I can't fall asleep on my back—or rather, I don't dare to. In that position I often slip into a fugue state where my mind wakes up from a dream, but my body remains immobile. In this limbo I can still sense things around me: sunlight trickling through the curtains, passersby on the street below, the blanket tented on my upturned feet. But when I tell my body to yawn and stretch and get on with the day, nothing happens. I'll recite the command again—*Move, you*—and the message echoes back, unheeded. I fight, I struggle, I strain to twiddle a toe or flex a nostril, and it does no good. It's what being reincarnated as a statue would feel like. It's the opposite of sleepwalking—it's sleep paralysis.

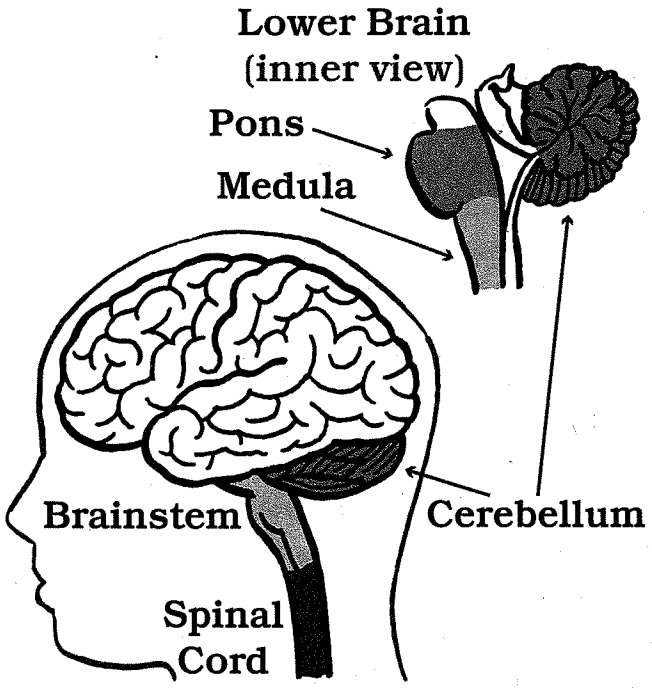
The worst part is the panic. Being awake, my mind expects my lungs to take full, hearty breaths—to feel my throat expanding and my sternum rising a good six inches. But my body—still asleep, physiologically—takes mere sips of air. I feel I'm suffocating, bit by bit, and panic begins to smolder in my chest. Even now, just writing this, I can feel my throat constrict.

As bad as that sounds, some sleep paralytics have it worse. My episodes don't last that long: by concentrating all my energy, Zen-master-like, on twitching my right pinky, I can usually break the trance within a few minutes. Some people's episodes drag on for hours, full nights of torture: one Korean War vet reported feeling more terror during a single episode of sleep paralysis than during his entire thirteen months of combat. Other people nod off narcoleptically and slip into this state during the day. One poor woman in England has been declared dead three times and once woke up in a morgue. Still other people have out-of-body experiences and feel their spirits careening around the room. The unluckiest ones perceive an evil "presence"—a witch, demon, or incubus—pressing down on their necks, smothering them. (The very "mare" in nightmare refers to a witch who

delights in squatting on people's chests.) Nowadays people sometimes weave this feeling of paralysis into alien abduction stories; presumably they're strapped down for probing.

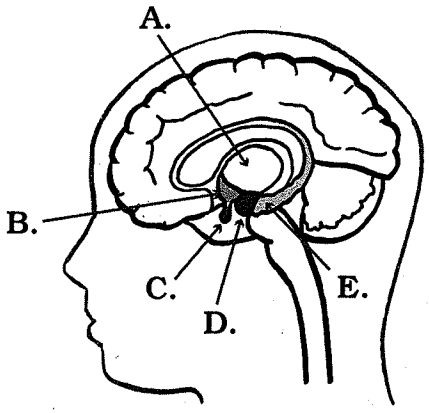
Sleep paralysis doesn't actually open a portal into the supernatural, of course. And despite what I may have thought when young, sleep paralysis doesn't offer proof of dualism, either: the mind cannot appear outside the body, independent of it. To the contrary, sleep paralysis is a natural by-product of how our brains work. In particular, it's the by-product of faulty communication among the three major parts of the human brain.

