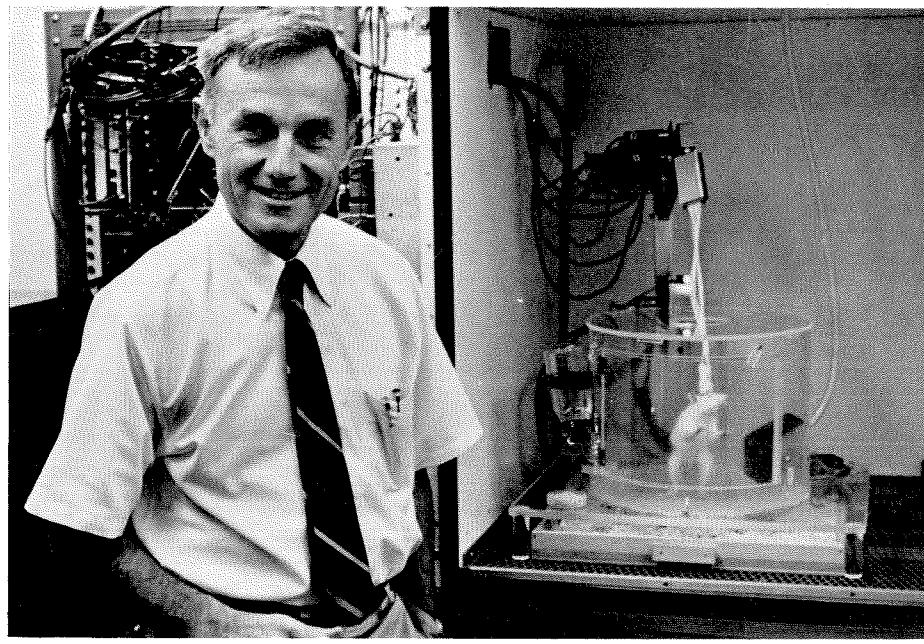
Research Notes

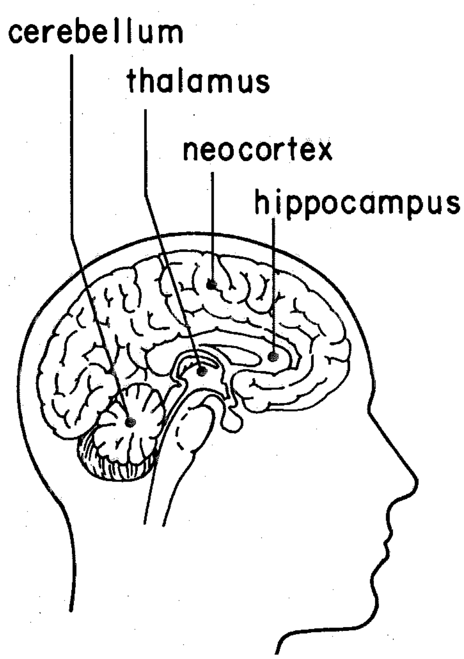
Learning about Learning

The brains of laboratory rats may seem unlikely—or at least unflattering—places to look for information about human brain function, but a learning experiment being conducted by James Olds, Bing Professor of Behavioral Biology, is providing key insights into the location of the brain's memory storage areas. And since the brains of rats and men share the same gross features, much of the knowledge gained from studying rat brain function is probably applicable to the human brain as well.

Olds and his colleagues have developed a method for monitoring individual brain cells during the act of learning—a technique that pinpoints where and when learning takes place while the rats are experiencing a simple learning situation. So far the research group has observed four main areas of memory storage in the brain (and there may be as many as six). Probably different *kinds* of learning take place simultaneously in each of these areas, but much of this activity is redundant, and the same facts are often written down in several places in the brain.



The reactions of the occupant of this transparent rat's nest help provide James Olds with data about learning centers in a rat's brain, and—by projection—in the human brain.



The brains of rats and humans are structurally enough alike to function in a similar manner.

Olds lists the four memory storage areas so far noted as the posterior thalamus, the neocortex, the hippocampus, and the cerebellum. The learning that takes place in the posterior thalamus is thought to be temporary and of a nonspecific nature. Olds compares this area to a computer's accumulator that fills with information about one learning task, then quickly empties and fills again with data about another task. The neocortex, on the other hand, responds more specifically. It is believed to be where memorization of actual objects occurs and where stored neuronal models are formed. Olds likens it to a computer's memory bank that retains specific information for long periods of time. The hippocampus, located above the thalamus, is thought to serve as a memory device much like a tape recorder, and the cerebellum at the lower back of the brain is probably the chief site for learning skills.

