9

Legacies of Evolutionary History

The past! the past! the past!
The past—the dark unfathom'd retrospect!
The teeming gulf—the sleepers and the shadows!
The past—the infinite greatness of the past!
For what is the present after all but a growth out of the past?

—"Passage to India" by Walt Whitman

Phil, the unfortunate television weatherman who lives one day over and over again in the movie *Groundhog Day*, enters a restaurant just as a diner begins to choke on a bite of food. Phil, having observed this scene many times before, calmly steps behind the gasping man, wraps his arms around the man's upper abdomen, and suddenly squeezes hard. The food is expelled from the diner's windpipe and he can breathe again, his life saved by Phil and the Heimlich maneuver.

About one person in a hundred thousand chokes to death each year. While this death rate is small compared to that from automobile accidents, choking has been a persistent cause of death not only throughout human evolution but throughout vertebrate evolution because all vertebrates share the same design flaw: our mouth is below and in front of our nose, but our food-conveying esophagus is behind the air-conveying trachea in our chest, so the tubes must cross in the throat. If food blocks this intersection, air cannot reach our lungs. When we swallow, reflex mechanisms seal off the opening to the trachea so that food does not enter it. Unfortunately, no real-life machinery is perfect. Sometimes the reflex falters and "something goes down the wrong pipe." For this contingency we have a defense, the choking reflex, a precisely coordinated pattern of muscular contractions and tracheal constriction that creates a burst of exhaled air to forcibly expel misdirected food. If this backup mechanism fails and an obstruction blocking the trachea is not dislodged, we die—unless, that is, Phil or someone like him happens to be nearby.

But why do we need the protective mechanisms of traffic control and a backup choking reflex? It would be so much safer and easier if our air and food pathways were completely separate. What functional reason is there for this crisscross? The answer is simple—none at all. The explanation is historical, not functional. Vertebrates from fish to mammals are all saddled with an intersection of the two passages. Other animal groups, such as insects and mollusks, have the more sensible arrangement of complete separation of respiratory and digestive systems.

Our air-food traffic problem got started by a remote ancestor, a minute wormlike animal that fed on microorganisms strained from the water through a sievelike region just behind the mouth. The animal was too small to need a respiratory system. Passive diffusion of dissolved gases between its innermost parts and the surrounding water easily supplied its respiratory needs. Later, as it evolved a larger size, passive diffusion was ever less adequate, and a respiratory system evolved.

If evolution proceeded by implementing sensible plans, the new respiratory system would have been just that, a new system designed from scratch, but evolution does no sensible planning. It always proceeds by just slightly modifying what it already has. The food sieve at the forward end of the digestive system already exposed a large surface area to a flowing current. With no special modifications, it was already serving as a set of gills by providing a large proportion of the needed gaseous exchanges between internal tissues and environment. Additional respiratory capacity was created by slow modifications of this food sieve. Rare minor mutations that made it slightly more effective in respiration were gradually accumulated over evolutionary time. Part of our digestive system was thereby coopted to serve a new function—respiration—and there was no way to anticipate that this would later cause great distress in a Pennsylvania restaurant on Groundhog Day. Today, the food-sieving worm stage in our evolution is still found in the closest invertebrate relatives of modern vertebrates, which have combined respiratory and digestive passages, as shown in Figure 9-1.

Much later, the evolution of air breathing caused some other evolutionary changes that we now have cause to regret. When part of the respiratory region was modified to form a lung, it branched off the lower side of the esophagus that led to the stomach. Accessory openings for air breathing at the surface of the water evolved, understandably, from the already available olfactory organs (nostrils) on the upper surface of the snout, not on the chin or throat. So the air passage opened above the mouth opening and led into the forward part of the digestive tract. Air then passed back through the mouth and larynx to where the trachea branched off and went through this passage to the lungs. This is the lungfish stage (see Figure 9-2).

Subsequent evolution moved the connection from the nostrils back into the throat so that the air passage was as completely separate from the digestive system as it could become without redesigning the structure of the head and throat. Thus a long dual-function passage was gradually shortened until only the crisscross remained, but we and all higher vertebrates are still stuck with it. Vertebrates have the unenviable capacity to be asphyxiated by their food. Darwin pointed out, in 1859, how difficult it is, from a purely functional perspective, to

> understand the strange fact that every particle of food and drink which we swallow has to pass over the orifice of the trachea, with some risk of falling into the lungs, notwithstanding the beautiful contrivance by which the glottis is closed.

