The Reality of Knowledge

George Towner

University Press of America, Inc.

ISBN 978-0-7618-5483-8

Library of Congress Cataloging-in-Publication Data

Towner, George , 1933—
The Reality of Knowledge.
Includes index.

1. Philosophy.
2. Theory of knowledge.

Contents

Acknowledgments

This book is the product of an extended inquiry into the nature of knowledge. My previous books—*The Architecture of Knowledge* in 1980 and *Processes of Knowledge* in 2001—examined the ways that knowledge comes into being and evolves. I treated the act of knowing as an instance of behavior that can be described and analyzed, but in those books I postponed the question of how knowledge fits into the rest of reality. The present work is intended to fill that gap.

During separate phases of my work, three different groups of people helped me realize the analysis presented here. First were my professors and colleagues in the Department of Philosophy at Berkeley, primarily Stephen Pepper, William Dennes, John Myhill, and Bertram Jessup. Next were my colleagues at the Kaiser Foundation Research Institute, particularly Ellsworth Dougherty, who introduced me to some of the basic mechanics of biology.

In the third phase, my coworkers on the technical staff at Apple Inc. gave me a fresh perspective that is reflected in this book. Among those who generously spent many hours discussing computer technology with someone whose degrees were in philosophy were David Casséres, David Gatwood, Steven Gulie, Michael Hinkson, and Bernard Tagholm. Those talks evoked ideas in me that I might never have developed on my own.

I am grateful to Brooke Bascietto and the staff of University Press of America for shepherding this book through publication. All the while my wife, Danielle, supported my labors during many long periods of abstraction, as the work presented here gradually took form.

George Towner
October, 2010

You can assess any position in philosophy by the relationship it proposes between being and knowing. Some traditions, like the Greek one of Plato and Aristotle, place ontology in the center, while others, like the modern period inaugurated by Descartes, put the emphasis on epistemology. Clearly, however, a complete philosophy will have to do justice to both.

Palle Yourgrau

Introduction

> We know then the existence and nature of the finite, because we also are finite and have extension.
>
> PASCAL

The act of knowing reality creates more reality. Whether we treat knowledge as a mass of sensations, or a series of reactions, or a set of mental models, it is clear that knowledge itself is different from what it knows, as much as a photograph is different from a landscape. Yet knowledge is real, just as a photograph is real. Knowing is an activity carried out by living things, on the same level of reality as metabolism and reproduction. The knowledge that results is also real. It is as much a product of living activity as body tissues or heat. Knowledge may be sought after, created, given and received, modified, and possessed.

In the past, philosophical attempts to analyze knowledge in terms of a reality that is known versus a body of understanding that is not real, or less real, or real in a different way, have all perished in a morass of artificial distinctions. Neither science nor common sense can stand back from reality, moon-like, and pretend to contemplate it without being part of it. This is the core of the notorious "mind-body problem."

At the most fundamental level, the answer to the question "what is knowledge?" is simple: knowledge is a modification of living things. As we understand the word, "knowledge" is something that only living things can have. It is also something that living things acquire; at one moment a living thing lacks knowledge about something and at the next moment it has it. What has it acquired? A change in itself. Acquiring a bit of knowledge makes the living thing different in some way.

But the story does not end there. The change in a living thing that occurs when it acquires knowledge is not simple, like storing a picture or making a notation in a register. Whether the living thing is a human or a one-celled protist, elaborate transactions take place between it and its environment. What it winds up knowing is a small part of all of the unknown reality that it might know; it is what I call "known reality."

In my previous books I analyzed the "why" and "how" of knowing. Here I analyze its "what"—both the reality that is knowledge and the reality that knowledge knows. It turns out that the latter, known reality, is not just a passive "external world," waiting to be discovered and understood. My analysis shows that living things construct the reality that they know for the purpose of making it knowable.

Consequently, my account of known reality tries to show how three constructions are related to one another: the living organisms that know reality, the reality which is the object of their knowledge, and the knowledge that they create. Within the world of living organisms, of course, we find ourselves. So it is of particular interest to understand how we humans construct a reality that we can know out of the raw reality in which we exist, and how we construct our knowledge of that known reality within ourselves.

Sidebars. Philosophical analyses are notorious for floating off into the abstract. Every philosophy student who has listened to a lecture on Hegel has experienced a moment of wondering "What does this mean in the real world?" So the sections of this book alternate between straight analyses and sidebars, the headings of which are in italics. The sidebars are intended to provide examples and analogies related to my train of argument. Their intent is to anchor my analysis by comparing it periodically to more familiar, tangible subjects.

Computer analogies. In several places, I relate philosophical issues to certain techniques of computer operation and programming. These analogies are apt because computer designers have invested years of effort toward devising ways to make machines perform lifelike tasks. Some of the techniques that they have come up with work because the techniques mimic—deliberately or unconsciously—the ways in which living things actually construct and process knowledge.

Computer architects constantly deal with quasi-philosophical issues. They are employed to design machines which can perform tasks that would otherwise require human intelligence. They ask questions such as: How can the realities of words and images be "represented" inside a machine? How can a machine that represents these things make useful decisions about them? What are the elemental acts of reasoning in a machine? And unlike philosophers asking similar questions, computer architects can verify their answers by incorporating them into machine designs and seeing how well the machines work.

Computer technology is the closest that people have yet come to emulating human life. Software, in particular, is specifically designed to accomplish humanlike tasks and to be understood in human terms. Yet unlike human life, computer operations can be analyzed in minute detail, because we built these machines and we know the decisions that went into their construction.

Thus I believe that we can learn a lot about the human condition by understanding how computers work—not because "people are like computers," but because *computers are designed to work like people*. At every juncture during the evolution of digital technology, computer architects intuitively or consciously incorporated truths about human functioning into their designs.

Our computer age is a fortunate time for epistemology, because many clues to the way that human knowledge works can be gleaned by studying the ways that computers work. At the same time, computer technology can provide insights into ontology, because much of it winds up creating new objects of knowledge. Hardware and software engineers construct entirely manufactured worlds of dynamic, lifelike entities. And although these worlds are wholly artificial, working in them requires knowledge that is as detailed and objective as knowledge of the "real world" outside. I believe that a careful analysis of how computer realities are constructed can furnish clues to the ways in which "real" reality comes to be.

The analysis presented in this book leads to a kind of holistic view of knowledge and reality, in which both knowledge and what is known exist side-by-side and are equally real. Both are in fact constructed by living organisms, including ourselves. How that happens and what comes from it is the story of the reality of knowledge.

1. Known Reality

The known is finite, the unknown infinite.
T. H. HUXLEY

An obvious separation within reality divides what is known from what is unknown. If we do not make this separation, we must suppose that all which can be known is already known and that no new knowledge is possible. Yet it is evident that the whole history of knowledge is one of making the unknown known.

Metaphors for Known Reality

What I call "known reality" in this book comprises several different things. Reality is commonly supposed to consist of a huge "external world," stretching from the depths of the earth to the farthest reaches of the universe, including all the things that are found in it—ships and shoes and sealing-wax, cabbages and kings. Parts of this material world are known to someone, somewhere, and thus belong to known reality; but beyond a thin skin that covers the surface of the earth, most of this "external world" is unknown.

In addition to the external world, everyone knows a personal inner reality of sensations, images, ideas, emotions, and so on. We also know (usually with less certainty) the inner reality of other people and their public extensions: languages, laws, agreements, institutions, and so on. Finally, we know a great number of abstract truths—that 2+2=4, that a color cannot be both orange and blue, that cruelty is wrong, and so on. We know all these things with at least as much certainty as we know ships and shoes. For most people, Kant's "starry sky above and moral law within" are equally knowable and equally real.

The discovery metaphor. It is commonly supposed that known and unknown reality are identical, and that the two are distinguished only by the extrinsic accident that the former has become known. We turn over a rock, spy something under it, and say to ourselves, "What was under the rock, previously unknown to me, is now known." Or we may ruminate on some past experience and suddenly think, "Now I know what that was about." The methodology of much traditional scientific research, which assumes "hands-off" observation, is based on some sort of turning-over-rocks model. Good scientific experiments are explicitly designed to "reveal" parts of unknown reality—convert them into known reality—without interacting with them or changing them in any significant way.

But even in strictly scientific terms, the possibility of experimental nonintervention is nowadays questioned. Quantum physicists believe that the act of observing small particle interactions inevitably alters them, making it impossible to observe these events "as they really are." Physicist Bernard d'Espagnat states this view succinctly:

> The doctrine that the world is made up of objects whose existence is independent of human consciousness turns out to be in conflict with quantum mechanics and with facts established by experiment.[1]

Similarly, scientists who study behavior frequently have to compensate for "reactivity," the tendency of experimental subjects to modify their actions when they are observed. An often-cited example in psychology is the "Hawthorne effect," where a study of environmental influences on factory work seemed to show that *any* change in working conditions increased productivity. In anthropology, a much-discussed issue is the validity of Margaret Mead's studies in Samoa, where it has been claimed that her respondents made up the data she reported as a kind of practical joke. Although anecdotal, examples such as these illustrate the inherent difficulty in ferreting out private motivations by observing public actions. Besides the inherent difficulty of relating mental states to physical comportment, cultural and projection biases come into play.

One might think that the abstract disciplines, including mathematics and logic, would yield uniquely definitive truths. But innovations such as hyperbolic and elliptic geometries, as well as "deviant" and "fuzzy" logics, produce compelling results that contradict classical theorems. Gödel's incompleteness theorems of 1931, which used a numerical metalanguage to examine formal systems in general, demonstrated the impossibility of finding a complete and consistent set of axioms for even such a simple system as formal arithmetic. One consequence of this negative result has been the rise of "mathematical logic," which tries to determine what kinds of abstract statements can and cannot be proven. A branch of mathematical logic studies mathematical models, which are sometimes constructed to determine the "undecidability" of propositions:

> Each undecidability proof requires construction of a model in which the proposition in question is true and another one in which it is false: the undecidability of the proposition follows from the existence of such models, for no general proof or refutation will be possible if the proposition is, in fact, true in some models while false in others.[2]

Here a mathematician creates two consistent abstract models, both of which are designed to describe some kind of system. Both models can express a particular statement in rigorous form, but they disagree on its truth. It is natural to ask which of them (if either) is a "representation of reality."

All these examples—the physicist's inability to untangle physical events from the act of observing them, the anthropologist's struggle to "get inside" the minds of other people, the mathematician's need to construct alternate systems of thought in which propositions are both true and false—illuminate the interactions between reality and our acts of knowing it. Knowledge is not a one-way process in which reality lies pristine, waiting to be discovered by impartial observers. Instead, every act of knowing requires a complex interchange between reality and its knower. "Turning over rocks," if it happens at all, is only a first step.

The interpretation metaphor. As a consequence of these issues, scientific accounts of reality have tended to evolve from descriptive to interpretive. What we may think are solid objects are "really" mostly empty space, in which tiny particles are bound together by tiny forces. What we experience as sensations are "really" electrochemical events in our nervous systems. What we may think of as universal truths are "really" just constraints on our ability to "process information." When scientists poke and dissect the known reality of ordinary life, through experimentation, they wind up asserting that most of our ideas about it are naïve and incorrect.

How can one "interpret" reality? We like to think that the reality doesn't change during interpretation—we just see it differently. It's like discovering the outline of a rabbit in the bushes or seeing an old man's face in a mountainside. What was unclear before is now brought out and understood. But from this perspective, interpretation is just a more complex way of turning over rocks. We are turning over rocks in our own minds as well as in external reality.

The key characteristic of reality known through interpretation is that it changes while purporting to reflect the same unknown reality. The discovery metaphor tries to explore different parts of unknown reality using a single viewpoint; the interpretive metaphor tends to change its viewpoint while uncovering the parts of unknown reality that it seeks to make known.

The changeability of interpreted reality, as science has applied this metaphor over the last few centuries, has proved embarrassing. If the reality known through science is just an attempt to interpret unknown reality, then it is hard to see how it could have gone through so many different incarnations. In physics, for example, the basic constituents of unknown reality have been described as particles, as force fields, as "clouds of probability," as "strings," and so on. Nonscientists may well be justified in questioning the common physicists' claim that "We were wrong before but now we have it right."

Examples throughout this book cite familiar areas of reality that have been interpreted by radically different scientific explanations. One of them is a summary of various scientific theories of heat (page 190), where something so easily observable has been variously described as an element, a manifestation of motion, an imponderable fluid, the result of mechanical work, and two kinds of energy. We all know what heat feels like, but scientific attempts to say what it *is* have led to an abundance of widely differing explanations.

It's clear that the process of describing reality through scientific method involves far more than merely standing back and watching while reality reveals itself. It involves preconceptions (the theorizing modes that Kuhn calls "paradigms"),[3] modeling, sorting through data, and complicated processes of interpretation. In many cases, scientific research is more like a *construction* project than a program of neutral observation followed by simple interpretation. It can be said to reveal the nature of unknown reality no more than baking bread can be said to reveal the nature of flour.

The construction metaphor. "Reality construction" is a phrase that appears in sociology when human groups institutionalize the values and perceptions of their members. Nineteenth-century anthropologist Émile Durkheim wrote about "social facts" that are independent of individual humans and as real as material facts. In 1966 two sociologists, Peter Berger and Thomas Luckmann, published *The Social Construction of Reality,* a seminal book in which they treated social institutions as both objectively real and as humanly constructed:

> An institutional world, then, is experienced as an objective reality. It has a history that antedates the individual's birth and is not accessible to his biological recollection. . . . Since institutions exist as external reality, the individual cannot understand them by introspection. He must 'go out' and learn about them, just as he must learn about nature. . . . It is important to keep in mind that the objectivity of the institutional world, however massive it may appear to the individual, is a humanly produced, constructed objectivity. [4]

A language is a good example of a constructed social reality. French and English, for example, have both been constructed over centuries so that people may use them to communicate. For their speakers, who have had to learn about them, they are parts of external known reality. But they also purport to represent other parts of known reality. When I say "the pen is on the table" or "la plume est sur la table," I am using two different constructed realities to represent one material reality. The transition from the material fact that a pen is on a table to its "correct" description in English or French is like a transition from unknown to known reality. We might say that material facts are unknown to Berger and Luckmann's "institutional world"; to become known, they must be converted into sentences of a language constructed in that world.

Two features are noteworthy about the transition from a material fact to the "social fact" of a linguistic expression. First, the two facts are completely different in kind. Pen-on-table is a physical arrangement of molecules; the expression "the pen is on the table" is something that is behavioral or sociological. If we try to characterize the expression as merely a string of marks or sounds, we find it impossible to discover any law of physics that might connect it with the material pen-on-table fact. Second, the makeup of any linguistic expression is dependent on its language. English and French come up with two completely distinct social constructions for the same physical fact.

Few sociologists would venture to describe the "pragmatic" world of science and common sense as socially constructed. In fact, the first part of Berger and Luckmann's book is about "the reality of everyday life."

But philosophy traditionally assumes greater license. In the rest of this book I will borrow the "constructed reality" metaphor to analyze how unknown reality becomes known reality—not just for "social facts" or institutions or linguistic expressions, but for *everything*.

How does the construction metaphor for known reality differ from the discovery and interpretation metaphors? At the risk of explaining metaphors by analogy, discovering reality is like finding a house to live in; interpretation is like remodeling an existing house; and construction is like building a new house from raw materials. We can further note that in discovery, one unknown fact becomes one known fact; during interpretation, one unknown fact may become any of several known facts, depending on how we interpret it; and with construction, many unknown facts become many known facts that all "work together."

Example: The Value of π

One would think that the calculation of a number would be a perfect example of the "discovery" metaphor for converting unknown reality to known reality. A given number may be unknown, but it is just waiting for us to turn over a mental rock and figure out what it is, after which it will be known. The mental process may be simple, as in finding the sum of two numbers, or it may be difficult, as in calculating the prime factors of a number, but doing it simply makes an unknown number known. Let's see how this worked historically for a famous number—the value of π.

Pi is easy to characterize physically: it is the ratio between a circle's circumference and its diameter. The earliest Egyptian and Babylonian geometers knew that its numerical value was greater than three and that it was the same for every circle. By 1900 BC the value of π had been approximated to within 1% by fractions such as 25/8 or 256/81. In the fifth century AD, a Chinese mathematician gave π the value 355/113, accurate to six decimal places.

In terms of the present discussion, the fact that for every circle the ratio of its circumference to its diameter could be measured by a single number was an unknown bit of reality waiting to be discovered. Saying that this number was a particular fraction, however, required an act of interpretation. It was like saying, "If we unwind the rims of 113 wagon wheels and lay them end-to-end beside 355 cross-braces (or 8 and 25, if we are less demanding), the two lengths will come out the same." The thinkers who came up with various fractions were no longer measuring π in itself; they were measuring something that they thought was "like π." It was interpretation because different fractions all more or less "worked." To satisfy the test of objectivity, people believed that there was always the chance that a fraction might be found that "really was" the exact value of π.

Attempts to interpret π as a fraction became futile in the eighteenth century when it was proved to be irrational—no fraction was waiting to be found. Moreover, in 1761 π was shown to be "transcendental"—its value could not be expressed by *any* combination of numbers. The first letter of the Greek word περιμετρος was adopted to symbolize this mathematical constant that could not be expressed numerically. By that time, methods had been found to approximate its value by summing fractions in infinite series. Converted to computer algorithms, these methods ultimately led to the billions of decimal digits for π that are posted on Web sites today.

Approximating the value of π by summing an infinite series is an act of construction. We are no longer investigating circles. We are not even defining a normal number, because the value of π cannot be expressed algebraically. The infinite series approach marks the end of attempts to interpret π or even ask what π "is." Instead, we construct mathematical models that help us work with π regardless of its value. We understand that no numerical representation of π will ever be exact.

Thus π, whatever it "is," remains a part of unknown reality. We work with numbers in known reality, but none of them is the value of π. This does not mean that π is not useful. It appears all the time in the known reality of mathematics, physics, and statistics. What appears, however, is a constructed mathematical object—a number-like "value" that is useful in our equations and that represents in known reality the circular ratio of unknown reality.

Is the value of π as it is currently known discovered, interpreted, or constructed? It is clear that it has become constructed, as part of the whole edifice of modern mathematics. It is no longer a fraction waiting to be found, nor a number waiting to be interpreted by a formula. It is something that must be constructed by a series of calculations.

Nevertheless, π plays multiple roles in our knowledge of other facts. As a number it shows up in Euler's remarkable formula $e^{i\pi}+1=0$; as a quantity it shows up in Einstein's cosmological constant; and as the product of calculations it shows up in many probability distributions.

Characterizing Known Reality

To pursue seriously the concept that known reality is constructed from unknown reality, we must start by characterizing known reality. If known reality has been constructed, then we should be able to describe it in its own terms, not simply as a reflection of something else. It would be like asking what a house looks like, not just wanting to know what its materials are. So what can ordinary experience tell us about the part of reality that we know? Three primary characteristics stand out: our known reality is made up of discrete objects, at least some of it is external to our experience, and it is divided into regions that contain different kinds of objects. Let's analyze these characteristics separately.

Discreteness. Ordinary observers, and most scientists, agree that known reality is composed of many separate and discrete objects. Whether we see these objects as the familiar ones of everyday life—ships and shoes—or the more recherché objects of physics, such as strings and fields, most people assume that the reality they know is made up of many specific items that exist separately from one another and which can each be located and described.

Indeed, much of the traditional progress in science has consisted of identifying new objects in our everyday world. For example, the four substances of Empedocles—earth, water, air, and fire—gave way to the 100+ chemical elements recognized today. The atoms of Democritus were resolved into the atomic particles of the twentieth century. A loose tradition of biological distinctions was systematized into the species of Linnæus. The syllogisms of Aristotle gave way to the variables and propositions of symbolic logic. In all of these cases, we might say that reality was "chunked" to make it more understandable. What had been poorly understood substances became clearly defined discrete objects.

The "chunking" of object formation is not just a matter of dividing reality into more easily understandable pieces; it involves the whole process of reality construction that I discuss in Chapter 3. For example, transitioning from the ancient idea of substances to the modern system of chemical elements and compounds required certain beliefs—such as that matter is conserved during its transformations and that repeatable experiments can establish general truths. With these beliefs in place, showing that water could be synthesized from two gases "proved" that the gases were its elemental constituents. For the ancient philosophers, without these beliefs, the notion of water as the union of two different kinds of air would have seemed far-fetched. What happened during the eighteenth century was that a part of known reality was "rechunked" into new objects—including hydrogen and oxygen—that had hitherto been unknown or poorly understood. The new objects were part of the construction of a whole new understanding of matter.

Objectivity. A second characterization of known reality, widely agreed, is that at least some of it is "objective": it is outside ourselves and not under our control. Objective reality appears to us whether we want it or not. Thus I may imagine that I am fishing in a forest stream or sitting in a warm bath, conjuring up these experiences at will. I will usually realize that I am not actually in a forest or a bathtub; but, as Descartes argued, the fact of my imagining is itself real. It is also under my control; I can usually stop or start it at will. If someone sticks me with a pin, however, *that* experience will normally force itself upon me regardless of my wishes.

The only way I can make sense of the pinprick is by hypostatizing an intractable objective reality that is separate from my experience and my will. The "slings and arrows of outrageous fortune" are a constant preoccupation for all living things. We humans may have a refuge from objective reality in our conscious imagination, but it appears that most other forms of life deal almost exclusively with "the outside world."

From pinpricks and all their ilk flow the conviction that at least part of known reality consists of an objective external world. Its objectivity makes it an actively pursued object of knowledge. But we feel that the external world does not exhaust known reality—in the case of humans, at least, a separate "inner" or subjective world, a world over which we have more control, is also part of everyone's known reality.

What do we mean by objectivity? A later part of this book discusses the act of *relating* one thing with another—one of the basic ways by which living things understand their environment. Relating is a crucial part of testing a thing for objectivity, because if a thing can be related to other things that are known to be objective, it must have "being" of its own. You can't relate nothing to something.

Disparate orders. A less commonly recognized characterization of known reality is that it is composed of radically different kinds of stuff. Every act of knowing locates its subject matter in one of three distinct areas of known reality. In my previous work I call these areas "orders" and name them "physical reality," "behavior," and "ideals." Everything we know is either physical, behavioral, or ideal.

In philosophy, this tripartite division shows up mainly as differences among ontological schools. Various philosophers have maintained that one of the three orders is “true reality” and the others are derivative or illusory. The champions of physical reality include materialists, some logical positivists, and many scientists. Philosophers who believe that only behavior is real include solipsists and some phenomenologists. Those who believe that only ideals are real espouse various kinds of idealism and often trace their philosophical descent from Plato.

It is hard to “define” entities as large as the orders of known reality. We understand them because we are part them and have to deal with them all the time. Anyone who cannot tell the difference between a physical act, a behavioral urge, and an ideal goal will soon fail in the business of life. As I will discuss later, dividing reality into orders is prerequisite to knowing it. For present purposes, however, it may help for me to specify some typical things I think of when I talk about the orders of physical, behavioral, and ideal reality:

- By the **physical** order I mean the familiar world of tangible things, the world explored by physics, chemistry, physiology, and other “hard” sciences. Physical things range from subatomic particles up to the universe as a whole. In particular, the bodies of living things and all their parts are physical, including every nerve impulse and brain wave. Some thinkers (with whom I disagree) maintain that physical reality is all that exists—that the areas of reality that I call behavior and ideals can somehow all be explained in physical terms.
- By **behavior** I mean the world explored by psychology, sociology, ethology, and similar sciences. It is a world populated by sensations, ideas, intentions, emotions, and so on, as well as by the behavior of other living things and by human languages, institutions, and beliefs. Behavior is most commonly associated with individual living things, which have physical bodies; but behavior is real and independent in itself. An ethologist, for instance, can describe the typical behavior of a species without identifying any individual animal. In the same way, a linguist can describe a language apart from its speakers—indeed, ancient languages can be real subjects of study even though nobody speaks them.
- By **ideals,** I mean the world of mathematical and logical entities—numbers, functions, geometrical shapes, etc.—plus the “subsistent universals”—this-ness and that-ness—which have always formed a

> vital thread in human thought. Every time we think about something or try to describe it, we are forced to fall back on ideals; we say that a thing has this quality, that shape, and so on. As Plato pointed out, the qualities, shapes, and so on that we cite cut across many objects; that is why they are called "universals." Therefore, he argued, every universal must be independent of the objects that "participate" in it. Yet universals are real objects of knowledge in themselves. We can talk about "circularity" as meaningfully as we can talk about round things or about our sensation of seeing a circle.

The disparateness of the orders of reality is directly experienced in the ways that we know them. Physical things are known by handling and measuring them, behavioral things by experiencing them, and ideals by abstracting and defining them. But it is important to understand that the distinctions between physical reality, behavior, and ideals are not just artifacts of knowledge. They are not like the distinctions between "things we see," "things we hear," and "things we feel." Each order forms its own "closed world"—roughly, a physical world, a world of behavior, and a world of abstractions.

Here we encounter the concept of *grouping*—another basic way by which living things understand their environment, along with chunking and relating. The physical, behavioral, and ideal orders represent the most fundamental ways that the objects of known reality are grouped.

Any serious attempt to understand reality must treat these worlds as naturally disparate. For example, one of the first things a baby learns is that wishing a block to move, or imagining it moving, will not in fact make the block move; one must reach out with a physical arm and push on the block in the physical world. Much of daily life is practical only to the extent that we (and other living organisms) distinguish between behavioral intentions, physical actions, and ideal goals.

At the same time, the parts of each world interact within each one. Physical things influence other physical things, one train of behavior leads to another, and ideals are defined in terms of other ideals. Thus a beam of red light interacts with physical things such as photometers; a sensation of red interacts with other behavior, such as deciding to stop at a red light; and redness is part of the ideal "color spectrum," which can be defined in terms of numerical frequencies and wavelengths.

Discreteness and objectivity of the orders. The other assumptions about known reality—that it is composed of discrete things, some of which are external and objective—apply separately to the contents of all three of its orders. Discreteness is found not just in physical objects; our sensations and volitions are things distinct from one another, as are the idealizations of mathematics and philosophy. Among the objects in each of the three orders of reality, some are external—forced upon us—and some are internal, under our control. Physically, this difference is clear in the distinction between events that I will and events that may happen despite me. In behavior, the practical conduct of life assumes that some experience is private and internally governed, while some is governed by institutions or people outside ourselves. Similarly, we must distinguish our own ideal values and propositions (which we can think up at will) from logical certainties and ideal formulas "established by proof," over which we have no control.

Discussion: Specificity, Variability, Determinacy

Why does known reality come in three "orders"—physical, behavioral, and ideal? The reason, which will be repeated throughout this book, is that known reality must be this way for it to become known. Knowing has evolved to be a complex process; it is not just a matter of "holding a mirror up to nature." It is a construction job that requires a variety of materials for its various tasks, just as it takes bricks and beams and mortar to build a house.

Three characteristics that knowledge needs to find in known reality are specificity, variability, and determinacy. But knowledge does not find these characteristics all mixed together; they appear separately, as features of the three different orders:

- **Specificity** is a characteristic of physical reality. The more we dig into it, the more we find. Its details, when examined, yield further details. At the other end, its great cosmic structures turn out to be parts of even greater structures. Despite the perennial talk in physics of a "theory of everything," there seems no end to what science can discover in the material world. Physical reality appears to be in some sense "infinitely specific."
- **Variability** is typical of behavior. Our thoughts and experiences are diverse and unpredictable. If this were not the case—if our behavior were not "infinitely variable"—we would have to abandon hope of being able to understand the "infinitely specific" details of physical

reality. Knowledge is possible because behavior can embrace so much—images, plans, conjectures, experiences, and so on.

- **Determinacy** is a feature of ideals. Once we know an ideal, we have exhausted all there is to know about it. Philosophers such as Locke, Descartes, and Spinoza often cited the notion of having a "clear and distinct idea" as in some sense "infinitely determinate" of what I call an ideal. For them, a given ideal was real just to the extent that we could determine what it was.

Known reality is constructed in three disparate orders so it can have the characteristics of specificity, variability, and determinacy. These three characteristics then help make reality knowable. This complementarity is typical of the reality construction metaphor. If known reality were a house, we would always be careful to select materials for building it that, when assembled, would become a house and not something else.

Divisions in Known Reality

At first, the division of known reality into orders may seem strange. It conjures up the bogey of "Cartesian dualism," said to engender all kinds of philosophical ills. Worse, it's a "triplism," which must be half again as bad as a dualism.

My main evidence is empirical. Search through the reality you know. In it you will find a concept of "blueness," which you use to decide whether a color is really blue, not green or purple. You will also sometimes experience a blue sensation in your mind. Finally, you can look at the sky and see that it is blue. The physical blue light from the sky is completely different in kind from the blue sensation in your behavioral experience, which is generically different from the ideal of blueness. These entities are all parts of your known reality, but they are radically different in kind. In my terminology, they are parts of disparate orders of reality: physical, behavioral, and ideal.

When formal studies of the contents of the world are undertaken, the resulting academic disciplines naturally separate themselves into three areas. We talk about the physical sciences (such as physics, chemistry, geology), the humanities (history, languages, the arts), and the abstract disciplines (mathematics, logic, philosophy). Some colleges segregate their faculties on this basis, as if different skills or temperaments were required to teach each kind of knowledge.

Yet for many thinkers, the assertion that the objects of known reality are naturally of three kinds—physical, behavioral, and ideal—is far from obvious. My earlier books presented extensive arguments for treating these three orders of reality as totally separate and equally real. But many people believe that only physical things are real and all else—our thoughts and sensations as well as the truths of mathematics—can all be explained somehow in terms of physical processes. In the same way, many past and present thinkers have also believed that only sensations are real, or only abstract universals.

To all such monistic beliefs I reply that everybody experiences the divisions of known reality directly. In our everyday lives we constantly encounter objects that we routinely assign to one division or another. Living our lives uncritically, we naturally understand that the world contains things—stones, words, and triangles, to take a random sample—that are fundamentally different in kind. We comprehend innately that physical, behavioral, and ideal objects are generically different.

But in addition to our natural inclinations, an analysis of how we generate knowledge shows that divisions in reality are essential to forming workable theories about it. I discussed this subject at length in *Processes of Knowledge* and a recap of that analysis is presented in the present book, Chapter 6.

At the same time, we understand that objects within each division of known reality have a natural affinity for one another. Physical things act on other physical things, trains of behavior influence one another, and ideals are understood in terms of other ideals. Objects of each kind form a world that is closed to objects of the other kinds. This is why I call the totality of each kind of object an "order."

From the viewpoint of knowledge, we grasp objects differently in each of the three orders of reality. We comprehend physical objects as discrete things with tangible properties—things we can manipulate, measure, and inspect at our leisure. Scientists have become quite good at predicting how physical objects will react with one another in various situations, and these reactions are generally repeatable. Behavior, on the other hand, is less tangible and less predictable. Few scientists would try to predict another person's thoughts, for example, or even their own thoughts. Psychologists have developed some general rules for understanding behavior, based less on measurements and more on natural empathy; but in the final analysis we know behavior primarily by being part of it, not by making it an object of study. Finally, we grasp ideals simply by thinking about them. Ideals are both intangible and independent of our behavior. We determine what 2 plus 3 add up to by examining these objects in our minds, and once we determine the answer neither our behavior nor our physical actions can change it.

Analogy: Image Digitization

Let's talk about computers for a moment. Parallelisms exist between the ways that computers process information about the world outside them and the ways that living things accomplish similar tasks. This is because during the evolution of computer technology, designers tended to emulate in machinery the methods of human work with which they were familiar. Computers were designed to work like people do.

Computer processing includes the technologies of analog-to-digital and digital-to-analog conversion, which translate between things in the "real" (non-computer) world and sequences of bits that a computer can handle. These technologies let computers deal with text, images, sounds, and so on, none of which are made of bits in the "real" world. As an example, seeing how computers "represent" images as bits can help us understand the orders of known reality.

An image in the real world is a configuration of light on a surface. It can be detected by a matrix of photoreceptors, which generate electric currents that a computer can interpret as binary numbers. Conversely, binary numbers in a computer can modulate color cells in a flat panel display, producing a configuration of light on its surface. In both cases, the computer treats external images as continuous regions of light that blend into one another, not sets of discrete "light objects." That is why images are called "analog." The computer must represent such analog objects as bit sequences, a task that it can perform in several ways:

- The computer can divide the image spatially into "pixels," storing a measurement of the light present at each small location. We may call this "physical digitization," because the bit sequences represent physical light occurring at specific locations in the image.
- The computer can create numerically coded instructions for drawing the image. This technique is most commonly used when the nature of the image lends itself to delineation—for instance, a block of text lettering. We may call this "behavioral digitization," because what is stored is a sequence of drawing *instructions*.

- The computer can analyze the image into geometric regions, each of which is defined in a file of equations for generating standard shapes. It then encodes the location, dimensions, color, and so on of each shape, thus representing the image as a collage of predefined geometric objects. We may call this kind of representation “ideal digitization.”

Note that all of the digital representations are generically different from the analog original—regions of light on a surface are represented by sequences of bits. Also note that the different ways which computer engineers have devised to represent images—as pixel maps, as drawing instructions, or as geometric decompositions—correspond to the orders of known reality: physical, behavioral, and ideal. And finally, note that each of the three digitizations represents the external analog image with a completely different sequence of bits.

What happens during image digitization? At one end, we have a real thing, a visual image, that the computer needs to “know.” At the other end we have a choice of digital representations, each an ordered set of binary digits that the computer can digest. In the middle lies a process designed to generate digital numbers that “represent” the image. The computer can never “know” the image directly, for configurations of light are intrinsically incomprehensible to it. It can only process binary numbers, and it turns out that each image can be represented by at least three totally different sets of numbers—numbers that not only differ in value but also differ radically in the ways they are used. The physical pixel numbers are used to lay down points of color; the behavioral drawing numbers identify routines that outline and fill spaces; the ideal shape numbers are used to retrieve graphic definitions from memory.

Working on a single image, the three digitization processes not only produce different sets of numbers, but also numbers that have different “meanings.” For the computer to treat the pixel representation as a set of drawing instructions, for instance, or as callouts from a library of standard shapes, would constitute a fatal processing error. Inside the computer, these different ways of “knowing” an image stay confined to separate processing tracks. This is analogous to the imperative that each order of known reality has its own way of being understood.

Although “unknown” to the computer, the image being digitized in our analogy is objective. In the computer’s “known reality,” any of the three bit-sets intended to represent the external world—a physical pixel set, a behavioral instruction set, or an ideal shape set—is objectively "bound" to the unknown analog image. Changing a single bit makes it more or less "faithful" to the original. Veracity is a crucial property of each of the three digital representations of the image, even though their bit-sets are completely different. This "truthfulness to nature" is like the fact that unknown reality determines known reality, even though known reality may appear to us in a completely different form.

Space, Time, Pattern

To summarize the preceding discussion, we know reality to be filled with discrete objects of three disparate kinds—physical, behavioral, or ideal. Everything we know falls into three great "orders," because our understanding of reality easily connects the objects in each order while resisting attempts to connect objects of different orders.

While our understanding easily connects objects within each order of known reality, it also easily separates one object from another. So I do not use the term "order" casually—within the physical, behavioral, and ideal orders, known reality depends on different ordering methods to separate the objects each order contains. These methods are familiar; they are *space, time,* and *pattern*. Knowledge employs space, time, and pattern to separate objects from one another in the physical, behavioral, and ideal orders of reality, respectively.

Note that space, time, and pattern show up implicitly in the analogy with image digitization just discussed. "Physical digitization," which divides an image into pixels defined by their location, orders its results in space. "Behavioral digitization," which converts the same image into a sequence of drawing instructions, uses time as an ordering algorithm. And "ideal digitization," which decomposes the image into geometric shapes, depends on the computer being able to associate patterns with an image's configuration of light.

The ordering methods of space, time, and pattern provide essential support to our human knowledge of the physical, behavioral, and ideal orders of reality. For example, **space** makes it easier for us to separate objects in physical reality and tell them apart. By assigning a unique location to a physical object, relative to other physical objects, we can tell that it is distinct from the other objects without needing to know any other difference. Spatial location lets us distinguish two physical things that might otherwise appear identical.

Existence in space is also the primary indicator that something is physical. Classical philosophers called it "extension" and treated it as an attribute that separated the material from the incorporeal. Today, physicists generally require an entity to have a location in space, even if only briefly, to regard it as having existence in their descriptions of known reality.

Time orders behavior. Behavioral objects have no spatial location but they do form sequential "trains," in which the ordering relations "before" and "after" are crucial. Before and after ordering is necessary to link behavioral objects such as stimuli and responses, emotions and expressions, intentions and executions. Without time, behavior would be chaotic and would not easily become a part of known reality.

Time has been a perennial bugaboo for philosophers and scientists. It has been variously called an absolute feature of nature (Newton), an "intuition" (Kant), or something entangled with space (Einstein). Past attempts to find the "direction" of time in physical laws have depended primarily on the statistical methods of thermodynamics, an approach I criticize in an earlier work.[5] All this confusion results from trying to define time in physical terms. In the context of behavior, time is easy to understand: it makes behavior work.

Pattern, the way that ideals are ordered, is not usually compared with space and time. But we use patterns for the same basic purpose, to order and separate objects in known reality. We can place ideal objects within a pattern, just as we locate physical objects in space and order behavioral objects in time. As with space and time, patterns help us separate objects without being objects themselves.

An analogy may help illustrate the role of pattern in ordering ideals. Imagine first the blueprint for a house. It expresses the location of the house's various parts in spatial terms—a door here, a window there. Two windows may be identical, but the blueprint uses space to separate them by showing one on the north side of the house, the other on the east side. Now imagine a cooking recipe. It is a series of instructions—add this, stir, add that, stir again. Two stirring operations may seem identical, but the recipe uses time to separate them; one occurs before adding the salt, the other after. Finally, imagine a collection of color samples, of the kind used to sell paint. They may be arranged in a rack or on the pages of a book, but always in a pattern—for example, from red hues through the spectrum to violet, with each hue's different tints and shades laid out next to it. We "navigate" through the color samples by understanding their pattern, making it easy to find the one we want.

In all three of these cases—the blueprint, the recipe, and the color samples—an ordering method separates and arranges objects without being an object itself. In the blueprint, space separates the parts of the house but is not a part of the house; in the recipe, time distinguishes the instructions without being an instruction; and with the color samples, a pattern arranges them but is not itself a color.

Patterns take myriad forms. They include hierarchies, aggregates, linearities, networks, and all kinds of linkages. In mathematics they are identified as fields (of numbers), manifolds (of points), functions (of variables) sets (of elements) groups (of transformations), and so on. In other disciplines, information is arranged in lists, arrays, hierarchies and the like. For example, the entries in a dictionary are arranged in a hierarchical pattern: first by each word's orthography, then by its parts of speech, and finally by its different usages in various contexts.

We frequently visualize patterns spatially—a list by a vertical stack, an array by a table, a hierarchy by a tree. But our doing so does not mean that patterns are spatial, any more than our visualizing time as a horizontal line means that time is a kind of space. Patterns are made up of *relations,* just as space is made up of distances.

Pattern is as central to human life as space and time. From the days of Aristotle onward, our ability to order ideals by pattern has been a fundamental method for obtaining, preserving, and communicating the sophisticated knowledge that we possess. Many of the ideals that we understand would be useless to us were we not able to arrange them in lists or hierarchies. And our speech and writing would barely serve our needs if it were stripped of the analogies and other "figures of speech" that depend on people's mutual recognition of patterns.

History: The Reality of Physics

From the eighteenth to the twentieth century, scientific investigations of "material reality" assumed (sometimes tacitly) that the physical world had three underlying properties: **locality, seriality,** and **predictability.** Locality meant that for one thing or event to influence another the two had to be spatially proximate. Seriality meant that time flowed forward the same for everybody and for every event. Predictability meant that every physical thing or event obeyed the same "laws of nature." These assumptions characterized a universe that was composed of spatially connected objects, all changing together through time, each of which interacted with its neighbors in ways that were capable of prediction. It was the vision that Laplace enunciated in 1796:

> In the midst of the infinite variety of phenomena which succeed one another continuously in the heavens and on the earth, one is led to recognize the small number of general laws which matter follows in its movements. Everything in nature obeys them; everything is derived from them as necessarily as the return of the seasons, and the curve described by the dust particle which the winds seem to carry by chance, is ruled in as certain a manner as the orbits of the planets.[6]

In terms of the present discussion, this vision amounted to embedding space, time, and pattern in physical reality. The "material world" *was* spatial, it *did* change through time, and those changes *always* followed inherent patterns.

Doubts about this vision began to crystallize in 1905, when Einstein proposed a physics in which seriality was not uniform within physical reality. An event that was happening "now" for one observer could be in the past or future for another observer. Experiments showed that this "relativistic" effect actually occurred, and today the design of global positioning systems must take it into account.

Predictability was questioned in 1925 by Heisenberg, who came up with a way of describing small particle events using matrices instead of scalar quantities. The spatial and temporal measurements of particles—their position and velocity—became fused into a "wave function" that produced indeterminate physical effects. Again, experiments supported this interpretation, making it an integral part of "quantum mechanics."

In 1964, John Bell proposed experimental methods to test "quantum entanglement," a situation in which particles spatially distant from each other appear to interact. Multiple tests since then, measuring particles up to 18 kilometers apart, have confirmed what used to be decried as physical "action at a distance" and is now called "nonlocality." Widely separated particles *do* "talk to each other," but no one knows how.

From the viewpoint of this book, the early physicists' assumptions of locality, seriality, and predictability in known reality were a result of misapplying the roles of space, time, and pattern in human knowledge. As later parts of this book will argue, these ordering methods are tools that we use to understand unknown physical reality, not characteristics of that reality itself. Space, time, and pattern show up only when we and other living things construct and understand *known* reality.

Consider an analogy. Psychologists often use "projective tests" to elicit people's underlying attitudes and motivations. The Rorschach ink-blot test, for example, asks the subject to describe a meaningless shape; the Thematic Apperception Test asks for an explanation of a scene in which people are interacting in no obvious way. One might come up with a spatial description of an inkblot ("Two people face to face") or a temporal description of a scene ("People walking with each other"); but does that mean that space is an inherent part of the blot or that time is embedded in the drawing? Either might also be described as merely a pattern. Something like projection takes place (on a more basic level) when people construct known reality out of unknown reality. Space, time, and pattern are products of the construction.

Physicists' papers often treat questions about locality, seriality, and predictability in physical reality as "philosophical issues." As long as the mathematical models work and produce useful technology, these questions take second priority. But many important changes in science (what Kuhn calls "paradigm shifts")[3] have started out as philosophical issues. This book will raise more of them in the pages that follow.

Unknown Reality

If known reality is discrete, objective and divided, does it inherit these characteristics from unknown reality? Or are they introduced during the process of making unknown reality known? While this book is mainly about known reality, a few suppositions can be made about unknown reality. Since that understructure of reality is by definition unknown, these suppositions are largely negative.

I believe that one of the main characteristics of known reality cited in this chapter, *discreteness,* is introduced entirely by the process of knowing it. A second characteristic, *objectivity,* is entirely inherited from unknown reality. The third characteristic, *division into orders,* is not an inherent part of unknown reality, but it inevitably becomes a part of known reality when unknown reality is chunked into objects. The following analysis discusses these characteristics as they may apply to unknown reality.

Discreteness. The argument that unknown reality is not made up of discrete objects is fairly simple. If it were, we should have discovered them by now. Yet physicists and philosophers propound theory after theory about the "ultimate constituents of reality," all of them based on different models. We have no reason to believe that this divergence of explanation occurs because the right experiments have not been tried, or that the supposed objects of unknown reality are so small or elusive that they have thus far escaped detection. It is simpler to believe that each model of reality that scientists and philosophers have asserted is just another way of picturing a reality that "actually corresponds" to none of them.

The conversion of unknown reality into known reality begins as a process of "chunking." The discrete chunks that result may be physical things, or trains of behavior, or ideal abstractions. All of them are valid parts of known reality; but because they are products of chunking, none of them are exactly the same as the material in unknown reality from which they are drawn. Moreover, a given part of unknown reality can be converted into different chunks. A rock may be for most people a single thing; but a geologist might chunk it into crystals, a chemist into molecules, and a physicist into particles and forces.

The simplest way to understand how unknown reality can be chunked in various ways into the discrete objects of known reality is to visualize it as "smooth"—devoid of natural boundaries within it. Then chunking it into discrete objects can introduce boundaries anywhere without constraint. In mathematical terms, this characteristic would identify unknown reality as a "continuum."

One characteristic of a continuum is that it is treated as "infinitely specific." Every part of it is composed of other parts, *ad infinitum*. As a consequence, the continuum of unknown reality can be chunked into any number of discrete objects, each of which can be chunked into more objects to any level of detail. Lacking compelling evidence to the contrary, we can assume that unknown reality contains no inherent "granular structure" that would constrain our ability to convert it into the objects that we know.

In science, the search for inherent granularity in reality has taken place mainly in physics; few thinkers in the humanities or the abstract disciplines have tried to find "ultimate constituents" in their fields of study. Assumptions of granularity in the physical world have come mostly from understanding physical reality in mathematical terms. If we were to add to unknown reality the ordering methods of space, time, and pattern, without chunking it into objects, the result would resemble the "space-time continuum" of physics. It could be depicted as a block universe, with space and time forming its four dimensions and linear "world-lines" representing things and events within it. In the terms used in this book, such a four-dimensional universe would be organized as an ideal pattern and its world-lines would be physical chunks within it. The block universe viewpoint is a product of what I call "framework theorizing," a subject discussed in Chapter 6.

Objectivity. Saying that we construct known reality from unknown reality does not mean that we are free to describe the world any way we like. To make sense of knowledge we must treat at least some unknown reality as "hard," something that places restrictions on what we can know in known reality. Behind the struggle to know unknown reality, which helps us understand *what* it is, lies the conviction *that* it is. Our trying to know reality is not just a game.

Again, the analogy of digitizing an image suggests a model for the objectivity of known reality. Any digital representation of an image, by whatever method it is created, has the property of **veracity.** If we change the value of a single bit in it, we expect that its veracity will either increase or decrease. One way to test a digital representation's veracity is to create a new analog image from it through a digital-to-analog conversion process, and then compare the new image with the original image that the digital bits are supposed to represent. This is in fact what computer designers and users often do.

Unfortunately, we humans (and living things in general) are unable to perform the same kind of test. We cannot convert known reality back into unknown reality and compare the result with the original. Instead, we are forced to perform roundabout veracity tests entirely within known reality. The veracity of our reality construction then acquires support when the tests "work." It's as if a computer could verify that it had correctly digitized an image only by performing calculations on the resulting numbers. Computers are sometimes programmed to do this—to verify that the edges in an image are continuous, for example, or to test areas of uniform color for "artifacts."

This limitation—the inability to verify known reality by comparing it directly with the unknown reality from which it came—engenders much of the behavior discussed in this book. We constantly work to construct new known reality that we can compare with the reality that we already know. If all our known reality then "fits together" we treat it as correct, regardless of whether we constructed it through daily life, by scientific research, or through purely mental processes. All of this work takes place in known reality, even though its source materials come from unknown reality.

Thus we can say that unknown reality is objective, in the sense that when it becomes known it sets limitations on known reality. Unknown reality "in itself" is different from known reality. It is not composed of discrete objects and it is neither physical, nor behavioral, nor ideal; we make it so during the process of knowing it. Yet every time we convert a part of unknown reality into a new object in known reality, we find that the new object interacts in specific ways with the rest of the world that we already know. Unknown reality must make this so, which is why we are justified in calling it "objective."

Division. Are the divisions we find in known reality—between the physical, behavioral, and ideal—derived from unknown reality? The analogy of digitizing an image (earlier in this chapter) suggests that they need not be. It illustrates how one can construct three completely different kinds of reality from one source. Computer designers devised these various ways of converting images into numbers to make their software run more efficiently, not because images inherently require different kinds of processing.

Evidence that unknown reality is not divided can also be found in the existence of living things. As Chapter 2 describes them, living things are objects in all three orders of reality. All life is concomitantly physical, behavioral, and ideal. Since these divisions are absolute in known reality, we must ask how living things can display integrity in known reality without a unified origin in unknown reality. If unknown reality is undivided, then we could imagine that living things might freely chunk continuous parts of it into objects of any kind. If unknown reality were divided, then its "fractures" could cut through living things and prevent their construction of known reality.

The foregoing suggestions—that unknown reality is an objective continuum that becomes three kinds of reality when it is "chunked"—are all that I propose to say about it here. When we go beyond the "turning-over-rocks" model of knowledge and propose fundamental differences between unknown and known reality, we forego the ability to "know" more directly what we have characterized as unknown. As Wittgenstein famously advised, "What we cannot speak about we must pass over in silence." The reality we know is the only reality that we can analyze, which is why it is the subject of this book.

Analogy: Converting Reality to Data

Back to computers. Earlier I drew an analogy between the orders of known reality and the different ways that computers digitize graphic images. That discussion could be expanded to an analogy with the ways that living things convert unknown reality into known reality. In such an analogy, unknown reality would be like a natural scene being captured and digitized. Known reality would be like a digital record of the scene that a computer can process.

In computer terms, the scene—a landscape, say—is unknowable. It contains no binary numbers that can be processed. However, a device can focus light from the scene onto a grid of sensors, each of which will measure a small region of it. As described earlier, these measurements can then be manipulated into a binary record in any of several ways: as an array of pixels in space, as a series of drawing instructions, or as an assemblage of shapes taken from a library of standard figures. This is like "chunking" unknown reality into known objects, the objects in our analogy being either physical pixels, behavioral drawing instructions, or ideal shapes.

To complete the analogy, we must assume that different parts of the scene are digitized differently. Thus trees in the landscape, with their many leaves, are digitized as pixels; the rounded contours of a cow are rendered as drawing instructions; and the rectilinear sides of a barn are decomposed into shapes. Computers sometimes change their digitizing processes to increase efficiency; for instance, the leaves on a tree may be mapped as pixels in space because such a map consumes less data space than the instructions required to draw each leaf. But this choice is made for efficiency in computation; there is nothing in the scene that requires any part of it to be digitized in any specific way.

Without being able to see (or even understand) the visual scene, we could deduce some of its characteristics from the three kinds of digital records that can be made of it. The possibility of making a pixel record implies that its content is *conserved,* for each pixel represents one and only one part of the scene. Our ability to render the scene as a series of drawing instructions implies that it is *organized*; there is an order among its parts that can be replicated by the order in which an image of it can be drawn. And the fact that we can decompose the scene into geometric shapes implies that it is *rational*; every part of it can be represented by an abstract shape in a standard library. We might say that the scene's properties of conservation, organization, and rationality remain invariant under digitization.

These characteristics show up in digital constructions of the scene as "ordering principles" for different kinds of digitization. Because the scene's content is conserved through digitization, a pixel map of it is valid if every point of the scene is assigned exactly one pixel. Because the scene's orderliness is invariant, every part of it can be drawn. Because its rationality is invariant, every part of it can be rendered in terms of geometric shapes.

Thus some characteristics of the scene become ordering principles for the digital records made from it. The digitizing process may choose different types of records for different parts of the scene, but once this choice is made it must order the contents of each digital record in one of the ways mandated by the nature of visual images. This is like the influence that unknown reality has over the kinds of objects that result when it is chunked into known reality. The analogy as a whole helps us understand how unknown reality can be such that when chunks are made from it, we know them as either physical, behavioral, or ideal.

Multiple Realities

If we believe that reality is something we must discover—through what I call the turning-over-rocks model—then the idea of multiple realities is repugnant. Most of us would feel that reality must be one fixed thing that we explore bit by bit. But if we grant that what we know as reality is constructed from something else—the model I propose here in which known reality is constructed from unknown reality—then the idea of multiple constructions naturally follows. Unknown reality might be one continuous thing, but the constructions we and other living things make from it could easily constitute separable "worlds."

I have already discussed the physical, behavioral, and ideal orders of known reality. These areas appear to be naturally separable because we understand them in completely different ways. Similarly, most people understand that their "inner experiences"—their thoughts and feelings—are separate from their environment, from the "external world" in which they live. It is clear that we and other living organisms construct multiple realities, including the realities of our selves as living things distinct from the environment in which we live and the realities that we construct within our own minds. When we consider other species, it is further clear that their constructions within the common environment are at least separable worlds of knowledge, if not different realities.

A simple example of alternate environmental worlds unfolds every time I walk my dog. He mainly sniffs, I mainly look. His is a world of odors, of evanescent molecules carried by the air and drawn over his olfactory epithelium. Mine is a world of sights—streets, buildings, cars, signs, and so on, which I recognize with my eyes. His eyes and my nose also function, but much less effectively. For both of us, much of what we perceive in our shared environment has a social meaning. In his world it is a tradition of territorial markings and clues about other animals, all inherited from his species. In my world, it is a learned set of rules and information about the culture in which I live.

He can't read my street signs and I can't interpret his scents. With the help of instruments and research, I might be able to identify the molecules he smells and trace them back to their sources. It is possible that he might be trained to distinguish my street signs. But even if I could sort out his scents and he could identify my sights, these would only be parts of larger constructions of known reality—constructions so different that we could never casually exchange them. He lives in a dog world; I live in a human world. Philosopher Thomas Nagel addressed this problem in his classic essay "What is it like to be a bat?" (1974):

> I want to know what it is like for a bat to be a bat. Yet if I try to imagine this, I am restricted to the resources of my own mind, and those resources are inadequate to the task.[7]

This difficulty arises from the fact that constructed realities, *because they are separately constructed,* tend to be incompatible. It is no easier for me and my dog to swap parts of our constructed realities than it is for us to swap parts of our constructed bodies.

Why do my dog and I construct disparate realities? *So we can each know the reality that is significant to us*. With a little effort I can breathe the same air he does, but I cannot construct the same olfactory world he knows. By looking around he can see the same things that I see, but he cannot construct my civilization. Each of us constructs the reality he needs to know and the rest remains unknown.

Despite the differences in the realities we construct, my dog and I share some basic techniques. We both seem to chunk reality in similar ways, converting the unknown into the known. It also seem evident that he recognizes the same divisions in known reality that I do—he knows the difference between a beefsteak and the smell of a beefsteak, and his reactions to food lead me to believe that he understands the ideal of "meatiness" in its abstract sense. In other words, the ways in which we construct reality are similar even though the results are different.

Just this simple example of disparate realities raises a clamor of questions. How are realities constructed? How are they shared by the living things that know them? What roles do space and time play? These questions are among the many addressed in the rest of this book.

Summary of this Chapter

When we try to characterize reality in general, one of the first things we notice is that parts of reality are known (by someone or something, somewhere) and parts of it are not. We may regard this distinction as uninteresting; we may feel that reality, like ol' man river, just rolls along, whether or not it is known. But when we focus on the known parts of reality (which, by definition, are the only parts we can analyze directly), we find that known reality does anything but "roll along." Not only do humans know and understand the same parts of it in different ways than other living things (such as bats) do, but even among people there are perpetual arguments about what known reality "really is."

Various reasons thus lead me to regard known reality as *constructed,* much like a house is constructed. The raw materials for building known reality come from unknown reality; the builders are living things; and the purpose of the construction is to create a reality that is best suited for the builders to know.

Once we agree that known reality is purposefully constructed, not just accepted "as-is," then it is useful to ask how it is built. For starters, this chapter introduces the concept of three actions that are basic to the construction of known reality: *chunking, grouping,* and *relating*. These primitive actions shows up repeatedly in later parts of this book—as the fundamental operations that living thing perform, as the basic mechanisms of reality construction, and as the underlying techniques of knowledge. At the simplest level of analysis, it is through chunking, grouping, and relating that life and the reality it knows come into being.

It is also useful to ask in what fundamental ways known reality turns out to be different from the stuff that goes into its construction, which I call unknown reality. To answer this question, we determine the most basic characteristics of known reality and then ask whether it is likely that they also apply to the unknown stuff. I analyze three attributes of known reality: the fact that it's made up of discrete objects, its trait of objectivity so that at least parts of it are not under our control, and its evident division into different kinds of things.

Divisions in known reality are particularly interesting, for when we survey everything that we know we find three primary kinds of entities —*physical, behavioral,* and *ideal*. They form orders of known reality: physical things affect other physical things, behavior interacts with behavior, and ideals are defined by other ideals. There are even unique ways in which the entities in these divisions are arranged. Physical things are ordered in *space,* behavior is ordered by *time,* and ideals are ordered by their *patterns*.

