruist task), whether what is going on in Lawson's modifications is best described as providing additional information that allows for uniform processing of the available data (produces better systematic processing) or whether Lawson is merely providing a verbal heuristic (which provides more uniform heuristic processing).[296] As we will illustrate, the pattern of results on some Wason tasks can be explained by an assessment of whether the participants are using the words in the rule statements as templates to pick out cards. In some instances they can treat the words as verbal heuristics (or, in the language of neuro-linguistics, the words in the rules are priming the card selections). It other instances they cannot.

Compare, for example, the standard "abstract" problem to the "drinking age" problem. The latter is a familiar social contract problem and it gets the highest levels of "P + not-Q" answers. The former is a non-social contract problem that consistently gets the lowest levels of "P & not-Q" answers (see Table 10.1). In the "abstract" problem, the stated rule is "If a person has a *'D' rating*, then his documents must be marked code '*3*'" (our emphasis). The most common answer given to the task of locating violations of this filing code is "D" and "3" (where the "more logical" answer is D and 7). This choice is consonant with the heuristic rule "look for the verbal components in the rule on the cards" which might be mechanistically constituted simply by the priming of "D" and "3" in the neuronal network by the immediately previous triggering of those neuronal webs by the rule statement (priming through prior neural activation is a generally accepted phenomenon). In the absence of motivation to search the neuronal web further, this primed response may be deemed sufficient by most participants. The lack of motivation may arise not only from the lack of suspicion cues, but also from other elements of the scenario. The story asks the students who are its participants to take the role of a file clerk checking on student records. This cross-identification might well be de-motivating. Moreover, the students are told to apply an "alphanumeric rule." Many are unlikely to understand the term, and therefore to assume that they do not have access to sufficient knowledge for processing the task in a specialized fashion.

The use of verbal heuristics does not occur in the Cosmides' and Tooby's versions of the Cheater Detection and "Descriptive" problems. As many as 80% of the people in the Cheater Detection scenario choose the card with the *reverse* of the second verbal element of the rule: "If you get a tattoo on your face, then I'll give you cassava root." That is, they choose "did not get cassava root." To understand why it might be that in some cases verbal heuristics are employed and in others they are not, we consider a series of increasingly complex processing scenarios.

In a standard "social contract" example—the "Drinking Age Problem" (Cosmides, p. 192), the stated rule is "If a person is drinking beer, then he must be over 20 years old" and the most common answers are "drinking beer" and "16 years old." This is the "logically" correct answer, and it differs from the common answer given to the "abstract" problem. In this case respondents do not select the "25 years" answer that is the parallel of the "3" answer (that is, it is the "Q" matching card, rather than the not-Q card; see Table 10.1). They cannot do so, because there is no match in the available answers between the primed numbers (20) and the answers ("16" or "25"). So participants *must* look for some other age-based answer. They must take another processing step. Since 25 years is "older" than 20 years old, that person is eligible to drink, so a plausible answer that matches the second part of the rule readily is suggested-- "16 years." Participants can get this information either from their previous knowledge about drinking laws or by reasoning through the simple arithmetic with which most will have experience (25 is greater than 21; 16 is not).

The results of this experiment sponsored the hypothesis that the real cause of differences in the cheater detection research line was subject familiarity with some scenarios and lack of familiarity with others, which was called "availability theory." This possibility motivated Cosmides and Tooby to shift to unfamiliar scenarios to rule out the use of readily available information (such as "I already know that people who are 16 can't drink and people who are 25 can"). Their results in the new comparison experiments showed that familiarity makes some difference, but it does not account for all the difference. They indicate that their "social contract" explanation accounts for about 50% more of the variance than the familiarity component.

Their reasoning, however, assumes that "familiarity" pertains only to experiences with the concrete components of the scenario (mollo nuts, cassava roots, tattoos, etc.). It is also the case, however, that the various scenarios offer more and less familiar *tasks*. Social exchange, whether or not it is accompanied by a specific brain module, is a highly common human activity. Experience with social exchange will have built dense neuronal networks. These paths will generally have become structured in ways that produce desired outcomes from social exchange. However exotic the setting for the "social exchange" situation might be, it is likely that the general roles in the exchange are familiar to the participants. It is not surprising therefore, that when it is engaged by suspicion cues, systematic processing produces similar answers.[297]

In contrast, the "Descriptive" problem asks students to play the role of an anthropologist. The description of the task they are given essentially tells them to search for correlations between tattoos and different kinds of foods. This is not a type of task with which most undergraduate college students have any experience, let alone a common base of experience. There is, therefore, nothing to "fill in" the meaning of the ambiguity of the "If, then" sentence. Participants are likely to "give up" answering or to appeal to a wide range of different parts of their neural networks. Because these other parts of their neural networks will not have been tested through experiences relevant to the specific task, they will not necessarily be successful. We can't assess whether their answers were reasonable or not, because we don't know what assumptions they made.

The results of Lawson's revised scenarios (card cheater and card winner) also support an interpretation based on access to stored resources for interpretation. The rules given are "If anyone happens to end up with a card that has a *vowel* on one side and an *odd number* on the other side, then they have cheated," and "If you happen to end up with a card that has a *vowel on one sid*e and an *odd number on the other sid*e, then you win" (our emphasis). In these scenarios, the participants cannot use a direct verbal heuristic, because the options available are not "vowel" and "consonant" or "odd number" and "even number." So they must do additional processing to find the answer. However, regardless of whether they are familiar with the particularities of the scenario, they have stored in their verbal neuronal webs the fact that vowel= a,e, i, o, u, and that odd numbers are 1,3,5,7, etc. So the translation from "vowel" to card choice does not require extensive additional processing. In this particular case, the heuristic verbal fill-in strategy produces a "logically correct" answer (in contrast to the "abstract" Wason task) because the formal logical prescriptions are consonant with the verbalistic strategy. The results of these modified cheater detection and non-cheater tasks are the same because any motivational differences or any familiarity with different rules are negated by the fact that extensive systematic processing is not required.[298]

We therefore believe that the best account of the full range of the "cheater detection" experiments is provided neither by the modular brain hypothesis nor by the "misunderstanding" hypothesis, but rather by a neuronal network model that posits variations in 1) depth of processing (cued either by motivational factors or by success in initial processing efforts during a task), and 2) variations in density and applicability of neuronal webs (gained through experiences that provide tested strategies). Over 80% of people give consistent answers on the original "cheater detection" task and there are inconsistent answers on the "descriptive" task because there are strong and clear cues in the cheater detection scenarios that discourage heuristic processing (the activation of suspicion); when participants move to systematic processing, they can readily access a neuronal web that fits the situation and provides a reliable outcome. In the "descriptive" task, in the absence of a motivation to use deep processing, some participants may simply apply the verbal matching heuristic, failing to assess its appropriateness further; however, other participants may be cued by the inappropriateness of the verbal match to search further, but when they do so, they lack an appropriate match, and any matches they find can not provide reliable outcomes because they are based in different ranges of experiences and their conditions. Dispersal of answers results *both* from the low motivation for systematic processing *and* from a lack of stored analogous experiences. In contrast, in scenarios where there is low motivation for systematic processing (the "classic Wason test" and Lawson's modified tests) and no obvious cues that disqualify verbal heuristics, or readily available translations when verbal heuristics fail, then people produce remarkably similar answers (which may or may not match those interpretations based on formal logic's definitions of the meanings of sentences, depending on the task).

Further testing of this explanation will obviously be appropriate, but because of the multi-causal nature of the responses, designing and executing definitive experiments that employ alternative scenarios with alternative phrasing and that measure speed of responses is not a trivial matter. However, this dual-pronged explanation accounts for the results of a wide range of experiments, whereas the previous two theories do not. The neuronal web approach is also consistent with the larger body of research on deception detection, as well as well-established information about brain processing. It also satisfies "Occam's razor." It does not require the brain to have evolved a specific mode of logic for some functions and different modes for others. The distinction between more rigorous as opposed to more cursory processing does not constitute two independent brain modules. Instead, it represents merely the amount of energy or time spent searching one's neural net for relevant information. The results of such searching are not context-independent. Some searches will turn up useful information and some will not, because sometimes there is useful additional information available and sometimes there is not.[299] The relative ease of accessing that additional useful information will also vary. In some cases the information retrieved will be common among humans and in some cases it will not be common.

Whatever the best account ultimately turns out to be, however, our point is not that we have definitively explained these complex patterns of results. Instead, we think the above analyses establishes three crucial points for research on human behavior. First, the proposition must be taken seriously that precise language choices may in many instances play a definitive role in behavioral outcomes (especially when verbal heuristics are used). Purely verbally-based heuristics seem to provide the logic of people's responses to some of these scenarios. Indeed, such verbal cueing seems to provide a "first option" for human reasoning in some situations. While that may seem a suggestion so dispiriting to many intellectuals that they wish to reject it in favor of the hope that people are "more logical than that," such a response is not sufficiently thoughtful. It may be that using verbal heuristics as initial strategies in response to verbally posed queries is a highly efficient (because very low cost) approach to reasoning, one that works most of the time because verbal neuronal webs are encoded through processes that establish essentially reasonable relationships (i.e. relationships that match life experiences). The availability of alternative strategies (more "systematic" processing both within and beyond the neuronal web) corrects for deficiencies in the strategy in conditions where deficient reasoning is likely to be particularly consequential or where deficient cueing is likely to exist (e.g.with an untrustworthy conversational partner).

Even when verbal cues don't constitute the primary logic of decision, shifting a few words here or there (changing from "altruistic" to "selfless" (Cosmides and Tooby 1995)) makes a difference in the choices people make, as does eliminating words describing the Chief as "ruthless".[300] Indeed, we suggest that the analysis above indicates that it is reasonable to assume that the specific words in these scenarios, when taken as a whole, are in an important sense, responsible for the choices people make on these tasks. The words participants receive cue their choices, specifying which other components of the brain should be involved and how the varying components can be brought together, and thereby they produce outputs that are limited by the characteristics of the words themselves. Changing the words changes the behavioral choices. With these scenarios, as in much of contemporary human life, if there were no words, there would be no behaviors.

The importance of the way in which the scenarios constitute the behavioral context and the way in which a few words may make substantial differences also emphasize our second conclusion, that many crucial patterns of human conduct cannot be explained without research designs that take into account the role that language processing plays. Cognitive research designs must take scrupulous account of word choice and potential theoretically based roles for linguistic processing in most human research efforts.[301]

Third, our account shows how it is possible to take the impact of language seriously without denying the role of evolutionary forces on capacities of the brain. We do not think it is an accident that telling someone to “look for cheaters” cues systematic processing more effectively than telling them to “look for errors in the filing system.” It is simply that both the way in which symbolic cues function and other evolved components must be rigorously accounted for. There is some evidence that humans exhibit so-called “moral” emotions (as do other animals that calculate alliances, maintain them across time, and seek to enforce them). The symbolic codes for cheating that we amass (and their motivational force) may well be influenced by these emotions. This, however, is not to be accounted for by appeal to independent modules. Recent research indicates that social interactions are modulated by balances among networks of different parts of the brain—the amygdala, and the dorsolateral, medial and orbitofrontal regions of the prefrontal context. Thus, a neural network model is relevant here as well.[302] Symbolic cues (“look for a cheater!”) likely activate portions of verbal webs that have been tightly wired into these “social interaction” networks, but their specific outputs are likely to be a product of the gestalt produced by way in which these wirings—within and between both symbolic and non-symbolic portions of the web--have been built up over time through experience.

This account is obviously different from a view that sees words as merely a conveyer belt for pre-existing logics and objects. Taking this more materially substantive account of language opens up better explanations of human behavior. Instead of looking for fully genetically encoded, self-contained logic-boxes, we should be looking for how brain architectures that include verbally-dedicated neuronal webs function to produce particular words and through those word processes link into particular other parts of the brain, and together then produce particular choices. Such an approach does not cut off the influence of evolutionary forces, but it does force us to take seriously a central human medium through which those evolutionary forces must function--symbols. In humans, previous experiences are encoded in the word webs in the brain. While experiences are not exclusively coded through words, they are likely to be accessed through words whenever words are present.

This story about "deception" thus suggests that an approach that links up biology and symbolics, rather than an approach that seeks a radical overthrow of the social sciences, especially one with too-hastily drawn "just so stories" about human evolution, is more likely to be fruitful. The social sciences have amassed both deep descriptions and successful explanatory theories of human behaviors. These theories are interesting and often times individually and even socially useful. Biological correlates may interface in productive ways, but abstract biological theoretical structures are so distant as to offer direct predictions only in limited arenas.

The program of sociobiology that provides the model for consilience has seemed so attractive, we believe, merely because it offers a set of explanations that seem novel to most people (and the mass media is interested in nothing so much as novelty). These explanations rest on the claim that human behavior is the same as that of other animals. Because lay people resist that comparison so much, consilience and sociobiology seem to have some novelty value. But this sense of "novelty" just reproduces the problem that the social scientist has always faced. When social scientists teach students theories with which the students agree, the students say, "so what, I already knew that." When social scientists teach theories with which students disagree, the student s say, “I don’t believe you.” Evolutionary theory currently falls in the “I don’t believe you” camp with enough sufficiency to retain shock value. As that shock value wears off, there may simply be a slide to the “I already knew that” camp. Evolutionary theory will come to seem as banal as approach-avoidance theory at that point. Evolutionary theory and other biological approaches cannot escape these and the other major limitations on the social scientific study of human beings—including multiple inputs, experimenter effects, sampling problems, interpretive complexities, ethics, and even problems of memory overload. The most productive prospect for the future, therefore, is to engage biology with the knowledge the social sciences have already produced, rather than merely seeing whether evolutionary studies can produce something “better” in splendid isolation.

Our review of the social sciences has suggested to us, however, that a different kind of research is necessary as well. Once one comes to recognize the flow of symbols as a material entity rather than an ephemeral dance of “ideas”, it seems obvious that a series of basic observations of the nature of the social level flow of symbols needs to be undertaken. Scholars need to know if there are patterns of symbolic change on the social level. For example, as societies go through cycles of quiescence and change, do type/token ratios change? Is there greater heterogeneity of symbols as a society approaches major changes such as the Civil War or the realignments of the mid-20th century? Does heterogeneity manifest itself in polarities? Do narrative contents shift, or do narratives become either more fragmented or more complex? Are there shifts in patterns of what have elsewhere been called “character-types”?[303] There are currently no answers to such questions, and if symbolic processes are to be understood, these are questions that need to be pursued.[304] The rise of computers capable of handling enormous numbers of symbols has made such work newly feasible. Indeed, resources such as the Tobacco Settlement Documents are now allowing corpus linguists to take on some interesting work of this sort.

Similar questions might profitably be addressed at the institutional level, and scholarship might then be in a position to trace the circulation of symbols through different components of the social matrix. Gradually, the patterns of symbolic flow, if such there be, might be understood and this would create the possibility not only to understand ourselves better but potentially even to begin to ask questions about effectivity. Tying these questions to issues of biology will be challenging, but given the novelty of both enterprises, this might represent a uniquely interesting and powerful opportunity to envision a research area in a combined fashion. The achievements of the social sciences have not been inconsiderable, but this entire intellectual territory remains largely unexplored.

Summary

It has taken us two long chapters to survey a substantial portion of the methods that have traditionally been used to explore the symbol-using capacities of the symbolizing animal. This survey has for the most part omitted one major group of studies—the social level studies common in sociology, political science, and economics. That omission has been due both to our sense of the limits of our reader's patience and our own competencies. Similar accounts of the productivity of these areas could, however, be written. To take only one quite important example, social-level studies have shown that the clearest factor for predicting a wide range of individual characteristics such as voting behavior, intelligence test performance, church attendance, or physical activity level is socio-demographic status.[305] Studies that focus solely on individuals cannot identify such patterns or delineate the networks of forces that link these disparate phenomena. Social level studies thus add to understandings of the patterned character of the world humans live in and the constraints on the paths human lives might take. A detailed exploration of the methods employed in such social-level analyses would not add significantly to the methodological repertoire, though the parts of the tool-box that were utilized most often would be different. Most notably, post-hoc modeling similar to geological and ecological work would be more common than laboratory experimentation.

In spite of this large lacuna in the overview, the distinctive patterns of the methods of study in the traditional humanities and social sciences should by now be relatively clear. *Human studies have used all of the methods of the model of physics and integrated these with the additional methods of the natural sciences, including those distinctive to biology*. In addition, because human symbolizing is so intensely historical, valuation-laden, and derives its effectivity from convergences, human studies have expended disproportionately large parts of their resources in history, evaluation, and analogical pattern recognition.

All of these tools produce knowledge about human beings. Some of this knowledge is produced by what are generally recognized as scientific methods, and some by the methods specific to symbolization, but it should be clear from the preceding account that there is no bright line separating the two. Watson and Crick did not discover the structure of DNA using critical experimentation, yet their melange of pattern recognition, induction, and deduction is counted as one of the most important *scientific* contributions of the 20th century. One moral of this story is that increased care is needed to ensure that knowledge is not identified as “scientific” merely because it is about the so-called natural world and not about humans. *An explanation counts as knowledge to the degree that it is secured by a convergence of evidence, inter-locking theories, patterns, and predictive or performative utility*. If an explanation is extensively researched using a variety of methods and it is the best-justified of a set of well-justified explanations, it stands as the knowledge for its day. This is not because one can be certain that it is true, but rather because sustained collective efforts have ensured that it has the best possible chance of not being a substantially false account, and constructed it positively as the account with the greatest probability of serving a wide range of uses.

There is, however, inevitably a difference in the level of contestation and even certainty about knowledge gained through different means. Knowledge gained through critical experiments is often capable of garnering a level of inter-subjective agreement that is more difficult to achieve via other approaches, and this difficulty means that, in fact, much of the knowledge gained about humans remains to date far less secure than most of the knowledge gained about atoms. But level of contestation cannot be the definitive test. A high level of disagreement over a conclusion does not disqualify something as knowledge, or the theory of evolution could not yet count as knowledge. Political motives make knowledge about humans more widely contested than knowledge about the natural world, but a well-secured knowledge set in either area has equal validity.

Humans can and do know things about human being, using a wide range of tools. The persistent sense, however, has been that knowledge of humans has not "progressed" as far as knowledge of other natural beings. When cases of disagreement are no longer given center stage, and the necessity of multiple inputs (and hence multiple different theoretical bases) are accepted, the remaining reason for that perception is that our theories about humans have not produced the ability to predict and control at the level of the physical and biological sciences.

Prediction and Control in Human Studies

Prediction

We have already illustrated the ways in which the theories generated in the social sciences and humanities improve one's ability to predict human behavior. It is true, however, that these predictions are probabilistic and collective rather than certain and individual. In other words, you can predict who is likely to vote Democratic based on their social class, race, or gender, but you will only be right more often than someone who is predicting without knowledge about these factors and their links to voting behavior. You will not be right all of the time. Moreover, with many social scientific theories, the marginal improvement in predictive success achieved by knowing a given variable or theoretical component is quite small—perhaps only 10% or so. Both natural scientists and social scientists keep hoping that they will discover a magic theory that will increase that predictive power massively.[306]

Genetics, sociobiology, or "evolutionary psychology" have recently presented themselves as such magic bullets. But as we have seen, such single-variable theories are likely to have rare or modest applications, for most human behaviors have multiple causes. Inputs to human behavior include genes, symbolic codes, economic factors, political structures, cultural norms, architectural designs, the specific patterns of communication networks, and much more. Of equal importance, humans have the option for many different behaviors, even conflicting behaviors: to cooperate or to compete, to paint or to play football, to watch television or to travel. The enormous range of inputs to behaviors combined with the enormous range of potential behavioral outputs mean that even if one locates a few relationships with that magic bullet magic quality--where specific outcomes are produced with high fidelity--one will not have told the full story about humans. We will not know all there is to know.

These realities do not daunt all comers. Advocates of biologization have repeatedly used heritability estimates to make claims to large genetic inputs.[307] Even E.O. Wilson, however, has recognized that heritability estimates of humans do not indicate how much of a behavior is caused by genetic factors.[308] Most heritability estimates of humans only indicate what part of a behavior is caused by genetic factors *within* a given environmental range. Moreover, heritability estimates are generally produced for human personality variables, and not for specific behaviors. Introversion may have a strong genetic component, but its relationship to actual behaviors such as writing checks, dancing jigs, petting cats, or painting numbers on a hill is a different matter. As a general rule, any single genetic or other factor accounts for a small part of the determination of any specific behavior. Those factors that account for large parts of the determinants (the need for air, food, water, sleep, parental care, etc.) tend to form uninteresting, uniform backgrounds. This means that whatever it is that is learned about the relationships between genes and behavior will not increase the size of the predictions that can be made about human behaviors, at least not in most so-called "normal" cases.

For scholars, this should not be such a hard pill to swallow. We should be content to face reality as best we can, in all its complexity. However, because funding, social status, and even personal ego are tied so closely to "big bangs" in research outcomes, the low levels of predictive outputs have serious implications for control, and this makes us constantly wish for something more spectacular.

Control

If the explanations of human studies produce modest levels of predictive improvement, it is not surprising that they do not produce high levels of control. Yet, if one could improve society only 10% by knowledge about an aspect of human behavior, that would surely be an improvement worth making. Indeed, advertisers and marketers have whole-heartedly adopted the findings of social scientific research to improve their yields. Although the social scientific techniques they adopt may only help convince a few percentages of their audiences to buy their products, this means millions of dollars in sales. For such groups, therefore, the control offered by the knowledge of the traditional human sciences, while not ideal, is none-the-less useful.

This does not, however, hearten the average citizen greatly. People are quite reasonably nervous about the fact that marketers use social scientific knowledge to manipulate people into higher consumption of a marketers' goods. Even within the field of health communication, where better health is the perceived goal, there is some debate about the ethical appropriateness of using fear appeals and other techniques to "manipulate" people's behavior. The discomfort with such applications of social science has a deep root. Unlike control of atoms and even plants and animals, most people don't really want anyone to have a powerful set of knowledge that allows them to control others. The very important value of respect for human dignity suggests that when one person or group of person's tries to control the behavior of other persons, that is treating the others as objects and not persons.

For this reason, control in human studies has generally been conceived as self-control, rather than either expert control or manufacturing-style leveraged control. To date, the most important pragmatic gains that human studies offer have been to the lucky individuals who learn the knowledge and practice its prescriptions. The well-educated person may live a better life because that person can understand the forces operating upon them and sometimes counter those forces in productive ways. Although social scientifically based knowledge is often nothing more than an "improvement" on a folk psychology, these improvements have considerable merit. By broadening folk wisdom about the recurrence of "buyers remorse" to approach-avoidance conflicts, one learns to recognize a pattern in one's self, and to learn to understand its sources. This gives one the power to assess the behavior and the opportunity to choose to change it. With regard to some conditions, such knowledge may also better identify the social conditions which might be changed to enable people to more readily bring about the behaviors they want to exhibit.

Sometimes social scientific knowledge allows understanding of the quantitative contributions of different components of folk models (as in the Extended Parallel Processing Model), but even when it doesn't improve quantitative assessments, it enables us individually to objectify and externalize, and this gives us a unique capacity to change ourselves. Given a symbolic model of the approach-avoidance conflict, one can laugh off these tendencies in one's self, rather than spending days agonizing over the decisions one has made. To take a more social level example, having studied the symbolic history of Spain, one can understand the ways in which powerful leaders of powerful countries have repeatedly come to make decisions that destroy their nations for the most ungrounded of reasons. Seeing such behavior as a pattern of history helps one to cope with the emotional strain of living in the present place and time, not to mention the difference in makes in selecting political actions.

It is not enough, of course, to simply learn the theories human studies provides. One must also practice them. Because humans are organic beings, our habit patterns are engrained in our bodies. Exposure to an alternative understanding does not change those habit patterns by itself. Whatever means humans use to store theoretical knowledge in our brains is different from how we encode specific habits. The knowledge about behavioral patterns only gives us reason to practice and engrain new habits, it does not produce those behaviors of itself. This is to say that the control gained from much of the knowledge of human studies is such that it enables the possibility that one can perform differently, with greater effectivity, but it does not guarantee the practice that rewires the relevant parts of the brain.

Such knowledge also enables its bearers to produce better symbolizations. A person who has studied the theories of rhetoric (or at least has learned from touchstones) can write a better speech than someone who has not. This does not mean that the ill-defined quality called talent is irrelevant, or even that formal knowledge has greater effectivity than talent. It simply means that whatever level of talent a person has can be broadened and improved by specific knowledge.

An enhanced ability to shape one's self in ways one finds desirable is an enormously important contribution of human studies. Perhaps it must be sufficient. There is, however, the possibility that a social group might also want to shape behavior on a collective level. The example of the successes of the social program to reduce tobacco smoking suggests that one component of such shaping lies in limiting the circulation of messages that induce behaviors that are agreed to be undesirable. Limiting the reach of cigarette advertising helped limit the intensity of interests that competed with the anti-smoking messages.[309] A more powerful component, however, might be the shaping of environments to encourage or discourage particular kinds of behaviors. Banning smoking in most public places made it more difficult for smokers to maintain their habit comfortably, both for pragmatic reasons, and because it encouraged non-smokers to articulate their discomfort with being around smoking and. All these things helped tip the balance for smokers who wanted to quit, but who had not previously been sufficiently motivated and enabled to overcome their drug dependency.

The case of smoking behavior illustrates that one can exert social forces that shape human behaviors without direct coercion or even demeaning controls. Such methods maintain choices for individuals, but they also exert social force on individuals, a fact that both leftist theorists bent on the perpetual critic of all forms of power and right-wing marketers such as the cigarette and alcohol companies will decry. Such concerns are important and require constant thoughtful reconsideration, but social shaping of human behavior is inevitable and inescapable. A conscious, democratically deliberate approach to such shaping is surely at least as desirable as the “shit happens” approach advocated by some theorists on both political ends of the spectrum.

A minimal ethical standard for such deliberate social efforts must be the use of democratic methods in deciding upon the limits on messages and environmental parameters. This democratic standard makes it extremely difficult to produce such social controls. While obesity, excessive alcohol consumption, or other cases of extravagant consumption might qualify as behaviors that should be re-shaped among contemporary humans, the likelihood of our doing so is low. We may know how to reduce these behaviors, but the political constraints in our imperfect democracy make it impossible to apply that knowledge.

Political problems are, of course, not unique to human studies. Experts know, for example, that global warming is contributed to by identifiable human social behaviors and that it will have substantial negative results (though they may not know precisely how bad those results will be, or even what they may all be). However, enacting laws and social procedures that mitigate the negative human contribution to global warming is not in the interest of large and powerful sectors of U.S. society. So the U.S. has not utilized this knowledge. The case is similar with many of the findings of human studies, only more so.

To implement the knowledge gained from human studies on a social scale almost always requires facing political resistance, for every social action benefits some people more than others and may disadvantage some people more than others. Any change will therefore generate resistance. This resistance is aggravated by the fact that 1) social scale changes are inevitably large and expensive, 2) outcomes are probable, but not certain, and

3) knowledge is always contestable. In the long run, human societies may be able to overcome such resistance, but if this is to be done in a democratic rather than dictatorial fashion, the knowledge to be gained must run through the majority of individuals in the society. Most human societies are a long way from having the ability to share much of human studies with the bulk of their populations.

The knowledge produced by human studies does not generate enormous enthusiasm and financial support for further research because knowledge is so difficult to apply, and political interest groups have reason to resist many research findings. Slow, difficult processes of personal learning and remodeling of one's behavior are needed, and on the social scale these must be added to difficult, usually insurmountable, political challenges. Another way of saying this is that the control gained by knowledge about humans can't be leveraged. It can't be patented and manufactured. It not only requires expert knowledge (as in medicine), but personal absorption by all of the participants. The financial or social benefits may flow at the downstream end, but there is no incentive for anyone to finance their upstream discovery or their midstream implementation. Given social suspicion of giving mad scientists control over our behaviors, and a widespread belief that social science and human studies are undesirable or ineffective (because they necessarily produce something that is either different from or similar to what one already believes), research that provides this kind of control is not something human societies have whole-heartily pursued.

If in the next few decades, scholars were successful at adding a deeper level of understanding of humans as biological beings, these limitations would be unlikely to change significantly. Lay people will be as suspicious of biological controls as of social controls. Perhaps such research might generate a few drugs that would help individuals control more of their own behaviors, and some might even have tolerable side effects. Perhaps such research might generate some ethically problematic applications such as drug implants or surgery that reshape behavioral responses of convicted criminals. Other than such limited applications, knowledge about human behavior as biological based is no more likely to be leverageable than that of other types of knowledge about humans. The limitations lie not in the unity of the knowledge framework, but instead in the complexity of humans and their very important resistance to controlling other human beings as they would control electrons, barley plants, or even rats.

Conclusions

These two chapters have summarized some of the most important methods it takes to understand human beings, to understand, for example, the village of Arco, Idaho, USA. To explain the "Submarine in the Desert," why Pickle's Café names its biggest burger the "atomic burger," and the spate of local excellence in music, one needs to know the history of the town. The methods for selecting, assembling and transmitting cultural memory are therefore vitally important. To understand the numbers painted on the hill, one needes some hermeneutic analysis, for this is not self-evident (travelers have been known to ask if those are the high-water marks for floods). To appreciate the relatively high quality of the town murals, one needs the skills and experience of expert evaluation. And innovation is critical as Arco tries to remake itself from a residential community for a national reactor testing station into a tourist town with small-scale specialized manufacturing.

To understand Arco, however, one also must call upon generalizations. Some of these generalizations will be gained through humanistic methods. Arco can be compared to other small towns in America. In some ways it is like the many shrinking small towns of the mid-West that have lost their manufacturing base. In other ways it is quite different, because the National Reactor Testing Station was not a manufacturing center. It attracted a unique blend of highly-educated scientists and engineers and young, adventuresome sailors. The skills of pattern recognition and familiarity with a range of other towns and their experiences thus is part of the process that helps one to understand Arco and to predict, and perhaps contribute to, its future.

Many of the generalizable behaviors of the townspeople of Arco can, however, also be explained by social scientific methods. For the most part, Arconians act a lot like people everywhere. They have children and parties, they experience approach-avoidance conflicts, and they resist health behavior messages. Their social-scale behavior is also predictable. The on-going battles at the local public hospital are exasperating, entertaining in a grim fashion, and also highly predictable based on the economic interests of the parties and the political levers available.

The biological nature of Arconians also helps us to understand their behavior. The omnipresence of male status displays surely calls to mind the similarity of these humans to their biological relatives, and these humans absolutely must organize their lives so that they obtain sufficient nutrition, water, warmth, and atmospheric pressure.

The enormity of what is required to explain little Arco is surely dizzying, for it is obviously just one tip in a sea of icebergs. Small wonder that some are tempted to retreat to a narrow catalogue of broad generalizations. But that would be to fail to understand human beings, and worse, representing it as the only knowledge we need about humans is precisely to advocate mis-understanding human beings.

The program of consilience that Wilson sketched thus cannot take us far enough toward the necessary theories of everything. The next breakthrough in scholarship will require instead, a model of knowledge that incorporates all of the different characteristics of being and has all of the necessary tools for getting at them. Wilson's call for consilience, however, did recognize a real danger and concern. Wilson correctly sensed that a materialist view of knowledge must be able to connect up all of the kinds of being in some way. While biological being features emergent properties that are not shared with inert, inorganic physical entities, it arises from those entities in ways biologists have come to understand. Likewise, human being features emergent properties that are not shared with non-symbolizing creatures, but this does not permit humanity simply to discard its biological characteristics. We have suggested that a material theory of symbolization is the bridge that permits us to link up our biological character with the features of our being that are supervenient on that character. We hope that the preceding chapters have given sufficient support to gain consideration of that claim by most scholars, and to excite some scholars about joining the exploration. In the final chapter we will examine three sets of implications: understanding the academic enterprise, applying such knowledge to social systems, and developing and sharing future knowledge of this sort. First, however, the penultimate chapter will sketch a model and preliminary observed patterns of the interactions of biology and symbolics.

Chapter 11: The Bridge Between Biological and Symbolic Being

Summary: This chapter presents a model integrating biological and symbolic inputs to the individual and collective behavior of symbol using animals. The model integrates social and individual levels, it is probabilistic, and time-sensitive. In this model, which is illustrated in Figure 11.1, evolved capacities for behaviors (e.g., running, lifting, seeing) allow predispositions for certain behaviors (e.g. fleeing or working) under certain conditions. The environmental conditions inducing specific behaviors are transmitted to individuals via direct contact (e.g., the pain of an injury), indexes (the sight of torn skin), signs (the cries of pain from an injured friend), and symbols (the spoken report of the pain of an injury). This is to say that symbols often cue particular behaviors. Such cueing produces particular patterns of behaviors for individuals and social groups through three symbolic processes. Symbolization may amplify biological predispositions (e.g.,when conflict turns into world war). Symbolization may also channel particular dispositions (e.g. when status drives are manifested in snowmobile-in-the-lake competitions). Symbolizations may also fictionalize, creating worlds and responses that do not pretend to refer to an otherwise empirically accessible reality (e.g. playing videogames or describing the features of an afterlife). Through these symbolic processes, patterns of behaviors develop by accretion, so that an individual or society spends more time on some activities rather than on others. These behaviors also establish social structures (e.g., hierarchies, collectives, cultures, etc.) and lead to behavioral ensembles

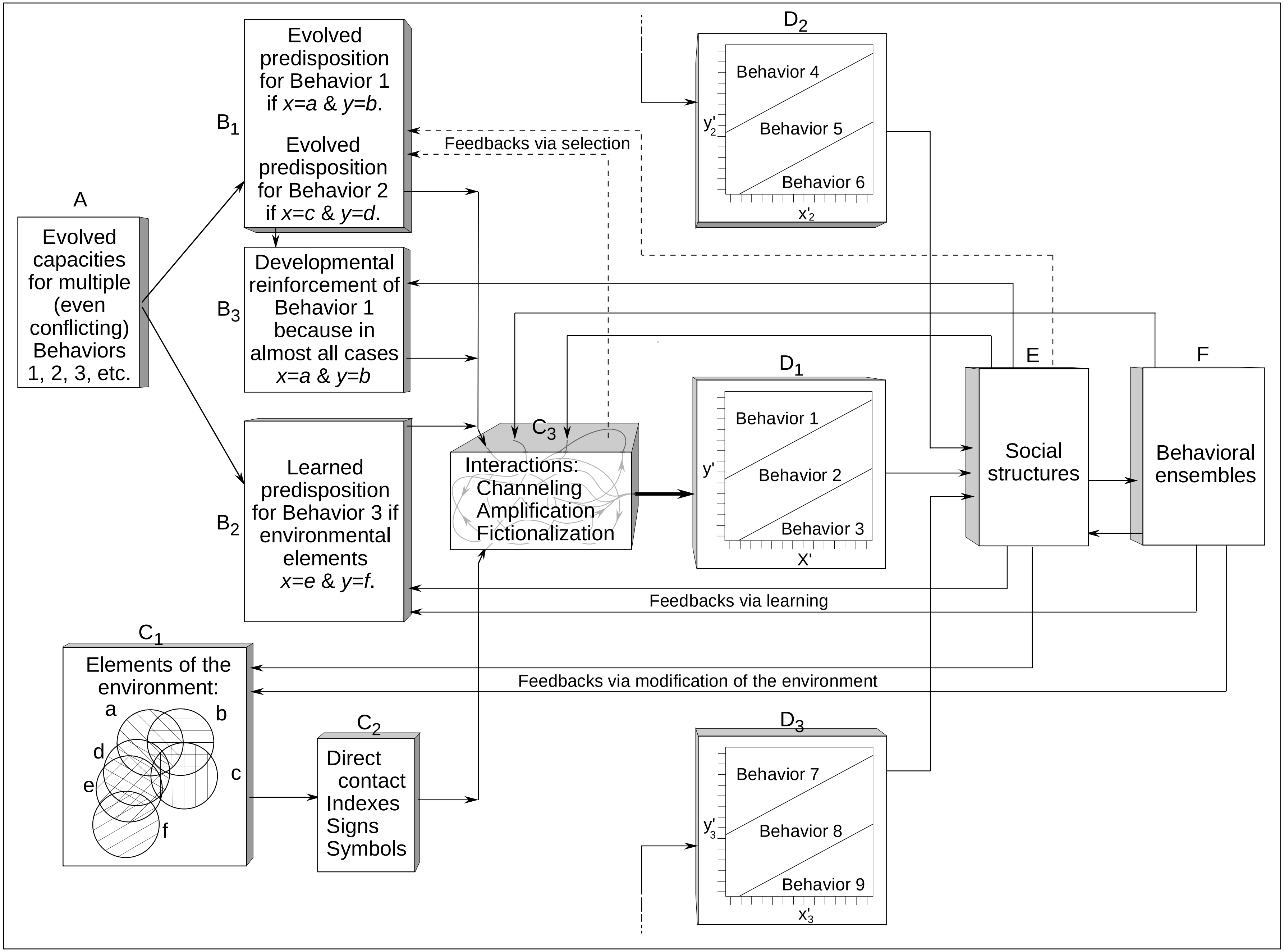

Figure 11-1: The Motivate model of the behavior of symbol users. Arrows leading back from E and F to B and C are feedbacks; additional feedbacks from D to B and C are omitted for sake of clarity. The greater depth of the volume for interactions reflects the greater extent of effectivity within. The Motivate model is named in parallel with the DYNAMATE model of Gowaty and Hubble.

(interlinked behaviors). Feedbacks from these behaviors and social structures include modification of the original environmental conditions, learned predisposition and reinforcement of some of the original behaviors, and even evolution (via selection) of biological predisposition for certain behaviors. One implication of the role of social structure in developing behavioral ensembles is that behaviors of symbol-users are not simply summative – the behaviors of individuals in a social structure will not simply be the sum of the behaviors each individual would perform on the their own. A second implication is that the aggregate life patterns among symbolizing beings may be quite different from the life patterns that established the predispositions, or be different among different social structures, because the aggregate of environmental cues (including symbolic ones) received are substantially different.

Evolutionary psychologists Randy Thornhill and Craig Palmer have written that "To argue that a given human life history feature is not a product of evolution would be to engage in mysticism."[310] We hope we have shown that this attitude, which neatly bifurcates the world into "evolution" and "mysticism," inaccurately restricts the description of the causal forces operating on symbolizing animals. Without denying that natural and sexual selection influence both the possibilities and patterns of human behavior, one can go beyond the old fear that to take seriously causal forces other than natural selection and sexual selection is to leave the realm of science and to threaten the hegemony of biology.

We have carefully described the properties of symbolic being in a materialist framework in order to allow the creation of a bridge between the biological and symbolic realms of being. We see this bridge as paralleling the way in which molecular studies of biological being have created extremely productive bridges between physics (or at least chemistry) and biology. It is obviously not possible to match the corpus of a hundred years of moelecular research in a single volume (or even decade). However, to encourage the development of such a research agenda, in this chapter we will offer a preliminary, general model of the interface of biology and symbology, which we call the MOTIVATE model. Similar bridging efforts have been undertaken from the biological side of the gap, most productively those of Richerson and Boyd (2005). Our model grows instead from the symbolic side of the divide. Instead of starting with the theories and perspectives of biology---primarily evolutionary frameworks—we begin with symbolic theories and perspectives, such as circulation, flows, and effectivities. Although we do not formally address where these two bridge-making efforts may meet, there are certainly visible points of contact in the two sets of work. We do not, however, believe that any of the components of this chapter are yet definitive. We suggest merely that they are both based on some solid evidence and are heuristic. Similarly, the second half of the chapter provides a preliminary introduction to three types of interactions between symbols and biology—amplification, channeling, and fictionalization.

Attributes of A Model of the Relationship Between Symbolic and Biological Being

There are three key attributes to the theory we will present that run against the grain of the way most bio-physical theories are formulated (as well as the way much other theory is formulated). First, the MOTIVATE model attends to the interface between the social and individual levels of analysis.[311] Second, the model is probabilistic and population centered. Third, the model is chronodynamic: that is, it takes place in a time-frame that transcends the effects of a single interaction, but instead is a product of multiple interactions that may be accretive, erosive, or multiplicative.

Interfaces Between the Social and the Individual

All communication is trans-individual. Symbolic activities therefore cannot be located exclusively in an individual's brain or even body. Instead, the effectivity of a communication phenomenon is determined by what goes on in more than one brain/body and also by what goes on as the symbols (the "text") travel outside the brain/bodies of the users. E.O. Wilson's proposed definition of the meme as "the node of semantic memory and its correlates in brain activity" is wrong.[312] Because the neural networks of all of the bodies involved in the communication phenomena are somewhat different, and because materially substantive things happen to the stream of symbols as they travel between bodies, one cannot simply look at a biological body to locate a meme. The individual brains are clearly a key part of the process, but they are not the full process. Consequently, any sufficient model of the interface of human biology and symbolizing must incorporate both the individual level and the social level (which is to say both the aggregate properties of the bodies of the different bodies of the symbol users and also the dynamics of the circulation of the symbols within the communication system). In the Motivate Model (Figure 11.1), Boxes A, B, and D represent aggregated individual level variables, whereas boxes C, E, and F represent stabilizations of the interactions of individual and social at the social level. This is an unfamiliar way to bring together these different kinds of variables, but it seems appropriate and necessary for the kind of phenomena that is human action.

Probabilities and Population Thinking

The integration of symbolic and biological being is only possible if one assumes a probabilistic rather than deterministic model of biological behavior. If genes simply determined a fixed pattern of behavior, then symbols wouldn't interact with biology to influence behavior. Identical twins would reply to the same sentences with exactly the same behaviors, including exactly the same words, all the time. While there is a tendency in some quarters to assume that biologically based behavior must be deterministic (in the sense that if one has a particular biological constitution, one can only produce one particular behavioral option), such a model is not accurate. Almost all biologists recognize that biological organisms tend to come with multiple behavioral options, and produce different behaviors in response to different environmental inputs.[313] To take an extreme example, animals may nurture their young or kill their young, depending on available resources and mates. Behaviors are not simply digital, however, but vary both by degree and by kind. The kinds and amounts of nurture provided to young varies not only across species, but also within species.

Recently, recognition of the availability of ranges of behavioral options has begun to produce a general acceptance that probabilistic models of behavior may generally be most appropriate. Within such models, one expects the behaviors within a given species or population to vary, and such variation to be a product of both differences in biological form (especially, but not exclusively, genetics) and also of differences in exposure to different environmental conditions at different life stages.[314] These distributions are increased by genetic variation within populations, but that genetic variation is itself a consequnce of nonconstant and nonuniform environmental conditions, because different genomes would have different success in different conditions. For this reason, and for clarity of exposition and diagramming, we ignore genetic variation within populations in most of this discussion. The key point is the focus on populations rather than on individuals, and the expectation that one can describe the range of behaviors and typical behaviors, rather than predict precisely an individual behavior.