We are actually worse off than other mammals because traffic control in our throat is further compromised by modifications to

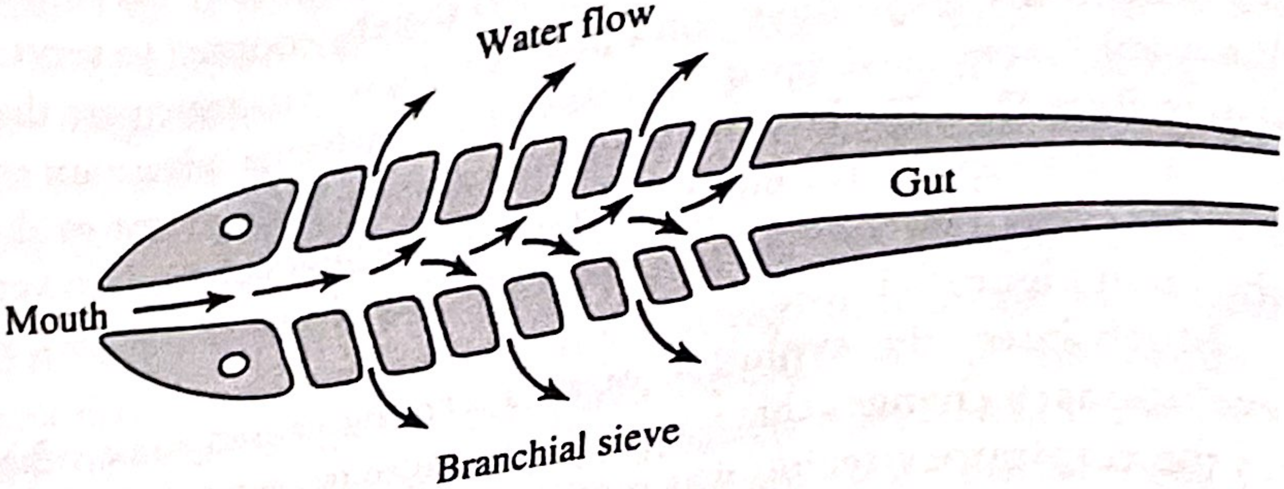

FIGURE 9–1.
Diagram of respiratory and digestive passages of a larval tunicate, and of the extinct ancestor of all vertebrates, as seen in a horizontal section through the forward end of the body.

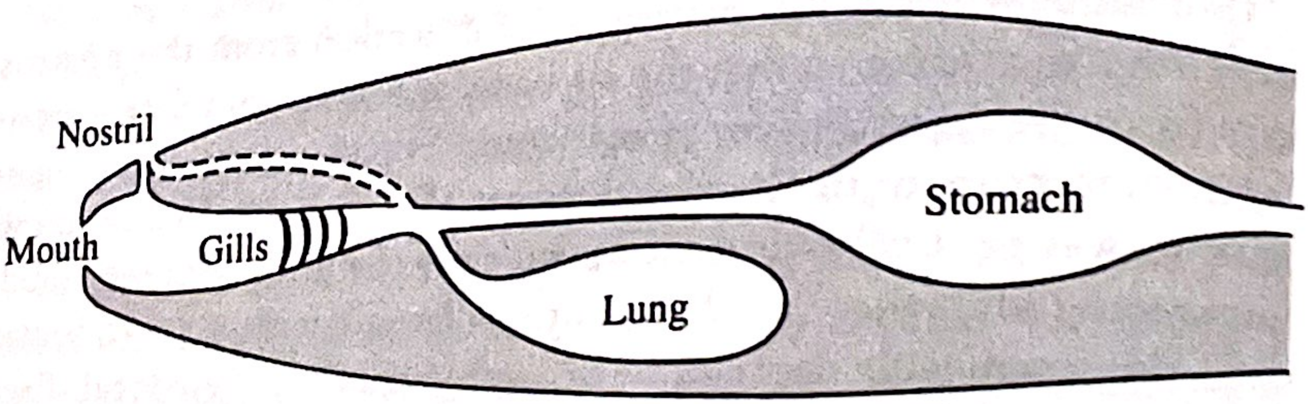

FIGURE 9–2.
The lungfish stage of the evolution of respiratory and digestive systems of higher vertebrates, as seen in a vertical section to one side of the midline. The dotted lines show the later shift of the nostril connection to the crossing in the throat, as is found in mammals.

facilitate speech. Did you ever watch a horse drinking? It keeps its mouth in the water and drinks without interrupting its breathing. It can do this because the opening from its nasal region can be precisely lined up with the opening into the trachea. The respiratory passage forms a sort of bridge across the digestive passage, so that when the horse swallows, it can make use of space to the left and right of the bridge. Unfortunately for us, our tracheal opening has slipped further back in the throat, so that the bridge connection can no longer be made. At least not for adults; babies, for the first few months of life, can swallow liquids and breathe simultaneously, like many other mammals. Once they start making the babbling that is the precursor of human speech, however, they can no longer drink like horses. The human capacity for choking represents an ancient maladaptive legacy aggravated by a much later compromise.