My conclusion is that unknown reality, the stuff from which known reality is constructed, is an objective continuum that becomes knowable when it is chunked into discrete objects of three different kinds. This continuous stuff ultimately determines the result; we can't construct known reality just any way we want. But the constructed reality that we wind up knowing is radically different from the material we start with.

Road Map: The Rest of this Book

For a minimum level of analysis, we might just say that known reality works because it consists of discrete things that are constructed from an objective but unknown reality. Why known reality is this way and how it comes into being are further questions this book tries to answer.

Thus the rest of this book explores the ways in which known reality is constructed, including the construction of knowledge itself. The whole process is performed by living things, and it uses both known and unknown reality as raw materials. The chapters listed below try to analyze this process in general.

- Chapter 2, "Organisms," discusses living things, the constructors of known reality. Organisms are the only objects in known reality that belong to all three of its orders—physical, behavioral, and ideal. They can exercise mastery over known reality because they are the objects that construct it and develop the means to know it.
- Chapter 3, "Constructing Reality," explores the processes by which organisms construct the reality we all live in. I find three primary techniques: objectification, categorization, and generalization. By

applying these techniques repeatedly among the three orders of known reality, life constructs everything it knows.

- Chapter 4, “Environmental Reality,” describes the known “external” reality that supports life. Organisms (ourselves included) construct this environment from both unknown and known reality.
- Chapter 5, “Organic Realities,” describes the kinds of reality that make up organic life. These include corporal reality (the bodies and actions of living things), the social reality that groups of organisms build, and the “internal” mental reality that humans and individuals of some other species construct.
- Chapter 6, “Knowledge,” analyzes the ways in which organisms, particularly humans, know the realities they construct. The primary goal of knowledge is to detect error, which helps check the validity of known reality.
- Chapter 7, “Human Realities,” focuses on the world that we humans construct and know. It uses the concepts developed in the previous chapters to explicate some specifically human ideas and institutions.
- Chapter 8, “Summary of this Book,” condenses this book’s whole analysis into a brief exposition.

2. Organisms

Man is a piece of the universe made alive.
EMERSON

The last chapter described known reality in terms of discrete objects that we know in three different modes: physical, behavioral, and ideal. Taking this reality as a whole, there are certain objects within it that are of special interest—those that are alive. I call living objects, including ourselves, **organisms**. In cosmic terms, organisms may not have much impact on the whole of reality, inhabiting (as far as we know) only one planet. But we humans are organisms, which makes this classification of objects special to us.

Organisms are also special to the present analysis. If known reality is constructed, following the metaphor that began the last chapter, then the question promptly arises, Constructed by whom? During most of human history the answer to this question has involved gods or a God, a subject I take up in Chapter 7. My answer is more pragmatic: *known reality is constructed by organisms*. Living things construct the reality they know, including themselves, just so they can know it.

Being Alive

What makes something alive? If we examine the range of living things, from viruses to mammals, we find one characteristic common to all. *Every organism is an object in all three orders of reality.* Every living thing has a physical body, exhibits trains of behavior, and incorporates ideals to define its goals and to reproduce itself.

For example, an ant scurries across the kitchen table and becomes an object in my known reality. How do I understand this living creature? Is it an assembly of chitin and tissues, molecules and electrical impulses? Is it a display of coordinated leg motions, following a trail of scent, seeking food? Or is it an example of superb technology, an object that fits an ecological niche because its construction is based on a highly evolved genetic code? It is all of these things, bundled together.

But this means that I understand the one object—the ant—in three different ways. The differences may show up in my reactions to it. If I just want to get rid of the physical ant, for instance, I brush it away. If I want to thwart the behavioral ant, I follow it and remove the food it is after. If I want to eliminate ants in general—the "universal ant"—I study the metabolic pathways or reproductive techniques of the species *Formicidæ* and design an effective control method.

To understand known reality (as analyzed in the previous chapter), we normally separate its objects into disparate orders; for instance, we know that the ideal of redness is different in kind from our behavioral sensations of red, which are different from the light beams reflected from an apple. Each of these objects is part of only one order: the ideal of redness has no physical being and does not behave, our sensations of red are not physical (unless you believe that they are "really" just nerve signals) and are not definable in terms of ideals; and physical light beams are neither behavioral nor ideal. In these cases of inanimate things, every object is present in one order of reality. Yet to understand an organism (such as an ant), we must know it as one object in all three orders, not as three objects. Organisms seem to violate the "rule" of known reality that every object is known in just one order.

Recognizing life. In our ordinary understanding, we depend on life's three-in-one nature to distinguish what it is for an organism to be alive, regardless of its other attributes. Destroy only the physical body and we have a ghost or spirit, once alive but not alive now. Stop behavior and we have something inert, hence dead, even though the physical body may remain. Remove ideals and what's left is an automaton or zombie —a physical body that may behave realistically but whose actions lack purpose or rationality.

In philosophy and theoretical science, the definition of what it is to be alive is hard-fought ground. Those who believe that nothing exists other than physical reality look for certain uniquely "organic" events, such as life's local reversal of the general tendency toward increasing entropy in thermodynamic systems. Those who accept behavior as real look for "lifelike" processes, such as metabolism and responsiveness to stimuli. Those who accept the reality of ideals look for "teleological" traits, such as evolution and purposiveness. In the case of human life (which includes consciousness), a traditional sign of ideal viability has been the presence of a "soul," which is said to leave the physical body at the moment of death.

In practical science, organisms may be identified by their presence in any of the three orders of reality. The existence of the elusive ivory-billed woodpecker, for example, is sometimes based on reports of call behavior, not on sightings of physical birds. Phages, which may be too small to be identified physically, are sometimes detected by the effects they have on the genetic coding of other organisms. Similarly, the search for "extraterrestrial intelligence" assumes that a radio signal that encodes (say) the binary digits of π would have to be sent by some form of life, even though it would be impractical to observe the sender physically or to interact with it behaviorally.

Once we discern that known reality is divided into physical reality, behavior, and ideals, identifying organisms becomes simpler: we just look for objects that are present in all three orders. Living organisms can reverse entropy because their bodies are physical; they respond to stimuli because they behave; and they have goals because they embody ideals. Some religions, including Christianity, personalize this test to characterize humanity. They recognize a corporeal body, an individual personality, and an immortal soul—three things that are united in life and separated in death.

My analysis does not depend on religious beliefs; it tries to be more empirical. Knowing the orders of reality, we look around and discover that some objects are present in all three. Moreover, those objects are all, without exception, what we call living organisms. As the analysis in Chapter 6 will show, this fit is not coincidental: organisms depend on theoretical knowledge, which they cannot create unless they are present in all three orders of reality.

Units of life. The next chapter, "Constructing Reality," examines the processes by which organisms build objects in known reality. Normally a new object automatically joins one of the three orders of reality—it is either a physical thing, a sequence of behavior, or an ideal. But in the case of organisms (including ourselves), we implicitly assume that something alive will have a body, will behave, and will be purposeful, all at once. In this way the very foundations of knowledge recognize a distinction between living and nonliving reality. Every known object that fulfills these three conditions is an organism, and if it fails one or more of the conditions it is a nonliving thing.

This criterion lets us catalog the units of life. While it is convenient to think of life in terms of individuals, it is clear that every grouping in biological taxonomy—every phylum, order, genus, and so on, as well as every species—is also a living object in known reality. Such "taxa" compete and interact in all three orders of reality, just as individuals do. Thus a species or genus may prey on another species or genus, using it as a source of support in the environment. Or one species may "outwit" another species behaviorally, by discovering better ways to access the food or shelter on which both species depend. Or a taxon as large as a phylum may evolve ideal techniques that let it dominate a particular ecological niche, to the detriment of other phyla. Such interactions within life take place in all three orders of reality and among all levels of biological grouping, from individuals up. One can even find levels within individuals: mitochondria, for example, are partly independent life forms with their own physical phenotype, behavioral functionality, and ideal genome.

A general understanding of life must recognize all its objects, from individuals through the distinguishable taxa of biology up to life as a whole. Because all those objects—and only those objects—are present in all three orders of reality, in my terminology they are all organisms.

Analogy: Playing Chess

The three-in-one nature of organisms may at first seem to violate the separation of the orders of reality. How can we know one thing that is physical, behavioral, and ideal all together? To approach an answer to that question, consider the process of playing chess—a process that resembles life but is not living. Let us ask how a position in a chess game—what we might call a "chess object"—might be described:

- *Physically:* certain pieces are located spatially on certain squares of a chessboard;
- *Behaviorally:* certain sequences of moves are possible in future time, resulting in new positions;
- *Ideally:* the pieces on the board form certain patterns.

The *physical* representation of a chess position is familiar to anyone who has seen the game. It consists of 32 or fewer little wooden tokens placed on a 64-square checkerboard. We can recite a purely physical and spatial description of the chessboard and its playing pieces that can be understood by anyone, including someone who doesn't know how to play the game.

The *behavioral* representation, described in terms of possible future moves, is more complex. It is understandable only by someone who knows how to play the game. We say that a particular pawn "guards" a bishop or that a knight "threatens" a rook. This description treats the pieces as acting in time—their guarding or threatening characteristics depend on their being able to move in certain ways in the future. It is a time-based description of the potential behavior of the chess pieces.

The *ideal* representation is couched in terms of patterns. The pieces on the board make up configurations that only an experienced player will recognize. Here's how a chess expert describes it:

> To a beginner, a position with 20 chessmen on the board may contain far more than 20 chunks of information, because the pieces can be placed in so many configurations. A grandmaster, however, may see one part of the position as "fianchettoed bishop in the castled kingside," together with a "blockaded king's-Indian-style pawn chain," and thereby cram the entire position into perhaps five or six chunks. . . . A grandmaster can retrieve any of these chunks from memory simply by looking at a chess position, in the same way that most native English speakers can recite the poem "Mary had a little lamb" after hearing just the first few words.[8]

In this way, a "chess object" may be understood as an ideal pattern made up of ideal subpatterns.

Which of these representations captures the "real" chess position? Is the position (and thus the entire chess game) a matter of physical piece distribution, temporal move behavior, or ideal patterns? Here are three equally valid descriptions of one thing, differing only by the orders of reality in which they are expressed. Yet their differences evoke entirely different ways in which chess players understand and play the game.

At any instant, the state of an organism is like a chess position. It can be described physically in terms of the distribution of molecules, tissues, organs, and other parts that make up its body; or behaviorally in terms of its actions and reactions with respect to its environment; or ideally, in terms of the plans, strategies, and other techniques it uses to function and thrive. Thus every organism is equally and conjointly a physical thing, a sequence of behavior, and a set of ideal patterns. But despite its presence in all three orders of reality, each organism is one object—just as a configuration of chess pieces constitutes one position, regardless of how it is described.

There is no paradox in the fact that a chess position has the same three-in-one character as an organism, but is not alive. Its three views exist only in the context of human life. A dog sees a chessboard only as a physical thing, a scattering of bits of wood. An ape might be trained to make "proper" chess moves and thus see it behaviorally. But only a human mind can grasp the ideal patterns of chess pieces along with their physical and behavioral views. Thus humans, who invented chess, are the only organisms who fully understand the game; in effect, chess is an extension of human life. The game is playable in three different ways because that's the way we humans deal with reality.

Aspects of Organisms

What is implied by the term "three-in-one," as I have applied it to chess and life? Is a chess position or an organism actually three different things? The rest of this book will call the three ways that life exists in known reality its **aspects.** The word "aspect" denotes a way of knowing something but not necessarily a separate part of it. The configuration of chess pieces on a chessboard is one thing that can be known in different ways. In its physical aspect it is an assemblage of pieces of wood; in its behavioral aspect, it is a set of game pieces that can move certain ways; in its ideal aspect, it is a combination of positional patterns. Similarly, in its physical aspect a living organism is a body with cells, tissues, and organs. In its behavioral aspect it is a process that metabolizes, grows, senses, reacts, and so on. In its ideal aspect it is a bundle of techniques, refined through evolution, for surviving, reacting with its environment, and reproducing—and also, in man and in some other organisms, for consciously reflecting, imagining, and reasoning.

The aspects of an organism compose its existence in known reality; they are products of our knowledge of it. Recall the discussion of known and unknown reality in Chapter 1. Every organism is united in unknown reality, but that union (whatever it is) remains unknown. What we know about an organism is what appears in known reality, and that turns out to have three aspects.

If we conflate an organism's aspects, in the interests of getting at "its real unitary nature," we just make it harder to understand. We ignore distinctions and throw away information. As living things, we know the reality around us in terms of disparate orders. When we examine other living things, including ourselves, we are forced to know them the same way. The only difference is that when we know a nonliving object—an object in what I call "environmental reality"—we know it in only one aspect: physical, behavioral, or ideal. When we know a living thing—an organism—we know it in all three aspects.

Ordinary discourse easily distinguishes an organism's three aspects while recognizing that they belong to one thing. With humans, we talk about "persons," each of whom has a physical body, a behavioral "life," and a set of ideal values and goals. It is even natural to call these three things aspects of the one person and discuss them separately. Thus, a person may be said to be handsome and eloquent but not honest. It is clear that we measure handsomeness, eloquence, and honesty on three different "dimensions" of humanity.

Having multiple aspects is the rule throughout all parts of the living world but nowhere else. We may talk about a rock in the same way that we talk about a person's body, but we do not talk about its experiences or goals. Rocks, we know, have a single aspect. Similarly, we may talk about a language in some of the same behavioral terms that we use for persons—indeed, languages are called "living" and "dead"—but we don't talk about a language's body or discuss its aspirations. And we talk in abstract terms about human ideals such as honesty and loyalty without suggesting that these ideals behave or have bodies.

Analogy: Computing

An important achievement of the twentieth century was the invention of software-driven computing. Machines that performed calculations and other data processing tasks had been proposed and built for centuries, but they all followed fixed routines determined by their construction. The insight that a machine's mode of operation could be determined by feeding into it a sequence of numbers—a "program"—opened up a whole new way of making machines perform human-like tasks.

Writing computer "software"—the instruction sequences that make computers work—has emerged as a new and unique art. Computing hardware provides an "instruction set" for the software designer—a hundred or so numbered commands that tell the computer to do basic tasks such as move data from one place to another, perform simple arithmetic, or "branch" to another instruction sequence. By stringing these instruction numbers together, with repeating loops and optional branches, software designers construct computer programs of immense complexity. Since the latter half of the twentieth century, creating and managing computer programs has become a major technology.

Early on, programmers ceased to work with the instruction numbers ("machine code") that computers actually follow. Software designers devised "higher-level languages" that allowed programmers to express generalized computer commands as lines of more-or-less readable text. Specialized programs ("interpreters," "assemblers," "compilers," etc.) converted this "source text" into machine code, which was then fed into physical computers.

Today, each higher-level programming language has its own lexicon of objects and concepts—objects such as "variables," "declarations," "statements," etc., and concepts such as "indirection" and "scoping." Programmers refer to the "software world" (as distinguished from the "real world") and often talk about it in terms that are incomprehensible to outsiders.

We could regard software design as the construction of a new kind of reality, a theme that runs through this book. It is a reality devised for programmers, with its own characteristic objects of knowledge. At the same time, it is a reality constrained by the "real world," because its purpose is to make it easy for programmers to tell computers how to perform "real-world" tasks.

When we analyze the "software world" in all its variations, we find a few common threads running through it. One thread is its division into disparate orders of objects, which software designers are careful to keep separated. These orders are commonly called *data, programs* (or "code"), and *algorithms*. We can draw an analogy between them and the physical, behavioral, and ideal orders of known reality that we construct in the "real world."

Data consists of digital representations of objects in the "real world." An example of the conversion of real-world objects into data bits was cited in Chapter 1 (page 15), which described three ways of digitizing a "real-world" image—as a physical matrix of pixels, as a behavioral sequence of drawing instructions, or as an assemblage of ideal geometric shapes. Each of these digital representations is an equally valid representation of the real-world image, but all three are fundamentally different in nature from the image itself. They are data and they are part of the "software world."

Programs convert data into other data. Ordinarily the resulting bits are translated back into real-world numbers, sounds, images, and so on, by reversing the original digitizing process. Programs are time-driven, like organic behavior; they are stepped by the computer's clock and act sequentially. Programmers think of program elements in temporal terms —do this, then do that.

What do programs do to the digital data inside a computer? Mostly they group data bits into "variables," attach identifiers to the groups, and use the identifiers to perform operations on the bits. Each variable usually has a "type" that tells what the bits inside it "mean"—whether they digitize a quantity, for example, or an image. Programmers often assemble groups of bits into "data structures," which are patterned as arrays or hierarchies. After all this grouping and labeling of data, the computer's actual transformations on the bits boil down to a relatively small set of operations—performing arithmetic, applying "bit logic," copying bits from one variable into another, and the like.

Algorithms are general techniques for manipulating digital data in useful ways to produce other digital data. To help humans understand what they do, algorithms are frequently couched in lifelike terms; but when its anthropomorphism is stripped away, any algorithm can be characterized as simply a recipe for converting groups of bits into new groups of bits. Algorithms do this by specifying patterns of arithmetic or logical operations to be performed on the bits. For example, several algorithms have been published for searching data structures to find specific patterns of bits. They have names, such as "binary search," "linear search," and "tree search." Each algorithm is an ideal pattern that guides programmers in the task of writing software.

Algorithms are independent of the programs that "execute" them. Most algorithms can be executed by programs written in a variety of programming languages, just as an idea can be expressed in various spoken languages. The differences among programs executing the same algorithm are more than just matters of expression, because different programming languages often produce different instruction sequences in the machine code that is fed to the computer.

Algorithms are expressible as ideals. They follow the logical and mathematical rules that govern numeric ideals, and they are abstract, enduring, and internally consistent. They are often the "intellectual property" in computer designs because they are the logical patterns for programs, which have commercial value.

These three kinds of objects—data, programs, and algorithms—are as disparate in the "software world" as are the physical, behavioral, and ideal orders of known reality in the "real world." Each kind of object is essential for a computer program to do meaningful work, but each can be developed independently. Data may be gathered before any program exists to process it; programs are written to process a variety of data; and computing algorithms are often devised abstractly, using tools such as flowcharting, before they are reduced to working software. The three must be brought together before a computer can do meaningful work. This is the software-world analog to saying that every organism in the "real world" must integrate its physical, behavioral, and ideal aspects to be alive.

We can draw an analogy between the components of the software world and the ways of describing a chess position, discussed earlier in this chapter. Data is like the physical configuration of a chessboard—a stored starting point for playing the game. A software program is like a sequence of chess moves, occurring step-by-step. And an algorithm is like a set of positional strategies for achieving some goal in the game.

Computers and organisms. Computers are not organisms and they are not alive. Why? Because their data, programs, and algorithms are not all aspects of a single object. These components of a computing system are built separately by humans, who endow them with physical, behavioral, and ideal characteristics to suit human needs. The resulting computer is an assembly of three objects in known reality that were never unified in unknown reality.

Every organism, in contrast, is unified because its three aspects are objects in known reality derived from a single base in unknown reality. But that process cannot be reversed—we cannot force together the three parts of a computer in known reality and expect to find them unified in unknown reality. Thus organisms are alive and computers are not.

Individuals and Species

The term "organism" is commonly applied to an individual animal or plant. Here I apply it also to species and other taxonomic divisions, up to the whole of life itself. Every taxon—every species, genus, etc.—is part of the three orders of known reality, just as every individuals is. The bodies of all the individuals descended from the taxon are a part of the physical order of known reality, the totality of their behavior is part of the behavioral order, and the strategies for reproduction and survival that are typical of the taxon are part of the ideal order. For example, the totality of passerine birds is an object in known reality—as a physical presence, as a mass of singing and other behavior, and by the set of perching techniques that are characteristic of the order *Passeriformes*.

How do biologists define a taxon, such as a species or a genus? By calling it a natural group of individual organisms that can be identified as a group over many generations. Beyond that simple idea, biologists have proposed at least a dozen more precise definitions, based on how they compare one or more aspects of individual organisms:

- Individuals of a "physical" taxon share easily recognizable body characteristics. Species are particularly easy to separate physically because interbreeding tends to conserve physical traits. The taxa that are distinguished this way in everyday biology cover most plants and "lower" animals.
- Individuals of a "behavioral" taxon share recognizable behavior traits, such as specific mate selection activities or the skills needed to survive in an ecological niche. Sometimes these traits are used to identify a subspecies or variety within a species. At the other end of the taxonomic scale, behavior such as photosynthesis may be used to distinguish very large taxa.
- Individuals of an "ideal" taxon share genetic coding, either from a common ancestor or through continued interbreeding. Our ability now to map the DNA of individuals makes it possible to test this definition for the simpler taxa, particularly species. From it comes the popular notion of a species as a group of individuals capable of breeding and producing fertile offspring.

Biologists today distinguish an individual's genotype—its genetic code inherited from other individuals of its species—from its phenotype—the individual's specific physical characteristics. Some biologists also talk about an individual's ethotype—its trains of behavior, including its physiological processes. The primary reason for using this terminology is to distinguish the variations shown by individual organisms within a given taxon.

Although species are not as clearly identifiable as individuals, most biologists have increasingly applied these "type" terms to them as well. For example, the purpose of Human Genome Project was to map the common genetic inheritance of mankind, not just the genotype of one person. Similarly, the term "phenotype" is frequently used in scientific literature to denote the physical features of a species or higher taxon, such as the mammalian "adipose tissue phenotype."

Thus biological terms originally adopted to characterize individual organisms are now commonly applied to species and higher taxa. They are used to denote the typical genome, physical type, and behavior traits that a species or higher taxon passes on to its members. In this way, such terms implicitly recognize that every taxon is an object of knowledge in all three orders of reality.

Richard Dawkins goes a step further and includes in the phenotype of some species all the effects that its individuals may produce on their environment.[9] Common examples of these effects include beaver dams and termite mounds. On this view, some species construct considerable "extended phenotypes" in physical reality, with humanity perhaps the foremost example. By analogy, we might also argue that the human species extends its genome by selectively breeding other species and exports its ethotype by domesticating plants and animals for its use.

Discussion: Speciation

The last chapter introduced three actions that are fundamental to the construction of known reality: chunking, grouping, and relating. Since life—the sum total of all organisms—constructs itself as part of known reality, we should expect to find it performing these actions. In fact, chunking, grouping, and relating are the primitive actions that underlie speciation and evolution.

One may ask the question: Why did life, emerging from unknown reality to construct itself and its known reality, wind up comprising billions of individual organisms in competing species? Why not just construct one organism? The answer is that if life had done that we would not recognize the result as alive. Instead, the available tools—chunking, grouping, and relating—afforded life the opportunity for a more complex approach, but one that ended up with the part of known reality that we recognize as living.

Each individual organism is a result of chunking reality, a coherent thing that lives by virtue of its separateness and coherency. Unlike inert physical objects, individual organisms cannot be arbitrarily divided and combined into other individuals. The construction of such inherently separate and coherent chunks is the most basic operation of life.

But if life consisted only of nonreproductive chunks—such as a host of individual cells floating in a primeval broth—we would again not see it as alive. It would look more like the result of some kind of chemical coagulation. So the next step was for life to construct groups of chunks, which we know as species. Each group would have a group identity because it would be capable of adding more chunks to itself.

Yet even then we would not recognize the result as living. A unique feature of life is that when we compare individuals within a species we find them generally alike, but when we compare them between species we find them generally unlike. And this result is not just an artifact of the way we know organisms; it is a feature constructed by organisms themselves, using the relations of "like" and "unlike."

The complete "recipe"—constructing individual organisms that are grouped so that parts of them within each group are alike but the same parts of them in different groups are not—creates what we know as life. The same recipe also lets life evolve. Once the groups of individuals that we know as species can generate new individuals that are like each other, but not like those of other groups, then groups can compete as a whole with other groups. The payoff for group competition is that the groups which succeed are able to evolve new kinds of life.

Constructing the Environment

Organisms constitute only a fraction of known reality: they are those objects that have more than one aspect. All other objects constructed from unknown reality are either just physical, behavioral, or ideal; they fill the **environmental reality** discussed in Chapter 4. Life constructs this "external" reality from unknown reality so it can know it. Thus we and other organisms literally live in a world of our own making.

A rock is dead because it is only physical; it does not behave nor does it represent an ideal pattern. Physicists may find ideal patterns in the rock's crystals, or primitive animists may regard the rock as having magical powers, but these attributes are *theoretical* constructions, a subject discussed in Chapter 6. They are not part of what an organism first recognizes when it chunks a rock out of unknown reality to make it known in environmental reality. Similarly, a word is only behavioral and a triangle is only ideal. We know all these objects as parts of single orders of reality, and taken together they constitute an environment that is distinct from the reality of living organisms.

When an individual organism dies, its three aspects in known reality separate and change. The organism's body becomes only physical and disintegrates as one would expect complex proteins and carbohydrates to do. Its behavior, deprived of physical expression, no longer supports a temporal "flow" (see page 103). The ideals that it inherited from its species and passed down to its progeny become knowable only through the ideal aspects of other organisms. At death the three-in-one objects that are living individual organisms become three separated objects in the disparate orders of known environmental reality.

Why should life construct the environment that it knows in multiple orders? One answer is that the objects in disparate orders "explain" or "give meaning to" one another. Organisms construct reality so they can know it, and they construct it in three orders so they can understand it. How this process happens and what kinds of reality result from it are subjects discussed in more detail throughout the rest of this book.

Analogy: Computing Processes

A few pages ago, this book compared organic life with computing—not because they are inherently similar, but because the engineers who try to make computers life-like have often been guided in their work by an implicit understanding of how life works.

This analogy can help us understand how organisms can function in three orders of reality and still be single objects. Consider a computing process as a whole. Our understanding of it naturally divides such a process into three aspects: the data to be transformed, the algorithm that defines its transformation, and the software that does the work. These three aspects appear in different forms in the whole process—the data as bits, the algorithm as logical relations, and the software as program steps. We can draw an analogy between these aspects of a computing process and the physical, ideal, and behavioral aspects of an organism.

For example, a typical computing process might accept time card data—hours worked and hourly wages for each employee in a work group—and put out a list of payroll amounts. The data aspect of this process would be numbers that represented tangible things: physical people, hours of work, and cash to be paid for each hour. Its algorithm aspect would be abstract: multiply the hours assigned to each person by the person's wage rate and associate the result with that person. The software aspect of the process would contain a series of actions to be performed: fetch two binary numbers, multiply their least significant bits, remember the carry bit, etc. These aspects are not only distinct parts of the computing process but they would also be separable tasks for a human accountant using pencil and paper—fetch the time cards, define the arithmetic involved, and do the calculations step-by-step.

Each aspect of this process, whether it is done by a computer or by a human organism, "gives meaning" to the other aspects. For example, the algorithm makes data such as hours worked "meaningful" because it tells the computer how to process the data usefully. Other data, such as telephone numbers and street addresses, would be "meaningless" to the algorithm because multiplying such numbers together would not yield any intelligible result. The algorithm also gives meaning to the processing program, because it explains why certain actions must be performed in a certain order.

Conversely, the data gives meaning to the algorithm. Just defining the task as multiplying two numbers together for each employee does not provide an understanding of what the algorithm "does." We need to know what the numbers represent—in this case, hours and a wage rate—before we can understand that the algorithm calculates payroll amounts. The data also gives meaning to the software, which branches differently depending on the data's values (carrying overflow bits or not, for example). We could, in principle, list all the possible sequences of program steps that might be executed and explain each sequence in terms of the combination of input numbers that invokes it.

Finally, the software and the algorithm give meaning to each other. Each explains what the other is about. For every algorithm there is a limited group of programs that "realize" it and for every program there is a limited group of algorithms that it might be trying to realize. Our understanding of one leads to an understanding of the other.

If we were to understand known reality in narrow terms, we might consider every computing process to be merely a complicated way of pushing bits around. Binary numbers go in, other binary numbers come out. In these terms, every living organism would just be a complicated way of transforming energy in a mechanical world. But known reality is not so narrow; it has disparate orders that are understood in different ways. As computers use different kinds of technology to get their work done—digitization to create data, logical analysis to devise algorithms, and programming to make software—so organisms construct different kinds of known reality to get work done in their environment.

Metabolism, Choice, Purpose

In each of their three aspects—physical, behavioral, and ideal—living organisms display characteristics that set them apart from all nonliving things. In physical reality they carry out *metabolism,* in behavior they exercise *choice,* and in ideals they evidence *purpose*. Understanding how these processes work is central to understanding what life is.

Metabolism, a physical process found in every organism and only in organisms, harvests energy from the environment and uses it to build the organism's physical body. By the act of concentrating energy, life runs counter to the "principle of entropy" that appears to hold for all nonliving physical processes in environmental reality. This principle predicts that every thermodynamic change tends to distribute energy, not concentrate it. As soon as an organism dies and its metabolism ceases, its accumulated energy starts to dissipate in accordance with the principle. Physicist Erwin Schrödinger put it this way:

> What an organism feeds upon is negative entropy. Or, to put it less paradoxically, the essential thing in metabolism is that the organism succeeds in freeing itself from all the entropy it cannot help producing while alive.[10]

Taking this cue, some automated experiments sent to the planet Mars looked for reductions in entropy as indicators of the presence of life.

How are organisms able to reduce entropy? Explanations that focus on purely physical processes collide head-on with the second law of thermodynamics. Explaining this trick requires an understanding of how behavior and ideals contribute to an organism's physical actions. Some scientific headway is being made through the concept of "Gibbs energy," the energy in an adiabatic system that is available to do work. One theory, which we may call the physical-ideal approach, associates "information" with available energy and has organisms increasing their complexity (thus reducing their entropy) by sucking information out of the environment.[11] Another theory, a physical-behavioral approach, has organisms selectively absorbing sunlight and nutrients, rich in Gibbs energy, while discharging high-entropy heat.[12]

Both theories require that organisms *choose,* in effect, to extract whatever they need from their environment, thereby defeating the mechanisms of thermodynamics. But how can a theory expressed in purely physical terms explain the process of organic choice?

Choice appears whenever change is inherently unpredictable. We can fairly well predict the path of a ball on a billiard table if we know its mass, velocity, direction, spin, and so on. We can only guess at the path of a live mouse on the same table. This is not because we lack full information about the mouse; it is because we know that the mouse can exercise choice, which makes its actions inherently unpredictable. We may influence the mouse's movements, using bait or electric shocks, but we can never fully eliminate the uncertainty that is a consequence of its power of choice.

Why are the physical actions of a mouse inherently unpredictable? It is because they stem from more than one order of reality—they are both physical and behavioral, or both physical and ideal, or a combination of all three. When a live mouse acts, any or all of its three aspects may come into play and influence its physical aspect. Trying to explain the motions of a mouse's body in purely physical terms is possible only if the mouse is dead.

In a typical instance, a physical stimulus impinges on the physical aspect of an individual organism. The organism relates the stimulus to a standard, either learned or inherited from its species. The relation that results determines whether the organism's behavioral aspect invokes one response or another—investigation or inattention, fight or flight, etc. Both behavior and the physical environment are involved in the choice. That's why the choice appears unpredictable when viewed in only one order of reality, such as only physically.

Purpose is evident when a series of events tends toward a goal. The common image is of a ship on the sea, which constantly reorients itself toward its destination port after being displaced by wind and currents. Such "goal-oriented behavior" by a physical object (such as a ship) suggests two facts:

- A living organism is directing the ship, or has designed it to execute a "seeking routine." The ship is not tending toward a goal, despite being displaced, solely as a result of physical processes.
- The ship is being guided by an ideal pattern, such as a map. Its path of motion is not being determined by a future physical state, such as "ship in harbor." If the map is faulty, the ship will not find the goal.

In his *Metaphysics,* Aristotle describes four kinds of causes: *material, efficient, formal,* and *final*. In the terminology used here, we could call material causes physical and efficient causes behavioral. They are the two ends of "causal links," discussed on page 183. Formal and final causes both involve ideals, a formal cause being an ideal pattern and a final cause (τελος) being a purposive goal.

Aristotle treated teleology, or "causation working backwards," as a normal principle of nature. An acorn grows into an oak because final causes draw it toward its formal cause, "oakness." But modern physics, which studies a nonliving reality that always works forward in time, has accepted teleology only grudgingly. Some physicists feel that it might be useful as a statistical concept in thermodynamics—for example, as explaining the "heat death" toward which the universe is said to be tending.

In the terminology of this book, a final cause can "work backward" in time because one end of the "causal link" is an ideal pattern, which is timeless. Purpose appears in known reality whenever an organism makes a behavioral choice on the basis of an ideal goal instead of a physical stimulus. The ideal goal is not something that happens after the choice; it is something that subsists independently before, during, and after.

In modern genetic science, based on Darwinian evolution, one may say that survival and replication emulate teleology by loading the acorn with a set of instructions for growing into an oak—instructions that are in the acorn because they have been tested and found to work in past generations of successful trees.

Both Aristotle's final causation and Darwinian genetics depend on the ideal aspect of organisms. Aristotle focused on an ideal model, "oakness," without which the fact of acorn growth was inexplicable. Darwin focused on the way that the same ideal model was constructed, through generations of evolution. In Aristotle's understanding, a "final" cause—working backward through time—was no more mysterious than other causes that worked forward. But in Darwin's understanding, final causes were "unscientific"—the acorn's growth had to be explained in terms of forward causes. Thus he analyzed the evolutionary process, which showed how final causes could be constructed in present reality.

Recognizing the role of ideals in life lets us understand how "final" causes are possible: it's because species construct ideal genetic codes that are inherited by individuals. The code is an abstract pattern—a sort of "blueprint" for constructing individuals. Each individual propagates the code (perhaps with minor changes) or does not. The sum total of all propagation events determines the state of the code in the species. The code in each individual is a part of that individual's ideal aspect, as real as its body or its behavior. The code of a species is also a part of ideal reality, called the species' genome. It is embodied in codons and can be expressed as 3-character "words" that a computer can process.

Analogy: Object-Oriented Programming

The first computer programs were written in a style that is now called "procedural." Data was stored in computer memory, and procedures—sequences of data-changing instructions—were "called" one at a time to transform the data in some way. The sequence in which various kinds of procedures were called was determined by the program's algorithm, its data-processing pattern.

The basic elements of procedural programming were kept carefully apart. Procedural instructions were different from data encodings, which were different from algorithms. Following our earlier analogy—in which data is physical, software is behavioral, and algorithms are ideal—keeping these three elements separate was like constructing a purely environmental reality. The "world" of procedural computing contained no "living" entities that bridged between its orders of reality. Data was data, software was software, and algorithms were algorithms. These three components were made to work together only by means of explicit directions from a human programmer.

In the 1990's a new style of programming emerged, called "object-oriented." This kind of software uses "objects," programming entities that mix data with procedures appropriate for it. Objects are said to be "instantiated" from "classes," which serve as templates for generating new objects. Objects interact with each other by sending "messages," encoded strings of bits that cause an object to apply one of its methods to some of its data. In a commonly cited example of object-oriented programming, a circle object might be sent a message telling it to "draw itself," whereupon a circle would appear on the computer screen.

The objects in object-oriented programming are patently lifelike. Besides performing tasks on their own—without the constant guidance of a programmer that procedural programming required—the classes of object-oriented programming can "inherit" capabilities from "higher-level" classes. Thus the circle object is able to draw itself because it has inherited the ability to draw from a higher-level object that "knows" how to create figures on the screen. Object-oriented software becomes populated with quasi-biological entities that reproduce, pass skills from generation to generation, and talk to each other. These software entities are actors, not just tools.

Object-oriented programming has made it easier for programmers to compose software that performs human-like tasks. In 2005, computer scientist Niklaus Wirth, one of the early proponents of object-oriented programming, described how it differs conceptually from procedural software:

> The novelty is the partitioning of a global state into individual *objects,* and the association of the state transformers (called *methods*) with the object itself. The objects are seen as the actors, causing other objects to alter their state by sending *messages* to them. The description of an object template is called a *class* definition. This paradigm closely reflects the structure of systems "in the real world", and it is therefore well suited to model complex systems with complex behaviour.[13]

Note that nothing has really changed inside a computer running the new style of program. At the "machine level," procedures are still called to modify data. What has changed is the way that programmers direct the machine's work. Instead of writing recipes of detailed instructions (fetch this data, multiply it by 2, compare the result with other data, etc.), programmers send commands to autonomous software "objects," which already "know" how to perform complex tasks and have inside themselves the code routines that do those tasks.

We can draw a parallel between the introduction of object-oriented programming into software design and the emergence of organisms in environmental reality. As Wirth noted, it was a case of art imitating life. Redesigning software to contain lifelike entities—new programming structures that combined physical data, behavioral operations suitable for that data, and computing patterns inherited from ideal algorithms—simplified the task of making computers perform as if they were living servants instead of nonliving calculators.

Repurposing and Iteration

Biology students of an earlier generation used to be treated to Ernst Hæckel's 1866 dictum that "ontogeny recapitulates phylogeny." The phrase meant that the stages of development (particularly embryonic) of many individual organisms mimicked the adult forms found in the evolution of the individual's species. Hæckel pointed out, for instance, that human embryos at one stage have gills, like the fish that were an early part of the human family tree.

Hæckel's idea, which was based or morphology instead of genetics, is no longer credited. But it served to expose many instances in which similar living techniques show up in different organisms, often with a direct line of genetic descent between the two. A more current view (1977) is Stephen Jay Gould's, that evolution is a mixture of processes which introduce new techniques and which repurpose old techniques by changing their timing in the developmental sequences of individuals:

> Evolution occurs when ontogeny is altered in one of two ways: when new characters are introduced at any stage of development with varying effects upon subsequent stages, or when characters already present undergo changes in developmental timing. Together, these two processes exhaust the formal content of phyletic change[14]

Thus life is both ingenious and thrifty. Once it has discovered how to do something in one area reality, it often tries to apply that technique to other areas, to see if it works. Like a cook trying old recipes with new ingredients, evolution tends to "repurpose" organic techniques that have already been found to provide survival value.

The same tendency shows up in human engineering disciplines. For example, when the Wright brothers had to design the frame of a flying machine, they called upon their experience building light, rigid frames for bicycles. Similarly, early automobile suspensions were constructed by coachbuilders; and so on. To an engineer, repurposing old solutions is often a useful and efficient shortcut.

Several places in the rest of this book will cite this general tendency of life to apply old technology to new problems. Such repurposing has played a key role in life's evolution. Life's widespread reuse of proven technologies also means that its success in constructing and knowing reality is based on a remarkably small number of basic techniques.

Organic iteration. Iteration is a common programming technique in which a data transformation is repeated, applying it each time to the result of the previous transformation. This technique is used to produce "cellular automata," graphic transformation systems that tend to act in lifelike ways. A popular example was the *Game of Life,* devised in 1970 by mathematician John Horton Conway.

Biologists today use computers to run cellular automata that model organic tissue growth. The computer iterates a single transformation, applying it separately to all the "cells" in a field, and the states of the field as a whole after each set of iterations model the states of a living tissue as it grows.

Cellular automata can be run visually, on a computer display. From a simple beginning, such as a figure consisting of a few black squares and an algorithm for adding more black squares based on the existing state of the figure, an automaton can fill the screen with complex designs. This was amply demonstrated in 2002 by Stephen Wolfram, who went on to speculate about "a new kind of science." He showed that many physical systems, constructed by iterating simple behavioral processes of computation, are very difficult to describe using ideal mathematics. They are "too complex." He concluded that

> it is perfectly possible for systems even with extremely simple underlying rules to produce behavior that has immense complexity—and that looks like what one sees in nature.[15]

Wolfram proposed an approach to knowledge based on computation—in effect, a formal discipline designed to emulate organic iteration.

Organisms regularly use iterative techniques to produce complex tissues out of simple ingredients. The key requirement is the interplay between two orders of reality—the behavioral action being iterated and the physical result of each iteration. For example, the result of each cell division in a living tissue is "saved" physically, becoming the base state for the next cell division. Only when two orders of reality collaborate, as happens in a living organism, is such a technique possible.

Summary of this Chapter

Life is something unusual in the world. Living things, which I call organisms, break several "rules" that otherwise hold in known reality. Their metabolic processes accumulate local stores of energy instead of dissipating them; they make choices that render many of their actions unpredictable; and they evidence purpose, actions that follow a plan.

Organisms can break rules because they created them, and they can create rules because every organism belongs to all three orders of known reality. They have physical, behavioral, and ideal aspects—a three-in-one existence in known reality that nonliving things don't have. In fact, life constructs known reality the way it does just so it will occupy this privileged position.

When I talk about organisms as the units of life, I include the many ways that the phenomenon of life can be divided. Organisms comprise not just individuals, but also species, genera and other taxa. These units of life, which interact with one another, all share the exceptionality of life in known reality. From the viewpoint of my analysis, the single ant and the phylum *Arthropoda* are both living organisms, although they differ in size and complexity.

In their physical aspect in known reality, organisms construct the bodies we recognize as living individuals. In their behavioral aspect, they construct the behavior that drives those bodies, from metabolism to communication. In their ideal aspect, organisms construct the goals and values that pattern behavior, as well as the genomes that determine the replication of new individuals. An organism remains alive as long as its three aspects remain united as a single thing in known reality.

Life is parsimonious. Once it has come up with a useful method to construct itself or the environment within which its organisms live, it tries to use that method as many ways as it can and as often as it can. Thus repurposing and iteration are fundamental techniques by which organisms succeed. This means that we can understand how life works by identifying only a few basic processes. A survey of these processes forms the subject of the next chapter.

3. Constructing Reality

> Whether something is a whole always depends on the point of view from which you look at it.
>
> MARY MIDGLEY

The preceding chapter characterizes organisms—the components of life—as the only objects that are present in all three orders of reality. Although it is unified in *unknown* reality, every organism has separate physical, behavioral, and ideal aspects in *known* reality.

Life has this three-in-one character because it has constructed itself that way out of unknown reality. The bodies of organisms are objects in physical reality, located in space; the behavior that animates them is a series of processes that take place in time; and the techniques that let life survive and evolve depend on ideal patterns. Only through such a combination of physical, behavioral, and ideal aspects can life exist.

While building itself, life has also built the rest of known reality. Thus all the characteristics of known reality discussed in Chapter 1—including its separation into objects in disparate orders arranged by space, time, and pattern—result from the work of living organisms. As a part of constructing itself and the knowledge it needs, life builds the reality it knows. How life does that is the subject of this chapter.

Knowledge and Constructed Reality

Why construct a known reality that is different from unknown reality? Like many simple-sounding questions, this one has a simple answer: *we and other living things construct known reality just so we can know it*. Yet this question and its answer have many ramifications. Knowledge and known reality are related in the sense that to achieve knowledge, we must construct the reality we want to know.

The question and its answer would be trivial if all knowledge was canonical—that is, if for any part of unknown reality the act of making it known always produced the same result. But experience tells us that this is not the case. Trying to know reality is always a struggle, and the history of that struggle is filled with disputes about knowledge. While some disputes are the result of imperfect understandings, most are the result of different constructions of the reality being known.

The mechanisms of reality construction. Organisms construct known reality, including themselves, using the basic actions described in Chapter 1—chunking, grouping, and relating. Living organisms are the only objects that can carry out these fundamental acts, and only by means of them has life been able to build the world we know.

What I call "chunking" takes a part of reality that is undifferentiated and delimits an object in it. The result is something a living organism can identify, a singular item in reality that is separated from everything else. Grouping takes multiple objects and makes of them a new object —their group. An act of grouping six objects, for example, winds up with seven objects: the original six and a seventh object that is the group. Relating takes two or more objects and constructs a third object that is their "relation." The relation object is different from any of the objects that are being related. The organism performing the relating understands the relation as something new in known reality.

These three actions, which I call the basic mechanisms of life, are all astonishingly simple. Each is a single operation upon reality, and each produces as its output one new known object—something that was not known before. Yet by using these operations repeatedly and in multiple combinations, building new objects by grouping or relating old objects as well as by making new objects from unknown reality, life constructs all the reality that we and other organisms know.

An earlier section (page 50) described the "repurposing" of organic techniques as life evolved. Once a living process has been found useful for one purpose, life tends to use that process in other tasks whenever it can. Thus, if the primal techniques of life are chunking, grouping, and relating, we may expect to see these techniques show up in nearly everything life does. In fact, *they produce the division of known reality into physical, behavioral, and ideal orders*.

Therefore I begin analyzing reality construction by envisioning these techniques being applied to unknown reality as the primitive first phase of making it knowable:

- Chunking turns a part of unknown reality into an object in known physical reality by constructing boundaries around it and locating it spatially.
- Grouping is an act of behavior that constructs a group from multiple objects. The group then becomes a new object in known behavioral reality. Because a group cannot be formed without the objects it groups, organisms establish a temporal order between groups and their members.
- Relating is the action of constructing a pattern among objects. The pattern then becomes a new object in its own right, a part of ideal reality. The most basic of such patterns is the dichotomy "like" and "unlike" between two objects, which shows up in logic as equality and inequality.

This is only the beginning of our analysis. We must next consider what kinds of reality life constructs by means of these fundamental acts—in particular, how life constructs itself and its knowledge as integral parts of known reality.

Yet these simple mechanics show us that life needs no complicated inventions to emerge from unknown reality. Indeed, it is not surprising that out of the great mass of unknown reality objects are somehow chunked, groups are formed, relations are made, and in this way life is launched, including the potential for all its variety and evolution.

Objectification, Categorization, Generalization

Thus living organisms construct known reality by repeatedly chunking, grouping, and relating parts of unknown reality. The aspect of organic life that does this is part of the order of reality that I call behavior, and behavior is composed of what I call *processes*. So the next step in our analysis of reality construction is to describe the behavioral processes by which organisms perform acts of chunking, grouping, and relating.

I call these organic processes *objectification, categorization,* and *generalization*. They are the three fundamental techniques by which life constructs the reality it knows.

These reality construction processes build on one another and take place everywhere and all the time. Analyzing them as phases of living behavior helps us understand both how life constructs reality so it can be known and how it constructs the knowledge that knows that reality.

Objectification is the phase in which organisms "chunk" reality into discrete, separately identified objects. Categorization is the phase in which organisms group multiple objects into what I call "categories." Generalization is the phase in which organisms construct what I call "models" by relating categories logically, one to another.

Objectifying, categorizing, and generalizing—chunking out objects, grouping them in categories, and making general models by combining categories—make up an endless process. While the process may start by chunking new objects out of unknown reality, the categories and models that it constructs around them readily become more objects in known reality. The processes feed on their own products, building the complex physical, behavioral, and ideal reality that living things know. This known reality ultimately comes from unknown reality, but much of it is constructed "second-hand," building new known reality upon objects that are already known.

Objectification. When an organism objectifies a part of reality, it sets boundaries around it—spatial, temporal, or relational. It decides (in effect) to know just so much of a specific area of reality, and no more, treating that specific area as a single object of knowledge.

One reason why organisms objectify reality is economics. However we might define an organism's "resources for living" (say, in terms of available energy), those resources are always limited. Objectification focuses an organism's resources into a conveniently small number of channels—one per object—instead of spreading them over its entire environment. Working with a few specific objects, instead of with its environment as a whole, helps an organism operate more efficiently.

Instances of objectification are common in studies of vision. Human vision, for example, typically alternates between "saccades"—rapid eye movements during which little is observed—and "fixations," where the eye settles on a specific part of the visual field and interprets it. Each eye fixation objectifies some part of what William James famously called the "blooming buzzing confusion" of visible reality. Similarly, most insects that have eyes see only certain kinds of objects or events in their environment, such as things in motion. An insect philosopher might describe known reality as that part of unknown reality on which his species is able to fixate, the rest being intrinsically unknowable.

But objectification is not just a way of seeing the world—whether by humans or insects—or indeed of using any sense organs. It shows up as well in scientific research, where objects are revealed by instruments.

Telescopes help us recognize distant galaxies and distinguish them from the background radiation of the universe; microscopes reveal tiny structures inside cells; chemical analyses separate elements from one another; high-energy accelerators wrest particles out of atoms; and so on. In every area of knowledge, objectification produces a fundamental "chunking" of reality that is prerequisite to every other transaction with it. Objectifying unknown reality is the starting point for making it knowable.

Categorization. While objectification is a process of separating out specific parts of reality, categorization is a grouping process. Multiple objects are "subsumed" under a single category. Again, the economics of living is part of the justification for this process. Every organism maintains a supply of responses to its environment, and the fewer the responses in the organism's repertoire the more efficiently it can work. Categorization lets each response cover many objects—perhaps not perfectly (one size never fits all), but adequately and efficiently. The role of categorization in supporting responsiveness is one reason we say that it "gives meaning" to objects in known reality.

But there is another result of categorization that is truly wonderful. The objects in any category are freely chosen. The list of those objects may be valid or mistaken, useful or useless, *but it is not preordained*. An organism builds categories while trying to understand reality. Each category is a sort of experiment—a trial to see whether a specific grouping of objects makes sense. If it doesn't work, the organism tries other categories, which group objects differently. This *freedom* to form categories is the key to knowledge, evolution, and free will. *If there was ever a single explanation for the miracle of life, this is it*.

Organisms often exercise freedom of choice and suffer the potential of error in objectification and categorization. Recall the struggles of the sycophantic courtier Polonius in Act III of *Hamlet*:

> *Hamlet*. Do you see yonder cloud that's almost in shape of a camel?
> *Polonius*. By th' mass, and 'tis like a camel indeed.
> *Hamlet*. Methinks it is like a weasel.
> *Polonius*. It is back'd like a weasel.
> *Hamlet*. Or like a whale.
> *Polonius*. Very like a whale.

Although most objects in known reality are more substantial than clouds, setting their boundaries and determining their categorizations can be a problematic task.

We might say that objectification chunks unknown reality into known objects, while categorization bundles those objects together in ways that let organisms "understand" them. The power of these two processes, as life carries them out alternately, is that the bundles—the categories—are routinely objectified into new objects. By objectifying categories, organisms construct new objects in their known reality that are not directly derived from unknown reality.

How does categorizing objects help organisms "understand" them? In the business of living, organisms tend to respond differently to every object, as a consequence of circumstances, lack of skill, mistakes, and so on. If objects were not grouped into categories, then the business of living would be just "one thing after another"—organisms would never apply the responses they used with one object to other objects. But when objects are grouped, the collection as a group becomes an object of knowledge. An organism cannot respond to a group object in the same way that it responds to the group's members, but it can respond in the same way to all the members of the group. Hence we say that the organism "understands" the members of the category group because it can now apply a single response to all of them.

As a consequence of organisms constantly categorizing objects and then objectifying those categories, knowledge develops cross-linked tree-like structures of understanding. As objects become understood, the understandings become new objects. When this scenario plays out across the three orders of known reality—objects in each order being understood by categories in the other orders—the evolving result is the richness and complexity of known reality.

Generalization. An organism's main goal in objectifying unknown reality is to create a known reality that contains a manageable number of bounded objects. But in creating new objects by grouping existing objects, the process of categorization tends to increase that number. New categories and objects made out of categories proliferate beyond their origins in unknown reality. The solution to this proliferation lies in the third phase of the process of constructing known reality, one in which the multiplicity of categories is refined down to a smaller set of universal models.

The generalization phase of reality construction uses what we know today as "logical operations" on categories to construct new groupings of the objects they subsume. Thus a model group may contain "every object that is in category A and also in category B but not in category

C." A model differs from a category because constructing it requires calculation. An organism must use a formula such as "A and B but not C" to construct a model, going beyond simple categorization. For this reason, models are usually constructed by species and higher taxa; only in humans and a few other species do individuals construct models.

For example, a species may evolve the ability to recognize objects that are common to several known categories, thus letting it construct new categories that include only those objects. These new groupings "recategorize" objects that have already been categorized in other terms, and each such grouping can then be objectified into a model against which other objects can be related. The species incorporates the model in the genetic instructions that it passes to its individuals, who then use it to understand new objects in their environment.

When constructing models of known reality, organisms usually try to discard the "inessential" parts of objects or categories, retaining only what is common or "universal." Then a new thing can be tested against the model by seeing whether or not it exhibits the universal traits that the model shows in pure form. This process reflects the philosophical issue of "essence versus accidents"—determining what parts of a thing are or are not essential for it to be what it is. For instance, inflatability is part of the essence of a balloon, but red color is an accident. Making such distinctions is an important skill in life.

Objectification, categorization, and generalization all use grouping and division as fundamental operations. We can think of objectification as a one-to-many division, from the continuum of unknown reality to the many objects of known reality. Categorization, then, is a many-to-many grouping operation, as many objects are variously grouped into many categories. Generalization, finally, is a many-to-one reduction—from many categories that explain specific objects to a few general models that can be used universally. These three ways of constructing known reality produce a kind of balance between the proliferation of objects and categories and their winnowing down to a manageable set of generalizations.

Models and categories. All organisms construct categories to help them understand known reality, and most species and higher taxa build models as well. These models show up as patterns of "reflex chains," where the completion of one reflex action triggers the start of the next. In many animals, for example, the reflex actions of salivation, biting, chewing, and swallowing follow a model constructed for the ingestion of food. Each species passes these models genetically to individuals, who do not need to understand or reproduce the logic by which the models were constructed.

The models that species evolve often appear as "wise" instinctive behavior in their individuals. A limited number of "intelligent" species, including humans, also give their individuals enough neural resources to perform the logic needed to construct new models. For us humans, the construction of models by individuals is an important part of our success as a species.

Organisms, both species and individuals, build models primarily as a part of constructing knowledge. Hence I will defer further discussion of models to page 196 in Chapter 6, "Knowledge." Categories, however, become objectified in the construction of all parts of known reality. For example, the categories "circularity" and "squareness" are objectified to "circle" and "rectangle," as abstractions from diverse perceptions of objects in known reality. But the model "geometric shape," constructed through a formula such as "circle or rectangle or . . . but not irregular or broken . . .," is built to aid our knowledge, not because we naturally distinguish geometric things from irregular things. We construct both knowledge and the objects that knowledge knows to populate our known reality, but we construct them for different reasons.

Analogy: Set Theory

Although barely a century old, set theory has become a cornerstone of modern thinking. For instance, the concept of the set is now widely accepted as the starting point for all mathematics. I believe that the reason why set theory has achieved such a grip on human thought is because it recognizes, in the discipline of formal logic, one of the basic operations that people use when constructing known reality. This is the operation of recognizing an aggregation of objects as an object in its own right, different from and independent of any of its members.

A set is simply a collection of things of any kind, considered as a group. The power of this concept stems from the idea that *the set is a new thing by itself,* different from its members. By forming a group we create an object.

Among the things that might be collected into a set are other sets. For example, we might form a set of all the inhabitants of a village, plus a number of other sets each of which contained the members of one family in the village. Then we could form a set of all the families in the village. This set would be a completely different thing from the set of all the inhabitants, even though the ultimate "real" constituents of both sets—people—might be the same. The set of inhabitants would still be a set of people, but the set of families would be a set of other sets.

Thus set formation can be thought of a tool for making new things—sets—that are considered to be as real as the ingredients from which they are made. In these terms, set formation resembles the construction of known reality being described in this chapter. We could expand the analogy this way:

- **Objectification** is like forming a set out of some part of unknown reality. The members of a set do not need to be countable or discrete—for instance, they can be points in a region of space. The principal requirement is that we be able to tell whether or not a given thing is or is not in the set. Hence our saying that an object in known reality is like a set whose members are parts of unknown reality need not ascribe any properties to unknown reality beyond the possibility of separating parts of it from other parts. "Object sets" can be formed simply by delimiting parts of the continuum of unknown reality.
- **Categorization** is like forming a set whose members are sets. Thus the object sets made by delimiting unknown reality may become members of new "category" sets. At first, categories would only be sets of object sets that we associate in some way—for example, "red objects." But as sets, categories may themselves be categorized; this is what is meant by "objectifying categories." In set theory, a set (*e.g.* a category) becomes a member (*e.g.* an object) when it is placed in another set. So the processes of set formation and the use of sets as members of other sets can result in hierarchies of sets—categories that explain other categories.

  The importance of categorization is that it lets us construct objects that are not formed directly from unknown reality. In set theory, an apple might be treated as an object set formed from unknown reality—a set containing the apple's physical constituents. That object set could then become a member of the category set "red objects," which would contain the apple and other object sets that we choose to group together while attempting to understand reality. Another category set, "colors," could also be constructed in known reality, containing the sets "red objects," "blue objects," "green objects," and so on as its members. Making the set "red objects" a member of "colors" would change it into an object in our known reality. What had been only a grouping of apples and other objects that affected our vision in similar ways would become "red," an object that we understand as a color because it is a member of the category set "colors." Note that we have constructed an understanding of color from grouping objects in known reality, not from delimiting parts of unknown reality.

