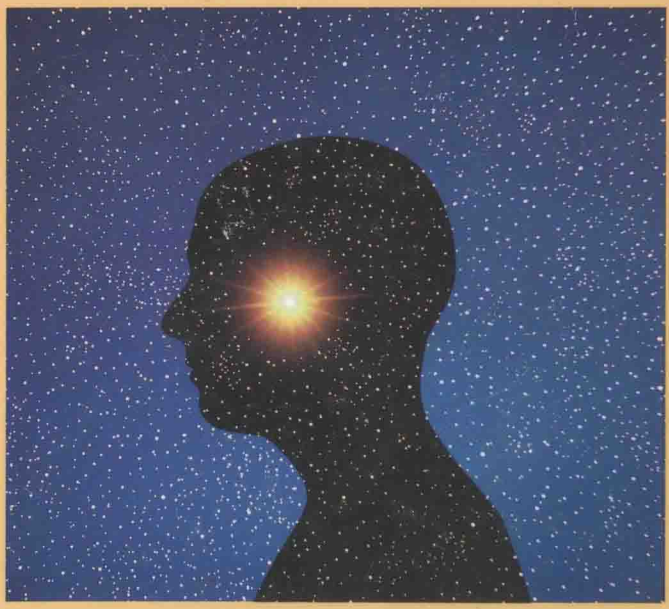
3-POUND UNIVERSE

Revolutionary Discoveries About the BRAIN – From the Chemistry of the Mind to the New Frontiers of the Soul



"Wonderfully Provocative...A Relentlessly Fascinating Tour of Neuroscience."
New York Times Book Review

Judith Hooper
Dick Teresi

Foreword by Isaac Asimov

THE THREE-POUND UNIVERSE

JUDITH HOOPER AND DICK TERESI

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Foreword

BY ISAAC ASIMOV

Nowadays we take it entirely for granted that the human brain is the organ that controls thought. We say, "He has brains," when we mean that he is intelligent. We tap our temples significantly when we wish to indicate that someone doesn't think clearly. Or else we say, "He has bats in his belfry," meaning that disorderly and unpredictable events take place in the highest portion of the body (the brain), which corresponds metaphorically to the highest portion of the church (the belfry), in which bats might literally exist. This might be shortened to a simple "He's bats."

Yet what we take for granted was not necessarily obvious to the ancients. The brain, after all, does nothing visible. It simply sits there. How different from the heart that beats constantly all the moments you are alive and no longer beats when you are dead. What's more, the heartbeat races after muscular effort, or when you are stirred by deep emotion of any kind, and it slows during sleep, when you seem to be simulating a kind of death.

There is a certain sense, then, in supposing the heart to be the seat of life and emotion. The long ages in which this supposition held sway remains enshrined in our language. A person who is brave is "lion-hearted," while a coward is "chicken-hearted." If we embolden ourselves to dare a difficult task, we "take heart," and if we suffer a sad disappointment in love or ambition, we are "broken-hearted." (Needless to say, the heart has nothing to do with any of this.)

If the heart is central to our life, surely that must be so because it pumps blood. A wound that involves the loss of blood weakens us and, if bad enough, can kill us. Blood surges into our face and reddens it during physical exertion or when we are driven into anger or shame. On the other hand, blood drains from our face leaving it pale when we suffer fear or anxiety.

The importance of blood also leaves its mark on our language. When we act under the stress of emotion, we do something "in hot blood." When it is not emotion but calculation that is the spring of our action, we do it "in cold blood." Someone who is commonly emotional is "hot-blooded,"

someone commonly intellectual is "cold-blooded." (Needless to say, the blood remains at the same temperature under all nonpathological conditions.)

Organs particularly rich in blood are also suspected of having much to do with one's state of mind. The liver and spleen are two such organs. Blood is pictured as leaving the liver at moments of fear just as it leaves the face. Under such conditions, it is imagined that the dark color of the liver pales, and a coward is spoken of as "lily-livered." The word *spleen*, on the other hand, refers not only to a blood-filled organ of our body but also to such emotions as anger and spite. (Needless to say, the liver and spleen have nothing to do with the emotions.)

But what about the brain? Does it do *anything*? Aristotle, the most renowned of the ancient thinkers, believed that the brain was designed to cool the heated blood that passed through it. It was merely an air-conditioning device, so to speak.

