Death from a Distance and the Birth of a Humane Universe:

Human evolution, behavior, history, and your future

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Chapter 1 **The journey we will take**

What does the nine-month human pregnancy have to do with Wall Street? What does the history of archaic states (like the Roman Empire) have to do with daycare centers? What does your sexual behavior have to do with Amazonian rain forest cultures? What does DNA sequence information have to do with the economy? What does wildebeest biology have to do with human political systems? What does a Homo erectus fossil have to do with baseball? What do handguns have to do with the Scientific Revolution? Why do our minds cause us to say that a person who beats another to death behaved "like an animal"? What does human evolution have to do with war?

The answer to each of these questions is EVERYTHING. Our social, sexual, political, cultural, and economic lives are also our biological lives. Humans are absolutely unique among all Earth's creatures. Our existence presents what scientists sometimes call the "human uniqueness problem." Nevertheless our uniqueness emerges directly and simply from our biology. We are going to explore a fundamentally new scientific theory about exactly how and why this is.

Our journey will commence at the birth of the solar system about five billion years ago. After briefly exploring only the few things we need to know about the emergence of organisms in general, our careful attention will turn to ourselves as a very specific new kind of organism. This exploration of ourselves will begin with the rise of the first humans around two million years ago. We will then turn to the essential features of our two-million-year history, from the emergence of language, our unique sexuality, and our powerful minds to events like the invention of agriculture and the rise of the first states. Our quest will not stop until we stand in the present instant looking forward into the human future. We will attempt to explain all the important things encountered along this journey as a single, coherent whole with no missing pieces, no magic, no hand waving.

Once this tour is completed, we will argue that we can comprehend the place of humans in the world with an entirely new totality. A far better understanding of our origins, our properties, our history, and the contemporary world will be our prize.

Once we grasp the concept of our real biology, we will comprehend ourselves with a stunning new simplicity. Arguably, we will understand ourselves for the first time. Much of what our exploration uncovers will be surprising. Though we will not always be pleased at first glance by what confronts us, we will ultimately find a new, deeper respect for human life, a vastly enlarged hold on our common humanity, and a realistic hope for a more humane future.

At the end of the book, it will be up to you to decide if this ambitious purpose has been fulfilled.

What is our theory?

Before we outline the theory that will (ostensibly) give us this new level of insight, be aware of two things.

First, you will, most likely, not fully understand the theory initially. Its reach is wide and far. Though the theory is ultimately simple, full assimilation of its insights and implications can only emerge gradually as we proceed.

Second, aspects of this picture will seem ethically disturbing at first. Be patient. Followed to its logical conclusion, our theory is richly humane. It puts our common humanity and our need for an ethical vision of our lives on a firmer footing than we have ever had before.

What is our theory of human uniqueness? It emerges from the fact that all biological creatures have what we can call *conflicts of interest*.[*] What this phrase means is that all organisms have an incentive to compete with one another for access to the scarce and crucial assets we each must have from the world to survive and reproduce. These conflicts of interest normally limit social cooperation between non-human animals to very close kin—parents, offspring, and siblings. Animals compete intensely with all *other* (non-kin) members of their species almost all the time.

It is helpful to visualize *conflicts of interest* from a simple, everyday human point of view. We all have conflicts of interest with merchants who sell us things we need, like food, for example. If we could take food without paying, we could get more food or more of other things we might also need. On the other hand, the merchant will not be able to buy the things she (or he) needs for herself and her family if we shop lift. Our interests

[*] These conflicts of interest result directly from the fundamental physical and chemical nature of all biological creatures, as we will see in Chapter 2.

and the merchant's interests are in conflict. (We rarely think consciously about these facts, but they exist nonetheless.)

Of course, we have a legal system, complete with law enforcement, that usually prevents us from stealing the merchant's food. If we steal, we will be prosecuted and incarcerated, suffering a much larger cost than would be justified by the food we might realistically be able to steal. We anticipate all this, though usually not consciously, and we are thereby prevented from stealing. As a result, food stores work, the merchant survives, and we eat. This legal system will be very important to us in a minute, but we need to understand three other things beforehand.

First, you might be thinking something along these lines. We are aware that, if we steal, the merchant will go out of business and we will not be able to obtain food from her in the future. Thus, even if we did not have a legal system, we still would not steal. Stealing would ultimately be futile.

But, for a moment, imagine there is no legal system. Now, suppose there are just a few individuals who choose to steal in spite of its being ultimately self-defeating. They will have more food now and do better than we do. Soon others will see that the thieves are doing better and join them. Ultimately, even you and we would be forced to steal to feed our children. We would have to seize some of the food before it all is stolen by those already choosing stealing over buying. In short order, everyone is forced to steal, the merchant goes out of business, and we are on our own for food. The fact that this outcome is stupid and self-defeating has nothing to do with it. This is precisely the way non-human animals live, and it is exactly their inability to prevent "stealing" (to control conflicts of interest) that forces them to live this way.

Second, you might be thinking that these rules for a trip to the grocery store might be interesting, but they are local and trivial. Surely, they cannot be the basis of a vast theory of everything it means to be human. If you think this, you are perfectly wrong. The laws of inertia pervade everything about our physical world, from a dribbled basketball, to a landing passenger aircraft, to the path of the Earth as it orbits the Sun. Likewise, conflicts of interest pervade every crevice of every event in the social lives of every creature, always. Everything about the social lives of human and non-human animals is completely determined by conflicts of interest and their immediate implications, no exceptions. Conflicts of interest are the central *force of nature* throughout the social world.

Third, alternatively, you might be thinking, "rubbish, social behavior at the grocery store doesn't work this way. People would not put up with stealing even if there wasn't a formal legal system." You are exactly right. ***People*** usually do not put up with stealing and other such behaviors, formal legal system or not. But non-human animals do. In other words, humans usually control and suppress conflicts of interest and non-human animals almost never do.

The question is why? The answer is simple—cost. It is too expensive for individual non-human animals to participate in control of conflicts of interest. In contrast, for humans, law enforcement is cheap and a good investment. It has become an innate natural behavior for us, one we usually take unconsciously for granted.

How did this difference between humans and non-human animals come to be? The ancestors of the first humans evolved, inadvertently, the capacity to kill or injure *conspecifics* (members of their own species, fellow humans) from a substantial distance. These ancestors could kill *remotely*, from many body diameters away. This ability arose, in turn, from the evolution of human virtuosity at accurate, high-momentum throwing. No previous animal could reliably kill or injure conspecifics remotely.

This novel physical virtuosity at throwing probably evolved at first as part of a local professional hunting or scavenging adaptation.[*] However, this elite throwing had unexpected, revolutionary implications for the evolutionary future of this new animal.[1] This unprecedented remote killing capability permitted multiple individuals to simultaneously project violence at vastly lower cost than in any previously existing creature.[†]

As we will see in Chapter 5, these reductions in cost are huge and highly significant. Thus, a radically new adaptive opportunity was *inadvertently* created. For the first time in the history of our planet, an animal came into existence who could suppress the conflicts of interest between non-kin (unrelated) conspecifics at low cost. "Law enforcement," thus, became a self-interested behavior for the original human individuals.

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[*] We will explore this in Chapter 7. For now, it is sufficient to recognize that humans throw the way a cheetah runs or a dolphin swims—with elite skill. We are "born to throw." Elite human skill at throwing has been recognized by many authors, from Darwin to William Calvin; however, before now, we have not had a sensible theory about why human throwing might be central and important.

[†] The capacity to project violence cheaply also means that the *threat* of violence can be projected believably or credibly. In practice, day-to-day, it is threat that is more commonly employed than actual violence.

For the first time, natural selection could now “reward” individuals who actively suppressed conflicts of interest ***in*** others and responded to this suppression ***from*** others.* Not putting up with thieves became biologically adaptive. This drastically altered social environment is the one we have inherited and know so well. We will refer, collectively, to all the many new social behaviors that evolved as a result of this environment as ***kinship-independent social cooperation***.

