COLUMN ONE; THE BRAIN: A WORK IN PROGRESS; Unraveling the Riddle of Identity; Exotic devices that allow the brain to be caught in the act of thinking let researchers explore science's last frontier--the source of human consciousness. Series: THE BRAIN. A work in progress. Last in a series:[Home Edition]

ROBERT LEE HOTZ. **The Los Angeles Times (Pre-1997 Fulltext)**. Los Angeles, Calif.: Oct 16, 1996. pg. 1

Full Text (3759 words)

I have something in mind--a thought so evanescent that it comes and goes in milliseconds.

To capture it in the act, UCLA neuroscientist Mark S. Cohen has trained on my brain a 22-ton experimental imaging device, twice as powerful as--and 30,000 times faster than--any conventional medical imager. This nuclear magnetic resonance (NMR) imager generates a magnetic field so forceful that, as it pulses and flexes around my head, the room shakes with a 100-decibel pile-driver roar.

Every 50 milliseconds, it captures an image of the physical spark of my imagination at work--and something more.

Only part of my conscious mind attends to the mental exercise that Cohen is recording. The rest is abuzz--worried whether I can perform the task properly, curious about how well my mind will photograph, and wondering most of all about the motives of these scientists who are so intent on the neurobiology of my thoughts.

This irrepressible mental chorus constitutes the background noise in the NMR image Cohen takes of my brain. It is also the core of the most perplexing problem in science: What is consciousness?

The human brain, and the self-awareness that arises from it, is a mystery wrapped in an enigma, swaddled in a tough, protective membrane and sealed inside the skull, unknowable until now except by the most indirect means.

Until recently, only a surgeon ever saw an exposed, living brain. A neuroscientist could learn more about its intangible mental functions by reading poetry or arguing philosophy than by examining the dead organ on an autopsy table.

Today, scientists have at hand an array of exotic devices that can peer through the skull to catch the living brain at work. Researchers at UCLA and other centers are using them to explore one of the last uncharted territories: the structure and cognitive functions of the human brain.

Emboldened by their ability to capture the image of something as intangible as imagination, a growing number of scientists are trying to study the one thing that many believe cannot be labeled, scrutinized or even defined--human consciousness.

The effort to understand human consciousness is an inquiry older than science itself. It is at the heart of a riddle of identity that has preoccupied philosophers, mystics and theologians for as long as there have been words to frame the query: Who--or what--am I?

Many neuroscientists hope that by studying the neurons of the brain, its genes, sensory perceptions, memory and language systems, they may be able to collect enough information about the way it works to finally discover the organizing principles underpinning all subjective experience.

Consequently, researchers for the first time feel confident enough to frame serious questions about the physical foundations of the human spirit.

How do the physical processes of the brain give rise to subjective experience?

Somehow, the fragile synapses and cells of the human nervous system can perceive the world around them, learn from their perceptions, reinforce memories with the force of emotion, plan ahead, decide and act on incomplete information, as well as sleep, dream, wake and pay attention.

The brain captures its moods in melodies. It invents stock markets, founds religions and orbits telescopes. It is introspective enough to develop psychoanalysis.

"There is something very mysterious about consciousness," said Christoff Koch, a theoretical neurobiologist at Caltech. "Why can objective physical systems have subjective states? It is baffling.

"It gets at the central idea of the soul."

For the human brain, the scientific investigation of consciousness is the beginning of an unusual journey of self-discovery.

"We are trying to understand who we are by studying the organ that allows you to understand who you are," said Antonio Damasio, an expert at the University of Iowa on the brain, cognition and behavior.

"Consciousness," said David Chalmers, a cognitive scientist and philosopher at UC Santa Cruz, "is the last frontier of science."

Chemistry and Electricity

Unraveling the nature of consciousness, however, is a problem too daunting for any one scientist to address in its entirety.

Instead, researchers are teasing apart isolated neural processes, such as how the brain perceives color or how neural cells focus attention, in the hope that they can gather evidence of how a conscious mind is assembled from different brain processes.

On scores of university campuses, scientists trace the ebb and flow of chemicals that trigger brain functions, the blood flows that nourish them and the electrical patterns they generate. They are trying to catch the mind in the act of being.

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As they pull together new insights into how the brain functions, a growing number of neuroscientists believe that the mental processes underlying consciousness arise from an intricate madrigal of two languages--chemistry and electricity--communicated through networks of millions of neurons, all orchestrated precisely in time.

"We are the activity of the neuronal machine," said Rudolfo Llinas, an expert at New York University on the brain and cognition.

For the first time, researchers are identifying the connections between the brain's physical anatomy and the mechanisms of perception, learning and other, higher cognitive functions.

Investigators are beginning to understand how experiences can lodge permanently among millions of scattered neurons--to be revived in milliseconds by the smell of a baking pastry, a familiar melody or a photograph.