- **Generalization** is like forming a set using the logical operations of set theory. Logicians have extended "first-order logic" (by itself an extension of Aristotle's syllogistic logic) to define ways of making new sets from existing sets. For example, the "union" operation forms a new set by combining the members of multiple other sets, discarding duplicates; the "intersection" operation forms a new set from the members common to several sets. These operations on sets are often illustrated by means of Venn diagrams. By combining them with other operations, any number of new sets may be formed around members selected from other sets. Using "Boolean algebra," we can express the selection criteria for forming these new sets to virtually any degree of complexity. Their membership is determined by relating other sets, not just by aggregating members of sets.

The axiom of choice. The "miracle" of life that I mentioned earlier—its freedom to form categories by making arbitrary groupings—appears in set theory as the "axiom of choice." The axiom asserts that from any collection of sets, a new set can be formed by selecting one member from each set in the collection. In terms of categorization (following the present analogy) it is like asserting that there is no natural limit to the ways we can categorize the objects of known reality.

The minimum requirement for our understanding any object in known reality is that it be a member of at least one category. Most objects belong to many categories and most categories contain many objects as members. When we encounter a problem with understanding one or more objects, a common solution is to place them into another category. The axiom of choice guarantees that we can always do this. It lets us take objects we don't understand from the categories they are in and construct new categories around them that may help us understand them better.

As Georg Cantor was developing what is today called "naïve" set theory, at the end of the nineteenth century, his guiding concepts arose from lifelike operations—grouping things, determining their number by counting them off ("one-to-one correspondence"), dividing groups into smaller groups, and so on. Although these concepts were subsequently formalized into rigorous axiomatic systems (including the addition of the axiom of choice in 1904), Cantor's original concepts have survived as the "meaning" of set theory. It seems evident that they tap some deep understanding in human experience.

Infinities. Cantor also exposed the three orders of known reality in developing his concept of the different orders of infinity. He started by asking how one could express the number of members in an "infinite set," such as the set of all integers. His remarkable conclusion was that there are many different cardinal numbers which can express our naïve concept of infinity. These "transfinite cardinal numbers" form a natural series in which each number is 2 to the power of the previous number.

In terms of the orders of reality, Cantor's lowest transfinite number, "denumerable infinity," can be interpreted as counting behavior in time—for example, the number of steps needed to count the integers. The next order of infinity, that of "the continuum," counts locations in physical space, such as the points in a line. The third order of infinity, sometimes called the cardinality of "the functional manifold," counts ideal patterns such as the number of ways that points can be arranged.

By means of thought experiments, Cantor showed the impossibility of achieving one-to-one correspondences among the operations of counting integers, points, and functions. Similar arguments could be used to demonstrate that the objects that Cantor's transfinite cardinals count—behavioral objects in time, physical objects in space, and ideal objects distinguished by pattern—are equally impossible to compare. The orders of known reality—behavior, physical reality, and ideals—are as different in kind as are integers, points, and functions. But they all contain objects that can populate categories and become the bases for models.

Relating Objects

We have discussed two of the three basic actions by which organisms construct known reality: chunking unknown reality into objects, which I call objectification, and collecting objects into groups, which is the basis of categorization. The third basic organic action, which supports generalization, is the action of relating objects.

The logical operations required to build models require that objects be related. For example, to form a model that combines categories *A* and *B* according to the formula "categorized by *A* but not by *B*," an organism must be able to relate objects categorized by *A* with objects categorized by *B* and omit them if their relation is that of equivalence. An organism that cannot relate objects in a given area of known reality will be unable to build or use a model in that area; we would say that such an organism is unable to "generalize" its knowledge.

Once a model is constructed, it is an object with which other objects may be compared. For example, imagine a predator hunting prey; say, a wolf after field mice. At first, signs of the prey may just be categorized: the sound of a rustle in the grass, the right scent, a sight of movement. But then these scattered categorizations—auditory, olfactory, visual—give way to the act of comparing an object "out there" with a stored "field mouse model." The wolf's known reality now contains both the physical object being pursued and the relational fact that the object is a field mouse, with consequential effects on the wolf's behavior. The wolf benefits from the process of generalization because the multiple categorizations that would be needed to identify a field mouse are now conveniently packaged into a single act of comparison with a model.

As with the chunking of objectification and the grouping that is the basis of categorization, every action of relating objects to construct a generalization is always on trial and subject to error. Some supposed field mice might be lures to trap wolves, or might turn out to be birds taking flight. That is why generalized models are constantly refined through evolution and learning.

Analogy: Conditional Branching

The most fundamental instruction in computer programming is called the "conditional branch." It causes a computer to relate one chunk of data with another. Often the relation being tested is the identity of their bit patterns; but if the data is linear the chunks may also be tested for the relation "greater than" or "less than." The result of relating the two chunks determines whether the computer continues to run its current code sequence or branches to another sequence. This is how computers make choices.

Conditional branching is the key to the complexity of computer operations. A given program may branch on some data values but not on others, and a given data value may make some programs branch but others not. When a mass of data is fed to a set of programs with many conditional branches, the combinations of branch routes can multiply exponentially. Computers make complex processing decisions that are based on the interplay between their software programs and the values of their input data.

The complexity of much living behavior also reflects conditional branching. An organism's response to a physical stimulus is normally based both on the nature of the stimulus and on the organism's learned or instinctive behavior. Thus my dog and I, with our different mixes of instincts and learning, respond differently to many stimuli; he responds to scents that are trivial to me, and I respond to written messages that are trivial to him.

But organisms don't always use conditional branching directly in their responses. Often they use it to construct models. Models are then related to other objects in known reality and the resulting ideal object influences behavior, as described in the previous section. Species build models through the trial-and-error process of evolution, and pass them to individuals as instincts. Some species endow their individuals with the resources to construct personal models through learning. The wolf in our example inherited an instinctive model of a field mouse, but he undoubtedly also refined that model during a lifetime of hunting.

Interestingly enough, computers can accomplish all the tasks they do today without using conditional branch instructions. This was shown in 1996 by neural network programmer Raúl Rojas.[16] To work without conditional branch instructions, however, a computer must modify its own software while it is running. This is usually considered a bad idea in computer design, but of course it's the way most organisms work. In species it's called adaptation; in individuals, it's called learning.

Using Space, Time, and Pattern

Chapter 1 (page 17) introduced the concept of space, time, and pattern as "ordering methods" that separate objects one from another in known reality. Before the twentieth century, many thinkers assumed that space and time were "prerequisites" to the construction of objects; *i.e.,* that no thing or process could exist unless space and time were already in place to contain it. But Einstein introduced a successful physical worldview by reversing this order of priority. In relativity theory, the propagation of electromagnetic radiation is a defining event around which various "observers" construct local versions of space and time. Today many theoretical physicists have no problem with positing objects in reality first, then asking how many dimensions of space or what kind of time flow would be required to accommodate them.

If the content of known reality is constructed by living organisms, as I maintain, then there is no reason to assume that the ordering methods for that content are not also constructed. Space, time, and pattern are techniques that life has evolved to separate multiple objects. As such, they are behavioral objects—processes that help organisms construct and understand known reality. These ordering methods, which separate objects, complement the grouping processes of categorization. They are adjuncts to life's division of known reality into physical, behavioral, and ideal orders.

It is relatively easy to imagine that space could not exist unless there was something in it, that there would be no time unless the world was changing, and that no patterns could exist unless there was something to arrange in a pattern. This accords with a general tendency of life—to not try to process data until it has some data to process. But as soon as known reality acquires a multiplicity of objects, organisms need to build ordering methods in their behavior to keep track of them. Space, time, and pattern satisfy this need.

Yet attempts are constantly made to treat space and time, at least, as objects in orders other than behavior. Thus Newton believed that space and time were absolute things in the physical world and Hegel argued that they were absolute patterns in the ideal *"Geist."* The problem with such attempts is that they try to convert behavioral objects—the ways that organisms construct known reality—into physical or ideal objects. Absolute space and time are rightly criticized as too intangible to be physical and too changeable to be ideal. They belong to life's recipe for cooking reality, not to its list of ingredients.

History: Newton's Bucket

In 1687, Newton supported his case for absolute space by describing a simple experiment he had performed. If you hang a bucket of water from a twisted cord, which sets it spinning, here is what you see:

> the surface of the water will at first be flat, as before the bucket began to move; but after that, the bucket by gradually communicating its motion to the water, will make it begin to revolve, and recede little by little from the centre, and ascend up the sides of the bucket, forming itself into a concave figure (as I have experienced), and the swifter the motion becomes, the higher will the water rise, till at last, performing its revolutions in the same time with the vessel, it becomes relatively at rest in it.[17]

Newton also noted that when the rope had unwound the bucket would stop spinning; but the water would continue to spin and still push itself up the sides of the bucket.

This experiment seems unexceptional until you ask, as Newton did, how you would measure the rate of rotation of the water. Against what fixed reference is it spinning? Not the bucket, for at one point the water is stationary with respect to it. Relative to the earth? Instead of trying to take his bucket away from the earth, Newton imagined two rocks tied together by a rope and set spinning like a bola in deep space. It was clear to him and his contemporaries that the rocks would pull the rope taut, even if there were no planet nearby from which their spin around the center of the rope could be detected. Pursuing these reflections, Newton concluded that the water in the bucket and the rope assembly far from earth had to be rotating with respect to "absolute space."

Absolute space. Both Mach and Einstein wrestled with Newton's conclusion by conjuring up various thought experiments. Imagine two spheres in empty space. Observers on both spheres agree that they are rotating with respect to each other; but with no other object to provide a reference, only their relative motion can be verified. Do both spheres rotate, but at different rates, or is one stationary? Now imagine that one sphere is seen to be oblate, the other is not. The earth is oblate because it rotates. Mustn't we therefore conclude (in some absolute sense) that the oblate sphere is rotating and the other sphere is stationary?

In constructing a relativistic physics, Einstein eventually substituted the general mass of the universe (the "fixed stars") for absolute space. This provided specific objects in known reality in place of objectified space, but at a cost. To make this solution work, Einstein had to replace our evolved grasp of space and time with the relativistic notion of "curved space-time." The centrifugal effect that Newton had observed then became a "pseudo-force." The particles of water, which seem to us to be following curved lines, were actually trying to follow straight lines in a framework that was curved by the presence of matter.

The general problem with this whole argument is that it tries to turn a method of ordering objects—a behavioral process—into something physical. Einstein's curved space-time is just as physical as Newton's absolute space, but it's farther from our natural grasp of space and time and thus harder to disparage. Leibniz found it easier to criticize the Newtonian notion of absolute space because he felt that it converted something we do (locating things spatially) into a pre-existing object (the space-thing). In his correspondence with Samuel Clarke (1715-16), who represented the Newtonian view, Leibniz averred that "space is nothing else but an order of the existence of things."[18]

Problems with understanding space and time will continue as long as behavior lacks ontological force in the physical sciences. What is needed is a physics that explains physical objects entirely in physical terms, and then explains how we humans understand those objects by using the ordering methods that we call space, time, and pattern.

Constructing Common Sense

When an organism objectifies a part of reality, the resulting object is automatically placed in one of the orders of known reality. It is either physical, behavioral, or ideal. This process of assignment is necessary for any organism to make sense of its environment.

The first result of this process is what I call **common sense,** because the new object is normally first understood by grouping it with other objects of the same order. More sophisticated understandings may soon follow, as I will discuss presently, but they depend on the new object's primary assignment to one of the orders of reality.

Organisms at every level of life acquire common sense. We may marvel at how a newborn animal "knows" how to survive—or a plant "knows" how to find sun and water—but most of this knowledge is just the common sense of its species. Each species in turn acquires much of its common sense from its genus, family, and higher taxa. Birds know how to fly and fish know how to swim with a minimum of individual learning.

Common sense in human individuals. We humans are born with instincts inherited from our species, but we also acquire common sense as individuals. Like other organisms, every person has aspects in three orders of reality—a body, a personality, an intellect—all integrated into a whole. We may contact unknown reality in any of these aspects.

When our bodies contact any part of reality, known or unknown, the objects it constructs from that reality will be physical objects. This is simply because a body can react only through its physical organs, and therefore it will objectify those parts of unknown reality that affect its organs into physical common sense.

When a person's train of behavior objectifies other behavior within the same individual (as happens in consciousness), or recognizes the behavior of another organism, or ascribes behavior to an inanimate thing, it chunks that reality into behavioral objects. I might observe, for example, "that dog is afraid of me." A new behavioral object—fear in the dog—becomes part of my known reality. I understand it because it falls immediately into several commonsense behavioral categories that already apply to my own behavior, such as fear, discomfort, and so on.

We frequently impute behavior to inanimate objects, primarily through our ideas of causation. "The fire makes the pot boil," we think, as if the fire and the pot were alive. In a sense we see them as two-thirds alive, for the physical fire and the behavioral "causal link" by which the pot "reacts" to the fire belong to two of our three aspects.

Humans are unique in their ability as individuals to access ideals. When a human individual objectifies a pattern among the things and events in its environment, that pattern becomes an ideal object. It may be recognized instinctively, through reactions evolved by the human species; but frequently it is recognized through individually learned mental processes. As a result, human individuals are able to construct a wide variety of ideal objects. We categorize these objects ideally and the resulting categories become new ideal objects. In this way we build hierarchies of ideal objects in human known reality, creating a body of "abstract" or "generalized" knowledge.

Common sense in other organisms. Nonhuman organisms follow much the same processes as humans do when they assign new objects to the orders of known reality. However, the taxonomic levels at which these processes occur—individuals, species, or higher taxa—are often different. The human species appears to be unique in the extent to which the construction of known reality is delegated to its individual organisms.

Behavior that is called "instinctive" typically reflects the common sense of a species. As a result of its evolution, each species develops physical reactions (such as metabolism), behavioral reactions (such as reflexes), and ideal patterns (such as its genetic code). Individuals are propagated to test and refine these commonsense objects by dealing with their environment and with each other.

The contents of commonsense reality. The objects that common sense knows are like stepping-stones to the more interesting objects that organisms construct through "cross-categorization," a way of building reality that I will discuss shortly. Commonsense reality is simplistic. Physical situations are understood only physically, behavior is dealt with by more behavior, ideals relate only to other ideals.

Philosophizing about commonsense reality tends to transport us into rarefied areas of metaphysics. In the physical order, we could say that this reality corresponds roughly to the "substances" of Aristotelian and medieval philosophy—stuff that is tangible but has no attributes other than extension. All we know about it is that it is "out there" and that it occupies space. In the behavioral order, commonsense reality is filled with processes. It is like the "flux" of Heraclitus or the "becoming" of Hegel; time is everything. In the ideal order, common sense knows the "Platonic heaven" of essences (ειδε), which exist independently of the material world.

It's a colorless world that contains only substances, processes, and essences, however we may understand those entities. The actual world of organisms and their surroundings is much richer and more complex. This is so because life uses common sense only as the starting point for reality construction. Beginning with commonsense reality, which was constructed from unknown reality, living organisms construct the world of cross-categorized environmental reality described in Chapter 4.

Analogy: Decrypting a Bit File

The notion of "constructing reality" can have spooky connotations. It may suggest that organisms are free to cook up any reality they want. An analogy from the technologies of computing and cryptography may help to clarify what I mean, and to illustrate how the known world that life constructs is anchored to the larger world of unknown reality.

The bit file. Imagine a vast computer file. A minimum description would say that it contains nothing more than a very long sequence of 0s and 1s—a huge binary number. All we can say about this sequence is that every bit in it—every binary digit—is part of a specific series of bits. But for any given bit, we don't know where in the file the series that includes it begins or ends. This file of endless bits is like unknown reality. It is real and objective, but we cannot grasp its contents beyond 0s and 1s.

How might we convert our bit file into something more meaningful? This is a problem in cryptanalysis. We need to do some "codebreaking." My earlier analogies imagined a computer trying to "understand" the reality that humans construct—for example, by translating between an image in our known reality and a sequence of data bits (see page 15). Now I envision a more difficult process—humans trying to understand the reality that a computer might construct.

Let's start with a couple of assumptions: first, that different parts of the file may be encrypted in different ways, and second, that all the encryptions are relatively straightforward. The bit file was not created with the intention of concealing its meaning—it was created the way it is because 0s and 1s were the only elements it could contain.

Approaching the bit file as cryptanalysts, we would be likely to assume that it does not have one single meaning; different parts of it have different meanings. So our first step would be to divide the bit sequence into sections that might have separate meanings. This is called "parsing"; it is like chunking unknown reality into objects.

One way that cryptanalysts discover how to parse a simple code is by looking for repeated sequences. Some repetitions are accidental, but most are the result of encrypting the same word or phrase multiple times. Repeated sequences "stand out" from the run of codetext, just as objects in known reality stand out from the continuum of unknown reality. Gradually our file becomes resolved into bit sequences, many of which are duplicated in different areas of it.

Let's now turn briefly to the answer page and imagine a particular interpretation for our bit file. Like many computer hard disks, it has a jumble of different sections in various formats: text messages, graphics, music files, videos, numeric databases and spreadsheets, and so on. But we know nothing of this; and even if we did, let's assume that we have no clue to the format standards by which the bits in the file determine the words, pictures, songs, movies, numbers, etc., that can be rendered from different parts of it.

It's a tough cryptanalytic problem, but not insoluble. It requires trial and error and luck. Picking away at various parts of the bit file, looking for repetitions and similarities and patterns—over the 3 billion or so years that life on earth has been at work on the analogous problem of understanding unknown reality—should do it.

The emerging reality. As a result of our cryptanalysis, eventually much of the contents of the file should emerge as pictures, music, numeric structures, and so on. This is like the known reality that comes out of unknown reality. It is a reality filled with physical, behavioral, and ideal objects.

For the purposes of this analogy, we need not specify the forms in which the pictures and so on come out. The crucial fact is that the new objects are completely different from the 0s and 1s, yet they are tied to them objectively. They constitute a new, *constructed* reality. Note some general features of this process of construction:

- There is no certainty in our results. For example, what we thought was a small picture might "really" be a database of numbers that just happens to make a visual design when decrypted graphically. It is a principle of cryptanalysis that any codetext can yield any plaintext of lesser information content, given a sufficiently complicated key. Our results are provisional because we have made choices, rightly or wrongly, throughout the process of cryptanalysis.
- However, our results are controlled by the original file. If we change a 0 or 1 in the file to the other value, we can expect a change in our decryption of the part of the file containing that bit. Our results may be provisional, but they're not arbitrary. This fidelity of our results to the original bit file is like the objectivity of known reality discussed in Chapter 1.
- When going from the uniformity of a vast field of 0s and 1s to the variety of pictures, music, spreadsheets, etc., we are forced to treat our results as several different kinds of things. Pictures and music are not comparable, and neither of them are like numbers or words. At the same time, each kind of thing easily merges with its like—pictures can be collaged, songs can be harmonized, databases can be consolidated. These natural affinities within our decrypts are like the internal affinities within the orders of known reality.
- Finally, our results force us to adopt ordering methods that are not found in the bit file, including space, time, and pattern. Pictures must be appreciated spatially, songs and movies temporally, and numeric databases by their patterns. We have gone from the austerity of a bit file, a mass of 0s and 1s with no interpretation, to the complexity and richness of a known reality containing images, sounds, words, numbers, etc., all arranged spatially, temporally, and in patterns.

One might argue that our decrypted results are strongly determined by the contents of the bit file. For example, decrypting the billions of bits that make up a video could yield only the actual video; any alternative interpretation of so many bits would be certain to yield only inchoate nonsense at some point.

This might be a valid argument for a bit field. But recall the surmise of Chapter 1 that unknown reality is a continuum. A continuum, which has infinitely many points between every point, would be interpretable infinitely many ways. Among those interpretations, we would expect infinitely many alternatives that have equal apparent "validity," only one of which would be the actual video of our analogy. The problem is that our analog of unknown reality as a bit file is "unrealistic," because the file has already been chunked into bits. It is not a continuum.

In decrypting a bit file, we are dealing only with the physical part of a computing process (see "Analogy: Computer Knowledge," page 170). Decryption is analogous to objectification, but not to the entire process of constructing known reality. In particular, the analogy assumes that an organism—a cryptanalyst—is performing the construction. A more complete analogy would locate the cryptanalyst within the bit file, as part of its reality. Thus, an extension of the present analogy would find "executable code" in the bit file, which performs cryptanalysis on the rest of the file.

Categories

The process of categorization—grouping objects to understand them—is a train of behavior in an organism. It is a tool that every organism uses to work with its environment. The groups that result are routinely and easily objectified, thereby becoming new parts of known reality. Objectifying a category group makes it into an object that can become a member of another category group, so categories become categorized. This is the principal way that known reality grows.

In a typical scenario, the parts of some area of reality (call it "area X") may be separately objectified and then recognized as parts of a larger whole. The category "parts of X," by which the parts were grouped in known reality, becomes the new object "Y." The separate parts of X are still objects in known reality; but the object Y, their collection, has now been added to known reality. Object Y might then be further categorized as a part of some more inclusive object, or it might be categorized by various qualities that it exhibits independently of any of its X constituents.

Consider an example. In an unknown land, an explorer encounters piles of rocks, a rising grade, a tumbling stream, etc. For him, all these are separate objects in known reality. But finally the explorer reaches a viewpoint from which he can survey the rocks, the grade, and the stream. He realizes that together they can be categorized as “parts of a mountain.” He names the mountain, thus creating a new object in known reality. The newly objectified mountain immediately joins a host of existing categories. It may be “high” or “low,” volcanic or orogenic, etc.—all categories that apply only to mountains as complete objects, not to their parts. Understanding the mountain as an object may also suggest new categories to which it belongs, such as “parts of the Y mountain chain” or “mountains in climate zone Z.” Applying these new categorizations gives “new meaning” to the mountain and expands the explorer’s known reality.

By a similar process, categorizing the qualities of separate objects may suggest a new object that is the quality itself. For example, seeing many blue things leads to the objectification of “blue,” a new object in known reality that is separate from any blue object. Blue as an object can then join the larger category of “colors,” which may become yet one more object. Every categorization is freely made, by an organism trying to know and understand reality; they are trials in the business of life that may fail or succeed.

Lest we imagine that the construction of color categories is purely objective, not subject to knowledge-building decisions, consider the case of the color indigo. While identifying the colors of the visible spectrum, Newton distinguished indigo from blue for numerological reasons—to make the number of colors come out seven. For decades afterwards, scholars distinguished the category “shades of indigo” from “shades of blue,” and the two colors are taught as separate objects in schools today. Thus a categorizing decision made by one man, some 300 years ago, is regarded as a part of human knowledge today.

Cross-categorization. The singular power of categorization comes from the freedom with which organisms can form category groupings. In particular, categories and the objects they categorize *may be chosen from different orders of reality.* I call this “cross-categorization.” Thus physical objects may be grouped by behavioral categories, objects in behavior may be grouped physically or ideally, and so on.

Chapters 4 and 5 discuss at length the results of cross-categorization. Besides being used to construct most of environmental reality, cross-categorization is a vital skill for human thought. In the playground of consciousness, for example, I can categorize objects with almost total freedom—things I like, or big things, or things whose names begin with the letter K. The constraint on this freedom is that some categories are valid or useful, while others are irrational or useless. But for life as a whole, the ability to freely categorize objects across the divisions in known reality has been crucial for the survival and evolution of living organisms.

History: Categorization

The notion of categories as general explanatory groupings is not new. Aristotle introduced the idea in his short work *Categoriæ,* which had a lasting effect on medieval and later thought. For him, categories were headings under which all the single things we could talk about were classified. He listed ten, all quite abstract: substance, quantity, quality, relation, place, time, position, state, action, and affection. To explain what is meant by "the horse runs," Aristotle would say that a horse is a particular instance of substance and running is an instance of action. His categories were hardly more than a catalog of general ideas.

In his *Critique of Pure Reason* (1781), Kant developed a list of twelve "fundamental concepts of the pure understanding," which he proposed as an absolute framework within which anything we can think about must be cast. He arrived at his list through a process of purely logical deduction, proposing categories that were even more abstract and more difficult to visualize than Aristotle's: unity, plurality, totality, reality, negation, limitation, inherence and subsistence, causality and dependence, community, possibility, existence, and necessity. Kant writes of Aristotle as having "merely picked [his categories] up as they occurred to him,"[19] whereas Kant regarded *his* categories as the logical forms of thought and thus independent of any empirical justification.

Kant called his metaphysics a "revolution" because it focused on our ways of knowing instead of on the things known:

> Kant's most original contribution to philosophy is his "Copernican Revolution," that, as he puts it, it is the representation that makes the object possible rather than the object that makes the representation possible. This introduced the human mind as an active originator of experience

> rather than just a passive recipient of perception. . . . Perceptual input must be processed, i.e. recognized, or it would just be noise—"less even than a dream" or "nothing to us," as Kant alternatively puts it.[20]

But Kant, who died before Darwin was born, had no idea of the range and adaptability of living things. For him, organic life was as fixed as "the starry heavens above." So he picked one organ of knowledge out of the biosphere—the human mind—and built his philosophy around that. In the context of the present analysis, Kant concentrated too much on ideal categorization. He glossed over the other two kinds of categories—physical and behavioral—that "make the object possible."

Both Aristotle's and Kant's analyses were attempts to find the most general and absolute possible categories. In neither of their lists could any category be explained by referring to another category. But their lists did little to improve anyone's understanding of reality. Today the concept of category groupings is used any time many different objects needs to be comprehended—in commercial inventories, for instance, in biological taxonomy, library science, and even in the foundations of mathematics.

Modern categorization also assumes that categories can be nested in hierarchies. In a hardware store's inventory, for example, the category "wood screws" might be under "fasteners" and include the category "slotted wood screws." Such explanatory groupings make it easier to understand what is on the store's shelves and where items can be found. In a very similar way, life in general uses categorization to understand its environment and figure out how to work with it.

Objectifying Categories

We might say that organisms form categories at an "operational" level, where they are just trying to cope. When a new category is constructed, it's at first only a convenient explanatory grouping; it says that certain objects are associated in some way. The group itself is not "known," even though an organism has created it. In a sense, every new category belongs to unknown reality. It has the characteristic of unknown reality that it has not yet been chunked away from the rest of the organism's behavior.

Eventually most categories become objectified. They become new parts of known reality. But we can distinguish them from other parts of known reality that came from objectifying unknown reality external to organisms. All known reality is "constructed," in the sense that it has been chunked into objects; but some of these objects are—in effect—thrust upon organisms by the unknown reality in which they live, while other objects (including objectified categories) are inventions created by organisms to help them understand and work with their surrounding environment.

Once both kinds of objects exist in known reality, organisms treat them the same. Objects do not bear tags identifying their provenance—from unknown reality or from a process of categorization. It might seem that this should be a crucial distinction, for objects of the first kind would constitute "true" reality while objects of the second kind would constitute some kind of "artificial" reality. Indeed, much science and philosophizing has gone into trying to tell the one from the other. This is the problem that Kant attacked with his concepts of the "thing-in-itself" versus the "categories of the understanding."

But, as Kant concluded, there is no need to distinguish the origins of objects in known reality. If we could determine that a given object was not the result of objectifying unknown reality, what would we do with that information? The best we could do would be to "re-objectify" some area of unknown reality, chunking it into different parts of known reality with perhaps new categories. No such process could give us a new kind of access to unknown reality that was "more direct."

Analogy: Categorization and the World Wide Web

The Internet's World Wide Web grew out of Ted Nelson's concept of hypertext, which was in turn inspired by a seminal article Vannevar Bush wrote in 1945 for *The Atlantic Monthly.* That article envisioned an information storage and retrieval system that would operate through *association* instead of by indexing: "any item may be caused at will to select immediately and automatically another." The system's purpose was to emulate the operation of the human mind, which is why Bush's article was titled "As We May Think."[21]

Categorization, as I use the term here, is a process of association. It groups objects together because an organism finds such groupings to be useful. The organism then does something I call "miraculous"—it converts the group *as a group* into a new object. The new object can then be associated with other objects, forming yet more categories that provide further understanding.

If the structure of the Internet were likened to the structure of known reality, then its pages would be like objects and its links would be like categorizations. An organism—a Web constructor—objectifies an area of binary memory cells on a server, coding them into a Web page. To make that page understandable, the constructor links it to other pages, each of which explains part of it. Each page that it is linked to is like a category for all the pages that link to that page.

Taking as an example a red balloon, the Web's balloon page would contain links to pages about the color red, pneumatic inflation, spheres, and so on. Each of these pages would be a destination for links from pages about other red things, other spherical things, and so on. The page about the color red would link to pages about light and hues, while the page about spheres would link to pages about geometric shapes. The entire system of associative linkages would work together to explain itself, just as known reality does.

Even the most dedicated Internet surfer might balk at the notion that "the Web is like reality." But making that analogy can help highlight several morphological similarities between the two:

- The Web's "unknown reality"—the stuff from which it is made—consists of binary digits, which are unknowable and meaningless by themselves.
- It requires computers, machines that have many of the attributes of organisms, to construct and "render" the Web's page-objects.
- These computers (with their human operators) are free to construct associative links from any page to any other page, and to construct new pages to link to, when doing so would make the Web as a whole more understandable.

Of course the analogy breaks down because computers are not parts of the Web, whereas organisms are parts of known reality. But the key similarity—of a network of objects, grouped by association, in which the groups are also objects—holds between the categorization of known reality and the structure of the World Wide Web.

The Efficiency of Knowledge

Organisms categorize objects so they can "understand" them. At a more mechanical level, they do it to fashion simpler responses to reality. They form objects into groups for which a single response works with every object. Many objects become categorized as "uninteresting" and are ignored. Many others fall into categories where they can be dealt with summarily. Only a few objects become categorized in such a way that they require careful responses, but it is with these objects that the day-to-day life of most organisms is primarily concerned.

If life were a business, we might talk about the "process efficiency" of an organism's routines for building its known reality—separating new objects from unknown reality, categorizing them, and responding to them in ways that work for various categories. A businessman might analyze the efficiency of the organism's routines by measuring the time and energy it took to execute them, and might improve the process by grouping more objects into fewer categories, thereby accomplishing the same work in fewer and simpler steps.

In epistemological terms, we could add to the traditional properties of knowledge—its "truthfulness," its usefulness, its testability, and so on—the property of efficiency. We could say that knowledge is more efficient when it knows fewer objects and offers broader explanations. Knowledge is less efficient when it knows more objects or categorizes the objects it knows into smaller groups.

Of course this is not a new idea. The 14th-century logician William of Ockham is noted for formulating the *lex parsimoniæ* in knowledge—"entities should not be multiplied beyond necessity"—which we know as "Occam's razor." The roots of this advice go back at least as far as Aristotle and show up today in judgments such as Karl Popper's, that simpler theories are better than more complex ones because they cover more cases and are therefore better testable.

The commonest way that human knowledge is made simpler is by creating more inclusive categories. We aggregate several special cases into a more general case with correspondingly fewer explanations. For example, we may notice that chocolates, sugarplums, and jellybeans all taste pleasant and sweet. We construct a more inclusive category, "candy," that covers them all. Previously the answer to the question "Why is this pleasant and sweet?" required three different explanations —"Because it is a chocolate," "Because it is a sugar-plum," etc. Now it requires only one, "Because it is candy." When we taste a new object that is pleasant and sweet, we can simply call it candy without needing to inquire further about its composition. In this manner our knowledge become more efficient: we have fewer facts to remember, and our known reality becomes more concise.

Because organisms can freely choose to group categories that have been objectified into other categories, there is no natural constraint on the process of building categorical hierarchies. There are size limits, however, because every new grouping tends to include more reality. Eventually the top group of a hierarchy may categorize so much that it tries to explain a major portion of reality, or in some cases everything. One of the ways such grand explanations are objectified is by making them into gods, as I discuss in Chapter 7. Such explanations are often highly efficient, because many questions about reality can ultimately be settled by the single answer, "Because God [or a god] makes it so."

Discussion: Entropy

While discussing organisms in Chapter 2, I mentioned that one of the ways that living organisms differ from their environment is that they "reverse" entropy. If organisms construct environmental reality, then it is fair to ask whether this difference is accidental or a product of the construction process. The answer is that organisms reverse entropy in the physical world by exercising their behavioral freedom of choice.

Physicist J. W. Gibbs called entropy a measure of the "mixedupness" of physical systems. We can see examples of entropy increasing in everyday life, when heat disperses throughout a room or a stirred mixture becomes more homogeneous. This effect is related to the "second law of thermodynamics," which asserts (in one formulation) that the total entropy of every isolated thermodynamic system tends to increase as the system changes.

But the "principle of entropy"—that it tends to increase—has an iffy status among the strict laws of physics, because it is "statistical" rather than absolute. Nothing in the physicist's model of particle interactions prevents the heat in a room from spontaneously concentrating in one corner, or prevents a mixture from separating while it is being stirred; it's just that such events happen very rarely.

Over the years, "entropy" has taken on different meanings. Clausius coined the term in 1865 to measure the capacity of a thermodynamic system to "do work," which is possible only as long as heat flows out of regions of concentration. When the heat in such a system is completely dispersed—the condition of maximum entropy sometimes called "heat death"—no machine can perform work in it. Some physicists believe that this will be the ultimate fate of physical reality as a whole.

The general idea that concentrations inevitably disperse took hold in areas of knowledge such as sociology and economics, and became linked with the ideas of order and disorder. That's why Schrödinger described life as "feeding on negative entropy" (see page 46). Entropy ultimately wound up in information theory, where it measures the amount of uncertainty in a message.

Entropy can be described in terms of objectification. Boltzmann, in 1896, showed that the different measures of entropy could all be derived mathematically from the number of "microstates" in a physical system (for instance, from the number of distinct configurations of the molecules in a gas). This was just another way of saying that entropy measures the number of ways that an object can be interpreted as made up of other objects.

The reason why entropy "tends" to increase can be explained in terms of categorization. Just counting the number of "microstates" in a system—the number of distinguishable objects into which an object can be divided—does not help us understand what is inside the system. To understand the system, we must group its microstates into categories. When we do this in a physical system, it inevitably turns out that we identify many more microstates as "mixed up" than as "sorted out." As the system then changes, running through different microstates, there is little wonder that states we understand to be "mixed up" predominate. There are simply more of them.

The statistical nature of the "principle of entropy"—its status as less than an absolute law—stems from trying to characterize physical events in behavioral terms. From the beginning, entropy was a measure of how much "work" a system could do. It carried behavioral categories into physics, a science based on explaining physical reality through ideal categories. Its behavioral categorizations explain why the concept of entropy became so congenial to the social sciences, as well as why we have no trouble understanding its effects in everyday life.

By themselves, physical systems "don't care" what configuration they're in. When viewed along a timeline, in known reality, a physical system just runs through a series of states. But organisms are able to understand those states behaviorally and choose states of low entropy. Thus, for example, living metabolism can specifically target glucose for oxidation, storing some of the resulting energy by attaching another phosphate group to adenosine diphosphate. Without behavior present, a physical system would never do that.

Objectifying Organisms

My earlier discussion of objectification emphasized that when objects are chunked out of reality (known or unknown) they automatically fall into one of the three orders of reality. A new object is either physical, behavioral, or ideal. However, the case with organisms is somewhat more complicated.

Organisms are objects, like everything else in known reality. How does an organism come to be known? It may be observed physically, as when one sees a bear in the forest; or it may be known by its behavior, as when one suffers from a pathogenic disease; or it may become known ideally, as when one comes across an artifact (such as a nest or a tool) that was evidently produced by a living being.

In all the cases just cited, identifying an object as a living organism requires corroboration from at least one other order of reality. The bear sighted in the forest must move or otherwise behave, to distinguish it from a dummy or a dead body. The effects of a disease must be traced to an organism visible through a microscope—otherwise the disease might be systemic, not pathogenic. An artifact must be associated with other evidence of life to rule out its having been accidentally created by inanimate forces. An organism is like a box with three handles; picking it up by one handle does not give us a firm grip on it as an object in known reality. Unlike the other objects of known reality, an organism must show us its presence in more than one order of reality before we can know it as a living thing. Yet once we incorporate an organism into known reality, we know it as a single object.

Being one object in all three orders of reality is a trick unique to life. Like a magician's trick, however, the secret is in the setup. Life can claim a special status for its organisms because it created the orders of reality in the first place. Dividing known reality into three orders gives organisms the freedom to rise above common sense—to understand and manipulate known reality in the ways we recognize as unique to life.

Having constructed known reality in a way that would normally tear each organism apart into its separate aspects—and which does, every time a living organism dies—organisms maintain their integrity through cross-categorization. Every organism constructs its aspects in terms of other aspects: its behavior to understand physical things, its physical body to carry out behavioral actions, and so on. These processes of organic cross-categorization are analyzed in detail in Chapter 5.

Analogy: Categorization in Data Processing

At several points in this book, I have drawn analogies between the ways that life operates and the ways that computers work. This not because "living things are like computers," but rather the converse: computers have been designed to act like living things. This analysis is now at the point where we can draw additional comparisons between fundamental organic processes and the analogous data processing techniques that computer designers have developed.

It is not farfetched to characterize as "miracles" these two abilities of organisms, which help make life possible:

- The ability to convert chunks of unknown reality into known objects.
- The ability to categorize known objects by grouping them, thereby making them meaningful.

If we substitute for unknown reality the "real-world" entities—images, numbers, texts, etc.—that data processors are designed to process, and substitute for "categorize" the means by which the processing software distinguishes one kind of data from another, then these two abilities could also be cited to explain how data processing systems differ from all previously designed machines.

Objectifying unknown reality. Organisms objectify specific parts of unknown reality, making them known, by delimiting those parts and rendering them into configurations that life can know. This is like the processes of constructing data discussed on page 25. Like organisms, data systems use various "sense organs"—keyboards, microphones, cameras, etc.—to bring external reality into a processing machine. But once inside, the resulting data is totally unlike the reality it represents. It consists of sequences of digital bits, not numbers or words or sounds or images.

The bits that represent each object to be processed are contained in a software "variable." The processing system's software establishes each variable specifically to contain the data for one object. The data may vary over a range of bit configurations, but the variable that contains it is a bounded, identified object in the data system. This is analogous to life's ability to construct discrete objects out of the continuous stuff of unknown reality.

Every variable has an identifiable location in the data system; it can be "addressed" as an object regardless of the kind of external reality it encodes. This is analogous to an organism's ability to order physical objects spatially. If a data system cannot distinguish variables from one another by examining their contents, it can always tell them apart by their different addresses. Similarly, an organism can always distinguish physical objects from one another by their spatial locations.

Making objects meaningful. Organisms understand objects by grouping them. An object may belong to many groups, each of which adds to its "meaning." For example, an object that belongs to the groups "red things" and "round things" might be an apple or a ball. If it also belongs to the group "sweet things" it is more likely an apple. The more groups that include an object, the better we understand it.

In data processing, variables are given meaning by assigning them "data types." Typical data types are "integer," which says that the bits the variable might contain should be interpreted as a whole number, "string," which says that they should be decoded to a sequence of text characters, and so on. A variable may be assigned multiple data types; an integer, for example, may also be a phone number. Each type helps the data processing system handle the variable. For example, knowing that a variable contains an integer helps the system parse the bits in the variable, but knowing it contains a phone number prevents the system from trying to perform arithmetic on its contents. Thus data types group variables as things to be processed in the same way. A data system will typically use similar routines to handle all variables that are typed as phone numbers, just as an organism will use similar behavior to eat all objects that it categorizes as apples.

Variables occupy specific "spatial" locations in the data processing system's memory but data types do not. Data types are parts of the data system's software. Even though programmers identify data types when writing programs, in traditional programming there is no specific area in computer memory that one can identify as an encoded data type. The only way we can know which data types a computing system processes is by observing what its software does—by analyzing its program steps. The software will indicate which data types it handles by the program instructions it uses and the way it orders them in time.

In a similar fashion, organisms demonstrate their understanding of objects by their behavior, by the ways they "process" things over time. Eating an apple is a different process from kicking a ball, and one might call it a "type error" for someone to try to eat a ball or kick an apple. The primary evidence that an organism understands an external thing is its behavior toward the thing. Similarly, we can tell whether or not a data system is working correctly by seeing how appropriately it handles various types of data.

Here we may see, through analogy, the "miracle" of categorization. Digitized images and binary-coded phone numbers may both become objects—variables—in a data system, but the system's software knows what to do with those objects because it has categorized them—given them data types. Similarly, an organism may know what to do with an apple and a ball because its behavior has categorized those physical things.

A further miracle is that the objects belong to one order of reality and the categories to another—in the case of computing, to data and software, and in the organic case to physical reality and behavior. Only living things—or the machines they create—can "cross-categorize" the objects they process.

Kinds of Reality

The present analysis has reached the stage where we can summarize the various kinds of reality that have been discussed so far.

Unknown reality underlies all the other kinds of reality. However, it is never known directly; it must be objectified before it can be known. The parts of unknown reality that undergo this process change from continuous to chunked (from "analog" to "digital") and from undivided to separated into three orders—physical, behavioral, and ideal. Even though unknown reality undergoes this transformation in the process of becoming known, it objectively determines the known reality that is made from it.

Commonsense objects constitute the first "layer" of known reality. When a part of unknown reality is chunked into an object, that object is automatically assigned to one of the three orders of reality. Depending on the order, the new object is separated from other objects in the same order by space, time, or pattern. Assigning an object to one of the three orders of known reality gives it the minimum amount of categorization needed to be understood: the object is either physical, behavioral, or ideal. But most new objects are also grouped in other categories, drawn from the same order. As long as an object is not cross-categorized—as long as its categories are all objectified in the order which contains the object—that object is part of what I call "commonsense reality."

Commonsense reality is thus populated by three kinds of objects that are understood in three different ways. There is no interaction between the three orders. Physical things interact only with other physical things, trains of behavior only with other behavior, and ideals only with ideals. The objects known by common sense are "given" because they are understood only in their own terms. Common sense provides no mechanism for questioning them nor impetus to recategorize them.

Cross-categorized reality is a second and more complex "layer" of known reality. Organisms construct it by cross-categorizing the objects of commonsense reality. When an object is categorized by including it in a group that is objectified in a different order of reality, it becomes understood differently. Although its origin in unknown reality may not have changed, it becomes a different kind of known object. One might say that it has become "customized" to a need or purpose beyond using common sense. Cross-categorization is the main tool that organisms use to construct the environmental reality in which we all live.

Unlike commonsense objects, objects in cross-categorized reality are not "given." They may be understood correctly or falsely, practically or uselessly, well or imperfectly. This potential error in understanding is a consequence of exercising choice in the categorization that explains each object. Because that choice is freely made, it may be wrong.

Organisms may cross-categorize objects indefinitely. As they do so, they construct a complex reality out of the objects of commonsense reality. What had been known "naïvely," as a member of groups that all lay in the same order of reality, is now known with "sophistication," by placing it into groups that are understood completely differently. This understanding often changes, so cross-categorized reality evolves and is often subject to misunderstanding and revision.

Organic reality consists of objects that are parts of all three orders of known reality, which I call "organisms." Being a single object in all three orders is what makes an organism alive. Chapter 2 introduced the term *aspect* for each organism's presence in the three orders of known reality, so we talk about a living thing's physical, behavioral, and ideal aspects.

The three aspects of every organism work together by constantly cross-categorizing each other. This process is the "glue" that holds each living thing together. For example, an organism's behavioral aspect may categorize actions in its physical aspect as responses to stimuli, while categorizing techniques in its ideal aspect as learned skills. The various ways in which organisms construct themselves are analyzed in detail in Chapter 5.

Because organisms are cross-categorized objects, they constantly "reinvent themselves." In the terminology used here, organic evolution is driven by the multiple ways in which the aspects of each organism are categorized by its other aspects. Species organisms, for example, categorize their genetic encodings by the varying physical aspects of individual organisms; each physical trait "gives meaning" to the gene sequence that determines its construction. By reproducing individuals who each carry the species' genome, a species can test its phenotype against its physical environment and use the results to recategorize its gene sequences, somewhat like a mechanic who corrects and improves the plans for a machine while building it.

Organisms (including humans) are the only objects that construct known reality. Besides the visible world that we share through space, time, and pattern, we and other organisms construct knowledge in our behavior, memory in our physical bodies, and the ideal techniques that make us thrive in our genetic code. Organisms are literally "self-made." Only life is capable of such activities, making it a unique part of known reality.

Summary of this Chapter

This chapter describes how organisms construct known reality out of both known and unknown reality by using the behavioral processes that I call objectification, categorization, and generalization. Objectification chunks regions of unknown reality into objects destined to be known; categorization explains those objects by assembling them into groups; and generalization creates ideal models by relating categories that are already known. Organisms construct known reality by repeatedly and continuously applying these techniques.

What I call a "miracle" is an inherent feature of these processes, for they are all freely done. Organisms choose the chunks into which they objectify both unknown and known reality; they choose the groups by which they form categories; and they choose they ways they combine categories to construct generalized models. All these choices which organisms make may be good or bad, wise or stupid, right or wrong, and organisms routinely perish for having made them poorly. But the choices are *free*.

While remaining a part of the known reality it constructs, life raises itself "above" that reality by the freedom inherent in its three processes of construction. Thus life is able to construct what it needs to know.

Analogies can help us understand how it is possible to construct a reality of objects that are chunked and grouped just to be knowable. In set theory, for example, collections of objects are given identities just so we can know each collection as something separate from the objects it contains. The theory's axiom of choice grants us the freedom to do this. In cryptanalysis, to take another example, we can objectify, categorize, and generalize the characters in a message, turning the contents of the message from unknown to known. Again, we exercise choices at every stage of decryption, and the only evidence we have of success is that the result "makes sense." Analogies such as these work not because we feel that living things are like set constructors or cryptographers. Just the opposite—the analogies work because people have developed set theory and cryptographic techniques to formalize our natural behavior when we build or try to understand the world in which we live.

Categorization is an exceptionally prolific process for constructing known reality. Assemble a grouping of objects, and lo! you have a new object. In human life, both our knowledge and the world that we know expand exponentially, as we categorize what we know and then proceed to categorize our categories. Our constructed reality remains objective, because it is ultimately traceable back to unknown reality; but its scope and complexity become practically unbounded.

The next chapter explores the environmental reality that life builds to house and sustain itself. Environmental reality is largely a product of cross-categorization, in which objects in one order of known reality are grouped to make an object in a different order. Cross-categorization works because everything life makes when constructing known reality can be treated as an object and hence is a candidate for categorization and generalization. But only some of the objects in known reality come from unknown reality; the rest are built on them. A single new object from unknown reality may evoke a cascade of categories and models as we try to understand it, all of which become additional new objects in known reality.

4. Environmental Reality

> The universe gives birth to communicating participators. Communicating participators give meaning to the universe. J. A. WHEELER

Organisms use the construction processes described in the last chapter —objectification, categorization, and generalization—to build and to understand the known reality in which we all live. Unknown reality, which we can think of as a continuum, becomes chunked into objects; those objects are grouped by categories that become new objects; and categories become generalized into models. I call the known external reality that is constructed by organisms **environmental reality.** The next chapter, "Organic Realities," analyzes other kinds of constructed reality that are specific to organisms themselves.

The easiest way to construct a known environment uses what I call "common sense." Each part of it is objectified and categorized in one order of reality: physical objects are grouped by physical categories, behavioral objects by behavioral categories, and ideal objects by ideal categories. Commonsense reality represents the simplest form in which unknown reality can become known.

But for us and other organisms, commonsense reality is less useful than the next stage of known reality, which we and other organisms construct through cross-categorization. Here categories are free to group objects that belong to other orders of reality. For example, a group of sensation objects in behavior may be gathered together by a category that becomes a physical object. As if by magic, sensations in an organism's behavioral aspect become perceptions of a "thing" in the organism's environment—a known object with which it can interact physically. The physical thing in environmental reality thus explains the behavioral sensations in organic reality, and life moves forward.

Organisms are themselves cross-categorized objects. As discussed in Chapter 2, every organism is present as one object in all three orders of known reality. This "three-in-one" feature of life gives organisms a unique ability: when they group objects of any kind, they can treat the group itself as an object of the same or any other kind.

The freedom to construct new objects by grouping existing objects in ways beyond common sense is the key to life. An environmental world constructed only through common sense would lack connections between sensations and their origins, materials and their properties, concepts and their universals. Our actual known environment, made complex and meaningful through cross-categorization, is the world in which we live and thrive.

Building on Commonsense Reality

Nevertheless, the process of constructing known reality from unknown reality starts with common sense. The first way that many new objects are understood is in terms of their native order of reality.

But reality constructed by common sense has limitations. It is really three disparate realities: a physical world without causation or pattern, a behavioral world without physical expression or rationale, and a realm of ideal patterns without usefulness or tangible form. Each of these worlds might be coherent and understandable—say, by a physicist, a psychologist, and a mathematician—but they don't "work together." All of the richness of reality, as we and other living organisms know it, emerges when these three disparate orders of reality interact.

Life provides interaction among the orders of reality. It escapes the limitations of common sense by cross-categorizing known reality—by performing that cosmic trick whereby a group of objects of one order becomes a new object in another order. For example, it makes a group of behavioral sensation objects into an external physical object. In one sense, this process of grouping and objectifying only produces a novel understanding of the objects of common sense. But because the new categories become new objects in known reality, the organic technique of cross-categorization constructs, in effect, a new reality.

The new cross-categorized reality is no less "real" than the reality of common sense. Both are parts of known reality. But cross-categorized reality displays a tentative, experimental quality not found in common sense. It is always subject to correction and reconstruction. This is a consequence of two basic differences between cross-categorized reality and commonsense reality:

- Cross-categorized reality can be "valid" or "not valid," "correct" or "incorrect" in ways that commonsense reality cannot. This happens because cross-categorization is inherently arbitrary. It attempts to describe apples in terms normally applied to oranges. This may lead to new insights and a richer understanding of known reality, but it is always subject to being replaced by a newer understanding—such as that apples are better described in peach terms. The price life pays for the freedom to understand reality in novel ways is a perpetual turnover in those understandings.
- The construction of cross-categorized reality occurs in different "styles," depending on which two orders of reality are involved. For example, categorizing a new physical object behaviorally produces a different understanding of it than that produced by categorizing the same physical object ideally. People may understand it in terms of causal events, for instance, instead of in terms of abstract principles.

The last point, differences in styles of cross-categorization, exerts a profound effect on the kinds of environmental reality that we humans construct. Styles of cross-categorization tend to support one another, so that the way in which an object is added to one area of known reality may affect the construction of other objects in the same area. The rest of this chapter explores some of the objects in environmental reality that result from different styles of cross-categorization.

Analogy: Digital Encoding

Various parts of this book describe computer processes, hoping those descriptions will help the reader visualize what takes place as unknown reality becomes known reality. These analogies and metaphors are not coincidental; I believe they are apropos because computer designers use their native understanding of how life deals with reality to construct machines that process data (which is derived from reality) in lifelike ways.

Underlying all computer technology is the idea that bits—binary units of "information"—can represent a variety of real objects: images, words, sounds, actions, etc., as well as numbers. Computers make these representations of reality through **encoding,** a process that is similar to cross-categorization. Knowing how computers encode data can help us understand how organisms cross-categorize known reality.

When computers process encoded data, the bits that make up the data have "meanings" in all three orders of reality: as ideal numbers (1 or 0), as physical voltages in computer circuits (high or low), and as behavioral decisions in software (yes or no, called "Boolean values"). When these data bits are assembled into groups they lose their separate identities. Applying a simple convention, such as positional notation (for example), we can interpret a group of bits as a binary number. Thus 101 becomes the number 5, because the digits now "mean" something like add-4-if-1, add-2-if-1, and add-1-if-1. Positional notation can give a meaning to a group that far exceeds the meanings of its individual members. Using other conventions, we could equally well interpret the bit group 101 as designating the first and third items in a collection of things, or even as a "yes" Boolean decision because the last bit is 1.

Computers encode larger pieces of data, such as sounds and images, using conventions that are far more complex than positional notation. In a video, for example, it may be hard to say what contribution a single bit makes to the viewer's experience. Every bit makes a difference; but the combination is more meaningful than the totality of the elements.

This meaning comes from a process similar to cross-categorization. Whether you call data bits binary numbers, circuit voltages, or Boolean decisions, groups of them can represent objects in all three orders of known reality—ideal numbers, physical images, behavioral language words, etc. Of course computers do not cross-categorize data on their own; they have to be fed conventions devised by human programmers. It is conventions that make computer data represent other realities. But once the conventions are established, groups of bits can "mean" almost anything.

Styles of Cross-Categorization

The examples of cross-categorization discussed earlier centered mainly around physical reality—perceiving it through behavior or analyzing it with ideal categories. But organisms use cross-categorization to build environmental objects in all three orders of known reality. There are six ways that each of the three orders can categorize one of the others—physical categories can group behavioral objects, behavioral categories can group ideal objects, ideal categories can group behavioral objects, and so on. Each of these six possible combinations results in a different "style" of cross-categorization, a distinctive way of constructing new parts of known reality. They are listed in Table 4-1, below.

Table 4-1. Six styles of cross-categorization

Order of reality of categories	**Order of reality of objects**	**Style of cross-categorization**
Physical reality	Behavior	P CAT B
Behavior	Physical reality	B CAT P
Behavior	Ideals	B CAT I
Ideals	Behavior	I CAT B
Ideals	Physical reality	I CAT P
Physical reality	Ideals	P CAT I

I use the notation "P CAT B" as short for "physical reality categorizes behavior." It is the style of cross-categorization in which categories that become objects in physical reality are used to group (and thus explain) objects in behavioral reality. Similarly, B CAT P denotes the style that uses behavior to categorize physical objects, B CAT I groups ideals into behavioral categories, and so on.

Different cross-categorization styles are an inevitable outcome of the nature of the environmental reality that life constructs from unknown reality. Organisms begin to construct this known reality by objectifying unknown reality into three orders—physical, behavioral, and ideal—and grouping objects in those orders into categories. The categories that group known objects are new entities, distinct from the objects they group. They are additions to known reality.

At first these categories are parts of the same order of reality as the objects, constructing what I call commonsense reality. But organisms go beyond common sense, grouping objects in one order of reality by constructing categories in another order. Each such process of cross-categorization links two orders of known reality, using one order as a source of objects and a different order as a source of categories. The categories collect the objects into groups and thereby "explain" them.

Let us take a moment to review what this means. Some objects in one order of reality—physical, behavioral, or ideal—become grouped together. The group itself is a category, something that is distinct from any object in the group, or indeed from anything else in reality. It is a new creation. But the category itself becomes an object that belongs to one of the orders of known reality. It is physical, behavioral, or ideal. When the category is part of an order of reality different from that of the objects it groups, cross-categorization has occurred.

Just as physical reality, behavior, and ideals are the basic orders in which life constructs known reality, the six ways in which life cross-categorizes the resulting objects constitute the most basic ways in which it expands known reality. And just as the orders of known reality cannot be reduced to forms of one another, the six ways in which the objects in those orders can be cross-categorized are different processes that are not reducible to one another.

Each style of cross-categorization makes a different contribution to the environmental reality in which we and other organisms live. In the table below, I propose ordinary names for the six cross-categorization processes listed in Table 4-1 and for the new objects that each process adds to the environmental reality that organisms know.

Table 4-2. Results of cross-categorizing environmental reality

Categorization	Process	New objects
P CAT B	Actualization	Things
B CAT P	Animation	Changes
B CAT I	Formulation	Propositions
I CAT B	Abstraction	Universals
I CAT P	Reasoning	Principles
P CAT I	Definition	Properties

The pages that follow contain frequent references to the processes and objects listed in this table. Instead of using symbols or coining new terms to denote them, I have tried to pick common names that suggest what these entities are. Thus, what I call **actualization** is the process of constructing a new physical object (what I call simply a **thing**) from a group of behavioral objects—typically a group of sensations that lead us to understand that we are observing a thing "out there." What I call **animation** groups the things constructed by actualization along a behavioral timeline, like the frames in a movie, so we understand that we are watching one object which is undergoing **changes,** instead of a succession of different objects. **Formulation** is the organic process of grouping ideals together into behavioral **propositions,** which we treat as true or false and which we use to help us deal with our environment. **Abstraction** is the process of finding new **universals**—ideal patterns that we can apply generally to the environment—from our experience using and testing propositions. **Reasoning** is the process of deriving the ideal **principles** that "underlie" the things and events of the physical world. Finally, what I call **definition** is the process of ascertaining the **properties** of physical things that ideal principles are about.