To be very clear about what are we saying, return to the merchant selling us food. We are saying the cost of law enforcement that prevents thieves from bringing down our local economic system is, in fact, the very thing that determines whether we have that economic system in the first place. Ancestral humans evolved a new ability that brought these enforcement costs down drastically, and uniquely human economic systems (kinship-independent social cooperation) became possible. Of course, we mostly do not throw stones to enforce the law these days. We prefer newer projectile weapons when we can get them. But the underlying principle used today remains precisely the same as it was in the ancestral environment.

When we go shopping or act as merchants, we are engaging in a behavior that is both ancient (probably about two million years old) and *uniquely* human. This novel way of getting along in the world is possible precisely and solely because we can afford not to put up with thieves. We can afford to control conflicts of interest. *Everything* else that distinguishes us from other animals flows from this utterly simple trick of enforcing social cooperation in spite of conflicts of interest.

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* *Reward* is a metaphor. Natural selection is a blind mechanical in-the-moment process, not a conscious forward-looking one. Of course, we are referring to natural selection and evolution here, not how you and I appear to make decisions in the present. The important terms are as follows. *Selection* for a behavior results when individuals who have the behavior leave more offspring who, in turn, inherit that behavior. Over many generations, this selection causes such a beneficial behavior to become more common until it is characteristic of most or all animals in a population. We refer to a behavior that is beneficial in this way as an *adaptive* behavior. Such behaviors are elements of *adaptations* (which also include adaptive changes in physiology and anatomy). By definition, a behavior is said to be adaptive because it increases the likelihood of survival and reproduction of individuals in a local environment who display that behavior.

Adaptive sophistication refers to the relative competitive competence and ability of an animal or a person. For example, a person with access to complex tools like a computer or an assault rifle has a substantially higher level of adaptive sophistication than an illiterate ancestral human hunter whose most complex tool was a bow.

We will enrich our understanding of biological evolution, selection, and adaptation in Chapter 2 and beyond.

At this early point in our journey together, many readers will be thinking that this picture is surely either incomplete or utterly incorrect outright. If you are thinking either of these things, you are almost certainly wrong. And in being wrong, you are closing off all possibility of understanding what it means to be human, how we got here, and why our history looks as it does. Our task throughout the rest of the book will be to try to show you that this simple picture of humans is not only correct and complete, but also startlingly, pervasively powerful.

This simple picture of human uniqueness will bear enormous fruit. Individual adaptations to coercively enforced kinship-independent social cooperation consist of ***the entire suite*** of traits we think of as uniquely human. These traits include complex language, large brains/powerful minds, our unique sexual and child-rearing behaviors, and our elaborate ethical and political sense. Just exactly how these human traits emerge simply from access to cheap coercion will not be obvious yet, but it will become clear in later chapters.

But there is more. Not only do we have a theory of our individual human properties and their evolution, we have a powerful new theory of history. We can outline this new way of understanding how human history apparently works for you right now if you consider a few more details.

First, the larger a cooperative collection of humans is, the more culturally transmitted expertise it can store. Larger social aggregates also can support much more individual specialization, permitting more new expertise to be discovered. As a result of effects like these, the scope of human capability (adaptive sophistication) is entirely dependent on the scale of our social cooperation. We will find that the major advances throughout our two-million-year history all resulted from increases in the scale of our uniquely human social cooperation.

Second, conflicts of interest are to social behavior as gravity is to astronomy. They are the central fact of our social existence, at every scale, large or small. For example, different nations have conflicts of interest with one another just like non-kin individuals do. Cooperation between either individuals or nations (or collections of people of any size) requires management of conflicts of interest *on the scale in question*. Thus, the scale of our social cooperation and, therefore, our adaptive sophistication, are determined by the scale on which we can manage the conflict of interest problem.

Third, the weapons that would make law enforcement feasible (cost-effective) in a local neighborhood (a police handgun, for example) are not the same as the weapons that allow practical law enforcement among nations (cruise missiles, for example). Thus, the scale of human social cooperation can increase over time, *but only* as new coercive technologies are invented that permit *cost-effective* law enforcement (control of conflicts of interest) on the new scale in question. Thus, adaptive progress will always await and flow from the introduction of new coercive technologies.

We will argue that this simple causal chain will prove to be a startlingly powerful and complete theory of history. All the important features of our two-million-year human journey are consequences of this single causal process.

Let us return to our ancestors and look at how these fundamental facts about the world have apparently determined the course of human history.

The original increase in adaptive sophistication from elite throwing in the first human ancestors produced biological evolution of new capacities. It also ultimately allowed diverse technical innovations. Eventually, among these innovations were new means for suppressing conflicts of interest on ever-larger scales with new weapons. As creatures now highly adapted to the coercive suppression of conflicts of interest, humans inevitably exploited these new technical means in pursuit of individual self-interest, precisely analogously to the smaller scale cooperative behaviors of their ancestors (originally sustained by elite throwing).

This pursuit, in turn, inevitably produced ever-larger cooperative social units, ultimately including enormous numbers of individuals. The resulting increases in scale of human social cooperation produced new adaptive revolutions.[*] This process was inherently autocatalytic. New adaptive sophistication produced further improvements in coercive technology, producing still further adaptive revolutions.

This ongoing process eventually became relatively rapid by the standards of traditional biological evolution. Moreover, it produced a long sequence of ever more sophisticated adaptive revolutions in the two million years since the evolution of the first humans.

These revolutions represent all the major transitions in human history including the behaviorally modern human revolution, agricultural revolutions, the rise of the archaic and

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[*] An *adaptive revolution* refers to the relatively abrupt acquisition of dramatically increased adaptive sophistication. We will see in later chapters that the important features of human history can be described as a series of adaptive revolutions. For now, what matters is that human adaptive sophistication is limited almost exclusively by the scale of our kinship-independent social cooperation. So, if the scale of this social cooperation increases, our adaptive sophistication will increase, producing a new adaptive revolution.

modern states, and the currently ongoing consolidation of pan-global human cooperation. Each of these adaptive revolutions has precisely the same underlying logic on our new theory—the self-interested application of *relatively* inexpensive coercion resulting in sustained social cooperation. This fundamental logic is merely applied at ever-larger scales with each historical transition.

The spectacular adaptive abilities conferred upon us by the huge scale of our contemporary social cooperation are the primary reasons that contemporary humans seem so totally different than non-human animals. While it is true that you and we are individually smarter than non-human animals, we are not nearly as individually smart as our personal conceit tempts us to believe. Rather, it is our capacity for cooperation with huge numbers of other people that really lifts us above the rest of the biological world, as we will explain in later chapters.

The fact that historical human adaptive revolutions are by-products of the *self-interested* application of coercive power has other important implications. First, human societies do not necessarily serve the interests of *all* their members equally. Rather, they are expected (inevitably) to serve the interests of individuals in proportion to the coercive power they exercise. Depending on historical happenstance and the properties of technologies, coercive power can be widely, democratically distributed or concentrated in the hands of a few. The resulting human societies reflect these distinct distributions of coercive power in predictable ways.

Second, interest groups within a local human society who hold decisive coercive power will resist the access to new coercive technologies by other disenfranchised individuals. The struggles to acquire and deploy new technologies for asserting coercive self-interest in the face of older entrenched interests are variously lengthy and chronic or cataclysmic and violent.

The "ideological" rationales (economic, religious, political, or ethnic) for these struggles prove mostly to be persiflage generated by our evolved human ethical/political psychologies. This ongoing competition for naked coercive dominance is the real story of history and a game our ancestors had no choice but to play. These struggles, together with the growth of knowledge/expertise with changes in the scale of social cooperation are the actual, substantive processes of historical change. These two processes (struggle for coercive dominance and accrual of knowledge) are the sources of essentially all the rich local color and superficial (false) appearance of complexity in the flow of human history.

You may want to reject these strong, simple claims about the nature of human history here at the beginning. If so, our task through the rest of the book will be to challenge your skepticism. As well, you may find this view of history grim and foreboding. However, we will see in later chapters that there is an alternative to this perspective. Coercive dominance by a democratized global *coalition of the whole* of humanity is probably an achievable outcome. Such a world holds immense promise both materially and ethically.