OTHER MALFUNCTIONAL DESIGN FEATURES

Many other serious design flaws make us susceptible to medical problems. Perhaps the most often recognized is the inside-out retina. Vertebrate eyes started as light-sensitive cells under the skin of a minute transparent ancestor. The blood vessels and nerves that served these light-sensitive cells came from the outside, as good a direction as any, for a transparent animal. Now, hundreds of millions of years later, light still must pass through these nerves and blood vessels on the surface of the retina before it reaches the rods and cones that react to the light. The nerve fibers of the retina gather into a bundle, the optic nerve, which must exit the eye to get to the brain. At the hole where the optic nerve exits the retina, there can be no rods and cones. This causes the eye's blind spot. To demonstrate it, close your left eye and focus your right eye straight ahead at the eraser end of a pencil. Move the pencil to the right without letting the eye follow it. The eraser will disappear at a spot about twenty degrees from the forward line of vision. The left eye is similarly blind twenty degrees to the left of its midline.

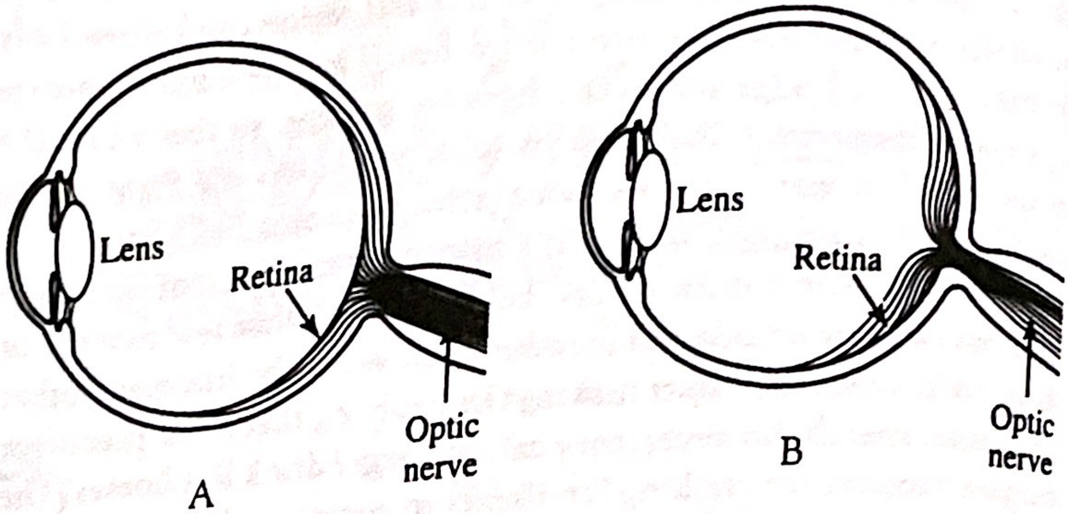

FIGURE 9–3.
A. The human eye as it ought to be, with a squid-like retinal orientation.
B. The human eye as it really is, with nerves and vessels traversing the inside of the retina.

The blood vessels on the retina create another problem. They cast shadows that create a network of blind spots on the retina. To overcome this, our eyes move constantly in tiny twitches so that they scan slightly different areas every fraction of a second. This mass of information is processed in the brain, which compiles it into a coherent image. We are deceived into thinking we see something continuously with both eyes when we may only be seeing it intermittently with one. Nevertheless, the shadows, like the blind spot, are always there. To demonstrate this useful self-deception, go into a dark room, press the light end of a penlight against the side of your closed eyelid, turn it on, and gently wiggle it around. When the lineup is exactly right, you will see the shadow of the intricately branching system of parallel veinlets and arterioles that supply the retina.

The inversion of the retina is a universal defect in vertebrates that makes no functional sense. As with the unfortunate intersection between the passages for food and air, the explanation is historical, and it applies only to the vertebrates. The functionally analogous eye of a squid has a more sensibly oriented retina with the nerves and blood vessels coming from behind the retina. The squid eye does not need secondary contrivances to minimize the effect of the design flaw that plagues vertebrates, any more than it need worry about eating interfering with breathing. The squid and other mollusks have their own suites of malfunctional historical legacies.

Our inverted retina is responsible not only for slight visual impairment but also for some special medical problems. Any bleeding or minor obstruction of blood flow in the retina casts a shadow that may seriously impair the visual image. Still more serious is the ease with which the light-gathering surface (rods and cones) can lift loose from the underlying interior of the eyeball. Once this condition of *detached retina* gets started, it is a dire emergency that, if untreated, can lead to blindness. The more sensibly designed squid eye, by contrast, has its retina anchored securely from below by numerous nerve fibers so that it cannot become detached.

