of a force field, drawing in to itself its own particular assortment of data, stories, and reflections. Special sensitivity halos our sense of self, our sense of control, our take on moral values, consciousness, sleep, and dreaming. We feel less sensitivity toward how our brain controls our body’s temperature than how it manages our autobiographical memory, though management of body temperature is certainly a crucial function. The sensitivity is spawned partly because functions such as self-control and consciousness are at the core of our very being. It is owed partly and reasonably to fear of the unknown, fear of changing our worldview and our self-view. It is owed to uncertainty about what exactly will change and how.

My take on the roster of sensitive issues is that although much is still unknown about the nervous system and how it works, what is known begins to free us from the leaden shackles of ignorance. It makes us less vulnerable to flimflam and to false trails. It grounds us in what makes sense rather than in the futility of wishful thinking. It adds to the meaningfulness of life by enhancing the connections between our everyday lives and the science of how things are. Harmony and balance in our lives are deepened and enhanced by that connectedness.

I began by saying that my brain, not a soul, holds the key to what makes me the way I am. That assertion is backed by science—actually a lot of science and not only neuroscience. Still, a fair question is this: Does the idea of the soul really deserve to be shelved, much as we have shelved the idea of spontaneous generation of mice from dirt or the idea of geocentrism or animal spirits? Might we have a soul as well as a brain? The next chapter takes a closer look at the heyday and then the slump of the hypothesis that the soul is what gives us a mental life.

Chapter 2

Soul Searching

For vast stretches of human history, no one knew that it is the brain that allows us to walk, see, sleep, and find mates and food. We just did those things—walked, saw, slept, found mates and food. You do not need to know that you have a brain for the brain to operate very efficiently in getting you around the planet and seeing to your well-being. You do not have to stoke up and direct your brain; it stokes up on its own and directs you.

The human brain has been shaped by hundreds of millions of years of evolution. A powerful driver in the evolution of the brain was the importance of moving the body and making predictions so as to guide movement appropriately. An animal needs to move its body for all the necessities—to get food and water, avoid predators, and find a mate. For an animal to thrive, its brain needs to respond to pain or cold, thirst or lust, in appropriate ways, and those ways typically involve organizing bodily movement. Better predictions allow a brain to make more successful movements, and more successful movements increase the animal’s chances of surviving and reproducing, thereby spreading the genes that built that better brain. To perform
these jobs more efficiently and thus to compete more successfully in a tough world, complex brains evolved neuronal circuitry to model the body—its limbs, muscles, and innards—along with relevant aspects of the outside world.¹

First, consider the brain circuitry organized to generate a neural model of the world outside the brain. Processes in this neural organization model events in roughly the same way that the features of a map model the features of the environment. The typical map does not resemble all aspects of those features—the squiggles for the river are not actually wet, for example, nor is the real river only a millimeter wide and completely dry. Still, the map does constitute a representation of certain relevant aspects of the environment. In particular, map features have the same spatial relationships with each other as geographical features in the world do. That is what makes the map a faithful model, and that is what makes the map useful for navigation. Thus, in both the map and the real world, the river’s headwater is closer to the mountain than to the sea, the river makes a bend to the north before going into the sea, there is a broadening of the river as its descends from the mountain, and so forth. In a somewhat similar way, a satellite camera’s image of Earth represents Earth, including the color differences between oceans and land. That image is not literally wet or cloudy, but it represents the oceans and the clouds.

Caution: Before getting too cozy with the map analogy, let me be clear about where it breaks down. When I consult a road map, there is the map in my hand and, quite separately, there is me. The map in my hand and I are not one. In the case of the brain, there is just the brain—there is no separate thing, me, existing apart from my brain.² My brain does what brains do; there is no separate me that reads my brain’s maps. This disanalogy with using a road map is part of what makes understanding the brain so difficult, especially since the idea of someone in my head reading the brain’s maps keeps sneaking back into my thinking. Ironically, however, that very disanalogy contributes to what makes neuroscience so thrilling. We understand, more or less, how I can read a road map. We do not understand nearly as well how I can be smart because my brain maps my inner and outer worlds, absent a separate me to read those maps. I want to know how all that world mapping and me mapping is done.

With the caution and thrill duly registered, we can now return to the idea of brain models, agreeing that no separate person is in our brain reading the maps or using the models. The brain models aspects of the external world, thereby creating the informational structure that allows us to interact productively with things in the external world. This roughly means that by virtue of brain organization, there is a relationship between the external events and particular brain activities that enables the brain to navigate the world in order to find what the animal needs to survive. When sensory representations in the brain are connected in the right way with the motor system, successful behavior, such as self-maintenance, is the outcome. Thus, the animal flees a predator or lands a prey or deposits some sperm, for example.

The “designer” of brain organization is not a human cartographer, but biological evolution. If an animal’s brain misrepresents its domain, mistaking a rattlesnake for a stick (rather like mistaking 4th Avenue for Stanton’s Creek), or if the mapping functions do not direct the motor system to produce the appropriate behavior—approaching a predator when it should flee—the animal will probably be killed before it has a chance to reproduce.

Suppose you hear the sound of a crow cawing. Although the activities of the auditory system neurons do not literally resemble sound waves, those activities zero in on the right place in your learned map of the typical sounds in the world, such as the cawing of the crow. The various differences in the physical patterns of sound waves made by whistles or cries or bangs are
represented in your neural model as differences in the positions within your internal neural map.\textsuperscript{3}

As we look at the specializations of the brains of different species, it is evident that brains have evolved to map their worlds according to their sensory and motor equipment and its evolution. More accurately, we see a coevolution of brain equipment and body equipment. Bats have an exceptionally large part of their cortex devoted to processing auditory signals because they use a sonarlike system to find, identify, and catch objects at night. Monkeys and humans, who tend to sleep at night, have exceptionally large cortical areas engaged in processing visual signals.

