2

The Architecture of the Modern Mind

What Does the Present Have to Do with the Past?

Even upon close inspection, the brain is a rather uninspiring sight, a mass of pinkish-gray, jelly-like material whose function is as inscrutable as its wrinkled, bulbous form. And yet this three-pound organ, the composite of approximately one hundred billion nerve cells and supporting tissue, is the seat of all that is human—more, it is the nexus of every human's world. It is the brain that oversees the life of the body, monitoring its well being, regulating its growth and development, coordinating its movements. It is the brain that interprets what exists beyond the body, translating and organizing the various forms of stimuli sent to it via the sense organs into recognizable patterns. It is the brain that creates a sense of individual self, washing experiences and perceptions with colorful emotions, harboring a lifetime of personal memories, decoding and formulating expressive language, and executing an astronomical number of thoughts ranging from the simple to the sublime.

By anyone's lights, the modern human brain is extraordinary; a marvel of organic engineering whose blueprint is only partly understood. Yet all of it, from its peculiar shape to its powerful calculations, is the result of selected adaptations accumulated over the course of hominid history, a testimony to the handiwork of evolutionary processes. This vital connection between present and past cannot be neglected by any study of human thought. In the same way that our now largely hairless skin still responds to cold with goose bumps and our slate of internal organs includes obsolete parts, the contemporary skull carries around an assemblage of neural tissue designed long ago. Nevertheless, this compact mass of tissue represents nature's best effort at intelligence as a tool of survival, and it is impressive indeed.

The previous chapter sketched in some of the details of the formative history of the human mind. This one will provide a similar line drawing of the brain itself: What are its structures and functions? How did these structures and functions come to be? How does cognition work? Most important of all, what does a brain assembled in an ancient world so very different from our own have to do with the way we think today? Answering these kinds of questions requires the aid of the powerful new discipline called evolutionary psychology, a recent synthesis of evolutionary biology and cognitive psychology. The fundamental premise of evolutionary psychology is that the complex design of the modern brain evolved through natural selection. Understanding the processes and products of the mind therefore requires close attention to their evolutionary background. As Robert Wright says, "if the theory of natural selection is correct, then essentially everything about the human mind should be intelligible in these terms" (1994: 28). True to such predictions, the work of evolutionary psychology is yielding striking insights into the architecture of the mind and human behavior alike.

There is a second side to the study of human cognition, however. While we were designed to live in an ancient natural world, we no longer do. It has been tens of thousands of years since humans have subsisted in conditions conducive to evolution. When one learns to tame and manipulate the very environmental and biological forces that drive natural selection, they lose most of their punch. That means that our brains, whatever they are like, are currently being put to use in novel and, importantly, nonadaptive ways. A day in the life of a Pleistocene hunter is a far cry from a day on the stock exchange or an assembly line. Stone Agers probably reflected on the world around them, but it is doubtful that atomic theory helped shape their conclusions.

This situation highlights two significant aspects of human thought that will become clearer as we look more closely at mental products such as religion. The first is that the mind is flexible; though our brains have been genetically predisposed to specific ways of thinking, we are quite capable of plying them to more generic and creative ends. For example, you can co-opt our innate theory of mind to personify and berate your insentient computer—something most of us in fact do when they seem to turn against us. Following on this is the further recognition that a great deal of what we think *is* rooted in mental predispositions. This reality is inherent to the kinds of brains we all have. The human capacity for imagination is immense, but it is also constrained by the functional design of our minds. A host of behaviors and varieties of thought that typify twenty-first century life can be characterized as nonadaptive by-products of cognitive mechanisms originally designed to serve other purposes. What most excites evolutionary psychologists is the discovery of the mind's innate faculties, their adaptive origins, and their contemporary expressions.

Alongside the adaptationist frame of reference contributed by evolutionary biology, the most valuable conceptual tool for understanding the nature of the human mind has been cognitive psychology's analogical comparison of brains with computers. Over the years, many attempts to describe the mind have been colored with technological comparisons, but likening brains to computers is much more than metaphorical language. Brains *are* computers. It makes no difference that computers are conglomerates of plastic, metal, and silicon while brains are wet, organic tissue. Computers, as Alan Turing defined them, are sets of operations for processing information (1950). The physical nature of the machine itself is only tangentially important since many kinds of devices, from an abacus to Turing's own mathematical abstractions, can process information. With respect to "hardware," then, both brains and computers are information processors that accomplish tasks by executing sets of computational operations.

In terms of "software," the analogy between brains and computers is exacting as well. What is essential to a computer is not its materials but what it does, its activities—in short, its programs. The programs of the brain, the computational activities it executes in its work of information processing, are reflected in the mind. Though attention to the brain's overall design and circuitry is certainly important to understanding what human thought is like, it is even more crucial to focus on the bundle of internal programs that comprise the brain's mental software. While perhaps drifting a bit back into metaphor, it is useful to call the brain hardware and the mind its software. A computational theory of mind, however, is by far the most powerful explanatory approach to mentation ever conceived; it is both accurate and amenable to testable hypotheses. It also provides a clean answer to the perennial mind-body problem. From the perspective of cognitive psychology, the mind is the activity of the brain.

This chapter describes some of the features of the modern mind by reporting on the work of evolutionary psychologists and other specialists who are hacking into the programs that comprise the brain's mental software. Though what we know, and what we think we know, about the inner workings of human thought has filled many volumes, the following, more modest survey will concentrate on a handful of cognitive processes that play a direct role in the subject of the rest of this book—the phenomenon of *religious* thought. While it is the brain's software that interests us most, first a brief overview of the hardware itself is in order.

The Development and Structure of the Brain

The story of the human brain does not begin at birth but at conception. The blueprint for each piece of biological hardware is located in a child's genes, a unique arrangement of DNA contributed, half each, by mother and father. Within hours of the union of sperm and egg, the factory that will build the newest human computer has already geared up for production. This single fertilized egg rapidly multiplies into a staggering number and diversity of new cells that will become a person. The construction of the brain and all the rest is guided by a schematic millions of years in the making. There is no room for error. The network of brain cells must be wired just like everyone else's, allowing each of us to perceive the world in the same way, to think in the same terms, to behave in similar ways, and to understand the same symbols and language.

The real work of brain construction starts at about day fourteen, when the sphere of multiplying cells begins to fold in on itself. A section of the outer layer of the embryo migrates inward, resulting in the formation of three cell layers, the mesoderm, endoderm, and ectoderm. It is from the ectoderm that the brain develops. In this earliest stage, the brain consists merely of a thin layer of cells on the surface of the embryo called the neural plate. The neural plate next folds in two, creating the neural groove. This groove then closes completely, forming a hollow structure called the neural tube, which provides the building material for the central nervous system. One end of the neural tube will extend to become the spinal cord. The central portion will provide the brain's ventricular system. The structures of the brain itself will emerge from the opposite end of the neural tube. All this development occurs with breathtaking speed. By the eighth week of growth, each of the major components of an adult human brain is already present in the fetus.

The building block of the brain, as for all organs, is the cell. There are two main types of brain cells: neurons, which analyze and transmit the electrochemical signals that are the basis of mental communication, and glial cells, which provide developmental, structural, and functional support to the neurons. Neurons are elongated cells of varying lengths composed of three structures: a cell body called the soma, a system of branching dendrites attached to the soma, and a nerve fiber extending out of the soma called the axon, which carries the electrical signals between connecting neurons. The axons of most neurons are insulated by a sheath of myelin, a substance made of fat that speeds the conductivity of nerve fibers.

Neurons communicate with each other using impulses that race from the dendrites of one neuron, through its soma, and out its axon to the dendrites of the next neuron. These impulses are propagated electrically within each cell and transmitted chemically between them. In a typical process of intercellular communication, the dendrites of one neuron receive a signal from the axon of another neuron using chemicals known as neurotransmitters. When an electrical signal reaches the tip of an axon, it stimulates small vesicles that contain neurotransmitters. These chemicals are released across the microscopic gap, or synapse, separating each neuron and attach to specialized receptors on the dendrites of the adjacent cell. This stimulus sparks a fresh electrical charge in the receiving cell that travels from the dendrites to the soma where it is analyzed, integrated, and transmitted along the axon again. Neurons are able to produce an electrical impulse using charged ions—positively charged potassium and sodium, and negatively charged chlorine—which, when depolarized, propagate signals along the cell membrane to the end of the axon. When the electrical signal arrives at terminals in the tip of the axon, neurotransmitters are released that convey it onward once more.