In addition to those flaws, which affect all vertebrates or all mammals, there are some that affect only humans, or only humans and our closest primate relatives. The appendix is an example. People who recover from appendectomies seem to suffer no disadvantage from not having this part of the human body. The only functional significance of the appendix, as far as we know for sure, is to enable us to have appendicitis. The appendix is the vestige of part of the caecum, a digestive organ in our early mammalian ancestors that helped to process plant foods of low nutritional value. For rabbits and many other mammals, the caecum still serves this function. The shift to a diet of foods with more concentrated nutrition, such as fruit and insects, caused the caecum to degenerate in the course of primate evolution because there was no selection to maintain it. Unfortunately, it has not yet entirely disappeared, and the vestige now makes us vulnerable to appendicitis.

So why does the appendix persist at all? It does make a minor—but by no means important—contribution to the immune system. We also wonder if it might, paradoxically, be maintained by appendicitis. The long, thin shape of the appendix makes it vulnerable when inflammation causes swelling that squeezes the artery to the appendix and cuts off its only blood supply. When filled with bacteria, an appendix without a blood supply cannot defend itself. Bacteria grow rapidly and eventually burst the appendix, spreading infection and toxins throughout the abdominal cavity. A bit of inflammation and swelling is less likely to disrupt the blood supply of a large appendix than that of a long, thin one. Natural selection gradually reduces the size of the useless appendix, but any appendix narrower than a certain diameter becomes more vulnerable to appendicitis. Thus, deaths from appendicitis may paradoxically select for a slightly larger appendix, maintaining this less-than-useless trait. Selection is also almost certainly very slowly making the appendix shorter, but in the meantime the appendix may be maintained by the shortsightedness of natural selection. We wonder if other vestigial traits might also be maintained because further diminishing them increases vulnerability to a disease.

Many primates and most other mammals can make their own vitamin C, but we humans cannot. Our ancestral shift to a high-fruit diet, rich in vitamin C, had the incidental consequence about forty million years ago of allowing the degeneration of the biochemical machinery for making this vitamin. Our frugivorous close relatives share our requirement for dietary vitamin C. All animals need particular organic substances (vitamins) in their food, but different groups have different requirements.

Some of our vulnerability to mechanical damage can also be blamed on various past evolutionary developments. A sharp blow to the side of the human head may fracture the skull, damage the brain, and cause death or permanent impairment. The same blow to an ape head may result merely in a bruised temporalis muscle and temporary impairment of chewing. The difference arises from the increased size of the human brain case and shrinkage of the jaw musculature, which incidentally rob the skull of its earlier cushioning. The hard hats construction workers and cyclists wear are a technological fix for a biological deficiency. If workers and cyclists go on being careless about wearing their hard hats, perhaps in another million years we will again have a thick padding of tissue under our scalps to reduce brain injuries.

The same increased skull size has resulted in a fetal head that fits through a human pelvis only with difficulty. A woman's pelvic structure is slightly different from a man's, so as to provide a large birth passage and, as childbirth approaches, the pubic joint loosens to further facilitate the passage of the infant. Yet childbirth is still more difficult than it would be if the vagina could open outside the massive ring of pelvic bone, perhaps above the pubis on the lower abdomen. The passage of the vagina through the pelvis is a severe historical constraint on the evolution of any further increase in fetal head size. This constraint, of having to fit an oversize head through the pelvic ring of bone, explains why human babies have to be born at such an early and vulnerable stage of development, compared to, for example, ape babies.

The prevalence of maladaptive human design features has been recognized for a long time. A 1941 book by George Estabrooks, *Man, The Mechanical Misfit*, describes many of the structural defects and compromises in human anatomy, especially those that result from turning a horizontal four-footed animal into an upright two-footed one. The weight of the top part of the body greatly compresses the vertebrae in the lower spine, and standing upright requires more muscular effort than a horizontal posture would. The pelvis was originally designed to resist a back-to-belly force of gravity, not the fore-to-aft force that ours must resist as long as we remain upright, either standing or sitting. Elaine Morgan's recent book *The Scars of Evolution* gives a readable account of these maladaptive legacies.

A long list of medical problems, ranging from minor annoyances to serious disabilities, results from the mechanical inadequacies of our adaptations for an upright posture and two-footed locomotion. Perhaps the most important is the episodic lower back pain experienced by so many people. Our knees, ankles, and feet are also extraordinarily vulnerable. How often do we hear of athletes missing games because of knee and ankle injuries? One of the authors once leaped high in a volleyball game, and when he came down only his left foot was on the court. The right landed on the foot of a teammate and turned sharply inward, seriously straining the vulnerable lateral ligament, which is usually the part that fails when an ankle is sprained. The author met his classes on crutches for the next week and was glad he was not part of a band roving over the Paleolithic savannah. He also regretted that the human ankle is not better designed.