Chronodynamism

A final attribute of a model of bio-symbolic action must be a framework that includes the accretion of events through time. In any non-universal (time-variant) phenomenon, a model that does not account for time is inaccurate. This is why developmental processes are essential for understanding biology, and why ecological models must specify time frames to avoid being non-sensical. Chronodynamic models—those that incorporate cumulative changes through time as a factor in models--face two obstacles. First, print media are incapable of capturing chronodynamism. We have not been able to overcome that limitation, but we have attempted to hint at the chronodynamism of the Motivate model by drawing Box C3 with multiple dimensions, and by making pathways in the model circular rather than linear. A much better model, however, would be a moving holograph.

The second problem with chronodynamic models is that the method of experimentation is better suited for single-event phenomena than for chronodynamic phenomena. This fact has led to an excessive and unproductive privileging of a particular version of reductionism that is incapable of coping with chronodynamism. In the worst cases, a false description based on an experiment is taken as more true than a more accurate description based on long-term observation. Expansion in the sophistication of methods can aid in this process, but it is an inevitable limitation that chronodynamic phenomena are more difficult to study than single-event phenomena. We have tried to infuse chronodynamism into our accounts of parts of the model, and especially to our exemplification of the three types of interaction between biology and symbology we describe in the second half of the chapter. Accretion of layers of symbolic effectivities, erosion of layers of symbolic effectivities, and unique interactions should all, however, be central concerns of such study.

The Motivate Model

We assume that such probabilistic, temporally sensitive, multiple-input models have the highest accuracy for most (but perhaps not all) behaviors of more complex life forms, and we base our MOTIVATE model of the interface of biology and symbology on this assumption (Figure 11.1). To say that the behavior of symbolizing beings is "motivated" (rather than merely "determined") is simply to say that in addition to the bio-functional and directly physical levels at which causation can be described in non-symbolizing beings, symbolic flows will provide a layer of explanation of the movements, actions or behaviors of creatures who respond to and produce symbols. The elements of the MOTIVATE model include an evolved capacity for a behavior, a set of potential sources for predisposing toward a behavior within particular conditions, and a set of cues as to the existence of external conditions. These combine to produce a range of behaviors within a population that may manifest an identifiable mean or modal character, but which, in symbolizing animals, may be aggregated in unique behavioral ensembles and shaped by social structuring of symbolic environments through learning or channeled cueing. We deal in turn with each level of the model in the following sections. Some of the details of the exposition may appear obvious, but if a precise platform for future research is to be established, it is better to over-specify than the reverse. Such overspecification will aid in identifying errors in assumptions as this area of research moves forward. After presenting the details of the model's components, we will turn to the more interesting phase of providing examples of three mechanisms for describing specific effectivities of such interactions between biology and symbolics.

A. Evolved Capacities (Box A of Figure 11.1)

The MOTIVATE model begins with the assumption that biological beings have evolved capacities for multiple behavioral responses. In other words, like all other biological beings, no symbolizing animal can do something it does not have an evolved capacity to do, *but biological capacities are not directly equivalent to behaviors*. Much intellectual error results from the failure to make this distinction. Humans could not use symbols if they had not evolved physiological capacities for speech production and reception, as well as brain capacities that allow generation of discrete signs, along with many other components. None-the-less, such capacities are not directly tied to single behavioral outputs. Some capacities are evolved specifically because they produce a particularly advantageous behavior, but other capacities are evolved to enable behavior A but consequently enable behavior B as well, especially in combination with other capacities.[315] Thus, for example, hands might be said to have evolved "for" grasping, but they also can be used for signaling. Capacities are not tantamount to behaviors, both because a single behavior may involve several capacities, and because tool use or symbol use may be part of a behavior or necessary to the manifestation of a behavior. Finally, animals have capacities for what are often perceived as conflicting or opposite behaviors—to fight or to cooperate, to run away or to approach, to nurture offspring or to kill them. This means that each manifested behavior arises from a selection or *specification* from a range of capacities as well perhaps from supplements such as tools or symbols.[316]

B. Behavioral Predispositions and their Sources (Boxes B1-3, Figure 11.1)

There is evidence that in humans evolutionary processes can predispose the running of some behavioral routines in response to some conditions, while different or even apparently opposite behavioral routines are run in other conditions. A simple and obvious example is the human tendency to sleep at night and to manifest greater wakefulness during the daytime. The more challenging instances are those in which multiple inputs may shape a balance between the specification of alternative behaviors. The research synthesized by Gowaty and Hubbell, which serves as an inspiration for our MOTIVATE model,[317] indicates that an animal may manifest either choosy *or* indiscriminate mate selection patterns depending on several factors, and each of the different factors may predispose the behavioral specification in different directions. Thus, for example, a large number of potential mates might push the animal toward choosiness, whereas a judgment of the relative fitness of the available mates might push it toward indiscriminateness**.** Furthermore, time is crucial to behavioral patterns**.** Long latency to mating produces different patterns than shorter latency to mating, because time matters in biological being (see Chapter 4; in the case of Gowaty and Hubbell's model time is a key constraining resource). In sum, while an animal may have the capacity to manifest either of two behavioral patterns, it is more likely to run one routine in a given situation rather than another, and environmental factors taken individually may be conflicting in their tendencies.

The patterns of behavioral specification for an animal may thus be quite complex, and any one species may have different patterns of predisposition for different behaviors. Some behaviors may be "obligate"; they are universally shared across almost all contexts for a given species (e.g. breathing patterns, only temporarily violated in pearl divers). Other behaviors may be widely or universally shared in some contexts (sleeping at night). Other behaviors may be shared on average, but not manifested by a substantial minority (serial monogamy), and the size of the minority may vary by context (a substantial increase in sex-segregated "monasteries" of one sort or another arises in certain conditions). Still other behaviors may be manifested only among minorities (e.g. shooting at cardboard targets in archery "hunts" and riding snowmobiles into lakes in the summer in the contests of Minnesotans').

These patterns are further complicated in some animals by multiple sources of behavioral predispositions. All of these sources must be encoded in the brain in some way, but they get encoded in different ways. Some behavioral predispositions appear to exist without active rehearsal or imitation or even in spite of alternative rehearsals and reinforcements (like the fright response in infants).[318] Some non-learned behaviors are obligate regardless of environmental conditions (e.g. breathing), but others may be manifested only in response to specific environmental conditions (e.g. falling). A different set of behavioral predispositions are engrained in the brain through learning (either through stimulus enhancement or imitation), as neurons that "fire together," especially repeatedly, "wire together" over time. Once wired together in a web, then when one neuron fires, it produces patterns of output leading to particular behavioral responses that did not previously exist.

This re-wiring mechanism also accounts for a third class of behaviors, those in which sustained developmental enactment strengthens some capabilities but not others, so that one among several non-learned options comes to have a higher potential. If a neural web related to the output of one behavioral routine is more frequently activated, the links of the web to other possible associations will grow, so that a larger range of conditions is likely to trigger this behavior rather than other behaviors. Consequently, if only one environment is encountered during development, one behavior may become habitual, and the animal may then become heavily predisposed toward that particular behavior, even if other behavioral possibilities would have been possible if a different range of environments had been encountered during development. The range of different causes for predispositions means that one can't assume that just because a behavior is exhibited in a context by a majority of participants that it is non-learned. The strength of a particular behavioral predisposition may also be a consequence of interactions among these different sources.

The variability of behavioral patterns and predispositional sources means that predicting which behavior will be manifested by an organism or set of organisms at a given time and context can be difficult. To take an example that is usually assumed to be non-learned, consider reproductive drives. A given human might be intrinsically predisposed to express sexual drives by interactions with persons of a different biological sex from themself (Figure 11.1, intrinsic behavioral predisposition 1), but that person might have been trained by their family through symbolic and other means to repress sexual drives (Figure 11.1 learned predisposition for behavior 3), and socially sequestered with persons of their same sex throughout the early reproductive years (developmental reinforcement of behavior 2, Figure 11.1). In such a case, it is not clear what the net predisposition toward sexual behavior of a particular individual or set of individuals will be. Moreover, all of those factors count as causes and predispositions of the out-put behavior.

C. Inputs as to Environmental Conditions (Box C Figure 11.1)

Whatever the strengths of various predispositions toward a behavior, the selection or specification of a particular behavior at a particular time is a consequence of environmental factors (for all non-obligate behaviors). For example, one does not express sexual drives at all times, but rather only at some times, and when and how these drives are expressed is a product not only of internal states such as those determined by the life cycle, but also of external cues such as availability of partners or safety. In humans, environmental cueing occurs either through direct contact with the environment (e.g. contact with sunlight increases wakefulness) or through indexes, signs, or symbols.

An index of an environment is an almost infallible indicator of an environment because it is in some sense a component of that environment. The visual appearance of a ripe berry is in this sense an index of a particular, desired environmental cue (a particular food is available). The index (visual image) of the berry is not, however, the berry itself, but merely light rays bouncing off the berry. There is none-the-less an extremely high correlation between the visual image of the berry and the availability of the berry for food. Rarely will a colored leaf of a particular shape be mistaken for the berry.

It is not surprising that indexes such as visual appearances, non-pheromonic smells, or even direct chemical contact with an environmental cue activate behavioral selections and produce predisposed behaviors. Many species, however, have also evolved the capacity to select behavior based on environmental signs. Signs, like indexes, are indicators of the environment, but a sign is not a necessary part of the environmental stimulus. An alarm call is the classic case. Pheromones probably also function as signs, since pheromones, unlike other smells, are evolved to communicate a specific state or presence, rather than being an accidental contingency (such as the smell of a rotting carcass). Clearly, animal behavior is specified in response to both signs and indexes.

The evolved capacities that enabled animals to respond to signs and select their behaviors based on those signs has, in some species, further evolved into the capacity for symbolization.[319] Symbolization is constituted by the interactions produced by a flow of signs. Thus, symbolizing species do not merely have the alarm call “Leopard!”, but they may also communicate more complicated information about the environment, such as

"It's not a very big leopard" or "You go that way, and I'll go this way, and we'll trap/avoid the leopard." Although symbolization is more complicated than sign response, and inherently more fallible, symbolizers use symbols as cues about their environment and thus as inputs to behavior specification on the same evolutionary foundations as sign users and index users. More research into neurobiology is needed to determine precisely the relationships between symbol processing and behavioral cueing. But it should not be controversial to understand symbolization as having inputs to behavioral selection of the same character as other environmental cues. This is the crucial point in the model for the integration of biological and symbolic modes of being. *THE FACT THAT AN ORGANISM CAN AND DOES INTERPRET ITS ENVIRONMENT BASED ON SIGNS OR SYMBOLS MEANS THAT SYMBOLS INFLUENCE THE BEHAVIORAL OUTPUT OF BIO-SYMBOLIC BEINGS.* As with all other cued responses, symbolic cueing must be conceptionalized as requiring material instantiations both in the brain of the responder and outside of that brain in "the environment." Both components must be present for the behavior to occur, and hence dual-causality is inherent to the process. However, the size and character of these inputs, and their independence from other biological inputs in the long term, require additional exploration.

The multiplicity of environmental inputs to some behaviors introduces uncertainty or variability into behavioral outputs, and symbolic processing magnifies this variability. Evolutionary processes probably pre-dispose behavioral responses to a small suite of generally co-occurring environmental conditions (e.g. "have sex if, appropriate sexual partner is available, and bigger nastier predator is not nearby, and if one's existing offspring are not threatened by that act, etc.). Presumably, the suites of behaviors are generally consonant with each other, or evolutionary forces would not have been consistent enough to produce an intrinsic predisposition. However, as the overlapping circle diagrams in Box C of Figure 11.1 are meant to indicate, compatible individual environmental components cannot be expected to completely overlap with each other. This creates “noise” in the selection process, and that noisiness increases variation in behavioral performance.

This noise is further increased by symbolic processing. Symbols may lack fidelity to the environment, either due to deliberate lying or to unrecognized discrepancies in symbolic codes exchanged between actors. While this lack of fidelity or code sharing cannot be too extreme, or organisms will presumably cease relying on the symbolic cues (or be extinguished), there is inevitably some degree of non-fidelity inherent to symbol use. Second, symbols may create artificial environments, either by constructing wholly or predominantly symbolic environments (e.g. videogames and novels) or because symbolizing enables the imagination and construction of artificial environments (e.g. space capsules or dungeons). Finally, as we will see in section E, symbols constitute a distinctive kind of behavior in themselves and they enable the creation of novel suites or ensembles of behaviors.

The complexities of the variability in sources for behavioral predispositions and the variability of symbolic and non-symbolic environmental inputs must be taken into account when describing the roles and relationships of symbolic and non-symbolic factors in specifying human behaviors. In those instances where symbols simply act as high fidelity cues as to environmental conditions, there is no tension between symbolic characteristics and traditional biological studies. Though biologists in such instances may argue that the symbol is simply a transmitter and the humanist may argue that without the symbol, the distant biological input could have no causal influence, in this category of behaviors, because there is seriality and consonance of the two components, one cannot distinguish differences in causal influence. To say one or the other is more definitive would be like saying that the first billiard ball that hit a second billiard ball was more important in the direction of a third billiard ball than was the second. In fact, the force and direction of the third billiard ball is equally a product of the size, and placement of both of the striking billiard balls, however much our psychology prefers to privilege "firsts". However, as should be clear by now, such instances of perfect reference cannot be assumed to be paradigmatic of behavioral causation for symbol-using species.

In some cases, symbolic inputs stand alone, largely independent of other non-symbolic environmental factors. In those instances, the characteristic features of symbol systems, as discussed in Chapters 6-8, exert a primary or dominant influence. Research on the influence of the mass media on people's attitudes exemplifies this point. This research indicates that the mass media exert a more powerful influence over issues such as foreign affairs, where individuals have less direct contact with the environments and events at issue, than they exert over more local matters.

In yet other instances, symbolic and non-symbolic cues might be dissonant with each other. For example, female heterosexuals might be told by the mass media that there is a deficit of high quality male partners for them, but a particular female heterosexual might see many high quality potential male partners around (or vice versa). A research program that sought to tease out the relative influence of symbolic and non-symbolic cues in cases of such dissonance would face substantial difficulties in generating purely non-symbolic examples, due to the ubiquity of symbolization for humans. However, in principle, one can imagine an experiment that exposed people to competing cues about the conditions for mate selection. If symbolic cues about the number of "high-quality" mates were disparate from environmental examples of the number of "high-quality" mates, it would be informative as to whether one set of cues dominated the other or whether both interacted to produce compromised responses. To be definitive such experiments would have to be of some extended duration, and this presents further difficulties for research design. However, such a research agenda would directly address the continuing and lively debate about the impact and importance of social portrayals of gender roles, race, sexual preference, disability etc. The debate about causes of gendered behavior has become a representative anecdote for the controversy between humanists and scientists in general. In truth, there is little empirical data that test such a hypothesis rigorously and no compelling syntheses of these data.

The relative influence of non-consonant symbolic and non-symbolic cueing is not the only interesting question. One might also to seek to understand whether consonant cueing produces stronger or even different behavioral responses from symbolic or non-symbolic cueing in isolation, and whether this varies by degree of consonance or other factors. More sophisticated questions about what constitutes symbolic cues with greater and lesser effectivity have already been asked by psychologists and communication studies scholars examining persuasion processes, but these might also now be related to variations in the biological basis of both the behavioral output and the related environmental inputs. Finally, research on the differential effectiveness of different "channels" of communication (oral, written, video) is a nascent instance of the further issue of the ways in which biological inputs and symbolic inputs affect behavioral cueing. By linking such research to neuro-science one might gain the avenue via which to generate the material bases for the relationships, similarities, and differences between symbolic and non-symbolic cueing.

A final key factor that shapes the behavioral outputs of symbol-users are processes that operate at the level of the symbolic flow, including amplification, channeling, and fictionalization. In Figure 11.1, Box C3, we have given these processes added visual depth to signify that these forces operate at two levels. First, they operate in the individual's brain by accretions that, over time, create specific processing biases. Second, they operate at the social level by channeling the flow of symbols that reaches the individual. Both of those levels affect what is commonly called the "interpretation" of the situation that an individual makes, and thus influence how a particular flow of symbols interacts with non-symblically based biological predisposing factors. Both processes also highlight the role of time in behavioral outputs.

Most analyses of the production of behavior conflate lifetime patterns with immediate responses. Such analyses assume that immediate responses and long-term patterns respond to evolutionary pressures, so that the relationship between a cue and a response is necessarily such that any given cued response produces, over the lifetime, fitness maximizing life patterns of behaviors. This assumption holds true if there is a stable environment. If there is a difference between the environment in which an organism's ancestors evolved and the environment in which it now lives, this match-up will not hold. If there is a different balance of environmental stimuli, the behavior pattern may be unbalanced. For example, an organism that responds to mating cues relatively more strongly than food storage cues might survive and reproduce profusely in a warm environment, but starve to death in the winter—thus ultimately producing fewer offspring over the life course—in a colder environment. For any organisms that have been living in substantially changing environments (as humans have), therefore, one cannot assume that the cued responses to immediate behavior are equivalent to optimal survival and reproduction patterns over the life span. Consequently, careful attention to the particular patterns of accretion are necessary to understand fitness, evolutionary forces, and behavioral outputs.

D. Variability of Behaviors (Box D Figure 11.1)

The consequence of multiple, variable inputs to bio-symbolic behavior is variability in actual behaviors and behavior patterns across a population. As Box D of Figure 11.1 indicates, there are not singular behavioral choices for each environment, but rather different distributions of behaviors in a given population, and the percentages change as environments change (as indicated by the diagonal lines across the box).[320] The areas in each box represent the percentage of a given population that exhibits each of the possible behavior types. The x- and y- axes indicate different environmental cues (to capture all of the possibly relevant environmental cues, an n-dimensional diagram would be needed). Key points are that 1) individual variation in behavioral repertoires will exist within a population for many if not most combinations of behaviors and environmental cues, and 2) in spite of individual variation there are detectable modal predispositions for any given environmental condition. To extend on the example provided by Gowaty and

Hubbell's research, for humans the MOTIVATE model leads us to expect that in most environments, some humans (of either sex) will be choosy about their mates and some will be indiscriminate about mate selection. However, there will be a distinctive mean degree of choosiness (or modal characteristic) for any environment (and because of different values for the inputs, for any gender).

Changing the environment (whether symbolic or nonsymbolic) in ways specified by the model can therefore be expected to change the distribution of behaviors.[321] However, whatever the distribution, different individuals will manifest different behaviors due to the particular intersections of environmental conditions they experience. This is true even if there were no developmental or genetic variation, because no two individuals live in exactly the same environment. Differences in environmental cues are likely to be magnified by a rich and diverse symbolic environment, both because of the enhanced environmental variation and because environmental variation may affect developmental patterns of exposure and what has been engrained on each individual brain through learning. The degree of variation in distributions and the degree of environmental variation required to change means is an empirical matter that may vary by behavior and environment. As implied by the discussion in C above, the degree to which some types of symbolic cues might substantially affect mate choice behavior is currently unknown. Not only is there relatively poor quality data on actual mate selection practices in natural human settings, but there is no reliable data on human mate selection practices in a wide range of potential environments. This same lack of knowledge about behavioral variation pervades the larger debate about whether humans manifest "universal" behavioral tendencies or not. The evidence most widely cited as to the manifestation of universal behavioral tendencies is Donald E. Brown's compilation of "universals" that appear in all cultures. This list does not address individual variation or even modal behaviors, but only indicates whether or not *any* members of a given culture manifests some set of behaviors that may be conceptualized under broad categories such as "cooperation" or "death rituals" or "decision making." In fact, most reports of human behavior do not identify behaviors that are universally observed. When universal claims are made, it is usually a mis-designation of mean behavior as though it were an intrinsic characteristic of an entire group.

E & F. Social Structuration and Behavioral Ensembles (Boxes E and F, Figure 11.1)

Where behaviors are interactive among species members, one of the inputs to behavioral patterns may be the individual and social behaviors of other members of the species (Box C). However, in highly social species, especially symbolizing species that develop "cultures," "political systems," "economies," and "institutions," an additional phenomenon develops. Individual behaviors may be cued in series or ensembles by symbolic inputs generated by social structures (Boxes E and F). Social structures consist primarily of patterned symbolic flows (e.g. laws, constitutions, ideologies, musical repertoires, politeness norms, social hierarchies, etc.), but factors that are not so exclusively symbolic may also play roles because symbolic interactions lay down specific physical configurations over time, to which individuals must respond (e.g. architecture, city-scapes, demographic distributions).

The elaborate social structures of species that are complex and sustained symbolizers have simpler analogues in other species. Wolves and chimpanzees have social hierarchies and exhibit some division of labor. Although the behavior of individual animals in such species is related to the social hierarchies, the hierarchies are relatively fixed in their forms, and they are constituted primarily through the interactions of individuals in contiguous space-time with each other. Honeybees form an interesting liminal case. The bees have both a simple symbolic language for communicating the location of food sources, and also a four-part social structure (queen, drones, nurses, foragers), which is in part organized around access to participation in the symbolic exchange.[322] The social role of individual bees is not determined solely by the quality of their particular interactions with other bees (as with wolves and chimpanzees), but rather also by developmental stage and social factors, such as how many bees are in the foraging stage of development at what time of year. In spite of this social level rather than individual level of determination of behavior, as far as we can tell, the bees do not build novel or highly complex ensembles of behavior and evolve new social categories. In contrast, complex symbolization capabilities, such as those of humans, seem to produce novel or highly complex ensembles of behavior and novel social categories.

When we use the term "behavioral ensemble" we are referring to a series of linked behaviors. The linkages of an ensemble are not only linkages of more than one behavior by an individual but also inter-active linkages with the behaviors of other individuals. Non-symbolizing species may exhibit simple behavioral ensembles (e.g. courtship and mating rituals). However, symbolizing capacities produce ensembles that may engage large numbers of individuals in highly interactive behavioral sequences (e.g. orchestral music or air traffic control) and especially sequences that have long duration (e.g. maintaining and running a school or business, building a cathedral, or developing a space-flight program). Such symbolically enabled behavioral ensembles have distinctive characteristics, including an extremely high diversity of motivations among participants (rather than single uniform causal inputs for all individuals) as well as a tendency to change patterns of symbolic flow and outputs through time. They are quasi-stable, rather than either stable or random.

The powerful and prominent role of social structuration in creating and directing behavioral ensembles invalidates E. O. Wilson's claim that human behavior can be understood solely as the "summation" of individual intentions, beliefs and desires. Social structuration is not a simple summative process.[323] Social structuration in symbol using animals arises from processes occurring both within individual bodies and external to them, as symbols have an existence outside of those bodies, whether in the air waves (where "noise" may distort them), in alternative media (where everything from the difference between typography and imagistics may shape them), or in distribution patterns among other human bodies (where circulation patterns give rise different effective force for different symbolizations).[324] It is in large part for this reason that humans, as symbol-users, cannot be studied solely by looking into their brains.

Social entities are often referred to by using organic metaphors, and this has been widely and carefully criticized. Although the move to a higher order of analysis is analogous, societies are quite different from organisms: they rarely reproduce high-fidelity copies of themselves in other entities (colonies might be an exception), their boundaries are far less distinct than cell walls or organisms, their political systems are far less centralized than central nervous systems, they have nothing akin to DNA guiding their development, etc. Societies are perhaps more like eco-systems. Symbolic societies manifest the looseness of connectivity and the non-discrete identity typical of eco-systems rather than the tighter functional connectivity and discrete identity of organisms. As we have recently been learning, however, understanding the inter-relationships of an eco-system is important for studying the evolution and behavior of any biological organism. Of course, because social systems are constructed of both symbolic and biological materials and processes, they are not exactly like eco-systems either. In the next part of this chapter, we will explore three of the unique features of social systems that arise from the interaction of symbolic and biological components.

Interactions of Symbols and Biology

The MOTIVATE model of the interaction between symbols and biological being should provide the basis for a variety of different theoretical statements about the ways in which symbolic processes interact with other biological processes in human beings. Many of these will be at very narrow and individual levels of analysis. For example, we are currently doing investigations into the relationship between symbolic labeling and perception processes. Other theoretical accounts will address processes that have social or broader chronodynamic frames. Investigations into gene-culture co-evolution may fall into this frame—and such a project has already independently been advanced by the brilliant work of Richerson and Boyd (2005). But social level processes that fall at shorter time frames will also be important. In the last half of this chapter, we illustrate the latter by describing three different social level patterns of interaction between biology and symbolizing that produce distinctive kinds of effects. We focus on these processes both because they seem to us to be major and because Chapter 12 will show how understanding such processes may allow better approaches to the social level shaping of human behavior. Proceeding from the most simple to the most synergistic, these processes are amplification, channeling, and fictionalization. This is not a complete catalogue, and we presume there are many interesting patterns that will eventually be added to this theoretical account, but these should indicate initial lines along which a research program directed at a robust understanding of biological/symbolic interactions might proceed.

Amplification

The simplest example of a social effect of the interaction of symbolizing capacities on biological characteristics is the amplification of selective biologically enabled or predisposed behaviors. Amplification via symbolization enables behaviors that may have small-scale evolutionary platforms to operate on larger scales. Thus behaviors such as kinship-based cooperation or tribal conflict can be escalated to produce global-level governments and markets and global-level war.

To think about how this happens, it is worth briefly thinking about modern warfare. Organized killing, most notably among chimpanzees, seems to indicate what might be called an evolved platform for "war".[325] However, such relatively small-scale conflicts can only be translated into global-scale *war* through symbolic processes. Modern wars are conducted through the organized efforts of millions of people, who are induced to cooperate with others thousands of miles from themselves, whom they would never otherwise contact. This occurs primarily, if not exclusively, through symbolic means, which enable the marking of people on the other side of the planet, people whom they would never otherwise have any reason to contact, as "enemies". Such symbolic marking processes engage with a series of evolved protective responses.[326] Subsequently, against these alien "enemies," millions of individuals risk their lives or at least spend their treasure. The identification of this large, abstract, and distant people as a threatening out-group is accomplished through symbols, rather than through experiencing direct personal threat from the "other". Similarly, the construction of the self-protective in-group is symbolic, as these groups do not have to be kin-based, and they do not even have to include people who know each other or are tightly interdependent.

The rhetorical processes that accomplish these tasks—identification, scapegoating, and dehumanization—are relatively well understood by symbolic theorists.[327] In addition, the ability to achieve the social organization necessary to execute such an effort is also enabled only through symbols. Fundamental aspects of symbolic processes—such as the highly nested hierarchicalization symbol systems facilitate as well as the pervasive binarism they encourage—can be traced to this capability for large-scale amplification, and even proclivity for war.

Amplification, of course, may also work toward more constructive ends. The vast cooperation required for the enterprise of science to succeed is surely based on an evolutionary platform of cooperation, which arose first among kin, and then among persons with whom one shared survival-dependence, particularly those who lived together (e.g. "tribes"; see Appendix 2). Today, however, changes in symbol-distributing mechanisms allow cooperation to occur among individuals who may never even meet and who do not have linked survival dependence. Scientists who live thousands of miles from each other and indeed, may not depend on each other for personal prosperity, routinely exchange samples and labor (for review of manuscripts and organization of conferences), as well as research materials and the bodies of their students. The patterns of cooperation among these groups is surely influenced by biologically based factors (such as status drives or even evolved mechanisms for cooperation). However, the ability to imagine and execute global scale cooperation among loosely networked individuals is made possible by the added properties of symbolic capacities and specific material forms of symbol-distribution.

Such processes of amplification are not, as Wilson described them, a "summative" process of individual intents and desires. The difference between a thrown rock and a nuclear bomb is, at the least, multiplicative. The rapid development of culture after the onset of human symbolization has not been directly quantified, but one would not predict that it would be describable in a formula that increases one unit of cultural diversity for each additional human.[328] Regardless of the precise mathematics of the relationship, the most interesting thing about symbolic amplification is not the shape of the curve, but rather the issue of under what conditions different, potentially competing processes of amplification occur. Within any set of large human groups there is sometimes warfare and sometimes only cold hostility. Likewise, levels of cooperation vary, during the late twentieth century biological science was characterized by high levels of cooperation, but the level of cooperation appears to be declining dramatically, and this appears to be due to changes in symbolic codes that valorize and make available financial gain for individual scientists or their institutions.

The questions of the extent to which amplifications can be deliberately forestalled or heightened by symbolic means, and under what conditions that can occur, appear to be open. The fact that conflict, cooperation, or competition have biological drivers obviously does not determine that war is omnipresent. Because war is dependent on symbolic mediation, it is possible that symbolic intervention might be effective at forestalling war, at least under some conditions (the case for the potential of symbolic means to have averted the genocide in Rwanda and Bosnia seem particularly strong). Because scholars haven't asked the question in this fashion, no one knows whether this is true. It may well be that symbolic interventions are always too weak to forestall the spiral of environmental factors that lead human groups to active warfare at particular times. Or perhaps symbolic processes can be used to preclude such environmental conditions in some instances. Developing a more precise understanding of these interactions would seem to be a pressing research agenda.[329] It may, in fact, provide humanity's only hope for long-term survival as resource shortages spread with the global population explosion.

Research agendas that explore the relationships between non-symbolic biological capacities and the amplification that is enabled by symbolic capacities will probably need to explore the variation in means of amplification, the specific types of biological capacities that can be amplified, and modifications that appear to occur in the characteristics of the effects of symbolically amplified capacities. Amplification is a potent but relatively simple example of the ways in which symbolic capacities create social-scale effects. Channeling is a more complex form of interaction.

<u>Channeling</u>

When social scientists insist that there are social scale processes that are not merely the sum of individual biological drives, they are usually referring to some component of what we would call channeling. *Symbolic systems can be structured to channel the flows of individual level behaviors to create novel ensembles of behaviors, to change the priorities and timing among behaviors, and to produce distinctive interactions among behaviors of different individuals.* While individual drives, interests or beliefs are a necessary component of symbolic channeling systems, one can only fully explain the system or the timing, patterns, interactions, or ensembles of behaviors by referring to something in addition to the individual level drives or behavior. Specifically deployed symbolic sets are able to select some biological predispositions for cueing in specific time and places and with particular frequencies.

This is to argue directly against Wilson's claim that "the rank order in dominance among categories [of needs] such as sex, status protection, and play appears to be genetically programmed." As our anecdote will reveal, symbolically generated, and symbolically interpreted, phenomena may induce specific rank orderings of many biological needs, at least if rank ordering is understood in material terms, for example, as amount of time spent engaging in an activity.[330] The selective distribution of biologically based behaviors is made possible by the historically material (i.e. "arbitrary") nature of symbols, and the particular means by which priorities are shaped are responsive to the micro-level characteristics of the symbolic flows (such as narrativity, evaluation, moral force, effective use of binarism, etc.). Because symbolic channeling is a pervasive feature of contemporary human life, this means that explanations of human behavior must focus on this symbolic or social-level explanation. To explain channeling, an anecdote is instructive. In this anecdote we will describe the ways in which cues from a set of symbolically instantiated structures produce particular behaviors at particular instants in time, and how those behaviors accrete over time to produce patterns of behavior that must be understood as a result of the channeling of biological predispositions that, without that channeling, would produce different behavior patterns.[331]

Imagine an average American's day. She wakes up in the dark to an alarm clock. The clock calls her to ignore her innate biological programming with regard to sleep cycles in favor of long term goals for feeding, status, pleasure fulfillment, or care of her offspring. The alarm clock is, of course, merely a proximate cause—a physical mechanism has been created to over-ride and reshape the biological sleep cycle. The more fundamental cause is the complex set of social patterns that give our average person access to desired or needed resources and activities only by over-riding her sleep cycles, and that have made her believe that she desires and needs particular resources and can best achieve them in this fashion.

These social patterns are symbolically enabled--she is aware of the need to violate her immediate biological programming only due to the symbols she receives. Do the social patterns in turn depend on "deeper" biological causes? Surely, in part. There are biological limits: if she does not eat, she will die. There are also biological predispositions: she enjoys sex and watching sexual displays on video; she enjoys the feeling of dominance that comes from high social status. But as we watch her day unfold, we will see how the biological drives are ordered and prioritized by the time-shifting and selective amplifications of the channeling process.

She dresses and feeds her self and her children, and she drives the children to their school complex, where they will spend 18 or more years learning about subjects as diverse as the organization of the solar system, thousands of years of human history in dozens of different cultures, as well as how to read, write, and calculate. None of these things were done by Paleolithic peoples. Moreover, taken together, they mean that human children in these societies spend well over a decade in formal learning before ever engaging in productive labor. The symbolic channeling systems thus not only create novel behavioral ensembles (formal schooling), but they change the time distribution of behavior patterns, which is tantamount to a change in priorities among them. Time that would previously have been devoted to reproduction is now, instead, devoted to training. (For many individuals, this will contribute to lower numbers of offspring).

After dropping off the children, our everywoman enters a vast freeway complex, which channels hundreds of thousands of people, scores of miles from their den, to a "workplace." This is not only an amplification of population and of mobility, but also a change in the character of the persons with which one will interact. These numerous interactions are among strangers rather than tribe-mates, and they are often cursory. This change in interactions will be overlaid upon engrained predispositions for different rules for interaction among "us" than with "not-us" in complicated ways, and overlaid by training in social norms in churches, schools, camps, and workplaces.

The workplace is a part of another symbolic circulatory system. If it is a "white collar" workplace, the day is spent almost entirely in the circulation of symbols. The "business" itself is constructed almost exclusively by the circulation of symbols. While the buildings that house the business may exert some influence on the character of the business, it is the written legal contracts and organizational policies that define the business and thereby stabilize it as an entity. The business is literally a circuit circumscribed by symbols and defined by the flows of symbols that circulate through its networks.[332] The utility of that flow to the larger world--manifested in forms of connections between internal and external circuits—also helps structure the local flow of symbols. In turn the flow within the workplace structures most of the workers' day.

If the workplace is "blue collar" there are more tangible material objects around—the widgets that get sold and the machines that produce the widgets. The material properties of these widgets and machines exert perhaps a greater (or at least more visible) force upon the behavior of the workers there. But the business is still constituted by symbols--legal contracts and organizational policies. The behaviors of the individuals in the workplace are still directed by the flow of symbols that indicates who is a manager, and who will work which machine, and when lunch hour will be, and who will get paid how much of the symbolic currency that links the business intricately to the rest of the society.

Our worker's day is programmed by symbolically-induced selections and orderings of the biological needs to gain the food and the status that enables survival and reproduction. Because the worker responds to the symbolic cues as environmental cues, the behaviors that she manifests at a given time, and cumulatively across time, are a product of the symbolic cues she receives. This means that directly the worker's day will be governed by the flow of symbols that is determined by the organization's circulation system. Where she will be at nine o'clock, with whom she will converse at ten o'clock, whether she will sit all day at a computer or a machine press, or spend all day meeting with strangers, are determined not by the interface of brain-intrinsic programs and local biological conditions, but by the supervenient force of the circulation system of the symbolic world in which she lives. Of course, the biological drives place constraints on the channeled possibilities. If there is no lunch hour at all, there will be consequences for productivity. This is thus an interaction between biology and symbolics, rather than an overwriting of biology by symbolics. Nonetheless, within these constraining forces, the symbolic system has enormous power to influence her behavior from moment to moment. Because it influences the behavior from moment to moment, it also has the power to influence where she spends most of her time and effort, and this may well be in proportions different than might be understood to be prescribed by biological predispositions.

Our worker will go home to her family, which bears some striking resemblances to her Paleolithic ancestor's family, but also some striking differences. For example, she lives in New York, and her parents are over a thousand miles away in Florida. She is alive at 45, and has taken active and difficult efforts to restrict her offspring to two. She may spend her evening vacuuming or cleaning her toilet bowl or she may spend at least some of it reading or locked into her television set, which beams her news and fantasies from around the world. The immediate draw of the pleasurable fantasy might be greater at the end of the day than the desire for sex, especially if the pleasures of sexual fantasy are more available, less energy intensive or risky than sexual intercourse. The draw of tele-fantasy certainly may be greater than the desire to procreate, which she can unlink from her desires for sex, due to her society's symbolic capacities.

Having responded each minute, each hour, each day, to the symbolic cues of organized and less-well-organized circulations of symbols, the total pattern of her life aggregates. *Although each response is in part a biologically constrained and even driven response, the total pattern is not simply a product of the net force of the biological drives of the human person.* Different people, with the same non-symbolic biological "drives" are living very different life patterns, even with regard to fundamentals such as mate choice, number of offspring, resource acquisition, etc. In other words, one can't understand why our average person has spent her life in a fashion that fails to maximize her reproductive potential, and perhaps even fails to maximize her wealth and social status, simply by adding up her evolutionary drives. To understand her behavioral output, and that of the members of her society cumulatively taken, one has to trace the symbolic channels.

The worker's day and the rest of her life is programmed not only directly and evidently by the symbol circulation system of her workplace, but also by the larger society. For example, on commercials and billboards and in vending machines, the appeal of tasty foods is used to get her to work harder to buy more expensive food that may actually shorten her life span and that may come at the expense of her reproductive potential. Rigorously describing what exactly constitutes "society" is not a simple matter. "Society" is a relatively abstract concept, but although society may not be as visible as a building or as localizable as a business, it is a powerful force that guides each of our behaviors in every day and throughout the course of our lives in the industrial and post-industrial eras. Contemporary society is the total set of inter-locking symbol circulation systems of the now global human community. The linkages may be denser in some places—greater in cities than in states, greater in nations than in the global economy as a whole—but the inter-circulation is pervasive. We can only see it if we follow the flow of the symbols and detect the repetitive patterns that they make, thus identifying the circulation system, and how it channels biological drivers.

The anecdote about the worker's day illustrates the ways in which symbolic channeling exerts profound influences upon the manifestations of human behaviors. 1) Symbolic flows reset the timing of biological clocks. Not only do they change the daily timing of events—when we get up, when we eat, or how much time we spend in work—they also influence life stages. Adolescence may be delayed and extended, reproductive activity may be delayed, truncated, or differently spaced. 2) Because they reset timing, symbolic channeling may also reset priorities. Whatever biological predispositions are fulfilled by "work" (status drives, security, mental stimulation, social interaction) have gained an apparently higher priority in post-industrial societies among professional classes than have biological drives such as maximizing reproduction. 3) Symbolic channeling also creates novel ensembles of behaviors and distinctive patterns of interactions among individuals or groups. These include changing our biological forms, by piercing body parts, cutting, curling, straightening, and dying hair, injecting silicone to reshape our bodies, injecting biological toxins to reshape our faces, and undergoing surgery to cut out our fat stores.[333] Human symbol-users also change their patterns of interaction. Using a computer is a novel behavioral ensemble that engages the human body-mind in ways unlike anything available to humans previously. Computer-mediated human interactions have some very interesting properties, including a heightened tendency toward extreme expressions of hostility and the creation of malleable identities, the extreme example of which is an adoption of alternative sexual identity.[334] Research by Walter Ong, Harold Innis, and Marshall McLuhan has already pointed up the ways in which new communication media alter human behavioral patterns and interactions.[335] Extending this research to neuro-imaging would seem to be a productive research program, integrating biology with symbology.

As we have constantly maintained, a research agenda focused on interaction must assume that symbols are operating as a material force. This means that they are not independent of other materials forces, but enmeshed with them. This requires a change in orientation within the old "behavior/environment" model. The existing model used by evolutionary behaviorists is focused on explaining when evolutionarily salient features of environments elicit particular behaviors from individuals. Thus, for example, it is assumed that suicide bombing must be explained solely in terms of its capacity for enhancing reproductive outcomes for the individual who commits the suicide. Given the MOTIVATE model, however, and understanding the power of symbolic flows to re-channel behavior, a more complex analysis is needed. First, one must account for the ways in which and extent to which the symbolic environment represents the reproductive outcomes of the individual in a fashion that enhances the perceived attractiveness of suicide bombing as compared to other cues about the available reproductive outcomes of the individual. Second, one must also account for the independent force of alternatively constructed symbolic goods. These include things such as status rewards in an after-life or perceived contribution to an abstract good. These symbolically constructed goods draw on biological predispositions, but the symbolic channeling may re-prioritize biological drives, so that an effect that has, in fact, greater selectionist value to the individual (or the individual's genes) may not, in fact, be the primary motivator that drives a crucial behavioral selection. This is, of course, tantamount to saying that a symbolic community may not be an evolutionarily stable one, or that the evolutionary dynamics of a symbolic community are as much culturally based as individually based. This challenges important biological orthodoxies, but it is a hypothesis that must be considered, given the apparent dynamics of symbolization.[336] It is not a hypothesis that has been formally considered from a perspective that understands symbolization as a material phenomenon, and we provide a partial address to it in Appendix 2. Here, however, we consider the most radically distinctive interaction between symbols and biological capacities.

Fictionalization

Fictionalization is the last component of our beginner's catalogue of mechanisms for the interaction of biology and symbology, and it is the most radically symbolic. Fictionalization is a product of the narrative character of symbol systems, but also of their basic categorizing tendencies. Because symbol systems enable the creation of extensive fictional realms, they enable a set of sustained behaviors whose internal logic is explained in large part by components that are not otherwise "real." That is, instead of symbols standing as cues for environmental factors, the symbols create an environment that is at least one step removed from the non-symbolic portions of the individual and social environment. To be effective fiction, the symbols must still cue biological phenemona (from stimulating visual or aural centers to activating sexual or dominance drives), and a biological being can never get completely away from the bio-physical realm (so that socio-economic factors still shape the fictional realms). None-the-less, the symbol system constitutes a buffer between the environment and the individual, rather than a reference to it.[337]

By fictionalization we mean to demarcate the creation of realms of activity where symbolic flows specifically pretend to denote no being outside their own symbolic realities.[338] In contemporary U.S. culture these include fiction appearing in television, film, and novels, as well as games, including video-games, some chat-room activity, and all viewer-oriented sports.[339] In the sense we use the term, however, "fictionalization" also includes the production of music (with and without words), art, and the fashion industry. Although these enterprises do not use words, they do use symbols as their currency, and these symbolic flows do not have primary denotative functions. In all these fictional realms, the fantastic character of symbolic being dominates. These "fantastic" qualities are linked as well to psychological processes of the un- or sub-conscious, though exploring these links is beyond the present scope.

The average inhabitant of the U.S.A. now spends an enormous amount of their time in this "made up" or fantastic realm. Although estimates that people have the television on 8 hours a day do not accurately denote levels of engrossment in the fictional realm,[340] it is probably reasonable to estimate that the average native of the U.S.A. spends at least 15 hours a week involved in producing, and especially consuming, fiction. Because of the time and economic resources devoted to it, not to mention because of its banner status as a distinctive human activity, the fictional realm constitutes *significant* human behavior. If we are to understand human beings, we must have academic work that treats of these symbolizing behaviors in their own terms, and we must have research that addresses the interactions of biology and symbology more directly. At this point, however, we can offer only an anecdote that may provide a focus for such a program and a few suggestive directions.