The work of the brain requires more than cell-to-cell signal transmission, however. Even the simplest behavior involves the organization of thousands of neurons. Feeling, acting, and thinking are the result of complex neural circuitry in which neurons are grouped together by function into systems controlling discrete sensory, motor, and cognitive tasks. So as one part of the prenatal factory continues to churn out more and more brain cells, another part is intensely focused on getting them arrayed and connected up in the right ways.

This task is achieved through a three-stage process involving cell proliferation, differentiation, and migration. In the first stage, beginning with the closure of the neural tube, brain cells proliferate in huge numbers. So great is the commitment to brain cell production that the brain weight of a newborn is proportionately much larger in relation to body weight than is the brain weight of an adult. Within months, though, more than half of these young cells die off, having exceeded the brain's structural needs. In the second stage, differentiation, newly created cells specialize, joining either the family of neurons or neuroglia. Glial cells are far more numerous than neurons and account for much of the brain's total volume. In the final stage of migration, the neurons travel to their permanent positions within the brain and begin to establish their crucial interconnections with other neurons. The fixing of brain circuitry through migration is a concerted operation involving glial cells as well as neurons. The neuroglia, whose name means "nerve glue," are responsible for both guiding and anchoring the neurons to their assigned locations. Radial glial cells send out long tendrils that construct scaffolding for the neurons to move along. The brain's growth and final form is the result of the thickening and expansion of this tissue formation.

Describing the finished brain's structural components requires zooming out from single cells to a global view of the brain itself. When that is done, one of the reasons for humans' superior intelligence becomes clear. Mental acuity is in part related to brain architecture, even if its exact mechanics are hidden from view. While all central nervous systems have many parts in common, the brains of humans are visibly different from all others.

The mechanical design of the human brain can best be described according to its three anatomical divisions. These include the large, domed-shaped cerebrum, whose matching hemispheres comprise the bulk of the brain; the cerebellum, two small spherical hemispheres hanging below and to the rear of the cerebrum; and the brain stem, a complex of structures attached to the bottom of the brain that gradually tapers off and exits the skull as the spinal cord. The primary functions of these three divisions, taken in reverse order, reveal what is common and what is distinctive about the human brain.

The brain stem is responsible for maintaining basic bodily functions like respiration, heart rate, digestion, and blood pressure. The upper portion of the brain stem, or midbrain, acts as a relay station for neurons transmitting input signals from sense organs to the cerebral cortex and, in turn, outgoing motor reflex commands. In the middle of the brain stem sits a bulging bundle of nerve fibers called the pons. Like the midbrain, the pons functions as a relay station for messages, in this case between the two cerebral hemispheres and between the cerebral cortex and the medulla oblongata. The medulla oblongata, the third and lowest division of the brain stem, routes incoming and outgoing signals between body and brain in such a way that the right half of the brain communicates with the left half of the body and the left half of the brain with the right half of the body. Running vertically through the entire length of the brain stem is a canal called the reticular formation that governs states of alertness and sleep.

The cerebellum looks like a miniature version of the cerebral hemispheres it sits beneath, hence its Latin name. These two laterally positioned lobes, which include several anatomical subdivisions, are located to the rear of the brain stem and connect to its three majors structures. The cerebellum is primarily responsible for maintaining posture, balance, and coordination. Utilizing motor and sensory input from the brain stem, the cerebellum helps to smooth basic movements like walking as well as to fine-tune the muscle control involved in more specialized skills such as writing and athletics.

Positioned above the brain stem and forming the core of the cerebrum are three interconnected sets of brain structures that comprise the limbic system, the basal ganglia, and the diencephalon. The limbic system, often referred to as the "emotional brain," includes the hypothalamus, pituitary gland, amygdala, hippocampus, fornix, mammillary bodies, and other related tissues. Constantly implicated in new and different brain functions, the limbic system contributes significantly to emotion, memory, and motivation. The basal ganglia are collections of nuclei and neural fibers crucial to the function of the motor system. The diencephalon includes two major structures, the thalamus and hypothalamus. Located in the heart of the brain between the two hemispheres, the thalamus acts as the nervous system's central relay station; all sensory input to the brain, with the exception of the sense of smell, passes through the thalamus. The hypothalamus, which sits just beneath the thalamus, is important for both the autonomic nervous system and the endocrine system. The hormones produced by the hypothalamus regulate vital body functions, and the structure also governs basic feelings and drives like hunger, thirst, and sexual desire.

The suite of mental skills most closely associated with human thought—reasoning, language, imagination, personality—originates in the cerebrum, which, true to its name, accounts for approximately eighty-five percent of the brain's weight. The exterior layer of the cerebrum, called the cerebral cortex, is the brain's most familiar feature, with its gray skin of convoluted grooves (sulci) and ridges (gyri). Yet this gyrencephalic landscape is a wonder of biological design, evolution's answer to brain growth that outstripped cranial volume. This extensive system of grooves and ridges, which hides nearly two-thirds of the cortex's actual size, allows about sixteen square feet of cortical surface to be folded up within the skull.

The cerebral cortex is divided into four lobes outlined by prominent sulci and named for their overlying cranial bones: the frontal, parietal, temporal, and occipital lobes. These regional divisions offer a convenient way to survey

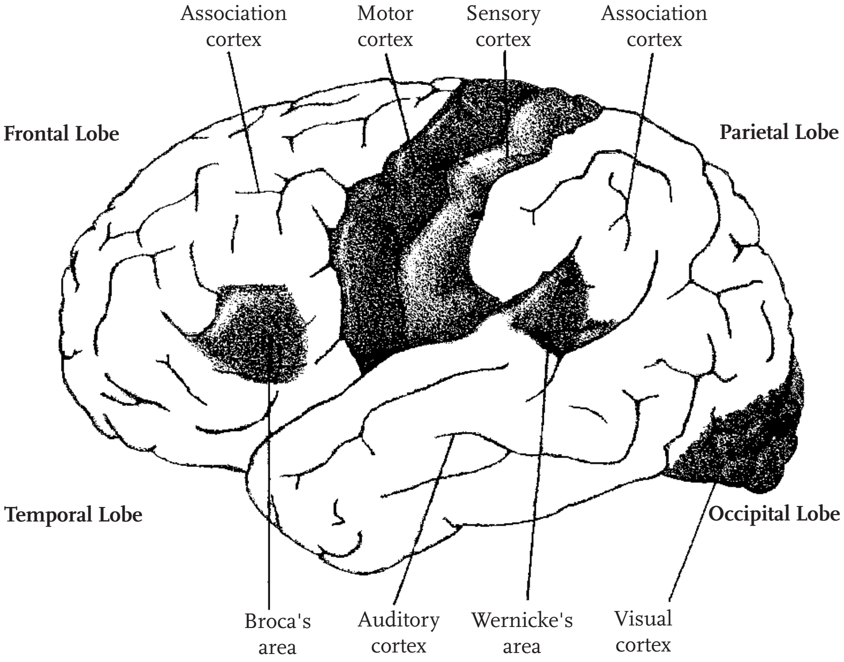

FIGURE 2.1. Major lobes and cortices of the human brain.

brain function. Each lobe carries out a variety of processing activities, and major neural systems can be localized within each lobe. This localization of specialized neuronal systems also allows brain structures to be linked with behaviors. Extensive study of healthy, diseased, and damaged brains has enabled researchers to map mental activities onto specific regions of the brain, though many processes, including memory, are associated with multiple areas of the brain.

The frontal lobe, the largest of the cortical regions, includes the area of tissue from roughly the midpoint of the head forward. The frontal lobe takes the lead in the planning and execution of movements, a specialization that is accented by the presence of the primary motor cortex and other neural areas dedicated to motor control. Further subdivisions of the frontal lobe contribute to higher-order human functions. The prefrontal cortex, for example, is involved in memory and behavioral processes. The frontal lobe is also the site of Broca's area, the part of the brain related to speech.

The parietal lobe, which abuts the central sulcus with the frontal lobe and extends toward the rear of the head, is mainly in charge of sensory processing. The major structure aiding in this task is the somatosensory cortex, which receives input from the thalamus and processes information about limb position, pain, body temperature, and touch. The occipital lobe, located at the back of the head, is devoted to vision. Here the primary visual cortex receives input originating in retina cells and transmitted along the primary visual pathway. This highly complex cortical region assembles visual images by coding features like brightness, color, and orientation. At the same time this information is shunted to other centers of the brain, which identify the "what" (form) and "where" (location) of each visual object. The temporal lobe, the region of the cerebrum along the side of the head, houses auditory processing areas. Sound waves received by the cochlea are routed to the primary auditory cortex via the thalamus, where perceptual qualities such as tone and volume are coded. The temporal lobe is also the location of Wernicke's area, the part of the brain related to language comprehension.