The abdominal viscera of a mammal are enclosed in sheets of tissue designed to hang from the upper wall of the abdominal cavity. This is fine for a mammal on all four legs, but in an upright mammal the sheets of tissue may be said to hang from a vertical pole, a grossly ineffective arrangement that causes such diverse problems as digestive system blockages, visceral adhesions, hemorrhoids, and inguinal hernia. The mammalian circulatory system is also compromised by upright posture. It works fine for a dog or a sheep, but our upright posture increases the hydrostatic pressure in the lower extremities and can cause varicose veins and swollen ankles. The opposite effect, deficient blood pressure in the brain, can result in dizziness or momentary partial blackout when we suddenly stand up from a recumbent position.

Sometimes the body's responses to problems are just the opposite of what would be adaptive. When the heart muscle is too weak to pump all the blood it receives, the blood backs up into the lungs and feet and causes shortness of breath, swollen ankles, and other symptoms of congestive heart failure. You might expect that this would cause excretion of excess fluid, but patients with heart failure retain salt and fluid, and this excess blood volume makes the problem even worse. This response is maladaptive in patients with heart disease, but, as internal medicine physician Jennifer Weil points out, the body's response is designed for a different problem. In a natural environment, most instances of deficient blood pumping would result from bleeding or dehydration, in which the fluid retention mechanism would be useful indeed! Heart failure occurs mainly in old age and mechanisms to conserve body fluid can be useful throughout life, so this system is a fine example of a cause of senescence which is maintained because of its benefits in youth.

We have been discussing defects in the basic plan of the human body. These should not be confused with mere inadequacies of execution and random departures from optimal values. As a general rule for any readily measured physical feature, it pays to be in the middle of the pack, as we illustrated previously with the birds with longer- or shorter-than-average wings, which were especially likely to be killed in a storm. Unusually tall or short people tend not to live as long or as healthily as those of average height. Babies of average birth weight are usually better off than those who are much heavier or lighter. Everyone knows that high or low blood pressure is not as good as normal blood pressure. A high level of adaptive performance usually requires that many quantitative characteristics closely approach optimal values. While no individual is perfect, the various parameters sometimes combine to yield remarkable excellence. Yet even in near perfection there is substantial variation—as is well known to those basketball stars who played against Michael Jordan.

Many design features, while not maladaptive, are functionally arbitrary and explicable only as historical legacies. In mammals, the right side of the heart circulates the blood to the lungs, the left side to the rest of the body. In birds it is the other way around, for no better reason than that birds and mammals came from different reptilian ancestors that took arbitrarily different routes to cardiac specialization. Either way works equally well. Some arbitrary features can be advantageously exploited. Many people who are alive today would be dead except for the happenstance of everyone having two kidneys. When one fails or is donated, the other is able to do double service. By the same logic, many people die of having only one heart. The reason we have two kidneys and one heart is simply that, right from their origins, all vertebrates had two kidneys and one heart. This is pure historical legacy and has nothing to do with the advantage of having two of one organ or the disadvantage of having only one of another.

We have belabored what is wrong or arbitrary with the human body because the design flaws can cause many medical problems, but we hope that our readers will also realize that much about it is just right. Our oversize brains may be vulnerable to injury and may impede childbirth, but they make us the unchallenged leaders of the animal kingdom in cognitive capability and in all the social and technological advances that this makes possible. No other species in the history of our planet has ever controlled its environment to the extent that we have since the invention of agriculture. Similarly, our longevity is impressive in relation to that of any other mammal, except a few, such as elephants, that are far larger than we are. We can live about half again as long as any other primate.

Moreover, many of our other adaptations are equal or superior to those in other mammals. Our immune system is superb. Also, despite conspicuous design flaws and individual imperfections, our eyes and related brain structures incorporate layer upon layer of information-processing marvels that extract the maximum amount of usefulness from visual stimuli. If hawks, for example, have visual acuity that is in some ways superior to ours, this one kind of superiority must be purchased with some kind of trade-off. Animals that can see better than we can in the dark cannot see as well in the light. Normal human vision approaches a theoretical maximum of sensitivity and discrimination over a wide range of conditions. We are only beginning to understand how it is that a face, seen from one angle at a certain distance, may later, from another angle and distance, be instantly recognized. No current computer can approach such feats. Our hearing is so sensitive to some frequencies that if it were more sensitive we would not hear as well. Informative sounds would be lost in the noise of random air molecules colliding with our eardrums.

The Finishing Touch

We have been discussing mainly attributes that humans share with other vertebrates, other mammals, or other primates. Our discussions of our problems with upright stature also apply to extinct members of our genus, *Homo*. We now turn to more explicitly human legacies, with an emphasis on the evolutionary adjustments made in the period from about one hundred thousand to about ten thousand years ago. While natural selection has been changing us in many small ways in the last ten thousand years, this is but a moment on the scale of evolutionary time. Our ancestors of ten thousand or perhaps even fifty thousand years ago looked and acted fully human. If we could magically transport babies from that time and rear them in modern families, we could expect them to grow up into perfectly modern lawyers or farmers or athletes or cocaine addicts.