The base of the brain, including the brainstem, controls breathing, heart rate, sleeping patterns, and other basic bodily functions; the brainstem also works closely with the nearby cerebellum, a wrinkly bulb on the brain's derriere that helps coordinate movement. Together, the brainstem and cerebellum are sometimes called the reptile brain, since they function approximately like the brain of your average iguana.



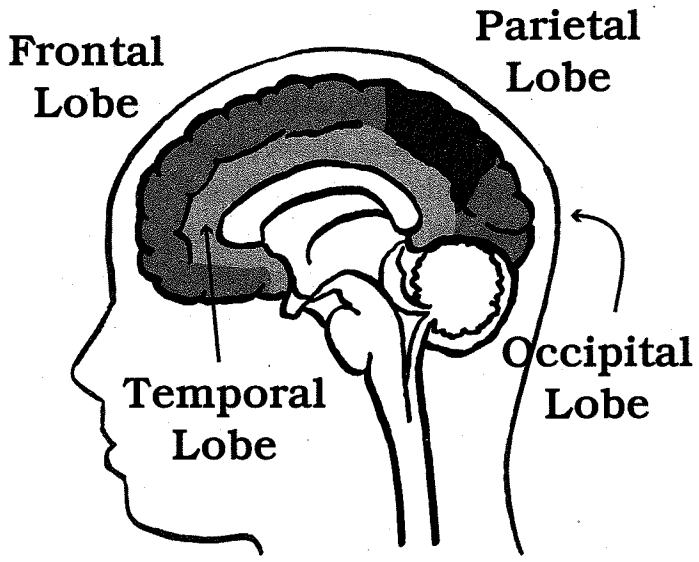
The second part, the so-called mammal brain, sits deep inside the skull, just north of the brainstem. The mammal brain relays sensory input around; it also contains the limbic system, which helps capture memories, regulate emotion, and distinguish between pleasant and rotten experiences. Unlike the instinct-driven reptile brain, the mammal brain can learn new things quite easily. To be sure, some neuroscientists deride the mammal/reptile division as too simplistic, but it's still a useful way to think about the brain's lower regions.

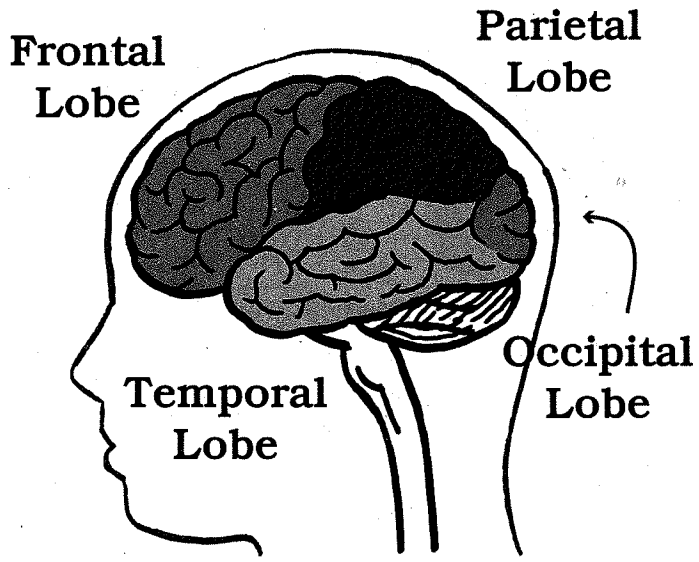
Middle Brain/Limbic System



A. Thalamus
B. Hypothalamus
C. Pituitary gland
D. Amygdala
E. Hippocampus

Both of these nether regions control automatic processes, things we don't think about, or want to. This autopilot frees up the outermost part of the brain, the primate brain, for advanced duties, especially in humans. We can further divide the wrinkly primate brain into four lobes: the frontal lobes (near the front of the brain), which initiate movement and help us plan, make decisions, and set goals; the occipital lobes (back of the brain), which process vision; the parietal lobes (atop the brain, the pate), which combine vision, hearing, touch, and other sensations into a "multimedia" worldview; and the temporal lobes (side of the brain, behind the temples), which help produce language, recognize objects, and link sensations with emotions.