A teenager reading a novel with sexually explicit or violent content responds in some sense to the mere words on the page as though they constitute "real" violence or sexual stimuli. The reader is likely to become sexually aroused or frightened, perhaps even aggressive. Nonetheless, the response to the fiction is also not quite the same as a response to "real" violence or sexual stimuli. The teenager doesn't really expect to be able to have sexual intercourse with the heroine of the novel, most readers contain their fear responses, and most (but not all) readers do not commit violent acts subsequent to reading the content. However, there is relatively clear evidence that sexual aggressiveness is higher among those who consume pornography, especially pornography that is more violent and degrading.[341] Fiction thus creates responses inter-related with but not exactly like responses to symbolic and non-symbolic cues that are understood as non-symbolic.

As many writers have already recognized, there must be both biological and social explanations for the distinctive behavioral responses generated by fiction. This calls for a program in neuro-imaging that is detailed enough and sophisticated enough to parse the similarities and differences between the brain's processing of responses to "real" violence and "fictional" violence (or other basic stimuli such as food or sex or cold). The program needs then to be able to link up those mental pathways to the different chains of symbolization that flow from those different cognitive responses, and to link them to social factors. Social factors are clearly important, because in some contexts a substantial number of people do, in fact, act out the violence they have seen, and in other contexts such responses are highly exceptional. (An example of a film that encourages people to act out violent responses is a military indoctrination film, as opposed to a Hollywood "war" film). There may be differences based on symbolic qualities of the stimulus material as well. For example, social critics of film have been engaged in arguments for the past two decades about whether parodies produce the same social effects as straight representations of undesired actions, even if they do not represent the same artistic sentiments. A more empirical program of research seems to be appropriate for this area.

There are, of course, other interesting research programs possible at this intersection, though some of them will seem at this point highly speculative. For example, are there large differences in the proportion of time and resources different cultures expend on fictionalization? If so, how might high-fiction cultures shape the biological development and evolution of their members?

The human ability and affinity for creating and inhabiting a fictional realm makes our behavior very different from our primate ancestors, at least in some ways. You don't see chimpanzees fixated in front of a television screen for hours on end. Studying chimpanzees and gorillas may give us some interesting information about why Shakespeare is considered the best play-wright of the Western world or why Toni Morrison is an award-winning novelist, but they cannot provide a full account. As we noted in Chapter 8, the "made up" beings of the fantastic realm are a product of the unique convergence of the time-space binding properties of symbolization and its arbitrary material character. Methods for studying such a phenomenon must be sensitive to those properties of being.

Summary and Forecast

This chapter has presented a heuristic model for understanding how it might be that symbols interact with other biological facets of humans in producing the distinctive patterns of human behavior in any time and space. It has suggested that the existence of symbols both inside and outside of human bodies, as well as the distinctive material properties of symbols, makes it possible that symbols exert a unique force upon human behavior that does not merely replay biological forces in a new way. The chapter has suggested how it might be that the processes of amplification, channeling and fictionalization might produce novel and distinctive patterns of human behavior, and it has offered some directions for studying those processes.

A major implication of this model and the analysis that undergirds it is that symbolic behavior may produce aggregate human life patterns that are not simply those biologically programmed by natural selection in response to physical environments. Symbolic environments, and the structural dynamics of symbolic processes, may also be crucial causal variables. As one overviews the patterns of human behavior around the globe, one sees evidence of this. War powers have been heinously amplified, and bouts of "ethnic cleansing" now claim the lives of hundreds of thousands of people in a few months. A global market amplifies basic biological capacities for trade to produce amazing flows of goods and ebbs and flows of wealth. As for channeling, people with more income and more education produce fewer children, even though their wealth would enable far more (and this cannot be effectively accounted for by a "quantity/quality trade-off").[342] In a related example of time allocation to the fictional realm, many men spend hours of time engrossed alone in videogames. This time may have payoffs in transferable skills and status, but it is probably a very low time-to-payoff ratio, and probably has very negative impacts on personal biological reproduction compared to other ways of spending time. Another vivid example of the effects of channeling and the advertising world's use of fictionalization can be seen as people around the globe waste time and resources driving personal automobiles instead of traveling in efficient mass transit systems or more healthful walking and bicycling. This pattern has developed because institutional entities such as automobile, trucking, and airline industries lobbied for the creation of public roads and airline systems instead of public sidewalks, bikepaths, trains, and buses. These campaigns were assisted by appeals to biologically-based drives such as autonomy and status (in the form of class appeals), and were assisted by the chronodynamic fact that in early phases easy parking and low traffic made personal driving efficient in a way that is no longer the case. None-the-less, it is not correct to say that the biological drives of autonomy and status are *the cause* of the transportation nightmares of industrialized countries. These biological drives were channeled in certain directions by the circulation of particular symbols rather than others, and are maintained by a fictionalized image of a freedom provided by automobiles to roam the globe that matches poorly with the actual experience of sitting in traffic jams and hunting for parking

Understanding the patterns of human behavior on both the social and individual level thus requires more than understanding biology. It requires understanding biology, symbolic processes such as channeling and fictionalization, specific symbolic contents, and the interaction of all of these. Of course, even if symbolic processes only can produce variation within the constraints of biological drivers governed by natural selection, human symbolic processes are interesting, for they do account for much of the variation within those constraints. However, we believe that it is possible that human symbolic processes may exceed the constraints of the biological components of natural selection. Those possibilities may operate in the mid term or even in the long term, and they deserve some careful thought (see Appendix 2). We have moved about as far as one can go in a single book-length treatment, however. We close, therefore, with some radical speculations about the implications of this transilient framework for social policy, education, and theory.

Chapter 12: Three Transilient Proposals

Summary: This chapter draws on the arguments and model developed previously to generate new approaches to three major issues. First, it proposes new ways to think about social policies and the kind of future humans create for themselves. Second, to better support the creation of such desired future paths, it proposes changes in academic practices including a new program of research integrating scholars from many fields, and it suggests that understandings of humans as symbol-using animals should be taught as a basic part of the knowledge needed by all people to understand themselves and their society. Finally, this approach requires a more realistic theory of knowledge with an expanded understanding of how science actually works, extending beyond the Popperian model still dominant today. This approach to science would also acknowledge, and hopefully ameliorate, the symbolic biases that affect scientists' choices of the hypotheses they investigate.

A mass of molecules moves forward and back in a square area approximately 10 meters by 20 meters. It emits sound waves in a sustained fashion. Another mass, one among many located approximately 30 meters away, receives the sound waves. Two rotations of the earth later, the two masses are in the same vicinity, although kilometers away from the original site. They alternate emitting sound waves. Gradually, through the next two lunar cycles, the two masses are in each other's vicinity with increasing frequency. They overlap their masses more deeply and more often. Approximately nine lunar cycles later, the mass that originally emitted the sustained sound waves expels a new mass of molecules.

This anecdote, the story of an American musician, the Australian immigrant she marries, and their child and eventual diplomat, puts in specific form a question that has had a particular intensity in the past few decades, even though it is a question that has been raised as long as humans have offered conflicting schemes to each other for understanding the world around them. How can we best describe human beings and their behavior? What can we know about them, and how do we go about knowing it? Are the best descriptions those that focus on the ideas and aspirations of the individuals involved, or are these just faulty veils over the true driving forces of biology and evolution? Or do even more "fundamental" descriptions—the interactions of molecules, atoms, quarks, or even strings—provide the accounts that tell us what "really" is going on when humans interact?

This book has argued that an adequate explanation of these transplex interactions requires at least three different types of explanations—physical, biological, and symbolic. An adequate explanation further requires not merely independent levels of explanation, but also an understanding of how the biological and symbolic forces interact to produce the distinctive patterns of human behavior. Human knowledge systems have accumulated a substantial amount of information about the physical, biological, and symbolic levels of explanation. They have accumulated relatively little about the interactions. We have tried to add some instructive examples to that storehouse, and to show the underlying logic that makes it conceptually rational to study interactions between biological and symbolic systems. In this chapter, we try to indicate how such a program of research might help us in the solution of pressing social problems, and then we discuss some revisions required in academic institutions and the theory of knowledge to achieve those goals.

Using the Products of Knowledge for Better Futures

In opening this book we indicated that what has been taken to be the model of physics has been widely cherished and admired because the study of physical being has brought humans such immense control over the physical world. Knowledge of physical being at some scales readily produces what we have called "leveraged" control that enables manufactured products from that knowledge. In contrast to this support for physical applications of knowledge, societal programs applying symbolic knowledge to solve societal problems are commonly viewed as either hopelessly ineffective or ethically suspect. Chapters 4, 9 and 10 explained why ethical concerns are ineradicable from symbolic applications, and there is, indeed, no means of fiating moral challenges. We have suggested that democratic social practice is the only morally acceptable way to proceed in applying the knowledge of symbolics or bio-symbolics to human beings and human societies. This is a difficult and unwieldy method, so progress will be slow and uneven. But on some major issues, accepting those challenges seems worthwhile.

What the theoretical formulations of this book suggest can be done differently is to add a distinctive self-understanding to the processes of social deliberation. This self-understanding replaces older visions of ourselves as merely smarter apes, merely rational agents, or as fallen angels passing time on earth until we get to heaven. This new vision sees us as a symbol-using animal--a creature guided by a complex set of interactions between evolved biological drives and accreted, but variable, socio-cultural patterns and institutions.

This bio-symbolic perspective on human beings can enable change in human behavior patterns because it overcomes the omissions of previous partial views. A view of humans as merely animals cannot support a vision of human change because animal behavior is solely programmed by biological factors in response to relatively narrow environments. It is, in fact, human symbol systems that enable humans to consider choices based on moral considerations rather than solely personal and immediate needs and gratifications. An understanding and appreciation of symbolic processes is therefore mandatory if one is to envision human change. But non-material approaches to symbolic change prove insufficiently effective. Human biological systems are amazingly flexible, and they can be pushed by symbols in many ways, but they cannot be pushed in just any direction, or to any extent, and there are always costs to such steering. It simply is not enough to provide a steady stream of symbols envisioning a symbolically-ideal utopia in order to get people to enact that utopian vision. The vision itself needs to be responsive to human biological constraints, and the symbolic stream that would channel behaviors toward the vision must also be planned in ways that take account not only of the socio-political history, but also of the biological forces involved.

Probing an Example: Poverty and the Environment

To make the implications of this third view more concrete, we here offer an extended consideration of what we believe to be the largest pair of problems facing the human species in the next couple centuries: our looming environmental catastrophes and our long-term socioeconomic inequities. On these problems, the biological view is hopelessly dismal. It suggests that it will be impossible for humans to avoid devastating the natural environment and pushing ourselves into a major population collapse (not merely unlikely or hard, but impossible), because our Darwinian desires for expanding our own genetic offspring and out-competing others cannot be controlled by so feeble a force as our desire to protect species biodiversity or even to avoid putting the human species through such a miasma of death and pain. The biology-only perspective suggests, as Malthus noted centuries ago, that poverty is a biological necessity for the majority of the human population.

The purely symbolic view is insufficient for different reasons. That view is extremely popular among the Left, especially the young Left. The view that everything is absolutely constructed exclusively and only by language (or other symbols) sponsors the major view of social change harbored by anarchists and revolutionaries. That view holds that humans are not naturally greedy, self-interested, and narrow-minded. Instead, human beings are made that way by Western systems of discourse (which are structured as Capitalism and Patriarchy). To bring about a better world, therefore, all one need do is raze Capitalism or Western Culture to the ground, and people will naturally create a better world.

While we are as disaffected with the inequities and environmental travesties of modern Western capitalism as most progressives, we do not find the symbolic constructivist view likely to create a better alternative. In the first place, most people probably cannot be made to believe that account. In the second place, it probably is not true (where "true" means likely to provide a reliable forecast). While all accounts may be tainted by ideological blinders, it surely seems likely that people do have some innate tendencies toward selfishness. While they also have innate tendencies toward cooperation, we don't see any evidence in global anthropological studies that the cooperative tendencies stamp out the selfish ones in non-Western societies. We furthermore do not believe that if we simply tell children repeatedly to "be nice and share" that they will do so. The experience of communist governments that have complete control over mass communications have not shown that they could convince populations of this fully. Notably, leaders of such governments often self-aggrandize. If we raze capitalism to the ground, we'll likely just see it grow up again.

Our preferred, third alternative is to assume that creating good societies requires the ability to envision better modes of action (a symbolic phenomenon), but it actively takes account of undesired human proclivities to rechannel them and de-amplify them, while amplifying desired proclivities. So, then, from this perspective, what are the major problems humans now face and what kinds of things might we do about them?

With regard to the ecological issue, the most extreme potential of the problem is the "Easter Island" scenario – the possibility that we will so destroy our environment as to exterminate ourselves.[343] Although little of the public at large presently believes that this is an actual possibility, the fact that the people of Easter Island did, in fact, chop down the last tree, use up the last resource, and therefore extinguish the possibility for human life in their universe should give us serious pause. Even skeptics of global ecological collapse have to be concerned about the more immediate environmental likelihood that we will so deplete our resources compared to the demands of our population that the standard of living of the average person will fall precipitously. Social planners must also be concerned about the health implications of populations living in degraded environments and the economic implications of widespread environmental change, of which global warming and rising sea level are the most dramatic examples. These economic and public health concerns demonstrate that environmental issues are relevant to the self-interests of all members of society.[344]

The second issue, socioeconomic inequity, has multiple facets well-known in poorer countries and increasingly of concern to thinking persons in wealthier countries. As an example of the latter, the U.S. has already seen a decline in its standard of living: the fabulously increasing wealth of the top 25% of the population masks the fact that the income of the bottom forty percent of the population has *fallen* over the past three decades, and more recently, middle income earners have joined them, experiencing a decline in inflation adjusted income while working increased hours during the first few years of the new millenium.[345] These sorts of economic trends are of concern because they threaten the continuity of the peaceful and relatively crime-free lifestyle that the U.S. enjoyed in the twentieth century. No one in a developed nation should want to see that nation sink into the economic syndrome of some Latin American countries, where an underclass has no recourse for survival other than to engage in crime, including kidnapping the economically advantaged classes, and where the economically advantaged classes are forced to lived in fortified homes with armed guards. Likewise, few in a developed nation should want to see their country sink into the economic syndrome of some twentieth-century Asian countries in which large under-classes pursued socialist-communist revolution in response to economic deprivation. These issues of personal and societal security demonstrate that socioeconomic inequity is a concern relevant to the self-interests of all members of society, regardless of their inherent generosity or tight-fistedness, their financial instability or personal wealth.

These two problems, environmental degradation and socioeconomic inequity, are intimately related. Economies with large under-classes breed environmental degradation because most of the population can be forced to live in environmental squalor and to work in environmentally threatening situations. A society without impoverished people, on the other hand, is a society in which unhealthy work environments will not be tolerated. Likewise, a society in which everyone's backyard matters is one in which localized environmental problems will not be tolerated. In the other direction, a society concerned about its ecology is a society in which environmentally-related health issues such as diseases caused by air pollution do not take an economic toll, and such a society is one in which environmental change does not cause economic disruption. From this perspective, ecology and economics show their joint etymological derivation from the Greek *oikos* for "habitat" or "environment": the economic habitat of a human population determines its willingness to suffer an unhealthy ecological habitat, and the ecological habitat of a human population determines the extent to which it suffers economic hardship. Economics and ecology thus need not be viewed as oppositional, but instead as complementary (though not, of course, completely co-extensive).

Thought about solutions to ecological-environmental problems spans a range of views. One influential group believes that these problems can be ignored because the millennium is at hand: all believers will be taken to heaven and non-believers will be left in the hell created on earth. Such a belief is both intolerably arrogant and irresponsible. Zealots have been actively preaching that the end is immediately at hand for over two thousand years. There is no reason to believe that the current crop of zealots are any better at divining the will of God than were any previous crop, and there is every reason to believe that they are instead self-interested purveyors of snake-oil, given their generally lavish life-styles. It also seems difficult to believe that any God capable of creation would wish human beings to destroy it.

A second response to our environmental and population problems is the belief that technological developments will provide sufficient solutions. Technological optimists believe the economic impact of resource limitation is temporary and local, whereas pessimists believe it is permanent and widespread, because there are limits on the earth's assets: there is only so much fresh water, so much photosynthetic capacity, only so much oil, so many minerals, and so much acreage that can be devoted to tree farms. Optimists argue that most, if not all, of these fixed assets can be replaced or substituted for in some way. For example, desalination can extract fresh water from salt water, and solar energy can in theory lessen the demand for fossil fuels. One can't reasonably be *too* optimistic, however, for each of these proposed transfers entails increased economic costs and environmental impacts. Desalinated water, for example, is far more costly than naturally occurring fresh water. Thus, although substitutions are possible, they entail increased costs. These increased costs must translate into decreased availability and thus decreased quality of life, unless science and technology are capable of producing presently unforeseen *and very large* improvements in efficiency. Betting the future on such great improvements seems irresponsible. Moreover, even if that low-odds bet pays off, one is talking about remaking the environment in ways that continue to destroy thousands of species annually. Rending the webs of life in this fashion seems likely to have unanticipated and disastrous consequences, given the understanding of living networks we have supported in this book.

A third response to our environmental and economic challenges is that they cannot be solved. This is the response of the biological determinist, and we had better all hope that such individuals are not correct. This view is so chilling that even people who base all of their descriptions of humans in biology, such as E.O. Wilson and Jared Diamond, end up writing books about social change and using symbolic implements as their primary tools.

A fourth response to our environmental and population challenges is to blame our symbol systems. On this account, we are only over-reproducing and over-exploiting our environment because we use bad rhetoric. Humans are either a "tabula rasa" or a benevolent race, and in either case our problems have been brought about by bad rhetorics superimposed on that naturally good or neutral base. While we argue that new symbol systems are key to the solution, we suggest that exclusively symbol-centered views ignore the biological underpinnings and symbolic characteristics that have predisposed us to particular kinds of rhetorics.[346] We will suggest that we cannot merely institute selfless or collectively oriented rhetorics and expect these to be either effective or sustainable. Effective use of symbols requires accounting for, dampening, and rechanneling biological and symbolic tendencies that have led us to where we are today.

In contrast to all of these possible responses, a bio-symbolic perspective suggests that the collective future of humans would be dramatically improved if we could achieve two objectives. First, we would need to limit (and preferably reduce) the human population to enable all people to have a decent standard of living without destroying the intricate and rich webs of life evolved on earth over many millions of years . Second, we would need to limit (and in some cases reduce) the standard of living of those relatively few individuals who take an onerously disproportionate share of the earth's resources. Of course, both of these proposals are political anathema. No politician can get elected to office in the present ideological climate by arguing for limiting wealth or human reproduction.

Changing that ideological climate would be the challenge of a societal-scale application of combined biological and symbolic understanding of humanity, and it would involve educating human beings about their combined biological and symbolic tendencies. Until the majority of individual human beings understand the forces that drive them toward excessive and competitive reproduction and excessive and competitive consumption (i.e., toward "greed"), there is little hope for collective agreement on policies that will enable restraint. We therefore need to consider the origins of greed.

There is a contemporary and long-lived scholarly debate over whether human beings are innately greedy, or whether they are simply conditioned to be greedy by their upbringing and society's symbol systems and structures. The answer offered by the theoretical framework of this book is that what we call "greed" is a product of both our biology and our symbolic frames. From the biological side, animals have drives to acquire the resources they need to survive and to reproduce. Among many mammals and especially among primates, those drives include status drives, because higher social status has historically enabled higher rates of reproduction. Human beings share the biological drive to acquire resources and status. However, humans are different, and worse, on three counts, all of which arise from the symbol-using capacities.

First, because of the massive technological power enabled by our symbol-using capacities, humans do not experience the physical limits on acquisition experienced by most species. We can carry over acquired assets for at least a decade, if not a century. Furthermore, we convert physical acquisitions (e.g., crops grown, ores mined) into symbolic units (money) so as to store resources across space and time. Symbolic mediation thus allows individual humans to sequester resources far beyond the most greedy squirrel's store of nuts.

Second, because of our symbol-using capacity, we can imagine an infinitude of assets and exploitations. We can imagine owning an entire island, by which we mean the access to exploit all of its resources in any way we choose. In fact, some of us do own small islands. Nothing is to stop us, however, from imagining owning the proverbial "small nation", and if not that, why not a large nation? And if not that, why not an entire planet? People do indeed refer to "owning it all." The symbolically-enabled capacity to envision the world beyond our immediate physical vision enables us to imagine owning or exploiting all of that world. Even the most greedy squirrel hasn't heard about, read about, or seen advertisements about all the delicious kinds of nuts found all around the world, and lacking such symbolic capability cannot aspire to own them all.

Thirdly, just as symbol-use allows symbol users to envision more extensive acquisition, symbol-using capacity allows symbol users to envision more extensive need. Having stored enough resources to survive the year, we can envision future years of hardship for which we would be wise to harbor resources. Having provided for the next few years, we can envision an old age in which we will need resources that we will no longer be able to produce. Having provided for our old age, we can envision a future in which our offspring would profit by our present acquisition of resources, particularly thanks to our symbolic storage of physical wealth as money. Symbolic being allows imagination of need for an essentially infinite future.

Thus humans have both an innate biological drive for some kind of acquisitiveness *and* symbolic capacities that, to use the terminology of Chapter 11, amplify the human biological capacity for “greed”. As inherently symbol-using animals, are we therefore doomed to be greedy, each of us seeking to acquire the entire universe? Clearly, this is not the case. Some people, and some peoples, are far more greedy than others. For example, in modern America, the dominant culture dictates that one display one’s wealth to the public by means of a freshly painted home, a groomed lawn of monocultural grass, the growth of at least some non-food flowering plants, a driveway paved with concrete or asphalt, one or more relatively new-model large automobiles, and clothing of recent manufacture. All of this requires resources: petrochemicals, ores, and agricultural products. In other cultures, display of wealth is considered embarrassing, and homes, lawns, and clothing are consciously designed to be inconspicuous rather than ostentatious. Even within their homes, the people of some cultures are far less prone to large-scale acquisition than people of others. This is not to say that status drives and even display of wealth may not have universal bases among human beings. It is to say instead that some cultures *amplify* these bases more than do others.

Given the obvious propensity of some social systems to promote greed more or less than others, the challenge then is to build social systems that can de-escalate rather than escalate those biological impulses. As we have suggested, self-knowledge is part of the formulation. Once most people understand that we are driven toward inflated, unproductive, acquisition by our animal natures combined with our status drives and our symbolic capacities, we have the first ingredient for what Kenneth Burke calls a "comic corrective" on our condition.[347] We can laugh at our foolish drives, understand them as counter-productive to our happiness, and back them down a bit. Most of us can recognize that buying three houses, three cars, and an ever-changing wardrobe does not really provide us much happiness. We should all laugh at the clowns who seem incapable of learning that lesson.

Self-recognition of the symbolic amplification of the biological drive for acquisition is not sufficient, however. If one accepts that human behavior is motivated by both biological and symbolic drives, one then appreciates that changing a society likely requires amelioration of symbolic amplifications and/or introduction of new symbolic strategies. For example, amelioration of the first amplification discussed above (hyper-natural sequestration of resources) would require human-induced limitation on sequestration of resources. Historically, this has been in part accomplished by progressive taxation, but this is no longer fashionable because those persons seeking wealth without limit object to any such limit. Progressive taxation may indeed do what its objectors complain it does—reduce the incentives for acquiring wealth—but that is a good thing, not a bad one. Endless wealth production is not a good in itself. There are, however, other strategies to achieve these ends.

One alternative strategy might be a balancing of incomes of managers/employers with those of employees. This seems particularly apt at the turn to the twenty-first century, because the most visibly out-of-control location of greed is the appropriation of corporate wealth by upper management for their own personal stockpiles. Substantial evidence has indicated that this does not contribute to the well-being of the corporation, and international comparisons make it clear that U.S. inflation in executive salaries has outrun other nationalities, regardless of how well corporations do compared to others (and in sectors such as automobile production, U.S. corporations are clearly managed in an inferior way).[348] The salary-grab of those at the top of the corporate ladder not only disadvantages workers, but also investors. Almost no one is happy about this, but virtually nothing is being done to end it.

To productively constrain greed, therefore, a society could constrain the earnings of any person employed by a corporation, institution, or person to no less than some consistent fraction of the total earnings paid to any other person by that corporation, institution, or person.[349] Such a system would preserve the capacity of any individual to accrue wealth indefinitely, and thus would preserve the promise of capitalism to allow unlimited accomplishment and motivation and to reward with unlimited gain. It would, however, also require that such a person's "coattails" measurably, definitively, bring along the well-being of those working with them. Status drives would be re-channeled from personal "richest person" lists to a "best tribal leader" scorecard. Tying wages into interdependent networks would thus accomplish two important goals relevant to the environmental and social issues discussed above: it would help eliminate an impoverished underclass engaged in crime and fomenting revolution, and it would help eliminate an underclass that could be forced to work in and live in environmentally degraded surroundings. In addition, it would strengthen capitalism by precluding the cynicism and distrust on the part of workers and investors inevitable in a system in which corporate leaders strip their corporations of all wealth.

Amelioration of the second amplification (the ability to envision infinite acquisition) would require symbolic amplification of countervailing drives. Acquisition is work, and often a less comfortable condition than non-work, so if there is a biological drive for comfort, it can be amplified. In fact, the dominant ideology of Western civilization has long provided a text that exactly urges that amplification.

> Lay not up for yourselves treasures upon earth, where moth and rust doth corrupt, and where thieves break through and steal. But lay up for yourselves treasures in heaven, where neither moth nor rust doth corrupt, and where thieves do not break through nor steal. . . .
>
> Therefore I say unto you, take no thought for your life, what ye shall eat, or what ye shall drink; nor yet for your body, what ye shall put on. Is not the life more than meat, and the body than raiment? Behold the fowls of the air: for they sow not, neither do they reap, nor gather into barns; yet your heavenly Father feedeth them. Are ye not much better than they? Which of you by taking thought can add one cubit unto his stature? And why take ye thought for raiment? Consider the lilies of the field, how they

> grow; they toil not, neither do they spin. And yet I say unto you, That even Solomon in all his glory was not arrayed like one of these.[350]

This is clearly an ideology that does not support acquisition, let alone infinite acquisition. If the book from which it is taken has dominated Western civilization for 1700 years, surely focused application of these lines from it could be useful in developing positive societal attitudes about acquisition in the twenty-first century.

Amelioration of the third amplification (ability to envision infinite need) is, like the first, possible through economic measures of good to all. Infinite need is not possible in a society with an effective social safety net. In the United States, this safety net has taken the form of the Social Security program begun in the 1930s. At this writing, concerns have been raised about the long-term solvency of that program, but simple revisions in the social security plan can resolve its long-term solvency. These revisions require that we admit that it is a safety net for all of us, rather than an investment program. Such revisions might include removing the present cap on salary that is subject to social security taxation, and they might include eliminating pay-outs to retirees whose income is more than two or three times the poverty level. Some people who paid into the system would never get anything back from it, but that would be because they didn't ever need the safety net. What such lucky people would get out of the system is two-fold. First, they would get security: the assurance that if their investments went awry, or their expenses were unforeseeably high, they would not need to live in abject poverty in their old age. Second, they would get the very tangible benefit of living in a society where no elderly or disabled person had to live in abject poverty, either begging on the streets or committing petty thievery, or worse, to survive. The wealthier one is, the less significant to them is their payment into social security for these benefits. For most people, however, social security would likely end up serving as at least part of their long-term income security, and for most people, therefore, social security would mean real security enhancement. As discussed above, enhancement of personal security lessens the likelihood of citizens resorting to crime and lessens the drive for excessive acquisition deleterious to the environment.

A watchful reader may remember that we argued that dealing with environmental and socioecomic problems required two actions, lessening economic acquisitions per person and limiting population growth. Thus far, the sample proposals have seemingly been designed only to deal with lessening drives for acquisition, in part by lessening socioeconomic inequality. However, experience has shown that lessening socioeconomic inequality leads to lesser population growth: reproductive rates among the native populations of developed European nations, the United States, and Japan have dropped, and similar trends are often (although not universally) observed as other nations approach similar affluence.[351] In short, solving one problem (socioeconomic inequality) at the global scale will do much to solve the other.

To summarize, the modern problems of environmental degradation and socioeconomic inequity can be traced in large part to the remarkable extent and effects of human greed. Human greed, treated as a factual phenomenon rather than a moral fault or laudable practice,[352] can be explained by the interaction of biologic and symbolic factors. We find the few sample solutions we've discussed here to be less than fully satisfactory, and we suspect most readers will also. The limitation arises because there is currently an inadequate knowledge base about what drives and what restrains human greed. Is the greediness in the contemporary U.S. a product of specific, localized status competition, or of more diffuse drives for acquisition? Is it driven more by fear of being at the bottom of the community's ladder, or by fear of real need? Are these underlying drives amplified more by television ads about commodity products, or by comparison with one's interaction group? If these drives can be understood more thoroughly through research that explores the interactions of the biology and symbolics by which they are created, then it might also be possible to predict (and test) what kinds of symbolic and social structures more effectively restrain this greed. In the absence of such knowledge, U.S. policy debate has been mired in competing defenses of the dichotomized positions that greed is "natural" (i.e. biologically programmed) or "cultural" (i.e. structured in economic systems or discourses). Provided with a model in which the biological and the symbolic are both "natural" to humans and in which symbolic processes channel and amplify biological predispositions, it may now be possible to ask a set of questions that offer more socially useful answers. From such research one can reasonably expect more effective proposals about how to shape societies to encourage the behaviors and the human selves we want to be.

Human biological predispositions are amplified and channeled in many negative ways by social-symbolic structures: aggressive driving, dangerous drinking and drug consumption, peer-based rearing of children, all have biological foundations, but are culturally amplified. They are susceptible to re-channeling and de-amplification. For example, the dangerously elevated levels of alcohol consumption on our college campuses appear to be based largely on status dynamics. Public service campaigns should de-amplify that status by mocking young men whose claim to fame is how many drinks they can swallow. Will that offend someone? No one who does not deserve to be offended. Will that "blame the victim"? One mocks the claim in order to help people avoid inhabiting the position of victim. Most crucially, will that work? One will have to try it to find out. But advertisements continue to try fear tactics and information tactics to reduce drinking, and those clearly do not work, probably because they do not address the biological predispositions of those biologically-programmed to be risk-taking youth. Similarly bio-symbolic based approaches might address other problems. If aggressive driving derives from the separation from a community and anonymity of drivers, let's develop mechanisms for reducing that anonymity.[353] If peer-based child-rearing produces uncivilized teens, let's require all parents (both male and female) to work one day a week in their child's daycare or school. These tentative ideas can only point to possibilities, but they are novel possibilities that may suggest how we might direct our attention in novel directions, some of which are likely to prove fruitful.

Self-governance

We have placed most of our emphasis on social level change processes, because individuals have difficulty behaving in new ways inside of symbolic flows that run counter to individual wishes. Nonetheless, bio-symbolic studies also have implications for the ways in which individuals chart the courses of their own lives, and these implications are important for one's own ability to live the good life of a human.

Some of the implications of a bio-symbolic perspective relate to highly pragmatic, relatively local decisions. For example, in the same way that viewing people as biological entities can help one to navigate the status hierarchies of the corporate world, viewing them as bio-symbolic beings can help one to plan ways to counter those hierarchies when they exert particularly vile effects on one's life. Similarly, understanding that the approach-avoidance conflict is hard-wired into our brains as a gradual approach gradient and a steep avoidance gradient, and that it is manipulated by the use of symbolic tactics such as "sales" and "hard sell", as well as often inauthentic "money back guarantees," may help one avoid being so easily manipulated by salespeople. If nothing else, the biological dimension can help overcome one's tendency to overrate one's own native capacities for resistance to persuasion, encouraging a more realistic planning of strategies, rather than a blissful (and usually incorrect) dismissal: "I'm too smart to fall for such ploys." The symbolic dimension is necessary both to a belief that one can resist, and to developing the strategies for resistance.

Informal observations of other scholars suggest to us that it is extremely difficult to move from text-book understanding of such forces to successful incorporation of such understandings into life practices. Even those who work deliberately at implementing the knowledge in practice achieve only partial results. But the authors' personal experiences suggest to us that the results that are achieved, even though incomplete and limited, are worth the efforts involved. Such applications provide a portion of the truly good life, where a "good life" is conceived as only symbol-users can conceive it—involving more than attainment of food, reproduction, and a high rung on the status hierarchy. This question of what constitutes the good life leads us to the most fundamental issue of self-governance that arises from a bio-symbolic account of human beings.

Why be moral? This problem has long bedeviled philosophers as well as other thinkers. If morality is what is good for someone else, why should I do that? Why should a moral code like, "Do unto others as you would have them do unto you," be followed? Isn't it smarter just to get others to treat you well while threatening them in whatever fashion serves your self interest (an approach that seems common today in everything from businesses to televangelism)? Doesn't evolutionary theory indicate that anyone who gives up their resources for others is just a "loser" plain and simple? Aren't arguments about "long term" benefits or what one "owes" to a society or what is required for maintaining the society that benefits one, just specious?

A material theory of bio-symbolic action gives a new and a clear "no" to these cynical questions. Such an account of humans indicates that one should follow the dictates of a moral code because one is part and parcel of that code. As a symbol-using animal, the symbolic structures of the moral codes of one's society are physiologically embedded in your brain. They are literally a part of you. Moreover, the way in which they have arisen and they way they are a part of you are both a product of biological programming and also socially and individually accreted experience. They are, therefore, wisdom. They literally describe what an empirical process has determined is the best way to act.

This force is made evident when one violates the code (except in the case of sociopaths). People who violate moral codes experience anxiety, guilt, worry, and remorse. In some instances, the emotion is so intense that people commit suicide. Others confess crimes that had long been hidden, even when there is little chance those crimes will be discovered. Even those who manage to repress their guilt, and project it as hostility, are experiencing the physiological and psychological impacts of that embedded code. Over time, they are literally, warping themselves, probably in unhappy, unhealthy, and unsustainable fashions. This warping is unavoidable, because moral code cannot be excised. The values are embedded in all the words that the person hears and uses. The process of combating inconsistencies between the behavior and the code is therefore constantly stressful.

To be a symbol-using animal is to be integrated into the symbolic web with other humans. This means that "you" are never simply you alone. This is true biologically, as every individual is a part of a family, a lineage, a population. It is particularly true of humans as a biological species that is fundamentally dependent on other human beings for survival. It may be even more true symbolically. The symbolic code is never yours alone. It is part of you, and yet it brings others, inescapably, irrevocably, into you as part of you as well. This whole of you—the selfish genes as well as the biological and symbolic network--must follow the moral codes, not only because it is the wisest choice, but because you experience a physiological compulsion to do so.

This is not to say that such compulsions are always the best available moral codes. One of the dangers of isolating people in different social castes is that they develop social codes that justify behavior for members of their casts that is immoral, because it takes advantage of other castes. This happens routinely among upper classes, and is particularly visible in contemporary U.S. culture, where the mantra "the rich are not like other people" has taken deep root. In such cases, the moral code that is embedded in the brains of the caste is not sufficiently generalized. A better moral code is available if one takes into account all people, but individuals within the social caste are protected from that larger code by the dominance of the local code. So saying that humans "should" be moral because the moral code has both a physiologically compulsive force on them and because the moral code offers the best available wisdom to their whole selves (understood as both a biological unit and a being-in-relation), does not say that people should always operate according to the best (i.e. most generalizable) moral code. For that other step, one truly needs the force of reason.

In this sense, our answer is not a "logical" answer to the question, "why be moral." It is a biological and a symbolic answer. But the symbolic power can accomplish what the logical power would wish (for logic for humans is partially symbolic, at least in higher order cases). One should act on the most generalizable moral code, when that code is made available to one, simply because one can come to understand that such moral codes are truly "better." The bio-symbolic force of the moral codes deeply implanted in one, thus are generalizable to the best available symbolic code. It is thus "unreasonable" to act immorally, according to the most general moral code of which one is aware.

These moral codes, of course, are pitted against other drives, and the moral codes do not offer solutions to every situation, because they are not simple templates for behavior. The tragedies in human lives arise when these other drives and the moral force come in conflict, or when conflicts exist within the moral drives themselves. Thus, "one should behave morally" is not the same thing as "one should always act for the sake of others and never for one's self." The devil, as it is often said, is always in the details. Moral codes offer a force to which one must, and should, attend. They do not offer, however, definitive templates on behavior, and the very pliability of symbolic codes gives humans a wealth of routes for determining that behavior which is self-interested is also really morally justified.

Thinking about morality as a coercive, material, bio-symbolic force embedded within us, instead of as an abstract set of rules imposed from the outside, should at least give one a different sense of one's relationship to moral codes. How humans will use that understanding of morality to govern their lives, like all of the other social suggestions we are offering, is still a very young work in progress. Implementing structures to forward progress on bio-symbolic understandings is the subject of the next section.

Creating and Sharing Knowledge

The knowledge that human beings use to re-formulate social policies comes from two different reservoirs. The first source is the knowledge that a political entity's population carries in their heads. The second is the knowledge generated in research institutions. Our analysis of the bio-symbolic character of human beings suggests the need for some substantial revisions in both of these arenas, our educational process and the organization of our research establishments.

Teaching Everyone

Depending on age cohort and geographic region, only about two thirds of the U.S. population graduates from high school. Little more than half of high school graduates go to college. Little more than half of those who go to college graduate. Even among those who graduate, the overwhelming majority do not have the basic knowledge detailed in chapters 2, 3, and 5 of this book. Less than 10% of our population has ever had a physics class. Less than a quarter have been provided any sustained account of the logic and evidence for evolution. Is it any surprise, therefore, that our television channels and movies are filled with plot lines focusing on witches, alien monsters, and magical powers? If you lack any understanding of the basic forces of the universe, witches and goblins are the most plausible and interesting thing you can conceive.

In this regard, of course, the present situation is little different from that of the Middle Ages, when an uneducated population was fed a similar diet of witchery and mystic tales. But such a comparison is a severe condemnation of our expensive education system. How can children spend eight to twelve years in an education system and not learn the basics of how the universe works, how biological systems operate, and the forces that operate upon them as human beings?

Political and social forces provide part of the explanation. In some places, parents don't want their children to learn how biological systems operate, or even the true age of the earth. But this is not the only source of the problem. Another source is a bootstrap challenge: how do you generate enough people who do know and understand in order to share the knowledge with a new generation? Children are taught ghosts and goblins at home from the time they can speak by everyone around them. It is difficult to replace those early brain wirings with alternatives that are not narratively framed (and are therefore "boring") and that may actually disagree with all of the senses and sources with which the students otherwise come into contact. Hence, for example, people's difficulties in learning and retaining the basic inputs to seasonality and the amount of daylight they experience. That challenge, however, can now be mitigated with good computer-based teaching tools and properly programmed videogames.

Finally, there is a major factor accounting for population ignorance in these areas that is unjustifiable and can be traced directly back to the science establishment itself. Too many scientists believe and promote the idea that science is hard and only a few special people can understand it. Concomitant with this attitude, college professors in the sciences see themselves as too important ("too busy") to teach classes, and they strive for endlessly reduced teaching loads. When they do teach, they are likely to shape their classes as "screens" to separate the future successful scientists from everyone else. Their pedagogy is based on a Darwinian "sink or swim" mentality. Those who are smart will succeed, and we don't really want the others around here anyway. This chains out into a curriculum that is accessible only to other scientists at the college level. At the high school level, it produces a curriculum that absolutely excludes the average high school student from physics classes. Ironically, all of this attitude is projected even as this same group of scientists claims that the only possible solution to every possible miscommunication with the public is "better education" of that public.

All of this is dreadfully wrong-headed. *Scientific curricula are inherently no more difficult than any other curricula.* The basic ideas of physics can be taught to the average 8th grader. It is only the status needs of physicists and their self-identification with inaccessible mathematics that leads them to insist that physics is beyond the average person. It is past time that we get over this ape-like status hierarchy. Likewise, the basic logic and evidence for evolution and the basic processes of biology must be taught to all 9th graders. Moreover, unless and until we do that, we need to produce new physics textbooks and new biology textbooks that do this effectively at the college level for all students.[354] No student should graduate from college without this basic understanding of the world. It is a travesty that this should be elsewise.

The horrors of the scientific curriculum have ripple effects in the rest of the educational system. Because science is supposed to be "hard", other classes are supposed to be "easy." Students repeatedly have manifested their sense to the first author that they have been cheated because their communication course was not "easy" as they expected it to be. Students expect higher grades in non-science courses, and because colleges have become a market economy, they get them (or students take their business elsewhere to more compliant departments). This means that teachers of non-science courses must teach less to their students than they otherwise might. The structural effect is that few students take science classes because the excessive rigor and alienating attitudes and teaching frameworks run them off and then the majority of students learn less in non-science courses than they otherwise might, because they are told these other things should be "easy". [355]

What exactly is it that students learn in these non-science courses, anyway? At the high school level, they learn historical narratives and basic facts about how their government works. Few learn any sociology, psychology, or communication theory. What they do learn is taught in isolation from any format that links up the commonalities in processes and intersections among economic systems, political systems, geographies, communication systems, and how these are related to individual psychologies (let alone biologies). So students come out of high school remembering a few plot-lines for history, a formal bureaucratic scheme for their government, and little else about themselves.

They certainly do not learn to understand their own drives and motivations and how those are shaped by social structures and symbolic flows.

At the college level, students mostly learn to memorize things for a short while and then forget them. At most large public universities, almost half of the curriculum is taken up with “lower division” courses. About half of these courses are “delivered” in large sections where multiple choice tests are the necessary evil. So students memorize for tests, and then they forget. They do not have an opportunity to talk through what they might be learning, and most importantly, they do not have an opportunity to apply what they are learning to problem solving. The “knowledge” therefore never gets integrated into the functional centers of their neural networks, and they therefore learn, effectively, nothing.

This is true especially in the social sciences. It is somewhat less true in basic English composition and foreign language courses, which tend to be small in size. So students do learn some language manipulation skills. They do not, however, learn the broad concepts about human being and then integrate those broad concepts in any pragmatic coursework. The skill training courses have almost no connection to the conceptual learning courses.

A bio-symbolic model of human beings requires us to think anew about what education means. There are, of course, many theories of education and this is no place to examine them in detail. However, some rough generalizations can be made. If one thinks about humans purely as animals, then education is about training students to do the “tricks” or skills necessary for survival in the marketplace. If one thinks about human purely as symbol-users, then one thinks about education as instantiating strands of text in people's heads. Oppositional theories then decry the "disciplining" of bodies that is endemic in the "tricks/skills" model or seek to implant alternate strands of texts in people's heads. In contrast, a bio-symbolic model indicates that people use symbolically dedicated neural networks in conjunction with other portions of neural networks. Consequently, merely learning words (memorization tests) is of little value, and merely learning isolated skills ("tricks") is of little value. An educated human being is one that can use different portions of the verbal network to think about the relationships within that network and of the relationships between the verbal and nonverbal neural networks in the mind, and adapt those to different situations recursively. Of course, that is a very abstract statement of what education is about, and though novel in form, it matches up well with some specific curricular movements. However, in general it does not accord with how we teach today.