Memory is more complicated than anyone had imagined. Researchers such as Larry Squire at UC San Diego have discovered that the brain harbors many independent systems of memory, while Erin Schumann at Caltech and her colleagues are revising ideas of how knowledge is retained in the chemistry of nerve cells.

Scientists have determined that the brain handles memories of events and emotions differently than memories of ingrained habits and tasks.

Short-term memories are fundamentally different from long-term memories and may be forged in entirely different ways. False memories appear to be handled differently in the brain than memories based on true events, brain scans suggest.

Memory's unexpectedly intricate arrangements mirror those of other neural systems involved in the operations of a conscious mind.

Until recently, most scientists believed that language was handled by the left side of the brain. But the mechanisms of language are much more decentralized than previously thought. And the way the growing brain handles language is much more flexible than previously believed, research by Elizabeth Bates at UC San Diego suggests.

Names of animals and names of tools are handled by largely separate brain regions, other scientists discovered. Knowledge of the concepts they describe is stored in another discrete system.

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The words, syntax and concepts of a person's native tongue are stored so separately from any language learned later in life that a stroke can knock out the ability to speak one but not the other.

By highlighting nuances of brain functions, sophisticated biomedical sensors offer glimpses of tantalizing relationships between physical brain structures and conscious mental activity:

* Subtle differences in brain anatomy appear to affect the ways men and women process information, even when thinking about the same things, hearing the same words or solving similar problems.

* The most efficient brains appear also to be the smartest, with the brains of those with the highest IQs using the least energy. Learning and practice appear to improve the brain's efficiency.

* Small structural abnormalities appear to develop in the brains of people with Alzheimer's disease or Huntington's chorea long before any noticeable behavioral symptoms can be diagnosed.

* Minor alterations in neural circuits for vision and hearing may be responsible for dyslexia, while brain abnormalities in regions involved in inhibiting mental activity could be the cause of attention deficit hyperactivity disorder, which affects about 5% of school-age children.

But the search for clues to consciousness leads down stranger alleys.

From nature's own experiments--the victims of disease and brain injury--neurologists are obtaining glimpses into the workings of the conscious mind by seeing how defects twist its usual attributes.

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What is one to make of an otherwise normal man--a victim of a rare mental disorder called Charles Bonnet syndrome--who occasionally sees leprechauns, the amputee who thinks he is holding a cup in the hand he no longer has, or the engineer who sees Technicolor cartoon characters cavorting in a blind spot in her visual field.

Stranger still are victims of a mental disorder called associative agnosia, who easily can draw any object but cannot recognize what it is, or those with "blindsight," whose sense of sight functions normally but who cannot make themselves consciously aware of what their eyes see.

Why should brain damage leave one woman unable to name animals, but able to name any other object?

From these and dozens of other hints, researchers today are identifying the puzzle pieces of the brain, yet they are far from understanding how they fit together into the cohesive whole of the human mind.

"Why does all this processing give you an inner life?" asked UC Santa Cruz's Chalmers. "Why is it that these processes should give rise to the consciousness in the first place?"

Our Uniquely Human Self-Consciousness

Some researchers argue that consciousness in some form may extend beyond humans to other species.

Each human mind may be unique, but all its higher cognitive functions take place in a brain closely resembling those of more primitive primates such as apes and chimpanzees, say experts in neural evolution.

The human brain appears to have no unique cells, chemicals, neural circuits or major anatomical structures, experts said. All the known differences are a matter of degree.

Other species can plan ahead based on experience, combining sensory stimuli, attention and short-term memory. Nor is the human mind unique in its ability to form concepts, some researchers contend. Even pigeons appear to be able to sort objects into categories and recognize abstract relationships.

What seems to distinguish human consciousness is its subjective self-awareness--the feeling of being "me."

And that is where most scientists throw up their hands in frustration, because human self-awareness is itself the best, and perhaps only, evidence of its existence: I know I have a mind because I have a mind that is aware of itself.

"How do you explain this quantum leap in control over the mind in humans, with basically the same machinery you have in monkeys?" asked neurobiologist Martin C. Sereno at UC San Diego. "People just have more control over what is going on in their heads--for better or worse."

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There is no shortage of new theories from scientists and philosophers trying to account for the novelty of human consciousness.

Some contend that consciousness is the byproduct of a Darwinian tooth-and-claw competition between mental states trying to dominate behavior.

On the other hand, Oxford University mathematician Roger Penrose proposed that consciousness must be a property of abstruse particle physics operating inside brain cells. Free will, he contends, must arise from the random character of quantum mechanics--a rolling of the subatomic dice.

Some experts in artificial intelligence conclude that consciousness is nothing more than sophisticated computer-like information processing. Special mental switching areas integrate all the brain's perceptions into a sense of self, they suggest.