There are also large areas of the cerebral cortex that are not directly engaged in motor and sensory tasks. Found in each of the lobes, these neural areas are called association cortex because they receive and integrate input from more than one modality. The association cortices are thus sites of higher-order mental processes, where information from motor and sensory areas of the brain is used analytically and converted into complex responses. The work of the association cortices also highlights the presence and importance of connectivity throughout the brain. Despite distinctions of function, locale, and "higher" versus "lower" brain structures, the mind operates as a complex system with multiple components engaged in the processing of almost all forms of perception and thought.

The most striking physical feature of the brain as a whole is the longitudinal division of the cerebrum into two nearly symmetrical hemispheres that communicate with one another via a dense bundle of neural fibers called the corpus callosum. Although the two hemispheres appear similar, study of split-brain patients reveal that they are functionally dissimilar. In addition to receiving sensory signals from the opposite side of the body and sending motor responses contralaterally as well, each hemisphere is specialized for different kinds of mental activity. Research has shown a relationship between hemispheric dominance and whether a person is right or left-handed. In most right-handed people the left hemisphere is dominant in processing skills associated with language, math, logic, and speech. The right hemisphere dominates in judging spatial relationships, recognizing emotional expression, and processing complex imagery and music. In left-handed people the pattern of hemispheric specialization is more variable.

With the in utero completion of each of the brain's major structures comes the initiation of functional development. As early as the first trimester of a pregnancy, the fetus already possesses centers of balance and motion that respond to the mother's own movements. At the halfway point of gestation a fetus can hear. Sight remains severely muted, though; unlike for the sense of hearing, there are few external stimuli in the uterus. But by the seventh month the eyelids are open and the fetus can see by diffused light coming through the abdominal wall. Taste, too, is working as the fetus takes in amniotic fluid. In addition to these basic functions of sense and motor control, there is also clear evidence that the human brain is busy *learning* in the womb. One example utilizes the fetus's well-developed sense of hearing. Clever experiments that chart the rhythm with which a newborn sucks on a rubber nipple reveal preferences for a mother's voice and other patterns of sound heard while in the womb (DeCasper and Fifer 1980). Numerous similar experiments confirm that before birth individual brains are already attentive and actively engaged with the surrounding world, however limited.

This is a very good thing. The larger world into which babies are born is a buzzing, flickering, chaotic place. They need to be able to make sense of all this noise, light, and movement around them. Some skills, like language, can be put off until later, but others are foundational to both immediate functioning and further development. There is a three-dimensional world to be surveyed, spatial maps to be constructed, social connections to be made, objects to be identified, and so on—all the kinds of abilities that *enable* learning and which are themselves not learned in the usual sense. Each new human brain is not only comprised of the mental hardware it takes to execute these kinds of tasks, but also comes with the requisite operating system as well. Without this innate bundle of mental programs it would be impossible for newborns—or adults for that matter—to recognize or understand anything at all.

This is the surest sign that human knowledge is a biological phenomenon, and developmental psychologists continue to probe the true depth of the knowledge that is already present at birth. Babies are born with complex brains that do complex things, not least the assembly of mental representations and responsive behaviors that go well beyond the level of the input received. Babies can differentiate between people and objects. They act according to preferences, discriminating between familiar and unfamiliar faces, sounds, and smells. They recognize expressions of happiness, sadness, and anger. They know how people move. Babies possess social minds, which they use to place themselves in relation to others. Newborns imitate facial expressions, and they coordinate their own movements, gestures, and emotions to those who hold them. So wide is the range of mental abilities with which babies come equipped, and so skilled are babies at using them to analyze and predict the world, that Alison Gopnik, Andrew Meltzoff, and Patricia Kuhl like to speak of newborns as "scientists in the crib," pointing out that the cognitive capacities that even the most sophisticated lab-coated researcher brings to a question about the world have their origins in infancy:

> Babies and young children think, observe, and reason. They consider evidence, draw conclusions, do experiments, solve problems, and search for the truth. Of course, they don't do this in the self-conscious way that scientists do. And the problems they try to solve are everyday problems about what people and objects and words are like, rather than arcane problems about stars and atoms. But even the youngest babies know a great deal about the world and actively work to find out more. (2001: 13)

In short, humans are born doing human things. Such a statement sounds commonsensical, trivial, even foolish, especially to anyone who does not view the minds of human infants as blank slates. Unfortunately, that's precisely how philosophers and psychologists have characterized them for a very long time. For most of the past century it was assumed that babies arrived in the world as empty vessels that do little more than respond to external stimuli and acquire knowledge only as they are exposed to culture. Mental ability and content were assumed to be the products of rigorous social learning, not of innate programming. Of course learning from others *is* important, and adults as well as babies spend a good amount of time doing it. But what is crucial to see is that biology has bestowed both the functional mental abilities babies are born with *and* the powerful learning mechanisms they use to rapidly increase and restructure their knowledge. Nurturing takes place *via* nature. Throughout one's life the mind retains a plasticity that allows for learning—the continual acquisition, reshaping, and revising of information. The link between learning and hardwiring is even graphically expressed in the first year of life, when a baby's interactions with the world are directly reflected in the connectivity of the brain. During this period the number of synapses between neurons multiples rapidly, creating millions of new connections each day. It is unclear to what extent this neural development is dependent on external experiences as opposed to simply representing the final phase of mental construction, since, as with the maturation of key cognitive abilities, all children follow similar timetables. Nevertheless, the main point being expressed here is *that* we come to learn, as well as *what* we come to learn, are both grounded in biological inheritance. The human computer arrives packed with both the knowledge it takes to immediately begin interpreting the world and the mechanisms necessary for assimilating new information. Additionally, as we'll see later, much of what we do come to learn, regardless of when, is built on the same innate forms of knowledge with which we all begin life. As Gopnik, Meltzoff, and Kuhl conclude, adults, even adult scientists, are just "big children" (2001: 9; see also Harris 1994).

The final section of this chapter will return to the subject of what newborns know, for it is precisely in studying the minds of babies and young children that we can begin to circumscribe the content and application of innate human knowledge. But before moving from the hardware of the brain to a look at some of its central programs, there is another—a hidden—structural level to the brain that is crucial for understanding *how* we think. Exploring the various anatomical segments of the human brain, even identifying their areas of specialization, does not tell us how thought takes place, why the brain is so quick and efficient, or what about its particular design gives rise to such distinctly human capacities as imagination and creativity. Answering these types of questions requires models that describe the brain's *activity*, that attempt to map the mind in the way that neuroscientists map the brain itself. To be successful, such models cannot neglect the connection between the present and the prehistoric past, since the same forces that shaped the hardware of the brain would also have been at work on its selection of software. Enter evolutionary psychology.

Mental Modules and the Hidden Structures of Thought

When we see a mother holding her newborn it often sparks thoughts of the future rather than of the past. The life of this brand new person extends forward into tomorrow after all, and for the moment it represents the most recent, state-of-the-art version of *H. sapiens*. In reality, this baby's biological continuity lies not with the future, which does not yet exist, but with the past, with its mother, who came before, and then progressing backward through "mitochondrial Eve" and beyond. In canvassing the basic structures and functions of even the newest human brain it is important to bear in mind that our mental equipment has a long evolutionary history with clear links to the rest of the animal kingdom.

The common division of the human brain into forebrain, midbrain, and hindbrain helps to illuminate this process of cognitive development, which involved both the reorganization of old neural structures and the growth of new ones. The hindbrain, consisting of the brain stem and cerebellum, is often referred to as the "reptilian brain" because it is the evolutionarily oldest and most primitive part of the brain. As described above, the components of the hindbrain support the types of vital bodily functions, reflexes, and involuntary actions shared by all animals. The midbrain, including the tectum, tegmentum, and surrounding fibers, is the next oldest in evolutionary origin. The midbrain is functionally more central in nonmammals, where it serves as the main site of visual and auditory information. In mammals this data is handled by the forebrain, though the midbrain continues to help control eye movement and other motor activities. The structures of the midbrain, however, are crucial to our experience of self-awareness—an experience decidedly different from mere reflex. The forebrain, comprised of the cerebral cortex, limbic system, basal ganglia, and diencephalon, is a more recent evolutionary addition to the brain, with the bulky cerebral cortex, or "neocortex," representing the newest improvement, both with respect to brain size and computational power.

