BREAKING INTO THE BRAIN

A journey into the vault holding our greatest mystery

BY ALLAN HAMILTON, M.D.

As a brain surgeon, I have made my living for more than three decades by "breaking and entering" into patients' skulls, much like a bank robber. In fact, the skull is anatomically referred to as the cranial vault. As with any good bank heist, there are two important rules. First, know where the money is. Second, get in and out as fast as you can. No alarms. And no one gets hurt.

How and where you open the cranial vault is critical. There needs to be an *exact* correspondence between where you create the opening in the skull—the so-called craniotomy—and the anatomical structures beneath, to which you want to gain access. You need to know exactly where the money lies. And gaining access—getting through the skull—is no easy task. The human skull can withstand more than 500 pounds of weight on it before cracking. That's like balancing two full-size refrigerators on it. And its walls are remarkably dense. To gain entry into the skull, you need quite a drill. Not one you might pick up at the Home Depot. This industrial-strength, pneumatic drill is powered by hundreds of pounds of pressurized nitrogen, with the working end made up of an inner ring of fluted stainless-steel teeth that spins inside a larger outer drill bit with even sharper, larger teeth. It can remove a quarter-size plug of incredibly dense bone in two or three seconds.

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After a few of these preliminary holes—burr holes—are drilled into the skull, we cut the bone in between them with a side-cutting instrument, spinning at 60,000 rotations per minute. When the saw has cut into every burr hole—when you've connected the dots—then, as we say, you've "cracked the coconut." All that's left is to peel back the skull flap, cut through one thin membrane, the dura, and you're in.

And there it is: the brain. It has no pain receptors of its own. Once we've drilled, sawed, and blasted our way in through the skull, we are inside what I call the Temple. The holy of holies. The brain sits there defenseless like pulsating, vascularized yellow custard. We can't even really cut it. We have to suck our way through it. Granted, we do it with small handheld suckers, machined by compulsive engineers down to the micron. But they are, even in medical jargon, still called suckers, and the sound they make is like a kid cleaning out the bottom of a milkshake. The drab, underwhelming appearance of the brain is disarming: what a simple-looking vessel for the most wondrous and complex object in the universe!

As neurosurgeons, we are all universally humbled by the brain. We struggle to grasp the grandeur and scale of its cytoarchitecture. Every day we confront its unforgiving fragility—be it clinical or just plain physical. How does one coherently understand an organ that bears an uncanny resemblance to an overturned bowlful of curdled custard and yet embraces as many interconnections as there are elementary particles in the universe? If you found it in your driveway, you might feel inclined to scoop it up with a dustpan, but once you become aware of its true nature, you might find yourself wanting to kneel before it. Because it is the embodiment of the truest mystery: It defines a human being.

CEREBRAL ENTANGLEMENTS

In October 1927, 29 of the most notable physicists gathered for an international meeting in Brussels, Belgium. It included some of the greatest geniuses humanity has ever assembled: Albert Einstein, Niels Bohr, Marie Curie, Erwin Schrödinger, John von Neumann, and Werner Heisenberg. More than half of the individuals in attendance would go on later to be awarded their own Nobel Prizes! During the conference, the attendees struggled with a thought experiment related to what is called quantum entanglement. Entanglement predicts that if one measures the properties of a particle and maps its location in one part of the universe, then that very act will instantly define and bring into existence an identical particle elsewhere—even if those two particles are at opposite ends of the known universe. So, while any information about the properties of one particle would take billions

of years—even traveling at the speed of light—to dictate those of its twin counterpart on the far side of the universe, they both come into existence with the same characteristics. It seemed an absurd notion: Time and space would have to "collapse."

It took nearly a century and three generations of physicists to carry out the thought experiment first imagined in 1927. In November 2016, hundreds of astrophysicists, working in more than a dozen laboratories on five continents, used two very bright stars (known as pulsars) that were millions of light years apart to prove that quantum entanglement exists. Collapse or no collapse, quantum physics describes and predicts some very unusual properties of our universe.

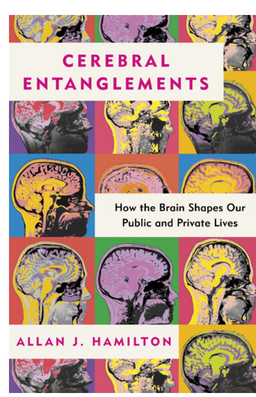
SEEING HUMAN THOUGHT

As a brain surgeon and a neuroscientist, when I heard about quantum entanglement, it leaped out at me as the perfect metaphor to explain how we have come to understand the true meaning of the human brain in the twenty-first century. If we look at properties of sensory perception, we see that they are properties derived from our brains, from our inner space. On the other hand, those perceptions correspond to a set of physical or sensory properties that we detected in outer space—that is, the physical world around us.

If I shine a flashlight in your eye, for example, the stream of photons from the light will impinge on the retinal cells in your eye. This will, in turn, engender a predetermined set of neuronal interactions in your occipital cortex and you will "see" the light. On the other hand, if I take that same configuration of brain cells and I simply stimulate them electrically, you will have the identical experience of seeing the light—even if the flashlight stayed in my pocket. While our perception of the outer world is dependent on the stimulation of our brain cells, the activation of our neuronal networks is what sustains the outer, physical world.

Our personal lives depend on this neuro-physical communion, and our being—our identity—flows from it. The physical world determines the properties of the brain's activities, and those operations, in turn, define our perception of the physical world. It is a never-ending cycle of perceiving and being perceived. In the past, only our outer world was accessible to us, but now, with the latest brain imaging (and its supporting neuroscience), we have been given the key to the equivalent inner world.

Until a decade ago, for example, if we wanted to know if an "eyewitness" was telling the truth, we might have resorted to a polygraph test (a "lie detector"). Polygraph readings, however, can be notoriously unreliable. Now we can add a functional magnetic resonance image, or fMRI, into the equation. If the witness is lying, his brain scans will show that his answers begin in the frontal lobe. That is because he has to think hard about how to fabricate his story. But if the witness actually did see the crime being committed, then his answers will originate in the occipital lobe, where vision is processed. This is just one small example of what I mean when I say we live in a new age where brain imaging is changing how we understand the meaning our brains give to our lives. &



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