In summary, our theory is apparently complete. It is a theory of human origins and of our unique properties as biological creatures. Moreover, it is also apparently a theory of human history and social organization of unprecedented economy and scope.*

The rest of the book will build this theory in detail, test the theory against the evidence from many different areas of the knowledge enterprise, and explore its numerous and diverse implications. Scientifically sophisticated readers who are prepared to dive into constructing the new theory can proceed directly to Chapter 2. The remaining sections of this chapter are for readers who still have some intellectual or ethical concerns about our objectives or methods. If you are not comfortable with the natural scientist's definition of *reductionism*, for example, you may want to read the rest of this chapter.

How big is our problem?

We have set ambitious goals. In order to achieve them, we need a clearer understanding of the uniqueness of humans. We really are very different than other animals. For example, we all know that Dr. Doolittle conversing with the non-human animals is a fantasy. Humans talk, but animals do not seem to communicate extensively in this way. Moreover, we travel in space; other animals do not. We are also aware that humans seem to be much smarter than non-human animals. Being smart and talking are important, but they are just two of our many unique features. We often do not fully appreciate just *how* different we are. We lack perspective because we live *inside* a completely human world, in a human monoculture, so to speak. But think about the following things.

Chimps are our closest living relatives. They are among the animals most like us, ***yet*** there is a vast chasm between their properties and ours. The epitome of chimp engineering is to strip a twig and stick it into a hole in a termite mound, fishing for a few insects to eat. Humans can engineer enormous sets of tools allowing us to fly directly from New York to Tokyo in a few

* It will even emerge that features of the contemporary economic crisis (2008/2009) are predictable on our theory, as are possible steps to reduce such problems in the future (Chapter 17).

hours, visualize structures ten thousand times smaller than a hair, or peer billions of years back into the life of the universe.

A talented chimp can break open nuts with a stone. Humans can mimic the nuclear fusion reactions that power the Sun, setting off titanic thermonuclear blasts capable of vaporizing whole cities.

Chimps have several calls including a pant hoot. Humans can sing opera, recite Shakespeare, or write the Gettysburg address.

Chimps are defeated if they have to count to thirty accurately. Humans can count the number of water molecules in an ice cube—about 54,827,952,000,000,000,000,000.

Our differences from other animals matter. They give us near total dominance of the biological world. Consider two examples among millions. Tens of millions of buffalo once roamed the American Great Plains, eating the grasses that grew wild there. The grasses evolved to prosper in the presence of the buffalo and vice versa. Humans drove the buffalo from the face of the continent and replaced *their* grasses with *our* grasses—a world-feeding, continent-sized field of wheat and corn. Buffalo shaped their grasses inadvertently. We shaped ours by conscious design, and our grasses can only survive with our constant, planned, mindful supervision.

Some animals live on the arctic ice, others in the sub-arctic tundra, and others in the forests and grasslands of temperate zones. Still other animals live in tropical and subtropical deserts, savannas, and rain forests. Humans live in ***all*** these places and the other animals in *each* of them survive (or die) mostly at our pleasure.

We need to account for all of these differences and all of these consequences. We need a *theory of human uniqueness*. Since Darwin, many attempts, some clever and brave, have been made to produce such a theory. All have failed. These earlier theories and the reasons for their failures are too many to review in detail. But two examples are illuminating.

It has been proposed that complex language distinguishes humans from the other animals. On this view, all our other remarkable properties result from the fact that we can talk to each other. This theory fails for several very good reasons. For one, it merely restates the question. If language distinguishes us from other animals, why are we the only animals to speak? For another, we can speak to one another for mutual benefit, but we can also use language to deceive and manipulate one another. Our dominance over other animals arguably comes from our capacity to cooperate. Why do we use language (often) to cooperate and not (always) merely to manipulate? A good theory must answer these questions. Ours will.

Alternatively, it has been proposed that our large brains and powerful minds provide the essential difference between us and other animals. On this view, language and all our other unique properties are somehow made possible by our unique minds. This approach suffers from precisely the same problems as the language first hypothesis. It restates the question of why are we so smart, rather than answering it. Likewise, it fails to account for why we also use our powerful minds to cooperate (often) with non-kin and not (always) merely to compete and manipulate.

We can, in fact, make bad theories like these appear to work. However, making them work requires that we make additional *ad hoc* assumptions. Such inelegance is not the sign of a good theory (Introduction). We will argue in later chapters that these complicated, inelegant theories are clearly wrong. In addition to the problems already mentioned, we will find that these and other earlier theories misidentify effects as causes.
Our challenge is to do better. We can. And the rewards will be substantial.[2]

Success will also bring us some indirect and unexpected rewards

We have forecast that a good theory of human uniqueness will give us unprecedented understanding of the human world. However, by being able to "subtract" these uniquely human parts of our nature, we will also discover how we are *like* other animals. These similarities are many, profound, and pervasive. These universal animal properties are just as important as our uniquely human features to authentic self-understanding. Our universal animal bits have been fairly well understood by biologists for several decades; however, a new, clear understanding of how our universal animal parts interact with our uniquely human parts will enrich us deeply.

Consider the following details of our existential state. They emerge at the interface between our uniquely human and universal animals parts.

Young adults give birth to infants and spend a large fraction of the remainder of their lives providing everything these youngsters need to survive and grow to adulthood. The first generation of adults dies and the youngsters-grown-to-adults carry out the cycle again, as do their offspring and theirs. Within four or five generations, their descendents often do not even know their names, let alone who they were and what they did.

Remarkably, rather than considering this utterly futile, we often consider having and raising children one of life's deepest satisfactions.

We fall in love. If our feelings are reciprocated, we are euphoric. Life is redolent with purpose and transcendent joy. If our feelings are not reciprocated, we are crushed, temporarily destroyed. Life seems valueless. We are the same person in both situations.

A man has sex with his mate. Though she might prefer otherwise, he finds it difficult to have sex with her twice within an hour. However, once, he has sex with both his wife and her girlfriend together. He finds that he is ready to have sex with her friend within seconds of his orgasm with his mate. His mate is annoyed and he is mystified and pleasantly surprised. On another occasion, he and a male friend cooperate to have sex with his mate. He is able to have sex with her over and over in a period of an hour, interspersed each time with his friend having sex with her. Again, he is mystified. This time his mate is pleasantly surprised.

Our theory will give new perspective to these and many other things about us.

Is that all there is?
The nature of reductionist, materialist explanation

What does it mean to construct a scientific theory of human uniqueness? We explored some facets of this meaning above and in the Introduction. However, it is now time to add a new element to our picture of good theories. The universe turns out to be organized in a very special way. We have learned to recognize this organization over the approximately four hundred years of the Scientific Revolution. This organization is not merely *reflected* in scientific theories; it is the very thing that makes science possible. The existence of this property of the universe also is a thing of immense beauty.

We can understand this property of the universe by defining a widely used phrase—*levels of complexity*. Though slightly fuzzy, this phrase is precise enough to be useful. We will take it to mean that the universe is organized hierarchically and that each level in the hierarchy has properties best described at that level.

An excellent analogy to what we mean by hierarchical organization is written language. When we write, we assemble elements of the first hierarchical level or the first level of complexity, letters, to create elements of the second level, words. We then assemble words into elements of the third level, phrases, and, in turn, assemble phrases into fourth level elements, clauses and sentences. Fourth level elements are assembled into fifth level elements, paragraphs, which are assembled, finally, into sixth level elements, documents like the Gettysburg address or this book.

Several things are important to notice about written language if it is to serve as a useful analogy. First, each level of complexity or organization in the hierarchy emerges from assembling combinations of elements from the level below. This feature or property is called ***combinatoriality***.

Second, combinatoriality allows tremendous quantitative accumulation (accretion) of complexity at each level. For example, a hardcopy dictionary on our desk has about one hundred forty-five thousand entries. Given that this outdated 1996 unabridged dictionary lacks such important words as *muggle*, *cell phone*, *truthiness*, and *blowback*, this is a conservative estimate of the number of English words.