It is interesting to note that the prenatal development of the human brain within each individual (ontogenesis) corresponds to the evolutionary development of the brain within the species as a whole (phylogenesis). The brain of a human embryo starts out as a simple tube of tissue that, within weeks, begins reshaping itself into three circular enlargements that will become, in developmental order, the hindbrain, midbrain, and forebrain. Later the cortex of the forebrain divides into the two cerebral hemispheres and grows outward to cover much of the lower brain regions.

Internal shifts in brain function, such as the rerouting of visual and auditory information from the mid- to the forebrain, offer other direct evidence of the brain's evolutionary past. A frequently cited example is the limbic system, which, while taking the lead today in the experience and expression of emotions, originally evolved to evaluate smell. For animals with powerful olfactory senses, smell is a primary means for negotiating the world, such as deciding whether an object should be approached or avoided. In primates and humans the sense of smell has been greatly superceded by vision. As a result, the structures of the limbic system have largely lost their links to smell yet retain their job of generating emotional reactions ranging from fear to elation.

As a biological machine, then, the human central nervous system has much in common with those of other living organisms, designed, as all are, to control bodily function and to interpret and respond to signals received from the outside world. The human brain, however, is clearly different from that of any other creature on earth in displaying the higher-order mental activities we label with names like "intelligence" and "consciousness." Just what such terms mean, precisely, is widely debated by cognitive scientists and philosophers alike, but few would argue with the fact that humans, while anatomically similar to other kinds of animals, are functionally very different. It is often pointed out, for example, how alike certain members of the primate family are, but likeness at the level of genes or gross anatomy in no way translates into likeness of cognitive ability. What makes us humans so different is the kind of mind we have, which in turn is the result of our brain's specific evolutionary development.

Tracing humankind's cognitive evolution returns us once again to basic principles—how natural selection works, and how it would have gone about sculpting the minds of our ancestors. The first principle is elementary: nervous systems, like all body parts, evolve because improvements enhance an animal's chances to survive and reproduce. While not all animals require more than simple reflexes to succeed at the game of life, complex mental abilities bring other animals decided advantages. Brains enable active, voluntary behaviors rather than passive ones; a thinking animal can seek out food and avoid danger instead of waiting for them to come to it. Inevitably, natural selection moved some trajectories of mental development in the direction of improved cognition over basic life support. As brains get better, so do their problem-solving abilities and the benefits that accrue to their owners.

The second principle is more complicated. Just how does natural selection shape minds? How is thinking improved within the context of a particular environment? How are adaptations reflected in the brain? What does the modern mind owe to its evolutionary past? The discipline of evolutionary psychology brings a provocative set of suppositions to bear on these questions, overturning, in the process, some deeply entrenched ways of viewing the human mind, such as the claim that babies are blank slates. The central suppositions of evolutionary psychology have already been introduced on preceding pages, but now it is time to look more closely at how these ideas lead to clearer, more accurate models of the modern mind and also provide essential background for understanding contemporary thought and behavior.

We start with the idea that brains are computers—an insight borrowed from cognitive psychology. Conceiving of brains as computers has proven tremendously fruitful to research on artificial as well as biological intelligence. On the one hand, a computational theory of mind helps explain how organic tissue can process information and execute complex responses. On the other hand, this comparison points up the profound gap between the respective talents of neural and silicon circuitry and hints at what it takes to create "smarter" mechanical systems. Today's computers can crunch mathematical formulas at mind-numbing speed, but they are woefully stupid when it comes to basic human tasks like recognizing objects in the world, reading expressions, or finishing a sentence. Two of the most immediate differences between artificial and biological intelligence, then, are complexity and flexibility. Just as it is, without need of additional software or plug-ins, the human mind can complete an astounding array of functional, interpretive, and analytical jobs, moving freely from one to the next, doing many simultaneously, even combining inputs across modalities to create new and novel outputs. No computer made of plastic, wire, and silicon can yet *transpose* a rose through simile, *get* a joke, or *feel* the death of the machines that made it.

The present differences between artificial and biological intelligence throws up all kinds of challenges to the computer industry, which strives to design systems that increasingly emulate the complexity and flexibility of human thought, but they have also forced brain researchers to revise their understanding of how the mind itself works. When cognitive psychologists first began to investigate the mind, they envisioned it as a very powerful yet very simple program. This early model saw the mind as a kind of "general-purpose problem-solver" that operated according to a set of procedural rules that could be applied to all forms of information. Testing this model of the mind, however, led one directly to the quandaries faced in computer design. It is easy to create simple programs that master specific tasks, even abstract tasks, but such programs aren't much good at doing anything else, let alone at achieving the level of multi-tasking typical of human minds.

For example, one might suppose—and rightly—that a finite set of procedural rules can solve a wide range of mathematical equations. In this case, a brain and a computer could be precisely the same. So far so good. Yet it takes little thought to realize that this suite of procedural rules for doing math would be of little value to the task of language, or much else for that matter. Now what is required is one set of procedural rules for mathematics and other, completely different sets of procedural rules for the coding and decoding of speech. But of course there are a multitude of other unrelated operations that the mind can do, all of which require their own sets of procedural rules as well.

So the early general-purpose problem-solver model of the mind simply wasn't tenable. The evidence suggested that this model of the mind needed to be replaced with a model of the mind as a system of special-purpose programs. Thus cognitive scientists have come to view the brain not as one big machine capable of multiple tasks, but rather as a consortium of numerous small, independent machines, each of which specializes in a single task, and which, working together, lend the mind its obvious complexity of thought.

This perspective is known as the "modular" model of mind and was first earnestly proposed in Jerry Fodor's book *Modularity of Mind* (1983). The modular model of mind accounts for the complex, flexible nature of human thought by delegating specific processing tasks to discrete domains hardwired into the brain called "modules." For Fodor, each encapsulated module carries out its singular work quickly, automatically, and without access to the information found in other modules. In his groundbreaking work Fodor argued for a limited number of modules that corresponds to the sensory inputs of sight, sound, smell, taste, and touch, as well as one dedicated to language. After completing their specialized tasks, these input modules send their information on to centralized processing systems that, because they are not themselves modular, allow for the assimilation of lower-level perceptual knowledge into higher, integrative, problem-solving forms of cognition.

While responsible for setting the study of the mind on the right course, Fodor's seminal idea has since been extended by evolutionary psychologists like John Tooby and Leda Cosmides, who champion a widely accepted model of the mind known as "massive modularity" (1992). The main arguments anchoring the massive modularity model are that Fodor's modular model, while correct in principle, is still too limited and too cumbersome to account for the speed and tremendous variety of computational tasks of the brain, and that massive modularity better falls in line with the engineering methods of natural selection. The second argument, drawn from evolutionary biology, is even more compelling than the one from cognitive psychology.

Recall that natural selection works by solving successive adaptive problems posed by an organism's environment. As a result, adaptations accumulate over time, with each modification representing the best available solution to a specific pressure. In Tooby and Cosmides's view, the entire mind, even Fodor's general-purpose central processes, must be modularized because in the context of adaptation there are no *general* problems only *specific* ones. Lacking both the time and foresight necessary to organize parsimonious mechanisms—which would be impossible in any case since different adaptive problems likely require different solutions—natural selection instead addressed specific problems using specialized mental mechanisms. Such mental mechanisms, or modules, are effective, reliable, and fast because they are dedicated to a single task and, key to the discussion, because they are "content rich"; that is, each mental module is already pre-programmed with the set of procedural rules and knowledge about the world it needs to execute its specific task. In this way, natural selection slowly designed processes of thought, what Steven Pinker calls "Natural Computation," that not only successfully met adaptive problems but also did so in a way that achieved all the coveted goals of "Artificial Intelligence" (1994: 83).

The massive modularity model understands the human mind to be a bundle of hundreds, perhaps even thousands, of specialized devices, each applying itself to a single processing demand. Here the mind might best be envisioned as a Victorian mansion rather than as Fodor's mental apartment. In the massive modularity model, higher cognition does not take place in a single main living area supplied by input from a few side rooms; rather, the specific tasks of intelligence occur in a labyrinth of rooms, closets, and corners, all of which function smoothly together to generate the thought life of the typical human being.

