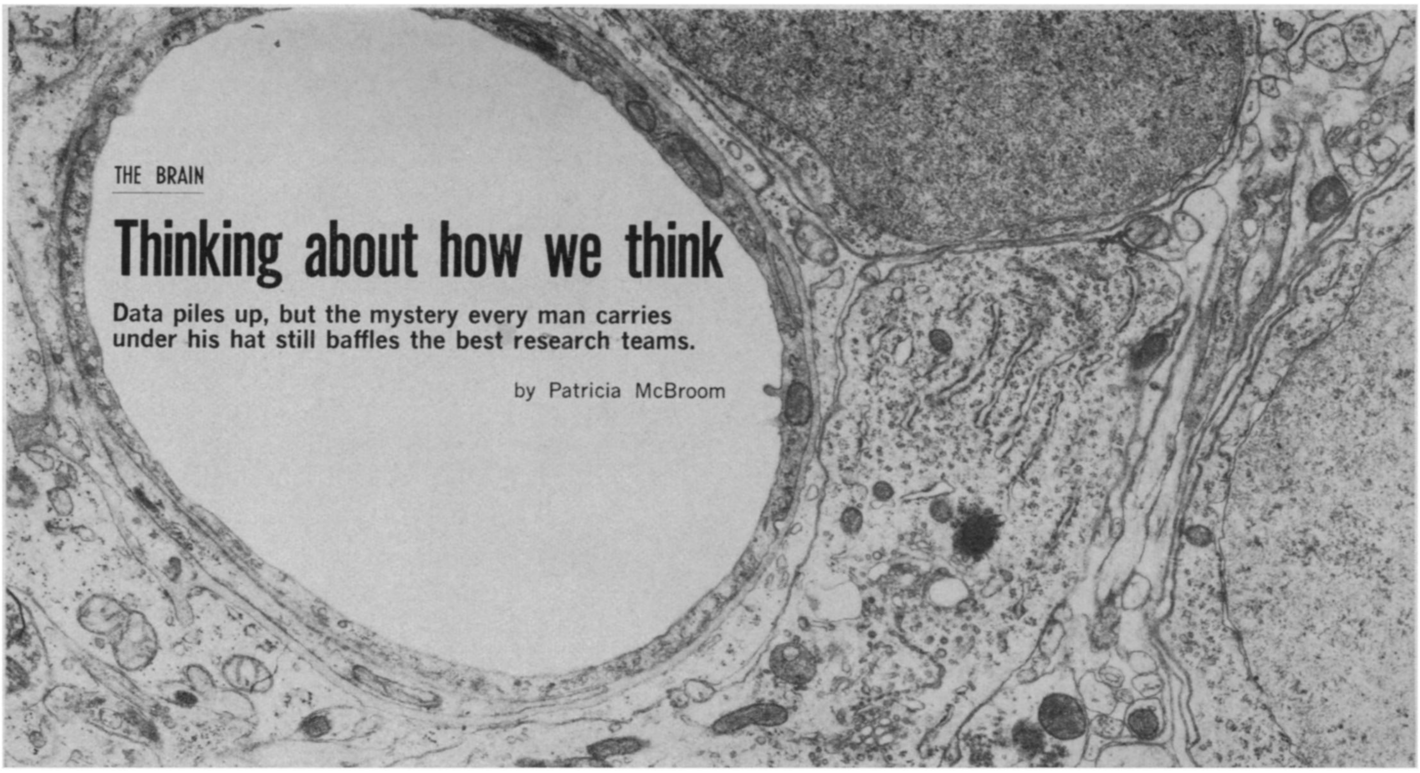


THE BRAIN

Thinking about how we think

Data piles up, but the mystery every man carries under his hat still baffles the best research teams.

by Patricia McBroom

NIMH

A capillary (white circle) highlights the complexity of surrounding nervous tissue in this slice of a rat brain.

Despite all the pioneering work done over the past 20 years in brain research, the mind is still very much a dark mystery locked in a bony box.

Scientists poke holes in the box and read the electrical activity of neurons. They slice brain tissue and view its immense complexity under the powerful electron microscope. They locate quantum amounts of chemicals at minute sites on nerves. But in no way can they visualize the system entire and explain what a thought is. The thing a man carries around under his hat is more complicated than anything known to science and at the moment there are no principles, physical or chemical, that will describe its action.

The lack of a conceptual framework in brain research is rapidly becoming crucial as experimental results on this or that chemical-electrical reaction pour out of laboratories at an accelerated pace year by year. By now the action of an individual neuron is fairly well understood, but scientists have no concepts to deal with the brain's integrative functions or, simply, its capacity for consciousness. A common belief is that they never will.