Nevertheless, this enormous collection of words (a level of hierarchy or complexity) is assembled from a mere twenty-six letters—the elements of the next level down. Of course, these many words can be assembled into an effectively infinite number of phrases and sentences. For example, some of the sentences in this book appear here for the first and last time in the history of the universe. More important still is the infinite variety of a written literary tradition. Documents from Hobbes, Faulkner, Shakespeare, Snoop Dogg, or Stephen Colbert are each utterly different compositions.

Third, all this complexity is assembled according to a few simple rules making up the standards of spelling, grammar, and clear writing.

It is important to recognize that the hierarchical organization of written language gives us profound complexity, BUT it does so simply and transparently.

The hierarchical organization of the natural universe gives us precisely these same things—profound complexity emerging with simple transparency.

Before looking at the universe more carefully, a word of caution. The analogy with written language is incomplete in one important way. For example, letters are “designed” to be assembled into words; words are designed to be assembled into phrases; and so on. From the bottom of the hierarchy to the top, written language is (ostensibly) an integrated whole.

In contrast, the levels of the hierarchical organization of the physical world have no such larger purpose. Each level merely arises because it does or it can. Each level has its own internal logic and its own absence of purpose unrelated to the absence of purpose of levels above or below.[*] As long as we keep this crucial difference in mind, our analogy with written language can serve us well.

Exactly how are the levels of complexity of our world organized? If we were subatomic particle physicists, we might be interested in the properties of individual electrons, protons, and neutrons. If we were atomic physicists, we might be interested in the properties of individual atoms made up of combinations of copies of protons, neutrons, and electrons. In other words, atoms are assembled combinatorially. If we were chemists, we might be interested in the properties of atoms as they react to form chemical bonds with one another producing molecules made up of multiple atoms—combinatoriality, again. If we were biochemists, we might be interested in the interactions between large molecules, each made up of many atoms.

Subatomic particles, atoms, and molecules each constitute a different level of complexity. Each level is assembled from the level below, analogous to assembling letters into words into phrases and so on.

Moreover, we can and will extend this hierarchy upward through a number of additional steps, ultimately arriving at human societies. These societies will represent a new level of complexity above individual animals and non-human animal societies. As we discuss these issues, we will sometimes use *level of organization* or *organizational level* as synonyms for *level of complexity*.

Defining levels of complexity is not merely a descriptive or rhetorical convenience. When properly done, this parsing of the world apparently reflects how causality is actually organized in the physical universe.[3] Thus, when we explain the properties of any level of complexity in the universe (for example, molecules) we invoke the properties of the level of complexity immediately below (atoms) and so on and so on. When we go through this process, we are constructing a ***reductionist explanation*** of the level of complexity in question.[4] We will use reductionism and reductionist explanation in this specific sense throughout this book. Our goal will be to construct a reductionist explanation of humans and of human uniqueness.

Reductionist explanations are actually far richer and more powerful than our brief discussion so far would suggest. Indeed, these explanations are the source of all the spectacular successes and profound intellectual beauty of the scientific enterprise.[5]

[*] This word of caution requires another. For reasons we will discuss in Chapter 2 and beyond, we humans habitually see "purpose" in the organization of the physical universe. This is an illusion produced by our "purposeful" evolved minds. It is not a fact about the universe.

Reductionist explanation ***IS*** the scientific enterprise. All the tremendous successes of science, ***without exception***, resulted from the discovery and development of reductionist explanations for ever-increasing portions of the universe and its components. Indeed, many scientists (authors included) would argue that the phrase *reductionist explanation* is redundant. We argue that ***all*** valid explanations are reductionist in the sense above. Equivalently, the phrase *non-reductionist explanation* is an oxymoron, on this view. *Non-reductionist* might be applied to a ***description*** or a ***tautological statement***, but ***never*** to an authentic explanation.*

It is very important to notice one other implication of this story. Not only must scientific explanations be reductionist, they also must be simple and transparent. The simplicity of reductionist explanation results from the fact that the properties of one level of complexity results from a *small subset* of the properties of the level below. For example, the properties of atoms result from a small subset of the properties of sub-atomic particles. Likewise, animal societies result from a small subset of animal behaviors. Reductionist explanations, therefore, remain simple, no matter how complicated the level of complexity they explain.

This requisite simplicity is sometimes called the *front-of-the-tee-shirt rule*. It states that a mature scientific theory should *not only* explain a big chunk of the world (an entire level of complexity, usually) *but also*, it should be simple enough to be written on the front of a tee shirt.

A great example of the front-of-the-tee-shirt rule is Newtonian mechanics—three laws of motion and a single law of gravitation. Each can be written as a simple algebraic equation and all four equations fit easily on the front of a tee shirt. If what purports to be a scientific theory is too complicated for the front of a tee shirt, it is probably wrong outright or, at least, unfinished.

Thus, the point and the beauty of science is simplification. It allows us to find and understand the fundamental simplicity that underlies the superficial, misleading appearance of overwhelming complexity we experience when we first confront some novel level of complexity in the universe. For example, many features of the complicated night sky are explained by the Newtonian mechanics we can write on the front of a tee shirt.

* For example, to say that the wetness of water somehow "emerges holistically" from many water molecules rather than from the aggregate consequences of the individual molecules is a non-reductionist (and non-useful) explanation (Chapter 2). To say that fire results from a fire spirit being chased from the fuel is, likewise, a non-reductionist (non-useful) explanation.

We will find this transcendental beauty and profound understanding yet again, as we build our reductionist theory of human uniqueness. So when a scientist answers the question about reductionism posed in the title of this section "Is that all there is?", she/he will answer, "Yes, but it is a great deal, indeed."

Fear and a theory of humanness

Our use above of the title of Peggy Lee's famous song *Is that all there is?* in relation to reductionism has an additional purpose. It captures the reaction many people (including some scientists) have when first confronted with the prospect of a reductionist theory of humans and human uniqueness. We tend to feel that such a theory would diminish us, make humans somehow less important, less remarkable.

Let us call this the *first fear* of a science of humanness. We have lived with a good reductionist theory of human origins for years. We can assure you that the opposite is true. A clear understanding of ourselves and of our origins only enhances our respect for and wonder at our common humanity. This understanding will emerge for you as you progress through this book.

Another, darker sense of fear is also impeding our progress. This is the fear that an objective understanding of ourselves and our history might somehow undermine our capacity to make humane ethical judgments. The definition of right and wrong might be taken out of our hands. We might somehow be forced to agree that "nature red in tooth and claw" is all there is. This fear is salient to us as we emerge from the 20th Century with its vast atrocities.

This *second fear* is also misplaced. While science is not a direct source of ethical judgments, it can inform them. A clearer understanding of our place in the universe will refine our grasp of our ethical frame of reference. More importantly, a complete biological theory of humanness will define the origins of our worst atrocities much more clearly, arming us to effectively confront and prevent similar events in the future. We will also see that the central point of uniquely human (and humane) cooperation is to raise us above and beyond the endemic violence of the non-human biological world.

Real knowledge is opportunity, here as everywhere.

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Chapter 2
We know what life is – a special case of chemistry

This chapter will summarize what kinds of physical and chemical things organisms actually are. Common properties are shared by all organisms—including human organisms—that we will need to understand.

The selected details we examine will all be very familiar to readers knowledgeable about biology. However, even biological sophisticates tend to forget the material nature of organisms when we think about ourselves. It is important to be reminded.

For non-biologists, this elementary information may seem both difficult and esoteric at first glance. It is neither. It is simple to grasp if you invest a little effort and thought. Moreover, it is central and vital. We cannot understand human uniqueness without this foundation.