These terms are just labels. What is important is to understand how different processes of cross-categorization construct various kinds of new objects. The next sections analyze in more detail what happens and what the results are.

While all organisms construct cross-categorized reality, we humans are directly aware of what we do. So a first approach to understanding cross-categorization is to explore some of the ways in which we, as a particular species of organism, use it in each of its styles to construct new objects in the environmental reality that we know.

Actualizing the Environment

The most fundamental of human experiences is our perception of an "external world." Our behavior constantly encounters sensations that we ascribe to external physical things. We group these sensations by the physical things we think they "come from"—red and round sensations from a physical balloon, for example. Thus we explain our behavioral experiences in terms of physical categories. When we objectify those categories, our physical environment—a part of our known reality—acquires new objects that I call simply "things."

The everyday process of distinguishing physical things outside of us is so ingrained that people commonly assume that we are just passively observing things that "already exist." But in fact what we are doing is constructing things one-by-one out of unknown reality. The process that I call "actualization" constructs specific objects in our known physical reality by objectifying categorical groupings of behavioral objects:

Categorization	Process	New objects
P CAT B	Actualization	Things

Each physical thing constructed through actualization is the product of a two-step process of cross-categorization. First we assemble a group of behavioral sensations to construct a category, and then we objectify that category as a physical object. Because every grouping—every category—is different in kind from any of the objects it groups, we can always construct a physical object that is a group of behavioral objects. By this process, we humans and other organisms actualize a physical world to explain our behavioral sensations.

It may seem hard to visualize such a basic process as actualization. Imagine a very blurred photograph, over which we pass the focusing lens of perception. As recognizable details come into focus, coherent images assemble themselves. We recognize a tree by its branches and leaves, an automobile by its wheels and doors. What had been a blur gradually becomes a field of specific, discrete things. Actualization is like that.

But the things that we construct from unknown physical reality are always problematic. The behavioral sensations of red and round that we attribute to a physical balloon might come from an illusion. The source of a furry sensation we suppose is a dog might be a toy. In fact, we spend much of our lives sorting out the physical categories that give meaning to our experiences. We are sure of our sensations but are less certain exactly what things they come from in the "physical world."

Chapter 1 (page 17) described how we distinguish physical objects by using the commonsense ordering method of space. As we actualize our known physical reality, we use space to separate similar things. For example, imagine that we are observing a cluster of red balloons. To understand what we are seeing, we must categorize our sensations of redness and roundness by grouping them in pairs, assigning to each pair the physical category of "being parts of one thing." Next we objectify those categories, calling them "balloon things." At this point we have populated our known physical reality with red balloons.

To distinguish the balloons from one another, we assign each one a position in space. The result is an explanation of multiple sensations that goes something like "red balloons are at locations *X, Y,* and *Z*." We have added our commonsense understandings of the spatial positions *X, Y,* and *Z* to the three groupings of red and round sensations, making each group into a different thing. Our multiple behavioral sensations of redness and roundness are thus explained by constructing balloons at different spatial locations in our known physical reality.

All phases of the process just described involve choice and hence are subject to error. Grouping a sensation of redness with one of roundness under a single physical category could be a mistake; for example, the round thing might look red only through a trick of lighting. Adding a space location to the red+round categorical grouping might be wrong if we stood in a hall of mirrors. And separating the categorical grouping from the rest of physical reality, by objectifying it, could be erroneous if it turned out that we had unknowingly been watching a video.

All organisms struggle to identify the things in physical reality that correspond to their behavioral sensations. Among humans, the struggle is complicated by the fact that populating physical reality with things is only one of six ways in which we understand the world. Nevertheless, the struggle mostly succeeds. To deceive ourselves, we have to concoct deliberate illusions and "virtual realities." The normal result is that we humans (like other organisms) construct a workable external physical world filled with objects constructed through cross-categorization, each of which explains some collection of sensations in our behavior. We recognize things outside ourselves.

Animating Physical Reality

Constructing an external physical world actualized into things explains our behavioral sensations, but it also raises a host of new questions. Why do things come and go, as when wood burns to charcoal? Why are the locations of things not always constant? Answering these questions requires a new style of cross-categorization, one that constructs change objects in behavior:

Categorization	Process	New objects
B CAT P	Animation	Changes

This style of cross-categorization, which I call **animation,** constructs behavioral groupings of physical things and objectifies those groupings into **changes.** The physical things that are grouped may be as simple as one thing observed at more than one spatial location, which we call "motion," or as complex as the transformation of one known thing into another. In all cases, however, the new object that groups these things is behavioral. Thus every change is an object in behavior that explains a physical group—a group that we might otherwise perceive as many physical objects—as "really" the modification of one thing.

An earlier discussion (page 17) described how behavioral common sense uses time as an ordering method to distinguish behavioral objects from one another. Common sense arranges behavior into "timelines." Cross-categorized change objects fit naturally into this scheme. They are objects in behavioral timelines that explain certain associations among physical things.

For example, imagine again the previous example of a cluster of red balloons. Now one of the balloons breaks loose and floats away. We have the same paired sensations of redness and roundness, but with one pair the spatial position that we add to the red+round grouping varies at different points along our behavioral timeline. We perceive a series of distinguishable balloon objects, each in a different location.

We explain this situation by grouping the multiple physical objects into a new category in our behavior, then objectifying the category as a change object. It's like assembling the different frames of a movie into a single "shot." As the balloon floats away, we call the new perception in our behavior a "motion change."

If one of the balloons is punctured, on the other hand, we observe it in two states—big and round, then small and floppy. We combine the two physical states in our behavior and objectify the grouping as a "transformation change." In both this case and the case of motion, what might otherwise be confusing in our perceptions of physical things is resolved along a behavioral timeline as a change in known reality.

Survey: Natural Reality

Table 4-2 on page 95 lists cross-categorizations in pairs: first the two cross-categorizations between physical reality and behavior, then the two between behavior and ideals, and finally the two between ideals and physical reality. The two styles of cross-categorization in each pair have a natural affinity for one another. When we understand one order of known reality, by objectifying category groups in another order, an obvious and useful next step is to turn around and understand those new objects by forming category groups in the first order.

The first pair of processes are actualization and animation, both of which cross-categorize physical reality with behavior:

Categorization	Process	New objects
P CAT B	Actualization	Things
B CAT P	Animation	Changes

In the process of actualization, organisms construct physical things to explain groups of behavioral stimuli; in the process of animation, they construct behavioral change objects to group multiple instances of things. While we may distinguish the two processes to help us analyze them, during the actual construction of known reality they cooperate in a virtually continuous stream. Every new thing becomes subject to change, and every change perception helps us recognize new things.

The result is the construction of what we might call **natural reality**. It is the part of our human environment that we share with all other forms of life. Every organism manifests its behavior in physical reality and most organisms (except the very simplest) modify their behavior to cope with physical objects.

A later section of this chapter discusses "intellectual reality," a part of human environmental reality that we construct by cross-categorizing behavior with ideals. To some extent we humans share that reality with other neurologically developed species. "Formal reality," also discussed later, is a part of our environment where we cross-categorize ideals with physical reality. As far as we know it is unique to mankind.

Constructing natural reality. The combination of actualization and animation, applied alternately, produces a complex interplay between behavior and the physical world. But the products of this interplay are not just things and changes. We can distinguish a hierarchy of objects that we and other organisms construct in natural reality:

- As described earlier, the process of actualization constructs external physical objects by categorizing groups of behavioral sensations, while the process of animation constructs behavioral perceptions of change by grouping actualized physical objects together as single objects undergoing motion or transformation.
- At the next level, groups of change perceptions are actualized into physical **events.** In my terminology, an event is something "out there." It is a physical occurrence, among things we already know, that explains a group of our behavioral change perceptions.

- Once we know physical events, it is natural to group them into chains of events that we perceive as **causation.** Event A causes event B, which causes event C, and so on. Causation is a behavioral way of understanding physical reality, a kind of second-level animation on top of mere perceptions of change.
- The interplay between behavior and physical reality goes on. Groups of causal chains become actualized into the kind of physical world-view that scientists sometimes call "animistic." It is a physical world made up of things and their causal links. Many people, particularly those unfamiliar with the abstractions of science, understand their environment in these terms. That's why I call it "natural reality."

The animistic worldview, made up of physical events and behavioral perceptions of causation, contrasts sharply with the abstract worldview that characterizes modern physics. If asked which of the two views is "correct," a majority of the world's population would probably opt for the former. Later parts of this chapter discuss reasoning and definition, the styles of cross-categorization typically used by physicists.

Physical events. Perceptions of change are like sensations, which we feel must come from something in physical reality. So we actualize groups of changes into physical events. Each physical event is different from any of the changes that compose it, just as the event of "floating" is different from various displacements of a balloon. Events are what we believe must exist in physical reality to explain our perceptions of changes among things.

Thus changes are objects in the behavioral order of reality and events are objects in the physical order. Changes give new meaning to physical things by grouping them chronologically. Events give new meaning to our perceptions of change by grouping them into unitary physical events.

Some changes sense simple events, such as a thing moving from one place to another. Because only its spatial location is different, it is easy to understand that one thing has endured through the changes that we perceived. Other changes are more complex—for example, burning a piece of wood to a piece of charcoal. At the beginning we construct the piece of wood from unknown reality and at the end we construct the charcoal. The two things didn't move during the combustion event, but now they are obviously different. In an act of cross-categorization, we recognize the event of one thing undergoing what we perceive as a transformation. Without this act of cross-categorization, common sense would tell us only that we constructed two unrelated things in physical reality, the wood and the charcoal.

Perceptions of causation. Physical events can be categorized in our behavior in terms of causation. We perceive that one event is the cause of another. For example, we may perceive that the burning of a candle flame is the cause of the candle becoming shorter. The burning is a physical event—the actualization of a group of change perceptions of the candle flame. Similarly, the shortening of the candle is an event that we actualize from a group of change perceptions of the candle. For any of a number of reasons—priority in time, regularity in our experience, success in prediction—we associate the two events in our behavior. We call the earlier event the cause and the later event its effect.

The groupings of causes and effects that we make in our behavior may be actualized in physical reality as "causal links." Constructing causal links deepens our ability to understand physical events. Yet the ontological status of causal links has been a perennial problem for both philosophers and scientists. The current state of the dilemma is thus summarized by scientist John F. Sowa:

> In modern physics, the fundamental laws of nature are expressed in continuous systems of partial differential equations. Yet the words and concepts that people use in talking and reasoning about cause and effect are expressed in discrete terms that have no direct relationship to the theories of physics. As a result, there is a sharp break between the way that physicists characterize the world and the way that people usually talk about it.[22]

Even though physical causal links are not constructed directly from unknown reality, they become vital parts of our known reality.

Animism. Natural reality fosters a form of understanding that may be called "animism." Piaget and other developmental psychologists have used the word to describe the reality that most young children construct. It is a reality in which physical and behavioral objects often are mixed together. Anthropology yields many examples of people who conjure physical things as if they were behaving organisms—boats, rain, the sea, inanimate totems, medicines, and so on.

In fact, ordinary people everywhere adopt a kind of animism in their everyday lives, as Sowa indicated. When we bake a cake we don't pay attention to the ionization potentials of sodium bicarbonate; we just know that baking powder "makes the cake rise." When I step on a floor-board I don't think about the elastic deflection moment of the board; I simply believe that "it will support me."

In a prior work,[23] I contrast this everyday animistic worldview with the "framework" theories of science. Animism explains physical reality using behavioral categories; science tends to use ideal categories. When we group physical objects behaviorally, the world appears to unfold in time—it is "one thing after another." When we group physical objects ideally, the world appears to consist of static objects located in a multi-dimensional space-like framework. It takes considerable ingenuity in theorizing, such as that displayed by the principles of thermodynamics, to translate between the two worldviews.

Thus what I call "natural reality" gives rise to the simplest form of epistemology. It is the "mirror of nature" view, in which our internal experience is treated as just a reflection of a solid "world out there." Sensations, changes, and causes, which are behavioral interpretations of physical reality, lead us to construct an animistic physical world of cause-driven things and events. These same things and events, which we constructed in physical reality to explain our sensations, become primary objects of knowledge. Our understanding bounces back and forth between behavior and physical reality, explaining each in terms of the other.

The "Flow" of Time

A prior discussion (page 17) described time as an ordering method that separates objects in behavior. But that separation alone, while vital to behavior's ability to appreciate change, does not produce the "flow" of time from past to future that is an ineluctable part of life. To it must be added the interplay between behavior and physical reality that occurs in the alternation of actualization and animation.

In this interplay, physical reality provides a kind of "scratchpad" for behavior—it allows an organism to objectify temporal separations as physical events, which can then be further separated in behavioral time-lines as "trains of events." Without making periodic "notations" in the form of physical event objects, behavioral time exhibits no sustained flow; it simply "happens." Conversely, without behavioral time what we call physical events are merely collections of distinguishable physical states that lack any serialization into "past" and "future."

"The moving finger writes," sang Omar. Had he stopped there, he would have symbolized the role of time only in behavior. "And, having writ, moves on" adds the metaphor of a physical record "left behind"—something of which no further behavior can "cancel half a line." When animation and actualization work together, physical events constitute "the past" and behavioral timelines constitute "the future." They meet at the point where behavioral perceptions of change in physical objects are categorized physically as events. Because events and timelines are parts of two disparate orders of reality, this "now" point appears to be constantly moving from a physical past, which is immune to further change, toward a behavioral future, which has no physical embodiment.

Thus the constant alternation between actualization and animation, which I have called "natural reality," makes time "flow." Each train of behavior that an organism constructs adds a bit of future; each physical event that it constructs adds a bit to the past. Behavioral and physical constructions alternate with one another so fluidly and in such small increments that the overall impression is that of an ever expanding past and an ever new future.

Unpredictability. This explains why we tend to regard the future as unpredictable. The whole of any given train of behavior is predictable in the sense that we know what we are trying to do. But as soon as we interact with physical reality our current train of behavior is cut off. A physical event intervenes and our next train of behavior is a new object. Any prediction that is part of the first train of behavior expires with it, although the second train may make a new prediction. The disconnect between the two trains of behavior is absolute, because the intervening physical event is part of an order of known reality that is inherently separated from behavior.

Example: Flipping a Coin

Games of chance provide good examples of how the "flow" of time leads to the inherent unpredictability of the future.

We toss a coin with no notion of whether it will come up heads or tails. The difference between these face markings on the coin must be physically insignificant—they matter only when we "read" the coin behaviorally. So when the coin tumbles in the air it must act just as a plain metal disc would; this is what it means for the coin to be "fair." The rules for coin tossing then specify three stages:

1. The behavior of our picking up the coin and flipping it without constraining or otherwise influencing its physical tumbling.
2. The physical event of the coin turning over multiple times in the air and landing without any behavioral influence.
3. The behavior of our interpreting the coin's face that is uppermost without acting on the coin physically.

Placing a physical event between two trains of behavior "disconnects" them. Our behavior that includes flipping the coin cannot be in the same train as our behavior of reading its upper face. Once the coin has been flipped, its physical actions go into the past relative to our "new" train of behavior of reading it after it lands.

We could "connect" the behavior of flipping with the behavior of reading by never letting go of the coin and turning it over by hand. That would let us predict whether it comes up heads or tails, but it would not follow the rules. The rules require the intervention of a purely physical event. The correct sequence—behavior, a physical event, new behavior—uses the flow of time to make the result of flipping a coin inherently unpredictable.

Formulating Propositions

A previous section described how we animate the physical world by grouping its static objects into behavioral categories, which become change perceptions. A similar process takes place with ideals, which might be characterized as static objects perceived by the "mind's eye." This process, which I call **formulation,** groups ideals into objects I call **propositions**:

Categorization	Process	New objects
B CAT I	Formulation	Propositions

Numbers and arithmetical operations are simple instances of ideals; for example, two and three and five and the operations of addition and equality are ideals. Grouping them as 2 + 3 = 5 produces a proposition. As in other cases of grouping, the formula is a new object in reality that is different from any of its elements. But it is not an ideal object, not part of commonsense ideal reality. The formula is a behavioral object—a speculation about ideals.

Each proposition constructed by the process of formulation has these general characteristics:

- We expect it to be either true or false. Our purpose in formulating propositions is to convert ideals into useful objects in our behavior. Merely contemplating numbers, or understanding them in common sense, does not help us in "the business of life." We must combine them in speculative ways—sometimes usefully, sometimes uselessly—to make propositions. Then we can see if the propositions work for us. This is another instance of life benefiting from the inherent freedom of cross-categorization.
- The truth or falsity of the proposition depends on the way that the ideals it groups are assembled. Thus 2 + 3 = 5 is true, but 2 + 5 = 3 is false, and 2 = + 5 3 is meaningless. Just as behavior can assemble physical objects into sequences that are "causally true" (the candle grows shorter because the flame burns) or "causally false" (the flame burns because the candle shortens), or even "causally meaningless" (the candle shortens and the flame burns because), so we can group ideals into propositions that are true, false, or meaningless.

We humans apply our skill in formulating propositions to all kinds of ideals, not just numbers. Values, for example, become grouped into propositions about virtue, honesty, piety, and so on. The old workhorse of college philosophy classes, "grass is green," is a proposition about two ideal universals, grass-in-general and greenness. We expect it to be generally true or false (some grass is brown) and use it as an aid in the business of life. In this role, formulation is a powerful tool. Our ability to form propositions out of ideals enables much of the world-changing behavior of humankind.

Abstracting Universals

Among all other living things, human individuals have the most highly developed ability to access and understand ideals. We accomplish this by grouping trains of behavior into ideal categories, then objectifying those categories into ideal objects. I call this process **abstraction** and its products I call **universals**:

Categorization	Process	New objects
I CAT B	Abstraction	Universals

We might think of abstraction as cognate to actualization. In the latter process, we gather a group of sensations in our behavior into a physical category and then objectify that category as an external physical thing. In abstraction we gather another group of behavioral objects—roughly, our behavioral speculations about some parts of known reality—into an ideal category that becomes an ideal object, which I call a universal.

Recall the example of the red balloons. We perceive each balloon by grouping a sensation of red and a sensation of roundness, thereby constructing a thing in physical reality. By a similar process, we could abstract the ideal of redness by grouping red sensations (which may be parts of our perceptions of balloons or of many other things) into an ideal category and objectifying that category as the universal "red."

The difference is a matter of grouping. We find that the group red+round is easy to categorize into a physical object; for example, we can construct causal events using it and other physical objects that we know through common sense. Similarly, the group of red+red+red . . . is easy to categorize ideally; for example, it is a member of the larger grouping of colors. But the converse categorizations don't work as well: a sensation of red plus a sensation of roundness doesn't make a useful universal, nor is it useful to try to construct a physical object out of multiple red sensations of balloons, apples, roses, and so on.

Abstracting behavior. All behavior is subject to abstraction, not just sensations of things. For example, the last section discussed the human behavior of formulating propositions about integers. But where do the integers come from? "God created the integers," Leopold Kronecker famously wrote, "all the rest is the work of Man." Well, not quite. Integers are ideals, which belong to an order of reality independent of behavior. But we know integers because they have become parts of the reality that is constructed by organisms such as man.

Integers are universals that we construct by abstraction from such behavior as counting: "If I tally that herd of animals with the fingers on one hand, and the tally comes out even, then there must be five animals because I know that I have five fingers." Such abstraction objectifies the integer "5" as the ideal that categorizes various processes of counting five things—in this case, a herd of animals and the fingers of one hand. The integer 5 is the one object that the herd and the fingers "have in common." This train of argument shows up more formally in Russell and Frege's association of any integer with "the set of all sets that have the integer's number of members."

A common use of abstraction in human cross-categorization is the valuation of behavior. Trains of behavior, both individual and species-driven, are grouped into ideal categories and objectified as "values." What kinds of behavior are noble, just, good, or ignominious, mean, evil? Ideals sort them out. Of course, humans often disagree about which trains of behavior fit into which categories—that's the way it is with cross-categorization. But the urge to abstract universal values from specific trains of behavior wields a pervasive effect on human life.

Survey: Intellectual Reality

An earlier discussion surveyed natural reality, which results from cross-categorizing behavior with physical reality. The next two processes that are listed in Table 4-2 (page 95) are formulation and abstraction, which cross-categorize behavior with ideals:

Categorization	Process	New objects
B CAT I	Formulation	Propositions
I CAT B	Abstraction	Universals

During the process of formulation, we group ideals into new true-or-false behavioral objects, which I call propositions. During the process of abstraction, we group objects in our behavior to make new ideals, which I call universals. The constant interplay between formulation and abstraction constructs what I call **intellectual reality.**

Although natural reality constitutes an environment for all forms of life, intellectual reality is an "environment" constructed primarily by human individuals. In our mental life, formulation and abstraction take turns constructing hierarchies of thought. Through formulation we group universals into propositions, and through abstraction we group propositions into new universals. In this way our known reality gains both behavioral propositions and ideal universals, all through the free use of the human neurological apparatus.

To see how this works, consider the example of Euclid's *Elements*. Most of its 13 books start by formulating definitions that abstract the universals to be used in Euclid's propositions. The first definitions use familiar notions such as parts, breadth, and length to abstract points, lines, and surfaces. These objects were known in Euclid's day, but his novel contribution was to formulate their definitions in ideal terms. His later definitions go on to abstract universals that were not widely known, such as prime numbers. Having made his readers understand these universals, Euclid was then able to formulate new propositions that truly expanded the knowledge of his day. For example, he was able to state what is today called the fundamental theorem of arithmetic, that any integer greater than 1 can be written as a unique product of prime numbers. Taken as a whole, Euclid's *Elements* is a remarkable example of the alternation of abstraction and formulation in intellectual reality.

Hierarchies. A hierarchy, as I use the term here, is a tree structure, like a genealogy. It is commonly found in intellectual reality. Ideals are grouped, through formulation, and the groups are abstracted to form new ideals. The ideals that are members of the groups are often called "subordinate" to the ideals abstracted from the groups that contain them. As we repeatedly formulate propositions and abstract ideals from them, we build trees of subordinate and superordinate ideals. In terms of the set theory analogy of Chapter 3 (page 61), the hierarchies we construct are sets of other sets. We may also regard such hierarchies as formulations in which ideals are not only grouped but also are "nested" within one another. Our behavior supports this formulaic nesting by treating some ideals as "logically prior" to others.

The "nesting" of ideals in hierarchies—a behavioral contribution to cross-categorized reality—helps us to understand ideals by relating them. For example, consider a typical hierarchy of human values, such as "beauty." Nested under the general ideal of beauty are various types of beauty—of music, of graphic art, of ideas, of places, and so forth. Within each of these are nested further divisions. If we visualize this hierarchy as a tree, its branches divide again and again until we reach the "leaves," which are the beauty of one specific piece of music or of one painting. The reason why we formulate such a tree in our behavior is that we often find a common experience while hearing a beautiful song and viewing a beautiful painting, but we cannot directly compare the song with the painting. Only by traversing the branches of the tree, up and down, can we appreciate that our common experience is their mutual beauty.

Hierarchies not only nest, they intersect. Cross-categorization lets us group the leaves of one tree with the leaves of another, constructing new formulations and abstracting new ideals. For example, we may fit the beauty of a painting into a hierarchy of aesthetic values and at the same time fit it into a hierarchy of economic values, based on its price. The two value trees, aesthetic and economic, may intersect at many points, yielding more propositions about the monetary value of beauty.

Notice that intellectual reality is built entirely between behavior and ideals; physical reality is not directly involved. Although a painting may consist of physical paint and canvas, we are not aesthetically moved merely by viewing paint, nor is canvas what we pay for when we buy a painting. We cross-categorize a painting in natural reality, by conserving it or displaying it; but in intellectual reality we treat the painting as a "connection" between behavior and ideals.

Because it is constructed between ideals and behavior, unconcerned with physical things, intellectual reality readily supports the human "spiritual life." People find it easy to formulate propositions about any subject, however intangible, and abstract from them a wealth of "other-worldly" ideals. This subject is discussed further in Chapter 7.

Reasoning Out Physical Principles

Universals are ideal objects that we construct by grouping objects that are parts of our behavior. As a result, they reflect our specific interests as behaving organisms. For example, the universal "chairness," which Plato discusses in *The Republic,* is part of our known ideal reality only because we make and use chairs. If we walked on four legs or lived in the sea, it might never occur to us to abstract such an ideal.

But there are other ideals that are not constructed by categorizing our behavior; we construct them by grouping physical objects. I call these ideals **principles** and the process of categorizing physical things ideally, which produces them, I call **reasoning**:

Categorization	**Process**	**New objects**
I CAT P	Reasoning	Principles

A principle is an ideal explanation of a group of those physical things and events that become part of known reality through actualization and animation. Although we could continue to work with things and their events by cross-categorizing physical and behavioral reality (building the "natural reality" described on page 99), we find promise in using ideals to enhance our understanding of our physical environment.

The entry point for reasoning out principles is our observation of regularities among the events that things undergo. When set afire, for example, a piece of wood usually burns to charcoal. Multiple instances of this event can be grouped into a "regular event" in our behavior. But mere events carry no guarantee of permanence; wood might cease to burn tomorrow. To better understand physical reality, we want to pick certain events and recategorize their contents under ideals. So we say that wood burns not just because we have seen it do so many times, but because its burning manifests the operation of "natural principles." In turn, the natural principles "explain" why wood burns—it's because that's the way the world works. Our understanding transcends simple belief, and science is born.

Laws of nature. Adopting science as a preferred way to understand reality leads to ideal objects in our known reality that we call "laws of nature." Every physical thing or event is said to exemplify them. Thus, geometry explains how the spatial locations of physical things must be related to one another; mathematics explain how our measurements of motion and other kinds of change are governed; and the laws of forces acting on particles dictate to the finest level how events turn out the way they do. The laws of nature can explain all the things and events of physical reality because, as Laplace put it, "Everything in nature obeys them."[24]

The recognition that ideal principles could explain the things and events of natural reality—the world we construct by cross-categorizing physical and behavioral realities—goes back at least as far as Aristotle. But Aristotle did not talk about "laws of nature." He was concerned to define and categorize natural events and then let causation run the world. He went as far as to write some unkind words about the abstract reasoning of the Pythagoreans:

> There are some people who would even construct the whole universe out of numbers, as do some of the Pythagoreans. Yet manifestly, physical objects are all heavier or lighter, whereas unit-numbers (being weightless) cannot go to make up a body or have weight, however you put them together.[25]

It was the successes of modern science that convinced many thinkers that there are real and enduring laws of nature, that these laws govern the physical events of the natural world, and that most of them can be expressed mathematically. As physicist Paul Dirac wrote in 1963,

> It seems to be one of the fundamental features of nature that fundamental physical laws are described in terms of a mathematical theory of great beauty and power, needing quite a high standard of mathematics for one to understand it. . . . One could perhaps describe the situation by saying that God is a mathematician of a very high order, and He used very advanced mathematics in constructing the universe. Our feeble attempts at mathematics enable us to understand a bit of the universe, and as we proceed to develop higher and higher mathematics we can hope to understand the universe better.[26]

Although Aristotle talked about the essences of natural events, he did not treat them in the Platonic sense, as independent ideals. We could say that to the extent he recognized "laws of nature," they were for him immanent parts of physical reality. Later philosophers, such as Hume and Mach, focused instead on behavior. Hume could find no sensory experience corresponding to necessity—the "law" part of every law of nature—and so concluded that laws of nature were just mental habits that we acquired from repeated experiences. It was not until modern times, with the proliferation of Dirac's "advanced mathematics," that hierarchies of ideals could be proposed as underlying explanations for much of the physical universe.

Defining the Physical World

The principles of nature, formulated through reasoning, turn out to be not about the ordinary physical things that we construct through actualization, or about the events that we recognize through animation. Their explanations are couched in ideal terms. Understanding these explanations requires a new cross-categorizing process, which I call **definition.** Definition constructs new objects in known physical reality that are the **properties** of physical things and events:

Categorization	Process	New objects
P CAT I	Definition	Properties

Through definition, we give physical reality new objects of knowledge. For example, actualization lets us objectify the source of some gray, solid, heavy sensations as a rock, a physical thing. Definition lets us add a new object to our known reality—the weight of the rock—and measure it. Our behavior acquires new routines to "perceive" the rock's weight, by constructing a weighing machine and a unit of weight. The weight comes out as a number—an ideal—but for us it is as valid as any sensation. The weight number, which we call a "property" of the rock, joins its grayness, solidity, and heaviness in our understanding of that physical object.

Of course we could also measure the grayness of the rock, using a colorimeter, and even measure its solidity by determining its hardness, density, and so on. But in so doing we would be adding new property objects to our cross-categorized reality, objects that we understand in terms of ideals, not replacing characteristics that we already know and understand in behavioral terms.

The natural principles of modern science are all about properties: mass and energy, for starters, plus velocity, density, entropy, specific heat and so on—a host of measurable properties that are required for the natural principles to work. When I pick up a rock and perceive it as an object, for example, I have little idea what its magnetic permeability might be. Yet that property is as tangible as its shape or color, although measuring it requires sophisticated instrumentation. Certain natural principles are about magnetic permeability and are meaningless unless we define such a property in physical things. So the rock I hold in my hands is a more complex object than my perception tells me, and I might be surprised by the ways in which it would react when placed near a powerful magnet.

As usual with cross-categorized reality, every physical property is always subject to redefinition. What is the thing that we know as fire? Is it the "dephlogistication" of a combustible material or is it oxidation? It took years of carefully measuring combustion in closed vessels before eighteenth-century science made a decision. The crucial observation was that the total products of combustion always weighed more than the original material being burnt. If burning were a loss of phlogiston, then phlogiston must have had "negative weight," a property unknown in any other material. Abandoning phlogiston became possible with the objectification of oxygen, an element absorbed during combustion. The properties of oxygen fit the natural principles that were known at the time better than the properties of phlogiston.

Thus definition constructs a new cross-categorized physical reality, built upon the reality we construct through actualization but expressed in terms of measurable properties instead of behavioral sensations. Once the properties of physical things are understood, and some of their measurements are known, we can relate the properties of any thing to those of any other thing by constructing natural principles through the process of reasoning.

Survey: Formal Reality

The last pair of processes listed in Table 4-2 (page 95) cross-categorize ideals with physical reality:

Categorization	Process	New objects
I CAT P	Reasoning	Principles
P CAT I	Definition	Properties

The process of reasoning groups physical objects and events into ideal patterns that I call principles. The process of definition groups ideals found in the principles, objectifying the groups as physical properties. The human behavior of reasoning out ideal principles and defining physical properties constructs what I call **formal reality.** It is the world of rationalism and science.

In formal reality, the physical things that evoke sensations in natural reality become replaced by quantifiable "phenomena" that fit into ideal principles. Our natural understandings are regarded as too "subjective" for common agreement; they must yield to measurements of defined properties and to a system of "laws of nature" that determine what those properties are and how they change.

A simple example is often performed in high-school psychology classes. You put one hand in a bowl of cold water and the other hand in a bowl of hot water. Then you put both hands in a third bowl of room-temperature water. One hand feels that the water is warm; the other hand feels that it is cool. Here your behavioral sensations actualize two different physical objects in one bowl of water. In "natural reality" you might assume that some water may be both warm and cool. But in formal reality, all bowls of water have one measurable temperature. The difference in the sensations felt by your two hands is an "artifact" of your nervous system, a defect that can be exposed by measuring the "real" temperature of the third bowl of water with a thermometer. Note that the result of measuring the water's temperature is a number, not a sensation. We enter mathematics, and the physicist's "laws of nature" are now available to us.

Why is this reality "formal"? It is because behavior is absent. The physical part of formal reality is explained by rational ideals, not by mere sensation or tradition. Conversely, the ideal part applies to "hard" physical reality, not to some arbitrary world imagined by our behavior. Formal reality is the reality of experiment and "objective" verification. It is a world in which every bowl of water has a definite temperature.

We humans use induction and deduction to construct theories about the contents of formal reality. The resulting "framework theories" of formal knowledge are discussed in Chapter 6 (page 205).

Constructing Environmental Reality

We humans use the six styles of cross-categorization described earlier —actualization, animation, formulation, abstraction, reasoning, and definition—to construct the bulk of what I call environmental reality. Through cross-categorization, each style adds new objects to a specific order of the known reality in which we live. These objects, which we construct by objectifying categories, are listed in Table 4-3.

Table 4-3. Contents of environmental reality

Locations of categories that become new objects	**Sources of objects categorized**		
	Physical	**Behavioral**	**Ideal**
Physical reality	*Substances*	Things	Properties
Behavior	Changes	*Processes*	Propositions
Ideals	Principles	Universals	*Essences*

The italicized cells in this table label the physical, behavioral, and ideal parts of common sense, which does not cross-categorize objects. As was discussed earlier, common sense underlies cross-categorization and is the primary source of known reality for most organisms other than humans. But for us, the cross-categorized parts of the environment that we construct form the principal reality in which we live. The origins and contents of these parts may be summarized as follows:

- During actualization, groups of behavioral objects are categorized as sensations of physical **things.**
- In animation, physical objects are grouped behaviorally in time as perceptions of **changes.**

- During formulation, ideals are grouped into behavioral categories that become objectified as true-or-false **propositions.**
- Abstraction groups behavioral objects into ideal categories that we know as **universals.**
- Through reasoning, physical objects are categorized under ideals and the ideal categories become objectified as natural **principles.**
- By means of definition, we group ideals into physical categories, which become objectified as physical **properties.**

Put another way, the cross-categorized part of environmental reality, which we construct out of commonsense reality, is populated with the following objects in its three orders:

- In its **physical** order, cross-categorized reality acquires physical things and their properties through actualization and definition.
- In its **behavioral** order, cross-categorized reality acquires changes and propositions through animation and formulation.
- In its **ideal** order, cross-categorized reality acquires universals and principles through abstraction and reasoning.

Finally, the three orders of known reality tend to cross-categorize each other in pairs, letting us construct what we commonly think of as three coherent "areas" or "kinds" of environmental reality:

- We construct **"natural reality"** by alternate acts of actualization and animation, producing a world of things and their changes. Through cross-categorization we understand this world as filled with events and their causes, and we experience it serially through the "flow of time."
- We construct **"intellectual reality"** by alternate acts of formulation and abstraction, producing a world of propositions and universals. We fill this world with intersecting hierarchies, through which some propositions "subsume" other propositions as "logically prior." It is a world of logical concepts and speculations, of abstract evaluations and judgments.
- We construct **"formal reality"** by alternate acts of reasoning and definition, producing a world of scientific principles about physical properties. It is a world of frameworks governed by laws, into which we fit "observed phenomena." It is a world of experimental science and rationalism.

Remember that our complex environmental reality is built by cross-categorizing a known commonsense reality in which objects in each order are grouped by using categories in the same order. Although cross-categorized reality often expands by cross-categorizing itself, at the bottom of the process are objects that are not cross-categorized—that are understood only "in their own terms" through common sense.

Choice and Novelty

Why does life bother to construct the realities of cross-categorization? What I call common sense—grouping objects in their original orders of reality—underlies most of its simpler processes. Why make life more complicated?

The answer, I believe, lies in the freedom that cross-categorization grants. Common sense provides only one way to categorize any object, hence one way to understand it. But because there are three orders of known reality, cross-categorization always provides two different ways to understand any object. For example, cross-categorization allows us to understand a physical thing either behaviorally, as a nexus of events and causation, or ideally, as a holder of physical properties that obey impersonal laws.

Why have we and other organisms created this freedom? Why is cross-categorization such a vital technique for life? At first one might judge that having two ways to understand a given part of reality would be less efficient than having one way. Our processes of understanding would constantly be faced with choices, and sometimes we would make inferior choices.

The answer to these questions, I believe, lies in the basic difference between life and the environmental reality that life constructs and knows. As the next chapter discusses, life constructs its own "organic" realities—the bodies of individual organisms, the social organizations among those individuals, and the mental realities within individuals. These organic realities interact with environmental reality. Organisms "win" when they increase the range, effectiveness, or insight of one of their organic realities.

Exercising choice. A part of environmental reality that "challenges" an organism must belong to one of the three orders of known reality. It must affect the organism physically, by impinging on its body in some way, or behaviorally, by forcing the organism to respond to events, or ideally, by requiring a grasp of patterns in the environment. These are the ways that organisms know the reality in which they live.

The organism's first reaction to such a challenge is to objectify it. The organism constructs a new physical, behavioral, or ideal object in its environment. It could then respond to the new object using common sense. This happens fairly often: the body can react physically as if it were merely a physical thing, or reflexively to a behavioral stimulus, or it may routinely adapt to a pattern in the environment. In such cases the organism categorizes the challenge within the order of reality to which the challenge belongs, without further discrimination or analysis.

But a more effective response would use cross-categorization. The organism would group the challenging new object with other known objects and then it would either understand it as an instance of a known thing (if the other objects had already been categorized) or it would construct a new object by objectifying the new group. In either case, cross-categorization would let the organism meet the challenge posed by the original object by using its existing knowledge of a different order of reality.

For example, imagine an animal walking on uneven ground. Its foot encounters a depression and its center of gravity shifts to one side. In pure common sense, the physical challenge of stepping on a hole is met by the physical response of leaning sideways. No other response arises, and the animal would have responded exactly the same way if it had been a wind-up toy. But now imagine that the depression in the ground is such that responding to it by shifting its center of gravity might make the animal stumble or fall. In this case, it may respond behaviorally to the physical challenge. The animal picks up its feet, jumps across, or copes in some way. This behavioral response to the physical challenge works and the animal goes on its way.

In this example the animal made a choice to respond behaviorally. But let us imagine that the depression in the ground was part of a cattle grid—a series of ground-level bars and gaps designed to deter cattle from crossing. If the animal had experienced this pattern before, it might categorize the physical challenge ideally. In that case it would not try to go forward or it would adopt some evasive strategy. We can deduce that the animal's categorization was ideal because cattle, once accustomed to a steel grid, will avoid the same pattern when it is only painted lines. This example illustrates several factors that come into play when an organism makes a choice in categorization:

- A response to a challenge may occur in the same order of reality (when you step in a physical hole your body leans sideways) or in another order (you decide behaviorally to step over the hole or you realize ideally that you can't go forward).
- There is no right-or-wrong choice when an organism responds in the same order of reality. Things just happen the way they do. But when the organism cross-categorizes, the result may be right or wrong. In this case, responding to a cattle grid behaviorally, as if it were just another hole, would be wrong. It would also be wrong to respond to painted lines ideally, as if they were a cattle grid.
- Every organism benefits from its ability to exercise categorization choices such as these. The physical response (leaning sideways) to a minor physical challenge is most efficient. The behavioral response to a larger challenge (hopping over a hole) is appropriate, to avoid falling. And the ideal response (recognizing that it is impossible to cross a cattle grid) is the correct one to avoid major injury.

Cattle grids are parts of the environmental reality of both wild and domesticated animals. But for cattle, they are also parts of the "social reality" that humans construct to work with livestock. Social realities are discussed in the next chapter.

Creating novelty. A cattle grid is something novel in the life of a cow. In the "state of nature" it would be unlikely that individuals of the genus *Bos* would objectify a series of parallel lines on the ground. But as a result of domestication, they often do. Such novelty cannot emerge from common sense; it requires cross-categorization.

Among humans, novelty is more the rule than the exception. Most of what we know comes from cross-categorizing objects that we construct from unknown reality. The test is: Might we be wrong? If the answer is Yes, then the object that we know has gone beyond common sense. It is something novel that we have created to enrich our known reality and to make our lives more effective.

Summary of this Chapter

All organisms (including humans) live in an external world that I call environmental reality. Starting with unknown reality, life constructs this world to provide a known reality in which organisms can thrive. Thus environmental reality is the first and largest field in which the reality construction techniques described in the previous chapter are applied. Organic processes of objectification, categorization, and generalization, used repeatedly and continuously, construct the known environment in which we all live.

As I discussed in Chapter 1, the objects in this known reality come in three disparate orders: physical, behavioral, and ideal. Organisms—objects with aspects in all three orders—are masters of environmental reality because they construct it so that every nonliving object is part of only one order. This increases the efficiency of life's knowledge of environmental reality.

Every organism starts its construction of environmental reality with the process I call common sense, in which it categorizes objects in each order by categorizing them in the same order. But every organism goes on from there and *cross-categorizes* the environmental reality it knows. Every time an organism groups objects in a given order into a category that becomes an object in a different order, it "gains perspective" on its environment. This mode of understanding turns environmental reality into the complex world that we know.

There are six ways that objects in one of the three orders of known reality can be categorized in another order. I have tried to give these six styles of cross-categorization common names: actualization, animation, formulation, abstraction, reasoning, and definition. We humans use all of them to construct the environment we know; other organisms use some of them less often or not at all. We also tend to link the six styles of cross-categorization in pairs, constructing areas of our environment that I call natural, intellectual, and formal realities.

A primary effect of cross-categorization is the "flow" of time and the consequent unknowability of the future. This effect, which is shared by all organisms, is an integral part of the separation between life, as the builder, and the external reality that life constructs.

Although organisms are embedded in the environmental reality that they construct, understanding them requires an analysis of the organic realities that life constructs for itself. These realities—corporal, social, and mental—are discussed in the next chapter.

5. Organic Realities

Everything you can imagine is real.
PICASSO

As an inherent part of the construction of known reality from unknown reality, life constructs itself. The construction methods it uses are the same as those discussed in Chapter 3—objectification, categorization, and generalization—but the end results are novel. Organisms construct "organic realities" that are distinct from the "inorganic" environmental reality in which they live.

Yet life builds itself out of inorganic parts. In the physical world it builds the bodies of organisms, including their organs and adaptations. In behavior it builds the reactive processes that are unique to organic life, ranging from metabolism and reflexes to individual learning and communication. In the ideal order it develops the basic patterns by which organisms survive and reproduce, including genetic codes for replicating individuals. Life is unique in known reality because every organism has facets in all three of its orders. Such integration of the physical, behavioral, and ideal is never found in the inorganic part of known reality.

In constructing itself, life introduces new ordering methods into known reality. It devises ways of separating and distinguishing objects—space, time, and pattern—that are not native to unknown reality. These ordering methods let life construct itself and the rest of known reality. The story of living evolution is that organisms construct their bodies in physical space; they compete with one another and exploit the inorganic environment along timelines; and they are guided by ideal patterns that they use genetically to construct more organisms. Thus the ordering methods of space, time, and pattern help organisms exist and thrive in the physical, behavioral, and ideal orders of the known reality that life constructs. Being one object in all three orders is what makes every organism alive, and being able to work in all three orders is what makes organisms thrive.

Organic objectification. Objectification is a specific kind of living behavior. Organisms do it as part of their process of making unknown reality known. We see the physical footprint of objectification all the time in organisms other than ourselves—when a frog captures a fly, when a plant turns its leaves to face the sun, when a bird answers the call of another bird, and so on. The fly, the sun, and the distant bird are objects that have been isolated from the rest of the environment and identified as objects of knowledge so an organism's life can go forward.

Multiple realities. By constructing themselves, organisms already depart from knowing a single reality. Organic realities, each with its physical, behavioral, and ideal aspects, are known realities that stand apart from the inorganic reality that organisms know.

"Being alive" gives organisms unique abilities, foremost among which is their ability to construct other known realities. Organisms, including ourselves, use this endowment to construct the inorganic world of environmental reality, described in the last chapter. Organisms do this to make for themselves a known resource for living processes. Thus organic reality constructs itself from unknown reality while it also objectifies more unknown reality to form environmental reality.

But life's construction of reality does not stop there. Organisms build several organic realities that are as different, as independent, and as well known as environmental reality. These organic worlds include the **corporal** reality of organisms themselves in known reality; **social** reality, a known reality constructed by groups of individual organisms among themselves; and **mental** reality, which is constructed and known by certain individual organisms alone.

All of life's species and individuals construct corporal reality, at least to the extent that they build their own bodies, behaviors, and genomes. Selected species and individuals also construct social and mental realities to different extents. Some species construct elaborate societies that dominate the lives of their individuals; other species don't. Individuals of "higher" animal species construct mental realities, among which those of humans are the most abundant. Individuals of many other species may know little or nothing beyond their corporal and environmental realities.

Organisms have evolved the abilities to construct social and mental realities because they find that these realities deliver specific benefits; species, groups, and individuals that do not need or cannot realize the benefits do not construct the realities.

Corporal Reality

Corporal reality comprises the bodies and actions of living organisms, including their physical morphologies, their trains of behavior, and their ideal architectures.

Corporal reality arises within known reality only because organisms are present in all three known orders—physical, behavioral, and ideal. As a result, corporal reality is inherently cross-categorized. The last chapter presented a table (see page 95) listing the six styles of cross-categorization by which organisms construct environmental reality—the part of known reality that is not organic. Table 5-1, below, lists the six cognate styles of cross-categorization through which organisms construct themselves.

Table 5-1. Corporal self-construction

Style	Organic process	New objects
P CAT B	Metabolism	Bodies
B CAT P	Reactivity	Reflexes
B CAT I	Learning	Skills
I CAT B	Ingenuity	Techniques
I CAT P	Evolution	Genomes
P CAT I	Variation	Adaptations

Like my naming of the styles of environmental cross-categorization, the terminology in this table is somewhat arbitrary. I want to put simple labels on the processes and objects that I will try to characterize more closely in the pages that follow. And as before, the notation "P CAT B" indicates that behavioral objects ("B") are gathered into groups (CAT-egorized) that become new physical objects ("P") in known reality.

Organisms use the organic processes listed in Table 5-1 to construct their own aspects in known reality. They construct bodies and organic adaptations in the physical order of corporal reality, reflexes and skills in the behavioral order, and living techniques and genetic codes in the ideal order. The six processes listed—metabolism, reactivity, learning, ingenuity, evolution, and variation—occur only in organisms. Below is a summary of some of the ways in which these processes construct and support organic life.

Metabolism comprises two organic functions: *catabolism* captures energy from the environment, and *anabolism* uses that energy to build the molecules and tissues that make up the bodies of organisms. The energy captured through catabolism also powers the physical actions of living things.

These processes would not occur in physical reality without help from behavior. Metabolism groups sequences of behavior—what we might think of as "recipes" for harvesting energy, assembling complex molecules, and so on—into physical categories. It gives "physical meaning" to these sequences of behavior. The physical categories then become objectified as new physical things: pyrophosphate bonds to store energy, for instance, and proteins to build tissues. Thus emerge the physical aspects of organisms.

Because the physical products of metabolism come from grouping behavioral objects, they appear to defy the "principle of entropy" that describes physical changes in environmental reality. Pyrophosphate bonds concentrate energy in living bodies (at the cost of dissipating it elsewhere) and proteins are complex structures that materialize from simple molecules. This "emergence of complexity" shows up as an anomaly in purely physical descriptions of reality.

What I call "internalization" is a form of anabolic metabolism that occurs notably in humans. We store memories physically, by constant changes to our neurological tissues. We can verify this when part of our neurological system is damaged or removed and memories disappear. But what we remember is behavior—our ideas, sensations, thoughts, emotions, and so on. Internalization is discussed as a process in mental reality later in this chapter (page 146).

Reactivity is my name for the ways that organisms interact with their environment. To support the catabolic phase of metabolism, for example, reactivity groups physical objects into behavioral categories. Thus an animal may categorize carbohydrates as things to be ingested; a plant may similarly categorize sunlight as a source of energy and grow toward it. To help anabolic tissue construction and preservation, reactivity may group other physical objects behaviorally as things to be avoided—for example, temperature extremes and chemically active radicals.

Reactivity constructs behavioral objects that I call **reflexes.** Most of these originate in species or higher taxa and are passed on to individual organisms, although some may become "conditioned" by personal learning. The hallmark of a reflex is that it is involuntary. Because it is constructed entirely between behavior and physical reality, a reflex is not amenable to the "reflection" that ideal categorization provides.

Sensations, which some philosophers call "qualia," are products of reactivity. In organisms that construct mental reality, a sensation is the behavioral facet of a physical occurrence in a sensory organ. It is a kind of reflex, but the behavior that a sensation constructs is confined to the individual organism's mental reality.

Reactivity includes manifest responses to stimuli, some of which can be dramatic. A tiny stimulus—a shadow in the sky or a rustle in the grass—can "trigger" a vehement response in some organisms. This happens because certain physical "cues" are categorized behaviorally as threatening, and the category which groups them may be objectified as a long and energetic sequence of behavior.

Just as metabolism is alien to physical reality, so reactivity is something new in behavior. It is part of organic reality. Because organisms have aspects in both orders of reality, they can "link" physical objects to behavioral objects through cross-categorization. As we shall see when discussing mental reality, behavior by itself may take little notice of physical reality.

Learning uses behavior to categorize ideals. Just as reactivity builds behavior in organisms from physical events, learning builds behavior from ideal patterns. The behavioral objects that learning constructs are what I call **skills**—individual extensions to the reflexes developed by species and higher taxa. At this point life focuses on the individual, and particularly on providing the individual with the neurological resources to construct new trains of behavior. The consequences for individuals of life's making this investment in "on-board computing power," instead of relying on reflexes alone, have been far-reaching. One product has been the construction of mental reality, which is analyzed later in this chapter.

Why does life bother with individual learning? We could visualize learned skills as filling "gaps" in chains of reflex behavior. Philosopher Stephen Pepper described the benefits of such an arrangement in 1958:

> It may at first seem strange to think of our highly developed intelligent behavior as based upon a gap opening up within an instinctive chain-reflex system. But once such gaps begin to appear in the evolutionary process, their biological advantages to organisms would become apparent on one condition: the provision of a technique of behavior, such as trial and error, which could be thrown into gear when a gap appeared, so that an organism could acquire by learning, and then maintain, a successful bridge over a gap whenever such a bridge had been found. [27]

Learning involves more than just trial and error, but in all its forms it requires access to ideals. In the case of trial and error, the organism must be able to categorize ideal patterns before it can plan a trial, and it must use ideal categories to evaluate the trial's outcome.

An important learned skill among animals is the use of language. Many animals communicate through reflexes—body movements, scents, vocalizations, and so on—but some also learn group languages. For example, some birds learn song "dialects" that serve to identify a specific flock. In humans, learning to communicate through language is an indispensable social skill.

The behavioral skills that learning constructs need not be complex—they are often small additions to inborn reflexes. In human infants, for example, the use of language is reflexive but specific speech behavior is learned. In Stephen Pepper's terms, words and sentences fill gaps in cries and "body language" until much of the child's communication takes place through the learned skill of socially-determined speech.

Ingenuity turns learning around; it groups skills that have been learned into **techniques** that use those skills. Here the categories are ideal and they group behavioral objects; thus the effect of ingenuity is to arrange behavior into patterns that can be objectified as ideals.

Animal psychologists identify what I call "ingenuity" any time an individual forms an abstract plan and then acts on it—for example, when a chimpanzee figures out that putting a chair on top of a box will let it reach a piece of fruit. The behavioral actions are said to follow an ideal technique, which categorizes the separate bits of behavior and makes them "meaningful."

Such ideal techniques, based on behavioral learning, are constructed by individuals. Ideal techniques determined by species are constructed by the process of evolution, during which it is the individual's physical genes that are categorized ideally. Ingenuity occurs in many animals, but it is most prevalent in humans.

As I use the two terms, ingenuity is different from intelligence. Yet the two work with each other to enlarge human capabilities. Ingenuity gives our thoughts and plans new ideal meanings and intelligence lets us think about our own behavior. Intelligence is discussed later in this chapter (page 156).

Evolution works out the ideal patterns for the physical construction of individuals in each organic species. It groups individuals into ideal categories that become objectified as genetic codes. Those groups that survive and reproduce contribute their codes to the **genome** of their species. Each ideal category appears as a "genetic trait" of one or more individual organisms; the ideal, a sequence of genetic code, is part of the genomes of those individuals. As more and more such individuals survive and reproduce, the code sequence becomes part of the species' genome—which is part of its ideal aspect—and the trait that it invokes becomes part of the species' physical aspect.

An earlier discussion (page 40) described some of the ways in which biologists distinguish one taxon from another: physically, through their phenotypes, behaviorally by comparing their ethotypes, or genetically by examining their genomes. According to the traditional definition of a species—a population of individuals that interbreeds—species would be the only "real" taxa. Every species delimits itself genetically, by its individuals exchanging DNA; in contrast, genera and higher taxa may be distinguished by habitat, behavior, or physical characteristics that are incidental to genetics.

Variation is the converse of evolution. It is the process by which ideal techniques for survival or reproduction are grouped and the groups are objectified physically by an organism. I call the physical products of variation **adaptations.**

Organic variation occurs constantly as each individual organism modifies its body to adapt to its environment. The resulting adaptations include changes in metabolism, reflex conditioning, and refinements of ideal goals. In species and higher taxa, adaptations occur as each taxon adopts ideal techniques in its genome. The ways in which organisms employ variation and evolution to develop their corporal realities are discussed under "Speciation and Individuation" (page 158).

Orders of organic reality. Organisms, self-constructed through the processes just described, are unique objects in known reality. There are no other things like them—because they are objects in all three orders, if for no other reason. But the uniqueness of organisms goes deeper; it shows up in different ways when we contrast living things with their environment in each of the three orders of known reality:

- In physical reality, organisms are "integrated." Each living organism is a complete interactive assembly, which ceases to be an organism if it is broken up. The difference between an environmental "thing," which is objectified through actualization, and an organic body, which is constructed through metabolism, is that the body is a "working machine." Every organism depends for its identity (as an object in known reality) on the interactions of its parts. An inorganic object, in contrast, can be broken up into other inorganic objects.
- In behavior, organisms act "against" the processes of environmental reality. For example, they extract energy from their environment and use it to protect their bodies and their genetic codes. When a timeline is applied to environmental reality, organic processes appear to run counter to its "normal" thermodynamics. Organisms also react in complex and unpredictable ways, as contrasted with the relatively predictable behavior of inorganic processes. In colloquial terms, they "don't follow the rules" of the inorganic environment.
- In the ideal order, organisms exhibit purposes. Aristotle saw living things as having immanent "natures" that they realize—the acorn to become an oak, for example. His view did not require an extrinsic designer, but only that some things had ideal patterns built into them. The patterns would then manifest themselves in the physical forms and behavioral actions of each organism. Inorganic objects do not exhibit such built-in purposive patterns.

Analogy: Time and Data Coherence

Modern complex computing systems resolve certain problems that are like problems found in the ecosystems of living organisms. As I said before, this is because computers are designed to perform lifelike tasks, and so their designers have tended to copy some of the workings of life itself. A particular computer problem that arose in the mid-1960's is called "data coherence in concurrent programming." The analogous problem that life dealt with early in the evolution of organisms might be called "time coherence among multiple organisms."

Computers perform concurrent programming when they execute more than one program "thread" in parallel, typically by dedicating multiple processors to a single task. The data coherence problem arises when different processors modify the same field of data. It's like the problem that can occur when two people share a bank account, each making deposits and writing checks. In a similar computer example, several program threads rendering a digital image in parallel must not arbitrarily change each other's data.

Although there are various "consistency models" for achieving data coherence in concurrent programming, one of the simplest is to depend on a master clock to propagate changes throughout the system. That way each step of the clock defines a state of the system, and changes of data between steps can be signaled from thread to thread.

Life's problem with "time coherence" is more fundamental. As was discussed in the preceding chapter, each organism constructs timelines to animate the physical objects that it actualizes from unknown reality. In effect, it creates time. This is necessary for the organism to react to objects in environmental reality—it must separate its stimuli from its responses. But for the life that we know to evolve, its total ecosystem must be time coherent; life must impose a uniform standard of time on every organism and on every process within every organism. The timelines that organisms construct with respect to environmental reality must be synchronized so that every organism and organic process lives, competes, and reproduces using a common timeline. Were this not the case, some organisms or parts of organisms might choose to "jump ahead" in time and thus no longer share their parts of environmental reality with the rest of life.

Einstein intuited the mechanism which life has evolved to preserve time coherence. He made a remarkable suggestion—that the speed of propagation of electromagnetic radiation is the same regardless of the motion of its source or the motion of any observer using it as a means to synchronize events in time. When the consequences of this idea were developed and tested, it appeared that separate space and time were not inherent to physical reality. Only the propagation of radiation was real.

