CHAPTER 1

Science, Evolution, and the Human Lineage

"Nothing in biology makes sense except in the light of evolution."
[Dobzhansky, 1973, *American Biology Teacher* vol. 35]

Science and the search for our place in nature. Where did we come from? How did we become the way we are today? These are among the most profound of human questions — common, it seems, to all cultures. Before the rise of science, answers to such queries could only be imagined, resulting in a dazzling display of creative myth-making which often invoked the activities of one or more supernatural beings. After the emergence of biological science about three centuries ago, a new way of thinking about these questions began to gain currency. It too involved creativity, but in a manner that was constrained by an emphasis on evidence and verifiability.

Science is a method for learning about the world and our place in the universe. It yields explanations and answers from reliable evidence, rather than assertions from ancient books or opinions of modern authority figures. (Miracles and super-powers are excluded from its deliberations). Instead, by careful observation and experiment, scientists have discovered that underlying the bewildering heterogeneity of the natural world there are a number of general operating principles, such as the laws of physics and chemistry. Science is humanity's most dependable, cumulative method for comprehending reality. It gives a valid description of the way objects interact with each other and how they change from one form to another [Koch, 2012].

Biological laws are required to account for the workings of living creatures, which are much too complicated to be explained by physics and chemistry alone. The unfathomable complexity of living systems (millions of molecules of thousands of different kinds in every living cell) delayed the discovery of biological laws. The fact that living organisms are either cells or made of cells was not revealed until 1839. Twenty years later the greatest of all biological laws was identified: all life on earth — past, present and future — stems from a natural process of evolution [Darwin, 1859]. Now upgraded to a theory, Darwin's concept of evolution is the foundation of biological science. Modern biologists heartily agree with Dobzhansky [1973], whose famous observation is stated in the epigraph above. It is largely within the domain of biology that answers to the age-old queries about human origins and evolution have been profitably examined, with major advances having been made in the last few decades.

Origins and evolution. This book addresses two linked issues: How did the human lineage get started and what happened next? I approach these topics using a new explanatory principle (based on Darwin's theory) which accounts for human origins, covers millions of years of human evolution, sheds light on the numerous ways our bodies changed during that transformation, and accounts for many features of our current anatomy and its related behavioral innovations.

Some important aspects of our evolution remain outside its scope: the rapid brain enlargement that took place late in the human saga, spoken language, social behaviors, and the cultural florescence in *H. sapiens* are left in the dark. However, its explanatory range is considerable, extending from rotation of the pelvis to the opposable thumb, from bipedalism to the orientation of the shoulder joint, from the ontogeny of throwing to the redesign of canine teeth, from unique handgrips to more massive legs, from diminution of the forearm to unprecedented motor patterns stored in the brain. It explains how and why our ancestors diverged from the apes, why they abandoned the trees, how they obtained meat, and provides a rich source of predictions. In addition, this new explanation is explicitly Darwinian. I have labored relentlessly throughout the book to construct an explanation of the evidence that is based on modern Darwinism.

Evidence and explanation. Scientific evidence consists of entities or processes that can be verified by other scientists. Such confirmable information is also called empirical or objective evidence. It is objective (not subjective) because the scientist's wishes and opinions are eliminated insofar as is possible by use of measuring devices and analytical techniques to examine the item of interest. Objective evidence represents the foundation of science. In the case of early human evolution it consists primarily of fossilized bones and teeth.

A particularly interesting question regards the *significance* of the evidence. What does the accumulated evidence *mean*? Scientists begin the quest for understanding by searching through the facts (verified units of evidence) for regularities. This can be done objectively (for example by statistical analysis), but eventually the only way to comprehend the meaning of evidence is through human intervention: the creativity and insight of the human mind must be applied to make sense of it. The ultimate goal of science is not simply more evidence, but *explaining* the evidence as completely as possible in the simplest manner. Only a very parsimonious explanation of a large body of evidence is worthy of the term "theory". A theory represents the highest level of scientific explanation attainable. In contrast, a "hypothesis" is commonly an impromptu explanation for a particular observation. Sometimes these terms are misused, or used interchangeably, even by scientists — but not by this one in this book!

In the following chapters I will review the evidence for human origins and evolution, examine earlier explanations of the evidence, and then present a new explanatory structure which (I assert and demonstrate) explains the largest body of evidence in the simplest manner — and as an added bonus can be *tested*. The nature of explanation, hypotheses and theories is treated at some length in Chapter 16. Because my explanation is explicitly Darwinian, before plunging into our evolutionary history, I will describe what I take to be the essence of modern Darwinism.

Darwinian evolution and genetics. Today, 150 years after the publication of Darwin's masterwork, *The Origin of Species* [1859], his bold and fertile theory has been so thoroughly documented, verified and confirmed that the notion it might some day be replaced is no longer seriously entertained. That is why some scientists say "it's not just a theory, it's a *fact!*" (By this they mean it is irrevocably established. Facts and theories are not synonyms).