All of this suggests the need to rewrite college curricula. Current curricula are shaped by individual disciplines and the requirements placed on students are the result of the political battle among departments to maintain requirements that sustain their own enrollments. This may be tolerable at the upper division level, but several pilot programs around the country have already recognized that such a basis for a curriculum makes no sense for the "core" learning that all college students should share. We believe that chapters 2 through 11 provide a template for the kind of learning college students should have. They should 1) understand the basic facts of reduced and aggregated physical being, the basic processes of organic being, and the basic characteristics of symbol systems,[356] 2) they should understand the basic methods by which knowledge is acquired, and 3) they should be ready to use these principles in their chosen majors in pragmatic applications, evaluations of scientific and non-scientific claims, and even through participating in the production of additional knowledge, and 4) they should have the ability to apply the general knowledge to their lives outside of their workplaces, including home, family, and community. All disciplines can contribute to this core knowledge, but not by teaching anthropology in one class, writing in another class, and economics in a third. Universities need to reconceive the connection between the academic discipline and core teaching. This isn't an easy management challenge, but it is not impossible.

Creating the New Knowledge

Generating knowledge about our bio-symbolic capacities will be an uphill battle. It requires overcoming current intellectual divisions and current financial trends. Contemporary research is conducted primarily in private venues, for-profit, and in research universities, with only a negligible amount of research conducted in non-profit, non-University venues. For-profit venues will have either no motives, or socially questionable motives, for conducting bio-symbolic research. Most of the research on humanity's bio-symbolic characteristics that will help contribute to better social outcomes must therefore come from research universities. However, disciplinary barriers within universities work against trans-disciplinary enterprises and the increasing de-funding by the public of state universities works against any research program that cannot return a financial profit.

Contemporary universities are organized into disciplinary entities with highly specialized, highly focused training. Large divides exist between those who study the symbolic aspects of human beings and those who study biological phenomena. There are differences of epistemology, of methodology, and of institutional structure. Regardless of the considerable strength of these divides, it is essential to attract participants for the pro-social Transilience agenda from both the biological sciences and from the traditional humanities and social sciences. Otherwise, there will be insufficient expertise to generate accurate theoretical bridges. Instead of an integration, one will merely replicate past efforts to overwrite the humanities with the natural sciences or vice versa. Indeed, we are all too aware of the extent to which our efforts in this book have been limited and shaped by the boundaries of our own knowledge bases.

Almost any type of scholar feels strong forces discouraging participation in a research program that requires bridging home knowledge bases with new knowledge bases. Scholars are rewarded by disciplines, and therefore they are rarely rewarded for inter-disciplinary work. More crucially, scholars are trained to think in disciplines, not in inter-disciplinary intersections. Even the researchers who might be most likely to be interested in the program of Transilience—that is, the many scholars who have been intrigued by Wilson's call for Consilience—come almost exclusively from the biological disciplines, and so will find Transilience a challenge. It is likely to be even harder to draw humanists to the enterprise. Humanists are not accustomed to working in teams or to envisioning their work as part of a cumulative effort. Many humanists are also rigidly closed-minded about assertions that humans have biological characteristics. But these limitations do not describe all humanists, and some of the most open-minded people in the academy are located within the traditional humanistic disciplines. They might be readily joined by the more creative of the social scientists, who are accustomed to cooperative work and to the conceptualization of research as a cumulative project. Social scientists also are familiar both with many of the distinctive problems of building theories about human beings, and with some methodological means of coping with those challenges. There are also roles for people who do not fit into the stereotypes we have been able to highlight in this book. Many physicists today are itching to contribute their considerable theoretical and mathematical acumen to great enterprises of the mind. Some artists are fabulous conceptualizers, and conceptualization skills and a gymnastic mind are always assets in new enterprises. Economists may not think of themselves as traditional social scientists, but they have acquired an enormous base of knowledge about a particular kind of symbolic exchange—monetary systems. Approached from the angle of bio-symbolism, there are fruitful translations to be made, as knowledge about the flow of the symbolic currency of money can inform studies of other types of symbolic flows. In sum, the full complexity of the studies humans have to date undertaken stands as a potential reservoir to use in the effort to build a broad and reliable bridge between understandings of humans as symbolizers and knowledge that we are still animals.

The intellectual talent pool is surely large enough to overcome the disciplinary barriers. There are, however, serious, growing, financial impediments as well. The need to halt and redress the de-funding of research on human symbolics is reaching crisis proportions. State governments are well along the road to minimizing state financial support of public universities. An increasingly large group of governors and state legislators have adopted as their models either private universities or the top-tier research universities. The few top-tier research universities are able to gain 40% or more of their budget from research grants and donors, and another 40% from tuition. That leaves the state 100% control of the institution, with only 20% of the bill. State government officials around the country see that as the tremendous deal it is, and would like to replicate it in their home state institutions. The problem with that model is that there is a limited pool of research grants. That pool is not growing in absolute dollars. Therefore, the model cannot be generalized to all state universities: a fixed sized pie can't be divided into more pieces without the pieces getting smaller.

The alternative model is the private university, which gets all its funds from tuition, grants, and donors. More gifts from donors seems possible, but both grants and the pool of students who can afford high tuitions are limited. Again, the model probably cannot be generalized to large numbers of state universities. In the process of attempting to generalize an un-generalizable model, state institutions of higher education are being de-funded.

The response to this defunding by those university administrators who care about the well-being of their institutions has been to try to re-orient the university to bring in more funds, either through donors, grants, or patent moneys. The interest in patents and royalties has been growing rapidly, and radically re-orienting university research offices. University administrators are trying to hire people who can generate patents, and feed them the resources that they need to do the work to generate patents. Secondarily, they are trying to hire people who can generate grant dollars, and feed them resources. Research areas that can generate patents are located almost exclusively in the natural sciences, but only in some branches of the natural sciences rather than others. The money to give such highly-sought researchers salaries that are much-above average and laboratory resources that are much-above average have to come from somewhere. In the de-funded university, some of the resources can come from the grants generated (and in those very few places with real patent revenues, from those revenues), but usually the high salaries and elaborate buildings they require come from the University's general resource base. All this means that retirements in non-self-funding areas are replaced by retirements in patentable and grant-fundable areas. Students in the non-revenue producing areas are then taught by graduate students or part-time instructors who are generally not selected with high criteria nor monitored for performance in the fashion that regular faculty are monitored. Students are not taught by faculty who contribute to research in the non-revenue producing area, and there is a reduction in the research produced in non-revenue producing areas.

These dynamics are not due to the resistance of humanists and social scientists to get on the grant-getting band-wagon. For reasons this book has detailed, the basic characteristics of physics, biology, and symbolic being mean that some branches of physics and some branches of biology have revenue-producing potential of the "manufacturing" variety and therefore have the potential to produce revenue for the university. There is no such potential in symbolic studies, because the output of symbolic knowledge must be learned and applied directly by each individual. Books, textbooks, and teaching materials do not have the profit potential of patents. Beause of these dynamics, the on-going de-funding of state universities is in large part a de-funding of human studies.

In part, this de-funding has been facilitated by the political problems involved in promoting public funding of human studies. If research in these areas produces new results, human studies are likely to be politically unpopular. If research in these areas merely reinforce the same old results (another study of Shakespeare), they may be seen as politically unproblematic, but they are also not seen as vital. This book's analysis of the goals and functions of symbolic studies, however, has suggested why societies need both the innovative potential of human studies and its function in preserving cultural memory. It is a pressing task to restore balance to universities and to build and protect traditional humanistic and social scientific study of human beings. This can be done through two avenues: targeted funding for human studies by state legislators and enhancing donor campaigns for these areas. Both of these are uphill struggles, but we have tried to make those efforts easier by presenting in Chapters 10 and 11 a clear explanation of what the humanities and social sciences do and why this kind of work is so vitally important to our species.

The program in bio-symbolics will share the same challenges as the humanities and the social sciences. To do the work well will require substantial funding, but the return on the investment is social; it will not provide patent money for anyone. There are very few research foundations that will fund research that is not focused on physiological health research or military defense. So grant dollars for this research will initially be difficult to obtain. The hope is that through time, the research will generate the kind of results that will convince legislators and university administrators and foundation officials that this work is vital to the survival and prospering of the human species. This is a fifty or hundred year agenda. One must hope that existing civilizations will have that much time to achieve it. To the extent that the research agenda is successful, a new educational program will be needed to make accessible the knowledge from the research bench to the general populace.

Placing a Theory of Science Within a Theory of Knowledge

The research synthesized in this book supports a variety of previous research efforts that have indicated that it is time to revise the common vision of "the way science works" that many natural and social scientists today continue to hold. Most scientists have gotten beyond simplistic Popperism in their practice, but fewer have gotten over the belief that what they are doing should match Popper's dicta.[357] Twenty years after Jared Diamond wrote dismissively of "Popperphilia"[358], one continues to hear at genetics conferences, social scientific institutions, and inter-disciplinary awards committees alike a remarkably consistent rendition of Popper's account of what makes science work. On this popular account, a practice is only science and can only produce knowledge that counts as such when a critical experiment definitively tests a tightly formulated hypothesis, producing quantitatively framed explanations of relationships (usually one-cause, one-effect in their form). As the many examples in this book have high-lighted, if such were really all that could count as science, then humanity would know very little about very little of the universe in which we live, or about ourselves.

Scientists have resisted ditching the Popperian account for at least two reasons. First, there is a large and important grain of truth in the popular Popper. Controlled experiments and quantitative analysis provide powerful tools without which science could not have developed as we know it today. Experiments and quantification are not merely historically important; they continue to provide crucial anchors for larger bodies of knowledge, much of which cannot be directly tested by experiment. The fact that hypothesis testing and experimentation are essential to the development of science taken as a whole, however, does not mean that they are either sufficient to define what science consists of or essential to any one subcomponent of scientific research. Once one understands that rigorous observations can function to test hypotheses, that answers to questions can be "yes" and "no" or "like this" rather than numbers, and that both generalization and specification are required for scientific knowledge, then one has the basis for formulating an understanding of knowledge production that is more general than the experimental method or hypothesis testing, even though it must retain the character of falsifiability, at least in principle, throughout.

Scientists have also resisted ditching the cartoon caricature of science offered by popular Popperism because they have understood the primary alternative as an equally cartoonish claim that there is nothing about scientific practices that escapes language. As the rhetorician of science, Alan Gross put it in describing Newton's *Optiks*, that "the triumph of the *Opticks* is *wholly* rhetorical because science is rhetorically constituted, a network of persuasive structures."[359] Scientists label such claims loosely as "post-structuralism," and there are certainly scholars who do, indeed, hold that science is nothing more than a particularly powerful structure of interests hiding its own biases behind the smoke and mirrors of lab coats and mechanical apparati. Fortunately, the post-structuralist and Popperian cartoons are not the only options. As physical scientists studying the aggregation of matter long ago established, it is possible to produce knowledge, even knowledge about very difficult matters, through an inter-related network of observations, experiments, quantitative and qualitative findings, pattern development, and analysis.

In this alternative theory of knowledge, laboratory experimentation and mathematical equations are not the required methodology for all scientific research, or for all sound research. Instead, the required methodology in any given instance is the methodology that best fits the nature of the subject matter under investigation. If there is an ideal, it is the use of *triangulation*—many methodologies and symbolic characterizations produce fuller understandings than any one alone.[360] What counts as scientific knowledge on this view is the inter-connected network of the best-justified of well-justified descriptions and explanations of phenomena (for more elaboration see Appendix 1). The standards of justification require using the most appropriate and rigorous methods available. Controlled experiments provide particularly valuable anchors in this process, and mathematical equations provide particularly powerful explanations because they may interconnect with each other in rigorous ways and because they generate a kind of control that is economically valuable because it can be leveraged. However, even in the study of physical being, equations and experiments tell us nothing unless they are embedded in a much larger knowledge base of description that is inevitably based on rigorous observation and interpretation as well.

In the study of most interesting kinds of phenomena, experiments and equations loose much of their utility and power because the characteristics of these phenomena preclude experimental control or cannot be summed up in time/space invariant equations. Gathering knowledge in such areas may be harder in some respects, and it may be especially difficult to come to agreement about what counts as knowledge. But such limitations can not be eliminated by changing to any specific set of tools. They lie not in faulty tools but in the nature of the phenomena themselves. Confining efforts to gain knowledge to only those things one can know experimentally and through time/space invariant equations would only create a dwarfed, perhaps even dangerous, understanding of our universe and ourselves.

This book does not constitute a new theory of knowledge, but rather provides a rationale for such revisions in understandings of how science works. It also suggests how such a theory of knowledge can be integrated with the most significant results of the post-structuralist challenge—the fact that science is conducted through symbols, and therefore is always influenced by the symbolic medium. One particularly productive way to approach this interface is to suggest that scientific research requires an effort to reach understandings through means that control for or challenge one's biases.[361] The value of experiments employed in the hypo-deductive method lies precisely in their ability to control for some dimensions of bias. But experiments can only test the hypotheses as formulated. They cannot test hypotheses that go unformulated, and it is now beyond contest that social biases contribute to the insufficiency of the hypotheses that are formulated.

Long-standing biases in research regarding assumptions about sexual bimorphism are the clearest, but not the only, example. The research by Patricia Adair Gowaty provides one of the most definitive examples of the value of examining the biases that go into the hypotheses one formulates. Gowaty's observations and experiments dispelled long-standing biases in hypotheses about the sexual monogamy of female bluebirds. Informed by readings of feminist scholars, she chose to test the hypothesis that female bluebirds were monogamous. The data indicated definitively, and to the surprise of those who held sex-role stereotypical conceptualizations, that female bluebirds were not monogamous.[362] Until someone chose to formulate and test that hypothesis, however, this discovery could not be made, and without a scrutiny of biases, sex-role stereotypes stood as such naturalized assumptions that they did not present themselves as hypotheses in need of testing. The experimental evidence followed the critical reflection; it did not precede it. While surprising experimental results may often generate new hypotheses in turn, some hypotheses will only occur to us through the processes of critical reflection on our biases.

Symbol systems are one major source, and always a mediator, of biases. But the prescriptions of the Enlightenment era theorists of science, to eschew such bias simply by choosing only "clear" or "unornamented" language have been proven insufficient. Apparently clear or unornamented language can simply be that which hides its biases most skillfully from us. *Critical reflection upon one's symbol systems is thus not external to scientific practice, but rather a key component of that practice*. If one un-reflectively describes forced copulation among animals as "rape", for example, one is unwittingly importing a series of assumptions from human behavior into one's observations, and these will influence the hypotheses formulated and perhaps the way experiments are set up.[363] If one is to be rigorously scientific and provide the best possible test of the research question, one must carefully scrutinize the words one chooses. What precisely are the hidden assumptions in calling a practice "rape"? Do these terms imply free will? Do they suggest the externally generated power imbalances analogous to the racial and class implications of the most popularly reported "rape" cases in human society? Do they thereby imply something about the respective interests of the "rapist" as opposed to the "rape victim" or the rape victim's sexual partner or parents? And how do those assumptions influence the way experiments are structured?[364]

Part of the process of rigorously examining the vocabulary one is using may include the replacement of particularly problematic terms, e.g. "rape", with less connotatively dense terms, e.g. "forced copulation", in order to mitigate as many of these unhelpful transferences as possible. But more neutral terms such as "forced copulation" still bear implications and require scrutiny and self-reflexivity. It is the process of carefully exploring the connotations and assumptions embedded in the terms one uses that enables one to do better science. Getting such assumptions on the table allows more rigorously framed hypotheses and more careful control of biases.

The best reason that can be given *against* taking seriously hypotheses that are based on critical scrutiny of one's symbolic biases is that scientific research is a scarce resource. Scientists like to build on prior research results, rather than on novel hypotheses, because the odds of success from research built on prior research results are higher. Such results already have substantial comparative, observational, or experimental evidence in their background. Hypotheses generated from symbolic scrutiny tend to have less of such bases. This makes testing of such novel hypotheses a bigger gamble. Additionally, research based within an established tradition has a constructive tendency, whereas research based on scrutiny of biases bears the threat of overturning large components of the existing knowledge set and its frame. The tendency of science to be constructive is one of its virtues, enabling it to produce certain kinds of goods for human lives. These economic factors, however, cannot be allowed to completely trump the force of analyses that reveal potential biases. Although science cannot be science if it is dominated by critical self-scrutiny, science also cannot progress as science if there is not a respected place for such scrutiny *within* the practice of science.

One might label the alternative to Popperism and post-structuralism that we are pointing toward as either a "theory of science" or more broadly as a "theory of knowledge." The label "theory of knowledge" seems more appropriate because there is no sharp break between science and other knowledge production practices; instead, differences in objects of study lead to differences in the frequency with which different tools are used. As we suggested in Chapter 10, the evaluation provided by an expert critic of literature or film is a form of knowledge analogous to the interpretations made by natural scientists. Although the film critique will generate a lower degree of agreement and respect, and its conclusions are generated through a different balance of methods than Gowaty's experiments on blue-birds, Watson and Crick's patching-together of the double-helical structure of DNA, or physical oceanography's inference of the movement of deep-water masses, such analysis may represent the best-justified of well-justified explanations, and they will use overlapping sets of tools, and may come to use overlapping sets of assumptions.

Perhaps it is nonetheless useful to maintain a distinction between "scientific" practices that rely more heavily on experiment, rigorous observation, and mathematics and other knowledge practices that rely more heavily on pattern recognition, analogy, and evaluation. At the least, it is past time to broaden our conventional wisdom about science to make it more accurately reflect how science actually works and must work, and it is equally important to understand that the production of knowledge occurs outside the realms that have historically been identified as "science." At the most, it may be necessary to abandon the distinction in order to integrate research on biological and symbolic facets of human beings.

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We began this book by quoting E.O. Wilson's claim that the effort to integrate the natural sciences and human studies was the most challenging possible intellectual project. We have attempted to rise to this challenge by providing a material theory of symbolization that enables understandings of how human behavior is influenced by interactions between symbolic and other biological features of human nature. To provide an intellectually balanced framework for such an integration, we found it necessary to modify or clarify prevailing understandings of how knowledge is created and how it is there can be different modes of being. We are painfully aware of many gaps and omissions in this product. We tremble at the likelihood that in stretching so far we have made some factual errors, and we anticipate that our theoretical sketches will need to be radically revised. But we humbly accept that to err is human, a symbolic possibility born of the amazing ability to conceptualize the goal of "saying it right", and we are delighted to have the opportunity to share with others of our species the effort to understand ourselves as dynamic, inter-related accumulations of matter with the heritage of animals and the capacities of symbolizers.

[1] Wilson, 1999, p. 8.

[2] A recent, thorough treatment of the Wilsonian approach is Buller (2005), whereas the are two other models of the relationship of biology and symbolics, though these deal at the evolutionary scale, and this treatment is directed at mid-level relationships (see Jablonka & Lamb (2005), Richerson & Boyd (2005)).

[3] We have tried to write this book in a fashion accessible to multiple audiences. If we had written it in standard humanistic academicese, it would have started something like this: This manuscript shows that physical, biological, and symbolic being share a common material substrate, but manifest different properties due to their different

arrangements. This description of a shared, but also divergent, ontology is compatible with a theory of knowledge that encompasses both the humanities and the natural sciences, but also accounts for differences in methodological leanings as well as different characteristics of knowledge sets about the different modes of being. This background enables a material theory of human behavior that integrates both biological and symbolic forces. The manuscript provides a preliminary and heuristic theory of the interaction of those forces at the proximal, albeit chronodynamic level. It uses the interaction between poverty, population, and environmental degradation as an extended example of how thinking about humans as entities driven by the interaction of biology and symbolics might help us to better shape our collective future. We encourage readers who are accustomed to the dry style of academic manuscripts and to academic conventions of arguing in detail with precise formulations of previous theories to consider the utilities of foregoing that approach in this case. We have been told that the use of multiple simple examples and translations out of technical vocabulary make this sound "too simplistic", but the argument is not at all a simple one, even if we have worked hard to make it clear.

[4] The theoretically astute reader will understand "transilience" as a post-post-structuralist theory. Post-structuralist theories ably showed the limitations in foundationalist theories that were built exclusively on presence, identity, and similarity. Post-structuralist theoretical work has undeniably revealed that the differences that are rigorously excluded by foundationalist theories are actively constitutive differénce. But in order to make this argument, post-structuralism was more or less forced to adopt the reverse of the presence/absence binary. A translient theory incorporates both presence and absence, recognizing that the particularity of being is always simultaneously the being that is

arrayed in relationship to what it is not. Transilient theory also recognizes that actually communicating with people with as much clarity as possible rather than hiding in the symbolic mystifications of "high theory" is necessary for transforming the species, even if it exposes one to the opposition. Nomadic hiding is only a temporary expedient of the self-centered, faint of heart, or excessively pessimisitic. It is not a long term strategy.

[5] Wilson, 1998, p. 132.

[6] Richerson & Boyd (2005), Jablonka & Lamb (2005).

[7] When debating the possibility that biological beings are organized in a fashion that produces differences from physical being, the acid test physicists are prone to produce is the question, "does biology require any new physical laws?" To this, the overwhelmingly probable answer is "no." However, this does not mean that biological explanation does not require biological "laws", or that biological explanations are not better than physical level explanations. Consider, for example, the workings of DNA. Weinberg has claimed that with a big enough computer you could calculate what DNA does, and he means by this that you could input the strengths of the chemical bonds and the distances of the atoms in the molecule, and all the strong and weak forces and electromagnetic fields and know what a particular molecule of DNA would do. But this isn't true for two reasons.

First, the Heisenberg Uncertainty principle has demonstrated that prediction of what any small physical entity will do is impossible. Prediction requires that one 1) have an accurate rule, and 2) know the initial conditions. For entities such as electrons, Heisenberg interprets physical equations as indicating that we can never gain accurate readings of all of the parameters of initial conditions: measurement disturbs the parameters. For large physical entities, this does not pertain, as the difference between quantum and classical scale effects maintains (which arises at least in part because aggregations of physical particles manifest average behaviors due to large Ns). However, for biological entities on the cellular scale, the same limitations pertain. One cannot gain a measurement of all of the characteristics of a cell without changing those conditions (or probably killing the cell). Additionally, these same limitations pertain at even larger scales (e.g. whole organisms). Unlike larger physical entities, each organic entity is unique (more on this in Chapter 4). Since initial physical conditions cannot be known, prediction based on physical laws cannot be achieved, even with a massively large computer. However, in many cases probabilistic prediction can be achieved based on biological laws. Because biological "laws" are identified at the level of an arrangement, and the initial conditions of an arrangement are sometimes identifiable without destroying them or seriously perturbing them, then some cases of prediction are possible based on biological-level explanations. As Chapter 4 will emphasize, this self-similarity of organisms does not approach the self-identity of physical beings, and so the level of prediction is not the same as for physical entities, but it is nonetheless superior to physical level-based prediction.

To treat this issue in a more concrete fashion, consider that the DNA that a physics-based model would use to "compute" the organism is organized within chromatin. Furthermore, how DNA functions is "determined by" chromatin (the macrostructure of DNA) and by hundreds of other cellular components. The nature of how the chromatin interacts is fully physico-chemical; there are no mystical forces here. However, the structural character of the chromatin is not determined by the "local physical forces," but rather by the historicized structural-functional workings of the cell. Which sequences of the DNA gets transcribed and when (that is, what DNA does) depends on where the cell is in its developmental cycle and what the environmental conditions are (both of which can constitute quite non-local forces). These structural characteristics of the chromatin in its living context are not simply a product of the local physical properties of the atoms of which they are made, nor are they a property of mere "chance" or "accident." They are a property of the lineage of the living entity and its history. Mayr calls this the cells' “program.”

The "computer" that is going to compute the workings of DNA based on physical properties alone, therefore cannot simply compute the physical properties of the DNA itself, or even of the chromatin. It has to "know" (take into account) the state of the entire cell and the cell's environment, which may include an entire organism or an entire tribe. In other words, it has to have as input to its calculations not merely information about how particular chemicals interact and the specific information about those chemicals, but also information about a huge string of events that may well chain out to all the accidents that have ever happened in the universe (and perhaps contiguous universes if such there be and they affect ours). It is this enormous set of events that has constituted the cell or organism's “program.” In other words, a calculator external to the cell and its program must compute all the physical forces of all of the particles in the universe simultaneously. Since Heisenberg tells us that the data for that calculation can't be achieved, then we can't "compute" what a pieced of DNA is going to do based on its physical level characteristics. Even if we could do it, it isn't really a "calculation" at all; it is more like a tautological description. Paradoxically then, an attempt at explaining biological being in terms of physical being becomes an exercise not in generalization, but rather a move to absolute particularity. If our understanding of what scientific knowledge means requires generalization rather than apprehension of the particular (see e.g. Feynman, 1965, p. 76), then knowledge of physics is incapable of predicting the actions of particular living organisms. In contrast, using a few biological level concepts, a biologist can neatly and cleanly tell what particular pieces of DNA are going to do (e.g. divide or produce heat shock proteins) based on local environmental conditions and history and state of the cell cycle). Biological concepts thus provide a fuller and better set of generalizations about physical being in those cases where it manifests itself in the forms of biological being.

[8] While Stephan Wolfram's (2002) simple operators can produce the shape of a leaf or shell, none of his published simple operators produces a phenomenon that looks like the functions of a leaf—that is, that has co-ordinated nested structures of different structural types. It is the level of nesting that constitutes the "complexity" of living beings (in our terms, "transplexity") and thereby provides greater possibilities for causal constraints emanating from the form (or arrangement, described more fully in Chapter 4). Of course, the systems themselves may be constituted of particularly arranged aggregates of simple operators.

Wolfram has described how simple systems can produce what he calls "complex" forms, but his forms lack what we would call transplexity from an organic perspective. His simple forms produce 1) simple uniform forms, 2) random diversity, or 3) patterned variation, but not nested circuits. In his discussions about simplicity and complexity he routinely misequated complexity with randomness.[8] Complexity does not mean, however, merely a lack of uniformity. Random lack of uniformity is equally simple with regard to form and order.

Wolfram's more formal definition of complexity is not much more helpful. He indicates that the shorter the description one can give of a phenomenon, the lower its complexity. But this is wrong, because, as he has already pointed out, absolutely random series have the longest descriptions. Contrary to what he indicates, in ordinary conversation, let alone technical talk, no-one--other than perhaps computer programmers struggling to compress data-- -assumes that randomness is equivalent to complexity. Instead, as has been previously recognized, complexity exists when different types of form are joined together via nested series of hierarchical rules that allow variable behavior within components of the system that are simultaneously related in rule bound ways to other components of the system. The more the levels of nesting, the more inter-related the subcomponents or nests, the more complex the being. Thus, when sets of forms are differentiated by local functionalities and co-ordinated by macro-functionalities we move to the most complex types of form about which we yet know—transplex forms.

Wolfram's claim that complexity and randomness are the same in common parlance is on p. 537 and an example of his own conflation of the two is on p. 315 (though there are others). His definition of complexity is on p. 558, and reiterated on p. 575. Interestingly, Wolfram is much better at defining randomness and simplicity than complexity. He recognizes the definition of complexity I have given above, on p. 1068, but seems to dismiss it because it doesn't fit in with the computational tradition, rather than giving any explicit reason why it doesn't suit our ordinary understandings or actual conditions. This suggests that the flaw is on his slavish use of computation as the reference point. All this says is that computers can't deal with organic complexity (which would be very interesting) or, perhaps more likely, that programmers have not yet figured out how to deal with organic complexity through computers (we suggest the meta-theoretical formulations we are providing might facilitate this). None of this detracts from the creativity and utility of Wolfram's book as a whole, which is admirable.

[9] If one is interested in maintaining the clockwork model for biology, a better way to look at the metaphor might be to say that clockwork is a bad model for physics. Mechanisms are actually efforts to imitate biological being with human-made physical materials (because naturally occurring physical systems do not have the property of mechanisms or clockwork). Thus, in actually, we have the metaphor reversed.

[10] Please review footnote 13.

[11] The claim that symbols have the same characteristics as all other things that we conventionally regard as material.is not a completely novel idea. Philosophers such as Daniel Dennett have embraced the general concept (although not always addressing the specifics of symbol use or language), and much of the research on language today presumes materialist assumptions, even if it is not explicit about its philosophical underpinning. However, in both the elite and popular consciousness of Western societies, the idea that language is material rather than "ideal" (or "ideational") has generally been alien

[12] de Romilly, 1975.

[13] Accessed Dec 5 04 http://www.hyperdictionary.com/dictionary/Transilience).

[14] The Population Genetics Approach To Speciation, (http://www.towson.edu/~scully/mechanisms.html). Accessed Dec 5, 2004.

[15] Feynman, Leighton, & Sands, 1963, p. 31-1.

[16] It may be that physical being does not have these properties, but rather that the physical being that we have been able to describe has these properties because that is the only kind of physical being we could find, given that we were looking with tools that could only fit with such properties. For the purpose of overturning the ideal of the physics model in other areas, this alternative possibility doesn't matter. For the purpose of providing a full and complete philosophy of science, it will matter. Our belief is a functional one, that physical being probably actually manifests these properties in a sufficient degree to treat these as the primary properties, otherwise we would have more anamolies than we find. We base this guess on the way in which applications of the methods of physics have constantly run into barriers in biology and symbolics, which suggest that where the properties are not manifest enough, the phenomenon will not simply conform to the methods, but will show evident signs of resistance. This does not mean that physics provides a complete description of physical being, but merely a functionally substantial explanation.

[17] Biologists battle over the relative importance of these forces. Evolutionary theorists seek to privilege the evolutionary causes by labeling them "ultimate" causes and denoting other causative inputs as "proximal" causes. Molecular biologists fight back by dismissing "evolutionary" causes as un-testable and therefore uninformative (though sometimes it is argued that evolutionary causes might provide clues to mechanisms, see e.g., Lazar, 2005).

[18] Narratives actually play an important role in translating physical equations into interpretable phenomena for human beings, but this role is treated as ancillary to physics, and in any cases is not as central as evolutionary causal narratives are to biology.

[19] Chemistry provides an intermediary between the model of physics and the studies of substantial aggregates. In its reductive moments, it utilizes physics, even becomes inseparable from physics. In its synthetic moments, it becomes more like the other natural sciences.

[20] Within the course of our normal lives, within a single semester, the first author heard the model articulated as a research standard in 1) a genetics conference (American Society of Genetics Conference, October 2004) as an argument against research on gene-environment interaction studies, 2) at a social science talk (at the Institute for Behavioral Research, Univeristy of Georgia) as an argument why research on suicide should not produce an explanatory framework that was multi-causal, and 3) at an inter-disciplinary awards committee meeting where it was used to argue that a prolific researcher was not qualified for the award because the work was not "hypothesis driven." We have also had conversations and overheard discussions indicating that many scientists recognize the limitations of the model, but in spite of conscious recognition, it still often governs expectations and norms. Only a few people have so far been able to integrate revised notions of science fully. We hope this book provides a large, integrative picture that assists those moving in that direction to have a more self-consistent account.

[21] Models play a key role in relating the laws to the experiments, as well as providing predictions of their own. Physics regularly employs models of relationships that we can't perceive directly. In physics, most models are simply representations, usually visual

ones, from familiar, everyday reality that help make sense of things that cannot be directly observed in action. Thus, for example, we cannot directly apprehend the whole of space-time and its meaning for all of the rest of the components of physical reality (such as electroweak forces), so physicists draw a rubber mat with a grid on it and a ball pushing into it and deforming it to try to imagine what space-time and the nature of gravity might be like. The ball and mat serve as a visual model to which we can compare the physical forces. Physicists are famously uncomfortable with models, and for good reason (e.g. Feynman, 1965, p. 57). Models are simply analogies, and analogies by definition compare two things that share some aspects, but are different in other ways. Consequently, analogies are always wrong in some respects. The pull of gravity might be well analogized to the downhill roll of two balls on a mat toward each other, but we know that space-time is not well conceptualized as a rubber mat in other respects.

Sometimes models are so appealing and so wrong that they lead us down the wrong paths for a long time. The struggle over whether light was a wave or a particle provides the classic example. Many pieces of evidence show that light acts as a particle, and many pieces of evidence show that light acts as a wave. It was about as hard to get discoverers of particle evidence to give up their model of the "particle" as it was for advocates of wave evidence to give up their model of light as "waves". Yet the equations of quantum theory show how it is that light, as a probabilistic phenomenon in motion, can demonstrate properties that are common to other waves, as well as behavior that is common to particles. The "double slit" experiment has become the standard way of illustrating this. Light moving through either one of two slits in a wall when the other slit is closed produces a wave function similar to a *particle* moving through a single slit (a series of discrete impacts leads to a homogeneous pattern). On the other hand, light moving through two slits evidences behavior similar to a *wave*, not to two or more *particles*. That is, the light produces interference patterns of dark and light, just like the patterns two different waves produce when they meet. These apparently contradictory results occur because the wave function of light moving through two slits is the product of the addition of their wave functions rather than the product of the addition of their probabilities. It was only by combining the wave and particle views into a "wave-particle duality" and in no mean measure by inventing a terminology and set of equations that transcended the earlier models that physicists got over the "it's a wave!" "it's a particle!" dissension.

Though this example illustrates the good reasons to be leery of models, physicists can't really do without them. A model provides a link between the mathematical equation and the real world. Even if highly inexplict, a physicist wouldn't know what measurements to plug into an equation if s/he lacked a model of the phenomenon under study. Indeed, without models that treat imperceptible things like quarks in familiar terms (a "particle"), we wouldn't be able to hold them in our visually predisposed minds. The "wave-particle duality" vocabulary retains the older models of "waves" and "particles" that signal that the new "wave" function integrates older models. But more than that, models actually do intellectual work for us. They suggest predictions about how a particular phenomenon might behave. If light is a particle, we expect to find certain kinds of results if we perform certain experiments. Sometimes the experiments bear out the model, and sometimes they do not. Just like mathematical equations, therefore, models provide a basis for assembling predictions, and they can be falsified or supported through experimentation. It is possible to adhere to models too tightly, but it is not possible to do without them altogether.

Evidence for these claims about models comes from the inability of physicists to teach physics without them. Physics textbooks are full of visual models that purport to show the nature of a phenomenon or the interaction of physical entities. In the 505 pages of Arthur Beiser's successful, *Concepts of Modern Physics (6th edition)*, we counted 46 visual models of the former type and 50 of the latter type. That's almost one model for every five pages. This prevalence of models cannot be dismissed as merely a "teaching" tool. Once one has worked one's way through a set of analogies (wave and particle) one can move to a vocabulary that explicitly eschews earlier models (though the concept of the "*wave* function" doesn't quite fully shed the old model, does it?). Though one may suppress the model, one never really fully abandons the train of associations a model brought with it, because it is precisely such associations that tell one what part of the equation goes where. An example that uses the evolution of one of the most important models in contemporary physics—the atom--will help clarify how it can be that a model, though dangerous, is essential to the understanding that physics gives us.

As the story is usually told in first and second year textbooks, atoms were originally assumed to be discrete, indivisible particles (e.g. Beiser 2003; for more professional, historical treatments see Kragh, 1999 or Segrè 1976). On this model, gold would be divisible into individual pellets, each of which had the properties of gold, but which were themselves indivisible. When it was discovered that atoms of individual elements like gold were divisible into oppositely charged particles named electrons and protons, a new model was needed. The resulting model was enabled by J.J. Thomson´s research on electrons, and he called it the plum pudding model of atoms. This model of the atom imagined the electrons to be evenly dispersed in the atom among the protons, like raisins in a plum pudding. A prediction from this model was that positively charged alpha particles shot at the center of an atom would tend to be deflected by the mostly positive pudding of the atom. But, as Ernest Rutherford and his colleagues discovered, this prediction turned out to be false. Instead, most of the particles shot at atoms went right through without even being deflected, and a few bounced right back. Thus, Thompson's model was falsified, and a new model of the atom was proposed that seemed more in accord with the experimental results. As a result, the solar system model of the atom came to prominence. If we imagine the electrons as little planets orbiting around the nucleus, filled with protons, then we can explain why positively charged particles shot at atoms mostly go through. The atom is mostly empty space. Occasionally, however, there is a direct hit that bounces the particle straight back. This solar system model provided the mainstay of chemistry textbooks for many years.

This new model had its own problems, however. If atoms are little solar systems, what keeps all those positively charged particles in the nucleus from flying away from each other? And why don´t the negatively charged electrons just spiral into the center of the positively charged protons? As physicists began to apply existing equations to predict the nature of the orbits of the electrons, they also found incompatibilities between various equations, measured quantities, and the model. Noticeably, the solar system model predicted that one should find a continuous range of frequencies for the absorption spectra of light coming from such an atom when it was charged and in a gaseous state, but instead only discrete frequencies were found.

Again, the disagreements between what the model led one to expect and the measured results of experiments pushed understanding forward. It also necessitated another change in the model of the atom. At this point, however, physicists began to rely more heavily on equations and less heavily on their models. First, physicists measured the frequencies of the spectrum of light produced by hydrogen atoms. Then, they tried to develop equations that could accurately summarize these frequencies, that is equations that produced results that were the same as the frequencies themselves. Johann Jakob Balmer was the first to produce such results. But these equations, though accurate, were something short of a satisfactory explanation. They were deduced by trial and error. They summarized the relationship of the frequencies, but they didn´t really *explain* why the relationship existed. Physicists couldn´t link a model to the equations and feel that they really understood what was going on.

Niels Bohr was able to develop the idea that the light emitted from these changed atoms was a product of electrons jumping from one higher energy "orbit" to a lower energy orbit. Based on this new model of orbits with different energies, he was able to mathematically derive the equations that Balmer had produced. He wanted to move physics solely to the realm of the empirical measurements that could be made and the equations that explained the specific measurements. He felt that the sub-microscopic world of the atom couldn't be accurately modeled by comparison to any visual representation with which we were familiar. The atom is just unlike anything we know more directly from the experiences we have at the daily-life human scale. For this reason, physicists today still decry the use of "common sense" models. But Bohr failed at his effort to convince people to operate without models, and actually went back to using them himself. Although the models could not be fully accurate—people, even physicists, still needed them as a tool to think with. The model with equations were needed to make people feel they understood the atom, and together they therefore provided a more sufficient explanation. However, the rise of quantum physics did signal a shift in the way models were used. No longer was a single model to be used to explain the entirety of a physical system. Instead, fragments of different models would be used to explain different parts of a physical system. The model no longer provided the over-arching framework—the equations did that. Instead, models explained how to hook up equations and measurements by suggesting how to understand the measurements as relationships. This can be illustrated by the next phase of the development of understanding of atoms, which sought to answer remaining worrisome "why" questions, especially, why were there just a discrete series of orbits that electrons could inhabit?

Research in quantum physics by deBroglie and Schrodinger and others brought an entire new way of thinking about the microscopic world and a new analogical model of the atom. Everything, it seems, at the atomic and subatomic level, comes in quantized packets of energy. The model usually offered for thinking about this today is a jump rope. If you shake the jump rope up and down, you can set up a standing wave in the rope, but there are only certain frequencies that will set up that wave. These are the frequencies at which the whole wave or exact multiples of the whole wave, will exactly fit on the rope. If you try to use a frequency that is 1 1/5th of a wave, the wave going out will interfere with the wave going in, and you won´t get a wave on your rope at all. The new model of the atom conceived of electrons as moving in such a wavelike fashion. So the atom was not to be envisioned as a solar system, but rather as a wave moving around the atom, albeit one that covered the whole surface of the three-dimensional orbit like a cloud (a three-d jump rope). Moreover, as things got even weirder in quantum research, the analogy got increasingly stretched. The cloud wasn´t really a cloud, but rather a set of probabilities about where the electron might be, even though it could really be virtually anywhere at all. At this point, the equations and the specifications of the electron´s orbit in terms of four quantum numbers and quantitative energy levels becomes central. There is no coherent visual image or analogical model of the atom per se. But bits and pieces of models (waves, jump ropes, orbits) nonetheless remain crucial for generating the conceptualization of what the equations of quantum physics could mean and how they could be applied. The orbits begin to be "explained" by a pastiche of theory (quantum based concepts), numbers (quantum numbers), equations, and patchworks of pictures that help visualize part (but not all) of the atom. The language also departs even further from ordinary familiar vocabulary, and terms like "wave function"—which explicitly blend the old pictures with the new mathematics--become central.

Analogies are so crucial to understanding the physical world because idealized physics, and much of specified physical research, operates on scales that exceed our everyday perceptions. Human understanding is built first and foremost on direct observation, and secondly on symbolic systems. We cannot directly see what goes on at the sub-atomic level, nor on the galactic level, nor through the history of a planet´s life. Our built-in sensory apparatus does not operate on the scale of atoms or planets either in terms of space or in terms of time. Being creatures that have a small amount of cleverness, we´ve invented tools to breach the gap between our direct perceptual capabilities and these scales of space/time. But these machines give us results that are different in form from our normal visual and verbal inputs. They give us squiggly lines on a graph, or patterns of dots on a photographic film, or sets of numbers. These squiggles, dots, or numbers don´t seem like explanations to us, until they are linked back to our basic perceptual patterns. Analogical models provide that linkage to our perceptual capacities. While physicists can and do learn to think within equations as an inter-dependent set largely independent of the analogies, and they may make great advances when they can do so, they can't explain the implications of those equations without reaching back to analogical models. It is, therefore, the scale problem that makes analogies essential for physics, and so we would expect a different role for analogies and models in scientific endeavors where scale was less of an issue and translation problems were not the same.

[22] See e.g. Balashov & Rosenberg (2002); Buchwald (1995); Cohen (1960/1985); Dubar (1995); Fahnestock (2003); Foucault (1970/1973); Fuller (1997); Gross (1990); Gross & Keith (1996); Harris (1997); Leplin (1995); Jaffe (1960); Jamieson (1998); Keller & Longino (1996); Kragh (1999); Krieger (1992); Latour Woolgar (1979); Lessl (1984); Mayor & Forti (1995/1999); Pickering (1992, 1995); Segrè (1976); Taylor (1996); Toulmin (1958); Tuana (1989).

[23] There is a relatively large literature on the methods of physics. We have found the most forthcoming information from physicists themselves in Richard Feynman's works, especially his <u>The Character of Natural Law</u> (1965). Also relevant are comments

in works by Einstein (1961), Greene (1999), Weinberg (1992/1993), Dyson (1964) and Hawking (1998).

[24] Early and increasingly intensive work in the philosophy of science has both defended and elaborated the physicists' account of the role of various components of the hypothetico-deductive method in exquisite detail (e.g. Balashov & Rosenberg, 2002). Dudley Shapere (1995) reviews some of the key points, and other essays in that volume (Leplin, 1995) provide an historically informed, sophisticated debate on these methods.