What kinds of mental modules does the human mind contain? The current module hunt was actually initiated in the 1950s by the linguist Noam Chomsky, who was struck by the fact that children easily acquire language despite the fact that their exposure to it is grossly impoverished (1959). Children, Chomsky noted, receive nothing resembling formal grammatical instruction. Our everyday speech consists largely of improperly constructed, halting, unfinished strings of words, as every journalist knows. Yet children take this mess of syntax and speedily become competent language users. The reason, Chomsky suggested, is that language is not so much *learned* as naturally *developed*. This hardwired capacity shared by all people represents the first mental module, which Chomsky dubbed the "language acquisition device."

Another early modular approach to the mind was taken by David Marr, who was interested in how the visual system recognizes and constantly holds external objects in spite of the fact that visual information (color, shading, shapes, motion, and so on) is even more chaotic and underdetermined than is conversation. To account for the wizardry of sight—a feat involving a substantial amount of mental *interpretation*—Marr constructed a theory of vision in which the final images that we see are the result of different modules dedicated to detecting edges, motion, color, and depth (1982). A modular model has also been applied to auditory processing, showing that different mental mechanisms are engaged in the analysis of speech versus non-speech sound. (Liberman and Mattingly 1989). As already noted, Fodor agreed with this empirical work in the domains of language and sensory perception and used it to compose his original list of innate input modules.

For evolutionary psychologists, the complete slate of mental modules will only be uncovered as we place the modern mind against the backdrop of its ancestral past. If mental modules are evolved mechanisms constructed in response to adaptive problems, then we must consider the environment in which these problems were faced. That means looking again into the Pleistocene's evolutionary forge. It is wrong to attempt to explain the architecture of the mind in relation to contemporary times. The human mind evolved under the selective pressures confronted by our Stone Age relatives. Indeed, the post-Pleistocene period—a mere tick of time constituting only about 5,000 human generations—is largely irrelevant to the composition of the mind. Our minds remain adapted to a Pleistocene way of life; the mental modules we use today are the same ones our hunting and gathering ancestors used to survive in their own unforgiving Pleistocene world.

Cosmides and Tooby point out that many psychologists also erroneously attempt to describe the cognitive architecture of the mind based on the study of what it *can* do rather than of what it was *designed* to do (1994: 95). The evolutionary engineering of the past was completed without regard to present circumstances or with an eye to enabling cognitive skills beyond those necessary to solve problems within the Pleistocene environment. The novel ways we use our minds today, however impressive, are but secondary consequences, or by-products, of their functional design and cannot be used as an explanation for how that design came to be. “For humans, the situations our ancestors encountered as Pleistocene hunter-gatherers define the array of adaptive problems our cognitive mechanisms were *designed* to solve, although these do not, of course, exhaust the range of problems they are capable of solving” (Cosmides and Tooby 1994: 87).

By exploring the selective pressures our Pleistocene ancestors faced it is possible to predict and test for associated modular adaptations. For those who doubt the possibility of bridging the cognitive past and present, a well-known experiment employed by Cosmides demonstrates our ability to see ancient mental mechanisms in action (1989). A creative twist on a standard psychological test called the Wason selection task reveals how abstract reasoning capacities like deductive logic are by-products of mental modules designed for other, more practical purposes.

There is a deck of cards with numbers on one side and letters on the other. Four of these cards are placed on a table in front of you in the following arrangement:

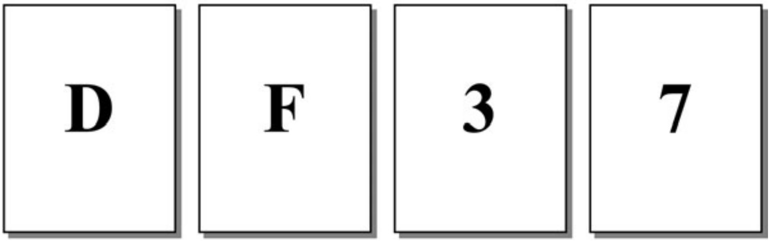

FIGURE 2.2. Wason selection task (deductive logic).

You are then told this single conditional rule: If a card has a “D” on one side, then it also has a “3” on the other side. The test of logic? Which cards do you need to turn over to determine whether or not this rule is true?

In point of fact, most people fail this test when it is presented in this way. The correct solution is to turn over the first and last cards, since the logically proper response for a rule of the form *If P then Q* is always *P and not-Q*. This form of reasoning is highly abstract, and it takes some time to arrive at the right answer. It is even hard for some people to see the logic of the solution after it is shown to them. What is intriguing, however, is that most people quickly and easily give the correct answer when the same test is presented to them in a completely different context. Cosmides (following Griggs and Cox 1982) set up the test like this:

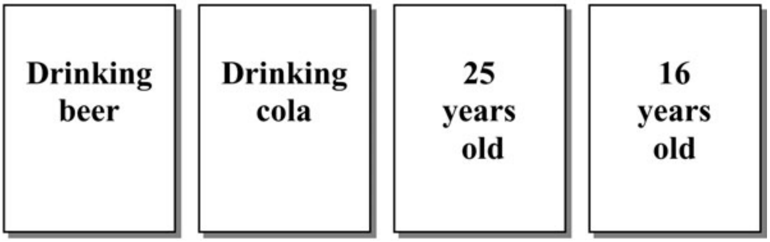

FIGURE 2.3. Wason selection task (cheater detection).

You are working at a local bar as a bouncer charged with policing underage drinking. The four cards now represent four different people, with one side showing each person's age, the other side showing what each person is drinking. Now, which cards do you have to turn over in order to determine whether the drinking age is being violated?

Note that the logical structure of both versions of the test is exactly the same, and yet the solution to the second is obvious. The immediate explanation for this is that human reasoning skills change dramatically depending on the context of the problem. But it turns out that only *certain* contexts markedly enhance performance. Other versions of the Wason selection task confirm that people are not highly competent at spotting violations of descriptive or causal rules either. What people *are* good at, and what the drinking-age test isolates, is deductive reasoning that relates to social exchange.

As the last chapter pointed out, astute social intelligence is critical to group living. Successfully navigating through complex social arrangements requires the mental skills involved in mind reading, kin relations, alliance formation, and many other facets of group life. The ability to detect individuals who cheat on the social contracts that underpin personal relations is among the most important of these skills, and we should expect this selective pressure to have been met with an associated mental adaptation—a module with specialized procedures for reasoning about social exchange. The second version of the Wason selection task capitalizes on this cheater-detection module; the logical problem is simple precisely because it is all about detecting cheats.

This sort of empirical evidence strengthens the argument for the modularity model of mind. If the human mind truly works like a general-purpose problem-solver, then context should make little difference to the outcome. The fact that the same problem is easy in one context and difficult in another suggests instead that specialized, context-dependent cognitive processes are at work. This test also reveals a second significant feature of mental modules. In addition to being *content-rich*, already pre-programmed with the processing information they need to do their work, mental modules are also *domain specific*. This means that a given module is only activated by input relevant to its specialized task. It also means that the processing information in one module remains inaccessible to others. One of Cosmides and Tooby's conclusions from their study of Wason selection tasks is that deductive reasoning developed as part of the cognitive processes regulating social exchange (1992). The first version of the test proves difficult because it poses a logical problem in an abstract form rather than in a concrete social one. As a result, it fails to activate the mental module capable of solving the problem with ease. If Cosmides and Tooby are correct, it suggests that the varieties of abstract logical thought unique to humankind are secondary consequences, or by-products, of cognitive capacities evolved for more worldly purposes.