The point of the rest of this chapter, and the following one, is that we are specifically adapted to Stone Age conditions. These conditions ended a few thousand years ago, but evolution has not had time since then to adapt us to a world of dense populations, modern socioeconomic conditions, low levels of physical activity, and the many other novel aspects of modern environments. We are not referring merely to the world of offices, classrooms, and fast-food restaurants. Life on any primitive farm or in any third-world village may also be thoroughly abnormal for people whose bodies were designed for the world of the Stone Age hunter-gatherer.

Even more specifically, we seem to be adapted to the ecological and socioeconomic conditions experienced by tribal societies living in the semiarid habitat characteristic of sub-Saharan Africa. This is most likely where our species originated and lived for tens of thousands of years and where we spent perhaps 90 percent of our history after becoming fully human and recognizable as the species we are today. Prior to that was a far longer period of evolution in Africa in which our ancestors' skeletal features lead scientists to give them other names, such as *Homo erectus* and *Homo habilis*. Yet even these more remote ancestors walked erect and used their hands for making and using tools. We can only guess at many aspects of their biology. Speech capabilities and social organizations are not apparent in stone artifacts and fossil remains, but there is no reason to doubt that their ways of life were rather similar to those of more recent hunter-gatherers.

Technological advances later allowed our ancestors to invade other habitats and regions, such as deserts, jungles, and forests. Beginning about one hundred thousand years ago, our ancestors began to disperse from Africa to parts of Eurasia, including seasonally frigid regions made habitable by advances in clothing, habitation, and food acquisition and storage. Yet despite the geographic and climatic diversity, people still lived in small tribal groups with hunter-gatherer economies. Grainfield agriculture, with its revolutionary alteration of human diet and socioeconomic systems, was practiced first in southwest Asia about eight thousand years ago and shortly thereafter in Egypt, India, and China. It took another thousand years or more to spread to central and western Europe and tropical Africa and to begin independently in Latin America. Most of our ancestors of a few thousand years ago still lived in bands of hunter-gatherers. We are, in the words of some distinguished American anthropologists, "Stone Agers in the fast lane."

Death in the Stone Age

Imagine what it must have been like in that idyllic era. You were born into a nomadic band of forty to a hundred people. Whatever its size, it was a stable social group. You grew up in the care of various close relatives. Even if your local band consisted of a hundred or more people, many of them were distant cousins. You knew them all and knew their genetic and marital connections to yourself. Some you loved deeply and they loved you in return. If there were those you did not love, at least you knew what to expect from them, and you knew what everyone expected of you. If you occasionally saw strangers, it was probably at a trading site, and you knew what to expect of them too. In a sparsely peopled world the necessities of life—plant and animal foods uncontaminated by pesticides—were there for the taking. You breathed the pure air and drank the pure water of a preindustrial Eden.

Having asked you to imagine an idyllic past, we now urge that you be more realistic. Like other Golden Age legends, such as the age of chivalry or that delightful antebellum world into which Scarlett O'Hara was born, it is a fabricated myth. Enjoy it in fantasy or fiction, but do not let it mislead serious thought on medicine or human evolution. The unpleasant fact is that our hunter-gatherer ancestors lived with enormous difficulty and hardship. Simple arithmetic on the rates of death and reproduction makes this conclusion inescapable. Death always balanced reproduction, even though people reproduced at something approaching the maximum feasible rate.

In most primitive social systems, women start bearing children as soon as they are able to do so, which, because of nutritional limitations, is often delayed until about age nineteen. Pregnancy and childbirth are followed by two or three years of lactation, which inhibits ovulation. Then the mother is soon pregnant again, whether this is medically advisable or not. In the unlikely event that she remains fully fertile and survives to menopause, she will probably produce about five babies. Having more children would require shortened lactation periods, and this is unlikely given the limited foods available for babies in preagricultural societies.

But even if hunter-gatherer women averaged only four children before succumbing to sterility or death, only half their babies could have survived to maturity. Otherwise the human population would have steadily increased, and this obviously did not happen. Even an increase of 1 percent per century would cause a population to become a thousand times as numerous in less than seventy thousand years, but populations remained extremely sparse until the invention of agriculture. The conclusion is thus quantitatively inescapable that deaths almost precisely kept up with births for nearly all of human history. The extraordinarily low death rates of the last few centuries, and especially in the last few decades in Western societies, show that we live in times of unprecedented safety and prosperity. It is no doubt difficult for most readers of this book to appreciate the harshness and insecurity of human life under natural conditions.