The recent trend in science studies generally has been to debunk the scientists' account. Debunking includes emphasis on the extent to which the hypotheses and other aspects of scientists are formulated in the inevitably biased terms of the social system from which they come (Keller & Longino, 1996; Krieger; Tuana, 1989)**,** emphasis on the extent to which the projects of science succeed or fail is a consequence of the broader rhetorical skills of the scientists (Fahnestock, 2003; Gross, 1990; Harris, 1997; Lessl, 1985; Pera, 1994), and emphasis on the role of economic and other social forces (Fuller, 1997; Latour & Woolgar, 1979**;** Mayor & Forti, 1999; Irwin & Wynne, 1996). Historians of science often mix agreement with the physicists's own description with an emphasis on serendipity on the progress of science (e.g. Jaffe, 1960). A large movement in science studies has treated physicists and their activities as an empirical object for observation and described the fully embodied "practices" of physics, emphasizing the fact that physics is not merely abstract hypothesis, disembodied experiment, and mathematical and logical deduction (e.g. Buchwald, 1995; Pickering, 1995). A useful bibliography, emphasizing the rhetoric of science, is available at www.rhetoric.umn.edu/rstc_reading.html. Our account of physics here presumes that the findings of science studies have added substantial breadth and sophistication to our understanding of how physics really works. To the extent that this work insists that physics is constrained by a socio-economic context and conducted through discourse, these accounts are correct, indeed more correct than the physicists' sometimes myopic focus on the laboratory and observation. However, the social conditions and rhetoricity of physics are only marginally different from the same factors in biology and somewhat more different from the factors in symbolic studies. Thus, except where those differences are highlighted, the science studies literature fades into the background of this particular argument. There is, however, one crucial turning point for this argument. There is a subset of members of the science studies community who believe that ideology or rhetoricity provide a full explanation of the forces operating in science. This claim is based on the idea that all human practices are "text all the way down." We disagree with this belief. Although, as symbol-using animals we can only know things through our symbol systems, this does not deny that there is input into scientific observation from the material world beyond our symbol systems. We think, in other words, that the best account is a "both/and" account that tries to incorporate both discursive and non-discursive material forces.

[25] Feynman, 1963 p. 1. As we note elsewhere, Feynman equivocates on his use of the term "experiment", sometimes including rigorous observation in the term when rigorous observation is used to test hypotheses. This conflation of terms creates conceptual confusion that allows scientists to systematically mis-identify their own procedures.

[26] Cohen (1960/1985, p. 207) gives a tidy summary of the hypothetico-deductive method. This account emphasizes the extent to which the hypothesis to be tested is a deduction

from a more general theorem that cannot itself be tested directly. See also Dunbar (1995).

[27] Krieger (1992) describes experimental control in an intriguing fashion as the search for "handles".

[28] This experiment may need to be replicated to provide certainty, but we are referring to the fundamental design of the experiment.

[29] Feynman (p. 156) is particularly thorough in describing the difficulties of identifying a good experiment from a physicists' perspective. Charles Taylor (1996) describes the difficulties in the case of the "cold fusion" controversy from a rhetorical perspective.

[30] The example of the elliptical orbits of the planets is based primarily in rigorous observation rather than in experimentation. This illustrates the tension between the belief that what makes physics work is "experimentation" and the fact that rigorous observation is often used as part of the hypothetico-deductive method. Feynman (1965, esp. Chs. 1 & 7) recognized observation as a mechanism of testing, in fact, defining "looking very closely" as an essence of science. However, Feynman, like most people, is imprecise in his use of the terms experiment and observation, sometimes distinguishing the two and sometimes subsuming observation within experimentation. Observation can sometimes be done to test a theory, but sometimes it is simply part of an inductive process. The imprecision of the use of these terms creates an inaccurate understanding of the scientific process. The idealization of physics is generally accompanied by an idealization of hypothetico-deductive testing using experiments (even though in fact, physics is also accomplished by hypothesis testing using observations *and* by inductive uses of observation).

[31] Cohen and Whitman's translation (Newton, 1999).

[32] For an account of the development of Newton's perspective, including its relationship to common sense perception see Cohen (1960/1985, esp. pp. 15-24, 122, 154). He also emphasizes the extent to which Newton's genius was a product of the ability to abstract rather than of experiment alone (pp. 106, 163), and he describes Galileo's use of the broad arsenal of human tools of thought (pp. 94, 99, 100, 125), as opposed to primarily experimental observation.

[33] Greene (1999) attributes Newton's success to "bringing the full force of mathematics to the service of physical inquiry." For physicists emphasizing the use of equations see especially Feynman (1965, Ch. 2), but also Weinberg (1992/1993, e.g. p. 59).

[34] Feynman (1965, p. 39).

[35] Weinberg (1992/1993, p. 7). His emphasis.

[36] Dyson (1964, p. 249).

[37] The calculus and trigonometry that are used to demonstrate these relationships themselves are inherently idealized. Calculus especially relies heavily on the concept of numbers that approach limits, but never reach them. This conceptual apparatus enables one to convert equations and demonstrate their appropriateness, but it introduces the strange concept of infinity into many equations. Such infinities are sometimes taken to be awkward annoyances inhibiting proper calculation, and at other times are taken to specify absolute prohibitions (e.g. if a denominator in an equation is zero, that is taken to mean a particular phenomenon can't exist). Such troubling misfits between mathematics and reality are swept to the side because, in enough cases, the match between the measured quantities of real phenomena and the equations is good enough for a broad

enough range of purposes to count as general. Examination of such points of anomaly are often useful. We suggest, for example, that Einstein's dual-perspectival account of relativity produces the famous infinities in his equations, whereas a truly omni-perspectival account of relativity would eliminate those infinities.

[38] Beiser (2003), p. 168.

[39] E.g. Heinrich, Gupta, Lutz, Eigler, 2004, pp. 466-469.

[41] As quantum physics turns its attention to the behavior of single atoms, one would expect that the kind of problems and issues faced in the biological and human sciences will become more salient, and methods will need to be developed to approach the single, highly variable case.

[42] Wilczek, 2002 (p. 165).

[43] On reductionism Weinberg (1992/1993) provides one perspective by a physicist, which is quite different than that provided by Feynman (1965, p. 147). A useful way of thinking about this, we believe, is to say that reductionism is a powerful methodological tool but insufficient on its own to comprise full accounts. Biologists are more open on this point (see Wilson (1998) and Mayr (2004)).

[44] When we say that physical being has this structure of types, what we are really saying is that the particular multifaceted characteristics of physical being can be organized into symbolic categories of this sort and that the resultant set of categories both serve a broad range of functions and that applications of the organization do not require so many exceptions and qualifications that the categories lose their functional utility. This reflects on the underlying properties of physical reality, even though the particular act of categorizing belongs to the symbolizing entity itself. That is to say that it is possible that

physical being might have had a nature that would not have permitted organization into a few stable types (as is imagined, for example, in many science fiction universes, where physical laws change across the galaxy and there is a proliferation of forces and phenomena). Some lines of argument in science studies would suggest that we can't know that physical being has these features that lend it to this kind of categorization. Their argument relies on the ubiquity of such forms of characterization, but that the categories tend to be different cross-culturally. Our response is that indeed, language appears to be an essentializing machine, and hence this kind of reductionism comes ready to hand to language-users. However, the application of reductionism to physical being has a particular kind of pay-off. The existence of cross-cultural differences only proves the point. Where category systems for physical being are different, one does not get the enormous range of functional payouts produced by Western physics. This is not to say that other category systems don't have other forms of functionality (or even that those other forms are equal in value or even superior). It is just to say that the set of functional products of the specific brand of essentialism of Western physics (i.e. "reductionism") stands as proof that there is a certain kind of product of the match between physical reductionism and physical being.

[45] In 21st century physics this may prove to be less a routine understanding. Because of goals for quantum computing and other nano-applications, physicists have begun to focus on single atoms, and when they do so, it begins to become apparent that single atoms are different from each other, both due to internal features (the quantum state) and also local nano-environmental interactions (see e.g. Heinrich, Gupta, Lutz & Eigler, 2004).

[46] Weinberg (1992/1993, p. 33).

[47] Actually, the strength of the strong, weak, and electromagnetic forces vary at short distance (with strong > weak> electromagnetic), but they converge at greater distance. Given the scale of distances at which they typically operate, this produces the separation of effects.

[48] On role of measurement in development of the Copernican system, see Cohen (1960/1985, p. 134). The role of measurement is inherently different in quantum theories than in classical, and the debate over the meaning of measurement in quantum theories remains a live one (see Cordero, 1995).

[49] This is an oversimplified translation of a complex mathematical relationship, but it is a translation routinely used, even in physics textbooks.

[50] Feynman had a prescient description of "how physics may end" that forecasts this possibility (1965, pp. 172-173).

[51] LaTour and Woolgar (1979) describe the output of scientific laboratory experiments quite perceptibly as "inscription devices", but in physics the inscription is most often translated through numbers.

[52] E.g. Heinrich, Gupta, Lutz, Eigler (2004).

[53] What go by the names of "complexity" theory or "chaos" theory operate in different causative paradigms, but these are unevenly accepted, though they've gained much larger acceptance in the past decade and their terminology has infiltrated many fields.

[54] A reasonable speculation is that humans are predisposed toward such OCOE models precisely because we evolved in a physical context where such models generally work. However, as we will see when we get to discussions of symbolics, this template is also in

conflict with a different potentially in-born "causation" model, that of the narrative or dramatistic framework.

[55] Physics is approaching that barrier today with applications in quantum computing. This does not mean that such applications are impossible, but they begin to include some of the kinds of difficulties we will see in controlling biological being. Expert knowledge comes to play a much higher percentage role compared to leveraged application in such systems.

[56] Compare Post 1999 and Zoti 1999.

[57] We owe our account of the contrast between the nuclear navy and commercial production to Clay Condit, who was involved for a long period of time in training the former.

[58] Compare Farrell and Goodnight (1981) to Klaidman (1991).

[59] Sibum, 2004.

[60] For a comparison with geology's 5000 minerals, consider that Feynman (1965, p. 153) described 48 particles as "a frightening array".

[61] See, for example, Railsback, 1998.

[62] It may be argued that the idealizations are useful and productive, which they are. However, the idealizations are useful for producing some kinds of knowledge about some kinds of things. They may also obscure other kinds of knowledge about other kinds of things. The ideal is an integrative model that idealizes and simplifies for some purposes and then is capable of integrating and dealing with complexity for other purposes. However, whether or not an idealization (such as treating a complex compound as though it were homogeneous) is an effective strategy depends on the relative impact of the

internal heterogeneity/homogeneity on the characteristics being studied. We suggest, for example, that physicists have been able to "black-box" the heterogeneity of atoms because the effect of the heterogeneity on the properties studied has been (until recent additions of new goals and interests) so small that it is negligible. This strategy will not work where the heterogeity impacts the characteristics studied. This points up the importance of our argument about the overlapping/nonoverlapping nature of the scales at which different forces operate.

[63] Maliva and Siever, 1988.

[64] Wedin et al., 2004. See also *Nature*, v. 433, p. 468 (2005).

[65] This distinction between the goals of physics on the one hand and astronomy and geology on the other has been discussed by Richard Feynman (1995, p. 65).

[66] The alternative method is to apportion variance to account for degree of cause, but this only allows a test of the relative contribution of different causal factors. It does not provide a means of discovering which potential causes might be involved in the first place. It is a confirmatory rather than discovery-oriented practice, and it does not produce predictive equations.

[67] This complex system is known to many in simplified form as the "global conveyor belt", a simplification that physical oceanographers love to hate. See Broecker, 1991, and Clarke et al., 2001.

[68] Tapponnier et al., 1982; Rosenberg et al., 2004. More generally, see Schellart, 2002.

[69] Grassl, H., 2001.

[70] Redfield, 1958.

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[71] Chamberlin, 1890; 1897. For a modern reprise, see the October 2004 Houston Geological Society Bulletin, v. 47, no. 2, p. 68-69.

[72] Harrison, 1963.

[73] Thomson, W., First Baron Kelvin, 1895.

[74] Lord Kelvin is of course considered one of the great figures of nineteenth-century science for his contributions to physics, as the familiar unit of temperature attests. However, as a natural scientist, Kelvin emerges as something of a tragic figure, trapped by his rigorous and quantitative understanding of thermodynamics into conclusions that the Earth could only be very young and that the sun could only be heated by the impact of meteorites falling into its surface. See Burchfield, 1990.

[75] Lawton, 1999. Lawton argued that ecology has few "universal laws" but several "general laws" that are "usually true".

[76] Horner-Devine et al., 2004; Rosenzweig, 1995.

[77] Connor and McCoy, 1979. Connor and McCoy found that the formulation $S = zA + c$ provided the best model in almost as many sets of data as did $S = cA^z$. Nonetheless, Rosenzweig's 1995 book showed almost exclusively plots and equations following the latter formulation, in part by restricting itself to sets of data from nested, rather than non-contiguous, areas.

[78] See pp. 148-149 of Urey, 1952. Urey was born in a small town in Indiana in Indiana, barely passed the entrance examination for high school there, and taught in a mining camp in Montana before enrolling at the University of Montana to begin an academic career that included a Nobel Prize, twenty-five honorary doctorates, and fifty-four years of scientific publication.

[79] Key papers in this saga are Veizer and Hoefs, 1976 and more recently Veizer et al., 1999; Claypool et al., 1980; Garrels and Lerman, 1981; Berner et al., 1983; Garrels and Lerman, 1984; Berner, 1991; Berner, 1994; Berner and Kothavala, 2001; and Royeret al., 2004.

[80] The geologic time scale that Berner used put the beginning of the Cambrian at 570 million years, whereas refinement of the time scale has lessened that estimate to 542 million years. Conversion from one to other requires a little effort, but the end result is only that Berner was working with slightly more detailed time increments than originally thought.

[81] One should not infer from the decreasing atmospheric concentration of carbon dioxide in the Tertiary and Quaternary that these results invalidate claims that the carbon dioxide content of the atmosphere has increased over the last two centuries. The two trends are at two different time scales: a detailed graph over the last fifty million years would show decreases over forty-seven million years, fluctuations for the last two or three million years, and then a sharp upward spike in the last two centuries.

[82] In parallel with the previous note, one should not infer that warmer global climates in the past invalidate present concerns about global warming. The changes in global climate across geologic periods discussed here occurred over millions to tens of millions of years, rather than in decades, so that rate of change was much less.

[83] These were the words of a University of Georgia professor of physics at a colloquium in the Physics Department there.

[84] Testing the model through new observations is a key part of the procedure, but only a part.

[85] Feynman, 1965, pp. 33-34, 171. See also Hideki Yukawa's claim that "nature is simple" in Hovis & Kragh, 1993.

[86] http://math.furman.edu/~mwoodard/ascquotm.html; http://www.zaadz.com/quotes/authors/bernd_t_matthias/; http://www.chemistrycoach.com/science_mathematics_and_beauty.htm; http://www.physics.montana.edu/students/thiel/quotes.html.

[87] Dirac quoted in Hobis & Kragh, 1993; Dirac, 1963, p. 47. Note that there is disagreement on this issue, as Feynman (1965, p. 156) wrote that "If it [a computation] disagrees with experiment, it is wrong."

[88] Wunsch, 2001.

[89] See, for example, page 4 of Feynman, 1985.

[90] Smolin, 2004.

[91] Lipton, 2005.

[92] Our argument about the nature of biological beings is based primarily on the observations of the first author of biology over the past ten years. Her work in biology began with a Study in a Second Discipline Fellowship in Genetics at the University of Georgia. This included undergraduate and graduate course work as well as very stumbling work in an *E. coli* lab under the gracious direction of Sydney Kushner and his post-docs Eileen O'Hara and Caroline Ingle. A brief stint as a Visiting Investigator with two fabulous and kind genetic counsellors at the National Institutes of Health (Barbara Bowles Biesecker and Don Hadley) allowed a bridge to both medical research and clinical applications. Throughout this time, she has attended conferences in genetics (including ASHG annual meetings, the NSGC meetings, and the SNP consortium

meeting), the genetics department colloquiums at UGA, and the UGA Winter Evolutionary Biology Seminars, as well as campus-wide presentations related to biology. She has tried to place genetics in the broader contexts of biology based on course work in biology as an undergraduate and by following developments in academic journals covering biology. During the second half of this period her own work has focused on social issues related to human genetic variation under an NIH "ELSI" grant, and so she has tracked fairly closely the technical literature on human genetic variation. None-the-less, her perspective on biology has no doubt been heavily influenced by the emphasis on genetics and especially human genetic variation in the research lines to which she was most frequently exposed. These biases are partially redressed by the fact that the second author's knowledge of biology has come through paleontological and evolutionary approaches. The concern about a molecular bias is also substantially alleviated by the fact that our observations seem to coincide nicely with Ernst Mayr's latest book, *What Makes Biology Unique?*(2004). Mayr is a veteran, esteemed biologist who has had a view of the broader realm of biology and has viewed it from the perspective of the internal expert rather than the observer. The fact that our observations coincide so closely provides an extremely helpful cross-validation.

There is a large literature on the biology in science studies, and this study is also informed by some of that literature. I have been particularly influenced by Fox Keller (2002), Ceccarelli (2001), and Lyne and Howe, (1986). Harris (1997) provides a sampling of essays from some of the "classic" works, as well as a bibliography of major works to that date.

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[93] Foucault (1970/1973) has argued that "life" did not exist as a category about which Westerners thought abstractly until the late 18th century. Those who take social constructionism most seriously have assumed that this means that "life" is not a "real" category. Another possibility is that our intellectual structures were not up to addressing such an abstract and dynamic category until then. Foucault's point is not that there was no concern about things we now identify as living, but merely that the precise demarcation of "life" was not a point of emphasis. Others trace the notion of "life" to the late sixteenth century; see Emmeche, "Autopoietic Systems," 245. Ernst Mayr (1982) has noted that the classical Greek philosophers also recognized the distinction between animate and inanimate matter: Whether one accepts the progressive narrative or the deconstructionist one, however, there is no doubt that efforts to pinpoint what makes living things alive have been regularly undertaken, and produced inconstant results. The authors in Table 2 provide what we think of as the best distinctive efforts to deal with this problem, and we will let the table stand in for a more discursive treatment.

[94] Schrodinger (1946); see also Schetjer & Agassi, 1994.

[95] Emmeche (1997), p. 257.

[96] The strength of the definition is suggested by the way it usefully clarifies a current point of contention—the status of potential "A-life" (artificial life). In organic being form is inherently bound to particular types of molecules. When we talk about the DNA "code" as the book of life, we are wrong not just because the metaphor is hyperbolic, but because in true code systems, the form is separable from the material on which it is transmitted. A morse code message can be transmitted on a telegraph, on a pipe, with a train whistle, or a shuttered light, or even through bases of DNA strung together. This

separation of form and matter is not the case with organic being (see Emmeche, 1997, p. 256). Thus, the variety of forms in which DNA and RNA are illustrated in the paintings and sculptures of Gregor Mobius, Jaq Chartier or Iñigo Manglano-Ovalle do not constitute organic being, but rather symbolic being (these were displayed at the Henry Art Gallery exhibit “Gene(sis)” , which is available on-line at http///www.Gene-sis.net). DNA is central to most life on earth because it is *more* than a code. The physical conformation of every nanometer of DNA exhibits physical attractions and repulsions that create specific relationships with other molecules to remake its self. Although the system in which it operates can be understood as an information system at a level of abstraction, the DNA does not work by “telling”; it works by *being* of a certain form that is enabled to repeat itself. Hopefully, the distinction and the difference it makes will become even more clear through Chapter 6’s discussion of symbolic being.

Computer programs are different from organic being in this respect. Their “software”—the program that constitutes them—is not tied to a particular physiological matrix. A computer program is best run on the conventional electronic set-ups that we use today, but in principle the program really is just a series of binary relationships 0,1 (yes/no), that may someday be run on organic matrices (current work on “DNA computers” is progressing, albeit slowly), or they could be run on completely mechanical devices, though they would not be nearly as efficient. Indeed, an abacus performs the same computations as modern computers, with a “program” that is installed in the human operator by learning.

This means that computer programs are not living beings, though it does not rule out that some kinds of computing entities could be created that would be living.

Currently, however, computer programs that are identified as "A-life" are more like non-organic symbolic beings than they are like organic beings. Our definition clarifies that it may well be the fundamental material duality that produces organic being, rather than any of the "life-like" properties that this duality generates, which give organic being a special value and status (cf. Lange, 1966). The status arising from any particular life-like property might be separately weighed. We might, therefore, decide to value organic being over other kinds of life, because the life embedded in organic being has a specific materiality that is non-transferrable, whereas the life-likeness of something like a computer program is transferable and iterable. Wherever that argument takes us, the description of organic being as materially specific reproduction of self-similar form indicates that the question of the value and status of organic vs. inorganic beings is a separate argument than that over whether artificial intelligences might be understood to be "alive." This accounts for our intuitive sense that a smart computer might, at least at first blush, seem to have less dignity and deserve less compassion and fewer rights than a less smart pod of whales, even if it does not yet answer the question of their ultimate treatment.

[97] On how and why complexity might have evolved through the variability introduced by sexual reproduction, see Mark Ridley (2001).

[98] Useful definitions must demarcate what is <u>not</u> within the category that they demarcate. This description of organic being might not seem sufficient because it does not neatly separate living and non-living organisms. Crystals, and perhaps bubbles, for example, might be said to loosely fit this definition, though their "recruitment" of other matter is more tenuous than in living beings as we think of them. More importantly, it is not a

separate self-similar form/matter pairing that is established through crystal growth, but rather an extension of the original entity. Such fine distinctions, and even ambiguity, are to some extent inevitable if the goal of the description is to identify *the transition* between physical and organic being. The ambiguity is appropriate, and even a sign that the definition is hewing as close to the core issues as possible, as long as it pertains primarily to elements that are at the boundary of the transition. Some research suggests that either bubbles or crystals might have, in fact, been originating points of life. As Noam Lahav (1999) reports, early research by Oparin and Fox has been further explored, showing that proteinoid microspheres look a lot like "protocells" and coacervate droplets, though less stable, also might have provided a bubble-like structure that participated in the beginning point of life. Bubble-like structures might well have provided a starting point because they allow the creation of "internal" and "external" and thus the creation of a separated being. The existence of some kind of membrane is, simultaneously, essential for the ability to resist local forces. Of course, this is not to say that the organic entity is fully separate from its surroundings or resistant to all local forces, as organic beings have semi-permeable and co-constitutive rather than discrete relationships with the rest of the world. Another tenable theory is that something like crystalline replication was a foundation for the beginning of life, providing a substrate upon which reproducing entities could form because of the stable, ordering qualities of crystals.

On the other hand, other conventional test cases, such as fires, volcanoes, and vortices—cases which are not in fact involved in the transition between inert and organic being--do not fit this definition. Fires do not maintain a particular arrangement; though they "recruit" other matter to the same process; their form is inconstant and dependent on the immediate external environment in a way that is not true for living organisms. The particular form taken by a vortex is likewise completely dependent on the immediate environment in which it is established. Although volcanoes have something like a basic form that is process generated, they don't reproduce that form or even function to maintain their own form, and again the form is completely determined by the local environment. Thus, the description seems aptly to divide those inorganic phenomena that might reasonably have been involved at the beginning of life from those that might not, even though these different groups might share some abstract features.

[99] This self-hood exists regardless of human abilities to identify it, because it indicates that each organism has its own locus and hence perspective independent of the perspectives of other beings such as humans. The existence of such a self-located "perspective" does not require verbal consciousness of a human sort. A perspective is a place from which a view is taken. Each organic entity constitutes a specific place that "views" the world around it in terms of what permits self-maintenance and self-reproduction, and that is all that we intend by the term "self". However, the existence of this self that is defined simply as the locus of these two functions means that "function" is a direct and inherent by-product of self-reproduction.

[100] Cite Mayr and Smith on functionality.

[101] It has been suggested, by Shrödinger and others, that in fact, living systems do violate the laws of entropy as they would be described in the absence of living things. Physicists have modified these laws to distinguish open and closed systems in ways that account for living systems or systems produced by humans, but this smacks of a post hoc modification. It might be argued that this is an example of where our understanding of

life influenced the formulation of the physical law, and thus, an example of the way in which living systems operate differently from non-living systems.

[102] Alex Rosenberg (1985) has provided one of the most thorough and thoughtful treatments of the concept of function in biology. Rosenberg's claim is that in practice function talk may be useful, but in theory one could successfully describe everything an organism does by using deterministic physicalist terms. He seems to mean that one could--if one had a sufficiently fast and powerful brain and infinite measuring devices that left no effect on the measured object--predict where the chemical components that constitute an organism were going to be and even what conformation the organism was going to take and what processes it was engaged in. On its face, this seems right, because organisms and their parts, like DNA, are completely bound by their physicality, such an omniscient being could successfully make such a prediction. However, as I indicated in Chapter 1 in answer to Weinberg's similar claim, that is no apt definition for knowledge. In fact, *and in theory*, no being could know the world in this way, for our more advanced physicalist theories tell us that every measurement of the universe that seeks to know what is/will be changes what is/will be. It is also weird to say that "in principle" there is a knower who can know without symbolic mediation (at least for Rosenberg, who does not believe that there is such a knower!). Instead of saying that "in principle" such knowledge is possible, let us say "in omniscio" such knowledge is possible, but the "in omniscio" state is in principle impossible and in addition our principles of physical being now show that it is *not,* in principle, possible to know the universe in this complete way, since all efforts to know entail modifications that change the object observed and therefore make stable total knowledge impossible, *in principle*.

If the lure of such mythic omniscience overwhelms good sense and physicalist theory, however, there is a more specific and equally devastating reason that Rosenberg is wrong about the sufficiency or superiority of physico-chemical explanation; as Mayr suggests, to be able to predict where an organism will be and what its internal and external physical conformation might be at any one time is *not* to have knowledge of an organic being. We literally do not understand an organism if we understand it merely in terms of physical being, that is as a collection of molecules in a particular space and time. Once the form/function of a discrete organic being has been set in operation, to understand it means to understand it in terms of that form/function. If we could use our magic omniscient, non-interfering physics computer to calculate where every piece of matter in the universe was going to be, *we wouldn't understand evolutionary processes.* Explaining where pieces of matter might be with regard to their electrostatic charges, inertia, and gravitational forces, even if possible, would not tell us why fish have gills. These are two very different types of explanation, which give us very different kinds of information. Even if the prediction of the location of all the particles in the universe were useful and interesting (which may itself be dubious), explanation of evolutionary processes and the functions of organs and genes and development would still be *more* useful and *more* interesting. This is to say that function based explanations of biological being are not just necessary evils but rather *better* explanations than physical explanations.

[103] When we refer to extremely simple forms, we are thinking of forms below the level of complexity of RNA. There may be upper limits on successful complexity or transplexity as well.

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[104] Mayr (2004), pp. 88-89.

[105] Whether or not they are correct, it is a vociferously held dogma in physics that every atom of a given type is identical to every other of that type. We have tested the adherence to this belief in discussions with physicists.

[106] On species definitions see Mayr (2004), 171-194 or Rosenberg (1985).

[107] Sneath & Sokal, 197;. Blaxter 2004.

[108] Horner-Devine, Lage, Hughes, & Bohannan, 2004.

[109] We are using Mayr's (2004; p. 105) estimates for numbers of phyla and species.

[110] It is the level of nesting that constitutes the "complexity" of living beings and thereby provides greater possibilities for causal constraints emanating from the form. Stephen Wolfram has described how simple systems can produce what he calls "complex" forms, but his forms lack what I would call complexity from an organic perspective. His simple forms produce 1) simple uniform forms, 2) random diversity, or 3) patterned variation, but never nested circuits. In his discussions about simplicity and complexity he routinely misequated complexity with randomness.[110] Complexity does not mean, however, merely a lack of uniformity. Random lack of uniformity is equally simple with regard to form and order.

Wolfram's more formal definition of complexity is not much more helpful. He indicates that the shorter the description one can give of a phenomenon, the lower its complexity. But this is wrong, because, as he has already pointed out, absolutely random series have the longest descriptions. Contrary to what he indicates, in ordinary conversation, let alone technical talk, no-one, other than perhaps computer programmers struggling to compress data, assumes that randomness is equivalent to complexity.

Instead, as has been previously recognized, complexity exists when different types of form are joined together via nested series of hierarchical rules that allow variable behavior within components of the system that are simultaneously related in rule bound ways to other components of the system. The more the levels of nesting, the more inter-related the subcomponents or nests, the more complex the being. Thus, when sets of forms are differentiated by local functionalities and co-ordinated by macro-functionalities we move to the most complex types of form about which we yet know.

Wolfram's claim that complexity and randomness are the same in common parlance is on p. 537 and an example of his own conflation of the two is on p. 315 (though there are many others). His definition of complexity is on p. 558, and reiterated on p. 575. Interestingly, Wolfram is much better at defining randomness and simplicity than complexity. He recognizes the definition of complexity I have given above, on p. 1068, but seems to dismiss it because it doesn't fit in with the computational tradition, rather than giving any explicit reason why it doesn't suit our ordinary understandings or actual conditions. This suggests that the flaw is on his slavish use of computation as the reference point. All this says is that computers can't deal with organic complexity (which would be very interesting) or, perhaps more likely, that programmers have not yet figured out how to deal with organic complexity through computers. None of this detracts from the creativity and utility of the book as a whole, which is admirable.

[111] Lee et al. (2002).

[112] Iafrate et al. (2004).

[113] Actually, these are really dual-allele disorders, further emphasizing the inherent characteristic of multiple causation in biology.

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[114] Yokoyama et al., 2003.

[115] This research is not yet definitive, and there appear to be many issues left to iron out, but these very complexities illustrate the complexities of developmental networks. The research literature supporting the following interpretations was summarized by Fernando Martinez at at the 2004 ASHG, and includes published research papers by Gereda et al., 2000; Eder & von Mutius (2004) ;Hoffjan, Nicolae & Ober, 2003; Waser et al., 2004**;** Romagnani, 2004. For an early model of gene-environment interaction studies see Colilla et al., 2003.

[116] This phenomenon has been researched in simpler systems in more detail. See especially Mackay, 2001.

[117] This variability of response is further amplified in animals that have relatively large capacities for learning. In these cases, encounters with the environment lay down specific microstructures in the brain, which the organism then uses in the future in response to particular environmental cues, or even in response to associated internal cues (e.g. the smell of burning charcoal may lead one to feel hungry or reading about a barbecue may lead one to be hungry). Historically we have assigned the label "non-determinism" to causes that appear to originate from an individual's brain, on the presumption that the operation of the mind was independent of prior training or of structures generated by the historical lineage of the species. But in the last two centuries, Westerners have come to understand brains as simply another part of the causal matrix. In other words, they don't violate physical laws and step outside of the physical matrix. However, they do not behave at the aggregate level in the same way that inorganic physical aggregates behave. Even aggregates as large as suns are relatively predictable.

They don't produce hundreds of types of behaviors on different days of the week. This difference means therefore, that it is not sufficient to try to treat organics as simple physical aggregates

[118] Its defenders will claim that they can, in fact, reduce the system to an OCOE system by specifying the particular state of each component of the system at a given time, and under such conditions, the system will behave as an OCOE system. This hypothetical is true, and what undergirds the logic of the preference for the OCOE model. It is also useful for experimental purposes for defining components of the system. However, adapting such a model requires one to imagine away a key facet of organisms as they really operate, which is the variability of the states of all of the nodes of the system and their inputs. It thus makes an insufficient explanatory model. The fact that the OCOE reduction provides a good tool toward producing the larger functional account should not be mistaken for the idea that the OCOE reduction is the explanation.

[119] Biologists typically recognize two of these levels of causation due to the way in which biology as a discipline has been historically organized (see Mayr, 1982 p. 67). The evolutionary level is routinely recognized. In the early 20th century, the functional level was recognized. This functional level has gradually been replaced in many quarters by the molecular level. What is needed is a recognition of the tripartite division rather than a bipartite one.

[120] The huge literature on Darwin's work, encompasses emphases ranging from his rhetorical skills (e.g. Campbell, 1975, 1986) to detailed analyses of the development of portions of his theories through particular naturalistic observations (e.g. Love, 2002).

[121] Mayr, 2004, p. 85.

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[122] Some religious based alternative explanations substitute an explanation based on "who" for "how". Others offer what appear to us to be either metaphorical accounts or so simple as to be incorrect: e.g. humans were made of blood clots or of mud.

[123] We used a convenience sample of introductory textbooks that were in the University of Georgia library, and this turned out to be a very small sample. It included 3 biology textbooks and 3 physics textbooks (one of which has two volumes). There were 3167 total pages, 292 equations, 98 pages with equations in the biology textbooks compared to 2569 pages, 6896 equations, and 1652 pages with equations in the physics textbooks. We thank Allison Trego for doing this research.

[124] Maddox, 1999, p. 66.

[125] Genetics provides the best example because it is the most "physics-like" component of biology in the late 20th century.

[126] As a dramatic example of the level of imprecision, consider that a speaker at the 2004 ASHG meetings expressed, with delight, the ability to reduce the confidence intervals from 10 to 2 centamorgans when examining phenomena at the 10 centamorgan scale! He et al., 2004.

[127] Blum et al., 1990.

[128] Bolos et al., 1990.

[129] Gelernter et al., 1991.

[130] Comings, et al., 1991.

[131] Cloninger et al, 1991.

[132] Goldman et al., 1993.

[133] This interpretation was also later supported by Blomqvist et al, 2000.

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[134] This research remains highly contested, although Michael Connelly, the President of the ASHG, an expert in the area of alcohol research and genetics, declared in his address at the 2002 ASHG meeting that the evidence indicated no association. A variety of additional studies have failed to support the putative association in additional populations (e.g. Chen et al, 2001; Matsushita et al., 2001: 19-26. However, there remain efforts to document an association, either in males (Limosin et al, 2002) or in high severity groups (Connor et al., 2002), or through animal and functional studies (Thanos, 2001).

[135] Cargill et al., 1999.

[136] Collins, 2004.

[137] See e.g . Schork, 2002.

[138] Walsten et al., 2003, p. 283.

[139] There are interesting exceptions. One appears to be the change of power of attraction as one approaches electromagnetic forces as opposed to strong and weak forces (Greene, p. 177). However, such complex contextual effects are viewed as unusual by physics.

[140] A formal recognition of this condition was made by the statement on standards of evidence by the Complex Trait Consortium, which wrote “There is no single ‘gold standard’ for the identification of a QTL. Rather, here should be a predominance of evidence that supports its identity.” Members of the Complex Trait Consortium, “The Nature and identification of quantitative trait loci: A community’s view,” Nature Reviews Genetics, 4, 2003, 913 (911-916).

[141] Fox Keller, 2001 provides an excellent treatment of the use of visualization in developmental biology.

[142] The requirement that one not know the results in advance does not mean that pre-existing collections of data have no role in science. Shaping a theory to fit a set of data is a time-honored part of science, even of physics. The solution to the ultra-violet catastrophe was simply the creative imagination of the mathematical conditions necessary to produce the observed data. However, such research, though important, is dismissed as "post hoc" theorizing until it demonstrates the ability to predict new, unknown results as well.

[143] One might have run a "control" in the form of DNA from the unmodified organism, but we assumed that we knew that result from previous experiments. If the result of the "experiment" had been anomalous, then the search for explanations of the anomaly (e.g. the wrong strain of bacteria was used!), might have led to a more controlled series of comparisons. This highlights the way in which observation is "taken for granted" as correct, and not needing control (see Fox Keller, 2002), but also the importance of comparison to rigorous observation.

[144] Wittgenstein (1963) turned the biological metaphor of families into a formal philosophical concept defining most sets in terms of a set of characteristics, some of which are shared by all members of a group, but all of which are not shared by members of a group.

[145] See Enard et al., 2002. The research is still early; it shows that disruptions of the human gene through a point mutation produces speech difficulties. It might be that the gene causes this disruption not because it is directly necessary for producing speech functions but because its mis-function impedes them, but this is seeming increasingly unlikely.

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[146] We borrow this example from Rosenberg (1985).

[147] Maynard Smith, 1986, p. 45.

[148] Lee, 2002.

[149] Milo 2002.

[150] Burke, 1969.

[151] The best example is provided by Meyers et al., 2004, but for an example in an organ system see Martinez et al., 2004, and for published statistical approaches see Battogtokh et al., 2002 or Pilpel, 2001.

[152] The basic structure of an argument, as elucidated by Stephen Toulmin (1958), is a claim, that is supported by evidence, which is linked to the claim via a warrant.

[153] Newport, 2004: our own data reinforces the interesting dichotomy in lay thought which tends to be more accepting of evolution of animals but not accepting of evolution of humans, Condit, unpublished data.

[154] Condit et al., 2004.

[155] The terms of the most common narrative theory would hold that the establishment of the major relationship is an establishment of the "narrative fidelity" and of the specific instance the establishment of "narrative probability." This distinction was offered by Walter Fisher (1987), but Fisher seeks to maintain a theoretical structure that does not account for conditions-in-the-world-beyond-human-discourse. He therefore describes this distinction in terms that are somewhat different. Because we do not accept Fisher's epistemological/ontological proclivities, we have not used these labels in our text. For theorists willing to divorce Fisher's terminology from his epistemology/ontology, we think the terms would be useful tools.

[156] Where there are serious social implications at stake, and where these are not widely agreed upon, the incompleteness of the evidence will produce disagreement based on political beliefs because the opposing group will hold a higher standard for the evidence needed and the proposing group will find a lower standard of evidence sufficient. In such cases, it is often wise to require either a middle-ground standard or the higher standard.

[157] Rosenberg (1985) suggests that these are applicable only to life on earth. However, that is an open question. Given the constraints of physical being, I believe that many of these motifs will have been developed in other living beings on other planets, if such there be and if any we contact. What will be unique is the pattern of the organization of the motifs, and no doubt there will be additional motifs invented in other genrelated living beings and some of the motifs used on earth will not be used. But all of this awaits first contact.

[158] Roderick, G. K, & Maria, N. "Genes in new environments: genetics and evolution in biological control," Nature Reviews Genetics, 4 (2003), p. 889 (pps 889-899).

[159] Morange, 2001.

[160] This is also why we must be so cautious about predicting what life on other planets would be like.

[161] Roderick & Navajas, 2003, 889.

[162] Couzin, 2004.

[163] Meagher overviewed the issues and approach at a lecture at the University of Georgia in February 2005, but elements are available in, for example, Bizily, 2000; Meagher, 2000.

[164] *Webster's New Collegiate Dictionary*, 1974.

[165] Recent efforts to build non-virally based gene therapy vectors are taking an approach similar to Meaghers. The researchers imagine the full circuit the new DNA must travel through the cell and design components of a vector to accommodate each of those cell component functions. This is nicely illustrated in Figure 1 of Glover, Lipps & Jans, 2005.

[166] Pinker, 1994, p. 82 (ck).

[167] Not all communication uses signs or symbols. As the definition above implies, signs and symbols are conventionalized or evolved. Some communication occurs through non-sign mediated direct apprehension, though with symbol using species, such communication is always influenced by the symbolic system on a parallel track (as indicated in Dennett's (1991) concept of the multiple drafts model of mind).

[168] We know only a little about the use of symbols by animals other than humans, and only in a few species. It is difficult to know in some cases whether animals are not using complex symbols, or whether they are simply using symbolic structures that we can't decode. The use of symbols is not the same thing as intellectual capacity more broadly. Our inference that humans use more and more complex symbols than other species does not mean that other species lack many kinds of reasoning capacities, as our distinction between ESSR and CS below will make more clear. We also do not think humans are "better" than other animals because of their use of extensive, complex symbolization, for these capacities appear at this writing to be as likely to produce global disaster as any over-all good.

[169] You can come up with many possible responses for any symbol, and there are probably few or no "signs" that humans treat as signs, because we are accustomed to

symbolic communication. Once you are within the realm of the symbolic, it is difficult if not impossible to operate on a sign logic. The distinction we are making is probably, like many distinctions, at least partially one of degree rather than absolute kind. The example of the pure sign simply helps us illustrate how symbols work, rather than being what we see as a pure condition existing in the world.

[170] For more on the negative, see Burke, 1966.

[171] One might believe that human psychology is strongly shaped by evolutionary inputs without believing that 1) humans manifest a defined suite behaviors or behavioral predispositions, 2) evolved from an environment that was the same for all members of the species 3) across a discrete time period that counts as "the" evolutionary period for humans. Because "uniformity" pervades these three levels, uniformitarianism seems like a useful label for distinguishing this subset of beliefs, all articulated as the foundation of evolutionary psychology by Cosmides and Tooby, among others.

[172] For a partial review and comparison, see Langer, 2001.

[173] The case is most forcefully put by Pinker (1994, 1997). Other evidence is taken to be provided by research on aphasia, but Pulvermüller's analysis effectively counters such interpretations.

[174] Bloom, 2004, p. 411, Bloom (2004) portrays this as the Augustinian view, notes that it is the view of many contemporary philosophers and psychologists, and argues that the research results of Gelman & Gallistel (discussed below) support that conclusion.

[175] Gordon, 2004.

[176] Gelman and Gallistel, 2004.

[177] Research is increasingly showing that animals can make sophisticated kinds of calculations (e.g. with regard to navigation) without symbolic systems. The biological means that they use for such calculation are clearly powerful. Humans surely have some of those underlying capacities. However, a biological programmed system, because it is not symbolic, is applied only to a specific domain on only within evolved parameters. The generality of a symbolic system allows it to be applied beyond the domain in which it originates and within modifiable parameters.

[178] Hespos & Spelke, 2004; Bloom, 2004.

[179] Wilson, p. 107.

[180] Friedemann Pulvermüller, *The Neuroscience of Language: On brain cricuits of words and serial order*. (Cambridge: Cambridge University Press, 2002).

[181] Pulvermüller explains the time-course pattern found in brain word processing as an initial ignition period of the web followed by a period of reverberation (leading to high-frequency responses in the gamma band" (p. 64). This is supported by the existence of

"priming" effects. As in the instance above, where my use of the example of hand movement and hand words led me to think of "waving your hand" rather than "eating tuna fish" as the example of verbal processing.

[182] Condit et al., 2002.

[183] The difficulty of using symbols to communicate about symbols also means that original literatures are often somewhat unclear, as a theorist struggles to understand a complex phenomenon and create a technical language for discussing it. Unfortunately, the humanistic academy privileges original texts and disvalues summary translations, so

that there is low incentive for the generation of summaries. In part, this arises from the belief that concepts are meaningful only within the entire symbolic web from which they come. While there is truth to this, it is only taken as sufficient to disqualify efforts to synthesize discoveries across theoretical vocabularies because of a belief that there is no reality independent of the discourse codes. We are here adopting the position that, while the symbolic flow does indeed give a unique interpretation to the nature of symbols, there are also characteristics to symbol systems that can be identified across disciplinary traditions. While our representation of these commonalities is inevitably partial, and incomplete, and does not faithfully reproduce the other traditions, we suggest that the synthesis none-the-less is useful for identifying some level of commonalities not usually otherwise recognized. A way of saying this that reconciles the position with relevant post-structuralist insights is to say that some fragments of some material phenomena exert a large force on human being, so that persons working from different theoretical assumptions all tend to notice these fragments (or forces or factors), though their theories lead them to assemble them differently. We are pointing to the fragments that seem to be common parts of the assemblies of different theories. Our own theorization inevitably gives them yet a new and distinctive assembly, but this does not deny the potential for that assembly to have some utilities for some audiences.