Darwin's theory has been fine-tuned in the decades since 1859, although its basic structure remains intact. Not only has accumulated evidence indicated that Darwin's insight was correct, it has also provided enhanced understanding of how evolution works, enriching the substance of his insight. Today the theory is expanded, improved and more intellectually satisfying than the original. The science of genetics, missing back then, has become a central element of modern Darwinism. It identifies the units of inherited information, the *genes*, which embody sets of instructions coded in DNA molecules. The genes provide continuity from one generation to the next, as individuals are born, reproduce and die. In Dawkins' classic metaphor [1976], each individual is a transitory vehicle, transporting its genes for a while, then passing them on to the next generation.

In this book I employ the word "genes" as shorthand for the inherited elements of living beings, including gene alleles (different versions of the same gene). Sometimes genes control other genes. There are complex networks of regulatory regions in the DNA which turn genes on and off or alter their activity. Rearranging the position of genes may also modify their expression patterns. Alternative splicing may lead to multiple proteins being coded by a single gene. Some genetic differences are due to extra copies of a gene, others to gene loss. New genes are occasionally created, often by copying errors, but these mutations occur by chance, not design. They bear no relation to what might be useful to the organism then or in future generations. While in the long run evolution depends on mutations, it can also draw on novelties provided by recombination, chromosomal rearrangement and other DNA copying errors.

In 1974 Hull wrote that the effort to reduce Mendelian genetics to molecular genetics had not been very instructive. Today, the concept of the gene at work in evolution still cannot be systematically related to what the molecular biologist studying nucleic acid structure calls a gene. I use the term to indicate the hereditary units whose changing frequencies underlie evolutionary change. The *genotype* comprises the inherited instructions in an individual's genetic code, the *genome* is the total of all genetic material in a species, and the *phenotype* encompasses the traits that emerge during development as the information in the genes interacts with environmental influences such as nutrition.

Natural selection. Darwin's great discovery, natural selection, is the essential causal process of evolution. Natural selection usually acts at the level of individual organisms, based on heritable phenotypic properties that are linked to reproductive success. Selection occurs when organisms reproduce. Those who produce more offspring transmit more copies of their genes to the next generation: their genes are naturally selected compared to the genes of those who produce few descendants or none at all. In this way a population, over the generations, comes more and more to resemble the individuals who reproduce most frequently. The population evolves as gene frequencies change due to differential breeding of individuals. Phenotypic variation due to underlying genetic variation is a prerequisite for evolution by natural selection. (If every individual had exactly the same genes, no evolution would occur). A casual look at our own species shows that there is plenty of inherited variability to work with: height, weight, muscularity, athleticism, skin and hair color, and many other traits "run in families". Some of these attributes provide an advantage to those who inherit them, yielding enhanced likelihood of survival to reproductive age and a greater chance of reproducing successfully and often.

The effect of environment. The "environment" is the context in which development or evolution occurs. It encompasses any factor outside the individual that may affect its well-being. Nutrition is an important aspect of the environment that influences growth, development, and reproductive success.

Climate is another environmental factor. Local environments change constantly (for example by growing colder or hotter, wetter or drier). Natural selection may track these changes to favor organisms whose genotypes are better designed to live in the changed habitats. In regard to *human* evolution, because we are preeminently social animals, and almost certainly have been since our lineage began, heritable variations that affected our relationships with each other, and with other species of animals (such as prey and predators) are environmental factors that were probably even more significant than climate or weather. Individuals of the same species compete among themselves for access to scarce resources, such as food, mating opportunities and enriched habitats. Nevertheless, a change in climate does seem to have had a major effect on the trajectory of our evolution, about half-way through our lineage, when our ancestors abandoned life in the trees.

Natural selection of behavior. Natural selection resulting from reproductive success due to a particular heritable trait can act continuously and cumulatively to produce dramatic and complex evolutionary changes called adaptations. The adaptive process is most striking when natural selection acts to improve *behaviors* which enhance reproduction, such as developing a new way to win fights over food and mating opportunities. As long as such a behavior provides reproductive advantages, it will continue to be improved because those who are born with inherited variations that enhance the behavior will be naturally selected and their genes will increase in frequency in the population's gene pool.

This can go on for *millions of years*, yielding a behavior that reaches unprecedented levels of prowess and results in a major transformation of an animal's body — as it does in the centerpiece of this book.

We are a special case of a general phenomenon. Each of the millions of species on the earth presents a specific case stemming from its unique genome, evolutionary history, and the nature of the environments in which it evolved. There are many provocative, unresolved questions concerning the singular narrative of our own lineage (the *hominin* lineage) which began about seven million years ago (7 Mya). I will use the term hominin (rather than the earlier "hominid") to refer to both modern humans and our extinct relatives back to the time when our lineage diverged from that of the chimpanzees.

Scientific research has revealed an outline of the way in which our earliest hominin ancestors were gradually transformed from tree-dwelling apes into the way we are today. Eventually, they abandoned the trees and, traveling on two legs, spread throughout the world, reproducing their kind, ineluctably molded by natural selection to create a singular, peculiar, former ape, *Homo sapiens,* in which no bone, muscle, nerve or organ remained unchanged and various new behaviors abound. *Homo* is our genus and *sapiens* is our species (optimistically, it means "wise").