Just as we should expect natural selection to have designed a cheater-detection module to deal with the exigencies of group living, we should also expect the modern mind to be loaded with mental modules for solving a host of other adaptive problems. The massive modularity model of mind argues for thousands of mental modules at work in human cognition, all of which make perfect sense in light of evolutionary history. Though the possibilities remain speculative, the following short list of mental modules serves as a sample of some of the more widely accepted candidates and illustrates the range of thinking and behaviors related to them:

- *Predator detection*: Fundamental to daily survival, mental modules related to predator detection rapidly distinguish threats in the environment and trigger avoidance or defensive behaviors.
- *Food preference*: Also fundamental to daily survival, mental modules regulating food preferences promote a desire for safe, nutritious foods (especially those rich in sugar and fat) and dislike and disgust for harmful or poisonous items.
- *Mate selection*: Daily survival is the means to a gene's ultimate end—reproduction. Mental modules help to discern sexual partners who are genetically and developmentally robust based on subtle aspects of physical appearance, such as body shape and symmetry. Mate selection criteria also include characteristics that suggest individuals will be good mothers and fathers, markers (for example, age, resources, and loyalty) that are gender specific. Conversely, related mental modules work at advertising oneself as a good choice for others.
- *Child rearing and kinship*: In many species reproductive success necessitates a period of childcare after offspring are born. Likewise, nonreciprocal support of close relatives helps assure genetic propagation. Related mental modules support familial behaviors, including skills such as face recognition and estimating degrees of relatedness.
- *Alliances and friendship*: For highly social animals, the ability to form mutually beneficial partnerships with conspecifics is vital to gaining and maintaining access to basic resources (food, sex, and protection).

> Related mental modules include the mechanisms involved in monitoring social exchange.

These mental modules are directly related to survival and reproduction within the ancestral environment (both ecological and social), and from an evolutionary standpoint this is indeed the functional raison d'être of all adaptations. But natural selection cannot focus solely on activities associated with food and sex since being good at living and reproducing requires a wide range of supporting skills. As Tooby and Cosmides argue, this requirement is responsible for the accumulation of distinct families of specialized information-gathering, inference, and decision-making modules that progressively increased the power and breadth of thought and, ultimately, gave rise to the polished cognitive capacities of the modern mind:

> By adding together a face recognition module, a spatial relations module, a rigid object mechanics module, a tool use module, a fear module, a social exchange module, an emotion perception module, a kin-oriented motivation module, an effort allocation and recalibration module, a childcare module, a social inference module, a sexual attraction module, a semantic inference module, a friendship module, a grammar acquisition module, a communication pragmatics module, a theory of mind module, and so on, an architecture gains a breadth of competences that allows it to solve a wider and wider array of problems, coming to resemble, more and more, a human mind. (1992: 113)

Tooby and Cosmides's massive modularity model is not the final word on the architecture of the mind; not all cognitivists are comfortable with it. Steven Mithen, for instance, argues that the only way to account for such unique and provocative human capacities as imagination, creativity, and analogical and metaphorical thought is to build into the mind processes capable of combining the many forms of thought in flexible, novel ways (1996). Dedicated, encapsulated mental modules like those proposed by Cosmides and Tooby should be inherently incapable of producing the variety of cross-domain reflection that appears to be the hallmark of modern intelligence. Resting his model of the mind on the classic idea that "ontogeny recapitulates phylogeny," and drawing evidence from the work of developmental psychologists like Patricia Greenfield (1991) and Annette Karmiloff-Smith (1992), Mithen argues that the mind of each person passes through three architectural phases of development resulting in what he calls "cognitive fluidity," the basis of our extraordinary mental abilities.

According to this model, babies are born with a "generalized mentality" very like the general-purpose problem-solver described above. The mind of the infant soaks up different types of information about the world using the same cognitive processes as its neural wiring settles into place. The phylogenic connection here is that the mind of the human infant is similar to the mind of a chimpanzee; both use general intelligence to interpret and interact with the world. At about the age of two, children enter the second phase of mental development, shifting from a generalized mentality to a "domain-specific mentality." This phase of mental development is characterized by precisely the kind of modularization articulated by Cosmides and Tooby, and it is no coincidence, Mithen argues, that much of the empirical evidence for modularized thought comes from the study of children around the ages of two and three. As expected, this is the period when specialized, content-rich intelligences take shape, such as language acquisition and an understanding of object permanence. It is also an important period in that cultural context plays a role in determining the range of domain intelligences that eventually develops. In this phase of modularization the child's mind is like those of our Pleistocene ancestors, whose intellectual and technical abilities were clearly superior to chimps and early hominids but who left little evidence that they were engaged in more sophisticated forms of thinking. During the third and final phase of mental development, marked by a shift from a domain-specific mentality to a "cognitively fluid mentality," the mind's suite of modules begins to work together, building connections that facilitate information exchange. Rather than remaining isolated in encapsulated domains, different forms of knowledge can be linked and combined, allowing for the diverse, intricate, spontaneous, and imaginative nature of truly *human* thought.

For Mithen, a developmental model of the mind explains both the unique mental capacities of modern humans and the mysterious period of cultural explosion evident in the archaeological record. As Mithen points out, the start of intense cultural proliferation some 50,000 years ago does not coincide with the appearance of the first modern humans around 100,000 years ago. While scientists have long found it easy to herald brain size as the defining characteristic of human evolution, Mithen asserts that intelligence has more to do with the design of the mind than with its dimensions. It was the later, final development of cognitive fluidity that brought about the "emergence of the modern mind—the same mentality that you and I possess today" (1996: 15) and ignited the cultural explosion. The fundamental changes in lifestyle and the many new artifacts that appear at this time were the result of nothing less than a major alteration in the very nature of the mind.

Whereas Fodor's model of the mind (limited modularity) is like an urban apartment consisting of a central living space and a few side rooms, and Tooby and Cosmides's mind (massive modularity) is like an immense Victorian mansion where thought takes place in hundreds of private rooms, Mithen describes the modern human mind (integrated intelligence) as a majestic cathedral, whose construction takes place in three phases as individuals move from infancy to adulthood. The finished edifice is comprised of many classrooms, offices, and chapels, each with doors opening to a grand central nave of general intelligence where knowledge and ideas flow freely and harmoniously between the domains of specialized intelligence and promote brand new forms of thinking and behavior.

There are other models of the mind that complement the ones presented here. Dan Sperber, for example, has proposed that the apparent gap between a massively modular mind and a creative one can be bridged with yet another specialized module, one that evolved to enable the forms of cognition described by Mithen and the developmental psychologists. Sperber calls this hypothetical mechanism or set of mechanisms the "metarepresentational module" and suggests that its job is to take the concrete mental representations produced by other modules and generate second-order "mental representations of mental representations" (1994: 60), precisely what takes place in instances of imaginative and metaphorical thought.

Regardless of the exact nature of mental modularity—limited, massive, or integrated—what ties these various models together is an understanding that all of the present structures and functions of the modern mind are selected adaptations accumulated over the course of evolutionary history. The mind did not develop all of a piece; rather, specific modules evolved to solve specific problems. The result is a complex assemblage of mental units that achieve rapid, efficient information processing, and which, either through generalized connections or thorough specialization, advance higher-order forms of cognition. Another commonality between all of these modular models is the recognition that the human mind comes loaded with lots of pre-programmed knowledge and hardwired cognitive skills. Reacting against the Standard Social Science Model, which views the neonate mind as essentially a blank slate and places a fundamental division between biology and culture, the models of mind put forth by cognitive, developmental, and evolutionary psychologists rightly include innate knowledge bases that facilitate computation in specialized domains. The rest of this chapter will describe three of these intuitive *kinds* of thinking as well as some *ways* of thinking, both because they help round out the survey of mental architecture provided in this chapter and because one of them, namely, intuitive psychology, is foundational to the discussion found throughout the rest of this book.

Some Programs and Processes of Human Thought

Already the cognitive scientist's preferred analogy for the human brain—the common computer—has provided a fruitful way to explore some of the structures and functions of this most outstanding biological organ. But there is one more likeness between the mind and the machine worth exploiting here. As the last paragraph affirmed, the newborn baby and a newly shipped Dell have something very important in common: they both arrive ready to hit the ground running.

Consider any infant and off-the-shelf PC. After jettisoning its protective sack of amniotic fluid, a baby leaves the safety of the womb and enters a bright, noisy, touchy world. It is poked and prodded, subjected to medical tests, and fondled incessantly by an array of people, only one of which is its mother. The computer arrives in a womb-like carton, ensconced in protective layers of cardboard and foam. There are no medical procedures to be completed and certainly no slap to be administered, but the ensuing set-up process, cable connections, and reference materials approximate the attention lavished on a newborn in the delivery room. Once this flurry of activity subsides and one steps back to observe the new baby and the new PC quietly doing what they were designed to do—being a human and being a computing machine—it becomes clear that each one already knows a great deal about what these respective tasks entail.