For their body size, rats have a huge somatosensory cortex, much of it devoted to mapping the activity of their whiskers. This is owed to the fact that rats do much of their business in the dark, where vision is useless but where smell and touch have proved invaluable. Rats and other rodents use their whiskers (vibrissae) to get information about the size of holes and crannies, to palpate objects, and to orient themselves in their surroundings. Their whiskers rhythmically sweep back and forth between 5 and 25 times per second (known as whisking), while the brain integrates the signals over time so that the rat can identify an object.\textsuperscript{4} This is the rat equivalent of what we do when we scan a scene by making many eye movements across the terrain. Humans use their eyes but not their whiskers to navigate their external world, making saccadic eye movements about three times per second. Inevitably, I wonder what identifying another person by whisking instead of by visual scanning is like. A congenitally blind person who reads Braille probably has a pretty good idea of what whisking is like.\textsuperscript{5}

I emphasize that the brains of animals map their worlds because no brain maps everything that is going on in the world as a whole. A brain maps what is relevant to how that animal makes its living. Accordingly, the brain models are beholden to the animal’s sensory and motor equipment, as well as to its needs and drives and cognitive style. Thus, some birds have systems that are sensitive to Earth’s magnetic field, guiding them at night on their migrations; some fish species—for example, sharks—have receptors to detect electric fields, allowing them to avoid electric eels, which can generate an electric shock to stun and kill their prey. Human brains do not map magnetic or electric fields. Luckily for us, however, we have other means, largely visual, for mapping our spatial worlds. Moreover, our flexible, problem-solving brains eventually made a device—a compass—that can give us information about Earth’s magnetic field by virtue of the magnetic needle’s causal connection to Earth’s magnetic field and our mapping of the relation between the compass needle and north.

Moreover, in the brains of different species, the resolution of the map—the degree of detail—varies, too.\textsuperscript{6} Here is what I mean: I could sketch you a crude map of the Yukon River on a table napkin, or you could buy a highly detailed map of the river and its environs. In a roughly comparable way, relatively simple brains have rather crude maps; more complex brains can map the environment to a greater degree of resolution.

Bats, for example, have very high-resolution maps of the auditory environment, because as mentioned earlier, they use an echolocation (sonar) system for detecting and identifying objects. (Many blind people use a similar strategy to navigate, making a noise by clicking their tongue against the roof of the mouth.) Notice, too, that the commercial map of the Yukon River could also contain representations of elevation, a rather abstract feature, without the map literally having little hills and valleys. Brains, too, can map abstract features without having neuronal hills and valleys. Importantly, they can map abstract causal relationships. There are simple causal relationships, such as between a splash in the stream and the presence of trout, or more complex ones, such as between the phases of the moon and
the rise and fall of the tides or between something unobservable with the naked eye, such as a virus, and a disease such as smallpox. This latter kind of causal knowledge requires a cultural context that accumulates layers upon layers of causal knowledge, won through experience and passed on through generations.

Sophisticated social behavior can also be mapped, as in this example of a foraging crow. The crow has observed a husky get his kibble at dinnertime. One day the crow approaches the husky as he begins to eat. The crow stealthily glides down behind the dog and yanks on the dog's tail. The dog turns, the crow flies, tantalizingly low but just outside the margin of danger, out of the yard and down the street. The excited dog gives chase. After a few minutes of chase, the clever crow flies directly back to the food dish and helps himself. The behavior strongly suggests that the crow predicts that his yanking the tail and his flying low will cause the dog to give chase. Thus is the dog lured away from his food.

Brain circuitry also supports a neural model of the inner world. It maps the muscles, skin, gut, and so on. By this means, you know the position of your limbs or whether something nasty has happened to the skin on your nose or whether you need to vomit. We are so accustomed to the smooth operation of our brains that we take it for granted that knowing where our legs are is just obvious and simple, even from the point of view of the brain. Not so. Not at all. Sometimes the mapping functions can get disrupted as a result of injury or disease. Then the complexity of brain mapping is revealed, as we shall now see.

A favorite way to spend time after our chores were done was to take our bicycles out on the back roads of the hills above the valley. For miles and miles we could explore, seeing no one. The roads were dirt, and if your bike plowed into a patch of gravel, you could lose control. My friend Christine and I peddled hard to the top of a hill, then flew fast down the hill to the bridge over the creek below. We both spun out. I bowled over into the creek and lost a fair bit of skin on my bare legs. Christine hit her head.

Only 12, I had never seen the symptoms of serious concussion, but after a few minutes it was clear that something was wrong with Christine's head, in addition to an egg-sized lump above her right ear. She did not know where she was or how she got there. Sitting at the creek edge, she stared blankly at her left leg and asked whose it was. She asked the same question about every 30 seconds. How could she not know the leg was hers? Who else could it belong to? I finally asked her. She said, "Maybe a tramp." A semireasonable answer, inasmuch as tramps were not uncommon in the area. Clearly, I could not let her ride home. Just as clearly, I could not leave her to get help.

The story ends well because about an hour after the mishap, a logging truck rumbled down the road. I flagged the driver down, we tucked the bikes in among the pine logs, and we got her home. After a few days of rest, Christine was fine, as the doctor had calmly predicted. She knew her leg was hers and was thunderstruck when told there was a bit of time when she did not. She remembered essentially nothing of the whole episode.

Later I came to know that subjects with damage to the parietal cortex of the right hemisphere may believe that limbs on the left side, such as an arm, do not belong to them, a condition known as somatoparaphrenia. It is often accompanied by loss of movement and loss of feeling in those limbs. Otherwise clearheaded, these patients say very bizarre things about the affected limbs. For example, one patient whose arm was paralyzed said that she could indeed move her arm. When she was asked to point to her nose and could not, she nonetheless insisted that yes, she had in fact pointed to her nose. Another said of her left arm that it belonged to her brother.