Mortality rates in the Stone Age, like those of today, were highest in infancy and declined throughout childhood. Many early deaths in some groups were from infanticide, motivated by parents' economic hardship or imposed by patriarchs. While fictional accounts of Stone Age conditions probably exaggerate the ravages of predation and other wild-animal attack, lions, hyenas, and venomous snakes were ever-present hazards and took a steady toll, with children especially vulnerable. Death rates from poisoning and accidents were far higher than they are now.

The infectious diseases, which were probably the most important source of mortality for all age groups, were not the same bacterial and viral diseases that afflict us today. Most of today's infections depend on rates of personal contact only possible in abnormally dense populations. Back then, vector-borne protozoa and worms were common causes of prolonged sickness and ultimate death. Many of these diseases are not merely lethal but most unpleasantly so. Some readers will know how unpleasant malaria can be, from personal experience or from knowing someone who has had the disease. It is a lark compared to other protozoan diseases such as kala-azar, which slowly destroys the liver and other viscera; parasites such as lungworms, which cause death by suffocation; hookworms, which are seldom fatal but can make children grow into physically and mentally defective adults; and filaria, which among other things cause elephantiasis. The name comes from the swelling of the limbs and scrotum to elephantine proportions because the parasites block the lymphatic vessels.

Food was often abundant for hunter-gatherers, but memories of bounteous fruit harvests or an occasional big kill must have been a poor solace during the regularly recurring famines. Climatic variations induce fluctuation in resources. Even in the most stable climates, food abundance varies because of plant and animal diseases. Prior to the invention of reliable preservation techniques, temporarily abundant food could not be saved for leaner times. Even foods preserved by drying or smoking could be attacked by pests that could frustrate the most careful planning for future emergencies.

Shortages of vital necessities were not only directly stressful, they also encouraged strife. Imagine that people from a hill tribe were suffering from a protein shortage, while people in the valley were feasting on the abundant fish from their lake. The people from the hills would no doubt insist that their leaders take them to that lake, no matter how loudly the valley people asserted their exclusive fishing rights. If catching the fish means killing the fishermen and appropriating their fishing gear, that is what the hill people might decide to do. Even in the absence of economic necessity, human nature often finds excuses for armed robbery and attendant taking of life. Fortunately for early tribal societies, they lacked the technology of transport and communication that permitted banditry on the scale practiced by Genghis Khan or Alexander of Macedon.

Human nature has, of course, its nobler aspects. There are such things as love and charity and honesty. Unfortunately, the evolutionary origins of such qualities are rooted in their utility in parochial tribal settings. Natural selection clearly favors being kind to close relatives because of their shared genes. It also favors being known to keep one's promises and not cheating members of one's local group or habitual trading partners in other groups. There was, however, never any individual advantage from altruism beyond these local associations. Global human rights is a new idea never favored by evolution during the Stone Age. When Plato urged that one ought to be considerate of all Greeks, not merely all Athenians, it was a controversial idea. Today, humanistic sentiments still face formidable opposition from parochialism and bigotry. In fact, these destructive tendencies are aggravated by what we just now called the "nobler" aspects of human nature. As Michigan biologist Richard Alexander so neatly put it, today's central ethical problem is "within-group amity serving between-group enmity."

LIFE IN THE STONE AGE

Human nature was formed in what anthropologists have recently termed (following a 1966 suggestion by psychiatrist John Bowlby) the *environment of evolutionary adaptedness*, or EEA. Despite their frequent reference to the EEA, anthropologists differ widely about what it was like. They cannot directly observe the ways of our ancestors of tens of thousands of years ago or the effects of environmental conditions on the human genetic makeup. They must base their conclusions on indirect evidence: skeletal remains, stone tools, cave paintings, and information about modern groups with seemingly primitive economies and social conditions.

The shortage of information is serious. What are the historically normal conditions of human childbirth? This is just one of many basic questions for which there is no assured answer. We suspect that the correct answer to many such questions is, *it was highly variable*. Attitudes toward childbirth differ enormously among different cultures today, and there is no reason to believe they were any less variable a hundred thousand years ago. They must also have been quite variable within social groups. The solicitude offered to a chief's wife no doubt differed from that proffered a concubine captured from a hostile tribe. Giving birth during times of plenty in a settled camp might have been rather different from giving birth in leaner times or during travel to a new location.

We also suggest that the correct answer to other important questions is, *it varied*. What sorts of rewards went to gifted poets, artists, or others of high intellectual attainment, compared to those who were good hunters or warriors? How stratified, by family connections or merit, were the socioeconomic conditions? Was inheritance matrilineal or patrilineal? What were the child-rearing customs? What were the religious doctrines and constraints, and how strong a factor was religion? These questions would have vastly different answers in different societies in the EEA. There is no one "natural" way of human life.