Our goal is to define the reductionist, materialist explanation of the **individual** *organism. This picture will show us the important properties of the level of complexity immediately below the level of social interactions* **between** *individuals. We will come to the powerful, but surprisingly simple logic of these social interactions, in turn, in Chapter 3. In Chapter 4, we will see how this logic of social behavior applies specifically to us as humans.*

Ours is a "chemical" world

Ours is a most unusual planet. The contemporary Earth (Mark II) and our Moon apparently arose from a spectacularly improbable collision between Earth Mark I and a planet sometimes referred to as Orpheus. Together with the unusual chemistry of our solar system, this collision created a planet that may be unlike any world anywhere in our galaxy or even in the entire universe.[1]

This incredible story has two implications. First, we probably own the galaxy and, possibly, the entire universe. Understanding ourselves takes on a new urgency in view of this insight. Second, all Earth's organisms, including you and the authors, are the products of this unusual planet. Our task, at the moment, is to take only from this story those details we need to understand the unique status of humans among Earth's progeny.

We are chemical systems, chemical children of the improbable chemical and physical system, Earth Mark II and its

Moon. To understand this story we need to recall briefly a few of the details of what we mean by the word *chemical*.

Most of us know that chemistry emerges from the combination of three sub-atomic particles to form what we call atoms. The diversity of atoms in our world is produced in the same way the diversity of English words is produced with an alphabet of merely twenty-six letters—combinatoriality (Chapter 1). Specific combinations of protons, neutrons, and electrons generate specific atoms with specific and predictable chemical properties. More than one hundred types of atoms are known, each with its own set of chemical properties. The same simple combinatoriality produces them all.

Of course, if our focus were the reductionist explanation of chemistry, the many interesting details of this story would be important to us. However, our focus is on the next-highest level of complexity, organisms as a specific class of chemical system. Thus, only a small subset of the properties of the chemical level of complexity need concern us.

First, the chemical properties of atoms result from the interactions of the outer layer of atoms (their outer electron shells) with one another. These properties of atoms allow them to bond with one another by sharing electrons.

Second, many atoms can simultaneously form bonds with two or more other atoms, allowing the formation of large chains and complex networks of atoms. When this happens, stable large aggregates of atoms called molecules can be produced.

Third, molecules can interact reversibly with one another through weak chemical bonding between combinations of their atoms, allowing one molecule to influence the behavior of another on a hit-and-run basis. The rules for these interactions also emerge from the behavior of electrons and are reasonably well understood.

Most atoms in our everyday world are in molecules (or molecule-like solids). The details of sharing electrons within these molecules determine how they absorb or transmit or reflect light, how easily the solids they form bend or break, whether these breaks form smooth or rough surfaces, how well or poorly these solids conduct heat or light, whether copies of the molecules dissolve in the air or in saliva and interact with our smell or taste receptors, and so on and so on. All the properties of the world we experience are inherently chemical.

Do not be distracted by the seemingly ***endlessly diverse, yet mundane*** character of the "stuff" of our world—the smell of coal tar, the hardness of ice, or the color of dirt, for example. Our understanding of these things is reductionism at its best, and most elegantly beautiful. The way our physical world looks, tastes, feels, and smells is ***entirely determined*** by the properties of its component molecules, whose properties are ***entirely determined*** by their component atoms, whose properties are ***entirely determined*** by their component subatomic particles.[2]

Moreover, at each of these levels, complexity emerges simply, combinatorially. All the properties of ice or dirt or organisms are ultimately and completely determined by the properties of combinations of multiple copies of *only three subatomic particles*.

Pause and reflect on this for moment. Allow yourself to "get it." Even to professional scientists long inured to them, these facts about our world are utterly shocking, and perfectly satisfying.

The "youth" of Earth Mark II – chemistry on a "gifted" planet

If life is just a particular case of chemistry, just exactly how did it arise on Earth Mark II? In fact, we have known the answer in a very general sense since Darwin and many investigators have contributed important additional insights in the ensuing century and a half. However, the molecular revolution in biology over the last two generations has spectacularly improved our understanding of the *details* of this story.[3]

During the gestation and birth of our particular solar system, heavy atoms were relatively abundant (including carbon, nitrogen, and oxygen among others). Radiation from various sources, including the dying stars that ejected the matter into the cloud that would ultimately form our solar system, drove many chemical reactions in this material. Atoms reacted to form molecules of many, many types.

All this chemistry produced enormous quantities of what we will call *small molecules*. These molecules contained atoms numbering from two to around twenty or thirty in the cases that will concern us. Moreover, some of these small molecules were produced over and over.

Once this material rained onto the surface of the young Earth Mark II (probably mostly from the comets that also delivered some of the water in our oceans), it formed a massive chemical system undergoing more and more chemical reactions.

There were probably so many of these molecules during the youth of our planet that they turned the ocean into a soup containing the water-soluble members of this group. Moreover, a truly stupendous "oil slick," containing the less water-soluble (oil-like) small molecules, covered this soup. This pan-global oil slick was probably many feet deep!

The young Earth Mark II resembled a planet-sized French onion soup.* This planetary soup contained uncountable billions of copies of the most frequently cooked up small molecules.

Of all the billions and billions and billions of chemical reactions of the young Earth, almost all are completely irrelevant to us here. However, a tiny, tiny fraction produced a very special class of molecules. These molecules were *polymers*—many-mers. They were long, linear strings of several similar (but subtly different) small molecules, like pop-beads of different colors making up a long linear chain. Each bead is referred to as a monomer—a one-mer. These molecular beads were joined to one another by a single chemical bond between one atom in one of them and another atom in the other.

The monomers of these polymers were among the more abundant of the small molecules present in the original planetary soup. In fact, many trillions of trillions of polymers of this general type would have formed and been destroyed in the volcanic heat and solar radiation churning the oceans of the young Earth Mark II. But, again, almost none of these polymers matter to us except one (literally one!). This one we will call the Universal Parent.

The Universal Parent was different from all the billions of billions of other polymers in the planetary French onion soup of the young Earth Mark II, in ***only one*** respect. Its chemical structure allowed it to fold up into a small molecular "machine" that could recruit from the surrounding soup other copies of the monomers that made it up and assembled them into new copies of itself.†

In fact, the Universal Parent probably did this by treating its own sequence of monomers as a guide or template to making new copies. In practice, a growing linear copy of the Parent was aligned with the sequence of the Parent molecule itself and each new monomer was added to the growing copy by virtue of its interaction with the corresponding monomer on the Parent polymer. We will call this particular kind of machine a *polymerase* because it promotes the formation of new polymers. Notice that the sequence of the new polymers produced by this

* Actually, this analogy is a little wide of the mark gastronomically. In reality, the toxic emanations from all of this cookery would probably have killed us rapidly. The young Earth Mark II was the ultimate "Super Fund site."

† Two pieces in the popular periodical *Scientific American* summarize some of our current picture in accessible form. These are R.E. Dickerson's 1978 piece (volume 239, p. 70) and Tom Cech's 1989 piece on RNA "organisms" (volume 255, p. 64).

polymerase is determined or controlled by the sequence of the parental polymer that is being copied.*

This original Universal Parent molecule would eventually go the way of all flesh. It would have "died" by being destroyed in some random chemical event—cooked when it wondered too near a super hot deep-ocean volcanic vent, perhaps. However, as long as it sent off at least two copies of itself (molecular driftwood in a planetary ocean) before its demise, it was "alive."

The Universal Parent was able to do this through the simple chemistry we alluded to earlier. The details of this chemistry are sufficiently complex that only a very, very rare polymer has the structure to fold into a machine that will carry out the necessary chemical step, as we said. However, once this molecule is accidently formed it will take over the world, inevitably. Indeed, it will leave uncountable descendents over billions of years, including maple trees, race horses, the HIV virus, and us.[4]

The Universal Parent will make copies of itself. These copies will inevitably contain errors occasionally. Most of these errors are irrelevant, but a tiny few improve the performance of the Universal Parent, making it better. These "better" derivatives will make new copies of themselves more efficiently (by definition), taking over Earth's oceans at the expense of less efficiently replicating sequences that will lose out.