[184] Spelke & Tsivkin (2001). Several essays in that volume illustrate well the current lines of research.

[185] Ong, 1993.

[186] Langer, 2001.

[187] Symbol use may be necessary to developing third order categorizations, but this does not mean that learning to manipulate symbols is a sufficient cause of third order categorizations absent the evolutionary engrafting of symbolic capacities in the brain. Langer indicates that chimpanzees taught symbols do not develop third order categorizations. However, this is something of a chicken and egg problem. For chimpanzees are not able to learn human language in its full complexity. They learn something that is a step away from signaling toward the full symbolic complexity of human language. This establishes that it is not merely introduction to the assembly of signs in symbolic sequences (i.e. multi-sign communication) that creates third order cognition. Without the specific components of the brain circuits that enable humans to manipulate symbols with the full grammars of human language, third order cognition does not appear to be developable. But this would only mean that third order "cognition" predates language if one took an idealist view that separated language from its material instantiations. If third order cognition is only possible with a symbolic system like language, then that language is necessary to it, even if it is not sufficient for it. Given that there is no evidence that such third order cognition develops "before" language, it would be incorrect to describe the cognition as "prior" to the language use. This idealistic fallacy pervades Langer's interpretations, although his assembly of the data and original research are extremely informative.

[188] Saussure, 1974. For some post-structuralists, this claim has turned into the over-statement that there is no input to language other than the symbolic structure. That overstatement is not inherent to understanding symbolic categorization as a process of abstraction and differentiation. It is surely difficult, perhaps impossible, to truly weigh

which input is greater--the structure of the symbol system or the properties of the items gathered together in a category--because both of these inputs always combine to make the symbolic category what it is.

[189] Wilson claims the rest of the series is green or yellow then blue, then brown (162); Delgado (2004) claims that the rest of the series is green, blue, yellow, grey and brown, though their data is not fully consistent with this finding.

[190] Delgado (2004), for example, gets a non-predicted order for "orange," but then dismisses this unpredicted variation on the grounds that "orange" is not only a color name, but also a name for a fruit. However, the fruit is named for its color, and so it is an indicator of the frequency of use of the color in the language (which is the measure used). It is precisely such cultural variations that influence symbolic patterns. They should not be dismissed as epiphenomenal, but rather understood as precisely examples of the "cultural" variables that have inputs along with biological factors. The either/or model used in this line of research precludes such approaches.

[191] Wilson, 1998, p. 162.

[192] Munsell, 1905, 1915.

[193] The potential for creating them of course existed, but whether or not any culture had *actually* hit upon precisely these two combinations of saturation and hue with any repeatability (e.g. just due to imitation or the properties of a particular naturally occurring dye) absent their symbolic specification we don't know.

[194] Burke, 1950.

[195] Pulvermuller, pp. 88-90. The phenomenon may, however, be related to the fact that neuronal activation is a discrete phenomenon: a neuron is either triggered or it is not.

Neurons individually do not activate in degrees (though the pulses they send out and the collection of pulses within the web can be measured in degrees). The relationship of this phenomenon to recognition of objects prior to language or in species that lack language seems to suggest that reification is a product of object recognition. The ability of humans to recognize objects may be a precursor that allows linguistic reification to "make sense" to human brains, but that reification process exceeds the basic recognition of objects substantially, as it is readily applied to phemomena that do not exhibit object status and in fact, leads to rigid mental processes that deny continua where they are otherwise evident.

[196] This insight is central to Jacques Derrida's claim that Western consciousness is logocentric, in contrast to consciousnesses such as those based on ideographic-based writing systems.

[197] This feature of categorization was first recognized in Western writings by Aristotle. He enshrined it as a law, declaring that "A is either B or not B" (but not both B and not B). Humanist theorists in the twentieth century have likewise observed the same tendency, but they have also recognized the problems that rigid categorization generates, and they have urged us to resist enshrining it as a law, and rather treat it as a dangerous proclivity that needs to be resisted. Alfred Korzybski (1933/1958) described the categorical tendency as our proclivity to misuse the copula "is". He noted that when we say "X is Y" we are always wrong. The characteristics of "Y" can never fully describe "X." We would be better to say "X can sometimes be seen as having qualities that are Y-like." He noted that our language was a series of abstractions: bar stools are sub-sets of chairs which are sub-sets of furniture which are sub-sets of possessions, which are subsets of material objects. He argued that the further up we were on the ladder of abstraction, the more likely we were to make mistakes because we were lumping together

large groups of items with many different characteristics. To solve these two problems of categorization, Korzybski urged, respectively, indexing of identity statements (not "Jane" but "Jane on August 25, 1999 located in the den while talking to her mother), and continual "consciousness of abstracting."

Korzybski spawned the intellectual movement of "general semantics," which had its heyday in the 1960's in U.S. western campuses. But the pragmatic nature of his approach was not to last in popularity. The more popular approach to categorization has come to be that offered by Jacques Derrida. Like most critical theorists of the Western academy in the 20th century, Derrida assigned the problems of categorization specifically to Western epistemology. He argued that the cause of the problems of reification were implicit in the intellectual systems of the West, especially the tendency toward phonemic instead of ideographic writing. Although Derrida's analysis was based on observation, there is now some brain scan research that suggests this analysis may be correct. This does not definitively settle the "mind" vs. "semiotic system" analysis, since categorization has been found as a universal, that is, identifiable in all human systems. Thus, phonemic writing may exacerbate discrete categorization, rather than being a cause of it. To date, no careful comparative studies have produced a definitive account of this issue, though it is clear that romantic notions that "primitive" (i.e. non-Western) people had more ideal language systems that do not create discrete categories or reify is probably seriously overblown . Definitive evidence, though, awaits clearer statements of the problem.

Although he may or may not have misidentified the source of the problem of categorization, Derrida accurately extended on Korzybski when he pointed out the tendency of categorical language to privilege the apparent ability of oral language to make particular things appear to be "present" and to prize and value that presence. Augmenting the work of the linguistic structuralists, Derrida argued that this presence was an illusion, and suggested that the meanings of signs were, rather, the results of the "tracks" and "traces" of previous speaking. That is, he highlighted the structural component of the meaning of language as a corrective to our over-emphasis on the representational component of language. Like Korzybski, Derrida's work is heavily vested in a plan to undo the failings of categorization (which he blends into representation through the presence/absence dichotomy). Derrida's approach included deconstruction--the revealing of the way in which binary relationships construct any category--and "dissemination"—an emphasis on the way in which words never name a thing, but rather meanings can be deferred to an endless chain of relationships of one symbol to another.

[198] Condit et al., 2002. The sets of meanings used by lay people for this term was consonant neither with the predictions of critics nor with experts in the area. The meanings lay people assigned were broader and less deterministic than those used by builders who must follow architects' blueprints quite closely. Indeed, critical respondents to our reports of this research informed us that we must be wrong, because they had experience with working with blueprints, and blueprints "were" very deterministic.

The differences in the range of meanings of the term "blueprint" illustrate the way in which the different history of the circulation of the term makes available different (but usually overlapping) meanings to different groups. Builders who work with "blueprints" had one set of meanings that overlapped in some ways with and diverged in some ways from lay conceptions of "blueprints."

Symbols thus carry a relatively wide range of potential meanings. These in some fashion "summarize" all of the salient previous uses of a term that a symbol user has experienced, at least as those have been stored by the biased processing systems of the individual's brain. However, when a particular context occurs, the context evokes some of those potential usages more readily than others. In complex symbol systems, each symbol has many possible usages and the particular meaning-in-use is a product of the context, where context is understood as the surrounding symbols, not merely those in the phrase or sentence or paragraph in which the term appears, but also those in the broader always-symbolically laden context that we might call "the situation."

[199] Post-structuralist theories have suggested that the "gun range" or the "crowded theater" only enter the flow of consciousness through symbols, so the only influence of context is as symbols. While the theory of consciousness we articulate in the Appendix agrees that "the firing range" can only enter the stream of consciousness that is symbolic in the form of a set of symbols that already select out of the physical environment what is relevant about context, we believe that the physical entities described as "gun range" can enter the brain as light waves or non-symbolic sound waves, or smell or touch. These inputs impact other parts of the brain, and may feed into the symbolic stream from non-symbolic inputs.

[200] The invention of writing and other means of inscribing strings of signs outside of the brains of humans allows contexts to vary radically. A string of signs can be transferred from the 15th century to the 21st century. In the twentieth century each of the symbols has

a different range of associations. For example, before the 18th century the word "revolution" was more likely to be understood through the association with a slowly revolving sphere. During the efforts to unseat monarchs in the 18th century it became associated with abrupt uprisings. So a sentence containing the word "revolution" that was written before the 18th century and then read by someone in the 20th century would appear to be a more radical statement than it would have been as understood by someone in the 17th century. Thus, a 20th century radical can cite a 17th century moderate and use the words of that moderate to support a specific radical enterprise (e.g. anti-GM food) in a very different context. As we will see below, this creates a more radical form of time/space variance even than exists with regard to biological being.

[201] We borrow from Burke's essay on the "5 dogs" (1966) throughout this section.

[202] This comes at the issue of indeterminacy from a physical perspective, and is complementary to the earlier description of symbols as abstract differentiations, and therefore not as related to singular "referents."

[203] Condit, "Mutation" article.

[204] Burke, 1966, pp. 419-480; Korzybski, 1938/1955; Derrida, 1967/1976**.**

[205] In apparent contrast, Derrida argues not only that Western thought is based in the presence/absence binary, but also that Western thought tends to privilege presence over absence. This may be an in-built bias of languages, because words make present specific qualities (and thus obscure other qualities). In spite of its reverse framing of the issue from Burke, both theories agree that difference is at the base of symbol systems and that words actually appear to "present" something. Our ordinary talk, as well as advanced theories, are littered with faulty assumptions based on the privileging of presence over

absence. For example, we tend to understand deceit as a defective form of communication and difference as less desirable than similarity. However, as Burke (1950, p. 21) has pointed out, the process of identification always requires both similarity and difference, and accounts of the evolution of language must attend both to the ways in which it coordinates behavior among groups and thus advantages the group but also the ways in which individuals use deceitful communication to coordinate behavior in such a way that it advantages themselves.

[206] The impact theory for the Cretaceous-Tertiary extinction event was first proposed by Alvarez, Alvarez, Asaro and Michel 1980. The notion of uniformity in extinction events was extended to regularity by Raup and Sepkoski 1984.

[207] These are actually ranges of weightings, but we are trying to introduce components one at a time rather than all at once, for the sake of intelligibility.

[208] Weaver, 1953.

[209] Condit et al., QJS, 2002.

[210] Fisher, 1985.

[211] On narrative see also Bennett, 1978; Mitchell, 1980/1981; White, 1980.

[212] Propp, 1968 is a widely sited source for this version of narrative structure. Propp identifies "functions" rather than "events" but we've altered the terminology in order to avoid confounding it with the biological notion of function. The shift is sufficient for present purposes but more precision will be needed in future development.

[213] Burke, 1969.

[214] Actually, the term "gestalt" is an oversimplification. As Dennett's (1991) "multiple drafts" model indicates, the brain is actually running on multiple tracks at all times,

producing constantly revised “summaries” (or gestalts) that are in some sense a series of fragmentary convergences. We will use the term “gestalt” as a shorthand for this difficult-to-describe process.

[215] This explains the phenomenon often found in split-brain experiments, where a behavior is narratively accounted for in terms other than the “hidden” information provided to the research subject.

[216] This appearance may be wrong. It is based on experiments that are designed in a fashion that would favor the appearance of these forms. More complex experiments to assess narrative form in non-humans are now warranted.

[217] One might even assign the less prominent role of agency in grammatical structures to the fact that humans only gradually acquired a significant stock of tools, but agent/act/purpose were crucial even at the dawn of language.

[218] Burke, 1961.

[219] See Chapter 8. Arguably these forces have always been the same, but the universe has been somewhat differently constituted, as a series of events occurred very shortly after the Big Bang in which the various basic forces are said to have “separated out” from each other. By about 5 minutes nuclear synthesis is said to have ceased. There is some controversy about the speed of light varying through time, though the dominant view still holds it to have been constant.

[220] The concepts of time and space binding were originally used in descriptions of particular media (e.g. Ong, 1988/1993; McLuhan, 1962; Innis, 1964), but any communication media accomplishes the objective; it is simply that media such as

telegraphs and telecommunication speed up and extend these basic capacities of communication.

[221] In the case of oral story-telling, the grandparent can tell the child a story about the missing parent. The symbols are inscribed in the brains of the two relatives, but the sound waves are not of their bodies. The theoretical dislinkage is increased when we consider that the child might have been raised in a different environment, so that the symbols that the child learned are not received from either parent or grandparent. This theoretical principle is fully instantiated when our discussants are not relatives (we use relatives in our story to emphasize the contrast with organic being, but there may be evolutionary lessons there).

[222] Even before writing, inventions could be generated through conversational dynamics that bring together different word webs to form new relationships. In spite of the movie-screen versions of individual genius, most inventions are the product of different people attacking a problem with different heuristics, and the intersections of these different heuristics generally produces novel possibilities that make a new invention actually work. A similar process can go on even in an individual brain when sections of the neuronal web that are previously unlinked are contingently activated. Even in cases where invention is not experienced as a symbolic activity we would hypothesize that the habits of systematic searching and inter-linking of the neuronal net that are built through symbolic activity create a platform for inventiveness. The ability to construct third order cognitions, whether its existence is created by or expanded by language, may be either the same as or related to the inventive capacity.

[223] Donald E. Brown (1991) has assembled a list of "human universals" that attempts to sum up the categories that exist across known human cultures. The list is fascinating, but it includes phenomena of radically different levels of generality, such as a color term for black, beliefs about disease, childhood fear of strangers, conflict, cooking, habituation, and economic inequalities. Brown also includes cultural variability in the list, and the list has grown with time. Most importantly, this category set is itself a product of our culture. All societies do not have the category "habituation," even if they habituate.

Some of Brown's list is a claim to the existence of universals in categorization—he lists classification of colors, fauna, flora, inner states, kin, sex, space, tools, weather, among other apparently linguistic categories. Much of the list is about the forms language takes—rhetoric, poetry, vocalic/nonvocalic contrasts in phonemes, polysemy, etc. But most of the list is ambiguous about the level of articulation of the category across societies. The important point is simply that enormous levels of novelty can coexist with some universality. The error would lie in attending only to one or the other.

[224] See Burke on "The Negative" 1966.

[225] Arguably, the process of natural selection in effect might make those parts of these different types of elements that preserve individual survival comparable over the long term by eliminating organismal lineages that do not take account of such components. However, if that happens, it happens on such a large time-scale that it is not meaningful from a life-course human perspective and we doubt that evolutionary processes can take such a long term focus because immediate needs for most organisms must trump longer term needs. It appears to us that only humans have the capacity to garner sufficient resources to consider both short and long term goods, but to date in history even we have not taken advantage of that theoretical capacity to any great extent. In any case, evolution's weighting in this fashion would happen only for a limited class of such goods—those that helped a lineage to survive—not on all of the possible goods identified in many human moral systems.

[226] Burke, 1950, pp. 19ff.

[227] A narrow biological determinist would try to explain these choices in terms of status drives or the opportunity for superior mate selection and provision for young upon the

return, and in such serious choices as this example, these factors play some role. After all, in a war where casualties are high, compulsory drafts are required, so that it is the absolute threat of prison that the person weighs against the potential for draft. Similarly, it is poor people who have fewer economic options that serve in the military in non-draft periods. However, there are clearly cases where "patriotism"—i.e. identification with the nation-state—plays a role, and others where "adventure"—i.e. symbolic constructions of war as glorious and exciting—play a role. In most serious cases, such identifications may play a supporting role or even provide a covering explanation (see chapter ??). However, the role of symbolic identification is likely to play a larger role where the evolutionary pressures are not quite so large, e.g. in donating money to feed children in other countries. This is different from the demonstrated "co-operative" action of animals, which is linked to self interest. The existence of such co-operative programs may, however, further facilitate identification or provide an evolutionary base from which identification arises.

[228] Brummett, 1976; Condit, 1987**;** there are three basic lines of the argument, all of which emphasize that humanly crafted moral codes are open, inclusive and inter-subjective rather than subjective: 1) as much or more evil seems to have been done in the name of supposedly objective moral codes as inter-subjectively crafted codes, 2) inter-subjective moral codes may actually require more moral accountability than objective codes, and 3) supposedly objective moral codes are always intersubjectively interpreted and therefore not really separable from intersubjective codes. It is only an un-grounded "belief" or "faith" in the superiority of some particular code that (mis)labels it as objective.

[229] For example, see Holland, DeAngelis & Schultz, 2004; Ferriere et al, 2002**.**

[230] Blackmore, 1999.

[231] For a careful parsing of what would constitute group evolution and an effort to explore this on the social scale see D. S. Wilson, 2002.

[232] The definition of identification as the basis of moral codes might seem to imply that the most effective moral code was the best because it best filled the telos of the system. We would say, instead, however that the key criterion for how good a moral system is that arises form this telos would be the extent to which it enabled people to include others unlike one's self in judgment processes. Thus, the telos is defined by the radicalness of the identification not by its mere numerosity. That criterion is not a logical necessity, but we would argue that it is a symbolic one.

[233] Assuming, of course, that Thucydides, from whom we get most of these speeches, was not merely trying to paint the parties involved in a bad light.

[234] There is substantial debate about whether at least some "more primitive" cultures had codes that recognized non-humans as moral entities. This is a difficult debate to resolve given the lack of written historical evidence and difficulties of translation. Even if this were true, it would not negate the possibility that within a self-contained human cultural strain, moral codes could evolve. It would merely mean that these so-called primitive groups were actually more highly symbolically evolved with regard to morality. Our claim is simply about the evolution of morality within the very diffuse symbolic web called "Western" society.

[235] On moral development research see Gilligan, 1982.

[236] Condit, Parrott, Bevan, & Bates, 2004.

[237] Incorporate list from old Chapter 9.
[238] Condit & Greer, 1998.

[239] The efforts to cope with this problem with regard to race are well reviewed by Schneider, 2004.

[240] Scholars for example tend to identify skin color based discrimination that existed globally before European colonization as something different from the "racism" that was generated by the colonization process, e.g. Bernal, 1997; Bowser, 1995.

[241] See e.g. Dow, 1996.

[242] Wilson, 1998, p. 182.

[243] Wilson, 1998, p. 216.

[244] Zelizer explains recent memory studies, "Used intermittently with terms like 'social memory,' 'popular memory,' 'public memory,' and 'cultural memory,' collective memory refers to recollections that are instantiated beyond the individual by and for the collective. Unlike personal memory, which refers to an individual's ability to conserve information, the collective memory comprises recollections of the past that are determined and shaped by the group" (1995, p. 214). Arguing that collective memory is a type of remembering that is processual, unpredictable, partial, dependent upon a social construction of time and space, usable, both particular and universal, and material, Zelizer points to the unique ways in which a public can formulate memories that suit a particular time and culture (1995). Judith Miller's work on the Holocaust, for example, speculates on how many different countries created specific lore about their relationships with the Nazis that limited the country's accountability (Miller, 1990, as cited in Zelizer, 1995, p. 226). Zelizer's work on the JFK assassination suggests that the media can also

play in an important role in cultural/collective memory by providing the public with images and narratives constructed through the practices of journalism (p.1992, 1-13). More recent work has argued for the importance of cinema in constructing cultural memory (Owen, 2002 and Sefcovic, 2002),

[245] The interest in the history of particular human experiences is clearly different from the project of fundamental physics, where there is no interest in charting where every atom has been from the beginning of the Universe. This difference arises in large part because the history of an atom is generally presumed not to determine how it will behave.[245] In the natural sciences, especially geology, there is a central interest in history, and in biology, there is interest in history, both of lineage and of individual development.

[246] These different possible foci for collective memory are represented in different disciplines and sub-disciplines: history, history of science, history of philosophy, rhetorical theory (as history), art history, archaelogy, anthropology, etc. Each different area has different tools for its detail work and different assumptions and concerns based on the unique characteristics of what it is studying—individuals, social movements, nation-states, scientific research, etc. They all, however, face the common problems of selection and retention.

[247] This is similar to the historical dimensions of the natural sciences. This is not how individual works of history, for example, are always or generally written. Individual works often propose individual factors of interest (e.g. the end of slavery was a product of the rise of an international economy based on wage labor as a more efficient form, the end of slavery was the product of Lincoln's decision to place Union over peace, it was a

product of basic constitutive values of the nation, it was a product of the slave's refusal to accept slavery, etc.).

[248] Aristotle (345 B.C.E./1998) explains, "First, to summarize what has been said so far about its nature: tragedy is the imitation of an action which is serious, complete and substantial. It uses language enriched in different ways, each appropriate to its part [of the action]. It is drama [that is, it shows people performing actions] and not narration. By evoking pity and terror it brings about the purgation (*catharsis*) of those emotions" (p. 9). Tragedy is distinguished from an epic in that epic is described as a narrative with no action (p. 33), and from comedy in that comedy is concerned with an more satiric form of imitation, one in which the "ridiculous can be defined as a mistake or a lapse from 'perfection' which causes no pain or serious harm to others" (p. 8). On unity he indicated: "Just as in other representational arts, 'unity of imitation' means that a single subject is imitated, so in literature the *muthos* must imitate a single unified and complete sequence of actions. Its incidents must be organised in such a way that if any is removed or has its position changed, the whole is dislocated and disjointed" (p. 13).

[249] Leff, 2000, p. 552

[250] G. Bush 1991, January 16; German, 1995.

[251] G.W. Bush, 2001, 2004; Murphy 2003.

[252] The use of deductive principles or mathematical formulations is an attempt to regularize pattern recognition. It is hypothetically possible to produce a knowledge that formalizes these patterns into highly complex chains of interacting principles. However, because it is not practically possible to do so, pattern recognition skills remain the best available tool.

[253] Campbell & Jamieson (*Form and Genre*).

[254] This includes vague borders and a set of relationship such that all members of the designated set share some, but not all, of a range of characteristics specifiable in another set.

[255] Jamieson, 1978, pp. 40-42.

[256] Campbell & Jamieson, 1990.

[257] According to Ware & Linkugel, 2000, the four factors that characterize the apologetic form are denial, bolstering, differentiation, and transcendence (p. 427). For applications and developments of the theory see Harrell, Ware, & Linkugel, 1975; Benoit & Nill 1998; Kramer & Olson 2002; Achter 2000.

[258] Although genre studies add efficiency to one's ability to produce effective discourse, this is only to the extent that one already has some relatively solid grasp of some set of touchstones. The value-added from genre analysis is that one need not have mastered the touchstones in a given sub-area in order to understand and implement the generalizations provided for a new area. A theorist who builds the theory of a specific genre must build that genre or '"test" that genre against a large number of cases of the genre. However, someone who has already mastered a more general set of touchstones can apply the knowledge gained from genre studies in areas they haven't mastered. Genre theory thus acts not just as an analogical generalization but as a rule-based generalization.

[259] . Terrill , 2003. Similarly LBJ used his Thanksgiving Day Address on November 27, 1963 to eulogize John Kennedy as well as to set forth his administrative goals, particularly that of the Civil Rights Act (Jamieson and Campbell, 1982, p. 150).

[260] For example, a student of mine who had studied Douglass's changed his "welcome" speech into a "not welcome until you deserve it" speech, using Douglass as a model to challenge newcomers.

[261] See e.g. Schegloff, Jefferson & Sacks (1977); Schegloff (1992).

[262] Fisher, 1987 Burke, (1950).

[263] Aristotle's *Rhetoric* (trans. 2001); indicates: "Of the modes of persuasion furnished by the spoken word there are three kinds. The first kind depends on the personal character of the speaker; the second on putting the audience into a certain frame of mind; the third of the proof, or apparent proof, provided by the words of the speech itself" (p. 181). Put in philosophical terms, Aristotle correctly observed some of the natural kinds in human persuasive interactions, and these natural kinds are evident enough to be visible to careful observation, rather than requiring unique tools for their observation.

[264] Reynolds & Reynolds, 2002.

[265] Burke, 1950; Toulmin, 1958.

[266] Wilson, 1998: For Wilson "mature" psychology would be the study of the ways in which "behavior is guided by epigenetic rules" (p. 193). In other words, for Wilson, the key to consilience lies not simply in adopting the scientific method, but in accepting the biologists' belief that human social behavior arises solely "from the summation of individual emotion and intention within designated environments" (p. 193).

[267] Ashe (1952); Milgram (1974): Zimbardo (1971).

[268] For an example, see Leff & Sachs 1990.

[269] Lucas 1990/2000.

[270] Leff 1988.

[271] Natural scientists may "evaluate" a theory, but by this they are judging the correctness of a theory, not its moral standing.

[272] See e.g. Root (1993) on the fact/value distinction.

[273] The production of theory that is focused primarily at novelty generation is, I believe, a product of the convergence of Jacques Derrida's (1976) theory of discourse as moving trace and Michel Foucault's (1988/1990) insistence on telos-free critique. It was early embraced by scholars such as Jean Baudrillard (1983/1990) and most fully exemplified in works such as Deleuze and Guattari's *Anti-Oedipus* 1996).

[274] Derrida 1967/1976, p. 163. The more accurate meaning is simply that as symbol using creatures we can never get outside of our textually based modes of understanding.

[275] Derrida is not single-handedly responsible for this. The perspective is traceable at least to Nietzsche, if not to the pre-Socratics, and it was developed in other idioms by theorists such as Alfred Korzybski's general semantics movement and Kenneth Burke's symbolic interactionism, among many others. The claim is not that Derrida single-handedly authored the insights that have developed with post-structuralism, but rather that he is one of the influential game-players, and the playing of the game has produced these insights.

[276] Post-structuralism maintains its claims to be novel for three reasons. First, there remain a few opponents with 18th-century mentality around to shoot at. Second, because language is a reifying machine, we are all born with reifying tendencies and post-structuralism is the currently dominant resource for helping generate self-reflexivity about those tendencies. Third, because some poststructuralist critics continue to generate insights about particular texts that are novel and interesting.

[277] See Wilson, 1998, p. 182; cf. Rosenberg, 1995.

[278] Note that much of the traction of both Rosenberg's and Wilson's complaint is gained by conflating humanistic approaches (generally critical and macro), with what we are

identifying here as social scientific methods. Although humanistic and social scientific methods often co-exist uneasily in social scientific departments, especially in sociology, communication studies, political science and decreasingly psychology, these are recognized by their participants as different research traditions. The arguments pertaining to the former are different from the arguments pertaining to the latter, although both offer useful and even necessary insights on human behavior.

[279] See Wilson, 1998, pp. 203, Rosenberg, 1995, pp. 7, 100-102.

[280] E.g. Janis, 1967.

[281] Witte, 1992.

[282] Witte, 1992, 1994, 1995.

[283] Rosenberg, 1995, p. 32.

[284] Another major line of objection Rosenberg offers deals with the difficulties involved with the notions of "intention" and "belief." By objectifying lay responses to surveys as symbolic output rather than as conscious intentions and beliefs social scientists overcome this problem. This also provides the needed linkage between individual action and social level structure (as suggested in Chapter 6). While still imperfect, social scientists have substantially improved their measurement skills as well.

[285] Cigarette Smoking Among Adults, 2001: decline in rates, p. 871; causes of decline, p. 872.

[286] This calls into question the current forms of meta-analysis in human behavior studies. Current versions of meta-analysis presume that some sets of studies are right and some are incorrect. Instead, the correct model of meta-analysis would be to find the variables

that produce different outcomes from different studies, and thereby to triangulate the boundary conditions or optional output conditions of a phenomenon.

[287] Lewin, 1935; Miller, 1951; van Hook & Higgins, 1988.

[288] This label is chosen due to the tendency of this perspective to assume that humans evolved a defined suite behaviors or behavioral predispositions in an environment that was the same for all members of the species and across a discrete time period.

[289] The slippage between "social contract", "social exchange" and "cheater detection" is problematic, but it is introduced in their theorizing, not merely in our rendition of their theories and experimentation.

[290] Lawson, 2002, Fodor, 2002.

[291] Lawson also argued that Cosmides' original "altruism detection" task confused participants by activating cues for both conditional and bioconditional logics because it described the chief as both ruthless and also potentially altruistic. In an experiment that made the "altruism detection" module truly parallel to the "cheater detection" module, the participants selected the "right" answer about 40% of the time in both the altruism and cheater versions (Cosmides and Tooby typically get around 80% for "cheater" versions and "40%" for descriptive versions, whereas so-called "abstract" experiments usually run less than 10% "correct" scores). Lawson also used a "Santa Claus" version of the task (which links children that are "naughty" and "nice" to getting or not getting Christmas presents), in an attempt to present a more familiar context, but the comparative results were similar to the "Big Kiku" versions.

[292] Levine, Park, McCornack, 1999.

[293] An evolutionary explanation is possible for these results as well. The explanation is that humans originally grew up in and even lived within kin-groups, where genes are shared. In such an environment, truth-telling is advantageous to the shared genes, and so truth-telling becomes the normal communication context. In such a context, a truth bias is parsimonious. This evolutionary account stretches perilously close to "group evolution", and does not sit easily with the vision of universal competitive interaction that underlies most versions of evolution, but it appears to be the required "just so story" for an evolutionary theory (but more on the evolution of cooperation in Chapter 10).

The point is that evolutionary psychology, although it might appear to offer a more constrained template for predicting human behavior than other evolutionary theories, is actually every bit as mobile and therefore limited in its predictive value. As we will suggest in the next chapter, there are simply better evolutionary accounts and approaches for human behavior, but these work with, rather than in competition against human adaptability.

[294] Maheswaran & Chaiken, 1991; Chaiken & Maheswaran, 1994.

[295] It would actually be the same thing to say that he provides information that facilitates systematic processing. This highlights the way in which the heuristic/systematic divide is not only a continuum rather than two discrete options, but the degree of depth of processing can be controlled not only by motivation for deep processing but also by the quality of the information immediately available (when high quality information is immediately available, the processing can be more rapidly terminated.

[296] Cosmides asks the former, but not the latter.

[297] We actually do not know the extent to which lack of suspicion plays a role in the difference between the descriptive and cheater conditions. By phrasing both in exotic terms, some suspicion should have been aroused. Conceiving the processing modes as a continuum rather than dichotomy handles that uncertainty by predicting that there is a dose-dependent response, when all information and experience factors are held constant.

[298] In a similar vein, Lawson shows that the mixed responses of the Original Altruist Detector" task result from confusion generated by conflicting information presented within the scenario itself.

[299] Also varies by person and subject (Linbladh & Hampus Lyttkens, 2003).

[300] One of Lawson's experiments uses a revised altruism task in which Wason eliminates what he views as confusing descriptions of Chief Kiku as both ruthless and potentially altruistic. This version produces equivalent performance between cheater detection and altruism detection. Lawson also changes the word "altruistic", arguing that this word may not be understood by all participants and therefore may produce the misunderstanding that produces inconsistent answers. Intereately, Cosmides argues that the change produces a "confound" because people will just match the description of the behavior to the cards directly. Our argument of course, is that the fact that they may do so is a crucial cue to how brains work.

[301] Scholars in communication studies have elaborated a series of procedures that help attend to the former, including formative research processes and manipulation checks, all of which are lacking in the published accounts of the cheater detection experiments.

[302] Persons with Wilson's syndrome lack connections between the amygdala and the orbitofrontal region of the brain and have stronger connections with the medial portion.

They are highly empathetic and unfearful in social interactions, whereas they are unusually fearful in non-social interactions. The medial part of the brain is believed to relate to social knowledge. This indicates how wiring among parts of the brain rather than independent brain modules can produce particular brain patterns.

[303] Condit, 1990, p. 14.

[304] In the individually-oriented studies that usually fall under the umbrella of psychology and interpersonal communication, only research on stereotyping has taken symbols seriously ; for an excellent review, see Schneider, 2004.

[305] English, 2002; Mishra et al., 2004; Nevitte et al. 2000.

[306] Beatty et al. 2000: Condit et al., 2000.

[307] Beatty & McCroskey (**XXX**).

[308] Wilson, 1998, pp. 136-140.

[310] Thornhill and Palmer, 2004, p. 253.

[311] We call it the "Motivate" model to draw on Kenneth Burke's distinction between action and motion, the former of which requires symbolic inputs, and because we were favorably struck by Gowaty and Hubbell's "Dynamate" model.

[312] Wilson, p. 136.

[313] Much of this body of knowledge is well summarized in West-Eberhard (2003).

[314] Gowaty and Hubbell's "Dynamate" model of mate selection provides a good exemplar of such probabilistic, multiple-input models. However, if one transfers their model to the population level and assumes that the relevant environments are always variable across the range of any animal, then one gains a model in which behavioral outputs are not

uniform among all members of a population, but rather represent a distribution around a mean tendency that varies by environmental conditions..In their model, the degree of selectivity in mate choice is determined by several factors, including length of reproductive latency periods, number of potential mates, and perceived quality of available mates. Their model remains a deterministic one, in the sense that they believe the model exactly specifies a behavior for a given animal in a given environment. One must also assume that the behavioral repertoire is continuous rather than dichotomous. Gowaty and Hubbell assume that an animal either exhibits "choosiness" or is indiscriminate, but at least in humans, degrees of choosiness seem to pertain; Gowaty and Hubbell (2004, unpublished ms **ADD NEW PUBLISHED VERSION**); Gowaty, Steinechen & Anderson (2004); Hubbell & Johnson, 1987; Gowaty, Drickamer & Holmes, 2003.

[315] In other words, we reject the "perfectionist" assumption that infects much evolutionary theorizing. Such perfectionist accounts presume that for every biological structure A there is one and only one biological consequence B. The rationale of perfectionist arguments is that competitive pressures push species to evolve to a state that is maximally efficient. Secondary consequences are inefficient, so they will always have already been eliminated by competitive pressures. Such reasoning falsely assumes that the existing state of a species represents a finished product of a final competition in an unchanging environment. However, the geological record makes it clear that environments are constantly changing (through time as well as within seasonality) so that no evolutionary competition is at a perfected end-state. Moreover, the limits of physiological forces may mean that the best competitive strategy is an imperfect one (i.e.

one with side effects), and all that is necessary is to achieve the best strategy. Finally, some side effects are not deleterious. Thus, while the perfectionist or teleological account of evolution provides a useful heuristic, if it is taken to this extreme it is simply false.

[316] We sometimes use terms "selected" or "chosen" because we take the organism as a locus where options are processed. *Webster's New Collegiate Dictionary* is silent as to whether these terms necessarily imply conscious, rational thought processes, and we do not use them in that sense. We also try to talk about behaviors being "specified" in order to avoid the implication of conscious intention. There does not seem to be a terminology that captures the co-determination of behavior through environment and organismal loci, and we propose using "specification" for that purpose.

[317] Gowaty and Hubbell's model is a formal, quantitative model, directed at accounting for a specific behavior set. We are addressing more macro-level concerns and we do not pretend to have achieved their level of rigor. In many ways we deviate from their approach (especially, for example, in the way we use box/angle diagrams). We believe, however, that the logic of their approach and assumptions are superior to most of the widely cited work in the area, and it is broadly consonant with, even when not identical to, our own.

[318] Previously, the distinction has been between "biological" and "learned" behavior, but if this is a false distinction, a new term is needed. We propose the use of "brain intrinsic" to refer to those instances where a biological behavior is embedded in the brain by normal biological developmental processes and where that program is resilient within the range of survival environments for that organism.

[319] In addition to humans, honeybees (Dyer, 2002) also appear to have symbolic capacities. Other species including ants and some aquatics may also have these capacities. Other primates appear to have some capacity to learn some limited symbolization (linking two or three signs together), but they do not appear to spontaneously manifest that behavior. As a matter of fact, human symbolization systems are also structured with what is sometimes called a "hierarchical grammar" (and which we have identified as a narrative framing. On primate use of symbols see Fitch and Hauser, 2004.

[320] Gowaty and Hubbell's DYNAMATE model introduces the box diagram with a line across it where the line is the "switch point" between choosy and non-discriminating mate selection. Our box diagram is a simplification in that it does not necessarily specify this line as an ecological switch point. Instead of integrating all behavioral inputs into a single equation which then produces a single switch-point model, we draw our box with multiple lines to highlight the possibilities of more than two behavioral options and we assume distributed population values rather than individual predictions.

[321] The term mode may be more accurate, because population dynamics may produce forces preferring a "normative" behavior. However, we will often use the term mean, as it is a more familiar term to a general audience, and an exploration of the impact of "regression toward the norm" in human behavior requires more research before it can be definitively modeled.

[322] Foraging is the last stage of development for non-sexually reproducing members of the species and foraging co-exists with participation in the symbolic exchange.

[323] Wilson, 1999, p. 193. He says that "social behavior arises from the summation of individual emotion and intention within designated environments." This summative model, as opposed to one that understands both the role of the material instantiation of symbols outside human brains and the long-term interactive process, is what we are arguing is wrong.

[324] Anthony Giddens's (1979) theory of social structuration aptly identifies the recursive way in which individual level actions create the social but social structures shape individual actions.

[325] For a review see Wilson & Wrangham, 2003.

[326] On the evolution of symbolic marking, see Richerson & Boyd (2005), p. 211.

[327] On identification, see Burke (1950), pp. 27 ff: on scapegoating, see Burke (1966); on the regular use of dehumanizing strategies see, among others, Ivie, 1980.

[328] Of course, such formulations will be difficult to pursue, because it appears that symbolization drives population increase. Richerson and Boyd (2005, pp. 169-187) explore these processes in a useful fashion.

[329] There are, of course, plenty of theorists who have argued that "war is inevitable when X, Y, or Z conditions hold" and likewise theorists who have argued that war is never inevitable if symbolic resources are properly used. The former argue from the basis of biological limitations (e.g. resource shortages), and the latter from the perceived role of symbolic processes in enabling war. However, arguing from either one or the other of these theoretical platforms is quite different from developing a research agenda to systematically explore the relationships between the biological drivers and the social scale symbolic activities. An interesting blend is approached in "Global Menace," 2003.

[330] Some phenomena that participate in this process, such as distributions, architecture, or city-scapes are not verbal and may not be solely symbolic in themselves, but nonetheless may operate in part symbolically.

[331] Richerson and Boyd (2005) provide a theoretically based analysis that captures a different set of patterns.

[332] We borrow the metaphor of "flows" from Deleuze and Guattari (1983/1996), but I put it to our own somewhat different usages.

[333] These respond, of course, to biological drivers such as group affiliation and sexual attractiveness, but in the symbolic context, these may violate other drives (e.g. the value of fat stores, the survival value of not piercing your tongue) and they may not even serve the ultimate motivation of producing more offspring or even higher quality offspring (in the sense that the offspring are more reproductively successful either, since they will engage in similar short-term responsive but not long-term effective behaviors: more on why this is possible in the last section.)

[334] See e.g. Roberts & Parks, 1999; Vrooman, 2001.

[335] Ong, 1993; Innis,1966; McLuhan, 1962**.**

[336] As we will note in Appendix 2, evidence of and explanations for this possibility are also offered in Richerson and Boyd (2005, p. 154 ff. "Why genes don't win the coevolutinary contest").

[337] There are extensive arguments purporting to show that symbol systems are not referential. These insightful arguments capture the important and correct notions that symbols are not solely referential and that they can never be exactly and fully referential.

However, in spite of its inherent imprecision and incompleteness, symbolic activity in humans usually includes a referential component.

[338] In actual fact, of course, they are dependent on other material factors, but they do not pretend to refer directly to "real" material facts. Philosophers have tied themselves in knots over the distinction between the real and fiction, and we could not resolve the symbolic problems that they have not been able to resolve, so we settle for an operational definition, rather than a philosophically rigorous one.

[339] Spectator sports are a liminal case. There really is a physically material game going on down there on the field (as opposed to a play or novel or video-game). However, the physically material game is scripted for spectator needs and exists for the purpose of spectation. Scripts are micro-managed to ensure maximum sustainable viewership: for example, the introduction of the three-point shot and the movement of the three-point shot line in basketball to increase and then balance offense with defense. The game itself is only a part of the entertainment package, which includes announcers who narrate the event as an epic battle and sexually stimulating cheerleaders, as well as clown-fans.

[340] Because people "have the tv on" even when they are not watching it, or not watching it closely.

[341] This is a highly disputed research area. However, we believe the preponderance of the evidence is fairly clear. There are virtually no credible studies that find empirical support for the "catharsis" hypothesis about violent and sexual materials. While not all studies find links between pornography and aggression, many do. Given the variability of the conditions in the various studies, we suggest this points to the fact that degrading pornography increases violence in some persons and in some conditions. See Carr &

VanDeusen, 2004. This is consonant with broader reviews of media effects on violence, see Felson, 1996**.**

[342] Richerson and Boyd, 2005, pp. 173 ff.

[343] The scenario has been popularized and well treated by Diamond, 2005.

[344] This is not to say that the problems have the same immediacy for all groups of people, or that they require the same level of trade-offs from all people.

[345] Economic numbers are highly controversial, and are produced through a variety of choices. These claims can, however, be supported by data produced at both ends of the political spectrum. Compare, for example, the re-analysis of census data by the ultra-conservative Heritage Foundation (Rector & Hederman, 2004). These analysts used several major counter-assumptions to re-analyze the Census Bureau data, and all these analyses achieve is to mitigate the gap somewhat. Most importantly, they concede that income has declined in the bottom two quintiles, but argue that this is compensated for by public programs that provide non-money income that is not included in Census counts. While these programs (which the Heritage Foundation's ideological position opposes) may mitigate the income decline, they do not change the fact that the earned income has declined for these people. Not surprisingly, on the other end of the political spectrum, the progressives provide accounts that show income decline for less-well-off and even average groups and increases in income inequality (e.g. Marien, 2005).

[346] Most of the books written to defend social policies based on biological proclivities have been politically regressive (e.g. Murray and Hernstein, 1994, although Peter Singer has made an attempt in the alternative direction (1999)). They have taken the putative existence of biological limitations such as differences in IQ or differences in gender

potentials as reasons for overturning social policies such as Head Start that sought equalization of potentials or restricting marriage laws that sought to counter-balance male tendencies toward philandering (Wright, 1994). Such works provide one possible avenue toward considering biological drives in formulating social policy. A bio-symbolic perspective, however, does not have to focus on the innate presumed differences among people, but rather may focus on our shared foibles. What kind of policies would help us, each and every one, avoid overweening greed? We do not offer these examples as definitive, but rather as a set of ideas, each of which illustrates a possibility that might be explored.