The origin of species. How do new species arise, and how can they be identified? The short but incomplete answer is that species arise through natural selection and different species are distinguished by their inability to breed with each other. This clear and satisfying concept (the "biological species") is unfortunately difficult to demonstrate, even in living populations. It is useful when it can be applied, but the more distant two populations are in space and time, the more difficult it becomes to test their species status relative to each other [Mayr, 1963].

The essential element for producing two biological species from one breeding population is that part of the population loses the ability to breed with the other part. How can something like that be lost? The reproductive isolation of one part of a formerly intact breeding population can occur as a result of geographic isolation: two parts of the original population become physically separated and subsequently evolve separately, each being naturally selected for optimal success in its own niche. In time, this can lead to divergence that results in sterile or nonviable hybrids when they reencounter each other and attempt to mate. Another way that new species can arise is when a subgroup comes to use resources in a way that sets them apart from other members of their species [NAS, 2008]. I will propose that something like this happened when the hominin and chimpanzee lineages diverged. Hominins initiated a distinctive behavior involving natural resources which eventually led to their reproductive isolation from other members of the breeding population.

The problem of how to define an *extinct* species is especially contentious. At the present time there are 23 species and seven genera on the hominin family tree. How can one determine interbreeding behavior in animals known only from fossilized bones and teeth? The species and genus names assigned to fossil hominins help us to keep track of which ones we are discussing, but the assignment of species names is necessarily based on *phenotypic* differences, sometimes as unimposing as tooth structure. The useful features that can be discerned in scarce fossil relics are inevitably few in number and individual variability is unknown, so the result is a tentative hypothesis [Wood and Lonergan, 2008]. A genus is a category whose borders are even less biological; generally it represents a collection of species grouped together because they appear to have had a common ancestry [Beckner, 1959]. Wood and Collard [1999] similarly defined a genus is a group of species of common ancestry, but added the idea that a genus is also adapted to a different ecological situation from that of other genera. Fortunately, the vexatious questions of fossil family trees are largely avoidable in discussion of the *process* of hominin evolution I shall describe.

The hominin lineage. A species comes to an end when it becomes extinct. If it first gave rise to another species, that part of the genome survives and may also split to form additional species. The result is a branching structure, with some branches dying without descendants. The fossil record shows that most branches end in extinction and this is true in our own ancestral branching bush. We are the last remaining hominins, the only survivors of a complex family tree of ancient ancestors (but reproduction is one of our strong points!). Somewhere in the maze of expired relatives there existed a continuous lineage — a single, surviving, often-changing packet of genes of which we are now the sole vehicles.

A few authors have expressed the view that there is a dis-junction between pre-*Homo* and post-*Homo* hominins (although they do not question the genetic continuity) leading them to conclude that whatever explains hominin origins cannot also explain human origins because not all hominins became humans. I prefer to emphasize the continuity of the hominin lineage during which the genome persisted, while undergoing modification by natural selection, even though the path through the hominin family tree cannot yet be precisely identified. The transition to *Homo* was certainly dramatic, but there is no reason to doubt it was due to the same process of natural selection that had previously acted on hominin genes for several million years and will continue to act in the future. A new genus designation may be appropriate for the first hominins to abandon the trees, particularly if one accepts the importance of adaptation to different ecological situations [Wood and Collard, 1999], but there is nothing biologically aberrant in the way it happened.

Human uniqueness. The genes we share today bear the instructions for an animal remarkably different from our earliest ancestors, who were arboreal apes. Why was our special collection of genes naturally selected? What were the reproductive advantages bestowed by our astounding mix of inherited traits? In this book I will develop the proposal that many of them can be explained by natural selection acting to improve an innovative *behavior* initiated by the first hominins — a behavior that provided reproductive benefits driving a process of evolutionary adaptation that persisted for millions of years.

If true, our species should be particularly skilled at this behavior, it should be inherited (developing in every child without teaching), numerous features of our body structure should be adapted for it, and it should have characteristics that reasonably could have provided enhanced survival and breeding opportunities throughout most of hominin history.

In what follows I will show that natural selection to improve this behavior can account for many alterations that occurred as our forbears were transformed from arboreal specialists to dedicated ground-dwellers. Modifications in body size, gender size differences, proportional changes in the size and mass of the arms and legs, transmutations that produced a waist, independent rotation of the pelvis and thorax, increased mobility of the shoulder joint and changes in its orientation, remodeling of the hand, the onset of handedness, smaller canine teeth, robusticity of bone and muscle, the innate development of throwing and club-swinging, a crucial contribution to the onset of bipedal locomotion, and modifications of the central nervous system in controlling the behavior in question are all accounted for. Each of these topics can be clarified by the proposition that our ancestors underwent a prolonged selection for improved *use of hand-held weapons from a bipedal stance*. The first use of weapons signaled human origins. This behavior continued to yield reproductive benefits in competition for enriched habitats, food and mates for millions of years.

What were we like at the beginning of the hominin odyssey? To identify the starting point of our lineage, we must look millions of years into the past for a glimpse of our earliest ancestors, the first hominins. This is the topic of the next chapter.