Life includes not only Einstein's observers, but *every* organism. If we were to visualize physical reality as a "block universe," with time as one of its dimensions, then we would see all radiant energy as aligned to a specific vector in that block. The origin of this four-dimensional vector would be the "birth of the sun," an event in space-time, and the vector's direction would make the relation between space and time into an object in known physical reality. This space-time vector of radiant energy would be the same for all organisms, and it would be unrelated to the space-time vectors of their movements or the motions of objects in their environment.

Building a successful scientific worldview around the propagation of electromagnetic radiation was no accident, because all living things depend on radiant energy. From the beginning, life on earth has evolved in the sun-earth thermodynamic system. Life's use of time to organize behavior places the birth of the sun in the distant past and its burning out in the distant future. If we were to liken the sun to a steamship, churning its way along the four-dimensional vector of electromagnetic radiation, earth's organisms would be like gulls scavenging energy in its wake. It is little wonder that we see our world in space and time, for these are efficient ways to understand a world in which we depend on radiant energy.

By definition, we do not know what radiant energy "is really like" in unknown reality. But we and other organisms recognize its orientation when we construct the ordering methods of space and time that help us understand environmental reality. We do this because every process and cell in our bodies exchanges energy. Regardless of what energy "really is," life has adopted it at the core of its physical aspect. Life—at least the life we know on earth—is time coherent because it has a single "built-in" standard in the natural vector of radiant energy. This vector is a uniform part of physical reality that has been incorporated into every metabolic process since life began, right down to the molecular level. Its function is similar to that of a master clock in a computing system.

Social and Mental Realities

Chapters 3 and 4 described the ways by which organisms construct known reality. The basic tools are objectification, categorization, and generalization; the richness of the result is due to cross-categorization, by which organisms are able to construct truly novel objects.

For simplicity, the examples given in those earlier chapters assumed that organisms construct a single reality, their environment. But when we analyze known reality in terms of its organic and inorganic parts, we find that we can identify several distinct realities:

- **Corporal** reality, described in the previous section, which comprises the physical, behavioral, and ideal facets of organisms themselves.

- **Environmental** reality, the "external world" constructed from unknown reality which houses and nourishes organic life. It is the reality of things, changes, etc., summarized in Table 4-2 (page 95).
- **Social** reality, a cross-categorized reality that organisms construct among themselves. It is as different from environmental reality as living organisms are from inorganic things. Various types of social reality are analyzed beginning on page 137.
- **Mental** reality, an entirely novel reality that is constructed only by individual organisms. Here we find memory, awareness, reflection, and other components of what is called "consciousness." This world, so characteristic of humanity, is analyzed beginning on page 145.

Why so many realities? Once life starts constructing reality, starting with itself, there is no natural end to the process. If it runs out of ways to construct known reality out of unknown reality, it can construct new objects in known reality by cross-categorizing existing objects.

What makes these realities distinct? The key is how we (and other organisms) know them. I know my own body, with all its reflexes and proprioceptions, its itches and urges, in a more direct way than I know the environment around me. I never confuse the two; in fact, if I were to treat my body as part of the environment a psychiatrist might diagnose me with "autoscopy," a recognized pathology.

Social reality is also known differently from environmental reality, as Berger and Luckmann argued in *The Social Construction of Reality* (1966).[28] Social institutions have to be understood in their own terms, and not (for example) by using mechanical concepts or mathematical statistics. Again, psychiatrists recognize several kinds of psychopathy among people who confuse the social reality in which they live with the inorganic environment.

Finally, mental reality is known differently from all the others. The objects in environmental and social reality—things and events, laws and obligations, and so on—are largely "common knowledge"; but mental reality is known only by individuals, separately. I may choose to "express" my thoughts, through speech or writing or by my actions in the environment. Otherwise, my mental reality is private. People who don't believe that their mental reality is private provide psychiatrists with yet another cluster of pathologies to diagnose.

The realities just cited—organic, environmental, social, and mental—are each complete and internally coherent. They are also disparate in much the same way that the physical, behavioral, and ideal orders of known reality are disparate. But they are different regions of reality construction instead of different ways of ordering those constructions. The orders of reality cut across the realities they order.

Again we may ask: Why so many realities? One reason is the way that multiple understandings can solve problems more effectively. For example, a problem in environmental reality may yield to a solution in social reality (get help) or in mental reality ("think of" an answer). The key benefit of separate realities is that each one provides a new way of dealing with problems in the others. An organism finding a solution in one reality may "repurpose" that solution for other realities. Through it all, every organism works from a unified base in unknown reality.

Model: Layers of Reality

The analysis in this book has so far described several distinguishable kinds of reality—from unknown reality to various realities constructed by humans and other organisms, including our mental and social worlds. Along the way I have noted how realities of each kind are built upon other realities, yet each is constructed in its own way.

In the analysis of complex computing systems, structures of this sort are often visualized as "layer models." For example, the "OSI Seven Layer Model" is a classic way to visualize how various parts of a data communication network can be designed separately yet work together. The model's lowest layer, physical transmission, just moves electrical signals from place to place. The next layer, data linking, assembles the signals into meaningful "frames" and checks each frame for internal coherence. The third layer, networking, strings frames together into messages, each of which is addressed to a specific destination; and so on. System designers talk about "interfaces" that separate the layers while letting them communicate with one another.

The point of depicting such a system in layers is that each layer is relatively independent. There are numerous ways in which electrical signals can be moved about; once they are moved, there are many ways to form them into frames; once the frames exist, there are many ways to make messages out of them; and so on. At the same time, the layers are not so independent that they can convert any string of signals into any arbitrary message. The layers build on each other in ways that preserve the functioning of the whole system.

Kinds of known reality. Such a layer model could be applied to the kinds of known reality described in this book. The result might look like this:

Table 5-2. Layer model of known reality

Layer	Kind of reality	Typical processes
Fourth	Mental	Internalization, sensation, imagination, awareness, etc.; see Table 5-4, page 146.
Third	Social	Communalism, authoritarianism, etc.; see Table 5-3, page 138.
Second	Environmental	Actualization, animation, etc.; see Table 4-2, page 95.
First	Corporal	Metabolism, reactivity, etc.; see Table 5-1, page 123.

This table is intended to be read from the bottom up. In the **first layer,** life constructs itself out of unknown reality by initiating the three-phase process of objectification, categorization, and generalization described in Chapter 3, "Constructing Reality." It chunks unknown reality into objects, groups those objects into categories, and combines categories logically into generalizations. During each phase of this process, life constructs new objects by objectifying groups, a trick that one might call its "miracle." Thus corporal reality builds itself in unknown reality.

Known reality is known in three "orders"—physical, behavioral, and ideal. But life transcends this separation by constructing objects that are organisms, which have aspects in all three orders. Life can do this by exercising the freedom of cross-categorization—the ability to construct new objects in one order of known reality by grouping objects that are parts of a different order.

Organisms construct the first layer of known reality "because they can." It is a reality populated only by organisms, and all they know is themselves. Hence each act of corporal construction is also an act of knowing, because organisms are inherently cross-categorized objects in all three orders of known reality. But the first layer of known reality contains no objects "external" to organisms, no "environment."

The **second layer** of known reality contains the inorganic objects that life knows. It is the environment in which organisms live. Through common sense, organisms know it as a world of substances, processes, and essences; through cross-categorization, they know it in more detail as the things, changes, propositions, etc. listed in Table 4-3 (page 115). Here life reaches out, constructing more known reality from unknown reality by repurposing the same processes through which it constructs itself.

True to the layer model, the first and second layers of known reality shown in Table 5-2 are conceptually independent. The organisms in the first layer construct themselves as objects fundamentally different from the objects they construct in the second layer, the environment they know. A given organism may know a range of environmental objects and a given environment may be known by a variety of organisms. The layer model helps us visualize how corporal reality and environmental reality work together while remaining independent of one another.

In the **third layer,** social reality, organisms know each other. While one organism may be aware of the effect that another organism has on its inorganic environment, this is not equivalent to knowing the other organism as a living thing. Knowing an organism requires objectifying it in more than one order of reality—as a physical thing that behaves, for example, or as a train of behavior that follows an ideal pattern. The outcome of such knowledge is the construction of "social groups" in which organisms may compete, cooperate, and communicate.

All levels of life construct social reality, not just individuals. The study of "ecosystems" has explored the many ways in which species and higher taxa interact with each other, in addition to dealing with the "abiotic" environment. For instance, species may interact physically, by competing for resources such as sunlight and water; behaviorally, through predation and parasitism; and ideally by evolving genomes that are more successful—in effect, by "outsmarting" other organisms.

It is within the human species, however, that social reality has been most fully constructed. While nonhuman animals readily form families and sometimes tribes, larger social constructions seem to be unique to humankind. These groupings (which I call classes, religions, societies, and states) are listed in Table 5-3, page 138.

Again, we can appreciate the ways in which the third layer of the model is independent of the first and second layers. Various organisms, living in different environments, are free (within limits) to construct a variety of social groups. As a result, some groups adapt to the common environment better than others. Much of the richness and complexity of life comes from the independence of the reality construction processes in different layers of the known reality model.

The **fourth layer** of known reality is the mental reality that is so characteristic a part of human life. It is a private reality, known only to individuals, and it is related only indirectly to the physical world. It may be just a byproduct of evolution. But the extent to which humans know it has set us apart from other forms of life. More on this later.

Relations between layers. Besides distinguishing independent parts of a system, the layer model shows how the work done in each layer is prerequisite to the work of the next layer. In the case of the OSI Model, for example, the construction of data frames precedes the assembly of frames into messages. They are separate tasks, but they are related within the system because they must be done in a specific order.

Analysis finds similar relations between the layers of known reality in our model. The bottom layer, corporal reality, is prerequisite to all the other layers because life is needed to construct known reality. The first new reality it constructs is environmental—an inorganic world that life transforms from unknown to known so it can sustain itself. Using the basic processes described in Chapter 3, living organisms construct in the environmental layer the resources they need to gather energy, build tissues, and reproduce themselves in the corporal layer.

If reality contained only one organism, or if corporal reality were such that no two organisms shared the same objects in environmental reality, social reality would never exist. But as it is, organisms find that they compete with other organisms in the environment, or they evolve advantageous ways to cooperate with other organisms. Living things benefit from knowing other living things.

Organisms cannot work with other organisms only in environmental reality, as if the other organisms were inorganic materials. They must construct a separate reality in which organisms can interact as living things—a social reality. This is the area of known reality that supports communication, competition, cooperation, and all the other ways in which organisms act upon one another.

As some organisms—particularly humans—exercise the freedom that cross-categorization grants, their social reality becomes filled with complex objects. Social life becomes more than just competition and cooperation; it involves values, moral dictates, legal constraints, and so on. Individuals find it increasingly hard to succeed in such a world. So individuals construct the fourth layer in our model, mental reality. This is a "private" reality, largely under the control of each individual, in which memories may be recalled and ideas developed. Using reflection and imagination as tools, individuals with access to mental reality can optimize their behavior in social and environmental reality.

Example. One way to "test" a layer model is to trace how the kinds of things it handles typically move through its layers. In the case of the OSI model described earlier, we trace information as it passes through the layers of a data transmission system; in the present case, we trace objects through the layers of known reality.

Imagine that I am working at a desk in a large office space. It is late morning and my metabolism wants a snack. A stomach contraction or salivation or other physical action is categorized behaviorally, and a new behavioral object—a reflex—enters the train of my work behavior. At this point I am not "aware" that I want to eat. I have constructed an object only in the first (corporal) layer of my known reality.

I look up from my work and scan my "environmental reality," thus entering the second layer of our model. Across the room is a bowl of fruit on a colleague's desk. My eye fixes on an apple, a new object in my known environment that I categorize as a snack.

If I had no knowledge of social mores, I might just walk across the room and seize the apple. But when I objectified the apple as a snack I also entered social reality, the third layer of our model, and categorized the apple as "someone else's property." The apple acquired a hierarchy of social meanings unrelated to my metabolism.

My resolution of the original interruption to my work behavior is to enter the fourth layer of our model, "mental reality." I become aware of the conflict between my metabolic wants and the social constraints that are associated with the apple. I reflect on possible ways to obtain the apple and construct a scenario in my mental reality. I will walk over to my colleague and say, "What good-looking fruit you brought in!" He, whom I know to be an obliging person, will probably reply, "Help yourself." If so, I will accept and eat his apple, and tomorrow I will bring in my own fruit and offer to share it with him.

This little playlet illustrates some of the complexity of human life. What we might call the "environmental apple" and the "social apple" are objects in two different kinds of known reality. When the corporal layer constructs a reflex such as hunger, it may take thought behavior in the topmost layer, mental reality, to recategorize the reflex into physical actions that will work in both social and environmental reality.

Social Reality

Organisms interact with other organisms differently than they react to their inorganic environment. Each inorganic object is known in only one order of reality, so an organism will respond to it in limited ways. For example, every organism knows that a physical thing can only be manipulated by physical action; behavioral wishing or ideal plans will not affect it directly. To move a rock, you must push it physically with your body.

But most organisms also know other organisms as single objects with physical, behavioral, and ideal aspects. When you contact another organism physically, it may respond behaviorally. For example, it may bite you or call for help, something that rocks don't do. Determining which objects in known reality are living organisms and which objects are inorganic things is a crucial task for every form of life.

So besides constructing their external environmental reality, many organisms also construct an external **social reality.** This reality is filled with other organisms, which compete, cooperate, and communicate with the organism that constructed it. It is not a completely disparate reality, for the organisms in it share the inorganic world, the "common environment." But social reality is different from environmental reality because the objects in it must be understood differently.

In passing, notice that it is not always easy for an organism to tell whether an object is inorganic or organic. To take a human example, the storm that rages clearly has a physical aspect; but is that all? Is it just a physical event, or might it also have a behavioral aspect, such as the displeasure of an angry god? Or might it represent the result of an ideal transgression—a broken law? Although they are "unscientific," such questions are a characteristic part of our human heritage.

Constructing social reality requires that the constructing organism recognize organic interactions among the three orders of known reality. Hence it requires cross-categorization. For example, many animals build social groups—such as families, packs, herds, and flocks—by cross-categorizing behavior with physical reality. The physical needs of individuals are categorized by group behavior, and the behavior of each individual is categorized by its being part of the physical group.

Human social constructions. One way to understand social reality is to analyze its most varied manifestation, in human life. It turns out that some of the ways in which we construct our social reality are also used by other species, but we go further than any other form of life. The names I give to our social construction processes are listed below.

Table 5-3. Human social constructions

Style	Social process	Typical social groups
P CAT B	Communalism	Families
B CAT P	Authoritarianism	Tribes
B CAT I	Intellection	Classes
I CAT B	Orthodoxy	Religions
I CAT P	Legalism	Societies
P CAT I	Collectivism	States

The processes of social construction in this table—communalism, authoritarianism, etc.—are analyzed at length in my earlier work under the rubric "organizations of behavior."[29] In Table 5-3 I have also listed some of the typical groups that each process forms in social reality. The following paragraphs give a brief summary of the how these groups are usually constructed.

Communalism is my name for the process of grouping individual behavior to construct new physical objects; for example, cooperating to produce food or shelter. The physical goals "give meaning" to the social behavior used to attain them. Individuals work as a group to plant a crop, build a house, raise a child, etc. The individuals that contribute their behavior become a *de facto* social group, the most common of which is the **family.**

Authoritarianism is the complement of communalism. It groups physical things together and objectifies the behavior needed to manage them. A division of labor emerges in social reality, enforced by people assuming social "roles." A **tribe,** for example, is a social group in which the physical tasks of bringing food and water, making tools, defending the homeland, and so on, may be allotted to individuals by the commands of a leader, by traditional practices, or by other kinds of authoritarian behavior.

Intellection is my name for the process of constructing individual behavior in social reality by categorizing ideals. The result I call a **class** —a group of people who "think alike." Notice that classes cut across tribes; a tribe may contain several classes and a class (such as a class of professional warriors) may be present in several tribes. This happens because the authoritarianism that constructs a tribal group uses social behavior to categorize physical objectives while intellection uses it to categorize ideals.

Orthodoxy grows out of intellection, as a result of the behavior that constructs a social class becoming categorized ideally. The behavior is given universal meaning beyond its merely being common to a group of individuals. The categorizing ideals typically become a tradition or a **religion.** Many religions are identified with their initial constructors—prophets or holy men—but a cluster of religious or traditional ideals typically emerges in social reality *any time* people are inspired to seek the universals that "lie behind" their commonly accepted behavior.

Legalism tends to be a late construction in social reality, for it does not involve behavior directly. In authoritarianism, physical things are managed through behavioral dictates; in legalism they are managed through ideal principles. The resulting social group I call a **society,** to distinguish it from a tribe or other authoritarian group. The physical acts of a society's members are categorized by ideals such as property, obligations, and rights.

Collectivism, finally, categorizes the ideals that legalism produces and objectifies the category physically—often, as an area of land and its improvements where the legalistic "writ runs." I call the result a **state.** The state acquires many physical parts: cities and harbors, roads and utilities, fortifications and walls. This physical property gives meaning to the ideal laws that govern its ownership, use, and disposition.

The social groups of individuals just cited, from families to states, get progressively larger and more complex. However, this doesn't mean that their development is a linear progression. Modern social realities usually contain a mix of groups. Moreover, the groups often interact. For example, the physical characteristics of a collectivistic state often recategorize communalistic family life within it—urban families do not behave like tribal families. The styles of cross-categorization listed in Table 5-3 only provide a minimal explanatory key to the very complex ways that human social reality is constructed and known.

Products of social reality. Organisms that construct social reality expand their behavior far beyond the range required to support their corporal realities. In particular, social organisms construct two classes of behavioral objects that help social groups work at all levels of life. Among humans these areas of behavior, **symbolization** and **mental**

reality, have become vital tools for living. We construct symbols to make languages work, and we construct mental reality to manipulate language objects and to work effectively in social reality.

Communication and Symbolization

Organisms affect one another through genetic inheritance and by their competition for resources in environmental reality. These mechanisms influence each organism's corporal reality. But it is advantageous for organisms to interact more directly in their shared environment. When they construct social and mental realities they need new ways to affect one another. Two key ways that organisms interact with one another in environmental reality I call "communication" and "symbolization."

Communication between organisms is widespread throughout life. The forms of communication are varied as well: scents, cries, songs, dances, displays, speech and writing. Communication is not confined to animals; individual plants, fungi, and even bacteria communicate with one another. Yet communication is unique to life; only organisms do it, and they only do it with each other.

As I treat it here, communication is a physical act. Sometimes that's all it is. Among plants, for example, the roots of some legumes secrete flavonoid molecules that are sensed by symbiotic *rhizobia* bacteria, which fix nitrogen in the soil. Animals may also communicate using molecules: canids mark territories by urination, felines by rubbing scent glands. Many animals display or highlight parts of their bodies to warn off competitors or to attract mates. In all these instances, the organism sending the communication constructs a physical object or event that the receiving organism identifies and categorizes.

But communication often carries a behavioral "message." Birds call, bees dance, wolves bare their teeth. While the communication may take place in physical reality, the message that it "carries" is behavioral or even ideal. The bird's call is meaningful because it is structured, not just sound; the bee's dance is more than just movement; and the wolf's teeth-baring is a harbinger of more aggressive behavior. In these cases, the organism that is sending the communication uses it to construct a **symbol**—a call or a dance or a threat—which the receiving organism understands through cross-categorization.

Symbols work because both the sender and the receiver understand them by sharing categories. Human languages are a prime instance of such shared categorization. The parts of any language are behavioral symbols that are categorized—given meaning—by other objects. Thus for a bird, the alarm call means that a predator is present; for a bee, its dance is explained by the location and nature of food; for a wolf, teeth-baring is given meaning by the physical act of biting. Among humans, the words you just read are categorized by objects such as birds, bees, and wolves, dancing and biting, etc. If both you and I didn't know and understand these objects in environmental reality, my words would be "meaningless" to you.

Organisms other than man typically construct language behavior that is categorized only by physical or behavioral objects. Thus the bee's dance is "about" the location of nectar; the bird's call may indicate physical danger or it may be an invitation to flock or mate; the wolf's display symbolizes behavior that may culminate in a physical act. But language behavior may also be categorized by ideals, particularly among humans. "See you at 5:00 pm" is meaningful not just in terms of behavior, but behavior joined with a specific time metric. Experiments designed to detect life in outer space try to discern ideal patterns in physical energy waves, supposing that such patterns would mark the presence of language behavior in human-like organisms.

The categorization of language behavior by ideals is an important form of symbolization. It lets language objects represent ideal objects that have been constructed in mental reality. Thus human individuals and individuals of a few other species can share ideals by means other than genetics. The symbolization of ideals also enriches other language behavior by "modalizing" it. Language expressions can be used to symbolize generic, hypothetical, or imaginary physical objects and trains of behavior. Using ideal categories, we can talk about things in general or events that might happen. Through its ability to symbolize all the orders of known reality, language thus becomes a powerful tool for constructing the social and mental worlds in which humans live.

Communication objects. Every act of communication involves two objects, one that is part of a medium and one that is part of a content. The medium object may be speech behavior, or physical markings, or ideal encodings in an electronic database. Similarly, the content may be about behavior ("π can never be calculated exactly"), or a physical fact ("π is the ratio of the circumference of a circle to its diameter"), or an ideal fact ("the first five decimals of π are 14159"). In constructing any communication, the content categorizes the medium; we say that the medium "communicates" the content. Consequently, a medium object —a piece of paper with marks on it, for instance—is understood in terms of its content, not just as another thing in environmental reality.

The medium and the content of a communication may both be parts of the same order of known reality. This situation, which we might call "commonsense" communication, tends to be the earliest and simplest way that a given medium is used. For example, human writing began in Mesopotamia with the creation of physical clay "tokens" that denoted physical objects such as jars of oil. Instances abound of other writing systems starting with pictographs, physical symbols for physical things. Similarly, every variety of speech behavior contains ideophones, words such as "splash" and "boom" that evoke behavioral sensations, and a simple cry may be behavioral speech with only a behavioral meaning.

But most instances of communication require cross-categorization. For example, a phoneme of behavioral speech is communicated by a physical, written alphabet character; or a computer transmits a physical image by encoding it into ideal numbers. The freedom that organisms exercise when they understand objects in one order of known reality by categorizing them in another order is what makes symbolization and languages work.

In all cases, communication requires a construction in social reality. To insert and extract content, the sender and receiver must agree on how they will categorize objects in the medium. Thus communication is an inherently social act. It is also a vital tool that groups of organisms use to construct social reality.

We humans tend to think of communication in terms of spoken or written languages. Our use of language, including the technologies by which we convey it, certainly makes us the best communicators on the planet, and it makes our social reality immensely complex. But we also use language to construct mental reality. It helps make the "stream of consciousness" possible. Consciousness has puzzled philosophers and psychologists for at least 400 years—so it may be helpful to discuss it briefly now, before analyzing mental reality as a whole.

History: Consciousness

"The Greeks have a word for it" goes the saying, but they didn't have a word for "consciousness" as it is understood today. Nor did medieval thinkers, although they wrote about the related concept of individual moral conscience. Not until the seventeenth century did philosophers formulate a clear idea of a "stream of consciousness." Locke, the arch-empiricist, described its self-referential nature in 1690:

> to find wherein personal identity consists, we must consider what Person stands for;—which, I think, is a thinking intelligent being, that has reason and reflection, and can consider itself as itself, the same thinking thing, in different times and places; which it does only by that consciousness which is inseparable from thinking, and, as it seems to me, essential to it: it being impossible for any one to perceive without perceiving that he does perceive.[30]

In his 1755 *Dictionary,* Johnson cited Locke to define consciousness as "the perception of what passes in a man's own mind."

Consciousness in this sense is what I call "awareness," and indeed it may have arrived relatively recently on the human scene. In his 1976 book, psychologist Julian Jaynes argues that human consciousness is a product of the evolution of language and developed during the second millennium BC, at least in the Middle East. In his account, the earlier human mental state dealt mainly with what I call environmental reality. Mental reality, to the extent it existed, was dominated by authoritarian dictates from rulers and gods, objectified as "inner voices." But as a consequence of having to grapple with social reality in an increasingly complicated mix of civilizations, people began to develop individual awareness. Jaynes concludes that

> consciousness is chiefly a cultural introduction, learned on the basis of language and taught to others, rather than any biological necessity.[31]

The present analysis would bear this out, for awareness—categorizing behavior by other behavior—does not yield major benefits in dealing with the environmental world. Reacting to environmental reality means doing *this* to *that;* the further realization that *I am doing this* does not add efficiency or effectiveness to the process. But when one is a player in social reality, the difference between knowing *I choose to do this* versus knowing that *somebody else is choosing instead of me* or *this is happening despite me* is crucial.

Today, psychologists and others who study this kind of reality often group several distinguishable mental processes under the single rubric of "consciousness." For instance, psychologist Steven Pinker cites three areas of human experience that "consciousness" might denote: self-knowledge, access to information, and sentience.[32] These abilities are the result of processes I call reflection, internalization, and awareness, which are listed in Table 5-4, page 146. These processes are "internal" in the sense that they are private to every human individual, but they are as important to human life as any "external" reality. Self-knowledge, stored information, and sentience constitute an "owned" reality that is unique for every person.

Self-knowledge is the certainty that I am I and not somebody else. It is only one example of reflection, but it is one that is easily verifiable. When I wake up in the morning, thus "becoming conscious," how do I know who I am? I don't have to check my physical appearance, like a chimpanzee looking in a mirror. Indeed, when Gregor Samsa wakes up in Kafka's story, he recognizes himself even though his body is that of a cockroach. Nor do I need to refer to my current behavior; no "stream of self-knowledge" flows through my mind. My "self-knowledge" is a behavioral conjecture that I construct through **reflection,** an act which categorizes my mental behavior using a group of remembered ideals that make up my "identity." My identity categories persist from day to day through the physical adaptation of memory, which bridges periods of unconsciousness and maintains a basis for my figuring out who I am.

At the moment of my awakening I may abstract other ideals from environmental reality: the current day, for example. If my current knowledge included the proposition that "today is Tuesday," I know to replace it first thing in the morning with "today is Wednesday." This proposition lets me abstract the ideal "current day," which I can relate logically to other ideals, such as the things I usually do on Wednesdays or events that are scheduled for this particular Wednesday.

So for humans (and for organisms in general) knowing one's ideal identity is just an item of individual knowledge. It has special interest for humans, but knowing my identity does not differ intrinsically from knowing that I play bridge on Wednesdays. Outside the human species, self-knowledge loses importance. In a chimpanzee's life, for instance, knowing that the image in a mirror is a reflection of "oneself" is much less important than knowing one's social position in one's troop.

Information access is the ability to call up personal sensations at will—the face of a friend, yesterday's lunch, *Yankee Doodle,* you name it. The information being accessed consists of physical objects that have been **internalized** in memory, a part of corporal reality. Such "memory objects" can be created in several ways, one of which occurs when an organism's sensory apparatus reacts to an external physical object.

The freedom with which memory objects may be "called to mind" greatly enriches our mental reality. The behavior of accessing internal physical objects is cognate to the behavior of knowing physical objects in the environment; in effect, we "relive" an act of sensation. But our mental environment is incomparably larger and more varied because our memories are stocked with the experiences and thoughts of a lifetime. When I objectify any part of reality, a wealth of stored memories is waiting to help me categorize it and give it meaning.

Pinker's **"sentience"** corresponds to the behavior I call **awareness,** in which the human mind objectifies its own behavior. It produces the "stream of consciousness," a train of human behavior that is known only to itself. It is the mirror-like action of behavior objectifying its own processes of objectification, where knowing and what is known constantly change places, that bedevils analysis. "Beats the heck out of me!" writes Pinker about awareness, and many other thinkers agree. The "hard" sciences, where objects of knowledge are supposed to sit still while we examine them, find it difficult to come to grips with the slippery, self-referential nature of awareness.

Mental Reality

The construction of mental reality accompanies the construction of social reality. Social reality, which is constructed to help organisms deal with each other, demands complex interactions among individuals. These social interactions are intrinsically different from an organism's interactions with environmental reality, and they are best done using knowledge of a new kind of reality within each individual.

In social reality, therefore, many of the tasks required to succeed in life shift from species to individual organisms. Individuals may rely on reflexes inherited from their species when coping with their inorganic environment; but when they are competing and cooperating with one another, they need more "individual initiative." *Proverbs* advises us that a soft answer turneth away wrath, but reflexes are more likely to lead to violence. The soft answer, and all the social skills it implies, must be formulated somewhere else. That other place, where one can "gather one's thoughts" and "think of a response" is **mental reality.**

Thus individuals who know social reality benefit from also knowing a "private" reality, a world that is largely under personal control. While social reality is shared, a forum where individuals can interact, mental reality is known only to each actor. Yet mental reality can deal with both the social and environmental realities that an individual knows. In effect, it constitutes a small stage, removed from the greater drama, on which an individual's part in that drama may be rehearsed and refined.

The contents of mental reality. For the reasons discussed below, mental reality is like a personal miscellany, without particular order. We can give names to some of its contents, as shown in Table 5-4, but such labels serve only to point out typical examples, not to define mental reality in canonical detail.

Table 5-4. Typical contents of mental reality

Categorization	Mental process	New mental objects
P CAT B	Internalization	Memories
B CAT P	Sensation	Experiences
B CAT I	Imagination	Ideas
I CAT B	Reflection	Conjectures
I CAT P	Induction	Paradigms
P CAT I	Deduction	Inferences
B CAT B	Awareness	Thoughts

The first process, **internalization,** constructs new objects in physical neural tissue which we know as stored **memories.** The second process, **sensation,** constructs new behavioral **experiences** by recategorizing those memories and also by categorizing the physical outputs of our sense organs. I call the loop through neural tissue "memorization" and "recall"; I call the one-way transmission from physical sense organs to behavioral experiences "perception."

In these processes we can appreciate life's efficient design of mental and corporal reality. Similar cross-categorizations construct experiences either by grouping physically stored memories or by grouping physical stimuli received from environmental reality. This makes an individual's neural memory apparatus, in effect, an "internal sense organ" designed to perceive the contents of a storehouse of memories.

The process I call "internalization" is analogous to communication, discussed earlier (page 140). Here the behavioral content is constructed in mental reality and the physical medium is part of individual corporal reality. Each of us remembers physically what we think and feel.

Like communication, internalization suffers from errors introduced by various stages of cross-categorization. In particular, symbolization plays a crucial role. But because internalization occurs outside social reality, its symbols need not conform to any established language. Mathematicians, for example, often think in symbols that are difficult to express verbally. Many insights in human psychology come from studying the symbols that people use when constructing memories. More on memorization later (page 150).

The two "creative" processes—**imagination** and **reflection**—relate ideals to behavior and back again. I call them "creative" because they generate behavior that goes beyond physical needs. The process I call "imagination" groups ideals to construct novel "patterns of behavior," which I call **ideas.** What I call "reflection" groups behavioral ideas into new ideal objects that I call **conjectures.** The conjectures can then feed back into this process, generating more ideas. Both processes take place within mental reality, so they happen rapidly. More on creativity later (page 153).

The two "analytical" processes—**induction** and **deduction**—relate ideals to physical memories in mental reality. They try to "make sense" of an individual's knowledge of physical reality. Thus "induction" tries to discover ideal **paradigms** that can recategorize the knowledge in a person's memory, and "deduction" objectifies new physical things and events that are **inferences** based on those paradigms. The inferences then become extensions of a person's or social group's knowledge.

Thomas Kuhn introduced the modern terminology of a scientific "paradigm" as a set of assumptions that constrains the operation of "normal science" in a given field.[33] I use the term to denote a coherent system of ideals that provides uniform categories for theorizing about a specific group of physical objects. Examples of common paradigms in science today are the various "frameworks" that support what I call framework theorizing. They are discussed in Chapter 6 (page 205).

Finally, **awareness** is a unique part of mental reality. It is behavior categorizing itself, thus constructing new behavioral "meta-objects" that I call **thoughts.** By categorizing memories behavior constructs experiences, and by categorizing ideas it constructs conjectures. The process of awareness can then construct new behavioral objects—thoughts—by recategorizing these experiences and conjectures. Since it is a behavioral object in mental reality, every thought is a potential starting point for further mental constructions. By constantly creating new behavior in this way, human awareness makes our mental reality a complex and convoluted place. More on this later (page 155).

Memory, sensation, creativity, analysis, and awareness all take place “inside” human individuals, separate from the “outside” realities of society and the environment. They construct the mental reality that we humans find to be vivid and ineluctable. Some philosophers regard it as the most certain reality, or at least a reality that any serious school of thought must address. For some scientists, however, the concept of a personal reality separate from the “empirically verifiable” reality of physics and biology is a puzzle and a distraction.

Mental reality at work. My earlier discussion of the “layering” of environmental, social, and mental realities included an example of my wanting to obtain an apple from a coworker in the social milieu of our common office (page 136). We can analyze part of this playlet in terms of the mental reality processes listed in Table 5-4.

The starting point might be my awareness that my work routine had been interrupted. Objectifying and categorizing my own behavior, I “become aware” that I have been casting about for something to eat. I also become aware that I have identified an apple in a bowl across the room as a possible snack. At that point I may recall the experience of eating apples as snacks—“I savor the possibilities,” as it were. Through imagination I form the idea of taking and eating the apple. But an act of reflection categorizes that idea as impolite behavior, because the apple belongs to a colleague. Just seizing it would conflict with several ideal social values that he and I share. I then “reflect on possible actions,” imagining how each one might or might not satisfy our social norms. Ultimately I conjecture that the train of polite behavior described in the earlier example would probably work.

Through all of this, my awareness has acted as a kind of “message boy” among other processes, letting me turn my acts of imagination and reflection into new objects that can be newly categorized and then put through more acts of imagination and reflection. This turnover of ideas and conjectures, mediated by thoughts running between them, increases my effectiveness in both environmental and social realities. It also produces the “stream of consciousness” that is such a precious part of my life.

So long as we understand how it happens, we don’t need to analyze the “stream of consciousness” in detail. Its contents are ephemeral by nature, so we can’t say much more than that it consists of behavioral thoughts about behavioral objects. However, it is essential to recognize that awareness is different from memory.

It is easy to confuse the two. For example, as soon as we “think about” a sensation we substitute a thought about the sensation for the original sensation of a physical thing. The two may seem to be the same, but they’re not. Instances abound in everyday life, such as when we are driving a car. I am talking to a passenger and I miss my turnoff. Did I fail to sense the physical turnoff—the sign, the familiar scene? No, because sometimes I can recall having passed them. But I was “not conscious” of them at the time. What I was not conscious of was the fact that I had sensed the turnoff. Driving a car involves continually sensing the road environment and the reactions of the car; a turnoff is just part of this process unless it “is meaningful” because another part of our behavior has decided to make it so. In that case, our awareness must objectify our behavioral sensations as we approach the turnoff, not just the physical turnoff that the sensations actualize.

Analogy: The Flow of Time in Computers

The present analysis describes how organisms order things spatially in their physical common sense, then construct temporal changes among those things in their behavioral common sense. The result of these two constructions is that organisms understand their environment in terms of “events”—spatially distinct things changing over time.

The analogous concepts in computer technology are data states and program steps. When a single-threaded program runs in a computer, without encountering the problems of data coherence discussed earlier (page 128), each of its program steps starts with the computer’s data in a specific state. After the program step has been completed, the data is in another state, usually different. Any computer processing “event” may therefore be described in terms of an initial state, a program step, and a final state.

Storing data in a computer is analogous to arranging things in space; every piece of data has an “address.” The way that programs run is analogous to arranging changes in time—their steps occur in sequence (but not always in the same sequence), and are “past” or “future” with respect to one another. There is always a currently executing program step, which could be called “now” and which is changing a past state of the computer’s data into a future state.

Any "past" data state can be copied and saved in the computer as an additional piece of data; this is what "backing up" does. "Future" data states cannot be copied, but they may be predicted by calculating what effect a program would have on a past or current state.

How do patterns figure in this analogy? Living organisms—either individuals or species—group events by ideal categories and order the resulting ideal objects by their patterns. These patterns help organisms construct future events in mental reality, which guide their behavior in environmental reality. In computer processing, the algorithm for which a program was written performs an analogous role—it defines the data state toward which the computer's current process is directed.

These analogies can help us understand why human awareness seems to be confined to a constant flow of time. Why can't we sense the future of environmental reality? Because we sense only through our physical bodies, and we construct the physical order of known reality to contain only what we call "past." It is like a program's inability to process any data states other than the current one or backups of past states. We can only *model* future states, using ideals in mental reality, and then try to deal with their patterns in environmental reality. All the while, we are aware only of our behavior, which is both processing the physical past and modeling the ideal future. It is this awareness, in our mental reality, of our own time-constructing behavior that is our most immediate experience of the "flow of time."

One might say that physical common sense, which sees the world only through sense organs and physical memory, comprehends the past. Ideal common sense, which understands only patterns, comprehends the future. And behavioral common sense, which constructs the objects of awareness, comprehends only the "evanescent present."

Memorization and Recall

Memorization, as I use the term here, is a change in the physical aspect of an individual organism, which expires when the individual dies. From the viewpoint of the individual's species, memorization is a "scratchpad" process, for each stored memory is as ephemeral as the individual who stores it.

During an individual's lifetime, however, memorization and recall can make a critical difference between success and failure. That is why most animals have some capacity to store memories. Birds remember where their nests are located, and even worker bees must remember to alert the hive after they have found nectar.

Human life, of course, involves a great amount of memorization. With humans and other craniates, memories are stored primarily in the brain. Neurological memorization and recall have the great advantage of being fast and easy, because these processes take no "loops" through other parts of the body. Memories are stored directly in sensitive and agile tissue, where they are immediately accessible as experiences.

Experiments with both human and nonhuman memorization and recall indicate that these processes occur in several ways and involve several kinds of neural tissue. One would expect this of a capability that has been evolving as long as life itself. Here are the characteristics of memory that are important to the present analysis:

- Memories are stored as physical changes in the corporal reality of individual organisms. Each memory has a behavioral content.
- The content of a stored memory may symbolize something physical (an event), behavioral (a sensation or conjecture), or ideal (an idea).
- The content recalled from memory consists of the behavior I call "experience." It is never absolutely faithful to the content stored. During the processes of storage and recall a memory's content tends to be degraded by various stages of cross-categorization.

Memorization is thus like communication, described on page 140. Both processes construct physical objects, but memories are constructed in an organism's corporal reality while communications are constructed in environmental reality. Both carry behavioral contents that represent other physical, behavioral, or ideal objects. Thus for humans the recall process is like "reading" symbols written in one's brain.

Analogy: Scratchpad Registers

"Scratchpad registers" play an essential role in computer technology. They are used to store data temporarily—for example, when it is being moved from one process to another or when it will be needed in a later step of a process. A scratchpad is a part of the computer's memory that is used ephemerally, to serve immediate needs. Often a scratchpad is "owned" by a specific process, which is uniquely able to access it.

Scratchpad registers are commonly used in program "flow control." When a program "loops," for example, registers may keep track of the number of loops it has executed, or the conditions under which it must stop looping. Thus a program designed to loop through the records in a database and delete those that are more than three years old might use one register to hold the identification number of the record currently being examined, another to compare that record's date with the current date, and a third to count the number of records examined so it can tell when the database has been completely traversed. While the loop is running, the contents of the scratchpad registers constantly change; and once the task is done the registers are discarded.

Mental reality also depends on organic capabilities that could be compared to computer scratchpads. Processes in mental reality often construct objects that are ephemeral and subservient to the process that constructed them. These objects are products of cross-categorization, but they are not intended to become objects of knowledge. They are temporary aids that support more enduring processes.

Computer programs could be written without scratchpad registers. When looping through a database, for example, the computer could write the identification number of the record currently being examined to another database, instead of to a scratchpad. To examine the next record, then, it would have to retrieve that number from the other database, increment it, and store the new value. Although workable, such an approach would yield a very slow program. It would also result in the storage of unnecessary data, for the second database would just be full of record identification numbers that are no longer meaningful. Hence the use of the quick, disposable scratchpad.

Scratchpads in mental reality. Life has produced capabilities like scratchpads, at least in animals, as a byproduct of cross-categorization. They are temporary objects created by the processes of mental reality listed in Table 5-4 (page 146). They normally do not become stored as memories, but are used and then discarded.

In mental reality, scratchpads serve the "onboard computers" that are made possible by individuation. Psychologists talk about "short-term memory," in which a half-dozen or so different ideas and conjectures may be held in the mind for a few seconds and then forgotten. When a human mind does a mental calculation, for example, the intermediate products such as "carry the 1" are normally remembered only as long as they are needed for the task at hand. Psychologists sometimes call this kind of memory "primary" or "working" memory, to emphasize its role in helping consciousness function.

Human scratchpad memory, used by awareness, cross-categorizes ideals with behavior. If human imagination and reflection had to store every idea or conjecture in physical memory, and later recall it for further use, conscious thought would slow to a crawl. We would also find it hard to tell whether we had just constructed a given idea to deal with our current situation, or had constructed it years ago for another purpose. The nimbleness with which we can "toss ideas around" in our minds depends on our ability to cross-categorize our mental behavior with ideal patterns, using scratchpads.

Imagination and Reflection

Imagination and reflection are what I call the two processes by which individual organisms access ideals in their mental reality. Imagination groups ideal objects, such as universals abstracted from environmental reality, to construct the novel kinds of mental behavior that I call ideas. Reflection groups the ideas constructed by imagination into new ideal objects that I call conjectures. These conjectures, plus more universals, can then be grouped by imagination to construct more ideas.

How is using imagination and reflection in mental reality different from using formulation and abstraction in environmental reality? The styles of cross-categorization are the same: B CAT I for imagination and formulation, I CAT B for reflection and abstraction. The difference results from the different needs that individual organisms satisfy by constructing environmental reality versus mental reality. Individuals construct environmental reality to serve largely physical goals—bodily survival, nourishment, habitability, etc. They construct mental reality to serve mainly behavioral goals—prudence, intelligence, creativity, etc.

This difference in "purpose" between the two realities shows up in the ways that individuals use ideals. Used with environmental reality, ideals provide fixed patterns by which physical events and the actions of other organisms can be understood. Used with mental reality, ideals provide stationary "stepping stones" between ongoing thoughts.

Thus imagination and reflection use ideal "scratchpads." Ideals are arranged as patterns, so using scratchpads requires an ability to store patterns in neurological tissue. Only brains appear able to do this, which is why imagination and reflection are found mainly in humans and other animals with well-developed brains. Electrical activity can be measured within human brains, which present complex waveforms with base frequencies up to 100 Hz. These "brain waves" may well encode the contents of ideal scratchpads.

If it seems strange that a "register" in physical tissue could contain an ideal pattern, consider how the moving image of a television picture is encoded into a complex waveform and recorded on magnetic tape. During the recording process, magnetic domains of varying strength are distributed linearly along the tape; during the reading process, the domains are retrieved sequentially to recreate the waveform. Recording creates an ideal pattern from the temporal stream of the video; reading rebuilds the temporal video from the ideal pattern. Although much of cerebral physiology remains obscure, it is not hard to imagine that "brain waves" are the result of behavior "reading out" stored patterns of electrical potentials—the scratchpads for imagination and reflection.

Reflection is my name for our grouping behavioral objects in our mental reality into ideal categories. We "see" patterns, form analogies, gain "insights," and so on. Reflection is usually what we are doing when we analyze something, as opposed to experiencing it in sensation or thinking about it in awareness. The ideal categories created through reflection give our thoughts universal "meanings."

Reflection is necessary for the complex life that human individuals maintain in "civilized" societies. Civilized life depends on our being able to abstract ideals from objects constructed in sensation, group them with other ideals, and use the result to categorize our behavior. Otherwise we may act "irrationally."

For instance, I depress the brake pedal on my car "because" a light is red. The red light has no direct physical effect on my foot; instead, my response is behavioral—it begins with a process of sensation. But the crucial factor, the unique link between red lights and foot movements, is a set of ideals that I memorized when I learned to drive. These ideals go beyond just associating my foot movement with a sensation of red; they include ideas of traffic accidents, conjectures about law courts and insurance payments, and many other complexities of civilized life.

Without storing these ideals in memory, and understanding them when they are recalled in experience, we cannot perform certain tasks. We could "go through the motions," but our behavior would not "make sense." This is the reason why it is impractical to teach a chimpanzee to drive safely in a modern city, even though the animal's natural skills might include superior dexterity: the chimp would not be able to learn the ideals that categorize prudent and legal driving behavior.

Awareness

What I call "awareness" is behavior categorizing other behavior within an individual. I avoid the word "consciousness" as having become too broad; see the historical summary on page 142. But a tradition that goes back to the seventeenth century recognizes the unique nature of what is called "the perception of what passes in a man's own mind."

Awareness is thus a kind of monitoring process. As part of the daily business of life, individuals construct behavioral objects—sensations, propositions, ideas, and so on. But aware individuals also construct behavioral categories that group the other behavioral objects, giving them "new meanings." *This is what I'm doing,* says awareness. These categories, constructed in awareness, become new behavioral objects in mental reality, and the "stream of consciousness" is born. Because awareness is behavior and knows only behavior, it is naturally ordered as a timeline.

The stream of consciousness that awareness constructs is a natural hodgepodge. Into it are deposited all the objectified categories that monitor an individual's behavior, plus hierarchies of those categories. It is a heap of ephemeral thoughts about the individual's living processes and thoughts about those thoughts. Because behavior is sequential and ordered temporally, awareness appears as a stream. To store a thought as it streams by, the individual must internalize it physically—either directly as memorized behavior or indirectly as knowledge of an ideal pattern constructed through reflection.

Of course, awareness may access memory, which is stored in the physical part of the organism. The contents recalled may symbolize past physical events, or behavioral sensations, or idea conjectures. So while "turning over thoughts" in awareness—my behavior objectifying my behavior—I may recall something I saw happen the day before; or I may recall the feeling of pleasure that resulted from a specific train of behavior; or I may realize that something it would be possible to do would be dishonest. In all cases, I am accessing in my nervous system a physical object that I constructed to carry a behavioral experience that represents some other part of known reality.

In humans, awareness tends to become the master controller for much of our behavior. I inadvertently touch something hot and jerk my hand away before I become aware of what's happening. My immediate action is triggered and controlled by reflex arcs that operate outside my awareness. But soon I become aware of my physical sensations of heat and pain, as well as the physical actions that I made “instinctively” in response. I assess the damage, decide whether to treat the burn, make plans to avoid the same problem in the future, etc. All this behavior takes place as a process of awareness in mental reality, triggered by my objectifying the behavioral sensations that resulted from the physical hurt. My original sensations were hardly more than the raw materials for an extensive train of aware behavior.

Discussion: Awareness and Intelligence

“Intelligence” is an umbrella term for a variety of mental capabilities that appear primarily in humans. Besides the original IQ-test concept, modern psychologists talk about analytical, creative, and practical kinds of intelligence,[34] which we might roughly correlate with capabilities in working with ideals, behavior, and physical reality. Many of the wider definitions of intelligence can also be used to describe the behavior of nonhuman animals, including apes, cephalopods, and some birds.

I believe the reason why intelligence seems to be a characteristic of so many kinds of behavior is that it is a manifestation of awareness in an organism’s mental reality. *Intelligence is the ability to think about thoughts*. It is mental behavior categorizing other mental behavior, which can be “about” anything. Many organisms can deal mentally with their corporal, environmental, and social realities; but when they are being intelligent they also deal mentally with their mental reality. This mental “meta-capability” lets an organism “preview” various ways of solving a problem entirely inside itself, all the while making mental appraisals both of its thinking processes and of their expected results.

Consider the traditional IQ test, with its images to analyze, word analogies to understand, and number sequences to extend. When I work on its questions I conduct an internal dialog in which I appraise my own theories. Is the square with the circle in it like the triangle with the oval in it because both are pointy figures that enclose a round figure? Is the relation of hand to glove like foot to shoe because in both cases a piece of clothing covers a part of the body? What kind of rule has been used to generate this number sequence?

Sometimes my internal check on my own thinking is more than “Yes, that works” or “No, that doesn’t work.” I may reject a theory because it “misses the point.” The relation of “foot to ski” is not like "hand to glove," even though skis are put on feet, because skis are not "the same sorts of things as gloves." And so on. An IQ test is said to measure my "intelligence" because it exercises my general ability to appraise my own thoughts.

Thus awareness—behavior categorizing behavior in mental reality—lets me sort through possible plans, actions, and solutions to problems before committing myself in corporal, environmental, or social reality. When I finally act visibly in a way that shows that I have made good mental choices, my behavior is called "intelligent."

Reality Bridges

Through cross-categorization, organisms are free to construct objects in any reality they know. (What it means to know a reality is discussed in Chapter 6). Often they construct objects that are deliberately parts of two different realities. I call the results of such behavioral processes **"reality bridges."**

We and other organisms construct reality bridges in many forms. A bird's call, for example, is an object in environmental reality—a sound—that is also an object in the bird's social reality. Among humans, three specific behavioral processes construct reality bridges that serve as the primary connections between our environmental, social, and mental realities:

- **Linguistic communication** behavior in humans constructs objects that are parts of both social and environmental realities. A human language expression is part of the environment, as speech, writing, binary code, etc. It also is part of human social reality as an object with an agreed meaning. Every use of language is constructed to "work" in both realities. For example, a piece of human writing must be both physically legible and behaviorally "meaningful" in some socially agreed script and language. This is analogous to saying that a bird's call must be able to travel through the forest and at the same time be effective in the bird's social reality.
- **Evaluation** behavior in humans constructs objects in both social and mental realities. A human value, whether it is moral, monetary, or hedonistic, must be constructed to "work" both socially, within a group of people, and mentally, within each individual person. "Shared values" are among the links between individuals and groups

that make social groups viable. An "object of value" may be ideal (a moral precept), behavioral (a tradition of interaction), or physical (a coin). In all cases, however, both the group and its individuals must objectify it—the group in its shared social reality and each member of the group in that person's mental reality. It is commonly said that the values of a group are "internalized" by its members.

- **Perception** behavior in humans constructs objects in both mental and environmental realities. When I perceive an object in "external reality," I construct two objects: a physical thing or event, which is part of my environmental reality, and a set of behavioral sensations in my mental reality. From the outset I treat these two as one object, to anchor my mental world to "the real world." As psychologists define it, my perception is "a single unified awareness derived from sensory processes while a stimulus is present."[35] Even in my most philosophical mood I believe, in effect, that "I see a thing," not that "I am having a visual experience of external reality." Later on I may deconstruct the perception into behavioral sensations, which I group in order to construct a physical thing. Until that time, I objectify the sensations and the thing together.

Constructing such reality bridges is crucial to the maintenance of the separate realities discussed here. We could not construct a social reality separate from environmental reality without linguistic communications to link them together. Once we construct a social reality, it cannot work without sharing values with mental reality. And mental reality can't support its host individual without perceiving environmental reality. Because we are able to move freely between our environmental, social, and mental realities, we construct reality bridges all the time to keep our lives "integrated." Language, values, and perceptions are important "reality links" that keep us sane and functioning.

Speciation and Individuation

At several points in this book, I have cited as the "miracle of life" its ability to treat a group of objects as an object in its own right. This is the basis of categorization, the key to life's ability to construct known reality. The converse of grouping is dispersal, and "dispersal from a common base" could be regarded as equally a "miracle of life." We see it at work in two basic life processes: speciation and individuation.

In **speciation,** genomes are dispersed through mutation and genetic recombination. Genetic codes are "tested" in environmental reality by constructing organic populations that embody those codes. Populations that are more successful carry their codes forward into new organic constructions. It is crucial to this process that the genomes being tested be relatively stable while the species performing the tests be relatively dispersed. The dispersal of Darwin's finches, from a few colonists into more than a dozen distinct species adapted to different environments in the Galápagos archipelago, is a defining example of speciation.

The same principle, on a smaller scale, shows up in **individuation.** Each species constructs individual organisms from its genomic base. Relatively small variations in each individual's corporal reality are then tested to find good "fits" with environmental reality. With the species serving as a breeding population, genomes of successful individuals are fed back into the "gene pool" through genetic recombination. By this means each species "learns" what kind of corporal reality works in its environment.

The description of organisms in Chapter 2 stressed that I use the term to denote species and higher taxa, as well as individual animals or plants. Yet we usually think of life as a collection of individuals. When we see a bear we normally see it as one animal, not as a fraction of a species or an instance of the class *Mammalia*. It's commonly felt that the business of life is accomplished by individual organisms.

This makes sense, because the dispersal technique of constructing many individuals for each species has yielded far-reaching benefits:

- It drives evolution by spawning multiple "tests" of each species against its environment. The parameters of these tests tend to vary—through mutation of the genetic basis, through geographic dispersal of the test individuals, through climate change, etc.—so life can seek out the best "fit" between each species and the environment. Those individuals who find an environmental fit and flourish in it can then contribute their genetic codes to the whole species.
- Through learning, each individual organism can develop personal skills. Such skills extend the repertoire of life techniques that are passed from each species to its individuals via reflexes. The genus *Ursus,* for example, gives the brown bear a set of claws and the reflexes to use them, but each individual bear learns how to employ this inheritance to fish effectively. Being able to learn the skill of

fishing benefits both the individual bear, by enhancing its survival, and the genus *Ursus,* by increasing the chances that its individuals will be good learners.

The bear's genus and its higher taxa support personal learning by giving each individual bear a flexible neurological apparatus. They have evolved to do this because *being able to learn how to fish* is a valuable trait—it makes each individual, the carrier of a genome, better able to find a good environmental fit and thus pass its genome on to its descendants. But some animals, particularly humans, have evolved the ability to learn new skills *in general*.

- The neurological apparatus just mentioned, originally evolved only to support personal learning, supports ingenuity and intelligence in a few animals. Ingenuity goes beyond learning—it lets the individual objectify new ideals. These new ideals, constructed by categorizing behavior, become the bases for learning new behavior. Intelligence then lets the individual monitor and appraise its own behavior. The result is a complex internal mental reality, which can construct new behavior that goes far beyond the individual's original need to learn new skills.

  Individual ingenuity and intelligence may constitute "unintended consequences" for life as a whole. Their principal manifestation—in humankind—has made us a dominant force on our planet, for good or ill. In terms of the present analysis, these abilities—the ability of human individuals to give behavioral objects ideal meanings while monitoring those objects through yet more behavior—has opened up a complex mental reality to our species.

For those species that have it, intelligence is a wonderful skill. It turns the brain from a learning machine into a playground for ideas. It lets us human individuals spend parts of our lives in mental reality—an inner world which we might say is related to the "external" world as known reality is related to unknown reality.

Privacy. Mental reality is a private reality. As William James put it, "the most immutable barrier in nature is between one man's thoughts and another's." This privacy makes human behavior far more diverse than that of other animals, for it lets individuals construct complex long-term trains of behavior without physical manifestations. Hence our mental reality is useful as a rehearsal or testing area, where we can evaluate behavior before revealing it in action.

The privacy of mental reality extends human individuation; it lets us act "individually," without having to act socially or in the common environment at the same time. Unfortunately this privacy also enables such typically human faults as malevolence and guile—behavior that would be hard to translate into action without a private arena in which to construct calculating plans.

Analogy: On-Board Computing

A challenging practical use of computers has been the guidance and control of space vehicles. Until 1965, space travel had been controlled by mainframe computers on the ground. Beginning with the NASA Gemini project, however, every space vehicle included an on-board computer that could guide the craft independently.

At first, on-board computing was used only for last-minute vehicle maneuvering, because it avoided delays in receiving instructions from the ground and would work during temporary communication lapses. But as time went on and computer hardware became more compact, the on-board computer took over more and more of the vehicle's control.

Within the context of space vehicle guidance, on-board computing would be like the "dispersal" technique of individuation, discussed on page 159. The guidance computer "species" spawns an "individual" computer to improve its fit with the space navigation environment. And in fact, during the Gemini III mission's splashdown, instructions from the on-board computer were more accurate than those from the ground-based computer (but were ignored).

An earlier discussion in this chapter described individual learning as filling a "gap" in species-determined reflex behavior (page 126). The ability to learn depends on the evolution of neurological resources in individual organisms that are like on-board computers. The individual inherits certain traits that promote learning, such as curiosity, and its "on-board" nervous system takes over from there. As time goes on and species evolve, nervous systems assume more and more control.