[347] Burke, 1984/1937.T his comic corrective, however, lies not simply in self-restraint born of self-recognition. For knowing what drives us is not tantamount to being able to restrain the forces we've identified. Indeed, the assumption of the bio-symbolic premise is that what we often call "personal will" is not the strong, powerful force independent of symbolic and biological inputs that common sense leads us to imagine. Instead, our "personal will" is a fragile narrative voice, unique to us, potentially gaining some power through our life histories, but buffeted by the symbols to which we have been exposed and the biological proclivities embedded in our brains and bodies. Identifying what drives us will not, therefore, allow most of us to exert a powerful will to restrain our selves (though hopefully it can do some of that). Instead, it can allow us to understand the desirability of social structures that encourage us to act out our drives in more desirable ways.

[348] See Bebchuck & Fried, 2004; for an international view, see "Lessons from America," 2004. The headlines all proclaim that the cause of U.S. automobile manufacturing

decline is the "global force" of lower wages abroad. This isn't particularly credible when Toyota and other companies are opening manufacturing and assembly plants in the U.S., and when the offer to reduce wages to global levels was never even put on the table.

[349] The statement in the text is an abridgement of the proposed Faith in Capitalism Amendment to the U.S. Constitution: "The total wages, salary, bonuses, and other compensation and benefits earned by any person employed by a corporation, institution, or person and working and residing in the United States or its territories or possessions shall be no less than one twenty-fifth of the total wages, salary, bonuses, and other compensation and benefits paid to any other person by that corporation, institution, or person, regardless of the latter's corporate rank, citizenship, or residency, or paid by that corporation, institution, or person to another corporation or institution for the services of any one person."

[350] Matthew 6:19-20 and 6:25-29.

[351] Pillai & Guang-Zhen, 1999.

[352] Greed has come to be treated as something of a social virtue through the perversion of Adam Smith's theory of the unseen-hand of the economy. Smith's analysis of the workings of the markets was embedded in a moral philosophy of human responsibility; markets were one component, but community structures (including families and moral institutions) were other equally important, if taken-for-granted, components. The contemporary disseminators of the gospel of greed have stripped the theory of anything other than market forces, and in so doing they have regressed human beings to a Hobbesian war of all upon all. Their doctrine that all that is needed to generate collective wealth is a free market is false. If human beings are not honest, responsible, and

moderately long-term in their thinking, markets cannot function. Moreover, economic wealth is not the only human good. We are in serious need of redress of this imbalance.

[353] Approaches might include any of the following: insurance companies observing drivers and pro-rating insurance fees based on aggressiveness, requiring drivers names to be posted prominently on their cars, or optional "purple banner" societies of cooperative drivers.

[354] Present textbooks in physics are bent on teaching students how to plug examples into mathematical formulas that illustrate different physical equations that exemplify physical laws. The physics-for-non-scientists textbook would start with the concept of atoms and go down to quarks and up to molecules. It would explain the basic character of the four fundamental forces and of electricity, magnetics, mechanics, and optics. There would be an introduction of the issues of scale, but no numerically based problem sets. The basic biology course would not teach all of the different organs of the cell nor word it teach how chlorophyll functioned. Instead, it would trace the evolution of life, showing how different adaptations were added at different junctures in time and relating individual life processes to environmental networks. There would be a premium on understanding of process and of the scientific method and a reduction of bulk memorization of biological factoids reflecting the individual instructor's own specialty.

[355] One way to reduce this market-driven grade economy would be to assign grades in every class by rank in the class, reporting rank directly or allotting a set proportion of "A's" "B's" "C's" "D's" and "F's" by rank.

[356] If a society is to develop in which people are capable of making policy decisions in light of self-understandings about the symbolic and biological inputs to their behavior, they have to understand these inputs. At the present time, the best example is the appropriateness of teaching students how to use a "tit for tat" strategy. The research base clearly supports the utility of such an addition to general curricula. Existing research indicates that people who are taught the "tit for tat" strategy not only learn it, but generalize it across situations. Self-consciousness about the strategy further may help people to enforce its use as a norm of social interaction. It is relatively easy to teach the

strategy, and it seems that the social and individual rewards justify its universal inclusion in school programs.

Developing a curriculum for all levels, K through college, is a prerequisite of the successful utilization of knowledge about bio-symbolic inputs. This will not be an easy endeavor. The curricula of public schools are political hot-potatoes, and school boards and higher level commissions do not place research bases as their highest decision factor. For example, although the evidence is incontrovertible that teaching students a second or third language in kindergarten and elementary school would be far more effective than the current curricular patterns that teach languages in high school and college, there is little chance of immediate reversal of the illogical pattern. The challenges are even greater for topic matter dealing with human nature. There are strong voices on both the left and the right who will resist sharing portraits of humans as subject to biological or symbolic drives. They will believe that such portraits will undermine personal responsibility or belief in God or belief exclusively in human's biological nature or belief exclusively in the power of social structure or even in an exclusively symbolic nature. Consensus is hard to imagine.

There is not currently sufficient knowledge generated for such a curriculum at present. In spite of these barriers, this should be a long term goal. An interim goal will be to develop and provide such a curriculum free on-line so that individuals who wish to take advantage of such knowledge will have access to it, for themselves or their children. Another interim goal is to try to ensure that all students, not merely the top quarter of students, receive training in the basic sciences, including basic physics, biology and social science.

[357] A vibrant counter-witness is provided by Harmon Craig, member of the National Academy of Sciences and winner of the V.M. Goldschmidt medal, the Arthur L. Day Medal, the Arthur L. Day Prize, the Ventlesen Prize, and the Balzan Prize: "I've never

used the scientific method in my life. I don't know of any good scientist who ever worked with the "Scientific Method". . . . . It's ridiculous to talk about the scientific method, which is what you learned in *My Weekly Reader* when you were a child" (Craig & Sturchio, 1999).

[358] Diamond (1986), p. 20.

[359] John Lynch (unpublished ms.) carefully analyzes Gross's (1988) account as part of an "occupational psychoses" of rhetoricians. Gross provides a particularly good example because he elsewhere insists his view does not deny the "brute facts of nature" (1990, p. 4), and he attends to the details of Newton's work carefully, but he is nonetheless moved to collapse those details into a rhetorical worldview.

[360] Condit, 2004, *Discourse and Society*, in press.

[361] In a talk at the University of Georgia several years ago, Patricia Adair Gowaty indicated that science was constituted by the effort to control for one's biases. She no longer professes this formulation, but it inspired our formulation.

[362] Gowaty & Bridges, 1991.

[363] See Gowaty, 1982, 1984.

[364] Harding, 1993.

Appendix 1: On Theories of Science and Knowledge

Summary: This chapter critiques both the prevailing philosophy of science, which was articulated by Karl Popper, and the post-modernist response to that tradition. In the place of these two major alternatives, the chapter offers a theory of knowledge as the best justified of well-justified beliefs. It suggests that ontology and epistemology are mutually interrelated such that what one knows about something is determined by the fit between the characteristics of being and the methods and assumptions that are brought to bear to study it.

The possibility that humans might be well understood as symbolizing animals does not find a ready made home in the Western academy. Both the organizational and intellectual structures of research entities charged with discovering, integrating and preserving knowledge rigorously divide the study of symbols from the study of animals. It might even be said that these two spheres of knowledge define their own practices largely in opposition to the other.

This sharp division has many manifestations, including separate locations on campuses, different styles of interacting with students, and major discrepancies in funding amounts and sources. Intellectually, however, the most fundamental loci of division are those related to an understanding of the nature of being (ontology) and those related to theories of how knowledge gets created (epistemology). We have already offered a theory of being that emphasizes the shared components of all being in physical energy-matter and also the dissimilar features that arise from differences in arrangement and circulation. Here we take on the issue of epistemology.

Modes of Study of Material Beings

Western epistemologies tend two emphasize two key binaries: science vs. non-science and knowledge vs. belief (or opinion). Science is generally associated with both experimentalism and studies of the natural world, and the science vs. non-science distinction is often used by natural scientists and their supporters to dismiss the humanities (and even the social sciences) as little more than untutored belief or opinion. This makes "science" equivalent to knowledge. Humanists rarely fight back by claiming the ground of knowledge for themselves. Instead, they argue either that science itself is merely disguised belief or opinion or that the humanities offer informed opinion (as opposed to the un- or less-informed opinion of those not paid by a University). The differentiable materialist ontology offered above provides another option. This option replaces the dichotomy of "knowledge/opinion" with a shaped continuum (see Figure X-2) in which some beliefs have accumulated probative value from triangulated research strategies, and many beliefs have not. Below, we will draw upon and extend the extensive philosophical debates about epistemology to define knowledge as the best-justified of the available well-justified beliefs. Throughout our discussion, however, we will not engage the philosophical debates in depth, because much of the debate is based on the problematic ontological and epistemological assumptions that we are trying to replace.[i]

This scaled rather than dichotomous epistemology lowers the tight definitional boundaries around "science" that lead it to be set off in opposition to other knowledge practices. The view holds that there is a wide range of tools available for gaining knowledge about any phenomenon. These include laboratory experimentation, field experimentation, naturally-occurring experiments, field observation, "laboratory" observations, rigorous comparisons, pattern recognition, hypothesis formulation, symbolic analysis, and synthetic interpretation These tools are used in different proportions and combinations in different fields of study. The differences, however, are not absolute but gradational along multi-dimensions. Thus the practices of "science" are more like the "humanities" than is generally admitted, with the differences lying not in the use or non-use of experimentation, but rather in a pattern of application of a variety of research tools and the relative focus on singular vs. more general phenomena. To understand what the relationship between "science" and "knowledge" might be in such an epistemological framework requires attending to the current reigning definition of science and then to its current competitors.

<u>Relocating Popper</u>

The force of scientific research is widely understood to arise from a model of science articulated by Karl Popper in 1959. We have routinely heard Popper's perspective invoked at research funding boards, at awards committees, and in research presentations at both major conferences and local presentations. Popper is often named by those invoking his ideas, but even when he is not named, the principles he articulated seem to represent for working scientists, as well as their supporters, the most commonly articulated vision of what constitutes science. Popper argued that what distinguished scientific from "conventionalist" claims was the principle of falsifiablity. All scientific statements (theories or facts) must be formulated in such a way that they could be falsified. If a statement could not in any way be falsified, then it was not a scientific claim. The primary method that Popper described for falsification was the hypothetico-deductive method. One formulated a prediction based on a theory and that theory was tested through either experimentation or observation. Popper provided no detailed accounting of the sufficient conditions for either experimental or observational tests. Popper's concepts have come to be generally conflated with controlled laboratory experimentation, and observational testing is either renamed "experimentation" or omitted as a valid possibility.

Popper postulated falsification through hypothesis testing as the single identifying criterion of science because he argued that it was necessary to deny a role for induction.[ii] He indicated that induction could not provide a standard of sufficient rigor because there is no logically adequate and precise rule for deciding when a sufficient number of instances has been gathered to determine that a law has been proven inductively. In contrast, Popper understood falsifiability as a deductive approach, which in the canons of philosophy meant that it could provide logically certain results. The potential for this deductively based certainty rested on Popper's descriptions of theories as "universal statements."[iii] If a theory could be framed as a statement that ruled out a specific phenomenon (or amount of a phenomenon), and an experiment could be produced that demonstrated the existence of that phenomenon or amount of it, then the theory had been definitively falsified.

Unfortunately for Popper's theory, in most cases it turns out that hypothetico-deductive testing is itself dependent on induction, because Popper's version of a "universal law" rarely holds. The lack of absolute law statements occurs in all research areas where there are large ranges of values distributed among a class of items and where the numbers of items sampled are relatively small. In such cases, a collective inductive judgment functions to determine whether a particular set of results does or does not falsify a theory. Whether the judgment is formalized (as in choosing a p-value of .1, .05, or.01) or informal (as in the very common process whereby discussions that never make print lead to decisions within scientific communities about how to treat a given theoretical claim), the process uses induction and thus lacks the definitiveness that Popper proposed as the core value.

Popper's ideal fails on its own criterion (avoiding means of ruling out knowledge statements that are not absolute). It is not particularly surprising therefore that it also fails on functional grounds. Popper admitted that the approach he offered only allowed one to rule things out of the bin of "scientific knowledge" but could never rule anything into that bin. Every theory has to remain perpetually open to further tests. It is never definitively demonstrated as "true". This principle of falsifiability is a vital one, because it protects science from becoming mere dogma. However, one of the strengths of science arises from its cumulative character: scientific knowledge only exists to the extent that different theories build on each other and interlink with each other.[iv] The principle of falsifiability and the practice of falsification do not indicate on what basis scientists accept some bodies of knowledge as well enough established to build upon. They only indicate which statements have been absolutely rejected.

A criterion for deciding what gets included as "current knowledge" is inevitably inductive. If Popper's attempt to rule induction out of scientific practice fails, the alternative is taking inductive practices seriously. Indeed, since Popper's time, statistical methods have developed enormously as the core of the process by which such inductive judgments are made. There is also usually a background of shared observations of similarities and differences that are obvious enough not to require statistical tests.[v] In other words, scientists rely on shared pattern recognition skills.[vi] As the descriptions of scientific practices in the earth and life sciences will further substantiate (Chapters 8 and 10), the use of induction and pattern recognition skills as criteria is not a deficiency, as Popper suggested, but instead is useful and inevitable to any process of knowledge production when the objects under study do not have the quality of uniformity and self-identity (with regard to the available measuring tools) but rather manifest only self-similarity. A good theory of knowledge should be able to account for science as it is actually practiced, rather than prescribing a standard that is alien to what scientists achieve and do.

A root problem of Popper's formulation is his identification of science as the construction of universal statements. This belief arose from the character of early physics, upon which Popper based his theories. This belief set is widely shared among scientists from many arenas today. Noble prizes are given to discoveries understood as "universal" rather than to those understood as particular. The analysis of programmed cell death is award-worthy because it is presumed to be "universal", not because anyone is interested in the fate of a particular type of worm.

Scientists maintain this quest for "universal laws" even to the point of systematically mis-recognizing the nature of their activities. An example is provided by a recent article from *Nature*, entitled "A universal trend of amino acid gain and loss in protein evolution." A general trend of the nature the authors identify is interesting and important, but although the general trend is a fairly strong one, it is hardly a "universal." As the article admits, this "universal" trend is clear in only 14 of the 15 taxa for gains in amino acids, while losses of particular amino acids occur in 10, 11, or 13 taxa depending on which amino acids are studied. Patterns in the other amino acids "evolve erratically."[vii] These variable trends do not exactly fit the model of uniformly regimented universal laws familiarized by the idealized model of physics. The exceptions to the trend surely invalidate any claim that a universal law has been discovered. But adding the term "universal" is a kind of importance-designator. An article is less likely to be gain wide attention and therefore be publishable in *Nature* if it identifies a "trend" instead of a "universal," so the authors (and perhaps editor) reach a happy compromise, with the language of a "universal trend." The compromise retains the older rhetorical aspirations to universals, while negotiating the realities of the character of biological research. While this is a particularly obvious example, and the tendency to seek for and misidentify universals is not always so blatant, the drive is pervasive.

There are many incentives to valorize universals. One arises from the linguistic drive to perfection or ultimate terms identified in Chapter 5. Another incentive arises from the greater audience likely to be attracted by something that is perceived to apply to the work of everyone rather than only to specialists. A third, and powerful, incentive arises from the greater economic gains of discoveries that have potentially universal rather than local applications. As Chapters 9 through 11 will highlight, however, true universals of the kind that Popper takes as paradigmatic are highly uncommon outside of the study of disaggregated physical being. A science that confines itself to this teeny fragment of knowledge would be a pathetic science indeed. As Popper notes, a universal statement requires time and space invariability, and these are two things that are not true of biological and symbolic being. Rather than applying gerry-mandered rhetorics such as "universal trend," or adopting the ludicrous position (which we have heard espoused) that time-variant disciplines cannot be scientific, it seems more appropriate to drop Popper's *a priori* criterion and instead formulate an epistemology that can accommodate what scientists in different disciplines actually do.

One important way in which Popper's falsification criterion is modified by scientists in practice is the shift from using definitive experiments (or controlled observations) to convergent experiments and observations as a means of discrediting a hypothesis. When a phenomenon has multiple inputs that vary their strength across conditions, a single definitive experiment may not be possible. In that case, as Chapter 10 will illustrate, information from a series of experiments and observations will need to be aggregated over time to produce a judgment about the appropriateness of an explanation. This leads us to suggest that the most definitive research strategy in many, if not most, cases is *triangulation* across multiple research approaches, rather than a single definitive experiment.[viii]

In addition to engaging in falsification by assembling a pattern of results, scientists also build a corpus of knowledge using precisely calibrated observation. Included in scientific knowledge are some universals, some generalizations (especially what we will call motif-like generalizations), and many precise, specific descriptions. Doing all of these things well, and doing them in proportions appropriate for the objects of study, is crucial to the growth of science. Precisely how these different practices are distributed in disciplines with different objects of study depends on the make-up of those objects. Not only are different levels of generality more dominant in different fields, but also the balance of direct falsification, induction, and observation is necessarily different as well.

In contrast to Popper's account, we offer an account of knowledge production that understands the hypothetico-deductive method as a crucial tool for falsification, and which accepts in-principle falsifiability as a key requirement of any knowledge claim, but which recognizes that in-fact falsifiability is not always feasible. Rather than abandoning the possibility of understanding in such cases, scientists and other scholars employ inductively based procedures. On this account, science necessarily consists of a broad range of practices in addition to hypothesis testing through experiments (or even through observations). Descriptions of particulars, descriptions of categories and their relationships, interpretations of large aggregates, and synthesis of models that can never be tested as wholes (though their predictions or sub-components can receive some tests) are all necessary, fundamental parts of science, as they are of other modes of knowledge production. Before claiming a privileged position for such a multi-aspect theory, however, an account must be made of the strong challenge to Popperianism and science in general that has been offered by some versions of science studies, usually identified as "post-structuralism."

Responding to the Post-structuralist Response

At the close of the 20th century, an inter-disciplinary formation of science studies arose from locations as varied as sociology, rhetorical studies, philosophy, literature, history, and anthropology (with occasional contributions by others from many fields). It is not possible to neatly summarize or categorize the contributions of this large and diverse literature. Some of the work is resolutely objectivist in its approach, others is functionalist, but the strand that has gained the most attention and notoriety has been the work identified as post-structuralist.[ix] In the heat of the so-called "science wars," some of the arguments of post-structuralism have surely been misrepresented, but because there is no single thing that stands as a post-structuralist perspective, sorting out misrepresentations is not a high priority use of the present space. Instead, we will identify two things that science studies have done that we believe are well-supported and important in their implications and one crucial way in which post-structuralist perspectives would take the research academy astray.

Science studies have provided overwhelming evidence that science is a human practice, and like all human practices it is embedded in economic, political, and social forces that shape what science can produce. There have been many detailed studies of the interfaces between specific scientific theories and the socio-political world around them,[x] but simple examples serve present purposes best. The decision to fund certain areas of study (e.g. the Human Genome Project or studies of the short-term positive effects of drugs) makes available certain pieces of knowledge (how genes work or which drugs work in the short term). Simultaneously, the decision not to fund other projects (the superconducting super-collider or studies of long-term health effects of drugs) makes unavailable other kinds of knowledge (is there a Higgs' boson? does our manufacture and distribution of thousands of chemicals increase our cancer rate?). The total shape and balance of knowledge that is available to a society is a product of ideology both in terms of what is fundable and what standards of proof are deemed sufficient in different areas. Ideology also influences which hypotheses are conceived and how they are conceived. The available store of what counts as knowledge inevitably and unavoidably has ideological or social implications (for example, we use drugs and other chemicals that have short-term utilities without being able to weigh their long-term consequences). Because societies fund science, these ideological and social factors necessarily play back into what science produces. There are other levels and ways in which scientific activities are inflected by socio-political factors, some of which engender much more contentious, but the simple examples establish the principle in a fashion sufficient for present purposes.

The second important contribution of science studies is the identification of the ways in which, because science is necessarily an activity conducted through various kinds of symbols (natural languages, technical languages, and mathematics), it is necessarily influenced by the symbolic practices of science in general, and also those practices germane to particular fields. G. Mitchell Reyes, for example, has recently illuminated the rhetorical difficulties faced by Newton and Leibniz in introducing their calculus. Because the concepts of the calculus exceeded the modes of proof available in both the Euclidean geometry of their era and empirical foundationalism, they struggled to make persuasive to the scholarly communities of their day the concept of the "infinitesimal," with which their insights were originally formulated. Ultimately, they both displaced the use of the verbal descriptions based on the infinitesimal (which arguably was linked to their discovery and described it well), with talk of ratios, that could be better negotiated to move the community's standards of proof in new directions.[xi] In this instance, the importance of particular symbolizations, independent of their pure truth value, is made quite clear.

In a differently structured case, Scott Montgomery has shown the ways in which visual depictions of the moon by early scientists (and artists) were a product of the symbolic conventions for both understanding the moon and representing landscapes on earth, rather than being direct visual representations. Galileo, for example, drew impact craters as simple circles, without the ejecta, even though the latter would have been clearly visible through his telescopes. In spite of his dedication to realistic depiction, Galileo's depictions were constrained by the symbolic codes of his day for landscapes.[xii] As we will further argue in the concluding chapter to the book, this insight means that part of the requirements of any knowledge practice must be critical reflection on one's symbolic choices.

Both these findings of science studies—the socially situated nature of scientific practice and its linguistic sensitivity—may be irritating to scientists who prefer to think of science in an idealist fashion. Nonetheless, recognizing these features of science and taking them into account in scientific practice does not delegitimate the scientific or scholarly enterprise. Instead, this knowledge can better allow scientists to achieve the goals of science. However, the third strand of science studies, if widely accepted in its totality, would vitiate the scientific enterprise, and that strand is the one that has come under the most vigorous attack from the defenders of science.

Getting outside the text

The most famous phrase associated with post-structuralism is probably Jacques Derrida's "Il n'y a pas hors du texte."[xiii] The phrase is generally translated as "there is no outside of the text." This does not have to be taken to mean that there is nothing but text; a weaker interpretation holds it to mean merely that, all human access to everything is tainted in some way by language. However, some post-structuralists appear to adhere to a fairly strong form of the claim, and they believe that only language has influence on what we know, or that the influence of language essentially relegates any other influences to insignificance. This is the interpretation that is attacked by most defenders of science. That strong claim is certainly incompatible with a definition of knowledge that distinguishes it from opinion or any common belief. On that view, "the world is flat" has as much claim as a knowledge statement as "the world is an oblate spheroid." Scientists, as well as many humanists, might well bristle at such a claim, because it indicates that all of their care in setting up experimental designs, all of the rigor of their observations and analysis, are for naught.

The leap from recognition that language, economic structures, and ideology play roles in science and other knowledge practices to the claim that they play an exclusive or definitive role is a rather large one. It is precisely this leap that post-structuralist philosophies of language work hard to authorize. Although this is not an appropriate venue to dwell in detail on the argument and its counter, the heart of the post-structuralist argument is a refutation of the absolutist objectivist position that would deny any influence to language, economic structure, and ideology. In essence, the post-structuralist argument readily refutes the claim to objectivity (which is understood as a position isolated from influences other than pure un-situated perception of a phenomenon). However, the post-structuralist argument presumes that if the vision of pure, unsullied objectivity is incorrect, if language, ideology, and economics can in fact be shown to influence actual scientific discoveries and outcomes at any given time and place, then there is nothing left but language, or ideology, or economic structure (depending on the critic's preference).

Derrida's own version of this assumption beings with the observation that the Western worldview derives from the nature of oral speech, which is taken to give "presence" to the phenomena that are articulated by it. Derrida shows how the concept of "presence" relies on its hidden binary, "absence", and he thus de-legitimates a foundational role for presence. He shows how language is as much a product of absence, difference, and deferral as it is a product of presence. At its base, this is much the same argument as we presented in Chapter 6 about the way in which the effectivity of symbol systems is a product of structure and history, but there are two important differences. Derrida assumes that since structure plays a role, then nothing else may play a role in producing the effects of language. Secondly, Derrida absolutizes the absence, difference, and deferral of language.

Both of these related, additional moves are difficult to justify, and they are specifically the source of the incompatibility of post-structuralist and scientific worldviews. There is simply no reason to assume that the discovery that structure plays a crucial role in language means that nothing else plays a role. It may have been difficult to articulate how it is that something like the real fuzz-and-flesh cat sitting on the mat actually gets taken up into something as ethereal-seeming as a language network, to produce a statement like "the cat is on the mat," but that surely does not mean that it is impossible. Moreover, today (decades after Derrida's initial writings) the neuronal web model shows quite readily how it is possible to integrate responses from visual and tactile pathways with linguistic ones. This integration may not indicate that there is an "objective reality" out there, but it indicates that the kinds of material reality to which one has access are not limited to human symbolic systems.[xiv] As Chapter 6 has shown, the fact that language adds something distinctive to other conceptualizations doesn't mean that it is fully independent of those conceptualizations.

A devoted linguistic absolutist might respond that the conceptualizations themselves are just another human-based web. In some sense that is true—evolution has programmed human brains to particular patterns (a theorization that leads to a strange convergence of agreement between the evolutionary psychologists and the post-structuralists). Nonetheless, those patterns do not exist as such without particular kinds of external inputs. This has been demonstrated empirically in studies that show that brains develop differently absent certain kind of stimuli (e.g. light and sound, or particular light patterns). For those who are unconvinced by such scientific evidence, the old "run into the wall" trick will suffice. Bumping into the wall is not an experience unmediated by language, but it is also an experience that is mediated by a physical substance that interacts with our own physical substance in highly predictable ways, regardless of whether or not we call the recalcitrant substance a "wall" or any other label.

More technically, this is to suggest that the absolutizing of difference is no more warranted than the absolutizing of presence. Derrida's argument essentially functions by the reversal of a binary and the endorsement of the formerly suppressed pole of the binary. Derrida has insisted that "difference" should not be read in such an essentialist (i.e. presentist) fashion. Differance should be understood as or treated as a principle of erasure, rather than a positive construction. But even according to Derrida's own description of language, every erasure is also always a (re)writing (also described as a re-tracing or new trace). Derrida's philosophical insights have spawned highly productive critical challenges to existing linguistic systems,[xv] but they cannot avoid having presence as long as they write (even if the presence of writing is also different from the presence of oral speech). At best, they can encourage the "consciousness of abstracting" that was also a primary goal of the general semantics movement (see Korzybski, 1958). This is because both presence and absence are features of linguistic systems. A structure is both what is here and what is not here: this and not that. The best identification and refutation of the singularity of the role of presence cannot create a symbolic system that is pure absence; it can only restore absence to a recognized role in the dialectic.[xvi]

This perspective on post-structuralism is fundamental to the way we have chosen to theorize, write and organize this book. Instead of writing a deconstruction of science, we have chosen to author a particular reconstruction of knowledge. Instead of choosing language strategies that emphasize deferral of understanding, we have attempted strategies that loosen binaries by engaging trinaries and bringing to bear multiple dimensions. Our language makes claims and creates images and models and theories, rather than simply trying to erase the creations of others (a tactic which we believe is recommended only due to a mistaken belief that absence or erosion is always better than any presence might be). We believe, indeed, that human knowledge will never be perfected, but that does not mean that all knowledge is equally empty (or equally valid), or that it creates worlds that are equally good or bad. Some knowledge is likely to be more reliable, more useful, and more durable than others, because humans have developed a series of techniques for making it so. Aristotle's rhetorical topics of "more and less" are ultimately more desirable than his absolutist logics "a B is either A or not A, but not both." Both the rhetoric and the logic are stuck in binaries (because that is what language does), but the logic absolutizes the binaries and the rhetoric does not, and the "real world" rarely exists in binaries—that is a linguistic imposition. So what then is this thing we call "knowledge" if we resist the absolute binary of true and false?

Knowledge is…..

To formulate the criterion by which we may determine which statements count as knowledge and which do not, it is useful to turn to the philosophers, who have done an admirably extensive job of exploring what it means to say that we "know" something. They have described "justified true belief" as an ideal standard, but recognized that it is an unachievable ideal. They have highlighted that we can never know for certain when our beliefs are true, independent of our justifications.[xvii] So in practice, humans must settle for something less than certainty that they have "true" beliefs.

"Justified belief" is not on its own a sufficient standard however, because anyone can come up with "justifications" for her or his beliefs. We suggest instead, that something (an equation, a law, a category system, an aesthetic judgment) deserves the standard of knowledge when it is the best justified of the available well-justified beliefs. "Best" and "well" are not happy terms for those who enjoy the feel of absolutes and of certainty, but absolutes and certainty are not available to us, so the psychological discomforts must be lived with. "Well-justified" means that one isn't entitled to claim that something is knowledge (as opposed to belief, opinion, or intuition) until it has been given a thorough investigation using the methods and knowledge networks available at the time. Knowledge is thus different from opinion because it makes claims to inter-subjective verification. It has become different from Popper's "conventionalism" because of the development of a wealth of techniques for such verification that exceed the older possibilities limited to reference to authoritative persons or texts.

The term "best" is even more difficult. Sometimes there are two well-justified sets of competing beliefs. Often this means that neither of the beliefs is fully sufficient. Before quantum theories evolved, one had good justifications for understanding light as a particle and other good justifications for understanding it as a wave. In this case, it meant neither the wave nor particle justification was "best": a third account was needed--wave-particle duality. Before the synthesis it was accurate to say, however, that we "knew" that light sometimes behaved as waves do, and that we "knew" that light sometimes behaved as particles do. But judgments of which account was "best" depended on the specific kinds of issues being addressed, and thus were not context-independent.

The specification that a theory or fact must be both well justified and the best justified belief to count as current knowledge provides a substantial bulwark against self-serving opinion and outright falsehood, as is illustrated by the example of our current knowledge that the world is an oblate spheroid rather than a flat disk. There are certainly some justifications for thinking of the earth as flat: it looks fairly flat (at least on a relative scale in many places). But that is not a well-justified belief. It is a position that hasn't considered potential alternatives and sought for counter-evidence. Even in Aristotle's day, people had counter-justifications: the sails of ships came over the horizon before their hulls did and the stars had different positions in the two hemispheres. With the evidence and analysis of Brahe and Copernicus and Keppler these justifications grew. With the orbiting of the earth by astronauts they grew even further. Today, one is well justified in treating as cranks those who claim to "know" that the earth is flat. The justifications for a round earth are clearly the "best" beliefs and are extremely well-justified. They aren't certain. We could be dreaming. NASA could merely have a studio hidden in Area 51. But considering all the different pieces of evidence together, the most likely explanation is that the world is not flat, but relatively round. One is not entitled to hold that one's personal "opinion" that the earth is flat is just as good and reasonable as the opinion that the world is an oblate spheroid. That doesn't mean that one can't ask for debate to be re-opened if one finds new evidence or reasons (the claim remains falsifiable), but merely that the preponderance of the evidence is overwhelmingly clear.

This example highlights the way in which claims to knowledge rest on relative degrees of probability or likelihood rather than on certainty. Both Popper and the post-structuralists made absolute certainty the criterion of knowledge. Popper left scientists with nothing that could be called knowledge—only a reject pile generated by painstaking experiment. The post-structuralists showed a way to skip the painstaking effort. A position that stakes knowledge claims on relative amounts of inputs and evidence, and that recognizes semi-stability as a good-enough resting place if absolute and permanent truth are unavailable, is able to produce a reasonable set of judgments about which statements count as "the best available for now." On this view, evolution is far better theory than Intelligent Design, and the theory that humans have accelerated global warming provides far better knowledge than "maybe the scientists are wrong about that, and everything will be ok if we keep on pumping $C0_2$ into the atmosphere."

The development of the understanding of the earth as an oblate spheroid also highlights the way in which knowledge results from accretion and inter-locking explanations, rather than from isolated definitive experiments. There is no one experiment that one refers to as falsifying the flat earth thesis and providing definitive proof of the shape of the earth. The same is true for evolutionary theory. It is not a singular piece of evidence, but the triangulation of evidence that establishes high probability. Scientific and other knowledge systems gain their authority and effectiveness not from isolated facts, but rather from networks of relatively self-consistent theories that are supported by a wide range of evidence gathered in different ways. While critical experiments might disprove particular theories, a single experiment can never conclusively demonstrate the truth of a theory. This much of Karl Popper's theorization is correct. What Popperians have ignored is the accretive side of the knowledge-developing enterprise. Physicists believe in the theory of relativity not just because Einstein's prediction of the bending of light waves by large gravitational objects was not disproven in later experiments (really observations), but also because the theory "hooks up" with other theories, each of which can be linked to many other experimental predictions and observed conditions of the world. Experiments provide the strongest possible anchors in these networks of theories, but in many areas experiments aren't possible. Therefore rigorous observations of empirical data are used, or experiments of consequents or related propositions are done, and the successful inter-relationship and accumulation of mathematical congruences, visual models, experimental evidence and observations together form the basis of our belief in a theoretical account.

The same standard for knowledge--the best justified, well-justified belief--applies in the symbolic realm. When a student alleges that a novel, poem, or film is "excellent," a teacher is right to insist that they parse this statement into two alternative possibilities. One is "I like this novel a lot." That is not a statement with intersubjective contents, but an expression of personal taste. The other meaning of the statement is this knowledge claim: "compared to a set of criteria drawn from the understandings humans have developed about the possibilities of literature, this novel manifests some particular features of those possibilities in better ways than most novels (and probably without manifesting any significant failures in central characteristics of novels)." This latter statement of knowledge presumes a well-justified set of statements about what the possibilities of literature are. These are drawn from exploring what literary genres have done in the past and from theoretical extrapolations of what literature may be. This is why the judgment of a literary critic is inherently "more knowledgeable" than the judgment of the 14-year-old audiences of novels, films, or other symbolic artifacts.

Judgments about symbolic artifacts tend to appear to be more contentious than old settled scientific beliefs because, unlike judgments about physical being, judgments about symbolic artifacts often have multiple possible criteria: ideological effects, novelty, depth of character, coherence of plot, etc. Therefore, there is often disagreement about whether a novel or film is "excellent" or not, because there is a difference in criteria. This disagreement does not necessarily reflect a lack of knowledge, but rather a lack of agreement on utilities. This merely highlights that what is "best" is usually dependent on "best for what?"

Here rests a key point of the disagreement between the understanding of "knowledge" promoted by physics and the understanding of "knowledge" promoted by other arenas of study. Most of the time, in physics, one can claim that the use and the context do not influence which criterion of judgment is most relevant (because physical being is time and space invariant). In the wave vs. particle debate, if different accounts seemed more true in different contexts, that constituted a sign that physicists didn't understand the phenomenon fully. But even physicists can't always reduce the world to a single context, and the ability to resolve criteria in almost all cases is not equivalent to a claim that one does not "know" anything about a phenomenon if there are different criteria for judgment in different contexts. For indeed, contemporary physics today faces incompatibilities between quantum theory and relativity theories: they are incompatible with regard to massive and small phenomena. There is no guarantee that this divergence in context will ever be resolved, though string theory has made a bid for a resolution. Fortunately, the absence of a resolution does not mean that either quantum theory or relativity theory does not count as "knowledge." Each is a well justified belief, indeed the best justified belief about huge areas of physical being. Physicists dream of "an ultimate theory" that will unite the two areas because they believe that incompatibilities signal the possibility of more comprehensive accounts. But few physicists would claim that they don't know anything about quantum phenomena or the effects of relativity in the absence of such a unified theory.

Claims to the status of knowledge do not require comprehensiveness or total explanation. Many scholars and scientists are predisposed to define as knowledge, or at least as the only valuable knowledge, only that which is universally true. But, as Chapters 4 and 5 emphasize, biology actually doesn't work like that. There are generalities about biological beings, but very few of these are universals, and even those that apply most generally usually apply only with significant internal variation. Many biologists therefore often operate with a schizophrenic consciousness—working with the natural variation of their subject but seeking for law-like universals—and therefore often mis-identifying generalities as universals (as in the example of the "universal trend" described above). The isolation of the trend is surely a valuable contribution, and an important generalization, but these variable trends do not exactly fit the model of uniformly regimented universal laws familiarized by the idealized model of physics. Such results highlight a distinctive and important facet of the epistemology that we present. This epistemology describes knowledge not exclusively as highly general theories, but as statements at all levels of generality and specificity. The Popperian fascination with classical physics has placed an unhealthy emphasis on high-level theories (universals), but as Chapters 4 and 5 indicate, biology is as interesting when it tells us about unique cases, or focuses on groups of species, or tells us about “motifs” and “model organisms” as it is when it churns out a few supposed universals (such as the centrality and common patterning of DNA or programmed cell death). The same value of knowledge at a range of levels of generality holds true for symbolic studies. Knowledge is knowledge, and it is valuable and worth pursuing whether it provides us specifics or universals, or most commonly something in between.

Finally, the drive for universals is related to the demand to incorporate not only “explanation” and “prediction” but also “control” as standards of knowledge. In some cases, one can provide innumerable “explanations” that have the attractive scientific properties of elegance or simplicity or comprehensiveness. Likewise, one can predict particular outcomes of singular variables in single experiments that are tightly controlled, merely on the basis of a “generalization” from previous experience with the same conditions. It is only when one can demonstrate “control” of a phenomenon that one has demonstrated a knowledge that is broad enough to satisfy and reassure us that “we really understand” something. This is because all of the different possible component purposes are specified in the effort to produce control. Here, not coincidently, is the place where scientific criteria merge with social purpose. Appreciation and funding of knowledge production by societies is related to the ability of that knowledge production to enable the societies to control things they want to control.

There is, however, a troubling difficulty in the emphasis on control as a standard for knowledge. The more things in the real world represent complex interdependencies, the less one can control them directly. Streams of light are relatively easy to control: eco-systems and human societies are extremely difficult to control. This would be true even if there were explanations and predictions that were equally deep for the different phenomena. Control derives not just from how good one's understanding is, but also from the number, interactions among, and accessibility of the levers that must be simultaneously manipulated to exercise control.

The superiority of the control that has been produced by physics is what has made physics seem like a superior science. Yet, as one's intuitions might suggest and this book elaborates, this is not intrinsic to physics as a method or to the quality of knowledge produced by physicists. It is intrinsic to the nature of physical being, as opposed to biological and symbolic being. The nature of control that is achievable in biological and symbolic realms is much different than that in the physical realm, and it will be useful to build intellectual frameworks and the teaching systems that sustain those frameworks in recognition of those patterns of difference. A more appropriate vision of knowledge will therefore not be one that demands leveragable, universal control, nor one that insists on absolute generality of context. It will be a form of knowledge that both recognizes the distinctive local features of a given phenomenon and attends to those rigorously and precisely, while also seeking to explore the bridging phenomena that may inter-link different locales. Such a transilient research program cannot hold out hope for the discovery of a small set of universal laws that allow reform of humans as one might move puppets on a string. It may, however, enhance understanding of our species so that it is possible to rechannel behavioral predispositions through the exercise of individual and collective democratically based self-control.

Ontology is Bound to Epistemology

We have provided a theory of being that identifies all of the modes of being to which humans have inter-subjective access as sharing a common physical substrate and different qualities arising from differences in arrangements in time and space. We have suggested that a theory of science as the generation of universal laws through experimental falsification is too impoverished a tool for accounting for human efforts to understand the variations within such being. We have identified an alternative standard for knowledge—the best-justified of the available well-justified beliefs—and, we have suggested that such knowledge systems are comprised of statements of varying levels of generality created through accretion of observations, experiments, interpretations, models, mathematical systems, etc. The final step we will take in tying a theory of knowledge to the ontology we describe is to suggest that *good* research strategies are characterized by the use of tools that fit the characteristics of the phenomena under study. Consequently, the mix of tools most useful in studying high energy physics is different from the mix of tools that are most useful for studying the range of human symbologies for representing death.

The knowledge one has is thus neither a product exclusively of the character of the beings under examination nor exclusively of the methodologies and assumptions brought to bear. What one discovers is a product of the intersection of a specific methodology with the particular characteristics of a phenomenon under study (the former of which is always embedded in a social context, and the latter of which may be). Consequently, knowledge about a phenomenon can never exceed the contours of one's epistemological assumptions (physical being might look different if we asked different questions about it from those asked by classical physics, as quantum physics has shown). However, one *can* falsify theories at a sufficiently high level of probability to serve most purposes, and this occurs whenever there is a mismatch between the characteristics of a phenomenon and the methodology and assumptions applied to it. The most fruitful methodologies are the ones that make the best match between the characteristics of a phenomenon and what the methodology and epistemology are capable of reporting on.

Appendix 2: Self-consciousness as Narration

Chapter 6 suggested that what we call “self-consciousness” is precisely our non-vocalized narrativizing. That is, it is the set of fragmented but connected stories a human being tells her- or himself about their behaviors, identity, and relationship in the on-and-off flow of discourse that happens “in the mind” (that is, without having to be vocalized to others, though vocalizations to others serve the same function). In this appendix we explain further this possibility and discuss the social and ethical implications of the perspective.

Discussions of consciousnsess are usually confused by the labeling of three different things as consciousness. The first is general awareness. Simply being awake is sometimes referred to as consciousness. Consciousness as awakeness entails peripheral awareness of many external and internal inputs in a way that being asleep does not. We presume most animals have this kind of consciousness. The second thing talked about as consciousness is “directed awareness”—that is, the fact that our attention seems drawn from one thing to another. Put differently “directed awareness” is heightened attention to or focus on some aspects of our surroundings or internal states (hunger, sleepiness) rather than others. The example of the deer shifting attention from shrubs to distant smells indicates that animals also have directed awareness. What most people believe constitutes a difference between symbol using and non-symbol using animals is the third type of “consciousness,’ which is often talked about as an “inner voice” in humans, which is also usually tied to what people mean when they talk about being a self as well as the exercise of human will and morality.

Several reason works have been at pains to argue that there is no unified “self”. Indeed, this is one of the few places where post-structuralists and biologists such as E.O. Wilson agree. By this they mean to emphasize that there is no unified, director of the activities of the mind. The mind is an orchestra-without-a-director, rather than a well-unified whole. The evidence and arguments for this position are pretty much definitive. However, they aren't widely accepted because they so much run up against the common-sense feeling of ourselves as a singular, unified Self. We argue that this singular unified sense of self comes from two sources. First is the biological fact that our nervous and other biological systems are linked to and control a moderately tightly defined "body". While post-structuralist critical analyses have shown that this body is not permanent and its boundaries can be expanded and contracted in various way by a wide range of prostheses (from contact lenses to canes to artificial lungs to artificial legs), this does not mean that there is not an interactive coherence to the body that is different from the relationship to the "not body." The body thus provides one physical stratum of the sense of self.

The other physical stratum of the sense of self comes from the "voice in our heads." Each of us has a running monologue that turns on and off in our heads. But we experience our self as self through this monologue. The monologue appears to us as unified even though neither it nor our brain is tightly unified. Our brain is not IN FACT a unified system, but rather a bunch of inter-related clusters firing and cross-firing, doing all kinds of things simultaneously (breathing, digesting, smelling, touching, talking), and "consciously" noticing only some of these things. Likewise, the monologue we run in our head, if it could be followed, would not be a very well-unified monologue. We indeed, contradict ourselves and re-write our past quite facilely. Nonetheless, the fact that there is what is experienced as a single voice in our head leads us to feel that we are indeed just one self. Indeed, people who experience inner speech as different voices experience themselves as multiple personalities or selves.