The innate abilities of mind and machine are not only intriguing but also essential. There is, of course, no mystery to the fact that the computer already has knowledge and can immediately begin its work, but thinking for a moment about this trivial fact helps to clarify the less obvious, and certainly less trivial nature of the newborn's mind. In short, computers work because they are programmed to do so. Every new computer comes complete with an operating system that contains instructions for how to be a computing machine as well as for how to recognize and process new input. Without this elaborate program the computer is nothing more than an inert sculpture. A computer that arrived at your doorstep as hardware only would be utterly useless. Even if you owned a library of software, the computer would understand none of it. It is the personal computer's operating system, call it PC 1.0, which enables the hardware to understand the meaning of any new input received from the outside world—from basic word processing programs to complicated flight simulation software—and to begin implementing it properly.

Living machines have the same operational requirements. From the moment of birth a baby is bombarded by input from its strange new world. Some sensations are random and incidental, others are deliberate and personally relevant. Some things in the environment are inanimate and insignificant; others are alive and intentional in their actions. Competency at the tasks of recognition and interpretation is crucial to survival and successful development, so it needs to begin immediately. Yet, if human brains were only hardware they would be functionally useless. All of that light, noise, motion, and touching, let alone the kaleidoscope of objects and people, would remain insensible. Without some rather crucial innate skills, newborns would be like new computers lacking operating systems.

So for mechanical reasons a blank-slate view of the mind is simply untenable. No mind could possibly understand, respond to, or use a piece of new information received from the environment unless it already possessed the equipment and knowledge that *enabled* it to understand, respond to, and use this new information. Nor can learning mechanisms alone account for the development of mental abilities. As Tom Lawson points out, though there are parents and other models for nurturing the growth of newborns, "from the child's point of view, the behavior of the parents and all the other things in the environment requires as much interpretation and explanation as all of the other things and events that the child encounters" (2000: 76). Newborns immediately begin the work of being human because they, too, come programmed to do so. The biological computer, model Modern Human Brain, arrives preinstalled with an operating system prepared by evolution that contains all the instructions for human computation as well as programs for processing new input. Like computer models whose operating systems are the same right out of the box, MHB 1000s run on MHB 1.0.

The efforts of developmental, evolutionary, and cognitive psychologists are rapidly adding to our understanding of how MHB 1.0 works and what some of its programs do. Because they were designed to help people successfully interact with their natural environment, the programs bundled into the human operating system work to organize, interpret, and predict objects and events in the world. One way that psychologists commonly refer to these types of crucial, innate programs is with the label "intuitive" or "folk" knowledge. The term "folk," coined by Daniel Dennett as part of the phrase "folk psychology" (1987), has come to denote the several systematic forms of knowledge and thinking that ordinary people use to explain the things, activities, and other individuals encountered in everyday life.

There are three categories of intuitive knowledge that are almost universally accepted and which illustrate well the nature of the operating system guiding human thought: intuitive biology, intuitive physics, and intuitive psychology. Developmental psychologists have come a long way in charting the innate foundations of these three knowledge bases as well as the astonishing speed and general timetables under which related interpretive skills mature. Such evidence strongly suggests an interactive understanding of cognitive development in which the experience of external stimuli interacting with innate cognitive mechanisms and predispositions results in the acquisition of new forms of knowledge (Groome 1999). What follows are general synopses covering the content and use of each of these important forms of tacit thought:

- *Intuitive biology*: Intuitive biology refers to the way minds categorize and reason about living things. The world is filled with all kinds of "stuff"—there's people, animals, plants, natural objects, and handmade artifacts. Humans naturally sort the external environment ontologically. At the most basic level, we know that living things and inanimate objects are fundamentally different. Thinking about the class of living things also prompts a wide range of inferences that apply only to biological organisms, including organic composition, vital functioning, movement, and intentional behavior. Extensive research shows that very young children possess this knowledge, too, and they reason accordingly. One intriguing way that living things are understood is through “essentialism.” What a plant or animal *is* is based on the attribution of a species-specific “essence” that cannot be changed despite appearances. For example, children will not call an animal shown to have gears inside its belly a living thing, or decide that a man who has lost his legs is no longer a person, or think that a mother hen will give birth to a hamster, or agree, as Frank Keil has playfully shown, that a horse fitted in a striped costume becomes a zebra (1989). Scott Atran has thoroughly demonstrated the universality and extent of intuitive biology, showing how people groups across the globe use the same systems of species exemplars and hierarchical taxonomy to identify and organize the natural world (1990).

- *Intuitive physics*: Intuitive physics refers to tacit knowledge about basic mechanical properties and principles that adhere in the world of physical objects, such as solidity, motion, and causality. Experiments with very young children confirm that they understand a set of rules that govern material objects—rules that differ from those that govern mental concepts and living things—and, like adults at a magic show, they are surprised when these rules are violated. Researchers such as Renée Baillargeon and Elizabeth Spelke have found that infants are capable of reasoning about the physical properties of objects involved in simple events (for example, Spelke 1991, Baillargeon 1995). Babies only a couple months old take into account the continuity and solidity of objects and have a range of expectations about how such qualities apply. For example, infants grasp the continuity of shape and make assumptions about partially occluded objects. They understand that solid objects collide with each other and do not normally pass through other solid obstacles. Additional expectations infants have are involved with cause and effect. Objects move when other objects push them; actions cannot be caused at a distance. Infants also grasp basic laws of motion. Moving objects must follow sensible, continuous trajectories. If a ball rolls behind a screen, for instance, then it ought to emerge again at a predictable spot and time. Spelke shows that children also count on the rules of gravity and inertia, though these physical concepts take more time to fully develop. Material objects are also recognized to be different in kind from the class of living things. The elaborate system of classification used to organize biological knowledge is not used in the world of objects. Most importantly, people do not employ the idea of essences when thinking about artifacts. Material objects can be put to new uses and therefore can be thought of in totally new ways. Things made of plastic blocks, for example, can be broken apart and remade into completely different objects with no sense of lost continuity. What a given object is, as opposed to what a living thing is, depends on context rather than on a sense of internal essence.

- *Intuitive psychology*: Intuitive psychology refers to the natural attribution of mental states to other people and the cognitive skills involved in the ongoing interpretation of those states. As the first chapter discussed, we are all consummate psychologists who spend large amounts of time and energy attempting to read the minds of others, especially as their beliefs and desires pertain to ourselves. But working from a theory of mind also helps to explain the causes of behaviors and events in the world more generally, particularly within the social networks that define human life. A large body of research in child development reveals the extent to which a mentalistic perception of the world is present at birth and the degree to which it matures in a few short years. In the crib babies favor social stimuli like faces and voices, and they soon begin to follow the gaze of eyes and check nearby people for clues about happenings. By the age of two children have mentally separated themselves from others, recognizing that those around them do not necessarily share their own beliefs and desires. They also grasp the difference between psychological and physical causality—in the realm of living things, actions can be caused at a distance after all! Pretend play, which begins in earnest, openly attests to the mentalistic world in which all humans live. By the age of four children reach a final milestone in the development of their psychological apparatus by coming to realize that other people can hold beliefs that they themselves know to be false. This ability opens the door to the full-blown theory of mind introduced earlier as well as to skills of deception and other mental strategies that comprise social intelligence.

As these three foundational domains of intuitive knowledge illustrate, there is an expansive bundle of programs hardwired into the human mind. These knowledge bases are species-specific and rooted in innate mental mechanisms. While some cognitive abilities require phases of maturation, it is impossible that these knowledge bases could be acquired, to such depth and with such speed, from infants' limited experience of the world. Rather, people possess minds designed to immediately begin recognizing relevant information about the environment. We are all intuitive biologists, physicists, and psychologists. From an evolutionary standpoint, these mental skills are crucial: intuitive biology provides detailed information about the natural world; intuitive physics makes it possible for us to count on a stable, lawful sphere of existence; intuitive psychology grounds the kind of intelligence it takes to interact with others. Natural selection has well equipped human beings with the mental tools necessary for life in the cognitive niche.

The presence of intuitive knowledge not only allows babies to hit the ground running but it also makes them (makes everyone, actually, regardless of age) ready learners. Because babies are born with foundational knowledge bases, they are able to assimilate a wide range of new information using these same intuitive systems. Young children are not confused when they encounter an unfamiliar animal for the first time because they already know what "animals" are like. Young children aren't shocked when a building made of blocks topples over because that's how "things" work. Some young children are shy around other people because they know that they are being watched, and that's normal too. The acquisition of a native language takes place in the absence of real grammatical instruction precisely because, as discussed earlier, it depends upon yet another domain of intuitive knowledge. Such intellectual feats in small children highlight the *noncultural* foundations of many forms of human knowledge. True, grasping the principles of Euclid geometry or Husserlian phenomenology may take a semester or two of intense formal instruction, but when it comes to new information about the world at large, "common sense" usually affords all the education that people need.