Other analogies in this book have described the binary "reality" that computers create. It is different in kind from the numbers, characters, images, etc. that computers process. We should then expect that our nervous systems would construct realities that are different in kind from the "outside" reality that we deal with. In fact these constructions, each one private to an individual, show up as mental reality.

Determinism and Free Will

A side effect of constructing mental reality is that human thinkers find a contradiction between determinism and free will. On the one hand, I may understand environmental reality as determined by factors over which I have little or no control; on the other, I may feel that at least some of my mental reality—my thoughts, my ideas, my "will"—are creations shaped freely by me.

Stoicism, the main ethical philosophy of the Greco-Roman world, used this contradiction to support a doctrine of training the individual will (*prohairesis*) to voluntarily align itself with environmental reality. As Epictetus put it, "Do not seek to bring things to pass in accordance with your wishes, but wish for them as they are and you will find them."[36] A constant thread running through stoicism was the struggle of each individual to deal with the freedom to construct mental reality.

In terms of the present analysis, free will is a natural consequence of cross-categorization. Organisms construct the "lowest layer" of known reality by objectifying unknown reality. Most of the resulting objects are known in only one of the disparate physical, behavioral, and ideal orders of this known reality. They are "determined" by their origins in unknown reality. But another part of known reality, comprising the organisms themselves, has facets in all three orders. This three-in-one nature of life lets organisms construct new objects in known reality by cross-categorizing the "determined" objects. The new objects are free, in the sense that they could have been created differently. Each object constructed by cross-categorization may become the basis for more such objects. At the far end of the chain of cross-categorizations lie the objects of mental reality, all of which are constructed by individuals. Hence mental reality is free, as the stoics believed.

An earlier example (page 104) described flipping a coin to illustrate unpredictability. Coin flipping is also commonly cited in discussions of determinism. Our native understanding of physical events, either as a chain of causation or as the workings of impersonal laws, leads us to believe that the coin's orientation when it lands—"heads" or "tails"—is determined once it has left our fingers. Even "quantum uncertainty" does not challenge this belief, for it applies primarily to our ability to predict the coin's trajectory, not to the question of whether or not the outcome of the toss is determinate. We instinctively feel that whatever is going to be is going to be.

But imagine that the faces of a tossed coin are indistinguishable, or that we arbitrarily decide which face we call “heads” and which we call “tails” after it lands. Now it would make much less sense for us to call the toss determinate or indeterminate, because we couldn’t define any difference between the two outcomes. We could equally well announce “heads” or “tails” without bothering to toss the coin.

Free will. The second coin-toss scenario is like the way that we and other organisms actually deal with environmental reality. The unknown environment contains stuff that we regard as undifferentiated, like coins with smooth faces. We and other living things objectify parts of this stuff and animate it, thereby making it meaningful for us. The process of objectification is like stamping identifiable faces on the coins of unknown reality, and the process of animation is like deciding what it means to toss them. But the resulting known reality does not thereby become determinate. We only think it’s so because that’s how we have evolved to understand it.

The ultimate basis of free will is the “miracle” of life that I have mentioned several times—our ability to make a new object out of a group of other objects. Every time we do that, we freely change the reality we know.

Summary of this Chapter

While it is constructing environmental reality, life constructs itself. The two kinds of reality work together: organisms construct themselves to know reality and they construct “external” reality to be knowable. But life has elaborated on this simple plan of having one reality for itself and one reality for everything else. Some organisms construct more than one organic reality, besides constructing their environment.

The three organic realities analyzed here I call *corporal, social,* and *mental*. Corporal reality consists of the bodies and activities of living organisms; social reality is built by groups of individual organisms to supplement their corporal reality; and mental reality is a world that individuals of some species construct privately. All species construct corporal reality; many species add a social reality to it; and we humans plus a few other species construct all three.

Corporal reality is constructed by cross-categorizing known reality to build objects that would never occur in the nonliving environment. They include the bodies and reflexes of living organisms, which are produced by cross-categorizing behavior with physical reality; the skills and techniques living organisms use, produced by cross-categorizing behavior with ideals; and the genomes and organic adaptations which result from cross-categorizing physical reality with ideals. The totality of these new objects, all constructed by living organisms, add up to the phenomenon called life.

Some species and higher taxa add a separate "group world" to their corporal realities, constructing what I call social reality. In a typical social construction, individual organisms may communicate with other individuals of the same or another species. Constructing social objects, such as physical communications in environmental reality, enlarges an individual's known reality.

Finally, a few species endow their individuals with the resources to construct mental reality. Mental reality is private—it can be known by only one individual. It gives the individual who knows it a perspective on other realities, social and environmental. It is not only constructed but also controlled, and thus it often acts as a kind of test facility where individual behavior can be rehearsed and evaluated.

At the core of mental reality lies the phenomenon commonly called consciousness, and at the top level of consciousness lies what I call awareness. Awareness is behavior objectifying and categorizing other behavior, constructing a kind of private messaging system within each individual. These messages, constantly passing in our mental reality, give us humans the experience of a "stream of consciousness."

In mental reality we also encounter the paradox of feeling that we exercise "free will" in an environmental reality that we have evolved to regard as deterministic. The resolution of the paradox is to realize that our mental reality is a product of organic cross-categorization, every act of which is the result of our freely choosing to group known objects. Cross-categorization guarantees the freedom of mental reality.

6. Knowledge

For nature conceives of innumerable things, of which those known to us are fewer than those not known, and this is so because nature exceeds understanding.

FRA MAURO

The last chapter discussed the realities that life constructs for itself. These organic constructions can be analyzed in terms of three “worlds”: corporal reality, the bodies and activities of organisms; social reality, in which organisms interact with one another; and mental reality, which is private to individual organisms. Separating these three worlds depends on organisms being able to separate the three orders of known reality—physical, behavioral, and ideal.

Chapter 3 described the processes by which organisms construct environmental reality, the portion of known reality that is not organic. Starting with unknown reality, organisms construct new objects through objectification, categorization, and generalization. By objectifying these new objects and cross-categorizing them, organisms become free agents in their known environmental reality and act organically. Life becomes something truly novel.

Organisms can do this because they are objects that exist in all three orders of known reality. They maintain their unique three-in-one status by constant cross-categorizing. The physical organism “acts alive” by exhibiting behavior and stays alive by following ideal genomic coding. The behavioral organism reacts with the physical world and sometimes understands it ideally. The ideal organism tests its living techniques by making generalizations and testing their contributions to its physical survival and behavioral success.

The process of knowing, a specific part of behavior, is vital to the reality constructions just described. Without its product, knowledge, life could not survive, respond to environmental reality, or evolve. The more that organisms know about the realities that they construct, the better they are able to live in them.

But knowing covers a spectrum of behavior. At one end of its range are simple habits and reactions. As I walk, I know that the floor ahead of me will support each step, just as a bird knows that the air ahead of it will support its wings. At the other end of the range are complex and sophisticated thoughts. I know, for example, how a floor is constructed and I have some idea of why it holds my weight. This part of my knowledge, however, is populated with ideas of compression strength, the cellular structure of wood, the shear strength of nails, and so on. I have acquired much of this knowledge second-hand, and my grasp of it depends as much on my knowing mathematics as on my knowing about wood and other materials. This knowledge is the result of theorizing, a kind of behavior that is added onto the customary business of life. The process of theorizing is discussed later in this chapter.

When I know something, some part of my corporal reality has been modified. I have constructed a new object in my physical, behavioral, or ideal aspect. Then I have either added it to my corporal reality or used it to replace or override an existing object. The typical kinds of objects in my corporal reality are listed in Table 5-1, page 123.

Physical knowledge modifies my body or one of its adaptations to the environment. It happens as I mature and cope with various physical challenges. For example, I know how to extract nutrition from a diet of cooked and processed food, while using it to build the body tissues I need, including my all-important neural tissue. My immune system knows how to resist many pathogenic diseases that might otherwise harm me. My body frame and musculature have adapted themselves to a largely sedentary, indoor lifestyle. As a result of these and other body modifications, my physical aspect differs in several ways from that of someone indigenous to a rainforest or an altiplano. I and my ancestors have made these physical modifications so we can better function in our accustomed environment.

Of course I also store knowledge in my physical aspect through the process of memorization, described in the last chapter (page 150). But physically stored memories should not be confused with physical knowledge. For example, my immune system knows how to deal with infections independently of any medical knowledge I may acquire about the way it operates. Memorized knowledge is subject to all the problems of symbolization and cross-categorization discussed earlier.

Behavioral knowledge modifies my reflexes and learned skills. It turns me from an infant into a functioning adult. Knowing how to speak a language is a prime example. But knowing how to walk, discussed earlier, is also behavioral knowledge. My behavioral aspect acquired knowledge of how to coordinate my leg and foot muscles when I was a toddler. Even simpler kinds of knowledge, such as knowing how to chew food, are adaptations of reflexes passed down to me through my genetic code. During my lifetime I have acquired more complex kinds of behavioral knowledge, such as knowing how to build a floor on which I can walk, through individual learning.

Ideal knowledge modifies my genome or my living techniques. It adjusts the general patterns in my life. Modifications to the genome usually take place in species or higher taxa, although individuals may affect the expression of their genomes through epigenesis. My living techniques are often shaped in social and mental reality. For example, as I have grown up I have absorbed the moral, ethical, and legal ideals of my culture. I know that certain kinds of behavior are inappropriate in "polite" company, that breaking my word is wrong, and that stealing may get me into trouble. I have made these abstractions primarily to deal with social reality—to become "civilized."

Other forms of ideal knowledge help me cope with environmental reality. For example, I can judge by looking at something whether or not I can lift it. I know when I put up a ladder whether it will be safe to climb it. I "know better" than to eat substances that might be toxic.

All knowledge can be right or wrong. Although I know that the floor will support me, it could give way under my next step. If this were to happen, my knowledge of the floor would still be a part of my physical aspect, but I would need to modify it with some behavioral or ideal knowledge about the ways that floors can fail. Perhaps my brain would interrupt my walking reflexes, forcing them to "think about" each step. While knowledge is part of every organism's corporal reality, it is a part that is constantly being modified, expanded, and refined.

If they don't know reality, organisms die. Yet starting with the same unknown reality, organisms in different areas of life routinely construct and know radically different realities. The world of fish is unlike the world of birds, and both worlds are unlike the worlds of protists and plants. Even within the single species *homo sapiens,* individuals may "see the world" quite differently. For example, the typical seventeenth-century Lincolnshire squire might have categorized Newton's mythic apple as round, red, sweet, and so on; but Newton also categorized it as a thing possessing mass and as possibly acting like the moon, with far-reaching consequences for scientific theorizing. Thus one object, an apple, can evoke two widely varying sequences of categorization and modeling in organisms as similar as two English gentlemen. Imagine how differently an apple must be categorized by an organism such as a codling moth, which understands it primarily as a place to lay eggs.

Knowledge helps determine the known reality that every organism builds. Because so much of known reality is constructed upon reality already built, each organism's knowledge of that reality is crucial to its success in life. Hence to understand fully how known reality comes to be, we must analyze the ways in which organisms know the reality that they construct and share with other organisms.

Constructing Knowledge

Life repurposes its technologies. When organisms have discovered how to do something useful, they tend to apply that solution to any problem it might help solve. A seminal example is how life applies the ways in which it constructs objects in environmental reality to the construction of knowledge in corporal reality. Organisms construct knowledge using objectification, categorization, and generalization. The main difference between knowledge construction and environmental construction is that organisms construct knowledge *explicitly to know other reality.*

Thus knowledge consists of known objects that organisms construct "in parallel" with other objects—environmental, corporal social, or mental. Yet it is always a part of corporal reality. Organisms construct knowledge so they can carry *within* themselves a "representation" of known reality *outside* themselves.

To understand how knowledge objects are constructed, we must first distinguish species knowledge from individual knowledge:

- **Species** construct knowledge objects mainly through evolution in life's corporal reality. The knowledge objects are ideal, and they are passed to individuals in an I CAT P cross-categorization through the genome of each species. As individuals vary one from another and succeed to varying degrees, their variations are carried back into the species' phenotype as P CAT I adaptations. The physical survival and breeding of individuals cross-categorizes their ideal genetic codes.

- **Individuals** construct knowledge objects in their corporal reality by using behavior to change themselves. These objects can augment their physical bodies, their behavioral reflexes and skills, or their ideal techniques. Individuals can also affect the genomes of their species by behavior such as mate selection and breeding decisions.

What I call "species knowledge" extends all the way up the taxonomic hierarchy to life itself. All organisms, including human individuals, are fitted out with knowledge constructed by their species, genus, phylum, and so on. Much of the knowledge in each individual is of this kind—knowledge of how to metabolize, grow, sense, reproduce, etc. That is why organisms can construct reality in so many different ways and yet share a single environment. Any two individual organisms, no matter how far apart they may be on life's tree, have some species knowledge in common. Taken altogether, species knowledge is "life's knowledge." Species even theorize, as I discuss starting on page 193.

Individual knowledge overlays species knowledge. The individuals of "primitive" species have very little; human individuals have a lot. This kind of knowledge, constructed during each individual's lifetime, may be shared with other individuals through social reality. In humans, much individual knowledge is constructed in mental reality.

Representing reality. Only organisms construct knowledge objects. Every organism's life is driven by a need to understand the reality it has constructed. But how can knowledge in an individual's corporal reality, or an ideal pattern in its genome, "represent" reality elsewhere? The answer is that cross-categorization makes it possible.

The last chapter discussed communication, a technique of life in which physical objects are categorized by behavioral contents. Life uses a similar technique to construct knowledge. In species, physical genes carry ideal contents; in individuals, changes in corporal reality carry physical, behavioral, or ideal contents.

The main difference between communication and knowledge is that communication is constructed between organisms, while knowledge is constructed within organisms. Indeed, it seems likely that knowledge evolved first in the development of life, and the processes by which knowledge was constructed were then repurposed into communication between individuals to support social reality.

Organisms construct knowledge objects as an integral part of life, as if each living unit came with a built-in recording angel. If the organism is a species or higher taxon, knowledge is recorded in its genome. If the organism is an individual, knowledge is recorded in its corporal reality. As with all communication, the internal communication of knowledge is never perfect. It relies on symbolization and multiple layers of cross-categorization. The result is error, a central problem of knowledge to be discussed shortly (page 179). But that is the price each organism pays for the freedom to represent reality in its own way.

Analogy: Computer Knowledge

Computers generate information that humans find useful. They cannot do this from scratch; although they are not organisms, computers must possess something analogous to knowledge to accomplish their tasks. Previous computer analogies in this book have noted that the designers of these machines were often guided by a natural grasp of the ways in which life works. So it is useful to ask how computers acquire and store "data"—the machine equivalent of life's knowledge.

Humans store complex knowledge in physical brains; computers store data in what is called "physical memory." The physical events that take place while a computer is acquiring and storing data consist of electric currents turning on and off and magnetic domains switching their polarity. From a purely physical viewpoint, the states that result from these events are not obviously related to the content they store. Similarly, the electrochemical events that biologists may observe when a person acquires or processes knowledge are not easily interpreted as anything other than electrochemical events.

In computers, physical memory is made "meaningful" by software. An analogy elsewhere in this book (page 37) describes the "software world" that computers create. Its orders of reality are data, programs, and algorithms, emulating the physical, behavioral, and ideal orders of the "real world." But data in the "software world" is utterly unlike the electromagnetic states of a computer's "hardware world."

To resolve the difference between software and hardware, data must possess three characteristics before a program can handle it: it must be *contained, typed,* and *structured*. Software gives the computer's input data these characteristics through processes that are analogous to the phases of reality construction discussed in Chapter 3—objectification, categorization, and generalization. In effect, software constructs a "data world" it can understand.

Data containers. A chunk of data is typically contained by storing it in a software "variable." All data in a computer consists of sequences of bits, or binary digits. The computer's physical memory is made up of many tiny "cells," each of which can be switched between two electromagnetic states. Engineers call these states "0" and "1" so they can match them with binary digits. The cells are given numeric addresses, usually in groups of 8, and each variable is assigned a range of those addresses. When data is "written into" a software variable, the memory cells at the variable's address are switched to represent its bits. The data is then said to be "stored" in the variable.

Variables in the software world fill the same need for computers as objects in the "real world" do for organisms. A computer's memory is a vast undifferentiated sequence of 0-or-1 cells; if it were read whole as binary digits, the result would be a huge, meaningless number. The computer's memory becomes useful only when it has been "chunked" into discrete regions with specific boundaries and locations. This is like saying that unknown reality can become known (and become useful to organisms) only if it is chunked into objects.

Computer memory is not chunked physically; it is chunked only in the software world. No purely physical analysis could distinguish a disk storing data in variables from one filled randomly with 0s and 1s. To make such a distinction we have to "read" the disk, using software that is designed to construct and know variable boundaries within it.

Data types. In the software world, every variable normally has a "type." An earlier analogy in this book (page 15) tells how different digitization methods can represent a graphic image as different sets of bits. For instance, one set of bits may describe a grid of pixels in space, another may specify a sequence of drawing instructions, and a third may define a composition made out of generic shapes. In software terms, these three sets of bits are said to have three different types.

Software uses a variable's type to limit the kinds of operations that it can apply to the variable's data. For example, two common types used in software today are "integer" and "char" (short for character). In most software, the sequence 01100001 may encode either the number 97 or the Roman lowercase letter a, depending on whether the variable that contains it is typed as integer or char. In the "real world," people know that it is meaningful to add 1 to a number and meaningless to add 1 to a letter; in the software world, this distinction is made by establishing a variable's type. Trying to do arithmetic on a variable typed as char is called a "type error." Some programs halt and display an error message if such an event occurs.

Typing variables does for computers what categorizing objects does for organisms. It lets software "understand" variables by gathering them into groups. All the variables of a type can then be processed by one program, just as all the objects in a category can be handled by one train of behavior. The equivalent of a software type error occurs in the "real world" when an organism categorizes an object incorrectly; the organism may halt, mentally post an error message, and figure out what to do next.

Data structures. Being contained in a typed variable does not by itself make data usable by a computer. The sequence of 0s and 1s that constitutes the data must also be structured. Some data structures are simple; for example, the bits in a binary number are ordered by powers of 2. But even in this simple case, computers use two orderings: the "big-endian" encoding of integer 97 is 01100001, whereas the "little-endian" encoding is the reverse, 10000110. With types such as digital video, encoded in billions of bits, the structure of the data contained in a variable can be extraordinarily complex.

As was the case with data containment and typing, data structuring is meaningful only in the software world. Examining a computer's memory with purely physical measurements cannot tell us what kind of data structures are stored there, if any. Only software can make such a determination.

Data structuring in the software world achieves the same goals for which organisms use generalization in the real world. A data structure is an ideal pattern applied to a collection of variables. For example, a typical database might contain a collection of "records," each of which contains a name, an address, and one or more telephone numbers. Each name is an array of char letters, each telephone number an integer, and each address a mixture of letters and numbers. Software recategorizes each record by grouping its variables into a generalized pattern—name-address-numbers. The resulting records become new objects that the software recognizes and knows how to read.

Data cross-categorization. Each of the foregoing three stages of data storage—containment, typing, and structuring—illustrate how software (which is analogous to behavior) cross-categorizes hardware, the computer equivalent of physical reality. By chunking together a run of physical memory cells in a field of indistinguishable units, software "gives meaning" to those cells; they "belong to a variable." We could think of this as the computer equivalent of actualization (discussed on page 96). The group of memory cells becomes a new object—a "thing." Typing the variable is software's equivalent of animating this "thing"; it tells other software how it may change. Finally, assembling variables into data structures is the software equivalent of formulation. By following an ideal pattern, the structure becomes a new object in the software's "known reality." The underlying hardware has not changed, but software has given it "meaning" through cross-categorization.

Data generalization. Chapter 3 (page 59) discusses the process by which organisms construct models through generalization. Computers sometimes perform a similar process when "compressing" video data. The contents of video frames, which run at 30 per second, are often nearly identical. If the camera is stationary and an actor is speaking, all that changes from frame to frame may be parts of the actor's face, which occupy less than one percent of the frame. To reduce the size of the data that needs to be stored, a computer may designate certain frames in the video as "key frames." The contents of these frames are digitized in their entirety, but the frames that precede or follow them are defined only by their *differences* from the key frames.

Thus a key frame is like a generalized model for all the frames in a given run of video. Other frames are enough "like it" that once the computer displaying the video "knows" the key frame it is much easier for it to "know" the others. Thus key frames play a role that is like the way that organisms use generalized models—to represent varieties of events or objects that are enough "alike" that they don't each need to be known in detail.

It is not a trivial task to program a computer to analyze a video and select key frames in it that do the best job of "representing" ranges of other frames. Such software often uses clever algorithms with intricate logic. Similarly, it is often not easy for living organisms to generalize known reality, constructing models that most efficiently represent wide ranges of objects or events that are "alike."

Commonsense Knowledge

The first layer of knowledge is what I call "common sense." Common sense groups objects in each order of reality by using categories that lie in the same order. Thus physical objects are categorized physically, in the sense that when their categories are objectified the category objects are also physical. Behavioral objects are categorized behaviorally as well, and ideal objects are categorized ideally. When using common sense, organisms understand reality by chunking it into objects and then finding the simplest available categories to group those objects.

In the complex range of human knowledge, how do we recognize common sense? Common sense comprises the "givens" of knowledge. Because the objects of commonsense knowledge are categorized by other objects in the same order of known reality, we don't know how to question them. As I will discuss later, questioning and error stem from "cross-categorization," the process of categorizing objects in one order with categories from another order. This complication doesn't arise in common sense—it is just knowledge of "the way things are." Here are some examples:

- **Physical** common sense knows the "tangible world," including the bodies of organisms, with uncritical certainty. Metabolic reactions, reflexes, instincts, and so on, just carry on the business of life with its environment. I walk along the floor without "giving thought" to either my leg motions or the nature of the floor. If the process fails in any way—if I stumble or the floor collapses—theorizing takes over and I look for cross-categorizations to "explain" what is happening. Otherwise, much of daily living consists of using physical common sense to deal with the physical world.
- An important part of **behavioral** common sense, for humans, is our conscious awareness, discussed earlier (page 155). Awareness knows behavior by categorizing it in behavioral terms. That is why it is called "subjective"; it exists entirely within our behavioral aspect and can be associated only by supposition with physical events or ideal rules. Modern thinkers sometimes use the term "qualia" for the units of awareness, citing our sensations of colors or pain as typical examples. Philosopher C. I. Lewis wrote in 1929, "The quale is directly intuited, given, and is not the subject of any possible error because it is purely subjective."[37] A persistent current in philosophy, from Protagoras to Wittgenstein, has been the proposition that our mental awareness is the only reality of which we can be certain.
- **Ideal** common sense includes the "primitives" of mathematics and logic, such as numbers, shapes, sets, and axioms. The idea that "God made the integers" began with Pythagoras in the fifth century BC,

> and later philosophers could have added that God also made the points and lines of Euclid and the laws of identity, contradiction, and excluded middle of Aristotle. Thinkers who work in the abstract disciplines find it hard to get around these simple notions because there seem to be no alternatives—no ways to "get traction" on such basic ideas and hold them in perspective. Primitive ideals are treated as "given" because they come to us already categorized in terms of other ideals.

The certainty of common sense—its "given" quality—does not mean that it is never wrong. Organisms can die when their physical common sense fails to comprehend an environmental challenge; awareness can be skewed by other mental states, such as hypnotic suggestion; and truths that appear self-evident are questioned by modern disciplines such as non-Aristotelian logic. But from the viewpoint of knowledge, common sense is hard to challenge. Because it takes categories from the same order of reality as the objects being categorized, common sense tends to resist recategorization. Different category groupings in the same order of reality? What was wrong with the old groupings? As I discuss in "Error Detection" (page 179), cross-categorization helps us to recognize category errors and recategorize objects. Commonsense knowledge, which lacks this technique, tends to preserve and protect the first categories it finds.

Why is common sense so conservative? One reason is because its categorizations are inherently "circular": they explain objects in terms of related objects, like the old saw about sleeping pills putting one to sleep because they contain a dormitive agent. As I describe it in the next section, "sophisticated" knowledge constructs categorical groups that are different in kind from the objects they group. Its explanations add a kind of "perspective" to knowledge. Ultimately, the explanations of common sense (as I use the term here) just amount to saying "that's the way things are."

Nevertheless, commonsense knowledge supports the basic ways that organisms interact with their environment. When an organism ingests food, for example, parts of the environment are objectified and then physically categorized as nutritive or not, to conform to the organism's metabolism. During prey avoidance, specific trains of behavior in other organisms are recognized and understood as threatening or not. And ideals such as simple syllogisms show up throughout the business of life (fish are edible, that object is a fish, therefore that object is edible).

Problems and opportunities in each of the three orders of known reality are addressed in terms of that reality.

But in its pure state, commonsense knowledge is more limited than one might at first think. For example, categorizing potential food only by its physical properties leaves important questions unanswered. Might the intended food behave in unexpected ways, such as attacking us or trying to get away? Physical categorization alone cannot tell us; to predict behavior, the feeding organism must also categorize the object behaviorally. In the state of nature, approaching potential food while knowing only its nutritive value can result in life-or-death errors—for example, what you try to eat may eat you. To escape the limitations of common sense, organisms cross-categorize objects in known reality.

Cross-Categorized Knowledge

Using common sense, organisms build categories by grouping together objects that belong to the same order of reality. Seeing that this thing is round and that thing is round, and so on, leads to the physical category "round things." Physical things are categorized physically. Similarly, finding that we sometimes experience a sweet sensation and sometimes not yields the category "sweet tastes," where behavioral processes are categorized behaviorally. The natural next step is to use these physical and behavioral categories to group objects of the other order. Such cross-categorization is the most common way that organisms expand their stores of knowledge.

For example, we may understand a physical object in terms of its physical attributes—it is heavy, cold, solid, and so, on. These are all commonsense ways to understand what the object is. But we may also know that the object interacts in certain ways with our behavior: it feels rough to the touch, it smells fruity, it tastes sweet, etc. This kind of knowledge groups physical objects using categories that we originally established to understand behavior. The distinction between the two kinds of categorization, analyzed in detail by John Locke (1690), goes back at least as far as Democritus.[38] In 1623 Galileo summarized the problem of categorizing physical things behaviorally:

> I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we locate them are concerned, and that they reside in consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated.[39]

Galileo preferred to apply *ideal* categories to physical objects, which is what physicists do today. A given object is roughly spherical, it is so many centimeters in diameter, it weighs so many grams, it reflects light at a wavelength of 700 nanometers, etc. But regardless of whether we categorize physical objects behaviorally or ideally, in both cases we are assigning categories from orders of reality that differ from the order in which the object originated in common sense.

Cross-categorization expands knowledge because it opens up new ways to understand reality. It lets an organism understand objects that it already knows in common sense "from a different perspective." When an organism reacts with its physical environment, for instance, it uses physical common sense to feed, avoid injury, and so on. It categorizes physical things by grouping them into other physical objects. But when it also categorizes the same things behaviorally—when it forms a new object in behavior that groups physical things—the organism begins to understand physical reality as a changing, event-driven world. What was understood physically as a group of separate objects now becomes understood behaviorally as a sequence of events. Changes and causes become new objects in the organism's known reality.

Conversely, an organism may group objects in its behavior, which it already understands behaviorally, into physical categories. Separate sensations, for example, may become categorized as "sensations of a physical thing." The organism adds a new object to its known physical reality, namely the object that is the source of the sensations.

Through the new objects that result from cross-categorization, every organism knows a world of behavioral interaction with physical reality. To a greater or lesser extent, depending on the organism, it also knows worlds of interaction between its behavior and ideals, and eventually between ideals and physical reality. These "worlds" of knowledge, based on cross-categorization, are added to the knowledge constructed by common sense.

Analogy: Galileo's Bookkeeping

Organisms use cross-categorization routinely to build complex bodies of knowledge. An example is bookkeeping, the cross-categorization of physical transactions in commerce with ideal quantities of money. This example is interesting because it was cited by Galileo to support the cross-categorization of physical phenomena with mathematical models that lay at the core of his *nuove scienze* of 1638.

Aristotle had made sport of his Greek colleagues who tried to use mathematics to explain the physical cosmos (see page 111), and his reasoning seemed obvious to practical people:

> Aristotle ruled out any mathematical approach to physics on the grounds that mathematicians pondered immaterial concepts while Nature consisted entirely of matter. And Nature, furthermore, could not be expected to follow precise numerical rules.[40]

But a "mathematical approach to physics" is precisely what Galileo proposed. In his analysis of motion, he had grafted the experimental method of Roger Bacon onto the abstract explanations of Euclid and Pythagoras. As Kuhn suggests,[41] Galileo saw a swinging pendulum as a "different kind of reality" from the reality his predecessors saw. His guiding vision is set forth in his often-quoted declaration of 1623:

> Philosophy is written in this grand book—the universe—which stands continuously open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and interpret the characters in which it is written. It is written in the language of mathematics.[42]

In his *Dialogue Concerning the Two Chief World Systems,* published in 1632, Galileo cites commercial bookkeeping as an analogy for using mathematics to describe physical phenomena. He cautions us against being misled by the inaccuracies of experiment when trying to get at the ideal truth, as if we were scientific bookkeepers ("computers"):

> Just as the computer who wants his calculations to deal with sugar, silk, and wool, must discount the boxes, bales, and other packings, so the mathematical scientist [*filosofo geometra*], when he wants to recognize in the concrete the effects which he has proved in the abstract, must deduct the material hindrances, and if he is able to do so, I assure you that things are in no less agreement than arithmetical computations. The errors, then, lie not in abstractness or concreteness, not in geometry or physics, but in a calculator who does not know how to make a true accounting.[43]

Galileo's comparing his new scientific method to bookkeeping was apt, for accounting was well understood in his time. More than a century earlier, Fra Luca Pacioli had published in Venice a handbook that set forth most of the principles of double-entry bookkeeping. Since then it had served as a primary textbook in the Renaissance *abbaco* schools, which turned out an army of accountancy clerks.

That Galileo should warn would-be scientists about the hazards of experimental measurements was also apt. He had labored long with crude equipment, such as using a water clock to measure the time it took a ball to roll down a wooden board. With the effects of friction and timing irregularities, it's a wonder that his data made any sense. Unlike Aristotle, who did little or no experimentation, Galileo knew that every experimenter had to "purify" his observations—remove or compensate for as many "experimental artifacts" as possible—before the inherent mathematical relations would emerge. It was like the trader's need to unwrap and clean his goods before weighing them.

In modern bookkeeping, the "money measurement concept" permits the assignment of an ideal monetary value to physical transactions—goods bought and sold, labor expended and paid for, financial papers received and given, etc. The physical transactions and their ideal values then cross-categorize each other.

For example, receiving a certain amount of goods, such as wool, can be understood "in monetary terms," while paying a certain amount of money can be understood in terms of the goods it can buy. People versed in these concepts did not find it hard to imagine that a moving body (such as a pendulum) manifested physical transactions that had analogous ideal "values," which could be measured and expressed in terms such as time and distance. Galileo's new science was simply a regimen of bookkeeping methods applied to the world of natural events instead of to the world of commerce. The underlying style of cross-categorization was the same.

Error Detection

A vital feature of cross-categorization is that it helps organisms tell whether their understanding is right or wrong. It introduces the idea of error into knowledge. The use of cross-categorization to expose error then plays a key role in constructing usable knowledge.

Only organisms can be right or wrong, act correctly or incorrectly; nonliving reality is simply the way it is. When an organism depends on commonsense knowledge, as defined here, it may act incorrectly; but it is hard for the organism to determine that it has done so or to figure out how to correct itself. To make that determination, the organism must "recategorize" its commonsense understanding by trying to understand the objects of common sense in terms of a different order of reality.

We humans routinely do this when analyzing the actions of "lower" animals. A fish strikes a fisherman's fly and is hooked. It is clear to us that the fish acted erroneously because the fly was a lure, not a piece of food. But in the commonsense reality constructed by the fish, the lure was first objectified by behavioral sensations—insect-like appearance, realistic movement, etc.—and then, at the moment of ingestion, it was objectified by its physical characteristics as food-like. In fact, a human had constructed the lure to evoke these commonsense categorizations. If the fish had escaped a few lures (as some long-lived trout have) it might learn to recategorize the behavioral sensations physically (hooks that look like insects) and the physical object behaviorally (food that leads to becoming hooked). The fish would have acquired some of the same perspective on the lure that we have, and it would understand the error that is inherent in striking every fly-like object in the water.

When an organism objectifies a part of unknown reality and then categorizes the resulting object entirely in the same order of reality—that is, when it constructs "commonsense reality"—it uses only one-third of its three-in-one presence in known reality. Either its body acts mechanically in physical reality, or it creates a new object entirely in behavioral reality, or it defines a new pattern in ideal reality. In none of these cases can the organism determine whether what it has done is "right" or "wrong," "correct" or "incorrect." It has simply performed an act of objectification followed by the minimum level of categorization needed to fit that act into its knowledge.

But when an organism cross-categorizes an object—explaining it by grouping it into one or more categories that become objects in another order of reality—it exercises a unique privilege of living things: it makes a choice. Error enters the picture, because the choice may turn out to be right or wrong.

The following two examples illustrate how cross-categorization can expose errors in an organism's knowledge of physical reality:

- **Actualization,** as I describe it (page 96), yields the knowledge that groups of sensations in behavior "arise from" specific objects in physical reality. An organism groups one or more sensations (say, red and round) into a new category; but instead of objectifying the category into behavioral knowledge, it objectifies it into knowledge of a physical object—a balloon. The sensations are still behavioral, but their group—their category—is physical. Life has exercised its exclusive ability to group knowledge objects together and then turn the group into new knowledge (of a balloon) that is different in kind from any of the knowledge objects (of redness and roundness) in the group. An act of cross-categorization has transcended the boundary between physical reality and behavior.

But the organism might be wrong. The red and round sensations might have come from a movie of a balloon or from some kind of optical illusion. Categorizing the sensations behaviorally, as a "red round image," would have been error-free—in their own terms, our sensations simply are what they are. Categorizing them physically was a leap of faith. To confirm the validity of its knowing a balloon, the organism must explore its physical environment, searching for further evidence of the balloon's reality.

- **Animation** (page 98) yields the knowledge that objects in physical reality are related along timelines, "in a behavioral way." A previous discussion (page 17) described space and time as ordering methods that separate objects. Physical objects can be distinguished by their locations in space, behavioral objects by their sequences in time. As an organism knows physical things, it also comes to know that things change behaviorally. For example, fire changes wood into charcoal. Three physical objects—wood, fire, and charcoal—occur in the same location but must be known sequentially.

  Wood burning to charcoal cannot be understood in purely physical terms. We could group three knowledge objects (of wood, fire, and charcoal) into a physical category (call it "knowledge of burning"), but such knowledge would not embody change. It would just be knowing three different things at one location. To understand the change we must construct a behavioral category—a temporal sequence in which wood comes first, then fire, then charcoal. The same three physical objects are still grouped, but the behavioral knowledge object lets us know their relationship in a way that no physical knowledge can.

  As with actualization, error becomes possible when objects from one order of reality are grouped by a category in another order. This time, the objects are physical and the category is behavioral. Taking the example of wood burning to charcoal, we can assemble various objects in a sequence, but it remains unclear what is changing. Many ancient belief systems treated fire as an element, so charcoal was the result of mixing fire with wood. Modern chemistry teaches that fire occurs when elements (mainly hydrogen and oxygen) *leave* wood, exposing the carbon that was inside it. Only by recategorizing the stages of combustion, and adding the physical combustion products (such as carbon dioxide and water) to its groupings, were eighteenth century scientists able to discern the error in the ancient explanation and come up with a new understanding.

Error becomes possible in all instances of cross-categorization, not just between physical reality and behavior. This is because the fundamental disparateness of the three orders of reality makes cross-categorization inherently error-prone. Physical objects cannot be finally explained in terms of behavior, nor behavioral objects in ideal terms, and so on. Any attempt to make such explanations is an artificiality waiting for a better explanation.

Errors in symbolization. The last chapter discussed symbolization in connection with communication (page 140). Human languages are collections of behavioral objects (symbols) that are categorized—given meaning—by other objects, which they "denote." During the first half of the twentieth century the study of semantics—the relations between words and their meanings—devolved into "analytical philosophy," based on the conviction that all philosophical issues could be resolved by analyzing how ordinary language was used. It seemed an attractive idea at the time because all philosophical discussions are conducted by using language.

The problem with this approach is that language (and symbolization in general) is inherently erroneous. Words and their syntaxes are parts of behavior constructed in social reality; their "meanings" may be any objects—physical, behavioral, or ideal—in the physical, behavioral, or ideal parts of environmental, corporal, social, or mental realities. As a result, words are the most widely cross-categorized objects in human knowledge. Studying language can only tell us how language works, not how any of the rest of reality is constructed. To understand the rest of reality we must *use* language, not examine it.

Organisms cross-categorize reality because it works—it enlarges knowledge. One way that we humans make cross-categorization work is by objectifying what I call "*minima*" in our known reality. Minima, as I use the term, are objects that we construct in such a way that they belong to two orders of reality. We then treat minima as elemental and unquestionable. Constructing minima and building theories on them tend to mask the error that is always potential in cross-categorization.

Minima

When constructing what I call minima, an organism objectifies parts of known reality for the specific purpose of cross-categorizing them. The main reason for so doing is to create knowledge objects that cannot be questioned. Such objects are often conceived of as "fundamental" or "elemental." They validate cross-categorization by "pinning together" two orders of known reality at crucial points. My earlier work analyzed in more detail the role of minima in theorizing.[44]

Examples of minima in human knowledge include the laws, forces, and particles of physics, which are both physical and ideal; causal links in everyday understanding, which are both physical and behavioral; and "universal human values," which are both behavioral and ideal.

How does the creation of minima help advance the development of knowledge? As I said earlier, cross-categorization is inherently error-prone—in effect, it forces apples into categories that common sense uses to understand oranges. To make cross-categorization work when constructing knowledge, it helps to be able to point to some apples that "really are" also oranges. The cross-categorizations of other objects (say, describing apple trees in orange-tree terms) then seem to be more "realistic" because we can relate them to these primal equivalences. That is why minima are often called fundamental.

We see this technique at work in physics. Do you doubt that events in physical reality follow mathematical laws? Then trace them back to interactions among fundamental particles, which are both physical and ideal. See how mechanical interactions, which we visualize physically, parallel mathematical equations, which we express in ideal terms. Even though the two understandings are utterly different in kind, one being physical and the other ideal, they can be "pinned" together at the points where they involve particles, because particles are defined as entities that are both physical and ideal. Such arguments justify the association of the physical world with mathematics that dominates modern science.

Examples of minima are found in all areas of cross-categorization. "Causal links," for instance, are minima that pin together behavior and physical reality. Returning to our previous example of change—wood burning to charcoal—we can find numerous "causes" at work without talking about particles, or energy, or any of the minima of modern physics. We say that the fire caused the wood to be destroyed and the destruction of the wood caused the charcoal to appear, and so on

The hypostatization of causal links has traditionally relied on three assumptions:

1) Every cause precedes its effect temporally;
2) Every cause and its effect are connected spatially;
3) Every instance of the cause is reliably followed by its effect.

Assumption (1) establishes causal links as behavioral, because their two parts always have a specific time order. Assumption (2) establishes causal links as physical, by constraining the spatial locations of their parts. Finally, assumption (3) makes the causal link a "minimum" in the sense used here. The causal link itself is unquestionable; it is "the way things work."

Physicists use assumption (3) to establish "laws of nature." Certain effects are always observed to follow certain causes; this constitutes the "reproducibility test" of experimental method. But the reason why the effect follows the cause so reliably cannot be found in the event itself; it is only a data point, a minimum. A large collection of such minima can suggest an ideal model or formula that "explains" why the causes are followed by the effects. Because the "causal links" occur so reliably, the ideal explanation is called a "law."

But minima are not just tricks we adopt to help make our theories work. They are crucial stepping-stones in the evolution of knowledge. We cannot change our minds until we have made up our minds, and hypostatizing minima helps us "make up our minds" in the quest for knowledge. For example, the historical theories of heat described later in this chapter (page 190) all rooted their explanations in fundamental elements that bridged the orders of reality—fire, motion, "caloric," etc. In each case, positing one of these minima to explain what heat "really was" gave thinkers something solid about which to argue—a fulcrum, as it were, for the levers of their understanding. When those levers were then pushed to their limits, the typical outcome was what Kuhn calls a "paradigm shift" in science.[3]

Minima often wind up at the center of conflicts between theories. For example, an inconsistency emerged in particle physics during the twentieth century, between theories based on physical-ideal minima and those based on physical-behavioral minima. This problem, now called "quantum indeterminacy," lies between physical particles categorized ideally, in which case each particle has certain absolute properties, and the same particles categorized behaviorally, in which case they are parts of certain causal links. If the causal links are to be regarded as reliable (which they must be to qualify as minima), then the particles do not have absolute ideal properties; and conversely, if the ideal properties are absolute (which they should be to figure in ideal formulas), then the causal links are unreliable. This inconsistency has yet to be resolved.

The present discussion has been about minima constructed between physical reality and either ideals or behavior. They are useful examples because physicists have devoted so much intelligence in trying to work with them. But minima are also routinely constructed in known reality between behavior and ideals. These objects, which show up in morality and valuation, are discussed in Chapter 7.

Discussion: The Particles of Physics

When we burn a piece of wood it becomes a piece of charcoal, which is a patently different object. It is obvious to ask, Where did the wood go when it burned and where did the charcoal come from? *Something* must have remained throughout the burning process. But whatever it was that endured must have been neither wood nor charcoal nor any other thing we observe directly.

One of the goals of modern science has been to describe such events in terms of "basic" entities that remain unaltered, while the things that come and go (such as wood and charcoal) turn out to be scientifically irrelevant. Thus we envision immutable "particles" (atoms in this case) which are in both wood and charcoal but which are neither wood nor charcoal by themselves. Burning wood then becomes just a process of rearranging these particles; in theoretical physics, it is immaterial that we choose to call one arrangement "wood" and another "charcoal."

By envisioning particles, physics is saved from having to cope with something inherently inexplicable—namely, the incessant appearance and disappearance of its subject matter. Gross things may be objects of interest; but when physics gets down to final truths, only fundamental particles are regarded as "real."

The fundamental particles of physics are classic minima, as the term is used here. They are both physical and ideal. In the "standard model" of present-day physics, such particles are either chunks of matter (quarks and leptons) or chunks of energy (photons, gravitons, gluons, etc.). Earlier theories hypostatized other particles, such as electrons, protons, and neutrons, and before 1900 whole atoms were regarded as fundamental. All these particles, from atoms to quarks, are posited to share three characteristics:

- They do not arise in common sense; that is, when an organism (in this case, a human) first objectifies a part of unknown reality it does not automatically categorizes that part as a fundamental particle;
- They are parts of the physical order of known reality because they are conceived of as constituents of the objects of physical common sense—they are the "building blocks" of mass and energy;
- They are also parts of the ideal order of known reality because each particle of a given class is fully defined by its measurable properties and is therefore absolutely identical to other particles of that class.

This last characteristic of particles—their ideal equivalence—is the key to their being "fundamental." Every "up quark" is indistinguishable from every other "up quark"; if this were not so, we would have to find particles more fundamental inside quarks to explain their differences. The "infinite specificity" of physical reality—its inherent capacity for ever-finer analysis—stops abruptly at the particle level. It is necessary that every particle be immutable; if particles were capable of change, physics would lose its reference points for the changes in gross objects that particles are supposed to explain.

Absolute particle equivalence was parodied, in effect, by Richard Feynman in the 1940s with his "one-electron universe" model. In that semi-serious worldview, the physical universe would be composed of a single electron that travels backward and forward in time at infinite speed, thus appearing everywhere at once and forever. By treating all of physical reality as consisting of just one fundamental particle, a physics based on this approach might have achieved the ultimate in minimization.

Because minima are artificial bridges between the disparate orders of reality, new ones are required as physicists explore new phenomena. In modern physics, the objectification of the electron in 1897 gave rise to a series of objectifications of new particles within atoms. Similarly, the introduction of the quantum concept of light in 1899 inspired the objectification of a new energy particle, the photon. The development of atomic energy, with its consequent boost to research into subatomic effects, then led to an intense proliferation of minima in physics. The "standard model" that is current in physics today aims to recategorize the resulting multiplicity of objects, in many cases by objectifying even smaller particles.

Why does theoretical physics exhibit such a need for particles? We can see how physicists explore subatomic effects in their laboratories: they produce unusual events, using high-energy equipment, and make increasingly refined measurements. At the same time, mathematicians develop increasingly sophisticated ways of manipulating abstractions, from complex analysis to group theory. Both scientific communities are exploring reality, but their explorations can never meet directly. Still it is clear that mathematics and physics are able to help each other. So physicists objectify particles—objects of knowledge that are posited to lie in both orders of reality. Particles are physical because they are the smallest bits of mass and energy, but they are also ideal because they can be completely described mathematically.

With particles serving as little "gateways" between physical reality and mathematical ideals, larger physical phenomena can be described in terms of ideal patterns. If one questions the general validity of such descriptions, as Aristotle did, the answer is simply that all physical "phenomena" are really just combinations of particle interactions.

Theories

The last several sections have analyzed ways that organisms expand their knowledge beyond common sense. To review that discussion,

- As organisms objectify unknown reality into three orders of known reality, they construct knowledge objects in each order. They then group these objects within each order, to minimize the number and variety of techniques needed to deal with them.
- The groups—knowledge categories—become objectified into new objects in known reality. Each category grouping helps organisms understand the objects that belong to its group. When a category and the objects it groups belong to the same order of reality, the result is what I call commonsense knowledge.

- Because life exists in all three orders of known reality, organisms can construct groupings in which the group itself becomes an object in an order of reality different from that of the objects it groups. Such cross-categorization in knowledge becomes an important part of every organism's understanding of known reality.
- Cross-categorization builds categories artificially, applying them to objects for which they may or may not be suitable. The value of an organism's doing this is that it exposes errors in knowledge. It lets organisms separate categorizations that work from those that don't.
- To make large bodies of knowledge work, organisms may create new objects in known reality that are deliberately cross-categorized. I call these objects minima. They mask the error inherent in cross-categorization at specific points in a body of knowledge, making it easier to detect error at other points.

The bodies of knowledge that use this treatment—cross-categorization to deepen understanding and minima to obscure the potential for error that comes with that understanding—I call **theories.** Building them—theorizing—is a common and often vital activity for many organisms. Among humans, theorizing can be a professional occupation.

At their origins, theories grow from commonsense knowledge. An organism objectifies some part of one of the three orders of reality and categorizes it in the same order. For example, a physical sensor such as an eye fixates on a part of the environment, separating and identifying that part as an object. Concomitantly, sensations arise in the organism's behavior: color, shape, etc. The coincidence of the physical act with the behavioral sensations may be a profitable addition to the organism's knowledge or it may be the result of an illusion. To try to find out more, the organism starts a theory by cross-categorizing the two. For example the physical object may be categorized behaviorally as red (because it coincides with a red sensation) and as round (because it coincides with a round sensation). At the same time, the behavioral experiences may be categorized physically: the red sensation means that the organism is looking at a "red thing," the round sensation a "round thing," etc. Thus the organism constructs an elementary theory of perception, in which behavioral sensations and physical objects "explain" each other through cross-categorization.

Theorizing constructs knowledge in corporal reality as new objects are constructed in the rest of known reality. In the example just given, an organism's known reality expands to include a round, red object (an apple or a ball). At the same time, its knowledge expands to understand the new object. In both cases, cross-categorization provides a vital link between behavior and physical reality.

Theories are always on trial. The next step after cross-categorization is error detection, to assess the validity of the organism's assignment of categories. "In theory" (as the saying goes) an organism can assign any category to any object. It could explain the red sensation by the time of day (at sunset everything looks red), instead of by its inherent color as a physical object. The simple theory "I am experiencing red and round sensations because my eye is looking at a red, round thing" is part of the more general theory of normal perception on which life depends. However, perception can be erroneous in specific instances.

How can an organism detect error in a theory such as this? Because the theory cross-categorizes physical reality with behavior, evidence for or against it can be found in either order of reality. In its behavior, the organism might look at the object again or try to get other organisms to agree with its theory ("Yes, I see a red ball, too"). In physical reality, it might manipulate the object to examine it more closely, or test it with tools. Such explorations might discover, for instance, that the supposed object was an optical illusion or the result of a defect in the eye.

After many different theories have been tried and some have been found erroneous, a more solid foundation for theorizing may become desirable. At that point minima come to the aid of theorizing. In human theorizing, certain parts of reality are objectified in such a way that they are understood from the start as cross-categorized. Their role in human theorizing is threefold:

- Minima "pin together" two orders of reality, letting us use our knowledge of one order to help us explore the other. Objectifying particles as bits of matter that have ideal properties is an example. Building theories about particles lets the physicist create parallel mechanical and mathematical models with the confidence that they are relevant to each other because they talk about the same minima.
- Minima represent the *ne plus ultra* of any theory. One may question a theory's objects and categories until one reaches its minima—then the questioning stops. Minima are "fundamental"—they simply are what they are. Thus minima serve to makes a theory more efficient, by setting bounds on the knowledge needed to support it.

- Because they bridge the divide between two orders of reality—which is where error is found—minima are inherently error-free. Thus including them in a theory tends to smother our doubts about the theory's validity. Many theories start with the "discovery" of new minima, giving the new theory's contribution to knowledge built-in validity from the outset.

In scientific research, new minima are often suggested by experimental invariances. If some effect comes out the same in a variety of different experiments, then it is a good candidate to be an unquestionable part of reality. Its nature cannot be further examined experimentally because every experiment yields the same data about it.

For example, when Thomson measured the deflection of cathode rays in magnetic and electrostatic fields (1897), he discovered that his measurements of the energy and mass of the tiny components of the rays were the same for different gases. On the basis of the observed invariance he assumed that what he called "corpuscles" (later called electrons) were fundamental ("primordial"):

> the molecules of the gas are dissociated and are split up, not into the ordinary chemical atoms, but into these primordial atoms, which we shall for brevity call corpuscles[45]

In a similar way, it was by imagining that the speed of light might be invariant in all experimental situations (even for an observer moving close to that speed) which led Einstein to propose a new set of relations among space, time, mass, and energy. He treated the speed of electromagnetic radiation as a theoretical "pin" between physical reality and ideals—a minimum that was physically real but also a constant in ideal models such as Maxwell's equations for electrical and magnetic fields. The assumption that the pin *always* held, even in experiments where two observers were making the same measurements while moving with respect to each other, led Einstein's theory to redefine other concepts in physics, such as absolute space and time.

History: Theories of Heat

As Chapter 4 discussed in more detail, the cross-categorizations on which theorizing depends come in various "styles," depending on which two orders of known reality are being cross-categorized. These styles exert a profound effect on theoretical understandings. In some cases we can trace theories about the same thing through multiple styles, as thinkers have recategorized their existing knowledge.

An interesting example is provided by the ways that scientists have understood heat, an object of knowledge that has been explained by means of at least six different theories during the last 500 years. These historical theories of heat are summarized below.

Table 6-1. Ways of theorizing about heat

Theoretical explanation	Categorization
Element	P CAT B
Motion	B CAT P
Imponderable fluid	B CAT I
Mechanical work	I CAT B
Thermodynamic energy	I CAT P
Quantum energy	P CAT I

Notice that these explanations cover the six possible ways that one of the three orders of known reality can categorize objects in another. Each represents an attempt to construct a better understanding of what heat "really is." The resulting theories can be briefly summarized:

The **elemental** theory of heat, in which fire is one of the four or five basic constituents of the material world, may be as old as mankind. In the West, it was enunciated by Heraclitus and became a part of the physical worldview of Aristotle, which dominated European thinking until the seventeenth century. In this theory, fire was a physical element that was more or less present in all matter, and heat was its behavioral perception.

The **motion** theory of heat distinguished heat from hot things (such as fire). In his *Novum Organum* (1620), Francis Bacon wrote

> When I say of Motion that it is as the genus of which heat is a species, I would be understood to mean, not that heat generates motion or that motion generates heat (though both are true in certain cases), but that Heat itself, its essence and quiddity, is Motion and nothing else.[46]

This view was echoed in 1665 by Robert Hooke, who was working with Robert Boyle on the properties of air. The breakthrough idea was to regard heat as a behavioral event—an internal motion—that takes place within all kinds of physical matter and is known because it makes physical things hot.

The **fluid** theory of heat replaced behavioral motion with an ideal substance, "caloric," that flowed from hot things to cold things. It was proposed in 1783 by Lavoisier to replace the idea of "phlogiston," an element supposed to be emitted by combustible materials when they burned. Caloric was defined as weightless and invisible—it could be detected only by experiencing the heat that it gave to physical things. Moreover, it had the characteristic ideal property that it could neither be created nor destroyed. It was decidedly unphysical.

The **mechanical** theory of heat was developed by Carnot and Joule. In a famous experiment, Joule converted the work done by a falling weight into heat generated by turning paddles in water. This allowed heat to be quantized in foot-pounds. As in the motion theory, heat was treated as a behavioral event that made things hot; but now it could be understood ideally in terms of weight and distance. Moreover, Joule's heat could be created, unlike the mysteriously ideal caloric.

Joule and Clausius developed the thermodynamic theory of heat in the latter half of the nineteenth century. The concept of energy had been waiting in the wings since the time of Leibniz and Newton, but no one had been able to find an "energy substance" in physical reality. Now that heat was definable in foot-pounds, **thermodynamic energy** was posited as a physical substance that could be understood ideally. Heat became the "lowest" form of thermodynamic energy, and a new ideal property, *entropy,* measured how much heat had dissipated and become "unavailable" in a given region of physical reality. The new "laws" of thermodynamics now treated energy, particularly heat, as something physical—it could be measured and moved around—but also a thing that was categorized ideally: it could be described mathematically.

Although the mathematical formulas of thermodynamics provided a great boost to engineers designing such machines as heat engines, they worked poorly with small-scale physical interactions. As Boltzmann and Gibbs pointed out, the laws of thermodynamics were inherently statistical. With the emergence of particle physics at the beginning of the twentieth century, a new understanding of energy was needed. This understanding was provided by Planck and others by means of the idea of **quantum energy,** energy that resides in mathematically definable "quanta." It is the common understanding in physics today, at least for small-scale phenomena.

Each quantum of energy has an integral value, and particles are said to be in certain "quantum states" definable by mathematical vectors. Thus energy has become an ideal property of physical things, with quanta as minima that pin together particle physics and mathematics. At the same time, the work of Maxwell, Einstein and others has resulted in the term "energy" being applied to a wide range of disparate physical things. Physicists today talk about energy not just in heat, but also as an attribute of light, matter, and gravity.

Table 6-1 (page 191) illustrates a common characteristic of changes in theorizing styles: a new theory may just switch the orders of reality of a previous theory's objects and categories. Thus, the element and motion theories of heat interchanged the roles of physical reality and behavior; the caloric and work theories switched ideals and behavior; and the thermodynamic and quantum theories of energy emphasized first the physicality of energy, understood through ideal laws, and then the ideal nature of energy, appearing everywhere in physical reality.

This alternation of object order and category order is common in theorizing. Once a theorizer has set up crossed categories to explain something, a question arises: Which part of the cross-categorization is object and which is category? If we identify the element "fire" because it makes things hot, then maybe heat is the true object to be studied and fire is only a manifestation. Some such idea may have occurred to Hooke as he carefully examined the zones of heat in a candle flame.

Not only have theorizers explained heat through different styles of cross-categorization, but there is a rationale behind the sequence of styles they have chosen. This rationale is explored in the next chapter (page 217).

Species Theorizing

The present discussion has been largely about human theorizing, but all organisms create and maintain theories. My dog maintains a theory that when the doorbell sounds he should go to the front door. His theory cross-categorizes the sensation of a specific bell sound with physical action at the door. My dog has acquired a conditioned reflex, which constitutes a minimum in his theory—a fundamental element that he does not question. And of course my dog's theory is subject to error, since a rainstorm might short out the wiring and ring the bell without anything interesting happening at the door.