Understanding consciousness will probably require entirely new scientific principles. Protein molecules, for example, the building blocks of living tissue, seem simple compared to what they evidently do in the brain; a framework for explaining how they hook up to produce consciousness is entirely lacking.

But over the past few years, a few researchers have had the temerity to attack consciousness directly. None claims to be near a solution, but there is a sense of optimism that eventually the dynamics of memory and learning will be clarified. And if memory is understood, much of what is called consciousness will also be.

Complexity is not the only reason science knows so little about the brain's dynamics. According to Dr. David Krech, a psychologist himself and a well-known brain researcher at the University of California, Berkeley, psychologists bear much of the blame.

He says early 20th century psychologists deliberately established an experimental science that was to be virtually independent of any other science, including physics and physiology.

Prophets of this "brainless psychology," says Dr. Krech, were the late Edward Bradford Titchener and John Broadus Watson who "joined together in a holy unconscious alliance to banish brain research from psychology.

"The brain researcher could always find room at the lab—someplace! But they were few and they were separated from the proudly self-sufficient system-builders, and learning theorists and rat runners and nonsense syllable teachers; and the brain researchers spake not unto the learning people, and neither did the learning people speak unto the brain researchers.

"I cry for so many lost years of work by so many good and true and bright minds," Dr. Krech lamented in a recent address before the American Psychological Association in Washington.

Lost or not, the years of what Dr. Krech calls brainless psychology are numbered.

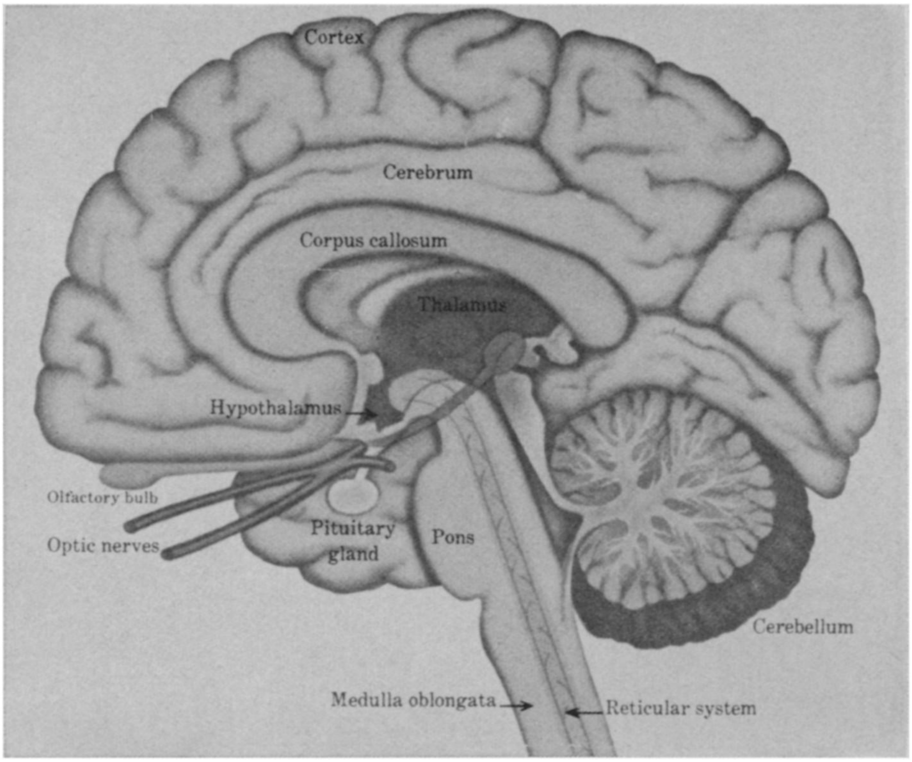
After an era of studying animal brains, researchers are now well-acquainted with the brain's anatomical structure. They know, for instance, where the major emotional, sensory and motor centers are located and what path impulses take from muscles and sensory organs to the upper brain. It is now possible with correctly implanted electrodes to control an animal emotionally and physically.

Equally well-understood is the nerve cell. Since the early 1950s scientists have progressively uncovered its electrical and chemical action. They know how it fires and how it communicates with other cells.

When the nerve fires, tiny amounts of chemical transmitters at the synapse or meeting of nerve cells are released to carry an impulse across the junction. These same chemicals have been deeply implicated in emotional behavior. Their discovery has given rise to an entire subdiscipline dealing with the biochemistry of the nervous system, particularly in regard to mental illness.