The reptile, mammal, and primate brains constantly exchange messages, usually via chemicals, and their various internal structures work together almost seamlessly. Almost.

Deep inside the reptile brain sits the pons, a hump in the brainstem an inch long. When we fall asleep, the pons initiates dreaming by sending signals through the mammal brain to the primate brain, where dreams stir to life. During dreams, the pons also dispatches a message to the spinal cord beneath it, which produces chemicals to make your muscles flaccid. This temporary paralysis prevents you from acting out nightmares by fleeing the bedroom or taking swings at werewolves.

While mostly protective, this immobility sometimes backfires. Sleeping on your back can collapse the airways in your throat and deprive the lungs of oxygen. This isn't a huge deal during nonparalyzed, nondream sleep: the parts of the brain that monitor oxygen levels will rouse your body a little, halfway to waking, and you'll snort, shift your head, or roll over. To get oxygen during dream sleep, though, the brain has to order the pons to stop paralyzing your muscles. And for whatever reason—a chemical imbalance, a frayed neural wire—the pons doesn't always obey. So while the brain succeeds in rousing the mind a little, it can't turn off the spigot for the paralysis chemicals, and the muscles remain limp.

Things go south from there. If this limbo persists, the mind wakes up fully and, sensing something amiss, trips a circuit that includes the amygdala, a structure in the mammal brain that amplifies fear. A fight-or-flight response wells up—which exacerbates the problem, since you can't do either. This is when the panic starts. And again, some people have it much worse. At least with me, the actual dream I'm having stops as soon as my mind wakes up. Not so in some people: they never quite escape the dream state. They're semialert to their surroundings, they're paralyzed, *and* their brains keep conjuring up dream nonsense. Because the human mind is quite good at making spurious connections, they then link the characters in these hallucinations to their paralysis, as if one caused the other. It's no wonder some people believe in demons and aliens: they actually see and feel them.

So, yeah, there's a reason I don't sleep on my back anymore. But

even though I dreaded the experience, sleep paralysis did teach me something valuable about the brain: that everything is interconnected. Starting with nothing but chemicals way down deep in the reptile parts, I could nevertheless—if I followed the tumbling dominoes far enough and patiently worked my way up from chemicals to cells to circuits to lobes—gain insight into the most rarified realm of the human mind, a belief in the supernatural. One little brain malfunction could be parlayed into so much more.

In fact, the more I read about neuroscience and the interplay of different neural structures, the more I realized that this huge yield wasn't unusual. Tiny flaws in the brain had strange but telling consequences all the time. Sometimes these flaws wipe out general systems like language or memory. Other times, something very specific dies. Destroy one small node of neurons, and people lose the ability to recognize fruits and vegetables but not other food. Destroy another node and they lose the ability to read—even though they can still write. Still other malfunctions tack a phantom third arm onto someone's torso, or convince her that the very hand on the end of her arm belongs to someone else. Overall, these flaws reveal how the brain evolved and how it's put together, and I realized that you could write a whole natural history of the brain from just such cases...

~

Until the past few decades, neuroscientists had one way to plumb the human brain: wait for disaster to strike people and, if the victims pulled through, see how their minds worked differently afterward. These poor men and women endured strokes, seizures, saber gashes, botched surgeries, and accidents so horrific—like having a four-foot iron javelin driven through the skull—that their survivals seemed little short of miracles. To say these people "survived," though, doesn't quite capture the truth. Their bodies survived, but their minds didn't quite; their minds were warped into something new. Some people lost all fear of death; others started lying incessantly; a few became pedo-

philes. But however startling, in one way these transformations proved predictable, since people with the same deficit tended to have damage in the same area of the brain—offering vital clues about what those areas did. There are a thousand and one such stories in neuroscience, and *The Tale of the Dueling Neurosurgeons* recounts the best of them, resurrecting the lives of the kings, cannibals, dwarfs, and explorers whose struggles made modern neuroscience possible.