And yet there is one point that might have stirred the suspicions of a careful observer. The abdominal wall contains no bone but is protected merely by a tough layer of muscle. The liver and spleen (and other abdominal organs) are thus not very efficiently guarded.

The heart and lungs, which are located in the chest, are more efficiently protected, thanks to the bony slats of the rib cage. This seems to indicate that the heart and lungs are more immediately vital to the body than the abdominal organs are. However, the protection isn't perfect, for a knife can easily slip between the ribs and into the heart.

The brain, on the other hand, is almost totally enclosed by a closely fitting curve of bone. The brain lies hidden inside the strong skull, well-protected from all but the most powerful blow. It is the only organ so thoroughly protected, and surely this must have meaning. Would a mere air-conditioning device be so tucked away behind armor, when even the heart is protected only by a slap-dash of ribs?

This may have been one of the reasons why the ancient Greek anatomist Herophilus, in the generation after Aristotle, decided that it was the brain that was the seat of intelligence. But his opinion did not weigh sufficiently against the overwhelming prestige of Aristotle, whose word was taken as final for nearly two thousand years.

It was dimly understood that the nerves were important, however, and in 1664, an English physician, Thomas Willis, wrote the first accurate treatise on the brain and showed that nerves emanated from that organ. That book (only a little over three centuries ago) marked the turning point and the beginning of the final realization of the brain's importance.

The more scientists studied the brain, the more complex it seemed to

be. In its three pounds are packed ten billion nerve cells and nearly one hundred billion smaller supporting cells. No computer we have yet built contains one hundred billion switching units; and if we did build one with that many there is no way in which we could as yet compact them into a structure weighing as little as three pounds.

What's more, the "wiring" of the brain is far more complicated than that in any computer. Each nerve cell is connected to many other nerve cells in a complex pattern that allows the tiny electrical currents that mark nerve action to flow in any of a vast number of possible pathways. In comparison, the structure of a computer's units is primitively simple and the patterns of flow easily calculable.

Finally, whereas in a computer the units are switches that are either "on" or "off," the nerve-cell units of the brain are themselves magnificently complex objects, each one containing enormous numbers of complicated molecules whose system of functioning is unknown to us, but which undoubtedly makes each individual cell more complicated than an entire computer is.

The human brain, then, is the most complicated organization of matter that we know. (The dolphin brain might conceivably match it, and there may be superior brains among extraterrestrial intelligences, but we have as yet very little knowledge concerning the organization of dolphin brains and none at all concerning those of extraterrestrial intelligences—who might not even exist.) The human brain is certainly more complicated in organization than is a mighty star, which is why we know so much more about stars than about the brain.

Indeed, the brain is so complex, and human attempts to understand how it works have, until now, met with such apparently insurmountable hurdles, that it seems a fair question to ask whether we can *ever* understand the brain, whether it is *possible* to do so.

After all, we are trying to understand the brain by using the brain. Can something understand itself? Can the brain's complexity comprehend a brain's complexity?

If one human brain were alone involved, these questions would be fair and might be answered in the negative. However, not one human brain but many are tackling the subject; not one human being but a scientific team that is scattered over the world is doing so. Each researcher may, after years of work, add only a trifling bit to the sum of our neurological knowledge, but all the researchers together are making significant and in some cases astonishing progress.

Considering that the human brain, thanks to its intelligence and ingenuity, is the greatest hope of humanity; and that the human brain, thanks

to its ability to hate, envy, and desire, is also the greatest danger to humanity—what can conceivably be more important than to understand the various aspects of the brain and to learn how, possibly, to encourage those that are constructive and to correct those that are destructive.

In this book, then, Judith Hooper and Dick Teresi tell of the progress in this research and forecast future potentialities. They tell the story of the ultimate peak of human seeking, the attempt of humanity to understand itself.

A New Introduction

It has been five years since the original publication of *The Three-Pound Universe,* and it is with an odd sense of deja vu that we return to our original inquiry: "Is the mind in the brain?" "What is a mind anyway?" "Can consciousness be explained?" "Is the mind a machine?"

Back in the early to mid eighties, when we began our research, we were swept up in the derring-do of this explosive field. We had the impression that neuroscientists were making such extraordinary rapid progress in mapping the brain's wiring that almost any day now a paper would be presented at a symposium announcing that a team of neuroscientists had found *it*—consciousness in a neuron, in a protein, in a receptor on a nerve cell terminal.