Talk of the noncultural foundations of knowledge, then, extends beyond natural *kinds* of thinking to natural *ways* of thinking; that is, to the cognitive mechanisms responsible for recognizing and organizing information received from the world. Think for a moment about the little considered but rather astounding process going on inside you at this very moment. All normal people see, hear, smell, taste, and feel the world "out there," but it's really amazing that they do. Sight, after all, is the result of nothing more than photons of light striking the retina. Hearing is the result of slight changes of air pressure that cause vibrations in the eardrum. In all areas of sensory perception the brain takes what are grossly impoverished stimuli and, through an intricate process of translation and transformation, literally constructs an accurate model of the world. The hidden nature of this mental construction project—and our wonderment at it—escalates as the level of complexity is extended. Why do you not only see the light reflected from a familiar face *as a face* but also know *to whom it belongs*? Why are you able to quickly recognize someone from behind as well as from the front? How can you picture someone who isn't in view? How, indeed, can you conceive of someone or something or some concept that doesn't even exist?

The starting point for the standard answer to questions about how we construct worlds of real and imagined objects and ideas is that our minds take the various forms of raw information—sensations, signals, communications, and so on—and turn them into mental "representations." A good definition of a "representation" is hard to come by, but essentially representations are internal pictures or models created by the mind that allow for beliefs, thoughts, and actions. The mind generates these pictures and models using cognitive procedures that are hardwired into the brain. Cognitive psychology is all about discovering the processes that stand behind our mental representations of the world. One of these complicated processes—pattern recognition—can be grossly simplified by imagining the mind as a kind of virtual workshop containing grids, gauges, and tools used to measure incoming information and produce the proper representations. In this capacity, the mind takes in a few clues about real things in the world and builds mental replicas of them based on patterns it already has on hand.

The subject of faces provides an excellent example of pattern recognition at work because, given humankind's gregarious past and present, our mental workshops are hypersensitive to patterns that resemble faces. We see them everywhere—in clouds, behind two blinking lights, on the surface of the moon, in the most arbitrary splotches of ink. In his charming book *Unweaving the Rainbow* (1998) Richard Dawkins describes a household experiment that illustrates the inexorable nature of pattern sensors like the ones responsible for representing faces. Dawkins urges readers to buy a rubber mask like those worn at Halloween. Set the mask up at the opposite end of a room and look at it. When faced toward you, the mask obviously looks solid, because it is. But when you turn the mask around so that the hollow side faces out, a remarkable illusion takes place. Despite your knowledge that the mask is hollow, and in spite of direct visual evidence reaching your retina that confirms that the mask is hollow, your pattern sensor for faces is so powerful that it trumps all other stimuli. The mental workshop naturally goes about its work of finishing the job and produces a complete image. You cannot help but perceive the empty mask as a haunting, solid face.

The same kind of cognitive process is at work in the internal representation of objects and ideas. Pascal Boyer speaks of another important supply of patterns found in our mental workshops as "templates," which help minds identify and organize what is observed and learned (2001). Boyer refers to these templates as "ontological categories," which align nicely with one of the intuitive knowledge bases. These templates work like folders in a mental file cabinet, with one folder for each kind of thing that exists in the world: *Animal, Plant, Person, Natural Object, Artifact,* and so on. These templates make concept building easy because they allow us to file new information rapidly and accurately. A young girl who encounters a giraffe for the first time may find its figure comical and quite unlike anything she's ever seen before, but she has little trouble placing it in the correct folder: *Animal.* Her mind simply draws out the template for *Animal* and creates a new concept, *Giraffe.*

What is particularly important about this system of ontological templates is that each one already contains lots of information about the kind of thing it represents. The *Animal* template, for example, includes general descriptions that apply to all animals: natural, living, eats, moves, and so on. These general descriptions are very different from those found on the *Artifact* template, for instance, which includes the information: not natural, inanimate, doesn't eat, doesn't move. Having generalized knowledge like this allows the mind to spontaneously infer a host of additional information when building new concepts. As the young girl sees the giraffe for the first time, much more takes place in the creation of her *Giraffe* concept than the acquisition of a new name. She also automatically adds to her new concept all of the information that applies to *Animal* in general. She may not know what a giraffe eats specifically, but she is quite sure that it does.

Conceptualization can also work backward from the generalized information to the proper template. If Boyer tells you, as he does in his book, that "Zygoons are predators of hyenas" and that "Thricklers are expensive" (2001: 58–59), you will likely infer that in the first statement he is talking about an *Animal* and in the second about an *Artifact*. These inference connections are made because the knowledge that predators eat other animals automatically activated the *Animal* template, and the knowledge that things are purchased automatically activated the *Artifact* template. Furthermore, after you activate the proper template, additional inferences will automatically be added to the original information, such as expectations about the Zygoon's other animal characteristics. This process of inference is also revealed through the ease with which we create concepts of unreal or imaginary things. The idea of a *Ghost* is easy to assimilate because it automatically activates all of the inferences that apply to the category *Person*, save for the one that makes it unnatural: not living.

Boyer refers to the networks of automatic connections that foster thought as "inference systems" and shifts from the metaphor of templates to the reality of cognitive inferences. Of course the mind doesn't literally contain file cabinets and templates, but it does think by utilizing complex inference systems. Through a process of intuitive leaps and systematic generalizations the mind is able to go beyond fragmentary information and build up rich representations. In fact, "the way people generalize is perhaps the most telltale sign that the mind uses mental representations, and lots of them" (Pinker 1997: 86). The employment of inferences and generalizations is one of the hallmarks of human cognition, accounting for the speed, efficiency, and flexibility of thought.

Yet it is also important to see that inferences and generalizations proceed along specific paths depending on the information given. The concept of an animal does not naturally activate inferences about an object. Thinking about a person does not naturally activate inferences that apply to a plant. This means that thought is not random but constrained in various ways. Two helpful terms for describing mental activities like pattern recognition and inference are "bias" and "predisposition." The human mind has a disposition to process information along particular channels that lead to predictable ends. This assures that representations remain constant—that when you see a face it's always a face rather than a cat or a rock and that if you encounter a tiger in the wild you won't assume it doesn't eat. Randomness in the generation of representations would be dangerous, not to mention utter madness. Among the notable features of MHB 1.0, then, are default settings that guide reasoning processes unless conscious effort is taken to override them.

Intuitive knowledge, pattern sensors, and inference systems are just some of the programs and processes of thought, but they sufficiently demonstrate aspects of human cognition that will be featured prominently in the next stage of this discussion. First, having minds that are predisposed to think in consistent, predictable ways means that all people everywhere build concepts using the same procedures and, ultimately, represent the world of things and ideas in very similar ways. This has important implications for the study of culture and the ideas that people share. A standardized mental operating system should result in, and consequently explain, a wide range of common and persistent representations.

Second, even a cursory look at the programs and processes of thought reveals how the finished products of the mind owe their existence to hidden cognitive mechanisms. One of the most significant findings of cognitive psychology is how much of our thinking takes place below the level of awareness. Representations are constructed in mental workshops outfitted with specialized machinery of all sorts, each contributing to the project at hand. Most of this work is automatic, rapid, and incorrigible; only the finished product is made available, by means of a mental dumbwaiter, to conscious inspection. Normally this process runs so smoothly that we experience a perfect constancy of thought and perception. Only clever experiments or tragic events like brain damage disclose how truly complex the simplest task can be.

Finally, the constructive nature of human cognition makes it clear that what we often refer to as imaginative, abstract, or even sublime ideas rest on banal, garden-variety forms of thought. We need not search for special cognitive processes to account for "special" kinds of thinking. *What* people think is explained by *how* they think. We can account for a great range of human ideas by connecting them to the kinds of hardwired programs and processes described above. Many of the marvelous thoughts we humans entertain rise well above the level of brute existence, but they can nevertheless be understood as by-products of cognitive skills and tacit forms of knowledge designed to accomplish more mundane calculations. This book, of course, is concerned with explaining *religious* thought, a mode of thinking long deemed "special." Yet the cognitive science of religion is demonstrating that religious ideas and behaviors—some of the most sublime uses of the human mind—are eminently tractable.