Despite great variation in the human adaptations to a variety of EEA conditions, the available evidence does support some generalizations. Social systems were constrained by economics and demography. No elaborately stratified societies with hereditary class structures were possible in the Stone Age, because groups that had to gather their food from within walking distance necessarily remained small. Likewise, no chief of a nomadic band can have dozens of wives when the band only includes a few dozen people. Prior to the development of agriculture, no chief could control enough land, wealth, and people to build cathedrals or pyramids.

Social systems were also constrained by the physiological and structural differences between the sexes. The physiological costs of reproduction involved in pregnancy and lactation are borne entirely by women. By what rules were the economic costs of reproduction apportioned? Again, we suggest, *they varied.* On the basis of what we know about current human groups, husbands no doubt contributed significantly in most cultures, but in others a mother's brothers and other relatives made a greater contribution. Likewise, the gross physical differences between the sexes imply behavioral differences. The greater size and strength of men suggest that these attributes provided important competitive advantages, especially in the competition for mates. We discuss this and related matters in Chapter 13.

Economic necessity often demanded that adults and older children of both sexes spend much of their time searching for and preparing food. It is usually assumed that men did the hunting and women the gathering in hunter-gatherer societies, although the antiquity and importance of big-game hunting have been exaggerated in fictional accounts of Stone Age life. Archery and other weapons effective against such animals as deer were in fact not invented until late in the Stone Age. Dogs, which can play crucial roles in many hunting techniques, were not common human associates before about fifteen thousand years ago. Meat or hides from large animals may often have been procured not by hunting but by scavenging or stealing from other predators.

The mainstay foods in the Stone Age would seem to us inedible or too demanding of time and effort. We would find most of the game strong-tasting and extremely tough. Most of us have little appreciation of the tedious skinning and butchering it takes to turn a wild animal carcass into a serving of meat. Many wild fruits, even when fully ripe, are sour to our tastes, and other plant products are bitter or have strong odors. We find them unpleasant thanks to our adaptations that make us avoid toxins, as discussed in Chapter 6. Most natural human foods require a far greater labor of preparation and chewing than the foods we eat now. Domesticated animals and plants have been artificially selected to be tender, nontoxic, and easily processed.

Despite the abundance of foods available in the EEA much of the time, the village elders would have been able to remember times of severe famine. Actual starvation may have been rare, but deaths from the combined stresses of disease, malnutrition, and poisoning by the excessive consumption of marginally edible plants were probably common. These same stresses also would have caused abortion of fetuses, curtailment of lactation, reduced fertility, and actions such as infanticide and the abandonment of the old or impaired.

In addition to xenophobic conflict with other groups, social strife within groups, famines, and toxic diets, there were many other environmental stresses. Our ability to tolerate the atmospheric pollution of modern cities may owe much to our many thousands of years of exposure to smoke toxins from woods and other fuels. Imagine living in a hut with a fire on the floor and only a small hole in the roof. Atmospheric pollution was different in the EEA, but it was substantial and real. We would find the odors of a Stone Age settlement most unpleasant. There were no soaps or deodorants, no flush toilets, or readily cleanable chamber pots, or any installations worthy of the term latrine. Wastes of various kinds were taken away to some customary distance and no further. Other wastes simply accumulated where they were produced. The average Stone Ager lived in a dump and moved away when conditions got really bad.

Children grew up, and adults lived out their lives, in the constant awareness, and sooner or later the personal experience, of woeful illness, painful injury, physical handicaps, debilitation, and death. There were no antibiotics, tetanus shots, or anesthetics, no plaster casts, corrective lenses, or prosthetic devices, no sterile surgery or false teeth. Our remote ancestors had few cavities, but they had many other dental problems. Teeth could be injured or lost in accidents, and they could literally wear out before what we call middle age. Abrasive plant products can wear molars down to gum level, as seen in some fossil skulls and even in some contemporary groups.

Lest it seem that our account of the EEA is merely a selection of items for a catalog of horrors, we should emphasize that we are discussing our fully human ancestors, with a fully human capacity for pleasure as well as pain and a fully human intellect. The bonds of kinship and friendship could be strong and a source of great pleasure and security. In seasons of plenty there would be abundant time for play: games, music and dancing, storytelling and poetry recitals, intellectual and theological disputes, and the creation of ornamental artwork. The cave paintings at Lascaux, France, created perhaps 25,000 years ago, have been described by anthropologist Melvin Konnor as "a Paleolithic Sistine Chapel" that impresses a sensitive observer "whether religious or not—whether expert or not—with a strong sense of the holy." And our ancestors also had the ability to look on the bright side in times of adversity and to find reasons for laughter. Mark Twain's hero Sir Boss in *A Connecticut Yankee in King Arthur's Court* lamented having to listen, at a sixth-century campfire, to the same jokes he had already found tiresome in the nineteenth. We suspect that if he had gone back to the Stone Age he would have groaned at many of the same jokes.