The primal drive in brain science was to *localize*. The localizationists tried to identify which parts of the brain might control hunger, thirst, anger, sex drive, even the recognition of faces. In fact, some of the major early discoveries showed that you *could* locate things like fear, perception of color, dreams and so on in a brain—even in specific clumps of tissue. If you stuck an electrode into a certain place, rats, cats, monkeys, or even human beings would fly into a rage; conversely if you removed that brain area, a raging animal would become tame as a lamb. Localizationists excitedly wrote up queer human disorders such as prosopagnosia, the utter inability to recognize faces, that resulted from damage to specific clusters of brain cells. Our personal favorite was a report of a stroke victim who forgot the names of vegetables, but no other words. It certainly looked as if the brain was merely an exquisitely complex bit of circuitry that could be understood (eventually) by dismantling it bit by bit, patiently labeling all the components and wires, until you got to whatever it was that controlled consciousness.

After all, that was the case in physics. Since the time of the ancient Greeks, physicists have looked for the *a-tom* ("not able to be cut"), the basic, indivisible unit of matter. Today, all of physical reality can be summed up by something known as the "standard model," which consists of a dozen or so elementary particles and four forces. That means that 2,500 years of experimentation with the universe can be compressed into

one diagram you can write out on a blackboard. It's an impressive victory for reductionism, the reducing of more complicated things to simpler ones; it is the height of what scientists call "elegance." It would be elegant indeed if the brain, being part and parcel of the physical universe, could be "reduced" to something comparable to elementary particles and forces.

But the more we researched *The Three-Pound Universe,* the more doubtful we became about this reductionist goal. In 1986, we were forced to leave the question with a large question mark. Now it's 1991, and surely, we thought, all those brilliant researchers must have come a bit closer to isolating the atom of consciousness. After all, we're in the 1990s, the Decade of the Brain by congressional fiat. This resolution of Congress, endorsed by President Bush, has prompted columnist Daniel S. Greenberg to wonder what part of the human anatomy would be commemorated next. But let's face it, we know the brain must be significant if even Congress has noticed it. And perhaps living in the Brain Decade will remind us of the importance of understanding our organ of thought as we hurtle toward a new millennium. Let's not forget that wars, genocide, Scud missiles, drug abuse, the destruction of rainforests—and the antidotes to all of the aforementioned evils—begin in the human brain!

In fact, the past five years have seen some spectacular progress in certain clinical areas of neuroscience. Brain transplants—actually, a graft of a small clump of brain tissue, or in some cases, of tissue from the patient's own adrenal glands—have been performed in Sweden, England, Mexico, and the United States, and some patients (victims of Parkinson's disease) have shown slight improvement. A new drug has come along that dramatically retards the progress of Parkinson's disease. There have been bold advances in the understanding of Alzheimer's disease and in the decoding of the genes responsible for several mental illnesses. All of which will doubtless alleviate a lot of human suffering. Yet, if anything, we seem to be even further from the consciousness atom. Not only have we been unsuccessful in tracking down consciousness in a brain cell; now we cannot even be sure that consciousness is contained within the brain at all.

A case in point is psychoneuroimmunology, or PNI, a field that has come into increasing prominence since we wrote *The Three-Pound Universe.* As its name suggests, psychoneuroimmunology is the study of mind (psyche), brain (neuro), and body (immunology) as *one system.* It used to be that the brain and the immune system were two separate worlds. The brain's hormones and chemical transmitters simply did not talk to the T-lymphocytes, killer cells, helper cells, macrophages, et cetera, that make up the immune system. It was as if brain chemicals spoke German and

immunological proteins spoke Cherokee. Or so everyone believed until a group of rats in Rochester, New York, enlightened us.

In a standard taste-aversion experiment, the rats had been conditioned to dislike the taste of a harmless sweetener when it was paired with a drug that caused stomachache. But what no one had figured on was that the stomachache drug, cyclophosphamide, also damaged the immune system. Later some rats died, and their mortality rate turned out to be proportional not to cyclophosphamide but to the amount of sweetened water they drank. This made no sense at all, and it set psychologist Robert Ader to thinking.