Neuroscientist Gabriella Bottini and her colleagues reported a remarkable case in 2002 of a woman who had suffered a stroke in her right hemisphere, with typical loss of mobility in her
left arm. One effect was that she believed firmly that her left arm belonged to her niece. She also seemed unaware of being touched on that arm, a not unusual feature in such a case. In one assessment, however, the doctor explained to her that he would first touch her right hand, then her left hand, and then her niece’s hand (when he actually touched her left hand). He did this, asking her to report what she felt each time. She felt the touch to the right arm, felt nothing on the left, but surprisingly did indeed feel the touch to the left when the doctor touched what she believed was her “niece’s hand.” The patient agreed that it was odd that she felt touches in her niece’s hand, but was not especially perturbed by the oddity.

I am dwelling on somatoparaphrenia delusions because they truly push our strongest intuitions about body knowledge, reminding us that intuitions are only intuitions. They are not always reliable, and they are no guarantee of truth. Knowing that your legs are yours or that a feeling on your legs is your feeling seems dead obvious. Because such knowledge typically is not something you consciously figure out, philosophers such as Ludwig Wittgenstein were motivated to assume that it was impossible for you ever to be wrong about whose leg this is. Not just irregular or unusual—but flat-out impossible. The problem was that he was listening only to his intuitions, which seemed so deeply true. He was not letting the data tell him what is and is not possible.

Normally, you are not wrong about your leg or arm; but in fact, your brain has to be working in just the right way, below the level of consciousness, for you to know that the legs you see are indeed your legs and that the feeling on your leg is your feeling. Disruption of processing resulting from brain damage, especially damage to the parietal area of the right hemisphere, means that sometimes we are wrong.6 The arm in the bed did not belong to the patient’s niece, however strong the patient’s intuition that it did.

In addition to the brain’s modeling the body it inhabits, some parts of the brain keep track of what other parts of the brain are doing. That is, some neural circuits model and monitor the activities of other parts of the brain. For example, when you learn a skill, such as how to ride a bicycle, subcortical structures (the basal ganglia) get copies of your current goal along with copies of the current motor commands from the cortex. When you get a movement right, given your goal, neurons in the basal ganglia in effect say “nailed it!” by releasing the neurochemical dopamine. The result of the precisely timed dopamine release is that connectivity changes are made in various parts of the brain to stabilize the circuitry supporting the set of movements that were right. The next time you try to ride, those movements—the right movements—will more likely be generated by your motor cortex. If the basal ganglia fail to get a copy of the current goal or fail to get a copy of the motor signal, or if the precise timing of the signal relay is messed up, the brain cannot learn. That is because it has no way to know which, among the many movements commanded, was the winning one—the one that caused the right movement.11

Here is another example of the brain monitoring the brain that actually changes our visual perception. Imagine that you hear a sudden bang and turn your head to see the source. You locate the source as a pot that fell off a shelf. In response to the bang, neurons in the motor cortex made a decision to turn the head in the direction of the sound. Patterns of light smeared across your retina as your head turned. In addition, a copy of the head movement signal went to other areas of the brain, including your visual cortex. This movement signal copy (efference copy) is very useful because it tells your brain that your head, not something in the world, is moving. Absent an efference copy, your visual system would represent the shifting patterns on the retina as owing to things moving out there. Then confusion would reign.

This organization for efference copy is very clever, because it
means that you are not misled about the origin of the shifting patterns on your retina when you move your head or when you move your eyes or your whole body. It is, I suspect, an important source of data that the brain uses in generating the complex sense of me versus not-me. Most likely, you are not even visually aware of moving patterns of light when you move your head. Your brain is extremely good at downplaying awareness of those moving patterns because those retinal movements are inconsequential so far as interpreting the external world is concerned.

Sometimes your brain can be fooled. Suppose you are stopped at a red light and the car next to you rolls back unexpectedly. Out of the corner of your eye, the movement is picked up. For the first second, you are apt to think that you are rolling forward, as that would be most probable, given the situation. With additional input, however, the brain makes the correction. Improbably, the car next to you is rolling backward. Is any of this soul business? No. This is brain biology, glorious efficient biology, doing its magnificent job, but not, of course, flawlessly.

A neuroscientist friend was fascinated by efference copy, wondering what his visual experience would be like if he paralyzed his eye muscles (transiently, by means of an injected drug), then formed the intention “eyes, move right.” In this condition, a copy of the intention to move would be sent to the visual system, which would not know of the eye muscle paralysis. Many years ago, he carried out the experiment on himself. What did he experience?21

His visual experience was that the whole world made a jump to the right. Essentially, the brain interpreted its visual input from the retina on the assumption that eye movement actually occurred, since, after all, the intention “eyes, move right” was registered. Since the visual input had not changed, however, the brain concluded that the world must have moved. Smart brain, to light on a reasonable guess.

This was a heroic and rather risky experiment, never published because it was definitely under the radar. Moreover, the experimenter was the subject and the only subject. It did nonetheless capture my imagination as I pondered the striking effect on visual perception itself—what you literally see—when you suppress the movement of the eyes. The brain evidently counts on the tight coupling of the intention to make an eye movement and the eye movement actually occurring. A breakdown, via the experimental paralysis, of that coupling affected the organization for distinguishing my movement from external movement.

Reflecting on efference copy made me appreciate anew that a basic job for a brain is to distinguish the me world from the not-me world. Efference copy is probably only one trick, albeit an important one, among many for achieving that distinction between me and not-me.

To return to the main theme of representations and maps, notice that when some part of the brain “reports” on its state to another part, you experience these reports as feelings, thoughts, perceptions, or emotions. You do not experience them in terms of neurons, synapses, and neurotransmitters. Similarly, when I am thinking about going fishing tomorrow, I am not directly aware of my thinking as a brain activity. I am aware of visual and movement images, maybe accompanied by a silent monologue. It goes sort of like this: I imagine myself at the creek side, night crawlers tucked in a can and speckled trout spooning in the cool shadows. I am not aware of this as the brain working. I am aware of it simply as making a plan. I do not have to tell my brain how to do any of this. The brain’s business is to do it. When I feel hungry, I am not aware that my brain makes that feeling; when I feel sleepy, I just feel sleepy. My brainstem, however, is busy making me feel sleepy. Among other things, it is decreasing the level of neuromodulators, in particular norepinephrine and serotonin.
Why doesn't the brain make it self-evident that it is doing all these things? "Oh, by the way, it is me, Brainsy—in here in your head. I am what allows you to maintain balance and chew your food; I am the reason you fall asleep or fall in love." Nothing in the ancient environment of brain evolution would select for brains that could reveal themselves thus. Similarly, there is nothing in our current environment to select for kidneys or livers that announce their existence and modus operandi. They just work the way they evolved to work.