But these are the mechanics of brain function and the gap between them and conscious behavior is wide.

At a few well-financed centers, particularly in California, people have begun putting together electricity, chemistry, anatomy and behavior creating what Dr. Krech calls the "era of the psychoneurobiochemists." It implies a



Fortune

In humans, a thick cortex overlies more well-defined brain structures.

shift from the statics of brain events to their dynamics.

One such interdisciplinary center is in Los Angeles at the University of California's Brain Resrarch Institute. There a research group headed by Dr. W. R. Adey and composed of people from a broad range of disciplines are attempting to pin down the learning process.

Some of their work suggests that the spaces between neurons have electrical and chemical properties that are highly relevant to memory storage.

Starting with an electrical effect, the group noticed that while a cat was learning, part of its brain showed an overall downward shift in impedance—the resistance of material to an electrical current. This lessening of impedance was not due to any simple factor such as temperature or blood circulation in the brain, but seemed to be directly related to neural activity.

Intercellular space has less resistance than the cells themselves to electrical current; during learning the shifts in brain impedance appeared to arise there.

The shift was a signal the animal was learning, says Dr. Ray T. Kado, an engineering member of the group who also teaches electronic engineering to biologists at UCLA.

At the same time, says Dr. Kado, they knew cell membranes are coated with large protein molecules that extend into the intercellular space, and it seemed these molecules might participate in the impedance shift. Calcium is a chemical that interacts with this mucoprotein coating; possibly it would also cause an impedance shift in the brain.

Minute quantities of calcium were injected directly into the cat's brain ventricles and within half an hour, impedance readings plunged, in some cases by 25 percent for periods lasting 36 hours.

In two areas of the brain, the calcium injections produced seizure-like discharges, indicating that the neurons were abnormally excited. After three or four such injections, the cat would go into convulsions and die.

The results are provocative, but not conclusive. It appears that calcium affects the shape of the mucoprotein coat and thus modulates electrical conductivity in and around the neuron.

Possibly, a change in configuration of the intercellular proteins brings about a shift in impedance. If this is true, says Dr. Kado, "it implies that the stuff on the outside of the membrane has something to do with learning."

Dr. Kado stops short of saying the mucoproteins are themselves the memory trace. Very likely, they and the neuron together make up a memory package.

In another attack on learning, the UCLA group has been feeding brain waves into a bank of computers. The computer stores each rapidly shifting wave, adds them together and produces a characteristic pattern for any moment of learning or recall.

According to one description, these restless waves recorded by the computer seem to be "whispering together." When the brain recalls a memory, its waves appear to find a "best fit" pattern, closely resembling the one present when the memory was originally stored.

It is possible, says Dr. Kado, to produce a characteristic brain wave pattern for each learning episode. It is also possible to produce characteristic patterns of each individual—a kind of brainprint.

But collecting brain waves, no matter how refined the art, gives little insight into neural processes.

"You can keep this up ad infinitum," says Dr. Kado. It's like learning a language by memorizing words.

Hopefully the UCLA group will come up with some rules. "But it's messy, it's so complicated," says Dr. Kado.

Whispering waves, impedance shifts, mucoproteins and calcium—all seem relevant to memory, but the integrating concepts have yet to be found.

"We're at the stage the physicists were when they were putting together the Bohr atom—just opening doors," says Dr. Kado.

Nobel Laureate Niels Bohr discovered atomic structure at the turn of the century. His description of an atom—electrons rotating around a nucleus of protons——suddenly made sense of the physical elements. Before that time, physicists could observe the behavior of elements and see their order, but lacked the key to explain why they acted the way they did.

Brain research, similarly, is now in the process of ordering many disparate elements.

Those who like to compare the brain to a computer often contend that its complexity is unapproachable and beyond the ken of science. When a system is so big, goes the argument, its processes become random, unpredictable and not capable of explanation by any scientific concept. With 20 billion neurons, each possessed of 25,000 to 50,000 connections, the brain certainly seems big enough for unpredictability.

But Dr. Kado and others question the mechanical analogy. People have always compared the brain to the most advanced instrument they knew, he says. First it was the clock—a man's head was supposedly filled with gears. Then when the telephone came in, the brain began to resemble a switchboard. Now it's a computer because that is the most complicated machine anyone can imagine.

Science needs new concepts to deal with neural activity—classical electrical physics won't do, says Dr. Kado. "We have to be able to look at this in an entirely different light."