"Since I didn't 'know' there was no connection between the brain and immune system, I was free to make up any theory," recalls Ader. "I said it was possible that while I was conditioning the taste aversion I was conditioning immunosuppression, and the mice might have become more susceptible to pathogens in the environment." Every time the conditioned mice drank saccharin, in other words, they *thought* they were drinking cyclophosphamide. This thought weakened their immune systems and left them defenseless against bacteria and viruses. The rats had been killed by their beliefs! But how could this be so if there were no connection between the nervous system and the immune system?

Ader followed up his serendipitous discovery with meticulously-controlled experiments that proved his hypothesis. And since then other researchers have demonstrated definite links between the brain and the immune system. Receptors for brain chemicals have now turned up throughout the immune system. When brain chemicals are mixed with immune cells in laboratory dishes, they exert powerful effects, for good or ill, on the white blood cells that produce antibodies, for example.

"It's all one system," says Candace Pert, a leading neuroscientist who has turned to immunology and become a prominent AIDS researcher. When she located receptors for opiates and other neurochemicals on the surface of immune cells, Pert began to wonder anew about the location of the mind. "I can't relate to the mind/body dichotomy anymore," she told us. "Is your consciousness in your head? No, it's in your whole body. I no longer believe in disease at all. Disease is a hundred percent mental. It's just your brain state being reflected in your body."

If the immune system is an extension of the brain, then perhaps we can think of it as having a kind of consciousness; perhaps we can even speak of "sad" blood cells or a "hopeful" spleen. By identifying the chemicals that carry messages about anxiety, hopelessness, or optimism into your bloodstream, we may learn to harness the mind's healing powers in whole new ways. Drugs that mimic brain chemicals may bolster an immune system debilitated by grief. A futuristic biofeedback apparatus linked to a blood

analyzer might train a person to crank out more antibodies or to mobilize natural killer cells. Faith healing, the placebo effect, laying-on of hands, even voodoo, are coming out of the twilight zone and into the fine print of learned journals.

At the same time, sensitive Jamesian reflections on the nature of consciousness will not teach us how to repair damaged nerve cells or make senile brains normal again. There will always be a nuts-and-bolts aspect to neuroscience, a fine-grained molecular view of the organ that will yield important discoveries like NGF, or nerve growth factor. When we wrote *The Three-Pound Universe,* we speculated that there might be a sort of "fountain of youth" inside the human brain, and that was several years before NGF, a natural product of nerve cells, hit the news. When NGF is injected into the brains of aged, demented rats, the animals' brain cells regenerate and their memories improve proportionally. Will it be possible to infuse NGF into the brains of Alzheimer's patients, rehabilitating their memory and retarding the disease? Well, you can hardly have people walking around with small, refillable tubes sticking out of their brains. But neuroscientist Fred Gage, of the University of California, San Diego, suggests the following scenario: "You can take cells from a patient's own body, perhaps from the skin, insert factor-producing genes into these cells, and then graft them to the brain." Perhaps neurografting, as this technique is called, will prove to be the antidote to some heartbreaking degenerative diseases of the brain.

Or, rather than brain-cell repair, we may look forward to brain-cell *replacement,* in which diseased or damaged brain cells are replaced with fresh cells from "brain banks." One early prototype may be a lab at Cornell University Medical Center in New York City, where scientists are growing rat brain cells in culture—specifically the cells from the basal forebrain that degenerate in Alzheimer's disease and the substantia nigra cells that are killed off in Parkinson's disease. Scientist Ira Black and his colleagues are probing these cultured cells with fresh combinations of genetic material in order to identify new nerve growth factors. They have been successful in getting embryonic nerve cells to continue to divide in a test tube, thus making cell banks a realistic option a decade or two down the road.

And as for the mind/body relationship: As you will read in Chapter 4 of this book, the discovery of the anti-psychotic drug Thorazine in the early 1950s was the opening chapter in a scientific detective story that remains unsolved today. In 1991, alas, we still don't know what causes schizophrenia, nor do we have a cure. But we can say with some assurance that it is an organic disease of the brain and not primarily the result of faulty

parenting. More and more, it becomes clear that "mental" problems, including disorders of thought, the holding of false beliefs, delusions, and obsessions, are not entirely mental. Mind and brain, mental and biological events, are inextricably intertwined in psychological illness, as has been borne out further since the writing of this book.