Because human consciousness of self is precisely the experience of talking to one's self, E.O. Wilson's claim that the self is written in the brain is wrong. One could never simply read a brain scan to discover the person inside it. This is because the self, as an activity that engages multiple diffuse brain centers that are not tightly bounded, and also external inputs that are not tightly bounded, is not reducible to a static picture, nor even to a moving picture. Although the human being is fully material, there is no bounded physical reduction that can re-produce that individual self.

Consciousness thus is an emergent property of the brain, but it is especially the action of symbolizing capacities, especially brain mechanisms active in the process of narrativizing, but this indirectly also includes participation in the full symbolic network. It doesn't seem all that difficult to propose that the discussions humans hold in our heads are a supervenient property of a particular biological arrangement of matter—symbolizing (in the same way that biological being is a supervenient property of particular arrangements of physical matter). The power of this symbolic system is particular unique because it often over-writes other brain processes due to its linear nature, as described in Chapter 7.

Understanding consciousness in this way provides us a better way to deal with the free will and determinism debate. What humans experience as the exercise of "free will" is really just our (accurate) experience of the fact that there are some cases in which we must make choices self-consciously (that is by verbalizing those choices). As an entity that "talks to ourselves," we assume that since we must make a deliberated choice (i.e. a choice about which we have sub-vocally "reflected" or discussed-with-ourselves), that we are "free" to decide one way or another.

"Free" will is a misleading term, however, because it is easily taken to imply that the choice made by the "I" who we posit as the author of the narrative voice in our heads is unconstrained. This is not true. Hundreds of pieces of evidence demonstrate that the choices individuals make are constrained by a complex set of processes external to the narrativizing voice in one's head; those forces include genes, developmental sequencing, cultural conditioning, structural constraints, and the particular personal history through which these forces have been imposed to shape each unique human body (that is, to shape the brain that is making the decision). A better descriptive label therefore is "personal will." Humans must, indeed, exercise our personal will, making some consciously deliberated choices, and only symbol using creatures can make such consciously deliberated choices, because only symbol using creatures have the narrative voice in their heads that allow (and mandate) such choosing.[xviii]

The fact that we must sometimes actively, consciously choose does not mean that our choices are unconstrained. How we will choose is strongly, if not completely, determined by who we have come to be at any moment and by the particular circumstances in which we find ourselves. However, this is not the simple determinism of the billiard ball struck by a cue stick. It may not even be the more seemingly random stochastic determinism of the uranium molecule's decay. This is because one of the major sources of inputs to the decisions of symbolic creatures is symbolic inputs. Symbolic inputs are more malleable than other inputs, and therefore allow the possibility of unique creation. One may never before have seen a fire, but one can still know of the advantages to be had from a fire and how to make one based on someone else's story about it. In any decision made by a symbol-using creature, the inputs are enormously multiplied by the fantastic volume of symbolic cues. Moreover, even the grossly physical or non-symbolic inputs are instantly modified by their processing through the symbolic system. Everything comes to the process of conscious deliberation through the narrativizing voice. This means that any individual human's choices are a product of the options before them, but it also creates a space for invention. Because language has that property of allowing things to be moved around in ways that are "not real" new ideas and options can be invented. This is what people often do when confronted with choices they think are bad. It is not only a special capacity, it is an individual one. Although every symbolizing entity shares an enormous amount of the constraining forces of their race, class, gender, region, religion, etc. with others similarly placed, the way in which all these forces come together in each individual is absolutely unique. This makes each individual an absolutely unique source of creative capacities, including creative moral capacities. This means that each individual's personal will has the potential to enact unique choices, at least in some cases.

Even if our ability to come up with new stories is stochastically overdetermined, surely we are right in saying that we have a creative personal will—that is, an individualized capacity to create that exists only in our brain through our narrativizing. We are surely right in recognizing this third type of consciousness as something special. Recognizing the unique human capacities as "creative personal will" thus provides as much protection to the dignity and value of humans as individuals as does the older formulation of "free will". Making such a shift in understanding of the nature of human will should not have any of the negative effects often posited for the decline of theories of "free will" by its defenders.

With regard to human moral responsibility the conceptualization of human distinctiveness as creative personal will even deepens it. Operating from the concept of free will ,theorists and practictioners have had a tendency to focus too much on "big choices" (although

Aristotle didn't make this mistake). Morality, on this account, is an isolated act, one great choice to "do good" or "do bad" in some particularly difficult decision (usually where doing *both* good and bad is inevitable!). In contrast, when one understands humans as symbol using animals with creative personal will, one begins to understand that every choice is a moral choice, not only for the immediate present, but also because it creates a particular set of tendencies in the embodied being of the human.

Moral instruction, for a body that can exercise creative personal will, is not merely a series of "thou shalt nots" (though those have their place). Rather, it is first, the regularized choice of a certain type of alternatives (other protecting, not merely self-serving), because the regular making of such choices produces a body predisposed to such choices (even against evolutionary programming, though one might have to work quite hard to over-ride evolutionary programming in individuals whose mutual reciprocity calculators are set to "free rider"). This is because the choice is embodied and determined at one important level by the body that has been formed and the practice of the neural circuits in executing certain kind of choices. But moral training is also the illustration of proper story lines for human behaviors and lives (morality plays), because making present particular narratives as desirable is one powerful input into the deliberative choice-making of the human brain. Moral training is also instruction in the range of alternatives that are available, and in how to generate additional alternatives, since it is the available range of alternatives that allows the creative personal will to discover, where available, choices that both optimize individual benefit and do so without unnecessary harm to others.

Appendix 3: Toward Resolutions of Conflicts Between Evolutionary Theory and Symbolic Theory

Summary: The integration of symbolic and biological being in the MOTIVATE model raises important challenges with regard to patterns of human evolution. Most importantly, the idea that symbolic systems might constitute partially independent sources of causation for human action appears to conflict with an absolutist vision of evolutionary theory. This chapter lays out several ways in which the accommodation of evolutionary theory and a bio-symbolic theory might be made. It then provides a case study of how a bio-symbolic model can be applied to improve research on human evolution, by discussing revisions to the modeling of evolution of cooperation.

Any attempt to integrate biology and symbolics must address the implications of the integration for the theory of evolution, because that theory is foundational to biology. There is an apparent conflict between the theory of natural selection and an independent role for symbols in the behavioral patterns of a symbol-using animal. We will first show how much of this apparent conflict is a semantic difficulty that can be erased with more appropriate framing of causal accounts. We will then entertain the possibility that the remainder of the conflict must be resolved by ceasing to assume that humans can be described as operating with an evolutionarily stabilized strategy. We will sketch several ways in which this possibility can be maintained without altogether forsaking evolutionary theory for "mysticism." We will then provide a case studies that re-envision the study of the evolution of cooperation by incorporating both biological and symbolic inputs.

The Semantics of Evolutionary Causation

The logic of evolutionary theory holds that all features of organic beings that currently exist must be the product of the forces of natural selection (including sexual selection). Because of the nature of biological inheritance, organisms that exist today must be descended from organisms that existed in previous eras. Assuming that resources are finite, all organisms cannot leave an infinite number of offspring. Indeed, there is some maximal level of organisms that can survive, and that level of organisms will always be reached in some finite period. After that point, if any pair of mating organisms attempts to leave more than two biological offspring, there will be competition for resources for those offspring and among those offspring. Obviously, biological being is so arranged that in all species to date, some organisms attempt to leave more than replacement numbers of their offspring. Hence, there is competition for the available resources. Some organisms appear to be more successful at garnering the available resources (including reproductively compatible mates), so that they leave more offspring than others. The organisms that are more successful are said to have been "naturally selected." Because organic beings have the capacity to pass on some traits and not others, this process produces a more-or-less gradually changing lineage of selected organisms; this process is called evolution.

Although ours is a slightly different way of framing evolutionary theory than is standard, it is sufficient to highlight the point that evolutionary theory is both broad and vague. Given the complexity of organisms and the variability of their environments it is one thing to say that the theory of evolution "causes" organisms to be as they are and to behave as they do. It is another thing to say that evolutionary theory gives definitive predictions of what constitutes the qualities that lead to fitness. Often, when people claim that something is inconsistent with evolutionary theory, what they mean is that it is inconsistent with some part of the middle level framework of evolutionary theory—a particular theory of mate selection or of sexual conflict, or of genetic "selfishness."

While we believe that our claim that symbolic processes have independent components of causality from biological evolution requires careful thought and is a serious conflict, we do not believe that conflicts between symbolic accounts and the most popular mate selection theories among biologists is so serious. There are several reasons for not treating conflicts with middle level theories of natural selection as conflicts with evolutionary theory per se. First, as Chapter 5 shows, biological theories tend to be generalizations rather than universal laws. Other than the universal existence of DNA among living beings (which is in itself, something of a tautological definition), there are very few universal generalizations among species and phyla. If humans just happen to be one of the exceptions to a general pattern, this would hardly surprise us. Moreover, many of these rules have so many "escape clauses" that virtually anything can count as fitting the prediction. If, for example, a theory of rape holds that men only rape when they don't otherwise have access to female mates, and one then discovers that highly attractive, high status men commit rape, one has not falsified one's theory. Instead, one can explain that "physically attractive men are preferred by women and this lowers the cost of rape." So the theory predicts both that highly attractive, high status men will be less likely to rape and explains it away when they do.

While evolutionary theory itself is logically airtight, the subsidiary theories that try to explain what will be "the fittest" in the competition to survive have to bootstrap their way up, negotiating between sets of theories and empirical observations. Few, if any, of these theoretical domains are so well established that suggesting alternative possibilities to them constitutes rejecting the theory of evolution itself. By avoiding conflating "*the* theory of evolution" (or the process of natural selection) with middle level explanatory theories of how evolution occurs, one can avoid assuming that every disagreement with an explanatory evolutionary theory arises from mystical alternatives to evolution itself.

A second major semantic problem that troubles debates about alternate causation to evolution arises from the popular distinction among biologists between "proximate" and "ultimate" causes. Biologists are quick to assert the primacy of evolution by describing it as "ultimate" causation, while relegating other causes to merely "proximate" status. This hierarchicalizing strategy makes biology the ultimate source of power and dismisses everything else as secondary.

The first problem with this strategy is that the physicists can trump it. If one is looking for "ultimate" causes, surely the Big Bang and the four "fundamental" forces of the universe trump evolution. But the nature of this trump card highlights that what is really meant by the duality is not "ultimate" and "proximate" but "distal" and "proximate" or in the case of evolutionary theory "historical" and "proximate." The legitimate distinction biologists are making by using this pair is to point out that there are historical factors which shape the organism that acts in the moment and that it is important to understand those historical factors in order to understand why an organism behaves as it does.

Unfortunately, the combination of the logical certainty of evolutionary theory with the reality of the input of history leads people to use the proximate/ultimate pairing to mistakenly assume that the only real causal force in biological being is evolution. But every causal influence in an outcome is a causal influence. None of them are irrelevant, and wholly subsumable under either a theory of evolution or an account of the four major forces of the universe. The particular concentration of Oxygen in a pond plays a causal role in determining what kind of aquatic life survives there. Dismissing the Oxygen as a “proximate” cause because the life that can survive there must have evolved subject to the forces of natural selection is like saying that the first billiard ball in a three billiard ball chain is the “ultimate cause” of the movement of the third billiard ball, but the second billiard ball is only a “proximal” cause. Some kinds of causes may be ordered into the relative variance they contribute to an outcome, or temporally ordered, but causes of different orders of generality and different realms of time-space or being cannot be hierarchically ordered in this fashion, nor can interactive causes be separated in this way.

Symbolic flows, like evolutionary chains, have their own histories, and thus might be described as having both distal and proximate components. Distal components include both the history of learned verbal associations in an individual’s brain as well as the history of the circulation of symbols within a culture. Proximate components include the particular segments of the flows of symbols that arrive at a given individual and perhaps also the particular state of the individual’s processing of those symbols. This latter inevitably involves biologically inherited components, which of course makes biology inheritance a proximate component in the larger or “ultimate” process of social structural flows.

Consequently, we would argue that much of the conflict between causal accounts that seek to incorporate symbols and evolutionary accounts that seek to discount their force could be eliminated by two simple means. First, eliminate the proximate/ultimate distinction (or trade it in for a historical/proximal distinction). Second, insist that the goal of causal accounting is to incorporate all causal factors and their interactions rather than to look for the "biggest" or "first" cause.

Resolving the Core Conflict

Much of the conflict could be eliminated in that fashion, but probably not all of it. In the discussion of channeling (Chapter 11), we indicated that organized flows of symbols produced sets of environmental cues that might lead people, through an accretion process, to produce a behavioral pattern for their lives that did not maximize their personal reproductive potential. Evolutionary theory indicates that this should not be a strategy that can be stabilized by evolutionary processes. People who do not maximize their own reproduction should be out-reproduced over time by people who do maximize their own reproduction, and so evolutionary theory would predict that we should not find most, if any, people engaging in behaviors that do not maximize their own reproduction. Many evolutionary theorists are willing to dismiss exceptions as "incidental" or as "side effects." However, a category as large as symbolic effects probably cannot be dismissed in that fashion.

The problem of the non-maximization of reproductive potential is only a particularly important example of the conflict that exists between theories of natural selection and any theory that attributes force to symbols that is independent of biologically engrained patterns. Evolutionary theory indicates that the biological patterns must be the product of the winnowing processes of natural selection, and these processes would necessarily have weeded out any behavioral drivers (such as symbolic ones) that did not serve the biological imperatives. If symbols cue animals toward behaviors, they should only be able to cue them toward behaviors that lead to maximal personal reproduction. People who responded to cues that did not lead to maximal personal reproduction would be eliminated from the gene pool.

If this version of evolutionary theory were correct, then symbols would never trump reproductive drives. But we have substantial evidence from birth rates in developed countries that the wealthier the society in which people live, the less likely they are to have large families.[xix] Evolutionary theorists have tried to account for this by claiming that such individuals are adopting a "quality" over "quantity" strategy of reproduction. While there may be components of truth to that analysis, it is not a sufficient account. Too many people with substantial resources choose to have one, none, or only two children. For many if not most of these people, at least three children are "quality" options (if not more). Many people clearly choose their own interests and pleasures over additional reproduction, just as a few people choose to commit suicide or enter monasteries rather than going on rape sprees, even when such choices do not maximize the reproduction of their kin. One is hard pressed to explain such behaviors without referring to a symbolic component that exceeds evolutionary advantage. Promises of glorious afterlives (even when those are populated by nubile consorts) seem to play a real role in determining some behavioral choices of some individuals (even though they are not the sole explanation).

Long-term Prospects

The major way of resolving such conflicts between natural selectionism and symbolic materialism is to suggest that such choices may occur, and they may be driven by symbols, but they are not sustainable in the long term. This would be to say that contemporary industrial cultures are not operating at evolutionarily stabilized strategies. Several facts make this a plausible claim. Human culture has been evolving with extreme rapidity in the 50,000-150,000 year period for which we have evidence of human symbolic behavior or anatomically modern human remains. Additionally, human population is currently in an explosive rise, but has not experienced comparable corrective falls that other animals, who are presumably operating with a distribution of stable strategies, have gone through (see Figure X.1). This explosive population increase has occurred because humans have been able to expand their ecological niches, effectively appropriating the resources of an increasing number of other species (and driving them extinct). While there has been some substantial within-species competition during this period, the variability of human ecological niches and the expansion of resources has probably seriously loosened the evolutionary noose—temporarily. Finally, the concept of an evolutionarily stable strategy presumes a constant environment to which a particular biological configuration is preferentially suited (i.e. in terms of optimal reproduction). If human culture contributes substantially to the environmental factors that influence human reproductive success, but human culture is rapidly evolving, then one cannot presume that an existing bio-cultural pattern is evolutionarily stable.[xx]

A much more careful analysis of this question is needed that considers the length of generations, the period required for substantive spread of allelic diversity, and a thoughtful analysis of the evidence about the relationship of the behavior and environments of pre-modern humans to modern humans. However, there is clear evidence of both the on-going biological evolution of humans during the cultural expansion of human capacities (e.g. the biological capacity for lactose metabolism in adults arose c. 50,000 years ago) and on-going evolution today (e.g. breathing capacity at high altitudes is continuing to spread in the gene pool of high altitude regions).[xxi] There are also good reasons to believe that cultural evolution interacts with biological evolution (as described above). Consequently, a balanced re-evaluation of the assumption of the applicability of the highly constrained versions of the winnowing version of natural selection to humans—in the present term--is required.

If human societies are not currently operating with an evolutionarily stabilized strategy, or with a distribution of such strategies, then it is quite possible that symbolic systems are exerting independent pressures on human behavior (assuming that their material characteristics harbor a source of causal effects). However, this leaves three possibilities for the future. One is that humans whose symbolic capacities override selectionist values are in the process of being weeded out by the more prolific reproduction of those who are less responsive to symbolic forces. This possibility accords with the classic eugenicists' nightmare, and we have no more to say about it.

The second possibility is that the individual reproductive costs of symbolic independence are more-than-compensated for by the mutualist advantages provided by symbolic skill. If independence from some biological drivers is a necessary cost of that advantage, then symbolic independence may persist in spite of this independence. This possibility is a revised version of the "incidentalist" exception. Instead of being merely a side effect with no consequence, however, the costs of symbolic independence are actually compensated for by its advantages. On this account, symbolic independence must be "paid for," but as long as it is capable of producing sufficient excess benefits, the independence may remain. A complex account of the long-term character of symbolic costs and benefits would be needed to assess whether, in some longer term, the biological costs would necessarily be raised to the point where independence was proscribed. This is a possibility, but given the greater fluidity of symbolic change than biological change, it is hardly a surety.

Memetics

The third long-term possibility is that the partial independence of human symbolic systems from human biological reproduction is stabilized by a larger force, and this is the claim of some branches of memetics. Evolutionary theory can be preserved without the concept of biologically based ESS. Susan Blackmore, for example, has posited that memes constitute replicators in the same way that genes are replicators. On her account, humans are therefore the products of two different evolutionary forces—one that replicates biologically through genes and one that replicates culturally through memes. She posits that in advanced human societies memes are maximizing their own reproduction through human beings. As Blackmore argues, because of the nature of memetic transmission, people who spend their time reproducing memes rather than reproducing their own genes, are more efficient transmitters of memes, and so memetic evolution favors non-maximization of biological reproduction.

This account preserves evolutionary theory, but posits alternative evolutionary substrates—memes alongside genes. It is not encouraging, therefore, that in spite of the creativity and insightfulness of works such as Blackmore's, we haven't been able to locate evidence that memetics is developing as a field of study. *The Journal of Memetics* published its final issue last year, and it never managed to publish a full slate of articles. While "meme" and "memetics" are almost house-hold terms, we cannot locate a growing body of theory, observation, and experiment that utilizes the concepts of memetics. There are certainly potent sociological reasons for this; there is not a pre-made audience for evolutionary modeling of human cultural activities and there are low incentives for funding. However, since our own project shares those sociological problems, we prefer to believe that conceptual weaknesses in memetics are at the root of the problem.

In the preface to Blackmore's book, Richard Dawkins takes on and attempts to refute the three commonly identified problems with memes: they cannot be physically identified, they lack copying fidelity, and there is no clarity about their size. We think that the first problem is the definitive one. Dawkins's answer to that problem merely claims that memes are like genes in that genes too are somewhat difficult to pin down, being a fusion of function and physical substance. But Dawkins's analogy does not hold, because there is no common physical substance identified by meme theorists. While the boundaries of a gene are certainly unclear, its physical substrate is DNA. In contrast, there is no physical "stuff" that meme theorists have identified as common to all memes. Some theorists identify memes with the vague label of "ideas", others point to varying substances, ranging from the kinds of components that make up wheels to fluorescence in colors, to series of musical notes. Without a physical substrate, memetics cannot construct a materialist theory, and so it has floundered in imprecision, lack of agreement, and indecisiveness.

We think, however, that Dawkins's preface and Blackmore's book also provides a useful clue to the missing substrate. Throughout, whenever transmission of memes is discussed, readers are referred to "instructions" as phenotypes. The authors repeatedly tell about the written or verbal transmissions of memes. That is, the transmission of memes is usually described as occurring through symbols. Because both Dawkins and Blackmore are trained in the Western tradition, they portray the words as mere conveyer belts of some more magical thing like "ideas." The fact, however, that copying fidelity is tied to the ability to give verbal instructions is not an accident. Ideas such as "the wheel" may not exist solely as words. They may even be transmissible without words, but it is the words that provide the common material substrate among memes. If scholars were to stop trying to think about the vague notion of "ideas" and instead focus on the physically material stuff we know as words or other symbols, then resarchers might make some greater headway on this line of approach to cultural evolution. One project that arises from a materialist theory of symbols can therefore be viewed either as a related alternative to or a maturation of the work of memetics.

For a variety of reasons that should be clear from Chapters 10 and 11, we don't think that the project of memetics as currently conceived provides a substantial alternative to the methods of study of symbols that already exist. However, the theory does suggest that it is quite possible for cultures (a.k.a. human constructed environments) to persist even when the individual humans who participate in those environments do not maximize their own reproduction. Two things are necessary. First, there needs to be a semi-stable material substrate that endures beyond the life of the individuals who participate in it. Although symbols seem to be immaterial, we have shown that they are, in fact, material structures, and it is possible to establish flows of symbols that are relatively enduring and strong enough to direct individual behavior.

Second, individual humans must exhibit behavioral flexibility great enough to allow them to adopt the behavioral practices directed by or consonant with different symbol sets. This is necessary to enable the genetic offspring of one set of persons to learn to operate according to the symbolic structures generated by another set of persons.

If humans have such behavioral flexibility and responsiveness to symbols, then their most important "evolutionarily stable strategy" is substantial behavioral flexibility that is "motivated"—that is, caused by an interaction of symbolic structures and non-symbolic biological structures. In that case, cultural change may or may not be cultural "evolution" in the selectionist sense of that term.

There seems to be overwhelming evidence that humans have substantial behavioral flexibility. As noted previously, the species has adapted to virtually every land-based ecological niche on the planet. This flexibility is further dramatically illustrated by the rapidity with which modern humans seem to have exited Africa and settled the globe, almost immediately out-competing other human (Neanderthal) and non-human (mammoth) species that had occupied the local environmental niches for hundreds of thousands of years. This kind of rapid adaptation seems to require something other than fixed-response routines to non-symbolic environmental clues. It seems to fit well with "motivational" frameworks, which allow symbolizations to articulate underlying drives but then to formulate and share novel responses. The enormous variety of customs and habits of people around the globe provide further evidence, as does the relative facility with which the children of migrants adapt to their new homes.

The existence of behavioral flexibility and a modification of the concept of ESS for understanding humans is necessary for a theory of biological and symbolic inputs that grants each its independent source of input to human behaviors. However, accepting human behavioral flexibility does not mean that genes and other biological factors play no role in human behaviors. Especially it does not require that all behavioral options be equally likely, or even that all behavioral options be equally likely given the presence of particular stimuli. Evolutionary theory and the methodological approaches of sociobiology are still of use. They may still identify behavioral predispositions among humans. The theoretical component that must be altered is the assumption that bio-behavioral predispositions are the super-ordinate drivers, or the exclusive drivers, rather than one set of forces that interact with other forces (even if the evolutionary forces are "stronger" in some time period). There is a great deal of work to be done to assess the extent to which each of several propositions that might relate to that alteration are true. 1) While there is already substantial empirical evidence that symbol systems exert independent force on behaviors, there is little evidence about the strength and breadth of such forces. 2) There is little careful assessment of the possibility that the symbolic capacities of humans have evolved with a rapidity that has to date prevented the establishment of evolutionary stable strategies. 3) There is little exploration of the potential strength of mutualist advantages of communication in comparison to their disadvantages. 3) There is little careful assessment of the possibility of alternative replicators to biological replicators.

While such very-large scale explorations go on, however, there is utility in the MOTIVATE model even if symbolic components are understood as more tightly linked to biological imperatives. The model allows formulation of specific mechanisms by which symbols allow human behavior to tailor itself to the general objectives set by the biological lineage and the specific conditions in which the organism must survive. By describing human symbol use as a material activity of human beings, we can enable better modeling of human behavior, including human evolutionary processes. We illustrate what such research approaches might provide with regard to the difficult concept of the evolution of cooperation.

How to Model The Evolution of Cooperation

Human cooperation has long constituted a major point of conflict between humanistic and biological studies. Because biologists were heavily invested in a particular version of the theory of evolution, and engaged in debate with Lamarckians, evolutionary theorists were slow to accept the idea that cooperation could represent a true phenomenon and that it could evolve.

In contrast, humanists looked around and saw cooperation everywhere among humans, and also saw the ways in which such cooperation was key to human accomplishments. This led to ideologically infused hostility between the two parties, which was caught up in the cold war debates over individualism and communism.

Part of the problem was that the original phrasing of the issue pitted "altruism" against self-interestedness. Altruism was defined as donating valuable resources (including time and effort) to others. Biological theories precluded the possibility that natural selection could produce organisms that were truly altruistic, because the cost to the organism would always disadvantage it in competition for scarce resources against non-altruists. Evolutionary theorists therefore generally (but not universally) tended to dismiss apparent acts of altruism on the grounds that they either produced advantage for kin (and therefore advantaged the altruistic organisms' genes, and hence were evolutionarily selectable) or that they "really" produced some other kind of advantage for the organism.

A profitable softening of the conflict has occurred with three developments. First, the phenomenon at issue was re-framed from "altruism" to "cooperation" or "mutualism" or "reciprocal altruism." Cooperation presumes the possibility of mutual advantage in interactive behaviors, rather than simply self-disadvantage. Co-operation does not require non-selfishness. A very simple example is pheromones or other signs that communicate sexual accessibility. The ability to emit and detect these signs is a cooperative endeavor that must evolve through time to coordinate behavior of two parties for mutual advantage. As in the case of other modes of sexual cooperation, there may be continual competition built into the cooperative process (who bears what costs), but the cooperation evolves none-the-less.[xxii] Second, computer modeling and experimental research increasingly have shown that cooperative behaviors have advantages in some ecological contexts, and might even be evolvable (though as we will see, the evolutionary mechanisms have not been fully resolved). Third, at least some biologists have begun to concede the possibility that humans were subject to "group selection" in some very tightly specified conditions, where the social group actually functioned as a supra-organism.[xxiii]

Today, there are several lively research programs playing out the newly enabled conceptualizations of human cooperation. We focus here on the efforts to use computer simulations to model the evolution of cooperation. These efforts go back to pioneering research by Robert Axelrod.[xxiv] He inaugurated a competition among computer programs to test what program design would out-compete others in a multiple-interaction "Prisoner's Dilemma" (PD) situation. A PD situation is one in which an individual must interact with another, but may co-operate or not, where the other party's behavior cannot be controlled, and where payoffs are ordered such that mutual co-operation produces a moderate gain for both individuals, non-cooperation where the other person cooperates produces a maximal gain for the non-cooperator and no or less gain for the cooperator, and where non-cooperation by both parties produces low gain for each party.

Axelrod pitted a wide range of submitted computer programs against each other, including ruthless non-cooperators, and a series of rounds revealed that the "Tit for Tat" program had unique strengths. "Tit for Tat" cooperated on its first encounter with another program. If the other program reciprocated with cooperation, then "Tit for Tat" did likewise. If, however, the other did not cooperate, then "Tit for Tat" refused cooperation as well. "Tit for Tat" was also forgiving. If a non-cooperator became a co-operator, then "Tit for Tat" would begin cooperating as well. Although the details go beyond present interests, "Tit for Tat" accumulated more points than non-cooperative programs and even more than more complex programs. As long as there are some other cooperators or Tit-for-Tatters, “Tit for Tat” strategies prove to be robust.

For many years, these findings were essentially ignored in much of the research on game theory. Game theory focused on single interactions, rather than repeat interactions. Game theorization indicated that a “rational” player would never cooperate in a single interaction “game” and by extension, would not cooperate in repeat interaction games; after all, a series of interactions is merely a single interaction repeated. An entire generation of business leaders was taught that a rational person never cooperates, but instead seeks only to avoid being a “sucker”. This has undoubtedly had significant consequences for the operation of corporations today, for empirical research has shown that students taught this version of game theory actually are less cooperative in their interactions than “naïve” individuals.[xxv]

Experimental results of multiple interaction games never supported the mathematically elegant, but empirically false, theorizations of game theory. While the amount of cooperation occurring in multiple-interaction games varies by condition and by player-type, in many conditions there is substantial cooperation. The experimental research supports empirical observation of human actions outside the laboratory: people cooperate in a wide variety of situations.

In the past decade, computer modelers have come substantial ways in efforts to demonstrate that the evolution of cooperation can be modeled i*n silico,* which is to say through mathematical equations run in the repetitive iterative series enabled by modern computers. The models have become quite complex, incorporating a variety of concepts including punishment of non-cooperators and the role of personal reputation. They also distinguish among different modes of cooperation, such as direct and indirect reciprocity and collective action directed not at other individuals but at the group in *toto*. The models assign variable roles to individuals, including punishers, shunners, defectors, and cooperators.

Such models have succeeded in creating a general consensus in favor of the possibility of the evolution of indirect reciprocity, but they still face several limitations. First, incorporating important variables such as perceptual errors makes the models too mathematically complex to be run. Second, the accuracy with which strategies such as punishing non-cooperators is implemented in the modeling has a strong impact on the outcomes, and this accuracy level is not well-characterized empirically. Third, there is as yet no successful model of individual engagement in “collective action,” that is good for a group as a whole, rather than reciprocal altruism among individuals, though there is evidence of the ability of indirect reciprocity to stabilize such collectively oriented behavior once it exists.

Consideration of humans as symbol-users implies that the inability to model such behaviors *in silico*, even though they appear to exist *in vivo* lies in the use of an inappropriate basic model. Understanding human language systems changes the models that must be employed in two ways, first by introducing the concept of human social networks and second by introducing the concept of “identification” as a mechanism that enables the generalization of reciprocal altruism into collective action.

The existing computer models treat human interactions something like the Brownian collisions of gas molecules in a jar. This model borrows inappropriate assumptions from the idealized disaggregating model of physics (see Part II). While there are repeated interactions in these models, each interaction pairing is equally likely. Assume molecules #6 and #7 interact at time 1, rather than molecules #6 and #8. Then in these models at time 2, an interaction between molecules #6 and #7 is as likely as an interaction between molecules #6 and #8. But this is not an accurate model of human interactions. Because humans build symbolic networks through time, the character of the interaction of human #6 and #7 at time 1 influences whether or not human #6 and #7 will interact at time 2. If human #6 and #7 both cooperate at time 1, then they are more likely to interact at time 2. If one or both "defect" at time 1, then they are less likely to interact at time 2. After only two or three rounds of interaction, the non-cooperators have been largely excluded from interactions with others as co-operators have found co-operative partners for most if not all of their interactions. This simple revision to the computer models would produce far more powerful results, and the revision rests on a more accurate description of the actual processes involved in the human behavior being modeled. Additional parameters that reflect human biology rather than atomic particles—for example, allowing cooperation networks to begin with familial members—would further model the evolution of cooperation in humans more accurately.

Interactions among kin provide an obvious evolutionary platform for the existence of a biological mechanism for co-operation. All that is required functionally is for this to be generalized to non-kin when a manifested co-operative behavior receives return co-operation that advantages both co-operators. Because human behavior in small-sized populations tends to be characterized by the potential for repeat interactions, this suggests that there would be extremely strong pressures for the evolution of a pre-disposition toward cooperation rather than against it. This does not preclude occasional "cheating" when defection is perceived as likely to go undetected or when the benefits to self are perceived to outweigh the long-term benefits of the relationship. Unlike the original platform of kin-based co-operation, the mechanism for non-kin serving cooperation is not genetic reproduction (which can't be cheated on, but whose costs and benefits can be calculated), but rather calculated self-benefit. However, when calculated self-benefit serves both parties—and can be enforced through the threat of future non-cooperation when cooperation would be advantageous—then cooperation is the expected behavior.

This network-based explanation gives a stronger account of the force for evolutionary co-operation in reciprocal altruism. However, it does not indicate how "collective action" (action that benefits a group rather than a reciprocating individual) can evolve. At the level of the group, the "free rider" problem still exists. What one contributes to a group benefits many people and the benefits one receives in turn are not proportional to one's contribution. Therefore, presumably organisms would be advantaged by not contributing to the group, even if the group's survival is necessary to sustaining the organism over the very long term.

The symbolic process of identification accounts for the evolution of collectively oriented altruism in spite of this advantage for non-cooperation. Symbolic identification processes function because co-operators do not always co-operate. They must select with whom and over what to cooperate. That selection is not random; it is symbolically cued. One co-operates preferentially not only with someone with whom one has co-operated successfully in the past, but also with persons whom one believes are likely to co-operate with you. One way of defining "people who are likely to cooperate with you" is the general concept of "reputation", but studies incorporating a general "reputation" for cooperation have not been satisfactory in producing evolution of collective action. Instead, we suggest that the operative mechanism is co-operation within a mutually co-operating network or "in-group."

A relational network is simply a reiterated chain of interactions among people, that is, person A preferentially co-operates with person C if person B has successfully cooperated with person C and person B has successfully cooperated with person A. It is crucial to note the difference in assumption between this network based model and previous models, which presumed that a reputation is accurate and shared by all parties, rather than that a reputation is a reputation for cooperation within a group or network. Observational data supports this. People often have an excellent reputation for cooperation within a particular group, but treat persons who are not a part of that dominant group despicably (this is the classic description of a racial hero, who has an excellent reputation of service within his own race, but discriminates ruthlessly against persons of other races). In less extreme forms, this is standard in-group/out-group behavior. Expectations for behaviors toward one's "team" are radically distinct from expectations for behaviors toward members of other teams.

This division into in-group and out-group behavior is parsimonious in two ways. First, it does not require the costly punishment mechanisms that have proven difficult to operationalize in computer programs. "Punishment" is simply exclusion from the cooperating network. Second, the division into smaller groups makes monitoring of relative gains and contributions to a group's well-being more feasible. Moreover, it keeps the well-being of the group more dependent on the contributions by each individual, so that each individual maintains a real stake in the benefit of the group; that is, the individual's well-being is directly threatened by the individual's lack of contribution to the group. To this extent, the contributions to a group more closely approximate reciprocal cooperation, albeit allocated over a greater time and space span. This effect is further heightened by the concomitant subdivision of co-habiting populations into competing sub-groups.

The mechanism that enables the distinctions among behavior for in-group members and behavior for out-group members is a symbolic one, called "identification". The symbolic process of identification gives shared names and attributes to specific sets of persons, and thereby encourages a person to treat members of that group as "like oneself". Identification of a collective rather than an individual or precisely delimited group of individuals as the partner for co-operation does not require the evolution of new symbolic strategies or characteristics. It employs the same processes of abstraction and categorization that are used in identifying an absent individual or a group of individuals, but generalizes it to a collective.

Although this alternative model is supported by common observations of human behavior, it will be readily amenable to experimental test in comparison with the atomistic non-symbolic model both through computer modeling and through direct experimental comparisons. The symbolic network model is also readily explainable in an evolutionary framework. First, it provides the conditions necessary for group level selection to operate by constituting many small groups between whom competitive advantage is gained by cooperative action within the group. Second, because *both* cooperation and "cheating" (i.e. taking advantage of others) have potential survival and reproductive benefits, an organism that is able to cooperate some of the time and cheat some of the time is likely to out-reproduce organisms that only execute one or the other of these strategies. Since cooperative behavior is not compatible with extensive cheating behavior within a dyad or small gorup, separating the people with whom one cooperates from those whom one may cheat is the strategy that maximizes alternative possibilities for self-advantage. Symbolic mechanisms make that separation possible.[xxvi]

To accurately describe the evolution of cooperation, therefore, one should not expect to use a model based in the atomistic, random behavior of physical phenomenon. Instead, one needs a model that can specify the networking and affiliative histories of human interactions. Mathematical and *in silico* models of these properties are possible, though perhaps more computationally complex. Even if computer models employing the atomistic physical model eventually demonstrate the possibility of evolution of "collective action", this will not mean that they are an accurate description of the way in which such action actually evolves in symbol-using animals, especially if such modeling requires problematic “simplifications” such as assuming that there are no perceptual errors. This is to suggest that using information about the basic structures of human symbolic processes is essential to improve the modeling of evolutionary processes among humans. Once one adopts a material theory of symbolizing, this resource is ready to hand for numerous analogous applications.

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[i] The idea that knowledge is constituted through the tripartite relation of truth, justification, and belief was introduced in Plato's *Theaetetus*. A recent "foundherentist" perspective that is broadly consistent with our perspective is provided by Haack (1993), but, as is common in the lineage of arguments in the philosophy of knowledge, she focuses on an individualist perspective (what is it to say that an individual "knows" something), rather than using the social perspective we are employing. For other perspectives grounded in the philosophy of science see Harding 1997, Gest 2001, Balashov & Rosenberg, 2002.

[ii] Popper, 1959, p. 30. Popper's choices were heavily influenced by his admiration of the model of physics of his era (although his formulation was disturbed by Heisenberg's Uncertainty Principle, which he wrote an argument against). A famous physicist of the previous era, Ernest Rutherford (1871-1937) once said, "If your experiment needs statistics, you ought to have done a better experiment." The ludicrous sound of that claim today suggests the change in the role of induction across the period. In Bailey, 1967.

[iii] Popper, 1959, p. 59.

[iv] This, in fact, is precisely what Popper was trying to get at when identifying good theories as those that ruled out the most (by most tightly specifying possibilities).

[v] I look at a lot of Y chromosomes and see degenerate little pieces of DNA and you look at them and see that they are pretty small too. We don't need a formal test to determine that the Y chromosome is a lot smaller than the other human chromosomes. For a fine analysis of the role of seeing, read Fox Keller, 2002, Ch 7.

[vi] Popper tries to rule out such factors by describing them as "psychological" rather than "logical" but there is no escape from our shared psychological predispositions, which also ground our ability to use deductive logic. The fact that we share basic cognitive apparatus for perceptual skills makes the agreement of observers on the existence of a visible pattern a reasonable test. Like all other tests, it is not definitive. We may find alternative lines of approach that reveal a "distortion" in our shared perceptual apparatus, but it is nonetheless often one reasonable approach. It is generally also the most efficient or cost effective.

[vii] Jordan et al. 2004, p. 635.

[viii] See Condit, 2004?.

[ix] It is not possible to be comprehensive or even to categorize accurately. We particularly recommend the work of Ceccarelli, 2001, and Fox Keller, 2002, but some examples that reflect different orientations include Buchwald, 1995; Campbell, 1975, 1986; Fahnestock, 1999; Farrell & Goodnight, 1981; Fuller, 1997; Gest, 2001; Gross, 1988; 1990; Gross & Keith, 1996, Harding 1993; Harris, 1997; Irwin & Wynne, 1996; Jaffe, 1960; Jamieson, 1998; Keller & Longino, 1996; Klaidman, 1991; Kragh, 1999; Krieger, 1992; Latour & Woolgar, 1979; Lessl, 1984; Love, 2002; Lyne & Howe, 1986; Mayor & Forti, 1999; Pera, 1991; Pickering, 1992, 1995; Segre, 1976; Selzer, 1993; Shapere, 1995; Shapin, 1985; Taylor, 1996; Tuana, 1989.

[x] For example, Kaye, 1993, 2000; Marks, 1995; Reeves, 1997.

[xi] Reyes, 2004.

[xii] Montgomery, 1996, 224-227.

[xiii] Derrida, 1967, p. 233. Derrida here is speaking specifically about Rousseau's text, but his next sentences signal that this is a general theory.

[xiv] The term "objective reality" has come, unfortunately, to stand for a material reality beyond an individual's oncsciousness. But the critics of "objectivity" have been extremely effective, and it is, we believe better to ground our confidence in the existence of a material realitly that exceeds our symbols and even our cognitive apparatus more generally in a framework that is probabilistic and inter-subjective, rather than absolutist and "objective." For refutations of the objective standard, see e.g. Brummett.

[xv] Michel Foucault (1988) translates these insights into a political philosophy that mandates only the value of "freedom" and that offers only perpetual critique of all other values and manifestations. As Chapter 12's analysis will suggest this is a useful single-mindedness.

[xvi] Another way of framing this is to say that a truly *post*-structural project is not possible within language (a position Heidegger arrived at).

[xvii] See note 2.

[xviii] This is not to say that our decisions are fully conscious and fully deliberated. It is just to say that that is the aspect of our choice-making that we think of as "deliberate." Furthermore, this is not to say that no animals narrativize internally. The evidence is not clear on that, and it is difficult to obtain.

[xix] On the complex dynamics of birth rate changes, see a useful summary in Pillai & Guang-Zhen, 1999.

[xx] The culturally based condition merely represents a dramatically heightened case of what is inherent to the concept of evolutionarily stable strategies in general. For environments on the planet earth are constantly changing. Therefore, presuming that biological populations are at some stasis point is always incorrect. However, environments at least in some times and places may have changed slowly enough to make the ESS concept useful, if not absolutely correct. The rapidity of cultural evolution vitiates the assumption operationally. It may also vitiate it on an additional conceptual level to the extent that biology and culture interact as evolutionary co-drivers, whereas in most (but not all) species the biological evolution of one does not constantly re-design the in novel ways the environment the species inhabits.

[xxi] On the lactose gene see Enattah, et al. 2004; On high altitude breathing genetics see Marris, 2004.

[xxii] Recent research on mutualism includes Ferriere et al. 2002, Holland et al., 2004. The best example of the way in which mutualism and competitiveness are compatible is sexual reproduction. On the one hand, male and female genes must mutually participate in and mutually be advantaged by the process or it would not exist and form the foundation of reproduction in sexually reproducing species. However, this does not rule out conflicts of interest internal to the mutualism, as for example, male-directed genes may function to maximize the amount of blood the offspring receives from the mother, because this maximizes the reproductive success of the father. The female builds responses to these genes because for her, the reproductive balance must take into account her long-term well being and future reproduction as well as the immediate fetus.

[xxiii] D. S. Wilson (2002).

[xxiv] Axelrod, 1984.

[xxv] We have lost track of the original citation for the study that demonstrated this, but the converse—the learnability of the strategy of cooperation is well documented in Sheldon, 1999.

[xxvi] The separation of cheating from cooperation can easily begin based on a kin-nonkin distinction and then be expanded to tribal group/non-tribal group and then to larger more abstract entities. One expects that the strength of the network within the family would be substantially stronger than the strength of effects of nonkin networks. One would likewise expect the behavioral uniformity (cheating vs. cooperation) to vary according to both intensity of identification with the network and advantages accrued from the network. This model clearly offers a wealth of possibilities for empirical testing.