By contrast, advantages do accrue to animals whose brains can map and remember the spatial layout of their neighborhood and its food sources. Consequently, many animals have nervous systems that are remarkably good at spatial learning. They know where home is, where food is cached, and where predators lurk. If you eat fruit, it is advantageous to have color vision so you can distinguish ripe from unripe fruit. If you are an owl hunting mice in the dark, it is advantageous to have superb sound location. If you are a social mammal or bird, it is useful in predicting the behavior of others to see their behavior in terms of having goals and feelings.

Because the models that brains deploy do not on their own reveal the nature of the underlying brain mechanisms, coming to understand the brain has been exceedingly difficult. When I first held a human brain between my two palms, I muttered to myself: "Is this really the sort of thing that makes me me? How can that be?"

BODY AND SOUL

Exactly when humans first began to understand the importance of the brain as the substrate for thinking and behaving is unclear. Certainly, there was nothing like a date in antiquity when the fact was established and thereafter widely believed. By contrast, there was a time in antiquity when it was discovered that by adding carbon to molten iron you could make it wonderfully strong—steel. Still, observations in prehistoric times regarding the dire effects of severe head injuries resulting from battle or accidents must have provoked a general appreciation of the importance of protecting the head from severe insult.

It is known that the great Greek physician Hippocrates (460–377 BCE), contemplating such data, opined that the brain is the basis for all our thoughts, feelings, and ideas. Precisely how he came to that pioneering insight in such ancient times is not known. As a physician, he undoubtedly performed dissections on people who died after stroke, and he may have seen soldiers with localized head wounds that correlated with the loss of specific functions such as vision or speech. He probably saw difficult births that left babies with severe disabilities. Hippocrates, like other ancient Greek thinkers, was a naturalist, not a supernaturalist; in looking for explanations of how things worked, he sought his explanations in the natural world. In his down-to-earth way, he reckoned spirits and gods and otherworldly stuff to be rather sterile in the explanatory business. Plato (428–348 BCE), by contrast, had a mystical bent. He assumed that each of us is endowed with a soul that lives before birth, inhabits the body in life, and departs after the body's death, dwelling blissfully in a Soul Land, which also contains all absolute truths. It was sort of like believing that the trash can displayed on your computer screen's dock survives the destruction of your computer—it goes to Virtual Reality Trash Can Land. Plato's musing launched, at least in the Western tradition, the idea of a nonphysical soul—a dualism of stuff. Even earlier, Hindu philosophers had come to a similar conclusion.

On Plato's theory of the mind, understanding and reason are the business of soul stuff, while movement, the basics of perception, and so forth, are the business of physical stuff—the body. Genuine knowledge is arrived at through reflection, according
to Plato, and is achieved bit by bit, despite the unfortunate interference of the physical body in the soul’s noble attempt to remember the absolute truths to which it was privy while resident in Soul Land.

Aristotle (384–322 BCE), despite being Plato’s prize pupil, was more firmly planted in the physical world. Like Hippocrates, Aristotle favored naturalism. He looked mainly to the organization of matter to explain how things work. The son of a physician, Aristotle was used to thinking about the body and mind in a medical framework. Although Aristotle’s ideas about psychological states are complex and susceptible to interpretation, he clearly thought that all emotional states (anger, fear, joy, pity, love, hate) are actually states of the body. He was less clear about whether the intellect—when it is doing mathematics, for example—is also a bodily function. Suffice it to say that Aristotle was very sophisticated about biological matters and also sensitive to the complexity of human affairs.

From Plato the mystic and Aristotle the naturalist emerged the two Western traditions: dualism (soul stuff and brain stuff) and naturalism (only brain stuff). Some 300 years later, the Christian Era (also called the Common Era) began. During the early part of the Christian Era, a prominent idea was that after a Christian died, the body would be resurrected and would physically ascend into a region somewhere above the moon. This did not require the idea of a Platonic soul, just the body.

Not surprisingly, many questions arose regarding the details of the promised resurrection and afterlife. People wondered at what age their body would be resurrected (in their prime, in childhood, or when decrepit?), whether a long-amputated limb would be reattached, whether wounds would be healed or remain festering, whether second or first husbands would be the husband (or whether people would have spouses at all), and so on. Eternity is a long time, much longer than a lifetime, so these questions were not trivial or merely academic.

Obviously, there were inconsistencies in the idea of physical resurrection, since decomposition of the body after death was well known. One way to square resurrection with the corruptibility of the human body was to argue that in heaven, Christ changes our corruptible bodies into spiritual, imperishable bodies. This borrowed a bit from Plato’s idea that upon death the soul returns to Soul Land, but at the same time, it was meant to reflect the Christian belief that Jesus changed everything when he arose bodily into heaven. Better bodies—glorified bodies—are the heavenly reward for believing in Jesus. The idea of a spiritual body may seem a bit like the idea of a square circle, and the details of how exactly this worked were left conveniently vague.

Much later, in the seventeenth century, René Descartes (1596–1650) puzzled long and thoughtfully about the nature of the mind. He knew that the brain was important, but believed its role was essentially limited to two basic functions: (1) executing movement commanded by the soul, and (2) responding to external stimuli, such as a touch to the skin or the light entering the eye. He sided with the Platonic ideas of the soul as the key to explaining how it is that humans use language and can make choices based on reasons, achievements that he thought were absolutely beyond any physical mechanism. Why was Descartes’s imagination so limited? Well, this was the seventeenth century, and the fanciest physical mechanisms with which he was familiar were mainly clocks and fountains. Although these devices could be impressive, they completely lacked scope for novelty. Human minds, by contrast, were capable of impressive novelty, especially in speech. Had Descartes had the opportunity to use my MacBook Pro, he might well have stretched his imagination much further.
In any case, Descartes concluded that all mental functions—perceiving, thinking, hoping, deciding, dreaming, feeling—all are the work of the nonphysical soul and not the brain. Where did he suppose the handoff of information between brain and soul takes place? In the pineal gland, providentially located in the middle of the head. As it turns out, the pineal gland’s main function is to produce melatonin, which regulates sleep/wake functions. Trafficking signals between body and soul is not one of its jobs after all. Descartes did not get this wrong because he was dim-witted. On the contrary, he was unusually brilliant, especially in geometry. He got it wrong because so very little was known about the brain at the time he lived.