The process we have just described is referred to as *natural selection*. It is sometimes also called *Darwinian selection* (after Charles Darwin, of course). Since the new versions of a replicating molecule produced by this process are different from earlier ones, change produced by natural selection is also often called *evolution*.

Over hundreds of millions of years, many, many cycles of evolution by natural selection produced increasingly complex descendents of the original Universal Parent molecule—ultimately, four billion years later, including you and us. A few additional details of these later-version chemical systems (like us) are important to our quest.

* Readers sophisticated in how molecular copying works in contemporary organisms will recognize that this description is over-simplified in several respects. However, it captures the parts of the process that are important for us here.

The chemistry of Earth Mark II grows up – complex chemical systems are vehicles for replication of design information (organisms)

The billions and billions of cycles of natural selection since the first Universal Parent approximately four billion years ago have produced the complex chemical systems we think of as *organisms*. The original Universal Parent arose by accident and would have been very inefficient (by our standards) at making new copies of itself. However, natural selection would have relentlessly improved these capabilities in the descendents of the Universal Parent. By looking at the chemistry or molecular biology of contemporary organisms, we can infer a great deal about how this process actually happened.

First, the original Universal Parent molecule probably recruited Partner polymer molecules forming multipart machines, through the action of natural selection. These Partner machines would have promoted other chemical reactions useful to the Universal Parent and to other Partner polymers. For example, one Partner molecular machine might have promoted a chemical reaction that produced new copies of the monomer components of the polymers from other small molecules in the planetary French onion soup.

This process of adding useful new Partners would eventually produce a relatively sophisticated "team" of molecules. We can call it the First Team. The First Team would have taken over the Earth's oceans by natural selection, displacing descendents of earlier, simpler teams.[*,5]

Second, because the members of the First Team were all copied or replicated by the same chemistry as the parent, their structure was constrained. They could only use copyable monomers. These are monomers that could be recognized by the copying process the Universal Parent polymerase was designed (by natural selection) to carry out. This property severely restricted the range of functions these molecules could take on.

Thus, a new trick was ultimately "developed" by the blind process of natural selection. Descendents of the First Team "learned" to make tools from other, very different kinds of monomer units. These new Derivative Tools were not copied directly by the Universal Parent polymerase. They were built secondarily by some of the First Team polymers.

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[*] In fact, formation of these teams of molecules creates a conflict of interest problem (Chapters 1 and 3). The policing of these conflicts of interest evolved early in the history of Earth's first organisms, but the details of these molecular law enforcement mechanisms will not concern us here. See Bingham, 1997.

Building these new Derivative Tools required the solution of some formidable chemical engineering problems. However, the "cooperation" of the multiple different members of the First Team—modified by natural selection—made this result possible. Indeed, the solution invented by natural selection was beautifully elegant. We know because you and we have inherited this solution. Its processes are still going on in our bodies as we speak, building the new copies of Derivative Tools that we need to stay alive from moment to moment.[6]

Third, after invention of superior Derivative Tools, continuing rounds of natural selection increasingly reshaped the descendents of the First Universal Parent Team and its set of structurally similar Partner polymers. Now most of the Partner polymers no longer acted directly to carry out machine functions necessary to replicate themselves. Rather, they merely encoded the instructions for building the new Derivative Tools. These new Tools took over the various necessary machine functions, and they did them much better. These new tools, thus, carried out nearly every chemical process directly necessary for replication of the Team. Ultimately, even the polymerase copying or replication function of the original Universal Parent, itself, was taken over by one of these newer Tools.

The descendents of the First Team polymers were now reshaped by natural selection to act virtually *exclusively* as the reservoir for storage and replication of the instructions for building the new Derivative Tools. We will call this descendant team the Mature Team.

This picture puts us in the position to define a term that will be very useful from here on. We will call the instructions for building the advanced Derivative Tools *design information.* Again, this design information is encoded in the sequence of monomers in the Mature Team polymers.

Now we are ready to give an initial reductionist definition of a *living* or *biological* organism. It is a chemical system (descended from the Universal Parent and the First Team through the Mature Team) that consists of ***design information*** chemically encoded in the sequence of monomers in a specific class of polymers. This encoded information has two properties, and two properties *only*. It can be chemically replicated and it chemically produces chemical ***tools*** that assist in that replication. For reasons that will become clearer in a moment, it will be useful to call the physical object consisting of the design information plus all its tools a *vehicle*.[*]

[*] To borrow Richard Dawkins' pithy term from his seminal 1976 book *The Selfish Gene*. Also see Dennett (1995) for a lucid, engaging discussion of these fundamental issues.

That is it. This is a complete description of every organism that ever lived on Earth. including you and us. We all are descendents of the original Mature Team. We have inherited the properties of the Team, including its design information and its tools. We all are vehicles built by design information.

When we look in the mirror, we see eyes, a nose, skin, hair. All of these parts are mostly made up of different sets of Derivative Tools encoded by the remote descendents of the original Mature Team that make up our human design information. These Derivative Tools are, in fact, ***protein*** molecules. Each polymeric piece of design information (descended from a member of the Mature Team) building such a tool is a segment of a polymer (***DNA***) making up a human ***gene***.

We are built by design information encoded in approximately twenty-three thousand such design-information-encoding polymers (genes) making up the *human genome*.[*]

Each of these genes or pieces of design information is still copied today by a process that makes occasional errors. In contemporary organisms, these errors are referred to as *mutations*. Mutations introduce new changes called *variation* into the copies of design information in a population of organisms. Natural selection acts on this variation to produce evolution in contemporary organisms just as it did long ago in the case of the Universal Parent, the First Team, and the Mature Team. Some versions of the variable design information replicate themselves better and take over their world while others are lost in this inevitable competition, now and always.[7] All organisms alive today (including us) have been shaped by about four billion years of this process.

What are we seeing in the mirror? Combinatoriality and complexity

When we look at ourselves in the mirror, we seem to see so much more than just an elaborate chemical system. We see a *person*—something living, feeling, thinking, believing, hoping. We feel that we cannot merely be a set of chemical processes shaped by blind natural selection. Yet, we have an overwhelming body of evidence that such a chemical system is just exactly *and completely* what we are. There really is not any more doubt about this fact than there is about the claim that the Earth is (roughly) spherical rather than flat.

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[*] See *The Molecular Biology of the Cell*, *5th ed.* (Alberts et al., 2008) for a good basic description of these molecular details of contemporary organisms—the surviving descendents of the original Mature Team.

So why are our intuitive impressions of ourselves so different and so much more richly evocative than our abstract, reductionist understanding of what we are? It is impossible to understand the evolution of organisms, including the evolution of their social behavior and the *unique* social behavior of human animals, without first answering this question. Our goal in this section is to find this answer and to begin to gain the intuition we need to be able to look at organisms (including ourselves) as chemical systems in a crowded world.

One of the reasons this picture is so intuitively challenging is that the complexity of organisms results from many layers of combinatoriality (Chapter 1). Small molecules make large, but simple linear polymers called macromolecules. Small numbers of these macromolecules make molecular machines and functional bits of cells (sometimes called organelles). Small numbers of machines and organelles make cells. Moreover, we can make a number of different kinds of cells by using somewhat different subsets of the molecular machines our design information can make. In turn, small numbers of different kinds of cells combine to make functional tissues, muscle fiber, or lung epithelium, for example. A few tissues make an organ and a few organs make a *system* like the digestive or circulatory systems. A set of organ systems makes a functional organism. That is it, that is all there is.

Organisms look complicated to us for the same reason a Maserati streaking along the autobahn looks complicated if we are not mechanically sophisticated. If we do not understand how spark plugs, fuel injectors, transmissions, and so on are assembled beneath the skin of the Maserati, the contraption looks like magic. Of course, it is not; it is just mechanics. Likewise, beneath the skin of an organism, it is just chemistry.

Needing time to get used to ourselves as chemical systems that have grown complex through multiple layers of combinatoriality produced by the blind, material process of natural selection is one large part of why our reductionist view of ourselves seems subjectively inadequate. We will gradually overcome this problem as we proceed through the book. However, there is a second hurdle to our intuitive understanding of reductionist interpretations of organisms. The following section will let us begin to deal with this problem.

