

Col 0

Who Are We?

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Take a close look at yourself in the mirror. Beneath your dashing good looks churns a hidden universe of networked machinery. The machinery includes a sophisticated scaffolding of interlocking bones, a netting of sinewy muscles, a great deal of specialized fluid, and a collaboration of internal organs chugging away in darkness to keep you alive. A sheet of high-tech self-healing sensory material that we call skin **Col 0** seamlessly covers your machinery in a pleasing package.

And then there's your brain: three pounds of the most complex material we've discovered in the universe. This is the mission control center that drives the whole operation, gathering dispatches through small portals in the armored **Col 0** bunker of the skull.

Your brain is built of cells called neurons and glia—hundreds of billions of them (**FIGURE 1.2**). Each one of these cells is as complicated as a major city. And each one contains the entire human genome and traffics billions of molecules in intricate economies. Each cell sends electrical pulses to other cells, up to hundreds of times per second. If you represented each of these trillions and trillions of pulses in your brain by a **Col 0** single spark of light, the combined output would be blinding.

The cells are connected to one another in a network of such staggering complexity that it bankrupts human language. A typical neuron makes about 10,000 connections to neighboring neurons. Given the billions of neurons, this means there are as many connections in a single cubic centimeter of brain **Col 1** tissue as there are stars in the Milky Way galaxy (Nash, 1997).

The three-pound organ in your skull—with its pink consistency of Jell-O—is an alien kind of computational material. It is composed of miniaturized, self-configuring parts, and it vastly outstrips anything we've dreamt of building. So if you ever feel lazy or dull, take heart: you're the busiest, brightest **Col 1** thing on the planet.

Ours is an incredible story. As far as anyone can tell, we're the only system on the planet so complex that we've thrown ourselves headlong into the game of deciphering our own programming language. Imagine that your computer

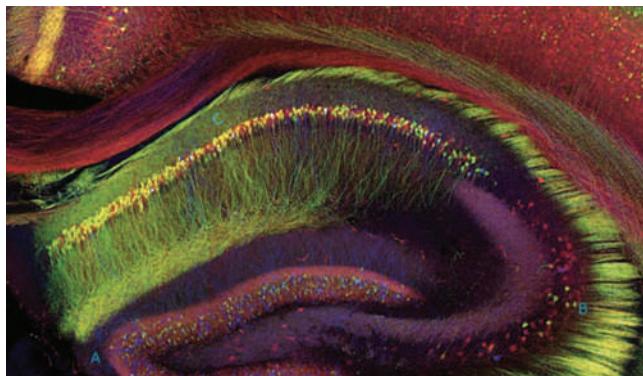


FIGURE 1.2 A view of the hippocampal neurons of the human brain, visualized using confocal microscopy and fluorescent protein labeling.

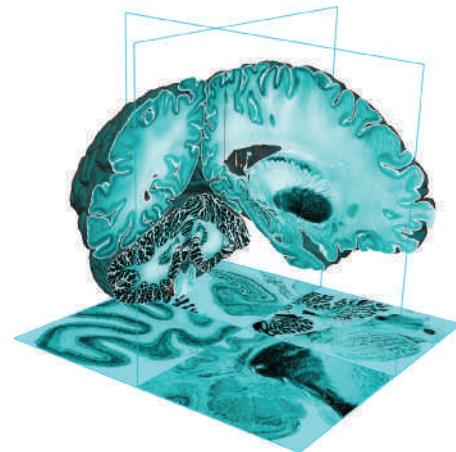


FIGURE 1.3 BigBrain ultra-high-resolution three-dimensional human brain atlas, reconstructed from 7,404 stained, microscopic sections of a single human brain at a resolution of 20 micrometers.

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began to control its own peripheral devices, removed its own **Col 2**, and pointed its webcam at its own circuitry. That's us.

And what we've discovered by peering into the skull ranks among the most significant intellectual developments of our species: the recognition that the innumerable facets of our behavior, thoughts, and experience are inseparably yoked to a vast, wet, chemical-electrical network called the nervous system (**FIGURE 1.3**). The machinery is utterly alien to us, and yet, somehow, it *is* us.

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The Mission of Cognitive Neuroscience

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The understanding of the three-pound human brain goes beyond a mere academic interest. Who are we if not our thoughts, decisions, sensations, hopes, dreams, fears, and aspirations? And what are these things if not the products of our brains? The field of **cognitive neuroscience** seeks to determine how the brain processes information, builds memories, navigates decisions, and ultimately produces a human **Col 2** being from trillions of smaller parts.

How are intelligent systems built from simple, senseless parts? How is a great orator constructed from speechless cells? How is a great football player guided in direction by billions of neurons—which by themselves don't know the rules of the game, know what a football is, or understand the concept of winning?

Although at first blush it seems impossible to build an acting, sentient being from neutral, ignorant parts, groups of interacting simple parts can lead to complex **emergent properties**—that is, characteristics of a system that do not belong to any individual component. If you were to decompose your television set into its constituent resistors, capacitors, and transistors, you would see that the comedies and tragedies played out on its screen are not a property of any given piece, but of the system as a whole. The same applies to biology: if