By the nineteenth century, a few scientists, but especially Hermann von Helmholtz, realized that souls, special energies, occult forces, and other nonphysical things were likely a dead end so far as explanations of mental functions such as perception, thinking, and feeling were concerned. With great insight, Helmholtz proposed that many brain operations happen without conscious awareness. He came to this hypothesis while pondering the fact that when you look around, you can see and size up a complex visual scene in less than half a second (500 milliseconds), all without any conscious thinking. Sizing up a scene is very complicated, since the only thing that stimulates your retina are patterns of light. Yet you see colors, shapes, motion, relative position in space, and you instantly recognize familiar faces and other objects. So how does the brain get from patterns of light to “Hey, that’s Queen Elizabeth!”?

Helmholtz reasoned that by the time you see and recognize a familiar face, a lot of nonconscious processing has already been done, and done with remarkable speed and amazing accuracy. He did not have a clue about the exact nature of that processing, since almost nothing was known about neuronal functions. Nevertheless, that such processing occurs, in parallel pathways and below the level of consciousness, is entirely correct. (I am using the words nonconscious and unconscious interchangeably in this context. See Chapter 8 for a fuller discussion of the scope of nonconscious brain functions.)

So Helmholtz rightly realized that the brain has to be doing lots of processing that is nonconscious and that to understand such processing, paying attention to conscious activities is not enough. Moreover, if conscious and nonconscious processing are interdependent, identifying a nonphysical soul with only conscious activity is far-fetched. It would be like identifying someone’s nose as the whole body.

By the mid-twentieth century, the steam had largely gone out of the dualist hypothesis as an account of thoughts, perceptions, and decisions. It was not so much that there was a single experiment that decisively showed that the brain does mental jobs such as seeing and deciding. Rather, it was the accumulation of evidence, from every level of research on nervous systems, from neurochemicals to whole systems, that collectively detracted from the idea of ghostly souls. This is typical of science generally, where a well-entrenched paradigm rarely shifts overnight, but imperceptibly, bit by bit, as evidence accumulates and minds slowly reshape themselves to the weight of evidence. In specifically religious contexts, however, dualism of some vague sort continued to be appealing.

Evidence did accumulate from many different directions. For example, physical changes in the brain produced changes in supposedly soul functions, such as consciousness, thought, and reasoning. Inhaling an anesthetic such as ether caused people to lose consciousness; ingesting a substance such as mescaline or peyote caused people to experience vivid hallucinations. Neurologists reported very specific losses of function correlated with damage to particular brain areas. A person who suffers a stroke in a very specific place in the cortex (the fusiform) will likely lose the capacity to recognize a familiar face; a stroke in a somewhat different area will cause the loss of the ability to
understand speech. Loss of social inhibition may follow a stroke that destroys the prefrontal cortex just behind the forehead. All these phenomena seem to point to the nervous system, not to nonphysical, spooky stuff.

One discovery in particular did cause a brouhaha among the remaining die-hard dualists. In the 1960s, Roger Sperry and his colleagues at Cal Tech studied patients whose hemispheres had been surgically separated as a last resort for the control of debilitating epileptic seizures. These subjects became known as the split-brain patients. Careful experiments showed that when the nerve bundle connecting the brain's two hemispheres is surgically cut, the patient's two hemispheres become somewhat independent cognitively. Lower structures, such as those in the thalamus and brainstem, are not separated—hence the qualification "somewhat independent."

In split-brain subjects, each hemisphere may separately experience the stimuli delivered exclusively to it. If, for example, a key is placed in the left hand and a ring is placed in the right hand and the subject is asked to use his hands to point to a picture of what he felt, the left hand points to a picture of a key and right hand to a picture of a ring. A split-brain subject may even make opposing movements with the two hands—the left hand picking up the phone, the right hand putting it down. Or if a visual stimulus, for example, is presented to just one hemisphere, the other hemisphere knows nothing about it. This was a completely stunning result. Did splitting the brain split the soul? The soul was supposed to be indivisible, not divisible like a walnut. But there they were, the split-brain results, available for all to see: if the brain's hemispheres are disconnected, mental states are disconnected. Those results were a powerful support for the hypothesis that mental states are in fact states of the physical brain itself, not states of a nonphysical soul.17

Descartes's notion of the soul did not work out very well with physics either. The problem is this: if a nonphysical soul causes events to happen in a physical body, or vice versa, then the law of conservation of mass energy is violated. The trouble is, so far anyhow, that law seems very resilient against all comers. Well, maybe—just maybe—it does happen. But how? Even very roughly, how? How can energy be transferred from a completely nonphysical thing to a physical thing? Where does the soul get its oomph to have such an effect? What kind of energy does a soul have? Is it measurable? If not, why not? Descartes, interestingly, was fully aware of that particular problem and despaired of ever solving it.

Once you give slow thought to what sort of thing a nonphysical soul might actually be, awkward facts begin to pummel the idea's plausibility. For example, think about what happens when my dentist "freezes" a nerve in my wisdom tooth and my "soul" ceases to feel pain in that tooth. The neuroscientist has a well-established explanation regarding why I cease to feel pain. Substances such as procaine (trade name Novocain) injected close to neurons emerging from the tooth shut down the neuron's capacity to respond. The result is that no pain signals from the neuron are sent to the brain. Moreover, we know exactly how procaine does that. For a neuron to be active, sodium ions first get pumped out of the cell, and then when the neuron gets a stimulus, the sodium channel opens and the ions flood back into the neuron. Procaine temporarily blocks sodium channels and hence prevents the neuron from signaling. With time, the procaine denatures and hence the effect disappears. The neuron's capacity to respond returns and the painful feeling returns.