Many of these people's lives are inherently dramatic, because their ailments felled them within days, even minutes. And as far as possible, rather than just recite the details of doctors' visits or provide a litany of one damn brain-scan study after another, this book enters into the minds of victims, to give you a sense of what it's like actually *living* with crippling amnesia or the conviction that all your loved ones have been replaced by imposters. While some of the stories have familiar characters (it's probably illegal to write about neuroscience nowadays without mentioning H.M. or Phineas Gage), many characters will be new. Even with some of the standbys, like Gage, much of what you "know" is probably wrong. Not all the stories are tragic, either. Some are plain enchanting, like those about people whose senses fuse together in trippy ways, so that odors make noises and textures produce flashes of color. Some are uplifting, like tales of blind people who learn to "see" their surroundings through batlike echoes. Even the stories about accidents are, in many cases, stories of triumph, stories about the brain's resiliency and ability to rewire itself. And these tales remain relevant to neuroscience today: despite the (often overhyped) advances of fMRI and other brain-scanning technologies, injuries remain the best way to infer certain things about the brain.

In general, each chapter here recounts one narrative tale; that's how the human brain remembers information best, in story form. But beneath these ripping yarns there are deeper threads, threads that run through all the chapters and bind them together. One thread concerns scale. The early chapters explore small physical structures like cells; think of these sections like individual red and green and yellow

fibers to feed into a loom. With each successive chapter we'll cover larger and larger territories, until we can see the full Persian carpet of the brain. Another thread concerns neural complexity. Every chapter adds a little more ornament to the rug, and the motifs and themes of the early chapters get repeated later on, allowing you to see the brain's intricate, interlocking patterns more clearly the closer you look, with each passing page.

The book's first section, "Gross Anatomy," familiarizes you with the brain and skull, providing a map for future sections. It also shows the genesis of modern neuroscience from one of the most important cases in medical history.

"Cells, Senses, Circuits" delves into the microscopic phenomena that ultimately underlie our thoughts, things like neurotransmitters and electrical pulses.

"Body and Brain" builds upon those smaller structures to show how the brain controls the body and directs its movement. This section also shows how bodily signals like emotions bend back and influence the brain.

"Beliefs and Delusions" bridges the physical and mental, showing how certain defects can (à la sleep paralysis) give rise to tenacious, and pernicious, delusions.

Finally, all these sections build toward the last section, "Consciousness," which explores memory and language and other higher powers. This includes our sense of self—the "inner you" we all carry around in our heads.

By book's end you'll have a good sense of how all the different parts of your brain work, and especially how they work together. Indeed, the most important theme in this book is that you can't study any part of the brain in isolation, no more than you can hack the Bayeux Tapestry up and still grasp its intricacies. You'll also be prepared to think critically about other neuroscience you read about and to understand future advances.

Above all, I wrote *The Tale of the Dueling Neurosurgeons* to answer

a question, a question that has clawed at me ever since those first scary episodes of sleep paralysis: where does the brain stop and the mind start? Scientists have by no means answered this question. How a conscious mind emerges from a physical brain is still the central paradox of neuroscience. But we have some amazing leads now, thanks largely to those unwitting pioneers—those people who, usually through no fault of their own, suffered freak accidents or illnesses and essentially sacrificed a normal life for the greater good. In many cases what drew me to these stories was the very commonness of their heroes, the fact that these breakthroughs sprang not from the singular brain of a Broca or Darwin or Newton, but from the brains of everyday people—people like you, like me, like the thousands of strangers we pass on the street each week. Their stories expand our notions of what the brain is capable of, and show that when one part of the mind shuts down, something new and unpredictable and sometimes even beautiful roars to life.