Indeed, if the raw meat of the human brain can develop consciousness, they speculate, why can't the silicon of integrated computer circuits?

Neuroscientists like Sereno and philosophers like Daniel Dennett at Tufts University believe that language is one essential prerequisite for the development of higher consciousness. How, after all, can a brain be self-aware if it cannot talk to itself?

Damasio thinks they have it backward. In his view, language developed well after the onset of awareness. The brain harbored a sense of self long before it had a word to name it, he said.

"If you look at a chimpanzee, I have no doubt it has a sense of self, just not as rich as yours or mine," he said. "What we have is enriched by a spectacular memory of our past and by a memory of the plans of our future, combined with the fact that we automatically translate whatever we think into language.

"That is truly, uniquely human."

However intoxicating the theoretical possibilities, Nobel laureate Francis Crick at the Salk Institute in La Jolla insists on keeping his ideas about consciousness tied as closely as possible to what can be measured in a laboratory.

"There was too much talk and not enough experiments, from my point of view," he said. "You really want new experimental data and to not get into too many highfalutin arguments about the nature of consciousness."

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In Crick's view, the sweeping question of human consciousness is too large to study. Instead he has teased off a more manageable piece of the problem.

With his collaborator Christoff Koch, Crick is looking for the neural mechanisms underlying visual awareness.

They are considering the role played by special neural cells in the higher visual cortex. Some cells respond to straight lines while other cells react to color, movement or even faces. To assemble a coherent image, rich with all the sensory impressions, memories, knowledge and emotions it conjures, these separate visual cells must somehow link up to all the other neurons that relate to what the eyes are seeing.

At the highest levels of this process, Koch and Crick believe, some cells must respond to the unified perception assembled from so many other active brain cells. It is those special cells, they speculate, that make someone "conscious" of what the brain has perceived.

"People think consciousness must arise from the incredible complexity of millions of interconnected neurons," Koch said.

"We don't think it is pushing the envelope to say there are specific neurons that give rise to consciousness."

Theater of the Mind

The scanner has finished imaging my brain.

My head, still enveloped in an imaging cradle, slides out of the massive machine like a spent artillery shell.

The experiment was deceptively simple.

I had been asked to tap the fingers of my right hand together slowly, then quickly, then more slowly again. Then I was asked to imagine doing the same tasks.

The machine recorded my brain functions by tracking minute variations in the scanner's magnetic field caused by alterations in neural blood flow.

It takes Cohen, who helped design the scanner, hours on a high-speed computer to transform those thousands of individual measurements into a picture of the brain that a human eye can comprehend.

Projected on a color monitor, the scans yield rows of wrinkled raisin-shaped images of my brain. Daubs of bright color highlight the regions that became active when I physically moved my fingers and those regions that became active when I imagined the same action.

Both tasks--real and imagined--lighted up the same areas of the brain responsible for movement.

At some fundamental level, thinking about an action and performing it appear to be almost the same.

"To me that is a fascinating response," said Cohen. It runs "counter to everything I was expecting."

The images his machine creates appear to draw a direct connection between the inner life of the mind and the physical mechanisms of the brain.

"In a sense, this kind of functional imager . . . allows me to study covert mental activity--in essence, thought," he said.

Other recent imaging studies of brain function reinforce the relationship between conscious mental states and the physical structures of the brain:

* When mental patients hallucinate and hear imaginary voices, those portions of their brain responsible for hearing respond as if the voices were real.

* When people are asked to picture a map of the United States in their mind, their brains respond as if they were looking at an actual map, activating that part of the cortex responsible for vision.

* When people are asked to picture an object and then rotate it mentally, their brains act as if the object were turning in front of them.

One surprising thing about these images of perception is that they do not show where or how the mind's eye is focused in the brain.

Subjectively, perceptions always appear seamlessly, presented in the mind as an integrated whole. But these scans showed no sign of an active anatomical area where sensory stimuli were coordinated and collated.

So how is consciousness organized in the physical structures of the brain?

To Cohen, the images suggest that consciousness is itself the act of attention.

As the brain evolved, it must have developed a way to focus itself selectively; otherwise, the constant burble of brain activity and sensory perceptions would overwhelm it. In this theory, consciousness may arise from the brain's need to concentrate, momentarily highlighting some neural activities at the expense of others.

Consciousness therefore may not be continuous, Llinas of New York University suggested.

It may flicker on and off as needed, like a spotlight flashing in the darkened theater of the mind.

An Elusive Quarry

Some scientists contend that consciousness emerges from the union of all the brain's physical properties, the way a rainbow arises from the interplay of light, suspended water droplets and air.

If that is the case, they argue, scientists will never find the human mind no matter how hard they scrutinize the brain's physical structure, any more than someone will find a rainbow in any one of its scattered parts.