The explanation of how procaine blocks the transmission of pain signals is satisfying because it provides details of mechanism, it can easily be tested, and the details fit with what else we know experimentally about pain and neurons. Such "fitting with the rest of the body of knowledge" is called consilience: the greater the consilience, the greater the coherence and integration of phe-
nomina and facts. Note, however, that consilience is not a guarantee that the explanation is right, because you can have a totally wrong theory whose bits and pieces happen to cohere.

This happened to Newton's contention that space is absolute, like an empty vessel, and is everywhere the same. This theory made sense of a huge amount of evidence. Einstein, however, conjectured that Newton's supposition about absolute space might be false and that mass might distort space. When Einstein's prediction was tested and found to be correct, Newton's theory had to be abandoned, though it had stood as certain for some 300 years. Space is not everywhere the same; huge gravitational bodies, such as the sun, measurably alter the geometry of space. Einstein's theory ended up having much greater explanatory power than Newton's and much more consilience with developing physics.

Back to my wisdom tooth. Can the dualist match neuroscience's level of explanatory consilience regarding why procaine blocks pain? Not even close. A dualist could say, well, the procaine also acts on the soul. But how, even roughly, does that work? What does it do to the soul—especially if procaine is physical and the soul completely not physical? This dualist proposal says nothing at all about mechanism. Consider the contrast with the neuronal explanation, which is all about mechanism.

In principle, a dualist could experimentally work out the details of a soul theory, finding out how souls work and what their properties are. Hypotheses could be tested. Experiments could be run. In principle, there could be a natural science of the soul that would explain why souls lose consciousness when the body inhales ether or why souls hallucinate when the body ingests LSD. In practice, however, there is no science of the soul. Apart from flimsy contrasts with the body (such as "the soul is not physical," "the soul has no mass or charge," "the soul has no temperature"), there has been no advance since Descartes's 350-year-old hypothesis. The odd thing is that dualists, even deeply convinced dualists, are not even trying to develop soul science, as though merely saying "the soul does it" for every it is explanation enough. It is not nearly enough.

We cannot be certain that no distinct soul science will ever flower, but as things stand, brain science seems to have the leg up on soul science. This suggests that soul theory is floundering because there is no soul. If you had to place a big-money bet, on which hypothesis would you put your money?

WHY IS IT SO HARD TO FIGURE OUT HOW THE BRAIN WORKS?

THE BRAIN is not an easy organ to approach experimentally. For one thing, it doesn't look like anything familiar—not a pump (as is the heart), nor a filter (as is the kidney). A neuron (the signaling cell in the brain and spinal cord) is very tiny, not visible with the naked eye. A bundle of neurons, such as those that make up the sciatic nerve, for example, is visible, but these bundles are composed of thousands of neurons. In the cortex, a cubic millimeter of tissue contains tens of thousands of neurons, a billion connectivity sites (synapses), and about 4 kilometers of connections.

Neurons cannot be seen as individual cells without a light microscope, a device not extensively used in research until about 1650. Even then, special chemical stains had to be discovered to make one single very tiny neuron stand out against the rest of the millions of very tiny neurons closely packed together. Only thus could the basic structure of the neuron—an input end for receiving signals and a long connecting cable for sending signals—be seen. Techniques for isolating living neurons to explore their function did not appear until well into the twentieth century.

Making progress on how the brain works depended on understanding electricity. This is because what makes brain cells spe-
cial is their capacity to signal one another by causing fast but tiny changes in each other’s electrical state. So if you did not know anything about electricity, you would be stumped when you wondered how neurons can send signals and what a signal is. You might have thought that neurons communicated by magical forces. And for a long time, people were stumped, even after something was known about the basic structure of neurons.

Owing to Luigi Galvani’s observations (1762) that a spark would make a frog’s detached muscle twitch, the idea that electricity might be important for the function of nerves and muscles was on the table. But how did that work? Galvani himself did not understand at all what the relation was, largely because electricity was so poorly understood at that time. He conjectured that there was a special electrical bio-fluid that was carried to the nerves and muscles. Not until the early part of the twentieth century was it discovered that signaling of neurons depends on ions (charged atoms) abruptly moving back and forth across a neuron’s membrane. Exactly how that produces a signal was finally explained in 1952 by two British physiologists, Alan Lloyd Hodgkin and Andrew Huxley. Their discovery revolutionized the science of the brain. But notice how recent that discovery was: 1952. After I was born.

Simplified, this is what Hodgkin and Huxley discovered. Like all cells, nerve cells (neurons) have an outer membrane, partly constituted by fat molecules, with special protein gates that open and close to allow particular molecules to pass in or out of the cell. In a resting neuron, the inside of the membrane is negatively charged relative to the outside, owing to active pumping out of positive ions, such as sodium. Negative ions, such as chloride, are sequestered inside. This voltage difference can change abruptly when the neuron is stimulated. This fast change in voltage across the membrane is what makes neurons special. For example, when you touch a hot stove, a heat-sensitive neuron responds, which means that sodium ions rush into the cell, briefly reversing the voltage across the membrane. Immediately thereafter, sodium ions are pumped back out, restoring the original condition. This fast reversal and restoration in voltage across the membrane is what is referred to as a spike. By placing a wire close by the neuron and attaching it to an amplifier, you can hear a snap when the neuron spikes.

Once started, the voltage change moves down the membrane of the neuron to the end (spike propagation). Also called a nerve impulse, this signal eventually (in a few milliseconds) arrives at the neuron’s tail. This can trigger release of a chemical (neurotransmitter) that then drifts across a tiny space to the next neuron, docking at a special site and causing a voltage change in the receiving neuron. Alternately, if the neuron contacts a muscle cell, the muscle will then react—for example, by contracting. Oversimplified to be sure, this account opens the door to the world of nervous systems in all their complex glory.