Matter and mind – how our nervous systems "understand" the world

Hidden layers of combinatoriality make it difficult for us to understand what we are. However, the way our minds interact with the world is another reason we have trouble accepting that maple trees and human beings are simply chemical systems. In fact, we encounter this problem every time we undertake a reductionist explanation of *any* part of the world. So let us first understand how our minds see the simple chemical and physical world around us and then return to what we see and how we feel when we gaze into our own eyes in the mirror.

Think of a piece of charcoal and a segment of copper wire. Visualize how they feel when you bend or crush them with your hands. Imagine the dry flat taste of the charcoal and the sharp metallic tang of the copper wire. The appearance and behavior of these two objects are very different. We know intellectually that they are both just solids containing many different copies of the same single simple atom chemically bonded in enormous arrays—carbon and copper atoms, respectively. Their differences result from the way electrons are shared between atoms of the non-metal, carbon, and the metal, copper. However, we have the strong intuitive feeling that this explanation is shallow, incomplete and, perhaps, even trivial. It seems to fail to capture what we most intensely experience about these two objects. It lacks subjective juice, it does not give us the look and feel, the essence of copper or charcoal.

Ironically (and beautifully), there is an excellent reductionist explanation for why reductionist explanations do not give us complete subjective satisfaction. Our minds are biological (chemical) devices designed by natural selection to interact with the world in ways that contribute to our individual survival and reproduction—ultimately, for the "purpose" of getting our design information replicated. Thus, one of the most important things our minds do is to give us the greatest possible capacity to discriminate between different useful (or dangerous) parts of the world.

However subtle the differences between two different physical substances might be in some objective, cosmic sense, our minds are designed to detect and amplify those differences, if they matter. Our minds have super *image analysis/contrast enhancement* capability, so to speak. They present a subjective world of sharp contrasts to us, because that is what works best from the point of view of natural selection.

When we construct detached, analytical, reductionist explanations of this contrasty subjective world, these explanations seem pallid by comparison. Thus, our subjective dissatisfaction with reductionist explanations is not due to their inadequacy. Rather, this unease comes from the distortion and exaggeration our subjective minds impose on an otherwise simple world.

Another example that might help is water. Individual water molecules consist of two copies of the hydrogen atom and one of oxygen. Strong chemical bonds hold together these three atoms in a water molecule formed by robust sharing of electrons.

Because of the way electrons are distributed between these oxygen and hydrogen atoms *within* a water molecule, water molecules also form weak, transient chemical bonds with other water molecules—the hydrogen of one water molecule forming a weak bond with the oxygen of another.*

If we remove enough heat energy (molecular motion) from a collection of water molecules, the molecules stick together stably through these weak interactions, forming an orderly lattice we experience as ice.

If we add back a little heat energy to the ice, the molecules move a little more rapidly. At any moment in time, some of them are stuck together in tiny ice-like aggregates of a few molecules and others are broken loose from their neighbors. These little moving aggregates form and break very rapidly, exchanging members like the people moving between the small groups in a large, complex square dance. This produces what we experience as liquid water.

As we add yet a little more heat energy, individual water molecules move still more violently, breaking completely free of one another. This is steam.

These are the element of the reductionist account of water. How does this picture square with our subjective experience? It is sometimes argued that this reductionist explanation of water must not be complete because its fails to explain things like the wetness of water—the way it looks and feels when we wash our hands, for example. Such supposedly unexplained properties are said to be *emergent*, to evade reductionist explanation.

At first glance, this objection to reductionism sounds right. Thinking of water molecules forming highly dynamic little aggregates forever trading members seems a long way from the look and feel of liquid water on our skin. However, before we

* These weak bonds are different than the strong bonds *within* the water molecule. These weak bonds are a little like the static electric bonds that holds your socks to your shirts as they come out of the drier.

take this objection to reductionism very seriously, stop and remember what our minds are designed to do. They are designed to present a sharply defined picture of what is important to our (chemical) survival.

With this in mind, notice water's importance. It is an essential component of our world. We need water as the solvent in which almost all our internal chemistry occurs. Indeed, when you step on the bathroom scale, most of what you are weighing is all this necessary water throughout the cells and tissues in your body.

In addition to this internal role, water is an extremely important element of the external world navigated by our bodies. For example, water has a very high heat capacity; so it is important for us to drink it when we are over-heated and to avoid it when we are cold.

Thus, our minds are designed to generate a highly engaging internal image of water—to produce a multimodal sensory blitz when confronted with water, particularly liquid water.

The existence of this rich subjective cocktail of image and sensation produced by the chemical device of our minds hardly constitutes meaningful evidence that a reductionist explanation of water's properties is inadequate.

When you hear arguments in the future about things like the supposed *emergence* of the *wetness* of water (and the ostensible incompleteness of reductionist explanation), ask the following question. *Do the supposedly emergent properties pop up precisely at the interface between the world and the human nervous system?* We find that they usually do and we predict you will too. Objections to reductionist explanation based on this interface are quite unreliable and very likely wrong.*

Now we can return to our reductionist explanation of the more complex physical objects represented by organisms. Other organisms (potential competitors, cooperators, mates, predators, prey, or parasites) are among the most important objects in our individual personal universes—as chemical systems (organisms) surviving in a crowded, competitive, *Malthusian* world.†

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* Of course, our argument here leaves us with the ultimate obligation to construct a fully reductionist explanation of the functioning of the subjective minds producing these intense subjective images of the external world. At the moment, reductionist explanation of all the properties of our minds is still incomplete; however, we know enough to believe that one will ultimately be forthcoming. Moreover, we know a number of useful things about minds that we will return to in later chapters.

† The crowded, competitive worlds that organisms inevitably occupy are called *Malthusian*, after Thomas Robert Malthus, the 18th Century thinker who first

Thus, we expect our minds, as shaped by natural selection, to construct rich and highly evocative subjective pictures of these other organisms and of our own bodies.

This feeling of recognizing some unexplained aliveness in ourselves and other organisms is just like the feeling of the wetness of water. It is a subjective effect produced by our minds—minds well designed by natural selection to contend with our world.

Information and purpose in our world

An organism is a chemical system, built by design information and capable of replicating that design information. It will be convenient to continue to use Richard Dawkins' term for this kind of chemical system. We will call it a *vehicle*. This term evokes just exactly what we need to keep in mind about organisms.

Vehicles that are alive today for us to find are the surviving descendents of those ancestral vehicles who were successful in leaving progeny in their crowded, Malthusian world. How do we expect such "winning" vehicles to behave? Such a successful vehicle will be good at making new copies of itself. Indeed, that is the reason (the ***sole*** reason) it wins this competition. There is no other criterion for victory in this arena than existence—and no ticket to individual existence in a Malthusian world other than successful replication by one's immediate ancestors. It could not be any simpler.

Thus, a surviving vehicle is inevitably "designed" by blind natural selection, acting on the design information in its ancestors to make copies of itself very efficiently. As a matter of fact, chemical vehicles are shaped by natural selection so that they appear to have one "purpose"—making new copies of themselves. This is true of all organisms, even a virus with no mind to feel purpose. Our use of the word purpose for any vehicle's behavior is, thus, strictly metaphorical. Purpose in this sense is entirely self-referential and internal to chemical replication in a Malthusian world.

Nevertheless, this metaphor of purpose is a perfectly complete and accurate *de facto* description of the *behavior* of biological vehicles. It is so powerful that we will use the word

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popularized the universal tendency of organisms to overgrow their living space over time. Notice that each organism produces copies of itself (offspring). *Each* of these offspring produces multiple copies of themselves, and so on. Thus, biological organisms grow in numbers explosively over multiple generations. They always fill their world to its limits to sustain them and this will happen rapidly, no matter how small the organism or how big the world.

purpose in this sense—never forgetting, however, that it is just a metaphor, another subjective illusion like the wetness of water, strictly speaking.*

We can generalize this argument. A living organism is a chemical vehicle built by chemically encoded design information. The sole purpose of the vehicle is chemically replicating that design information.