Indeed, Chalmers believes scientists will discover eventually that human consciousness is an irreducible quality of the universe, like space, mass or time.

"Instead of trying to explain consciousness purely in terms of its physical processes, you should take it as a fundamental entity in its own right," he said.

"We would like a unified theory of consciousness in the same way that physicists are searching for a unified theory of matter," he said.

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Some worry that by reducing human consciousness to its biological components, scientists will tarnish the worth of the human spirit or undercut ideas of personal responsibility and free will. But other researchers believe that a more detailed understanding of the brain will only enhance individual self-respect by affirming the uniqueness of each human mind.

"You will understand," said Nobel laureate Gerald Edelman at the Neurosciences Institute in La Jolla, "why your individuality is important."

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In some ways, the search for the roots of human consciousness stands much of traditional scholarly inquiry on its head.

Scientists who, by temperament and training, devote their lives to the collection of objective facts about the universe around them are forced to grapple with the imponderables of the world within.

Researchers who are trained to exclude the human element from experiments discover that the human element is the experiment.

Philosophers, more accustomed to purely metaphysical speculation, are now expected to buttress their ideas with hard data.

All of them feel caught up in a uniquely human endeavor that--for better or worse--promises to alter forever humanity's sense of itself.

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THE BRAIN: A WORK IN PROGRESS

A growing number of scientists are trying to study the one thing that many believe cannot be labeled, scrutinized or defined--human consciousness.

THE SEARCH FOR UNDERSTANDING

'There is something very mysterious about consciousness. Why can objective physical systems have subjective states? It is baffling. It gets at the central idea of the soul.'

--Christoff Koch, a theoretical neurobiologist at Caltech.

THE CHALLENGE

'We are trying to understand who we are by studying the organ that allows you to understand who you are.'

--Antonio Damasio, an expert at the University of Iowa on the brain, cognition and behavior

GLOSSARY

Cortex:

Where most high-level functions associated with the mind are implemented. Some of its regions are highly specialized. For example, the occipital lobes located near the rear of the brain are associated with the visual system. The motor cortex helps coordinate all voluntary muscle movements.

Cerebral hemispheres:

Symmetrical halves of the brain. There are two occipital lobes, two parietal lobes and two frontal lobes. The two hemisphere are in continual communication with each other. Each acts as an independent parallel processor with complementary functions.

Left cerebral hemisphere:

Appears most closely associated with a conscious self. The left hemisphere, which usually manages the right side of the body, controls language and general cognitive functions. It dominates in deciding what response to make.

Right cerebral hemisphere:

Controls the left half of the body. In most people it manages nonverbal processes, such as attention, pattern recognition, line orientation and the detection of complex auditory tones.

Frontal lobes:

Located behind the forehead. They are most closely linked with making decisions and judgments.

Limbic system:

A number of interconnected brain structures linked to hormones, drives, temperature control, emotion, and, in one part, to memory formation. Neurons affecting heart rate and respiration appear concentrated in the hypothalamus and direct most of the physiological changes that accompany strong emotion.

Hippocampus:

Plays a crucial role in processing various forms of information as part of long-term memory. Damage to the hippocampus will produce global retrograde amnesia, or the inability to lay down news stores of information.

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About This Series

Who are we? Where did we come from? While many scientists search for clues to these ultimate questions by probing the far reaches of the universe, others think the answers lie inside our own heads. Their probes are uncovering galaxies of neural cells, each twinkling with the brain's life forces. As it orchestrates human behavior, this symphony of electrochemical communication may indeed constitute our very essence.

Sunday: The explosion of knowledge in the field of brain development, where researchers are finding that those first few years of life are far more critical than anyone had guessed.

Monday: New technology is uncovering the brain's prominent role in emotions.

Tuesday: How brain researchers are overturning traditional ideas about mental illness.

Today: Human consciousness.

Special Internet Site

Beginning today, a special section of The Times' World Wide Webb will be devoted to information about the human brain. The full text, photos and graphics from this four-part series will be available, plus a wide range of additional information and graphics prepared especially for the Internet. Point your Web browser to: http://

www.latimes.com/thebrain

PHOTO: UCLA brain expert Mark S. Cohen operates a high-speed MRI scanner, top, and chats with reporter Robert Lee Hotz's brain functions, tracks variations in its magnetic field caused by alterations in neural blood flow. It also takes a detailed anatomical image, above.; PHOTOGRAPHER: IRIS SCHNEIDER / Los Angeles Times; PHOTO: A Look Inside: Tapping the fingers of the right hand and then imagining the same task both appear to activate the same areas of the brain responsible for movement, as indicated by the bright flashes in the two series of brain images below.; GRAPHIC-CHART: THE BRAIN: A WORK IN PROGRESS

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