Accustomed as we are to all manner of electrical devices, it takes us aback to realize that as late as 1800, electricity was not understood. Many considered the phenomenon to be occult, never to be explained as a physical phenomenon at all. At the dawn of the nineteenth century, all that changed when electricity was clearly understood as an entirely physical phenomenon, behaving according to well-defined laws and capable of being harnessed for practical purposes. Some people whined that this discovery was taking the divine mystery out of electrical phenomena. Others started inventing electrical devices.

Is there room among all the remaining puzzles in neuroscience for a soul (the nonphysical, Platonic variety)? Possibly. But not, it seems to me, remotely likely. Nevertheless, what has struck many people with a fondness for dualism is this: when a neuron responds with a spike, that neuronal response seems entirely different from the pain I feel when I touch a hot stove. How does the activity of neurons—possibly many, many neurons—produce pain or sounds or sights?
The answer is not yet known. There are many strategies for making progress in answering that question, however, some of which converge. So there is progress, if no fully detailed account of mechanism. (For more on this, see Chapter 9.) For example, much research has gone into trying to understand exactly what happens when a person is put under anesthesia and loses conscious awareness. Many anesthetics work by shutting down the activity of certain types of neurons, though there are still open questions about what regions are especially vulnerable to this inhibition. A different avenue of research studies the loss of awareness during deep sleep. Others study the absence of awareness of one stimulus when attention is paid to another. Difficult though it is, research on the interdependence of conscious and nonconscious processes is accelerating.

NAY-SAYING IS EASIER THAN DOING SCIENCE

Impressed by our ignorance, some philosophers have expressed certainty that no answer will be forthcoming—we will never know how the brain gives rise to thoughts and feelings. One popular reason offered for this is that no one can imagine what a detailed and satisfying neurobiological explanation would actually look like. So, the argument goes, the inability even to imagine an explanation is a sure sign that this is no mere problem, but an unsolvable mystery. Those who nay-say in this vein are not necessarily dualists, though they are apt to share almost everything except the name with Cartesian dualism. To face up to this nay-saying, we pause now for a philosophical interlude wherein we deal with this roadblock: Consciousness is too deep a mystery for us ever to understand. Give up trying.

Two things can be said at the outset about the nay-saying. First, the argument embodies a very strong prediction: no one will ever solve the mystery—not ever, no matter how science might develop. Never is quite long. Longer than a lifetime. This prediction, tendered as obvious, is really spectacularly rash. After all, the history of science is chock-full of phenomena deemed too mysterious ever to be understood by mere mortals, but which eventually did yield to explanation. This could be just one more of those.

The nature of light was one such problem. Well into the nineteenth century, the scientific consensus was that light is a fundamental feature of the universe, never to be explained by anything more fundamental. What happened? By the end of the nineteenth century, James Clerk Maxwell had explained light as a form of electromagnetic radiation—on the same spectrum as X-rays, radio waves, ultraviolet waves, and infrared waves. So the prediction, seemingly certain and unassailable, was flat-out wrong. Interestingly, it is now difficult to find anyone who even knows about the confident but misguided predictions concerning the inexplicability of light.

It hardly needs noting that it is preposterous to infer that something is unknowable simply because it is not known—especially when the science is in its very early stages. So much about how nervous systems function is not yet fully understood, such as how memories are retrieved or attention allocated or why we dream. Imagine a prediction made in year 2 CE saying that no one will ever understand the nature of fire. Certainly, at that time no one knew the slightest thing about what fire really is. No one knew that there was such a thing as oxygen, let alone that fire was rapid oxidation. It was widely thought that fire was a fundamental element, along with earth, air, and water, not to be explained beyond describing its behavior. The problem was eventually solved, though not until about 1777 by the French scientist Antoine-Laurent Lavoisier.

Or imagine a prediction in year 1300 that science will never understand how a fertilized egg can end up as a baby animal. Or a prediction in 1800 that no one will ever succeed in making
something that can control infections. Suppose someone predicted in 1970 that science could never find a way to record levels of activity in a normal human brain without opening the skull. Wrong. This technical achievement flowered in the 1990s as functional magnetic resonance imaging (fMRI) was developed. As a student of the brain in the 1970s, I would have been inclined to scoff at that possibility as science fiction because I could not imagine a device that would do the trick. My scoffing would have been merely an expression of my ignorance. So my imagination was not up to the job.

To the degree that the nay-saying rests on an unsubstantiated prediction, it need not deter us from moving forward.

Here is the second thing about nay-saying. There is something smugly arrogant about thinking, "If I, with my great and wondrous brain, cannot imagine a solution to explain a phenomenon, then obviously the phenomenon cannot be explained at all." Yet some philosophers and scientists find themselves strongly attracted to this assumption. They should not be. Why would you take my inability to imagine a future development in science as a reliable index of whether and how a problem can be solved? After all, I may have a pinched imagination, or my imagination may be limited by my ignorance (there it is, again) of what science will unearth a decade or two hence. What I can and cannot imagine is a psychological fact about me. It is not a deep metaphysical fact about the nature of the universe.

The flaws in the presumption that we will never explain mental phenomena in terms of the brain can also be analyzed from a slightly different perspective. An inference is supposed to take you from something for which you have very good evidence (such as an observation) to something else that is probably true. For example, I might infer that there is a forest fire on the other side of the mountain. My evidence is that I see firefighting helicopters carrying water to the other side of the mountain. Seeing the helicopter allows me to get new knowledge because I can infer something new. How does the naysayer's inference concerning neuroscience look?

The naysayer's inference takes us from ignorance—we are ignorant of the mechanisms for conscious awareness—to knowledge—we know that conscious awareness cannot be explained. This spells trouble. Suppose your doctor says, "We are ignorant of what causes your rash, so we know it is caused by a witch." You would get a new doctor. Fast. Inferring knowledge from ignorance is a fallacy, and it is why the ancient Greeks labeled this fallacy an argument from ignorance. Here is another obviously fallacious version of such an argument: I do not know how to explain how monarch butterflies navigate to Mexico, so I know it is by magic. Nuts. Ignorance is just ignorance. It is not special knowledge of magical causes. It is not special knowledge of what can or cannot be discovered in the long haul of time.