This is an incredible level of insight into the biological world. We really do understand just exactly what organisms are and what they are not. We know why they exist and what their properties are expected to be.

As we mentioned, fully assimilating this dramatically simple, powerful insight takes time. If this picture of a living organism is not already familiar to you, be patient. You will gain deeper insight gradually as we proceed. Indeed, even if this level of understanding of biology *is* familiar, the relentless subjective minutia of our everyday lives pulls our focus away from this insight. We are constantly seduced and harassed into experiencing the world *only* through our richly evocative subjective minds rather than *also* through our detached analytical minds.

We will return throughout the book to strengthen and enrich the analytical view of ourselves. True self-understanding absolutely demands it. We will find over and over that this view contains the power to enrich our comprehension of what it means to be alive and *what it means to be human*.

Keep your eye on the information

Consider the following facts about us. First, the design information that built you and us was inherited as a single copy of each human gene from our mothers and a second copy from our fathers, as we will see in more detail in Chapter 3. These molecules then made many billions of copies of themselves as we grew and developed—one copy in each of the cells making up our bodies. Moreover, design information molecules in our bodies are constantly vulnerable to chemical damage of many sorts such as UV damage from sunlight on our skin, to name one of many. These molecules require constant repair to remain intact.† This repair involves replacing damaged polymer

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* The astute reader will wonder how we know that our own subjective mental sense of purpose as human beings is not just as illusory and metaphorical as that of the original First Team. This is a most interesting question, indeed. We will return to it in later chapters.

† This design information is stored in the sequence of monomers in the polymeric molecule DNA in contemporary organisms like you and us.

segments with new ones. Material excised from a damaged segment of design information is recycled, ultimately being released into the surrounding environment (in our urine, for example).

The upshot of all of this is that the original DNA molecules we received from our parents at the moment of fertilization are long gone. The particular atoms that made up those specific molecules are now spread around the world. Some of these original atoms, no doubt, are floating in the ocean and the atmosphere. Others, might, perchance, be a part of a rabbit, an oak tree, the Prime Minister of England or the Secretary General of the UN.

We have ***not*** inherited atoms and molecules from our parents. Rather, we have inherited information. It just happens to be encoded in disposable molecules.

Second, we each have many memories from our decades of life to date. For example, Paul remembers being drenched by water as a four-year-old in the process of discovering the principle of the siphon (using a hose and a rain barrel). You have your own set of such memories. If we could go back and magically label each of the atoms in the body of the four-year-old Paul, we would now find that very few of them remain. They have all been dispersed around the planet after being exhaled or excreted from his body. They have all been replaced by the molecules from food Paul has eaten during the relentless repairing of damaged molecules and cells in his body over the last fifty odd years.

Yet…the memories remain. Memories are information stored (somehow) in our nervous systems. This system is repaired and maintained in such a way that information is retained while physical substance is replaced.

Both of these examples illustrate something very important. Our minds are designed to keep us alive in the physical world. So the material substance making up our bodies at any particular moment is highly salient and precious to us. We must protect this body if we are to survive from moment to moment.

This creates another of the subjective illusions to which our biological (chemical) minds are so prone. We see ourselves as these physical objects, our momentary bodies. In fact, however, what makes you *you* and us *us* is ***not*** this transient physical substance. Rather, we are really the information *encoded*

Moreover, DNA molecules are *double stranded*. This redundancy allows repair of one damaged copy of the design information (one of its strands) by templating that repair on the remaining, undamaged copy (the other strand).

in the parts of our physical bodies. In a very fundamental sense, we are informational objects, ***not*** material objects.

This is a profound fact about biology to which we will return again and again. BIOLOGY IS ABOUT INFORMATION—KEEP YOUR EYE ON THE INFORMATION.

How does all of this insight help us?

We apparently really do understand what organisms are. They are a specific class of chemical systems. Organisms are chemical vehicles built by chemically encoded design information for the "purpose" of chemically replicating that design information in a Malthusian world. This insight is one of the most monumental achievements of the human knowledge enterprise. It is staggering in its power and elegant simplicity, in its parsimony.

So what? Our purpose in this book is not to understand how all organisms are alike. Rather, it is to understand how one of them, we humans, got to be so different. Does this reductionist picture of organisms help us?

It does—in spades. We will see later that the fundamental thing that makes humans different from all other organisms, the thing that ultimately produces the entire suite of unique human properties, is how multiple individual non-kin human vehicles interact with one another. In other words, what is most fundamentally important and unique about us is our social behavior. But, why is the social cooperation of animals even an issue?

The picture we have just built of organisms lets us answer this essential question, right here and right now. Consider how two different vehicles who are members of the same species are expected to behave toward one another—two lions, for example. They live in a crowded, Malthusian world. They compete for the limiting resources they both need for successful replication—the *same* limiting resources, *inevitably*. What should their attitudes toward one another be? Hostile. The life or replication of one will often come at the expense of the other.

Our reductionist picture thus predicts competition—sometimes even fierce conflict—between members of the same species. As we will shortly see, this really is how most organisms behave most of the time, when they are not simply avoiding one another out of *anticipation* of hostility.

However, there are exceptions. A very select subset of members of the same species sometimes fails to compete. They may even actively cooperate. This cooperation between different individuals allows a new level of functional adaptive sophistication very analogous to the increased adaptive sophistication the Universal Parent achieved by cooperating with various Partner molecules.

Thus, social cooperation between animals is a new level of complexity in the biological world and it is very important. To proceed from here we will need to understand when, where, and how non-human animals cooperate or do not cooperate. In Chapter 3, we will find that there are some beautifully powerful and simple answers to these questions. Moreover, in Chapter 4, we will find that we humans also often (but not always) play by these same universal animal social rules.

With these insights in hand, we will find (in Chapter 5 and beyond) that we have the final pieces we need to understand how humans went on to build something ***new***. We humans added a fundamental new level to the rules of animal social cooperation. We retained the patterns of social cooperation that non-human animals have ***and*** we added, *on top* of these, a fundamentally new human pattern. This additional pattern of social cooperation, in turn, revolutionized the way we human vehicles pursued self-interest in a Malthusian world. This new human trick changed the biological world of Earth forever. This human *revolution* will be our focus from Chapter 5 throughout the remainder of the book.

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Endnotes

Numbered endnotes in text can be found online at
www.deathfromadistance.com

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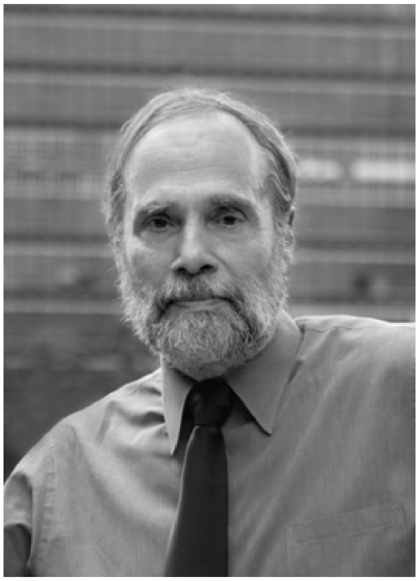
About the Authors

Paul M. Bingham earned his Ph.D. from Harvard University in Biochemistry and Molecular Biology, where he also continued to develop his fascination with fundamental unanswered questions about how humans evolved. During his 27-year career on the faculty of Stony Brook University, he has continued to explore human origins while also contributing to fundamental cell and molecular biology, including the discovery of the P element transposon and new approaches to cancer therapy.

Joanne Souza is a successful business industry consultant in health & education trained by AT& T and a faculty member at Stony Brook University. She earned her BA in Psychology, summa cum laude, from Stony Brook University, receiving a Recognition Award for Academics & Research and the University Award for Senior Leadership & Service. In the last six years she has continued to pursue her life-long research interest in human behavior, evolution, and history while earning a Masters of Science in Psychology from Walden University.

Photos courtesy of Christina Luciw