My dog is an individual organism, but the term "organism," as I use it here, denotes all levels of living objects, from individuals through species up to life itself. Species, in particular, are organisms that create knowledge, which they store in the ideal genetic code shared by their individuals. For example, the ants in my kitchen maintain a theory that sugar is nutritive. While my dog constructed an individual theory about the doorbell on his own, the ants' theory about the edibility of sugar was constructed by their species, genus, and higher taxa.

Biologist Jakob von Uexküll analyzed what he called the *"umwelt,"* or "personal world," of various animal species (1909). His main insight was that different species may experience life's shared environment in wholly different ways. The eyeless tick, for example, uses its general sensitivity to light to mount a blade of grass, there to wait for the scent of butyric acid that all mammals exude. On smelling that particular scent, it drops blindly, hoping to land on a surface with a temperature of 37 degrees Celsius. If successful with that, the tick uses its general sense of touch to locate a spot free from hair and burrows in.

Compared to the dog on which it lands, the tick knows very little about the world in which it lives. In its environmental reality it knows a half-dozen physical objects (butyric acid, blood temperature, hair, etc.); in its organic social reality it knows that its food source is provided by warm-blooded animals; and we can find no evidence that it knows any mental reality. Virtually everything that an individual tick knows is the result of cross-categorization by its species. Its species has theorized that physical butyric acid molecules should trigger the tick's letting go of its perch and that a temperature of 37 degrees should trigger finding a spot to dig in and feed. As a result of having inherited these theories, each individual tick is able to understand specific physical objects through instinctive behavioral categorization. But much of what my dog and I recognize as "known reality" is unknown to it.

Species knowledge. The result of species theorizing such as this could be called "species knowledge." Taking life as a whole, species knowledge is the primary tool that most individual organisms use to construct known reality. Consider some of the ways in which species create knowledge:

- A species may objectify its environment in several ways. At the most basic level, it matches its biochemistry to its environmental niche—for example, it creates metabolic pathways to process the available nutrients or it sets up photosynthetic systems. At a more complex level it objectifies parts of its environment by evolving sensors, such as olfactory cells and photoreceptors. The modes of objectification may vary from species to species; for instance, magnetoception lets migratory birds objectify the earth as a whole in ways unknown to other animals. Each such adaptation lets the individuals of a species objectify different parts of unknown reality. The required physical equipment in each individual—the phenotype of their species—is constructed by the species' genetic coding, or genotype. As a result of the selective survival of its individuals and the replication of their genetic codes, each species acquires knowledge.

- A defining characteristics of life is responsiveness, and each species categorizes the objects its individuals create by evolving responses to them. Responses range from fairly rigid instincts to learned or ingenious behavior, but in all cases they represent attempts by the species to "understand" objects by grouping them—things to eat, things to avoid, things to nurture, etc. The simplest examples of such categorization occur within one order of reality, as when a variety of different odors may trigger the same signal along an individual organism's olfactory nerves. But cross-categorization occurs too; for example, instincts passed from a species to its individuals associate specific responsive behaviors with groups of physical objects.
- Species' knowledge also depends on minima, in the form of reflex arcs. A reflex arc evolves as a kind of "elemental" knowledge about the species' environment—in many cases, a linkage of behavior with physical reality that the species' individuals cannot modify. In those cases, the reflex action is both physical and behavioral. Reflexes are typically found at the beginning and end of more complex trains of behavior. For example, a "higher" animal's eating behavior may start with the reflex actions of stomach contractions. The animal finds food, using individual learning or ingenuity, and ingests the food. Other reflexes then take over, such as digestion. In the animal's "knowledge of eating," which is passed down from its species, these reflexes provide an unquestionable justification for associating food acquisition behavior—hunting, for example—with nutrition. Each individual hunts when it is hungry.

The theoretical knowledge that species construct may be erroneous—that is a common reason why species become extinct. A species may adapt to a niche in the environment that vanishes, or it may fail to adapt to the intrusion of another species. In such cases, its theory of survival or reproduction has turned out to be false or inadequate. Individuals are like "test cases" for the theories constructed by a species; their living and reproducing validates the species' knowledge of reality.

Models in species knowledge. Chapter 3 (page 59) defined models as products of generalization, which is one of the three basic ways that organisms construct known reality (the others are objectification and categorization). Generalization combines categories logically ("*A* and *B* but not *C*," for example) to make new groupings of objects. Models can be constructed only by applying logical operations to categories; but once a model is constructed, an organism can use it to understand known reality without understanding the logic by which the model was originally built.

Most species and higher taxa evolve models and pass them to their individual organisms as instinctive understandings of known reality. A few species, notably humans, have also evolved neural equipment that allows their individuals to construct new models.

Models make understanding known reality more efficient by cutting down the number of groupings that organisms must use. For example, when a *Sphex* wasp lays her eggs she follows a single procedure in her behavior.[47] She digs a hole, finds a grasshopper, stings the grasshopper, drags it to the hole, drops the grasshopper, inspects the hole, drags the grasshopper into the hole by its antennæ, lays her eggs on it, and so on. Experiments have shown that this procedure is based on a few models that the wasp uses in sequence. For example, if an experimenter moves the grasshopper away while the wasp is inspecting the hole, the wasp on returning does not drag the grasshopper into the hole. Instead, she drags the grasshopper back to the edge of the hole and inspects the hole again. This sequence "move-to-the-edge-then-inspect-then-drag-inside but do-not-drag-inside-if-the-object-has-been-dislocated" conforms to a model that the species *Sphex* has evolved to maximize the likelihood that each individual wasp will propagate successfully. By combining a sequence of categorizations logically into a few models, and passing those models genetically as a chain of instinctive reflexes, the species has reduced the number of categorizations that its individual organisms must make, thereby simplifying its complex egg-laying behavior.

The individual *Sphex* wasp does not understand the logic by which her species evolved her egg-laying routines. But she *can* compare each routine—each model object—with her understanding of environmental reality. This ability to compare objects, discussed earlier (page 64), lets her compare each stage of her egg-laying process to a model, thereby objectifying an equivalence that triggers the next routine.

We human individuals construct models all the time, and for similar reasons of simplicity. For example, imagine that we see a bear and then consider how we know it is a live bear instead of a bear puppet or a man in a bear costume. We might create a long "Boolean formula" of category checks that identify a live bear—bear-shaped and hairy and moves with an ambling gait but does not speak English and does not have glassy eyes, etc. Movie technicians go through such logical filters when programming a computer animation or creating an animatronic robot or training an actor in a bear suit. But the rest of us just compare what we see with a model of a "generalized bear" in our mental reality. Even tiny elements of appearance or behavior can then tell us whether or not what we see conforms to our model.

Using Symbols

In *The Language Instinct* (1994), psychologist Steven Pinker echoes Darwin, maintaining that the behavior of using language is an ability developed by the human species:

> Language . . . develops in the child spontaneously, without conscious effort or formal instruction. . . . people know how to talk in more or less the sense that spiders know how to spin webs.[48]

Although Pinker restricts his use of the word "language" to humans, the same might be said of birds, whales, and other species that construct social realities using symbolic communications. Besides its social uses discussed earlier (page 140), symbolization is an indispensable tool for conveying knowledge.

A symbol, such as a word in a language, is an object in behavior. It is the objectification of a special kind of behavioral category, one that an organism constructs not to understand reality, but to *replace* it. The virtue of symbolization is that it is usually easier to objectify a symbol than to objectify the reality it "represents."

For example, a prey animal may have many behavioral categories for a predator—things to be alert to, things to hide or flee from, etc. All these categories contribute to the prey's understanding of the predator in environmental reality. But in social reality the prey animal's species may construct an additional behavioral object—a cry of alarm. While the cry may help to confuse or discourage the predator, it also works to categorize the predator to the group of prey animals. Other individuals in the group can react to the symbol—the cry—much as they would to the actual predator, with less danger.

Symbolization as a tool for communication is widespread in life's social species. The communication is physical, but the symbols that are communicated are behavioral. They usually evolve in social reality and become part of the common knowledge of a group. Human languages are a prime example.

Human languages. Every variety of speech, from BBC English to Tokyo street slang, is a collection of behavioral objects that humans construct in social reality. It is also a particular kind of knowledge—knowledge that provides behavioral categorizations for objects of all kinds. Each word or expression is a behavioral object that groups other objects, which may be physical, behavioral, or ideal. Thus in English the noun "rock" is an objectification of the language category that groups together all physical rocks; the adjective "circular" categorizes all ideal patterns of circularity; the verb "run" categorizes the behavior of running; and so on.

Language behavior itself is normally cross-categorized when it is "expressed." A run of language behavior—from a single word to a whole book—may be categorized physically, when it is communicated as sounds or written marks, or ideally, when it is encoded into a binary message for electronic transmission.

For humans, language can be a vital "glue" that holds social groups together. When a group has been constructed around ideals—religious, cultural, political—language can provide words as behavioral symbols for the shared ideals. When the ideals become contradictory or cease to fit ordinary life, the words remain. Thus groups may share traditions that are mainly linguistic; their "social values" are words and slogans rather than common ideals.

Mental speech. In the human species, spoken language behavior serves both social and mental realities. People use the same words and syntax to speak to each other in the environment and to speak to themselves in individual consciousness. Moreover, it is clear that what we may call "social speech" engenders "mental speech." We first learn to talk to one another in social reality and then import the same skill into mental reality, so we can rehearse or reflect individually on our social interactions.

One obvious argument for the precedence of social language over mental language is the way that languages diverge in separated human groups. The Caucasian mountains of Dagestan, for example, are home to more than 20 distinct languages, some with only a few hundred speakers living in a single village. Each speaker's mental reality uses the language of his or her village. It is hard to see how that situation could exist if languages were not passed down from social reality to mental reality.

Remembering thoughts. Species of all kinds use symbolization to simplify remembering. Food is symbolized by its odor, offspring by their cries, mates by their markings. Such simple physical objects are easier to imprint into memory than the complex mixtures of behavior and physical reality that they symbolize.

In human life, mental speech extends this useful mechanism. It lets us remember our thoughts. When we symbolize a part of mental reality using mental speech, the result can be stored in our physical memory as if we had heard it spoken in environmental reality. Moreover, the great flexibility of our languages lets us easily remember symbols that are categorized by ideals, a feat other species find difficult or impossible.

We can surmise the stages by which humans evolved symbolization from the simplifying mechanism used by other species to our present use of it to construct rich mental worlds as well:

1) In human social groups, specific vocalizations would have been developed to symbolize specific objects or events in environmental reality. For example, a variety of alarm cries would have identified various different dangers.
2) To be successful, social groups would have trained their members to remember, interpret, and reproduce these vocal symbols.
3) As interactions within social reality prompted the construction of mental reality in humans, vocal symbols would have been a vital part of that reality. At this stage people trying to remember or recall these symbols may have talked out loud to themselves, just as babies do today when learning a new word.
4) The ability to manipulate vocal symbols in mental reality without vocalizing them in social reality—for example, "rehearsing" an alarm call when there was no cause for alarm—would have helped

develop the mental use of ideals, which would have been required to construct hypothetical or prospective propositions.

5) People would have developed the skill of subvocalization—“silent thinking”—to further separate the mental use of vocal symbols from their social use. Mental reality would have become private.

Recall the cluttered state of the “stream of consciousness” described in the last chapter. Experiences, images, ideas, and thoughts tumble over one another in mental reality, propelled by the introspective action of awareness. Somewhere in that potpourri are behavioral objects that we may want to remember. Language lets us “encode” the contents of mental reality so specific objects in it can be stored in memory. To achieve this result, language categorizes behavior physically, converting it into speech. That internally generated speech can then be stored in corporal memory using much the same neurological apparatus as heard speech. Indeed, people sometimes find it hard to tell whether a bit of speech in memory was constructed *de novo* in mental reality or heard in environmental reality. Its trace in memory is not always tagged with clues to its origin.

Model: Layers of Communication

The last chapter presented a layer model of known reality (page 132), patterned after the “OSI Seven Layer Model” which is used to analyze data networks. The same concept of layering can be applied to organic communication, with the added benefit that the organic layers can be directly compared to the OSI layers:

Table 6-2. Layer model of organic communications

Layer	Kind of reality	Organic objects	Corresponding OSI layers
Fourth	Mental	Thoughts	7: Application
Third	Social	Symbols	6: Presentation
Second	Corporal	Reflexes	5: Session
First	Environmental	Communications	4: Transport 3: Networking 2: Data linking 1: Transmission

Like Table 5-2 (page 133), Table 6-2 is intended to be read from the bottom up. Note that the layering order of environmental and corporal reality is reversed between the two tables. That is because Table 5-2 shows how organisms construct new realities, while Table 6-2 shows how organisms recategorize objects in environmental reality that have already been constructed.

In its analysis of electronic data transfers, the first four layers of the OSI model cover the physical transmission of electrical signals, their assembly into frames, the assembly of frames into messages, and the transport of messages from senders to receivers. In the case of human speech this process is analogous to vocalizing phonemes, assembling phonemes to compose words, assembling words to make expressions, and delivering expressions to specific persons or groups. From the viewpoint of a human listener, communication at this stage is a purely physical event in environmental reality.

The OSI model analyzes the physical transportation of data into four layers to expose separate areas where technology can improve the whole process. Human communicators often make a similar analysis. Imagine that you are trying to say something to another person across a crowd in a noisy, echoing hall. In the phoneme layer you will choose simple, loud syllables; in the word layer you will choose short words that are hard to mistake; in the sentence layer you will avoid convoluted syntax; and in the delivery layer you will speak directly to your listener.

In our present analysis, the construction of a modulated physical sound in environmental reality—or of a written text or an animal scent or a bodily display—occurs in the **first layer** of our model of organic communication. The result is a physical object in environmental reality that conveys a behavioral message.

The **second layer** of our model is part of the corporal reality of an organism receiving the message. The receiving organism modifies its body reflexively to accept the communication, as if responding to a physical stimulus. This action resembles the opening of a session in the OSI model, as shown in Table 6-2.

In the OSI model, a session is sometimes characterized as a dialog between two computers, even when information is passing one way. The receiving computer activates processes to store the incoming data, to authenticate it if necessary, and to inform the sending computer of any problems with its delivery. The purpose of the session layer is to guarantee that the data gets across as intended.

Organisms receiving communications perform similar tasks in their corporal realities. In a human dialog, for example, each listener in turn “pays attention,” remembers what was just said, nods or murmurs, and may interrupt the speaker if something was not understood.

Language appears in the **third layer** of our organic communication model. In the OSI model, the “presentation” layer is mainly concerned with encoding and decoding messages—converting binary information between the computer’s native coding and that of the data network. A typical example of encoding is ASCII, the American Standard Code for Information Interchange, by which the letters, digits, and punctuation marks on the computer keyboard are encoded as binary numbers. The processes of encoding and decoding are called “protocols,” standard sets of rules that software must follow.

Organisms communicating with one another also follow sets of rules that we call “languages.” In the present context, this broad terminology covers bee dances, animal scents, bird and whale songs, and so on, as well as the 6,000-or-so human languages. In all cases, organisms have constructed behavioral objects in a shared social reality as symbols for other objects. The main feature that sets human languages apart is their ability to encode ideals, an ability that lets them symbolize all parts of known reality.

Finally, the **fourth layer** of our model deals with the “meaning” of a communication. It corresponds to the “application” layer in the OSI model, which for a receiving computer simply presents the properly encoded results of a data transfer to any program that can use the data. In addition, the application layer typically tells the program where the data came from and how it may be read. Thus the familiar “http:” in Web addresses stands for Hypertext Transfer Protocol, which is part of the application layer for Web browsers. When it receives this label on incoming data, the browser treats the data as expressed in HTML, the Hypertext Markup Language.

In the case of organic communication, particularly among humans, this is the point at which a message becomes an object constructed in mental reality. From the viewpoint of a human listener, for example, a modulated physical sound in environmental reality has been “heard”—incorporated into the listener’s corporal reality—and has been decoded as an expression of a behavioral language in social reality. The listener now becomes “conscious of what was said” by constructing objects in mental reality.

Language and Knowledge

"The limits of my language mean the limits of my world"[49] epitomizes a prominent thread in twentieth-century philosophy. But Wittgenstein's famous aphorism is more about knowledge than about reality. Did he really mean that without using language he couldn't interact with his environment?

One of my professors at Berkeley used to respond to the suggestion that there are real, inherent problems in philosophy by asking "What problems?" Regardless of how universal or primitive a problem might appear to be in thought, when it was stated to him in speech the use of "ordinary language analysis" would ultimately show its description to be vague, inconsistent, or undefined in some way. Thus for him all the classic questions of philosophy became reduced, one by one, to errors in using language.

The present analysis treats language—more generally, symbolization—as a technique for making communication more efficient, not more accurate. An object in environmental reality goes through several steps of categorization before it gives meaning to a language symbol that can be stored in physical memory or communicated to another organism. This string of categorizations is particularly complex for ideals, which are what philosophy is mostly about. Consider how a formulation about environmental reality—a proposition that is true or false—is normally communicated from one person to another, using language:

1) The proposition begins as a behavioral object that categorizes a group of ideals, as explained in Chapter 4 (page 105). From the viewpoint of the human organism that formulated it, knowing the proposition is simply a learned skill in that person's corporal reality.
2) Through awareness in the person's mental reality (see page 155), the proposition becomes recategorized behaviorally as a thought—a new behavioral object. The person now becomes conscious of a conjecture about environmental reality that could be true or false.
3) The thought is once more categorized behaviorally and a linguistic statement is constructed. We say that the person's conjecture has been "expressed in language."
4) The language behavior is communicated by categorizing physical objects, such as speech sounds or written marks, which the person (now called the "sender") constructs in environmental reality.

5) A person (the "receiver"), hearing the speech or reading the written marks, categorizes these physical objects behaviorally according to the socially agreed standards for the language that the sender used. Thus the receiver constructs a linguistic statement in mental reality that tries to "reproduce" the linguistic construction of Step 3.
6) The receiver's process of awareness in mental reality recategorizes the linguistic statement behaviorally as a true-or-false proposition—a formulation about ideals that is categorized behaviorally.
7) The receiver recalls or objectifies the ideal objects in environmental reality that the proposition categorizes. The receiver may already know these ideals or they may be new objects; similarly the formula that connects them together may have been part of the receiver's known or unknown environmental reality.

When every step in this process "works," the receiver ends up knowing an object in environmental reality—a proposition—that the sender also knows. But every step involves recategorization and the construction of new objects in mental or environmental reality. The sender's behavior categorizes ideals and then categorizes newly constructed physical objects, which the receiver must recategorize into behavioral objects that can be used to objectify new ideals. The freedom inherent in cross-categorization exposes every step to error.

Because every language depends on the use of physical objects in environmental reality (*e.g.,* speech sounds or written marks), it tends to "physicalize" the content it tries to communicate. When we analyze language itself, common sense tells us that physical utterances must be "about" physical things or events. The cross-categorizations required to accomplish the communication steps just listed do not show up in the language itself—they are applied externally, when the language is used. Thus the behavioral and ideal orders of known reality appear extrinsic to language, which seems to be inherently about physical reality. You can see this effect when tracing chains of definitions in a dictionary. Every word that denotes an abstraction or a train of behavior is defined by other words more concrete, which are defined by words yet more concrete, until the definitions end by denoting tangible objects.

Despite all its deficiencies, humans use language as a primary way to acquire new knowledge. In social reality language helps people move behavior from one person's mental reality to another's. In each person's mental reality, language makes it possible to remember thoughts. These two capabilities, so essentially human, enable much of the diversity and complexity of human knowledge.

Formal Knowledge

Among the six cross-categorizing processes that take place in mental reality (page 146) four use behavior, either to construct new categories or to be categorized. These four processes—internalization, sensation, imagination, and reflection—typically serve the "ongoing business" of mental reality, which is to construct a stream of thoughts in awareness. They are behavior generating more behavior.

The remaining two mental processes—induction and deduction—do not affect behavior directly. They cross-categorize physical and ideal objects in mental reality:

Categorization	Mental process	New mental objects
I CAT P	Induction	Paradigms
P CAT I	Deduction	Inferences

These two processes operate on stored physical memories instead of on behavior. **Induction** constructs ideal "paradigms" in mental reality that categorize the contents of corporal memory. **Deduction** constructs new physical "inferences" based on those paradigms. Both the paradigms and their inferences become stored in individual memory. This is the way that human theorizers construct knowledge of the "formal reality" discussed in Chapter 4 (page 114).

As I noted in discussing causation (page 102), formal knowledge is often completely different from the knowledge that we construct to conduct our everyday lives. For the things and changes of common knowledge it substitutes less familiar objects, such as particles and forces, that are explained by mathematical "laws." Yet this formal knowledge usually works better than "natural knowledge" when it comes to designing machines or predicting large-scale physical events. So we learn to use both, using them in different areas of the complex technological society in which we live.

Frameworks. Much of modern physics is based on what I call "framework theorizing." A framework, as I use the term, uses physical reality and ideals (usually mathematics) to explain each other. Ideal principles explain why physical properties are the way they are, and physical properties give "substance" to the ideal principles. A simple example is any of the multidimensional coordinate systems typical of geography, astronomy, physics, and other physical sciences. By giving a numeric "meaning" to every point of physical space, a coordinate system lets mathematical functions "describe" physical events and the properties of physical things, such as their extension and motion. It also supports more sophisticated ideals, such as vectors and tensors, on which much of modern physics and technology depend.

Being constructed between physical objects and ideals, frameworks lack natural references to behavior. In particular, it is hard to include time in a framework. This difficulty shows up in physics, where change and motion are regarded as fundamental "phenomena" that should be explainable mathematically. One solution has been to adopt statistical "principles," such as the principle of entropy in thermodynamics, which force time into the framework and hence generate predictions that are only "statistically true," not absolute.

Einstein's proposal that space and time be related by the invariance of the speed of light, and the subsequent success of relativity theory, embedded the concept of "space-time" in modern physics. Motion and change became properties of "world-lines," which were regarded as physical objects in a space-time framework. But smuggling time into a framework in this way has led to numerous problems. To account for gravitation, relativity had to assign properties, such as curvature, to the framework itself instead of just to the physical objects it was supposed to explain. In 1949, Kurt Gödel described a model of physical reality, consistent with relativity theory, in which "the resulting space-time structure could not reasonably be seen as representing intuitive time."[50] More recently, Nobel laureate David Gross quoted several physicists to the effect that when string theory is completed, the idea of space-time will be "doomed."[51]

In the present analysis, time is an ordering method for behavior; it is part of natural reality, where behavior interacts with physical reality to construct the "time flow" of human experience. But formal reality must stick to the interactions between physical objects and ideals. The frameworks of formal reality must use timeless principles to explain static physical properties. Time can then be introduced as causation or in some other form that permits scientific predictions to be made outside the framework.

History: The Properties of Air

The human process of induction, just discussed, can illustrate how the construction of known reality and the knowledge of that reality interact with one another. Although induction constructs formal reality, which only humans know, similar interactions between the organic processes of constructing and knowing reality occur in all kinds of reality and among all kinds of organisms.

A classic example of scientific induction was Boyle's formulation of the first gas law in 1662. We can use it to illustrate the sequence of steps by which formal knowledge of existing known reality leads to the construction of new objects in formal reality.

At that time, common air was considered to be one of the ancient elements. There were many theories about how it might combine with earth, water, and fire to produce the substances of everyday experience, but very little was known about its properties alone. So Boyle set out to create a framework theory about air.

1) Using a column of mercury in a tube both to vary the pressure on a column of air and to measure its volume, Boyle and his assistant, Hooke, drew up extensive tables of measurements. They stabilized the temperature of their apparatus and even allowed for air bubbles dissolved in the mercury and changes in barometric pressure. The resulting figures showed a nice reciprocal relation between volume and pressure, which we know today as "Boyle's law." In the terms used in this book, Boyle's law is a part of our knowledge behavior that categorizes physical events ideally in the formal reality which is part of environmental reality.
2) Boyle attributed his results to the existence of a hitherto unknown property of air, its "spring." He titled his report *New Experiments, Physico-mechanicall, touching the Spring of the Air and its Effects*. Thus was born a new physical object in the formal world, the "property of spring." Hooke went on to investigate "the laws or causes of springinesse"—soon renamed "elasticity"—in metals and other physical materials, publishing *De Potentia Bestitutiva, or Of Spring* in 1678. "Hooke's law" related the extension of coil springs and other elastic materials to the tensions applied to them.
3) In 1687 Newton derived Boyle's law by assuming that air consisted of many uniform particles at rest that repelled each other by forces

> inversely proportional to their distances apart. Thus the "spring" of air got a new mathematical explanation by introducing new minima —particles and forces of repulsion—into formal reality.

In this way, 25 years of English science changed air from an elemental constituent of other materials to something with its own properties that could be described mathematically. The formal world in environmental reality acquired new objects of knowledge—elasticity, tension, forces, and particles—which ultimately became part of the theoretical bedrock of modern physics.

Scientific Method and Rationalism

Aristotle believed that truly knowing a fact, instead of just believing it, depended on knowing its unique cause:

> We suppose ourselves to possess unqualified scientific knowledge of a thing, as opposed to knowing it in the accidental way in which the sophist knows, when we think that we know the cause on which the fact depends, as the cause of that fact and of no other, and, further, that the fact could not be other than it is.[52]

In his dialog *Theatetus,* Plato speculated that knowledge might be "true opinion combined with definition [λογος] or rational explanation."[53] But before the rise of empirical science, neither Aristotle nor Plato could fully describe what "the cause on which the fact depends" or its "rational explanation" might entail. Two millennia later the "Age of Reason" began to fill this deficiency and many thinkers adopted Plato's description of knowledge, rechristening it "justified true belief."

Plato ended the *Theatetus* with Socrates still puzzled about what kind of justification true belief would need to become valid knowledge. As epistemologists proposed various thought experiments since then, Plato's concept of justification eventually inspired two methodologies: **scientific method,** Aristotle's requirement that we know prerequisite facts, and **rationalism,** Plato's insistence on reasoning.

Using the terminology of this book, scientific method includes the categorization of behavioral experiences by physical "phenomena"—P CAT B. Rationalism is then the process of ideally categorizing those physical objects—I CAT P. To complete the ring, philosophers such as Locke called for the empirical understanding of scientific abstractions, categorizing them behaviorally. Thus arose P CAT B CAT I CAT P—a chain of cross-categorizations in which our scientific experiments give meaning to mathematical ideals, which explain physical phenomena, which give meaning to more experiments. Thus Galileo rolled metal balls down wooden planks to help him formulate the mathematics of acceleration, which explained the movements of physical bodies, which was why he reportedly dropped balls of different weights from the top of the Leaning Tower of Pisa, and so on.

Because the purpose of scientific method is to explain observations of physical reality, the weak part of this loop is the insertion into it of ideals. A tighter loop of explanations consists of just B CAT P CAT B, which constructs knowledge of what I call "natural reality," discussed on page 99. It is the way most individual animals other than humans learn to understand their environment. We generally don't find ideals used in knowledge until we reach the level of species, where they are needed to encode living techniques into DNA. Our individual use of ideals in constructing everyday knowledge makes humans an unusual species. It turns us into constant theorizers and explains why we're called *homo sapiens*.

In 1963, philosopher Edmund Gettier published a short paper that challenged the definition of knowledge as justified true belief.[54] It proposed two thought experiments in which rigorous chains of logic led to beliefs that were true by mere chance. Since then other philosophers have devised more examples and conducted a lively analysis of them.

The point of the "Gettier problem" is that logical reasoning based on empirical evidence can be used to justify a belief whose truth or falsity depends on extraneous facts. Because the controlling facts are not part of the reasoning, the reasoner has no way of knowing the validity of the knowledge. The good news is that every Gettier thought experiment so far proposed could in principal be resolved by further investigation. This is also the way that science works, and the reason why theorizing never comes up with final answers.

History: Reason and Noesis

A persistent question has run through epistemology since at least the time of Plato. It asks what roles are played by those processes the Greeks called διανοια and νοησις. *Dianoia* was what we often call discursive thinking, or "reason"; *noesis* was more akin to "intuition" or "direct knowledge." Plato believed that the proper role of reason was to bring the human mind to the point where it could achieve *noesis,* the direct perception of reality.

In his *Symposium* (385 BC), Plato describes how Socrates was led by Diotima of Mantineia, his "instructress in the art of love," from merely contemplating specific beautiful objects to understanding the idea of beauty itself, through direct apprehension:

> Do you not see that in that communion only, beholding beauty with the eye of the mind, he will be enabled to bring forth, not images of beauty but realities; for he has hold not of an image but of a reality.[55]

More than two millennia later, the British philosopher F. H. Bradley wrote about the "happy suicide" of thought when it was transcended by "that immediacy which we find (more or less) in feeling."[56] In between, Spinoza argued for the superiority of *scientia intuitiva* and Descartes asserted that anything which could be discerned through a "clear and distinct idea" must be inherently real.

Hard-headed thinkers have branded Plato's and Bradley's arguments as "mysticism" and have dismissed the ideas of Spinoza and Descartes as polluted by deism. But people have always found it hard to dismiss the feeling that what we know by intuition—however hard it may be to defend publicly—is often more convincing than what we laboriously figure out by reason.

Addressing the limitations of reason as a road to knowledge, Kant began his 1781 *Critique of Pure Reason* with the complaint,

> Our reason [*Vernunft*] has this peculiar fate that, with reference to one class of its knowledge, it is always troubled with questions which cannot be ignored, because they spring from the very nature of reason, and which cannot be answered, because they transcend the powers of human reason.[57]

This dilemma sprang up again in the twentieth century, when logician Kurt Gödel showed that it was impossible to construct an axiomatic system—a body of knowledge based on reasoning—that could prove all the theorems of arithmetic.

Attempts to understand human knowledge, varied though they are, run into the same difficulty. It is that reasoning, however rigorous or prolonged, does not answer all questions; and that some knowledge is ultimately derived from a kind of immediate apprehension of reality. Reasoning may lead us to truth but it doesn't create truth.

The analysis presented here would agree. From the viewpoint of mental reality—the arena in which all the philosophical investigations just cited take place—reasoning is primarily an attempt to understand environmental reality by ideal categorizations and model-building. As such, reasoning suffers from the problems of both cross-categorization and reality-bridging. Its ability to understand the "external world" is inherently limited.

But when we construct models in mental reality we are not bound by the limitations of reason. We are free to construct models any way we want. When we construct models to understand environmental reality the results may be off the mark, or even illogical, but they won't be limited in the way that reasoning is. And constructing models gives us humans a simpler and more efficient understanding of reality, just as it does for other species.

Intuition. Many psychologists recognize "intuition"—cognition without sensation or reasoning—as a valid phenomenon (it is one of the Myers-Briggs type indicators), but one that has no "scientific" basis. Thinkers in all fields report "flashes of insight" that intuit patterns in their data. These and other anecdotes support the proposition that we humans construct models that we know only in mental reality.

Yet it is easy to confuse the "direct apprehension" of a model—which in my terms is its objectification in mental reality—with various trains of behavior that may precede it. When learning a difficult branch of mathematics (such as the infinitesimal calculus), for example, the student may write strings of symbols by rote until the "Aha!" moment, when the "principles behind" the symbols become clear. To instruct a child about a general ideal (such as honesty), one cites examples until the child "gets it." That means that the child has constructed an ideal model in mental reality which it can compare with specific behavior.

In mental reality we imagine and reflect, but we don't often reason about our own ideas and conjectures. Instead, we use them as tools to help us reason about our environment. Thus when reasoning reaches its limits, our behavior can turn to models constructed out of its own ideas and experiences. These models have the advantage that they are objects of immediate apprehension. Thus external reasoning gives way to inner experience not because we are "mystically inclined" but just because reasoning has done its job. After reasoning has exhausted its ability to categorize environmental reality, our understanding turns to reflection. It is at that point that we construct the models that make our grasp of reality feel more "intuitive." When we use those models to understand reality, we experience the "got it" feeling that the Greeks called *noesis*.

Language in Mental Reality

Something like the Greek's *noesis* seems to occur when humans use language to transport information from one person's mental reality to another's. The transport vehicle, language, is a series of categorizations bound together by logical syntax. But the content being transported is frequently a model. When I make a statement to another person, I often want them to construct in their mind a model like the one in my mind. So language brings my listener only up to the point where it is possible to construct a mental model. Understanding what I said then depends on my listener constructing an appropriate model in mental reality and apprehending it directly.

The effectiveness of thought-to-language and language-to-thought protocols is crucial here. We often criticize language as an imperfect way to achieve a "meeting of minds." The Vulcan "mind-meld" in *Star Trek* became famous mainly because it portrayed a way of surmounting the language barrier.

A more terrestrial example might be found in silent reading. The skill of reading a text without reciting it out loud to one's self was not widespread before the seventeenth century, at least in the West. As an example, Saint Augustine is quoted as having been astonished to watch Saint Ambrose read a text without speaking it out loud:

> His eyes were led along the page and his heart sought into the meaning, but his voice and tongue were silent.[58]

In effect, Ambrose had replaced a "loop" through environmental reality —reading text to speech and listening to the result—by developing in his mental reality the process of converting the visual experience of reading text directly into thought. In fourth century Europe this was a feat only experienced readers could accomplish; by the seventeenth century it had become more common.

Today, speed-readers are taught to absorb large chunks of text "in parallel," without trying to vocalize them. Mathematicians learn to read formulas that cannot easily be represented by any spoken language. Computer programmers scan lines of code without try to vocalize the symbols. In all these cases, readers try to establish a path directly from writing into mental reality without the intervention of serial speech.

Nevertheless, tests with electromagnetic sensors pick up speech-like subvocal muscle movements during silent reading, and readers sense that words are "passing through the mind." I believe this is evidence that language is used inside human mental reality as models are being constructed. Words can turn ideals into behavioral ideas, which can be grouped into new conjectures (see Table 5-4, page 146). Thus language can provide "intermediate variables" for the model-building process, words serving as behavioral placeholders in mental reality for newly objectified ideals. This is how we can create hierarchical structures of ideals and ideals-of-ideals. Sensation is unwelcome behavior at these times, for it interrupts the free turnover of thoughts in awareness.

Serial and parallel data transfers. Computers move data in two different ways. Serial transfers move data sequentially, one bit at a time; parallel transfers move many bits at once. As a result of cost and efficiency factors, data is typically moved serially between computers and in parallel inside computers.

A similar situation appears to hold when language is used in mental and environmental realities. There is evidence that the main organ that constructs mental reality in humans, the brain, processes information in parallel. One would expect this result, since brain neurons are densely interconnected and it would be inefficient to use so many connections one at a time. So when we use language to construct models in mental reality, it seems likely that groups of objects—physical electrochemical states, behavioral brain events, or ideal patterns of neuronal excitation—are moving in parallel in our brains, instead of serially, one element at a time.

But when information is transferred from one brain to another, through environmental reality, it is normally confined to one serial channel. Speech, for example, must be delivered serially. The nature of human hearing does not allow us to hear all the phonemes of a word at the same time, nor would we be able to interpret a ten-word sentence if ten speakers pronounced its words simultaneously, in parallel.

A considerable amount of design effort has gone into working out good computer protocols for serializing data. These problems center around timing and framing—making sure that information fed into the one-bit-at-a-time pipe at one end can be reassembled correctly at the other end. They resemble the human problems of transporting models from one brain to another by means of language, which breaks them down into streams of less meaningful parts.

The problems of serializing models are most evident with individual knowledge, particularly where a human language is used to transfer models between human brains. With species knowledge, where models are encoded in DNA, the code is essentially transferred in parallel from one generation to the next. However, it is interesting to note that at the microscopic level of DNA polymerase reactions, DNA transcription is carried out serially, one nucleotide at a time. The process is accurate, producing an error rate of less than 1 in 10^7, but it is not perfect. Some polymerases even "proofread" the new DNA and correct errors. This similarity—between DNA replication and human communication—is one more example of life's remarkable ability to apply old solutions to new problems.

Summary of this Chapter

Knowing reality is the complement of constructing it. Living organisms construct reality so they can know it, and they know reality so they can construct more of it. Knowing takes place in the behavioral aspect of an organism; knowledge, its product, is a modification of the organism's corporal reality.

But the construction of knowledge within an organism never just copies the construction of reality outside it. The behavior of knowing evolves through its own processes, driven primarily by the organism's experiences of error.

Error is hard to discern in what I call commonsense knowledge, where objects are constructed and categorized in the same order of known reality. Detecting error requires the kind of perspective that comes from cross-categorization—from grouping objects in one order and then treating the group as an object in another order. The freedom to do this is a hallmark of life.

Thus arises theorizing, the deliberate use of cross-categorization to promote understanding. Theorizing supplements common sense with knowledge that purports to "look beneath" the surface of reality. But theorizing is inherently erroneous because it forms groups that are not comparable with their elements. Thus most theories depend on what I call minima—objects that are constructed as if they were parts of two orders of reality at the same time.

Typical examples of minima are the particles of physics, which are supposed to be both physical and ideal. Populating known reality with such objects allows physical observations and mathematical formulas to refer to the same things, namely particle interactions.

Species construct theories about the environment in which they live; they categorize its objects and form models that get encoded into the genomes they pass down to individuals. In many species, individuals then pick up the burden and theorize about particular situations during their lifetimes.

For many individual organisms, including humans, communication is an important knowledge skill. Knowledge expands when it is shared, both among contemporaries and over generations. But the processes of communication are filled with error-prone cross-categorizations—from the construction of behavioral symbols that represent physical or ideal objects to the construction of physical messages that have behavioral contents. Organisms are constantly adjusting and correcting their acts of communication, trying to make them better.

Through the basic techniques of objectification, categorization, and generalization, life thus constructs knowledge within organisms while it constructs worlds to be known. The whole system is never perfect, but it works—which is all that life asks of it.

7. Human Realities

> Each of us literally chooses, by his way of attending to things, what sort of universe he shall appear to himself to inhabit. WILLIAM JAMES

Known reality, as described here, is built using objects, the categories that group them, and models that combine categories logically. Living organisms, both individuals and species, construct these entities from unknown reality to make it knowable. But the result is not one reality, known in the same way by every organism. Every form of life—every individual, culture, species, and so on—chooses the kind of reality it constructs and the ways in which it knows that construction. Most of these choices are forced upon individuals, having been embedded in their species by millennia of evolution. But the choices are always free in the sense that they might be different.

Knowledge is a part of known reality that organisms construct so they can understand the rest. That understanding lets organisms extend their construction of known reality. Thus knowledge is a tool that life uses to build new objects upon the objects it knows. By exploiting the freedom of choice that is inherent in categorization and generalization, knowledge lets organisms construct new realities in which to live.

Nowhere is this process of proliferating realities more evident than in human life. We humans are constantly constructing new theoretical objects in known reality, each one a variant of some part of the reality that we already know. The products of this activity are the corporal, environmental, social, and mental realities described in the preceding chapters.

But human individuals also tend to construct different versions of these realities, and different theories to know them. As the saying goes, "everyone sees the world a bit differently." When disputes between competing theories arise in human life, the disputants usually try to win by citing "facts." A time-honored belief holds that theories can be proved or disproved through "comparison with reality." But when the disputing theorizers have constructed some or all of the reality that they purport to explain, arguments become stickier. It often turns out that the disputants are talking about different realities, not about different ways of knowing or understanding a single agreed reality.

This chapter explores some of the varieties of human realities and discusses some of the ways in which people try to understand them.

Cross-Categorization Sequencing

The six ways that the orders of known reality can be cross-categorized are listed in Table 4-1 (page 94). The order in which these six ways are listed in the table also shows the sequence in which they tend to build upon one another in human life, both when we construct known reality and when we theorize about it. This "natural" sequence is

1: Physical reality categorizes behavior (P CAT B)
2: Behavior categorizes physical reality (B CAT P)
3: Behavior categorizes ideals (B CAT I)
4: Ideals categorize behavior (I CAT B)
5: Ideals categorize physical reality (I CAT P)
6: Physical reality categorizes ideals (P CAT I)

Thus when we construct a new part of known reality, we commonly start by grouping some of our behavior in a category and objectifying that category as a physical object. If we are constructing objects in environmental reality, I call this process actualization; the same style of categorization in corporal reality is metabolism; in social reality I call it communalism, and in mental reality internalization. The next step, as shown in the list above, is to categorize the resulting physical objects behaviorally (B CAT P); and so on. The sequence as a whole is cyclical, so that the last style, P CAT I, is normally followed by a new use of the first style, P CAT B.

The reasons why this sequence of cross-categorizations is "natural" are analyzed in detail in my previous work.[59] They can be summarized by examining two kinds of transition from one style to another:

- The easiest transition from one style of cross-categorization to another is simply to switch the two orders of known reality: *x* CAT *y* is followed by *y* CAT *x*. This is the only possible transition that does not require knowledge of the third order of reality. A given style and its converse naturally work together when we construct objects in one of the areas of environmental reality surveyed in Chapter 4—natural reality, intellectual reality, or formal reality. I call this a **"converse transition."** After actualizing a physical object in natural reality (P CAT B), for example, it is easy and natural to animate it by constructing a change object in behavior (B CAT P).

- The next easiest transition from one style of cross-categorization to another uses an existing category to group objects in the third order of known reality: *x* CAT *y* is followed by *x* CAT *z*. This transfers a known mode of understanding to objects in another order of reality, hoping that it will help explain them. I call it a **"recategorization transition."** This kind of transition can construct new objects while changing our understanding of existing objects.

  For example, after we construct a new change category in behavior (B CAT P), we may formulate a proposition about the perceived change by using the new category to group ideals (B CAT I). Thus when a balloon pops we construct a change object in behavior that categorizes the before and after states of the balloon, as described in Chapter 4. We may then use the same behavioral category to group ideals of inflation and deflation, formulating a proposition about what it "means" in general for inflated objects to pop. This process is the first step toward discovering regularities in nature.

Looking at the sequence of cross-categorization styles on the previous page, one can see that it is formed by alternating the first and second kinds of transitions. P CAT B to B CAT P is an example of a converse transition; B CAT P to B CAT I is an example of a recategorization; then B CAT I to I CAT B is a converse transition again; and so on. At the list's end, a recategorization from P CAT I to P CAT B restarts the cycle.

So the reason why styles of cross-categorization tend to follow each other in a particular sequence is that each transition from one style to the next style is either the easiest (*x* CAT *y* to *y* CAT *x*) or second easiest (*x* CAT *y* to *x* CAT *z*). It is the natural parsimony of living organisms that drives cross-categorization from one style to the next.

This "natural" sequence of cross-categorizations is manifested both in the construction of known reality and in theorizing about that reality. In human thought it has often shown up historically as a recognizable sequence in the ways that theories have evolved while they have been attempting to explain common things.

Example: Explaining Heat

The last chapter presented a brief history of theories of heat (page 190) to illustrate how different styles of cross-categorization may be used in theorizing. This history can also be used to illustrate why these styles tend to follow one another in a specific order.

Table 7-1 lists the processes by which we construct objects (such as heat) in environmental reality (see Table 4-2, page 95). It also shows the explanations that human theorizers have proposed in attempts to understand what heat "really is," as listed in Table 6-1 (page 191).

Table 7-1. Sequence of explanations of heat

Categorization	Object construction	Theoretical explanation of heat
P CAT B	Actualization	Element
B CAT P	Animation	Motion
B CAT I	Formulation	Imponderable fluid
I CAT B	Abstraction	Mechanical work
I CAT P	Reasoning	Thermodynamic energy
P CAT I	Definition	Quantum energy

In the earliest cross-categorization, P CAT B, behavioral sensations of heat were categorized by actualizing a physical fire element. This fire element was more pervasive than simple flames, for it explained such phenomena as the warmth of the human body. It was the hot and dry component of every material substance, living or dead. Thus a minimal element was objectified—a physical substance that could be perceived as a behavioral sensation. This heat-as-substance construction remains the common nonscientific notion of heat to this day.

The next cross-categorization, B CAT P, was a process of animation that used perceptions of fire-as-an-element to construct change objects in behavior. The obvious manifestation of change associated with heat was motion: you could see flames constantly moving and feel hot air rising from a fire. Moreover, the pure motion of friction appeared to create heat out of nothing. During the seventeenth century, experiments with heat treated as pure motion seemed to work as well as when heat was treated as a physical element. Thus heat became objectified as something that became present when other things moved.

The next process of constructing heat was to use the categories of heat-as-motion to explain the ideal characteristics of heat (B CAT I). Lavoisier hypostatized an invisible and weightless fluid, "caloric," that carried heat from place to place and made things hot. The problem with caloric was that just defining something did not guarantee its physical existence. Yet despite the difficulties that arose from dealing with an imponderable substance, the behavior of heat-as-caloric was simple to understand. The explanation worked in practice for about sixty years.

But technology demanded that heat be something more concrete. Although Carnot was able to develop a useful theory of heat engines in terms of the behavior of caloric, explaining heat in mathematical terms was felt to be more "modern." Joule, a practical physicist, calculated the number of foot-pounds of effort required to raise the temperature of water by a given amount, thus measuring heat in terms of work. Heat had been created without any imponderable fluid. This new I CAT B cross-categorization reconstructed heat as an abstract quantification of behavioral work. As a side benefit, work was something already well understood, in mechanical devices as well as in human behavior.

All of this recategorizing had strayed away from physical reality. Heat now appeared to be something that was mathematically definable in terms of certain kinds of change—but what was it *really*? From the late nineteenth century into the twentieth, physicists had increasingly tried to theorize about tangible objects. Heat was currently not tangible.

The I CAT B to I CAT P transition required that mechanical systems be redefined as thermodynamic systems that contained "kinetic energy." Thermodynamic principles could now localize heat and predict its movements. Instead of being just a manifestation of work, heat was now an integral part of physical events.

Finally, science is still making the transition from I CAT P to P CAT I in its theorizing about heat. Conducted or convected heat is typically analyzed in terms of thermodynamics and kinetic energy. Radiated heat (for example, the heat from the sun), is more often interpreted in terms of quantum mechanics, where subatomic particles have "energy levels" and emit energy in the form of electromagnetic radiation when these levels change. In quantum mechanics, heat is thus a form of the energy that is a definable property of physical things.

Transitions between theorizing styles. We can briefly summarize the ways in which the later theories about heat built on the earlier ones in this example:

- From heat as element to heat as motion (P CAT B to B CAT P) was a "converse" transition in which the element and the motion-change switched places. First heat was a physical thing that showed up as behavioral sensations; then it consisted of behavior-like changes that manifested themselves physically.
- From heat as motion to heat as a fluid (B CAT P to B CAT I) was a "recategorization" transition in which the existing motion categories were used to explain the ideal characteristics of heat. This appeared to resolve the question of how heat moved, but it created new problems in explaining what kind of "substance" heat was.
- From heat as a fluid to heat as a work-equivalent (B CAT I to I CAT B) was a converse transition in which measurable work was seen to explain heat more "realistically" than an invisible fluid did. At the beginning of this transition, theorizers such as Carnot treated work as an activity that moved caloric, but later it became evident that work could be directly related to heat without using a heat-fluid.
- From heat as a work-equivalent to thermodynamic (kinetic) energy (I CAT B to I CAT P) was a recategorization transition in which the new ideal objectification of heat was applied to complete physical systems. Physicists found that heat (whatever it was) could now be located within changing physical systems and its movements could be described by ideal principles.
- From thermodynamic energy to quantum energy (I CAT P to P CAT I) is a converse transition in which heat, mathematically described, can be treated as an integral property of physical events.

Through all of these theoretical twists and turns, people in everyday life have tended to stick with the ancient Greek objectification of heat as just a physical substance. We close the front door so we won't "let the heat out." Yet the newer objectifications of heat have been essential to our modern technology. No one could design a diesel engine without objectifying thermodynamic heat, nor understand a nuclear reactor without objectifying quantum heat. These understandings deliver the payoffs that have driven human theorizing and technology through the cycle of cross-categorizing constructions just discussed.

Human Reality Sequencing

Chapter 5 describes the organic realities that life constructs for itself—corporal, social, and mental—in addition to environmental reality. These realities are all products of cross-categorization; and like the styles of cross-categorization, they build on one another. We humans construct all three, developing them in the following sequence:

- **Human corporal reality** includes the physical bodies and reflexes of human individuals, the behavioral skills and techniques that we accumulate during our lifetimes, plus our genomes and our physical adaptations. These objects, working together, provide the basis for each human individual's interactions with environmental reality. But by itself, corporal reality embraces only the "functioning animal." It does not include any of the social relations or mental abilities that make mankind an atypical species.
- **Our social reality** consists of the various groupings that we form—families, tribes, classes, religions, societies, and states—plus all the values, traditions, and institutions that support these groupings. Like many other species, we construct social reality to gain the benefits of cooperation and division of labor. Our social reality is constructed by individuals, but no one can construct a social reality without first constructing a corporal reality. The priority is clear from the fact that an individual can exist without belonging to a social group, but no social group can exist without individual members.
- **Our mental reality** includes all our memories, experiences, ideas, conjectures, paradigms, inferences, and thoughts, listed in Table 5-4 (page 146). As is the case with social reality, our corporal reality is prerequisite to mental reality; we can't have minds without bodies. But it seems clear that social reality also precedes mental reality. The link would be communication, as illustrated by the layer model in the last chapter (page 200). Communication appears to emerge within social reality and also seems to be a primary driver for the construction of mental reality. Evidence can be cited from studies of animal cognition, which is usually found in species that also exhibit complex social behavior.

Construction priorities. Analyzing the sequences in which humans construct and cross-categorize realities helps explain the priorities that we give to various processes in knowledge and in life. "The old ways are best" appears to be a rule of thumb for the organic construction of reality. For instance, despite the evolution of theories of heat described earlier (page 219), most nonscientists today think of heat as a physical substance that moves from place to place.

Through processes described earlier in this book, humans and other organisms construct their corporal realities from unknown reality while they also construct a known environmental reality to live in. The first objects in corporal reality are behavioral, but the first products of using behavior for cross-categorization are physical objects in known reality. In the corporal context this first living process is metabolism, discussed on page 124; in terms of environmental reality the same process is what I call actualization, described on page 96. By means of these processes, we construct ourselves while constructing a physical environment that we can know and understand.

As a result, physical reality becomes established as the primal order of human reality. We then come to understand behavior through our corporal reactivity and environmental animation. But for us, behavior is always in some sense secondary; metabolism precedes reactivity and actualization precedes animation. In terms of our constructed objects, bodies come before reflexes and things come before changes. In human life, the behavioral order of known reality follows the physical.

The ideal order comes last of all. Although species use ideals in their genetic codes, individuals other than humans use few or no ideals in their normal lives. When ideals are used—typically for constructing models of environmental reality—they are largely species-determined. It is not until we analyze human life that we find an abundant use of ideals in our social and mental realities.

This ancient sequence—first physical and environmental, then behavioral and social, lastly ideal and mental—permeates human life, from our problem-solving techniques to our basic values and lifestyles. Humankind's priorities, in order, seem to be "take care of the physical, then enjoy the behavioral, and finally seek the ideal."

Discussion: Private Realities

Although we humans are social animals, we spend much of our lives constructing private realities. Our individual mental realities constitute an obvious instance, as do our corporal realities. Although we may talk about "what we are thinking" and "how we feel," such communications are subject to all the problems of recategorization and symbolization discussed earlier (see page 203). The human language ability has evolved primarily to share knowledge about the environment, not to transfer private realities from one individual to another.

Our environmental and social realities are naturally public, although the groups of individuals that share them are always limited. Thus I and my dog know a shared environment of objects that we see, feel, and taste, but he knows an environment of odors that are largely unknown to me and I hear sounds of human civilization that are meaningless to him (except for the doorbell). Neither of us shares much environmental reality with (say) a fish in the ocean. Similarly, a group of campers may hear the same bird song that a flock of birds hears. The social realities of the two groups are so disparate, however, that the song means little more to the campers than their conversation about it means to the birds.

We share many objects through environmental and social realities, making them "public" objects. Yet some sharing processes are easier and more accurate than others:

- Physical objects in environmental reality are the easiest to share. My stone is your stone, and it is even to a large extent my dog's stone. Hamlet's cloud, on the other hand, was hard to share with Polonius and would probably have been insignificant to the palace dogs.
- Behavioral categorizations are next easiest to share. Man is a social animal, and social reality arises from sharing behavioral categories. Thus social groups tend to propagate corporal skills and propositions about environmental reality among their individuals.
- Ideals are the hardest to share. They typically move from one mental reality to another through communication, with all the consequent sources of error in symbolization and language discussed earlier (page 140). As a consequence, sharing ideals is a common source of discord among human individuals.

Ideals can be taught. Two people, a teacher and a pupil, can share a behavioral act of abstraction in such a way that the pupil constructs an ideal object. The teaching process typically starts with examples—a process often called "ostensive definition." The process ends when the pupil objectifies a part of unknown reality into an ideal object in known reality. The examples that composed the ostensive definition can then be categorized by the ideal. As a result, the ideal explains the objects it categorizes while the objects instantiate the ideal. Evidence of learning shows up when the pupil finds new examples, not part of the original ostensive definition, that are categorized by the ideal. We say that the pupil now understands the ideal as a category.

One difficulty with public agreement about ideals is that ideals are highly "granular"—one may vary from another by small details. This is obvious in mathematics; one real number, for example, may vary from another in a single decimal place. To reduce the granularity and make understanding easier, ideals are put into hierarchies. Thus integers are the easiest numbers to understand because they have no fractions. The same methodology works with social ideals. The ideal called "truth," for example, has many variations among individuals—with or without "white lies," more or less excused by circumstances, and so on. One might draw a tree diagram showing how these different versions relate hierarchically. Various public versions of "truth" could then be found on the tree and compared with one another.

Some individuals barely progress beyond ostensive definitions in their private grasp of public ideals. In colloquial terms, they never "get" many social values. Hence the private objects that people construct may become more and more personal as human knowledge becomes increasingly sophisticated. From physical objects that everyone can see and touch, to behavior that is private but often shared, to ideals that people construct individually, the world of each human individual tends to diverge from the worlds of others. Many of the objects in these worlds come from objectifying categories and models. These objects, which are built upon other known objects and hence are at least two steps removed from unknown reality, include the most idiosyncratic parts of each person's reality. We will consider several varieties of such private objects in the rest of this chapter.

Science vs. Religion

My earlier discussion of scientific method (page 208) described it as depending on a "chain" of cross-categorizations—B CAT I CAT P CAT B. Behavioral observations categorize ideal formulas, which categorize physical phenomena, which categorize more behavioral observations.

The value of such a chain of categorizations is that it constructs knowledge in all three orders of known reality. Our experiences when performing an experiment (such as rolling metal balls down a plank) give meaning to certain mathematical equations, which we can call "laws of motion." The equations then give meaning to physical motion events of all kinds—we say that the events "follow" the laws. Finally, the motion events that follow laws give meaning to other experiences, such as observing the changing positions of distant planets. Behavioral observations, physical events, and ideal formulas all explain each other. Because the chain forms a loop, its explanations encounter no natural limit and knowledge expands indefinitely.

Religious method. There are only two ways that the three orders of known reality can link up into such a chain. The other way reverses the sequence used in scientific method: B CAT P CAT I CAT B. For symmetry I will call it "religious method."

In "religious method," behavioral experiences categorize physical events, which categorize ideal values, which categorize more behavior. For example, imagine that a social group undergoes a physical disaster, such as a drought. Scientific method would try to explain that event by categorizing it ideally, but religious method looks for a behavioral explanation. It may conclude that a large-scale disaster could only be caused by an angry god. The physical event, in turn, must explain some group of ideals, such as transgressions that demand punishment. Once the transgressions are identified, they will categorize the behavior of the social group that led to the disaster, which must be corrected.

As with scientific method, religious method theorizes using all three orders of reality. Why did the physical drought take place? Because it was divinely commanded. Why was it commanded? Because divine laws were transgressed. How do we avoid or cure the transgressions? By correcting our behavior. While scientists may discredit such a chain of explanations (droughts are *really* caused by atmospheric events that can be modeled mathematically), the chain of categorizations it uses is routinely constructed by human social groups throughout the world.

Materialism and idealism. When human behavior is organized in the chain of categorizations typical of science—B CAT I CAT P CAT B—its resulting worldview is often called "materialistic." This approach to reality typically forms the dominant ethos of scientific, industrialized societies today. The complementary approach to theorizing—B CAT P CAT I CAT B—is commonly called "idealism." This approach to reality is more prevalent in the world's less industrialized societies.

Both materialism and idealism are chains of cross-categorization that purport to explain all the orders of known reality. The difference between the two lies primarily in the ways they use ideal categories.