It is conceivable that science will never understand how neurons produce feelings and thoughts. Nevertheless, you cannot tell just by looking at a problem that it is not solvable by science. You cannot even tell whether the problem is really hard or downright tractable. Problems do not come with levels of difficulty pinned to their shirts. Moreover, as science progresses, the shape of a puzzle often begins to change, and some scientist somewhere may look at the problem in a new way, or some unforeseen technological development may render the problem quite tractable. Here is an example to illustrate the point. In the early 1950s, many scientists thought that solving the problem of how information is inherited by offspring from parents—the copying problem—was really, really hard, perhaps unsolvable. On the other hand, the problem of explaining how a protein molecule takes its typical three-dimensional shape once it is made was thought to be relatively easy. It turned out to be exactly the other way around.

In 1954, James Watson and Francis Crick published their paper explaining that DNA is a double helix, with orderly
sequences of pairs of bases that look a lot like a code. This monumental structural discovery was the key to the solution of the copying problem, the details being worked out over the next decades. By 1975, every biology textbook explained the basics of genes, how DNA codes for proteins, and how proteins get made. What about the allegedly “easier” problem of how proteins fold into their three-dimensional shape once made? That answer is still a research project.

This smackdown has been a little drawn out for the following reason: a number of philosophers, most famously David Chalmers, made their reputation by (a) claiming that the nature of consciousness cannot be solved by studying the brain, (b) giving the problem a name (the hard problem), or (c) claiming that consciousness is a fundamental feature of the universe, along with mass and charge.24 No equipment had to be designed and maintained, no animals trained and observed, no steaming jungle or frozen tundra braved. The great advantage with naysaying is that it leaves lots of time for golf.

EXPANDING OUR SELF-CONCEPTION

so probably the soul and the brain are one and the same; what we think of as the soul is the brain, and what we think of as the brain is the brain. Can we still talk about a great-souled person and not mean a great-brained person? Can we still say that a tennis partner put up a spirited defense or that the spirit of the times is coalitional, not confrontational? Sure, why not? We know what we mean, because these are conventional expressions. Similarly, we may still say that the sun is setting, even when we know full well that Earth is turning. Soul music, soul food, and having soul are still what they always were.

Can a person live a spiritual life even if there is no soul in the Cartesian sense? Or if you no longer believe you have a soul?

For simplicity, let’s assume that spiritual means valuing certain kinds of things, such as reflection, passing quiet time in a quiet place, choosing to do some things slowly and thoughtfully, not hectically and anxiously. It may mean not valuing money and its power overmuch and finding contentment in simplicity. Notice that for none of these values and preferences do we need to rely on the idea of a nonphysical soul. Would certain lifestyles be better or more valuable if we did have a nonphysical soul? Not that I can see. How would having a nonphysical soul make enjoying silent periods better? Part of what is going on when you enjoy your spiritual times is that your brain detaches from certain worries and woes; your breathing slows, facial muscles relax, you let go.

Put this in the context of a yoga practice (or substitute running or chanting, if you prefer). I often experience semi-euphoric feelings after yoga class, during the meditation period at the end (savourana). Later, I wonder about what happens in the brain during practice such that the blissful feelings typically follow in savourana. Why does this lovely feeling reliably occur?

One hypothesis is that during yoga exercises, the intense focus on the task of getting the body into the right position causes a shift in the typical “oscillating balance of power” between two general systems of the brain: the task-oriented system (for example, when you ponder why your computer lost its Internet connection) and the so-called default system, a kind of “inner reflection” or “mind-wandering” system (for example, when you go over a conversation you just had or plan for the next one). This latter is engaged when you briefly switch off-task and worry about the next job or fret over the past one or fantasize about something (like sex, for example).

Using brain-imaging technology, researchers have shown that during meditation, the activity level of the self-reflection regions does decrease, and this occurs across various meditation routines.25 This finding is consistent with the claim that
meditative practices can increase feelings of peacefulness, contentment, and joy. I am guessing that many other practices that involve focusing attention away from worries and on the present task—prayer, chanting, running, playing golf, playing in a quartet—have similar effects.

Although there is a suggestive correlation between deactivation of the default network and feeling peaceful, this is not yet a demonstration of causality. Moreover, devoting a greater proportion of attention to on-task versus mind wandering may be only a small part of the story of postpractice bliss. For one thing, the value of spending more attention on the task likely depends on the task. If the task is one you do unwillingly, such as cleaning out horse stalls, then spending more time in the self-reflection (default) network having sexual fantasies is probably more conducive to joy.

So do I think of the joyful experiences during or following these practices as spiritual? Yes, I do, because they resemble experiences that other people describe as spiritual, including people who, like me, do not think we have a nonphysical spirit that we call forth during these practices. That the experience involves particular aspects of brain circuitry and chemistry is neither here nor there so far as the quality of the experience itself is concerned. Consider that people who take lysergic acid (LSD) or mescaline are apt to suppose that their remarkable experiences involve visiting a completely different but real world, a spirit world. Conviction of practitioners notwithstanding, the LSD and mescaline experiences are clearly brain-based phenomena. In both instances, the drug molecules bind to specialized serotonin receptors in the brain, changing the response patterns of the neurons. Understanding a remarkable experience, whether occasioned by drugs or meditation, within the framework of neuroscience makes no difference to the quality of the experience as such, but only to how we make sense of it.

The concept of the soul, though having a long and respectable history, now looks outmuscled and outsmarted by neuroscience, so far as explaining our mind and our behavior. Yet one important motivation for favoring the concept of the soul has stemmed from the possibility of an afterlife. Moreover, reports of life after death and out-of-body experiences abound. Surely, one might think, these accounts put the soul back in the story. Possibly. Let’s first find out how plausible these accounts are and what they really tell us.