At the National Institute of Mental Health (NIMH) Thomas Uhde and his colleagues have been studying people crippled by severe phobias, such as fear of eating in public, using public bathrooms, writing in public, or social interaction. One patient could not take her children to the pediatrician out of fear of being called upon to fill out a medical form in the presence of other people. Others never went out on a date because of a phobia of eating in public. These are people, you might say, who are paralyzed by an *idea*—a mental construct—and yet their illnesses turned out to have a biological cure: phenelzine, a type of antidepressant drug. Similarly, in another study, the antidepressant clomipramine (Anafranil), brought relief to people affected with obsessive-compulsive disorder, like a young mother who washed and rewashed the family laundry all day long because she was convinced that germs clung to the clothes as soon as they left the dryer. What does it mean, we may ask ourselves, when a belief, in this case, a deeply-entrenched belief, is changed by a chemical?

Yet eight years after we began researching *The Three-Pound Universe*, the word "consciousness" is still taboo. "It is not considered a suitable scientific topic," says Pert. Because it is far too fuzzy to measure in a test tube, or even in a T-maze for rats, most researchers continue to behave as if it did not exist. Although the American Association for the Advancement of Science (AAAS) recently held a symposium on the subject, mentioning consciousness at a meeting of the Society for Neuroscience would be a bit like mentioning God or flying saucers; it belongs to the realm of things that are primitive and unscientific, if not downright supernatural. "I don't even go to neuroscience meetings anymore," confesses Pert. "They're too dull; they're just recording some snail neurons or something." But even in snail neurons a scintilla of consciousness may be lurking waiting for scientists to notice it.

Judith Hooper
June 1991

Looking for Consciousness: A Time Line

c. 40,000 B.C.	Human brain evolves to its present form.
c. 430 B.C.	Hippocrates, the patron of physicians, calls the brain the organ of thought.
c. 390 B.C.	Plato declares that the soul is incorporeal and superior to the body.
c. 335 B.C.	Aristotle, watching headless chickens running around, decides the heart is the seat of consciousness.
1637	Réné Descartes divides *res cogitans* from *res extensa*; glorifies the pineal gland.
1748	Julien Offray de la Mettrie says the soul is superfluous.
1810	Franz Joseph Gall, seeking the source of thoughts and emotions, dissects brains, invents phrenology.
1848	Phineas Gage's brain is pierced by an iron rod, making him history's most celebrated neurological case.
1860	Pierre Paul Broca unveils the speech center before the Paris Anthropological Society.
1871	Camillo Golgi, an Italian physician, invents a silver stain that makes nerve cells visible under the microscope.
1874	German neurologist Carl Wernicke identifies an area specialized for speech comprehension in the left hemisphere.
1890s	Sigmund Freud grows bored with lamprey nerves, invents psychoanalysis.
c. 1900	Ivan Pavlov's dog discovers the conditioned reflex.
1901	Santiago Ramón y Cajal notices that neurons are separated by tiny gaps, or synaptic clefts.

1906 Sir Charles Sherrington describes how reflexes are "wired" in the brain.

1911 Eugen Bleuler coins the term *schizophrenia*.

1913 John B. Watson sets forth the principles of behaviorism; the brain becomes a "black box."

1921 Otto Loewi identifies acetylcholine, the first known neurotransmitter.

1926 Karl Lashley begins looking for the seat of memory.

1929 Hans Berger records brain waves from a person's scalp.

1930 B. F. Skinner invents operant conditioning, teaches pigeons to play the piano.

1935 Egas Moniz performs the first prefrontal lobotomy on an inmate in a Lisbon insane asylum.

1940s Some of Wilder Penfield's patients have interesting "flashbacks" during brain surgery.

1943 Albert Hofmann takes the world's first LSD trip.

1949 Donald O. Hebb describes the "neural net."

1950 Lashley gives up on the engram, concludes memories are not localized.

1950s America falls in love with psychoanalysis.

1952 Robert Heath implants deep brain electrodes in a human being.

1952 Alan L. Hodgkin and Andrew Huxley describe how neurons fire.

1952 Chlorpromazine alleviates schizophrenia; internal straitjackets replace the external kind.

1952 Paul MacLean names the limbic system.

1953 REM sleep is discovered.

1953 James Olds and Peter Milner activate a rat's "pleasure center."

1954 John Lilly invents the isolation tank, experiences "psychological freefall."