Materialism uses ideal categories primarily to explain physical events; idealism uses them mainly to interpret behavior. Once this fundamental orientation is rooted in a society, the other categorizing styles in the chain tend to follow.

Religious objects and minima. A basic symmetry holds between the objects constructed by religion—gods, rituals, and divine powers—and the basic elements of science, the minima discussed in Chapter 4. Both kinds of reality lie beyond the limits of common sense—religious objects because they are too large, minima because they are too small. In any comprehensive understanding of reality, religious objects and scientific minima exist at opposite ends of the hierarchy of categories. The minima of science are known through objectification, which probes downward to find ever more universal elements. The divine powers of religion are known by means of categorization, which probes upward to construct ever more universal explanations.

But the symmetry between these two ways of expanding knowledge does not lead to their cooperation in human societies. In fact, religion and science are famously antagonistic, as are materialism and idealism. Why is this? A minor explanation is that both categorizing chains try to formulate complete worldviews—"theories of everything"—and come up with incompatible results. But I believe the more compelling reason for their antagonism lies in the ways they work. Idealistic religion and materialistic science follow different paths in constructing reality; the first seeks general knowledge that is hard to prove in formal argument, the second seeks detailed knowledge that is hard to use in everyday life.

To return briefly to the example of a drought, willful punishment by divine command is as easy to understand as being sent to bed without supper. How water vapor condenses around aerosols in the atmosphere is somewhat harder to understand. But neither understanding explains the drought directly. The explanation in divine terms has to be scaled down, and the explanation in terms of elementary particles has to be scaled up. Because we live halfway between universal generalities and elemental particularities, our most satisfactory theories are neither all-encompassing nor built up by concatenating millions of tiny truths.

Comparison: Galileo and Aristotle

Many historians of science regard Galileo's 1638 work, *Discourses and Mathematical Demonstrations Relating to Two New Sciences,* as the beginning of modern physics. His two sciences were about the strength of materials and the motion of objects, and Galileo called them "new" because he expressed all his results in mathematical terms. His use of mathematics to interpret physical observations challenged the approach current in science at the time, which was inherited from the *Physica* of Aristotle.

Aristotle assembled commonsense explanations of physical events, forming categories from the same orders of reality. He occasionally adopted behavioral categories (such as in his theory of causes) but he seldom tried to cross-categorize the physical with the ideal. This is one reason why theologians such as Aquinas, in the thirteenth century, were able to integrate Aristotelianism with Catholicism—Aristotle explained the material world mostly in physical or behavioral terms and did little to usurp the Church's hold on ideal categories.

But Galileo explained the material world in terms of mathematical truths, bypassing the structure of divine truths on which Catholicism had been built. An earlier analogy in this book (page 177) describes how Galileo compared his interpretation of the natural world to a kind of cosmic "bookkeeping." The principal outcome of this approach was a tradition of physical-ideal theorizing that culminated fifty years later in Newton's *Principia*.

To understand Galileo's new methodology, consider the different ways in which Aristotelian explanations and the new Galilean analysis categorized the phenomenon of a swinging pendulum. Kuhn writes:

> Seeing constrained fall, the Aristotelian would measure (or at least discuss—the Aristotelian seldom measured) the weight of the stone, the vertical height to which it had been raised, and the time required for it to achieve rest. Together with the resistance of the medium, these were the conceptual categories deployed by Aristotelian science when dealing with a falling body. Normal research guided by them could not have produced the laws that Galileo discovered. . . Galileo saw the swinging stone quite differently. Archimedes' work on floating bodies made the medium nonessential; the impetus theory rendered the motion symmetrical and enduring; and Neoplatonism directed Galileo's attention to the motion's circular form. He therefore measured only weight, radius, angular displacement, and time per swing, which were precisely the data that could be interpreted to yield Galileo's laws for the pendulum.[60]

Modern enthusiasts of Galileo's methods like to talk about a "scientific revolution" that replaced centuries of ignorant authority with the clear light of observation and reason. The truth is more complex. Framework theories such as Galileo's flourish because they use ideals to categorize physical reality, and thus subscribe to the B CAT I CAT P CAT B chain of categorizations.

The B CAT I CAT P CAT B categorizing chain is not just the source of science and materialism in our knowledge of environmental reality—it also supports *individualism* in human social reality. I believe it is the promise of social individualism, more than a bias toward materialism, that makes science so deeply embedded in human thinking today.

Individualism vs. Statism

An earlier discussion (page 225) described the scientific and religious "chains" of cross-categorization and contrasted the kinds of knowledge they construct. The same two complementary chains also show up in social reality, but there they are used to *construct* known reality, not to know it.

In knowledge, the B CAT I CAT P CAT B chain supports science and materialism; in the construction of social reality, it supports what I call "individualism." The B CAT P CAT I CAT B chain supports religion and idealism in knowledge and what I call "statism" in the construction of social reality. Using the labels in Table 5-3 (page 138), individualism in social reality combines the social construction styles of communalism, intellection, and legalism; statism combines the social construction styles of authoritarianism, orthodoxy, and collectivism. The difference appears when we rework Table 5-3 to list the processes in each chain:

Table 7-2. Individualistic and statist social constructions

Style	**Individualism**	**Statism**	**Typical groups**
P CAT B	Communalism		Families
B CAT P		Authoritarianism	Tribes
B CAT I	Intellection		Classes
I CAT B		Orthodoxy	Religions
I CAT P	Legalism		Societies
P CAT I		Collectivism	States

One can "feel" the difference between the individualistic and the statist styles of social organization listed in this table. The communalism of the supportive family, the intellectual coherence of a social class, and the freedom of a society under the "rule of law" all promote individual values and efforts. Conversely, prescribed obedience to authority, the orthodoxy of established religion, and the physical demands of a state all support group control of individuals.

We could regard the **statist** construction of social reality as the more "natural" way of forming groups of individual organisms, because it mirrors the fundamental ways that organisms survive and evolve:

- *Ideals categorize behavior through genetic inheritance*. When we try to understand animal behavior, we frame our explanations largely in terms of the animal's species. Individual behavior may be triggered by local stimuli, but the response is usually fashioned by an instinct or other inherited trait. Thus one stimulus can trigger predictably different behavior in a dog and a cat; to understand what is going on, we refer to ideal models of canine and feline traits.
- *Behavior categorizes physical reality through organic reactivity.* Organisms react behaviorally to their physical environment, so it is behavior that explains an organism's physical actions. Among plants and primitive animals, most reactions are determined by species and higher taxa; but in higher animals they may come from individual learning. In man, where we find widespread ideal categorization, most physical acts are still driven by behavior. Using behavior to manipulate the physical environment is a hallmark of life.
- *Physical reality categorizes ideals through "natural selection."* What determines the ideal techniques of life—the tissue structures, metabolic pathways, reflex responses, and so on that are ultimately controlled by genetic and epigenetic codes in individual organisms? These codes are passed from individual to individual through the physical reproduction of molecules such as DNA. In this way the physical survival of the individual and its success in reproduction categorizes its codes as "favorable." When an individual fails to reproduce, its codes are implicitly categorized as "unfavorable." This was Darwin's seminal insight; he compared the selection that took place in nature—what Spencer called "survival of the fittest"—with the selection that breeders of animals (such as pigeons) performed artificially. Genetic codes do not automatically group themselves into categories; they are categorized by the physical survival and reproduction of the individual organisms that propagate them.

Thus the behavior by which organisms construct themselves and their known reality links up in an overall statist chain of categorizations, not in an individualistic organization. We might expect this result, because the primary technique of life is the formation of groups of organisms—species—that all follow ideal models, not the spawning of individuals each of whom struggles separately with its environment.

The **individualistic** attitude that is common in industrial societies today is the product of scientific and materialistic theorizing. It tends to be the preferred attitude of individuals who judge their lives primarily by their success in dealing with physical reality. The categorizations of scientific knowledge run "the opposite way" from those of statism:

- *Physical reality categorizes behavior in the behavioral sciences*. A common assumption in ethology and anthropology is that behavior is driven mostly by physical factors: climate, geography, available nourishment, and so on. Scientists working in these disciplines tend to explain animal and human behavior in terms of their subjects' physical needs. Psychologists, sociologists, and economists often produce explanations more removed from physical needs; but if a set of explanations loses its traceability to physical factors (such as in some theories of transpersonal psychology), it becomes criticized as "unscientific." An earmark of scientific truth is verifiability, which is commonly assumed to be possible mainly in the physical world.
- *Behavior categorizes ideals in the abstract sciences*. The earliest abstract sciences—mathematics, geometry, and logic—sought the "laws" that governed the human behaviors of counting, building, and reasoning. The ideals they discovered all had specific meanings in behavioral terms. Thus it was determined that the square root of two could not be obtained by dividing one number by another; if a wall of a building was set square with the foundation on one side it would be found to be square on the opposite side; an argument could not be defended if it violated one of the forms of the syllogism; and so on. Later theorizing in these sciences floated away from their practical beginnings, by abstracting the results of previous abstractions. But even such abstruse modern disciplines as symbolic logic deal with conceptualizations that are ultimately traceable back to operations in human behavior.
- *Ideals categorize physical reality in the physical sciences*. Using mathematics to explain physical phenomena gained minor currency

with Greek philosophers such as Pythagoras, but after Galileo and Newton it became an essential part of science. A key development was the creation of mathematical disciplines that could deal with change—the "fluxions" and "fluents" of Newton and the differential and integral calculi of Leibniz. These techniques, which originally used the Archimedean minima called "infinitesimals," let physical events—groups of behavioral changes—be categorized ideally. As a result, time became integrated into framework theories.

One might say of statism and individualism in human life that people are born to statism but they learn individualism. Hence the value that some societies place on individual action is often a by-product of mass education.

Example: Individual Liberty

Like the behavior of individuals, the behavior of governments can be good or bad. A common measure of the "goodness" of a government (for example, by Freedom House, an American organization that rates governments) is the amount of individual liberty that is enjoyed by its citizens. Individual liberty, in this sense, is defined as freedom from government coercion. In practice, it turns out that individual liberty is most often encouraged by governments whose powers are distributed among separate bodies.

The eighteenth-century French philosopher Charles de Montesquieu is commonly credited with having first delineated the separation of powers on which most modern governments are based. In his 1748 work, *De l'Esprit des Lois,* Montesquieu identifies three functions of government—legislative, executive, and judicial—and concludes that combining any two in one body entails a loss of individual liberty:

> The political liberty of the subject is a tranquillity of mind arising from the opinion each person has of his safety. In order to have this liberty, it is requisite [that] the government be so constituted as one man need not be afraid of another.
>
> When the legislative and executive powers are united in the same person, or in the same body of magistrates, there can be no liberty; because apprehensions may arise, lest the same monarch or senate should enact tyrannical laws, to execute them in a tyrannical manner.
>
> Again, there is no liberty, if the judiciary power be not separated from the legislative and executive. Were it joined with the legislative, the life and liberty of the subject would be exposed to arbitrary control; for the

> judge would be then the legislator. Were it joined to the executive power, the judge might behave with violence and oppression.
>
> There would be an end of everything, were the same man or the same body, whether of the nobles or of the people, to exercise those three powers, that of enacting laws, that of executing the public resolutions, and of trying the causes of individuals.[61]

Here we see cross-categorization laid bare in the construction of social reality. Governments affect their subjects physically by their executive power, which can arrest persons and seize property; their legislative power sets behavioral norms for their subjects; and their judicial power defines ideal values for them. As long as these three powers construct categories separately from one another, each category grouping objects in a different power, the whole machinery of cross-categorization comes into play. Each power in the society "gives meaning" to the other powers through categorizations that the other powers see as tentative and subject to error.

In a typical government that separates its physical, behavioral, and ideal powers, the physical power has a mandate to construct physical objects that "realize" the laws passed by the behavioral power. It builds roads, forts, prisons, etc., and provides personnel to administer them. While so doing, the physical power must be careful not to violate the concepts of "rights" constructed by the ideal power. The behavioral power constructs "laws" based on the wants of the social group; but it must take care not to construct a law that the physical power either will not or cannot execute, nor one that the ideal power may categorize as "illegal." The ideal power must try to abstract and express the universal patterns in social reality, while rendering judgments that will neither incapacitate the physical power nor radically contradict the behavioral power.

This balance of a government's powers mirrors the balance of cross-categorizations within each member of the social group that it governs. In a group of individuals who tend toward statism, the operation of the physical power of the group (in modern terms, the executive branch of the government) is categorized behaviorally in an authoritarian style of social construction; with individualism, it is categorized ideally in the style of legalism. With statism, similarly, the behavioral legislative branch is categorized ideally as an exercise in orthodoxy; individualism categorizes it physically as an instance of communalism. And statism categorizes the ideal judicial branch physically as a collective, a body that controls material transactions, whereas individualism categorizes it behaviorally as an exercise in legal intellection.

Individualism supports individual liberty within a group because it uses ideals to categorize the physical actions of the group's members, instead of using behavior. In an individualistic group, the ideals may be recorded in a constitution and laws; in a statist group, the behavior that categorizes the members' physical actions more often comes from a leader, a ruling class, or a tradition of conduct.

My discussion of individualism vs. statism (page 229) characterized statism as the more "natural" way to organize a human group. There is a "drag" toward statism that only individuals can counteract. But to pull a group toward individualism requires that its members maintain a clear separation between the orders of reality; that was Montesquieu's point. When categorizations overlap—for example, when behavioral dictates heedlessly replace ideal laws—individualism dissipates and individual liberty becomes lost.

Comprehensive Objects

Hierarchies were discussed in an earlier chapter (page 109). This kind of arrangement, where categories are grouped in ever larger containers, may result in a situation where one category becomes objectified as a "comprehensive object." Because it is the largest possible container, it categorizes other objects but is not itself categorized. It is like a "root node" in a hierarchical computer database.

Kant famously wondered at "the starry heavens above and the moral law within." Kant's "admiration and awe" stemmed from the fact that both are comprehensive: the starry heavens because the universe is the largest physical object we know, and the moral law within us because it is made up of absolute behavioral directives. For Kant, "the moral law" discriminated behavior but was not itself subject to discrimination or explanation. It was based on a "categorical imperative."

Human history has recorded myriad different sets of moral laws along with numerous concepts about the starry heavens. The present analysis, however, can help us understand such comprehensive objects in terms of their styles of cross-categorization. We humans construct comprehensive objects in our environmental reality as worldviews, in our social reality as ordained institutions, and in our mental reality as unquestionable behavioral directives. The following table proposes common labels for typical examples of these objects. As before, the labels are only convenient handles to assist discussion, not attempts to characterize the objects definitively.

Table 7-3. Typical comprehensive objects

Style	Worldviews	Institutions	Directives
P CAT B	Nature	Naturalism	Compatibility
B CAT P	Gods	Theism	Obedience
B CAT I	Revelations	Faith	Devotion
I CAT B	Moral order	Religion	Compliance
I CAT P	Natural law	Science	Rationality
P CAT I	Cosmos	Humanism	Objectivity

Of course the worldviews, institutions, and mental directives listed in Table 7-3 often coexist in an individual or a group of individuals. For example, one may easily believe in rational science and compatibility with nature at the same time. In fact most well-educated people know comprehensive objects created by all six styles of cross-categorization.

Still, it can be illuminating to analyze how the different kinds of comprehensive worldview objects are constructed. The next paragraphs consider them one-by-one.

Nature as an objective of compatibility. Much daily behavior is categorized by natural physical events in environmental reality. If we categorize these events physically, trying to understand them through common sense, we finally construct the largest physical category, which is commonly called "nature." It is easy to regard nature as "all there is," the philosophical position called "ontological naturalism." If nature comprises all reality, then the only valid human directive must be compatibility with it. Nature as a whole is not further categorized; it "just is," and people are bound to get along with it.

Gods that demand obedience. Besides inorganic physical events, human lives are full of humanly-created physical events. In behavioral common sense they fall into a hierarchy of ever-larger categories—events created by the behavior of individuals, of groups, of whole tribes or societies, and so on. Eventually we construct the largest category in this hierarchy, which explains all events. We cannot categorize such a category, but we can objectify it theistically as the behavior of a willful god or group of gods who create and run the world. As anthropologist Émile Durkheim famously observed, “God is society, writ large.”

Gods need not be merely willful; some create ethical systems that are understood to be largely independent of their whims. But as I use the term here, gods objectify comprehensive behavioral categories, for which the appropriate individual response is obedience.

Revelations that inspire devotion. A comprehensive behavioral category that explains ideals appears to be a revelation. It may take the form of a “spiritual rebirth” or it may come from the behavior of a prophet or spiritual leader. Mysticism often prescribes specific kinds of behavior that are designed to lead the initiate toward categorizing ideals. The result may be a comprehensive behavioral revelation that cannot be further categorized—it “rests on faith.” In the same way that a god represents a comprehensive behavioral explanation of physical reality, such a revelation represents a behavioral explanation of ideals. It understands ideals through “direct experience.” The mental directive for such a revelation is devotion to it, in belief and deed, as the practice of a personal faith.

A moral order to be complied with. The word “religion” is used to denote a variety of social institutions, from primitive nature worship to disciplines of meditation. For present purposes I use it only to denote a comprehensive hierarchy of ideal categories for behavior. All behavior is routinely categorized ideally—“these kinds of behavior are good, those are bad.” When many such categorizations are gathered together into a hierarchy with an enveloping category, such as “being Christian” (or Muslim or Jewish), the result is a moral order that resists further categorization. Each religion typically canonizes its moral directives as unquestionable, making compliance or transgression the only available responses. The kinds of behavior that are morally categorized usually go beyond “spiritual” practices and typically include the formation of families, uses of language, forms of dress, acceptable entertainments, and so on.

The remaining two ways that comprehensive objects are constructed do not involve behavior, as a source either of categories or of objects categorized. They construct comprehensive objects entirely through the cross-categorization of physical reality with ideals. As a consequence, they stoutly resist any notions of behavioral or spiritual entities, either as gods or as immanent moral directives. They ground their world-views, institutions, and mental directives solely in “facts and reason.”

Natural laws to be understood rationally. When ideals are used to explain physical reality, the most comprehensive ideals form a system of fundamental laws. Science becomes the dominant social institution that discovers these laws, and rationality becomes the mental process that interprets and applies them.

The worldview of natural laws that science supports has succeeded in helping to produce physical tools and goods, but it is less stable than the other worldviews listed in Table 7-3. It is revised more often than most religions or social orthodoxies or even personal revelations. As I argued in Chapter 6, this is because much of science has become a search for new theoretical minima. Each concept of minima in a new theory tends to cause what Kuhn calls a “paradigm shift” in science, sending subsequent research off in new directions.

A cosmos that ordains human ethics. The most comprehensive physical category that explains ideals is commonly called the cosmos—the physical universe as an orderly whole. The Pythagoreans used the word κοσμος to support the notion of an ideal “music of the spheres,” a system of mathematical relationships that they believed was revealed by the movements of celestial bodies. Their search was the converse of modern science, in the sense that they used their knowledge of the heavens to discover the truths of mathematics.

The Pythagoreans’ search for mathematical ideals by observing the physical universe resembles the modern humanists’ search for ethical ideals by observing man’s position in the cosmos. In both cases, ideals are given meaning by being categorized physically. For the humanist, such ideals have the virtue of being “objectively valid” because they are found in the physical cosmos—unlike ideals ordained by gods or given in personal revelations, which are behaviorally categorized and hence are inherently “subjective.”

Objectifying gods. Chapter 3 introduced the notion of efficiency in knowledge—the epistemological approach that advocates categories of increasing size as a way to reduce the number of explanations needed to understand reality. It is empirically true that we often construct larger and larger categories to explain the objects we know. In this way we are driven to carry to its limits the basic function of categorization. We try to make knowledge more efficient by fashioning fewer and and more general responses to the objects of known reality.

What happens when a hierarchy of categories reaches its practical limit—when the most inclusive category in the hierarchy appears to cover as much reality as possible? When that category is objectified, it may become what anthropologists call a "god."

In the present discussion, therefore, a god is an object formed from a category that is regarded as all-inclusive. This does not mean that the god necessarily covers all of known reality. But it does mean that it is as inclusive as possible in its area of categorization.

For example, the ancient Greeks objectified thirteen major gods and hundreds of lesser ones. But although the Greek gods were customarily portrayed as men and women, it would be a mistake to think of them in those terms. The Greeks' problem was that they had the intellectual power to conceive of very large groups of objects but not the detailed knowledge to characterize those groups. Lacking a more "scientific" system of identification, the Greeks fell back on labeling the groups with human personalities. Those, at least, they understood. The human personalities, as the objectifications of large categories, could then be further categorized. The result was a system of knowledge in which certain "intermediate variables"—categories "at the god level"—were identified in anthropomorphic ways that could easily be understood.

Consider Poseidon, the Greek god of the seas. The Greeks were good mariners, but they had virtually no knowledge of the worldwide extent of the seas, nor any idea of what lay below the depth of a free dive, nor much grasp of the relation between tides, currents, weather, etc. Yet they could conceive of a hydrosphere, a categorical grouping that included all these things. How might such a group be objectified? Given the Greeks' lack of detailed knowledge about it, trying to give it a "scientific" identity would just have led to endless arguments based on ignorance. The solution was to give it a man's name. Everybody, the wise and the unsophisticated, could talk about Poseidon. The fact that there wasn't "really" a bearded old man of that name was beside the point. When a sailor about to go to sea sacrificed to Poseidon, he was appealing to the hydrosphere, however that was identified. That it was objectified as a personality (and one with shifting love affairs, like the weather) made it seem more real, not less.

Where ignorance exists, and is not likely to be easily dispelled, it is often a useful technique to simply give something a name and go on seeking knowledge. That's why in modern physics, quarks are said to have "flavor." The same method applies to gods. Robert Browning may have seen the connection when he wrote, "Ah, but a man's reach should exceed his grasp, or what's a heaven for?"

Besides identifying multiple gods, humans also objectify categories that purport to cover *all* of reality. Several religions provide a place for an all-inclusive God, but the three that have acted the most militantly in excluding other gods are Judaism, Christianity, and Islam. In the first two cases, the God of *Exodus* is a "jealous God"; in the third case, Muslims are enjoined to declare the exclusivity of God by reciting the *Shahadah*.

Given that known reality is divided into three orders, it takes extra work to group objects in all three orders into a single theistic category. There must be a payoff for doing so. An example of why and how this may be done is the venerable Christian doctrine of the Trinity.

Example: The Christian Trinity

Someone learning about Christianity for the first time might well be puzzled by the central position it gives to the doctrine of the Trinity. Hotly argued since the fourth century, this concept defines God as the union of three separate "hypostases," or fundamental realities, rendered in ritual as the Father, the Son, and the Holy Spirit. Without going into its complex apologetics, we can usefully ask why such an odd doctrine came to mean so much to so many people. I believe that lay analysis can provide at least a partial explanation.

To be successful and durable, every religion must develop a general worldview—a theory of everything. One way to do this is to categorize everyday reality into a hierarchy containing groupings of greater and greater inclusiveness. If the religion is a true monotheism, its most inclusive category will be a single God, under which everything known is subsumed and hence explained. In a polytheism, the hierarchy may stop at various lesser gods, each of whom explains some part of the world.

From the outset, Christianity was committed to the monotheistic worldview that it inherited from Judaism. But Judaism had evolved among primarily pastoral tribes in the Middle East, while Christianity had to construct its doctrines within the more complex Greco-Roman urban society. In particular, Christianity had to square its worldview both with a wealth of Roman technology, from hydraulic engineering to bridge building, and with a long Greek tradition of abstract thought, exemplified by the works of Euclid, Pythagoras, Aristotle, and Plato. It had to show that it was abreast of the times.

Among the intelligentsia of Rome, Christianity must at first have seemed little more than the provincial following of a desert mystic. It stretched credulity to try to fit the Judaic law, which mainly regulated the social behavior of tribal groups, over the physical technologies of the Romans and the abstract discoveries of the Greeks.

It wasn't practical to simply define one God who simultaneously made technology work, regulated human behavior, and guaranteed the truth of Euclid's propositions. The solution that the early Christian theologians devised was to declare that the one God was at the same time three gods, each at the head of a hierarchy of categories in one of the three orders of reality. The Father devolved into the creator of the physical world, the *primum movens,* whose Church built great physical monasteries and cathedrals to manifest His power. The Son had come among men to teach them how to behave ("love one another") and to redeem them from their sinful desires. The Holy Spirit, "the Spirit of truth," objectified a complete hierarchy of universal ideals. Moreover, each individual communicant could access these ideals privately, in mental reality. In the words of the present-day Catholic catechism (1997), "those who believe in Christ know the Spirit because he dwells with them."[62]

Thus arose the Christian doctrine of the Trinity. The Father created and maintained the physical world, the Son inspired the behavioral world, and the Spirit ordained the ideal world. At the same time, all three of these grand explanations were really one because the Father, Son, and Holy Spirit were "consubstantial." In the terminology of this book, three comprehensive categories were objectified into one object, thus formulating the concept of a "living God" that emulated life itself. The Trinity was always a somewhat *ad hoc* doctrine—witness the blood spilled defending it—but it supported the worldview of a new religion that was struggling to gain a foothold alongside the knowledge that already existed in a mix of sophisticated, urbanized societies.

Universal Virtues

At the top of the hierarchy of ideals that regularly categorize individual human behavior, "good" and "bad" are clearly universal. Constructing other categories that naturally fall under "good" and "bad," however, has long been a puzzle for anthropologists, psychologists, sociologists, and theologians.

Several scholars have recently searched for categories under "good" and "bad" that are in some sense universal—that is, shared by the great majority of humans. They have collated replies to thought experiments from people around the world and have ransacked literature to surmise how people in other times might have replied. Two current books, by anthropologist Donald E. Brown[63] and psychologist Jonathan Haidt,[64] suggest a number of possibilities. Six prime candidates for individual human behavior that is universally thought to be "good" are **loyalty, deference, sanctity, purity, harmlessness,** and **fairness.** These virtues are not only valued across most human cultures, both past and present, but some of them show up in studies of animal behavior as well.

These different subcategories of "good" can be analyzed in terms of the six styles of cross-categorization, as shown in Table 7-4. The table also relates them to the social processes listed in Table 5-3 (page 138).

Table 7-4. Universally "good" categories

Style	Universal category	Social construction process
P CAT B	Loyalty	Communalism
B CAT P	Deference	Authoritarianism
B CAT I	Sanctity	Intellection
I CAT B	Purity	Orthodoxy
I CAT P	Harmlessness	Legalism
P CAT I	Fairness	Collectivism

Thus loyalty, for example, is a category in physical reality that groups various kinds of behavior under the social process I call communalism. Loyal behavior is regarded as good because it promotes the physical objectives of a communal group. We find it in humans and we find it in social animals. Deference, on the other hand, is a category in behavior that defines the physical actions of individuals in the social process of authoritarianism. A deferential act is good because it is directed by the behavior of someone else—a leader or a tradition. And so on with the categories listed in the table, which are discussed in more detail below.

Loyalty is a universal category in which the physical well-being of one or more individuals categorizes the behavior of other individuals. "Loyal" or "devoted" behavior contributes to the health or possessions of another individual or of a group. Note that the loyal individual need not interact directly with the beneficiary of the loyal behavior or even belong to a particular social group.

Deference is a universal category by which the behavior of a leader, a ruling group, or a tradition categorizes the physical actions of other individuals. An “act of deference” is one in which an individual cedes behavioral categorization of his or her physical actions to someone else; an “act of defiance” is the opposite.

Sanctity is a universal category by which human behavior gives meaning to ideals. The ideals categorized by sanctity are “sacred” or “holy,” as opposed to “profane.” Although sanctity is often associated with religion, its ideals need not be deistic; for instance, the “sacred honor” cited in the American Declaration of Independence was clearly a personal or political ideal. The point of calling an ideal sacred is to shield it from question; it guides behavior but behavior cannot elect or deny it. The category of sanctified ideals occurs universally in human behavior, although the ideals that it subsumes may differ widely from one culture to another.

Purity is a universal category in which ideals discriminate human behavior. The behavior thus categorized is “noble” or “virtuous”; other behavior is “tainted” or “corrupt.” Again, this style of categorization is universal in human cultures, although the ideal categories adopted and the behavior they discriminate tend to vary widely.

Harmlessness is a universal category under which ideals define the physical actions of humans. Such actions are “kind” or “considerate,” not “cruel” or “savage.” In the “state of nature” one animal may harm or kill another in whatever way it finds convenient; but the category of harmlessness proscribes many such acts. A typical ideal principle of harmlessness is the Golden Rule, which is found in one formulation or another in most cultures.

Fairness is a universal category in which physical consequences classify the ideals of human social life. Ideals in this grouping are “just” or “impartial,” as opposed to “unfair” or “biased.” The bases for selecting these ideals are the physical consequences that follow when they are applied to human affairs.

The six universal categories just listed often compete in determining specific trains of behavior. For example, burning a heretic is bad under the category of harmlessness; but at various times that physical act has been regarded as good, under the category of purity, because it has been thought that it removed a threat to the sanctity of a culture’s beliefs.

The Evolution of Known Reality

Organisms create known reality and organisms evolve. Hence we have *prima facie* license to speculate about the evolution of known reality, at least as it applies to the planet that contains most of the reality that we know.

The origin and early history of living organisms on earth are still mostly a mystery. However, the present analysis can suggest the origin and development of the realities that organisms have constructed. We can envision several stages:

- Known reality must have started with behavior in unknown reality. Chunks of behavior were objectified and grouped somehow, the groups becoming objectified as known physical objects. The objects might have been what we know today as molecules. They contained carbon or sulfur and acted differently than other molecules did. They grouped behavior in such a way that the outcome was what we call metabolism. They collected energy, conserved themselves in their environment, and proliferated more molecules like themselves. Such energy-collecting molecules were a novelty in unknown reality. They started the construction of known environmental reality.
- Metabolism led to reactivity, completing the cross-categorization of behavior with physical reality. Now molecules could form groups to perform behavioral processes, and those behavioral processes could be grouped to construct physical bodies. These processes, including differentiation, cellulation, growth regulation, and so on, began to construct living corporal reality within known reality.
- Ideals came next. If we follow the sequence of cross-categorizations listed in Table 5-1, page 123, the objectification of ideals in corporal reality probably began with the construction of skills and techniques among these early organisms. By cross-categorizing ideals with its behavior, an organism could "act smarter" and forge ahead of other organisms in environmental reality.
- This was not yet genomic evolution. But a small (albeit significant) next step was to construct ideal techniques that could be "recorded" physically, in corporal reality. Passing physical records of ideals from organism to organism would have let the techniques that they invented propagate through generations of corporal reality. It would have signaled the advent of speciation and the start of evolution.

- Using metabolism, speciation, and evolution, the corporal reality of living organisms constructed itself and enlarged its environmental reality. But life "feeds off" environmental reality, which eventually offers a limited amount of resources. As a result, species compete with one another. One competition technique would have been the construction of social reality as a "layer" on top of corporal reality. Besides constructing lone individuals to compete in environmental reality, species would produce families, tribes, or whole colonies, the individuals of which would construct social realities.
- The effective construction of a social reality required new corporal skills, such as communication. Species can evolve these skills and pass them genetically to individuals, as happens with social insects. But competition tends to make communications more complex. So some species evolved the individual neural equipment needed for learning, reasoning, and other constructions in yet a new reality—mental reality.
- In one species, man, the construction of mental reality has become a primary part of our behavior. We spend much of our time thinking. Not only do we have the required neural apparatus, but we have evolved the behavior required to use it. A key part of this behavior is awareness, a process in which we are able to think about our own thoughts. Awareness, as I use the term, is wholly or mostly absent in the individuals of other species; but it lets humans construct mental realities that are elaborate, flexible, and useful.

It is unfashionable to regard man as an exceptional species. In terms only of our bodies—the corporal reality we construct—we are not as strong as chimpanzees nor as agile as gibbons, and our brains are smaller than those of several other animals. All our senses are inferior to those of selected animals (the dog for smell, the eagle for eyesight, etc.). And when we are placed in the wild, without tools, our survival skills are below average.

So why do we think we're special? Because of the extent of the known reality we have constructed. Our environmental reality, which stretches from the bottom of the oceans to the surface of the moon, is larger and more varied than that of any other species; our social reality, thanks to our many verbose languages, extends worldwide; and our mental reality is unique in its scope and complexity. Taken altogether, the known reality we have constructed is the main human achievement.

History: Philosophy and Theorizing

Since this is a book of philosophy, it is fair to ask where it and similar works fit into human knowledge. In our Western culture, as I see it, the purpose of philosophy is exploratory. It asks general questions about the assumptions, procedures, and concepts that become the starting points for developing theoretical knowledge. Philosophy is the avant-garde of theorizing.

But like all avant-garde movements, philosophy often finds itself in conflict with established practices. It has flowed and ebbed several times in European history. Although today philosophy is largely at an ebb, I believe it is ready for another flow.

In the West, explicit philosophy first appeared among the Greeks and Romans, for whom theorizing was a novel occupation. The dominant human reality at that time was what I call natural reality (Chapter 4), the cross-categorization of physical reality with behavior. Philosophers such as Aristotle and Plato provided methodologies by which they and other thinkers could develop theories about human life and its relation to the material world.

A second wave of philosophy arose as Rome declined, this time about intellectual reality. Augustine's *City of God,* a philosophical work written soon after the sack of Rome (410 AD), was a seminal example. It advanced practical arguments for adopting Christian monotheism, portraying the City of God as a place where human behavior and ideals supported and explained each other. In the City of Man, obedient to its Greco-Roman pantheon, behavior was related mainly to physical needs. The *City of God* was an invitation to a new way of theorizing about life.

Many scholars judge that the theorizing which followed works such as Augustine's reached its apotheosis in the *Summa Theologica* of Aquinas, written in the thirteenth century. It set forth the ideals by which Catholicism categorized behavior. Its aim was to define Catholic dogma and establish its internal coherence; as a side issue, the *Summa* also explained why heretics should be put to death. After Justinian I closed all the non-Christian philosophy schools in 529 AD, that feature of Church doctrine exerted a chilling effect on secular theorizing.

But by the seventeenth century a third wave of philosophy managed to take hold. It laid the groundwork for theorizing about what I call formal reality, the cross-categorization of physical reality with ideals. "Natural philosophers," such as Francis Bacon, Galileo, Descartes, and

Boyle, defined the methods by which scientific theories could establish themselves. Before the end of the century, Newton had published his classic *Mathematical Principles of Natural Philosophy,* a "proof of concept" for explaining physical events through ideal categories.

Today, scientific knowledge is firmly established in Western thought and has become an integral part of daily life in the industrialized world. Its success has tended to preëmpt some traditional areas of philosophy. Metaphysics and ontology give way to physics, epistemology bows to experimental method, and so on. "Philosophy is dead," writes physicist Stephen Hawking, explaining that

> Philosophy has not kept up with modern developments in science, particularly physics. Scientists have become the bearers of the torch of discovery in our quest for knowledge.[65]

The successes of science notwithstanding, a fourth wave of philosophy began to emerge in the middle of the twentieth century. New openings for philosophical speculation have been created by the development of computing technology, an event as transformational in our time as was the adoption of modern science in the seventeenth century or the spread of Christianity in the fifth.

The pioneers of computing technology tried to determine how machines could imitate humans. Kurt Gödel and Alan Turing laid the groundwork for determining the ideal limits of computability. Claude Shannon analyzed how "information" could be defined and encoded so that machines could process it. And John von Neumann delineated a hardware architecture that could be programmed to operate in lifelike ways.

The work of these thinkers abounded with philosophical issues. But they weren't trying to probe the ultimate nature of existence or delve into human values; they were trying to make machines act like people. As part of that work, they made design decisions which we can analyze today for clues to the ways people function. That computers operate the way they do, and not in some entirely different way, is a fact as worthy of philosophical investigation as Newton's rotating bucket or Boyle's "spring of the air" were in their day.

Such philosophical investigations are already bearing fruit. Stephen Wolfram's "new kind of science" and Ulric Neisser's 1965 "cognitive psychology" are examples. The present work was written to provide further contributions to this new wave of philosophy.

Summary of this Chapter

We humans are organisms, and we share the basic characteristics of life with other organisms. Yet we are arguably exceptional in the variety and extent of the reality that we construct and know. The reality that we know covers the earth and extends to the stars, while our knowledge of that reality embraces a wealth of theories and beliefs, both simple and complex, that we express in thousands of different languages.

We are also able to examine a history of known reality going back thousands of years, so we can compare what we know today with what we knew in other times. When we make that comparison we discover that our constructions of knowledge and known reality have mutated through regular cycles of cross-categorization, each stage having set the foundation for the next stage. The reality of human knowledge tends to follow a definite sequence of categorizing styles.

In addition, we human individuals maintain at least three disparate kinds of reality during our lifetimes: the corporal reality of our bodies, the social reality of our interactions with one another, and the mental reality that is private to each of us. These realities build on each other in a definite order.

The interactions among all these kinds of reality and the sequences of ways in which we construct them produce the richness and variety of human life. But life, as I said before, is parsimonious. It always tries to limit the number of different ways it works. In the case of humankind, this tendency toward simplification has shown up in two forms—as a search for comprehensive categories (which ultimately turn into gods) and as a search for elemental objects, which engenders modern science.

A characteristic of our modern human species, which distinguishes us from all other organisms, is the extent to which our construction of reality and knowledge is handed off to individuals. People exhibit an enormous range of lifestyles, from naked forest dwellers to investment bankers, from lumberjacks to nuns. This variety is made possible by the human neurological apparatus, which gives each of us many options for cross-categorization.

Human individualism is supported by a chain of cooperation among cross-categorization styles. Behavior is categorized physically, physical reality is categorized ideally, and ideals are categorized behaviorally. In the opposite chain—statism—behavior is categorized ideally, ideals are categorized physically, and physical reality is categorized behaviorally.

The individualistic approach to knowledge is scientific, its construction of society is libertarian, and its philosophy is materialistic. The statist approach, by contrast, tends to be religious, coercive, and idealistic. Statism is more natural from the viewpoint of the species, but people commonly learn to value individualism.

Being human gives us a perspective on known reality, including the idea that that it has evolved while we have evolved. One way to use this perspective is to engage in philosophical speculation, which is the first stage of theorizing about reality. In Western history, philosophy was the precursor for both religion and science.

Philosophers sometimes wonder about "the mystery of life" or "the mystery of existence." A typical analysis may start by treating one of these mysteries as opaque—a datum that is given—and ask how it can shed light on the other. But they are really parts of the same mystery. Life constructs the existence it knows, building itself and its knowledge as parts of that existence. Life is like a great tree, with an existential root system that grows while the tree's leaves of knowledge sprout, change, and fall.

Each part of the tree—roots and leaves—supports the other. We may marvel at the roots of known reality, which nourish the life we enjoy. Or we may wonder about the variegated leaves of knowledge, always showing us new shapes and colors. But to grasp the "mystery" of life we must understand how it constructs both its roots and its leaves—both reality and knowledge. We must understand the whole tree.

8. Summary of this Book

> The point of philosophy is to start with something so simple as not to seem worth stating, and to end with something so paradoxical that no one will believe it.
>
> BERTRAND RUSSELL

Bertrand Russell meant the epigraph above as a quip, but it conveys a subtle wisdom. Any general analysis must begin with observations on which everyone may agree; but if it goes no further it will fail the main task of philosophy, which is to extend understanding. To say something useful, one must say something that is open to doubt. Analyzing reality itself carries the heaviest burden, for as soon as the analysis departs from beliefs commonly held its conclusions must seem unreal.

In this book I have tried to start with simple observations. Human knowledge is something real, which people routinely seek, possess, and exchange. The subject of knowledge is reality, but in every case only a portion of reality is known. Hence we may distinguish known from unknown reality, and say that the act of knowing converts the latter into the former. More generally, knowing is something that living things do, and after they do it there remains something called knowledge which is associated with something we can call known reality.

Known reality. A question immediately arises: Is the known reality that is the subject of knowledge the same as the unknown reality from which it came? It is commonly believed that reality is a fixed thing—it "is what it is"—and knowing it is just a process of adapting ourselves to its absolute nature. In this view, knowing something changes us but has no effect on the reality we know.

If this were the case, then a survey of knowledge should reveal broad areas of agreement on what reality is. We should have figured it out by now. But even physicists, following a rigorous methodology, argue about the constituents of reality; between them and other intelligent people there are deeper disagreements; and between humans and other animals, such as dogs, bats, and ticks, the differences in the realities that individuals know are profound.

These considerations suggest that known reality is constructed from unknown reality to aid the process of knowing it. Organisms—living things, including people—construct it differently. Why do they do this? The obvious answer is that organisms construct known reality in the ways they do just to make it easier for them to know it. As living things differ, so do the realities they know.

Perhaps at this point we have reached the consummation of Russell's philosophy—"something so paradoxical that no one will believe it." Constructing reality sounds like fantasizing, where anything goes. The task of analysis is to discover how known reality is constructed from unknown reality without sacrificing objectivity—how known reality is anchored to unknown reality while being different from it.

Computer analogies. Fortunately, we live in a time when instances of reality construction are ready to hand and are well understood. They are the mainstay of computer technology. I am not talking about virtual reality software or artificial intelligence, but about the basic underlying techniques that make computers act in lifelike ways. These techniques have been developed over the past sixty years, often by trial and error, to create machines that can process knowledge the way people do.

Being a part of reality, we find it hard to hold reality in perspective. But we can build a machine that holds reality in perspective and we can understand how the machine works. Our understanding of the machine is not a substitute for philosophical analysis, but it makes the results of that analysis more understandable. So one anodyne for the paradoxes that seem to be inherent in the idea of constructing reality is to study how computers manage it.

Orders of known reality. If we simply catalog the reality we know, free of preconceptions about what it "really is," we find that we know at least three kinds of things. We know a physical reality of everyday tangible things, including our bodies, that interact with one another. We know a behavioral reality of our own thoughts and sensations, plus the urges and emotions in ourselves, other people, and other living things. Finally, we know universal abstractions, such as the general qualities of things and provable propositions such as mathematical truths. These third objects of knowledge I call "ideals." Everything we know can be classified as one of these three kinds of things.

So we know three areas of reality—physical, behavioral, and ideal. I talk about “orders of reality” because each area is closed internally: physical things interact with other physical things, behavior affects other behavior, and ideals are understood in terms of other ideals. Our knowledge raises conceptual barriers between the orders, as well. We naturally understand that a physical patch of red paint is a different kind of reality from a sensation of red in our minds, and both are different in kind from the universal ideal of redness.

Here we meet the first paradox of reality construction. If the reality that we know is divided into three self-contained orders, how do we manage to deal with reality as a whole? For example, how is it possible that our behavior results in physical actions and understands ideal truths? These questions apply not just to us, as humans, but to all living things. Thus the answers to them are found in the nature of life.

Organisms. If living things construct known reality, then they must be more than just parts of that construction. In fact, life has given itself a unique advantage in the reality it constructs and occupies. The units of life, which I call organisms, exist in all three orders of reality. In my terminology, every organism is an object with physical, behavioral, and ideal “aspects.” Every living thing has a physical body, is animated by trains of behavior, and reproduces through ideal coding in its genome. The joining of the three orders of reality in one object of knowledge makes an otherwise inert thing alive.

In referring to organisms, I mean more than just individual creatures. Species, genera, and higher taxa up to the whole of life all construct known reality and have aspects in all three orders of it. We can analyze the reality that a species constructs and describe its knowledge of that reality. Life at all levels contributes to the totality of known reality.

Reality construction methods. Life is parsimonious; organisms don’t work harder than necessary to construct the reality they need to know. Thus a few basic techniques, iterated in different ways, account for the variety and complexity of the reality that we know.

Objectification, categorization, and generalization are life’s primary processes. Objectification chunks unknown reality into discrete objects that are knowable; categorization groups those objects to make them understandable; and generalization builds models by forming relations among categories. Objectification is necessary for us to know reality at all; categorization explains reality by grouping objects together; and generalization lets us find patterns in those groupings.

The power of these simple actions stems from the ways that they can build on one another. Because groups are distinct from the entities they group, categories and models become entirely new objects. By freely assembling objects and then knowing the assemblies as more objects, living organisms construct the vastness of known reality.

Of particular importance is the technique I call cross-categorization. This occurs when an organism groups objects in one order of reality and objectifies the group as an object in a different order. For instance, a group of behavioral sensations may become objectified as a physical thing in "external" reality. Cross-categorization bridges the orders of known reality and integrates the world we know.

Space, time, pattern. I call the divisions in known reality "orders" because we use ordering methods to advance our knowledge of them. We order physical objects in space, behavioral objects through time, and ideal objects by pattern. Using these methods helps us distinguish one object from another. For example, if two physical objects seem to be identical, we can tell them apart by their different locations in space. By combining these ordering methods with cross-categorization we also construct new objects of knowledge, such as changes and events.

If we add space, time, and pattern to reality as a part of making it known, what is reality like beforehand? What I call unknown reality is by definition unknowable, but we can make some suggestions about it. Because we chunk it into objects to know it, unknown reality is most likely a continuum. If it were already chunked, "rechunking" it would generate problems. But unknown reality must also be objective, in the sense that it determines the known reality we get out of it. So we can envision unknown reality as something like an objective continuum.

An analogy for the relation between unknown and known reality can be found in the relation between a computer's file of bits (say, a movie file) and the experience that the computer extracts from it. The bits are small, there are billions of them, and all we know about them is that some are ones and some are zeros. The bit file displays no evident space, time, or pattern: it approximates an unknowable continuum. But from it a computer can construct a movie—something knowable. Note that the bits in the file fully determine the movie, for if we change one bit the movie changes. This analogy can help us understand how known reality is constructed from something completely unlike it.

Worlds within known reality. If we examine human known reality, we find multiple worlds within it. Besides the corporal world of our bodies, there is the social world that we share with other people and the mental worlds that we each build in our minds. We construct these worlds as parts of known reality, but they are independent in many ways. Through cross-categorization, they interact with each other and with the environmental reality that supports life.

Other species construct similar worlds to the same or lesser extent. All species construct both the corporal reality of their bodies and the environmental reality that supports and nourishes them. Many species construct social reality, both within their species and between them and other species. A few species construct mental reality. We humans are not unique in the worlds we construct, but we excel in their size and complexity.

Consciousness is an important part of human mental reality. Its most characteristic feature, awareness, is simply behavior categorizing other behavior within the brain. The primary importance of awareness is that it lets an individual simulate external reality without overt activity. We can rehearse and refine our lives in the privacy of our own brains.

Human languages, originally developed to support our social reality, also play a role in our mental reality. But language is only an expedient for transferring knowledge within an individual's awareness or from one individual's awareness to another's. Translating objects in mental reality into language and back again not only involves multiple steps of cross-categorization, it requires stages of parallel-to-serial and serial-to-parallel conversion. It works, but far from perfectly.

Knowledge. If organisms construct known reality just so they can know it better, then knowledge determines the nature of that reality. There is no point in constructing reality that the constructor can't know. So an organism's construction of reality in its environment prompts the construction of knowledge within that organism's corporal reality. Knowledge is a modification of the organism's physical body, behavior, or ideals. By cross-categorizing other objects it can become knowledge of any reality that the organism can construct.

Theorizing is a behavioral process that uses cross-categorization to construct new knowledge out of old knowledge. What I call "common sense" is knowledge that groups objects using categories in the same order of reality. Theorizing reinterprets common sense by categorizing what it knows in terms taken from different orders of reality.

The main function of theorizing is to detect error. Here we discover the reason behind life's dividing known reality into disparate orders. To detect error, an organism must gain a perspective on known reality—a new understanding of objects already known. Such a perspective can be accomplished only by using different sources of categories.

Species and other units of life theorize, not just individuals. Through the trial-and-error of evolution, they conclude that certain genomic codes yield desirable physical structures in individuals, and that these structures require certain behavior to do their jobs. Many ethological explanations are simply descriptions of theories that species hold.

Because it depends on cross-categorization, theorizing is inherently erroneous. It tries to describe one order of reality in terms of another order. Nevertheless, theorizing produces new understandings. One way that human theorizers justify theories is by constructing what I call "minima"—elementary objects that are supposed to exist in two orders of reality. For example, the particles of physics are supposed to be physical things with ideal mathematical properties. Such minima bridge the orders of reality at the finest level of objectification, making larger theoretical constructions appear more "realistic."

Human reality construction. The cross-categorized objects that we humans construct in our known reality mutate in regular ways. The six ways in which one order of reality can be categorized by another order often support one another and tend to follow an historical sequence. This effect breeds regular large-scale transitions in our explanations of the physical world, in our behavioral traditions, and in the ideals by which we guide our lives.

Styles of categorization tend to form chains, in which the categories in each order of known reality are categorized by one of the other two. There are two ways that the three orders can be linked together, and the two chains that result show up as a basic dichotomy in the ways that people construct their worlds. One worldview supports materialism, science, and individualism; the opposite worldview supports idealism, religion, and statism.

Because they form closed cycles of explanation, each of the two chains achieves a complete worldview. In the first case, materialism uses ideals to explain physical events, science uses physical categories to explain behavior, and individualism lets behavior define ideals. In the second case, idealism uses ideals to assess behavior, religion uses behavioral categories to explain physical events, and statism employs physical categories to define human ideals. Both chains of explanation try to answer all questions by referring to another order of reality.

But chains of explanation can be frustrating, because every answer requires a further clarification. So we humans look for comprehensive objects—objects in known reality that can explain everything. One line of speculation leads to all-inclusive categories, the most prevalent of which are known as gods. Another line leads to a search for elemental minima, the building blocks of everything. A third line tries to elicit universal patterns in global human behavior.

None of these shortcuts works forever, because each of them tries to understand an evolving known reality. Yet new explanations always hold out promise as new reality emerges. I believe that the best way to expand understanding is what I called in a previous work the method of comparative theorizing.[66] This method substitutes a kind of creative speculation for the traditional "search for truth." Theories compete with one another to bring out their most usable concepts, without promising definitive explanations.

Life constructs facts in environmental reality and knowledge within itself. Truth mediates between the two; but it is understanding that makes truth useful, and understanding can be constructed only within organic reality. The difficulty with searching for truth is that reality evolves as knowledge evolves. To understand reality we have to forego the concept of final answers. Hence the primary human goal should be simply to understand the reality of human knowledge.

Notes

1. B. d'Espagnat, "The Quantum Theory and Reality," *Scientific American,* November 1979, p. 158.
2. L. A. Steen, "Foundations of Mathematics: Unsolvable Problems," *Science* vol. 189 no. 4198 (18 Jul 1975), p. 210.
3. T. S. Kuhn, *The Structure of Scientific Revolutions,* Chicago 1962.
4. P. L. Berger and T. Luckmann, *The Social Construction of Reality,* Anchor Books 1967, p. 60.
5. G. Towner, *Processes of Knowledge,* University Press of America 2001, pp. 122-129.
6. P. Laplace, *Exposition du Système du Monde,* Book III.
7. T. Nagel, "What is it like to be a bat?," *The Philosophical Review* LXXXIII, 4 (October 1974), p. 440.
8. P. E. Ross, "The Expert Mind," *Scientific American,* July 2006.
9. R. Dawkins, *The Extended Phenotype,* Oxford 1982.
10. E. Schrödinger, *What is Life?,* Cambridge 1967, p. 76.
11. J. Avery, *Information Theory and Evolution,* World Scientific 2003.
12. A Lehninger, *Principles of Biochemistry* (2nd Ed.), Worth Publishers 1993.
13. N. Wirth, "Good Ideas, Through the Looking Glass," posted by *Eidgenössische Technische Hochschule Zürich,* www.cs.inf.ethz.ch/~wirth/Articles/GoodIdeas_origFig.pdf, 2005, p. 26.
14. S. J. Gould, *Ontogeny and Phylogeny,* Harvard 1977, p. 4.
15. S. Wolfram, *A New Kind of Science,* Wolfram Media, Inc., 2002, p. 840.
16. R. Rojas, "Conditional Branching is not Necessary for Universal Computation in von Neumann Computers," *Journal of Universal Computer Science,* 2:11 (1996), pp. 756-768.
17. I. Newton, *Philosophiæ Naturalis Principia Mathematica,* 1687; tr H. Pemberton, 1726, p. 10.
18. H. G. Alexander (editor), *The Leibniz-Clarke Correspondence,* Manchester University Press 1956, fifth letter, par. 29.
19. Kant, *Critique of Pure Reason* (tr. F. M. Müller), Anchor 1966, p. 62.
20. K. L. Ross, "Immanuel Kant," posted in *The Proceedings of the Friesian School, Fourth Series,* www.friesian.com/kant.htm, 2008.
21. V. Bush, "As We May Think," *The Atlantic Monthly,* July 1945.

22. J. F. Sowa, "Processes and Causality," online paper based on Sowa, *Knowledge Representation,* Brooks Cole 2000.
23. G. Towner, *op. cit.,* pp. 57–61.
24. P. Laplace, *loc. cit.* (full quotation on page 20).
25. S. Toulmin and J. Goodfield, *The Architecture of Matter,* Harper and Row 1966, p. 55.
26. P. A. M. Dirac, "The Evolution of the Physicist's Picture of Nature," *Scientific American* vol. 208 no. 5 (May 1963), p. 53.
27. S. C. Pepper, *The Sources of Value,* University of California Press 1958, p. 58.
28. P. L. Berger and T. Luckmann, *op. cit.*
29. G. Towner, *op. cit.,* Chapter 5.
30. J. Locke, *Essay Concerning Human Understanding,* II.XXVII.9.
31. J. Jaynes, *The Origin of Consciousness in the Breakdown of the Bicameral Mind,* Houghton Mifflin 1976, p. 220.
32. S. Pinker, *How the Mind Works,* W. W. Norton 1997, pp. 131 ff.
33. T. S. Kuhn, *op. cit.,* pp. 10 ff.
34. R. J. Sternberg, *Beyond IQ: A Triarchic Theory of Human Intelligence,* Cambridge University Press 1985.
35. *Random House Dictionary,* 2009.
36. Epictetus, *Enchiridion,* VIII.
37. C. I. Lewis, *Mind and the World Order,* Charles Scribner's Sons 1929, p. 121.
38. See Sextus Empiricus, *Adversus Mathematicos,* vii, 135.
39. Galileo, *The Assayer* (1623).
40. D. Sobel, *Galileo's Daughter,* Penguin Books 2000, p. 301.
41. T. S. Kuhn, *op. cit.,* pp. 118 ff.
42. Galileo, *op. cit.*
43. Galileo, *Dialogue Concerning the Two Chief World Systems* (1632).
44. G. Towner, *op. cit.,* pp. 35-43.
45. J. J. Thomson, "Cathode Rays." *Philosophical Magazine,* 44:293 (1897).
46. F. Bacon, *Novum Organum,* Book II, Aphorism xvii.
47. See *Wikipedia,* "Digger wasp."
48. S. Pinker, *The Language Instinct,* William Morrow and Company 1994, pp. 4-5.
49. L. Wittgenstein, *Tractatus Logico-Philosophicus,* 5.6.
50. P. Yourgrau, *A World Without Time,* Basic Books 2005, p. 115.
51. D. Gross, "The Coming Revolution in Fundamental Physics," lecture at Korea University, February 22, 2005.
52. Aristotle, *Posterior Analytics,* 1:2.

53. Plato, *Theatetus* (tr. B. Jowett), 201.
54. E. Gettier, "Is Justified True Belief Knowledge?," *Analysis* 23 (1963), pp. 121-123.
55. Plato, *Symposium* (tr. B. Jowett), 212.
56. F. H. Bradley, *Appearance and Reality,* Macmillan 1893, p. 172.
57. Kant, *op. cit.,* p. xxii.
58. Quoted in R. Irwin, *The Origins of the English Library,* Greenwood Press 1958, p. 94.
59. G. Towner, *op. cit.,* pp. 258-268.
60. T. S. Kuhn, *op. cit.,* pp. 123-4.
61. C. Montesquieu, *De l'Esprit des Lois,* 1748 (tr. Thomas Nugent), 11.6.
62. *Catechism of the Catholic Church* (1997), 687.
63. D. E. Brown, *Human Universals,* McGraw-Hill 1991.
64. J. Haidt, *The Happiness Hypothesis: Finding Modern Truth in Ancient Wisdom,* Basic Books 2006.
65. S. Hawking, *The Grand Design,* Bantam Books 2010, p. 5.
66. G. Towner, *op. cit.,* pp. 137 ff.

Index

T

U

V

W