The research is based on observations of individual brain cells of wide-awake and freely moving rats before, during, and after learning. In a three-hour operation, nine fine-wire electrodes are implanted into each animal's brain to record the electrical conversation that goes on between the brain's cells.

Once the rats are "wired," they undergo two one-day testing periods in which three stimuli—two auditory signals and a food reward—are used to elicit responses. In the first phase the tones and food pellets are presented randomly, and responses to the tones are monitored so that a picture of the brain's reactions can be established. From the outset some parts of the brain ignore the signals, while other parts respond from the beginning and never ignore them.

In the second, or conditioning, phase one of the auditory signals is paired with the awarding of a food pellet, and the other tone remains meaningless. The animal soon learns the relationship between the stimuli and behaves accordingly. He goes for the food when he hears one tone, and he ignores the other one.

The experiments are regulated by a computer that makes the auditory signals and releases the food pellets at a prescribed rate. The computer also keeps track of the rate of electrical responses (recorded as spikes on a graph) generated by the "tapped" brain cell before and during the onset of the signal. The computer then establishes when the rate in brain cell electrical activity changes. Rate changes caused by the signals occur in some areas of the brain during the first phase of training, and these rate changes are termed old responses. Others, called new responses, may occur only after training.

Some new responses are considered secondary because they occur as long as 30 to 200 milliseconds after the signal is sounded. The primary new responses come much earlier—6 to 20 milliseconds after the signal. Olds assumes it is at the point of the primary response that the resistance of a synapse—a chemical junction between two brain cells—is lowered enough during learning to permit a nerve impulse to be transmitted across it. He thinks these synaptic gaps work in an opening-closing manner, much like an electric switch, sending impulses through or stopping them.

Although Olds' work has highlighted the general outlines of how the brain learns, the entire process from stimulation to response is not fully understood. No one really knows yet what happens to the message after it gets to the end of the input pathway. It seems to get lost in the central nervous system for one-tenth to one-fifth of a second, and then it goes racing down an output pathway almost as fast as it came in. There are probably many steps in the brief middle interval.

Olds, who is widely known for his discovery 18 years ago of the pleasure centers of the brain in rats (*E&S,* May 1970), reported his latest findings at the 79th annual meeting of the American Psychological Association, held in September in Washington, D.C. Collaborating with him are biology research fellows John Disterhoft and Richard L. Hirsh, and graduate students Menahem Segal and Carol B. Kornblith. The work is supported by the U.S. Public Health Service and the National Institutes of Health.

Extragalactic Chemistry — the quest for OH in space

When an important first in radio astronomy drew national attention to Caltech and its Owens Valley Radio Observatory last summer, the scientist who appeared least ruffled was the very scientist most responsible—34-year-old research fellow Leonid N. Weliachew.

By detecting the presence of OH, the diatomic hydroxyl radical, in galaxies M-82 and NGC-253, Weliachew demonstrated for the first time that chemical processes are occurring in galaxies other than our own Milky Way.

His announcement, reported in the July 15 *Astrophysical Journal,* fueled widespread interest in the enduring question of whether it is possible for life to originate in the gas and dust clouds of interstellar space. Some scientists view Weliachew's discovery and similar finds in our own galaxy as strong evidence that such life-building is going on.

Weliachew, who is visiting Caltech from Meudon Observatory in Paris, seems as unmoved by that prospect as he was unprepared for the excitement that greeted his disclosure. He insists that he doesn't know enough chemistry or biology to have an informed opinion about life "out there." As far as finding OH is concerned, he shrugs it off as much less earthshaking than news accounts made it appear. In fact, he confides that *not* finding the molecule would have been a more legitimate reason for astonishment than finding it.

This is because current theory, which Weliachew accepts and which his success has done much to strengthen, offered no grounds to doubt the existence of extragalactic OH. Since A. H. Barrett of MIT's Research Laboratory of Electronics, and J. C. Henry, M. L. Meeks, and S. Weinreb of the MIT Lincoln Laboratory first detected OH in our own galaxy in 1963, radio astronomers have discovered more than a dozen intragalactic molecules.

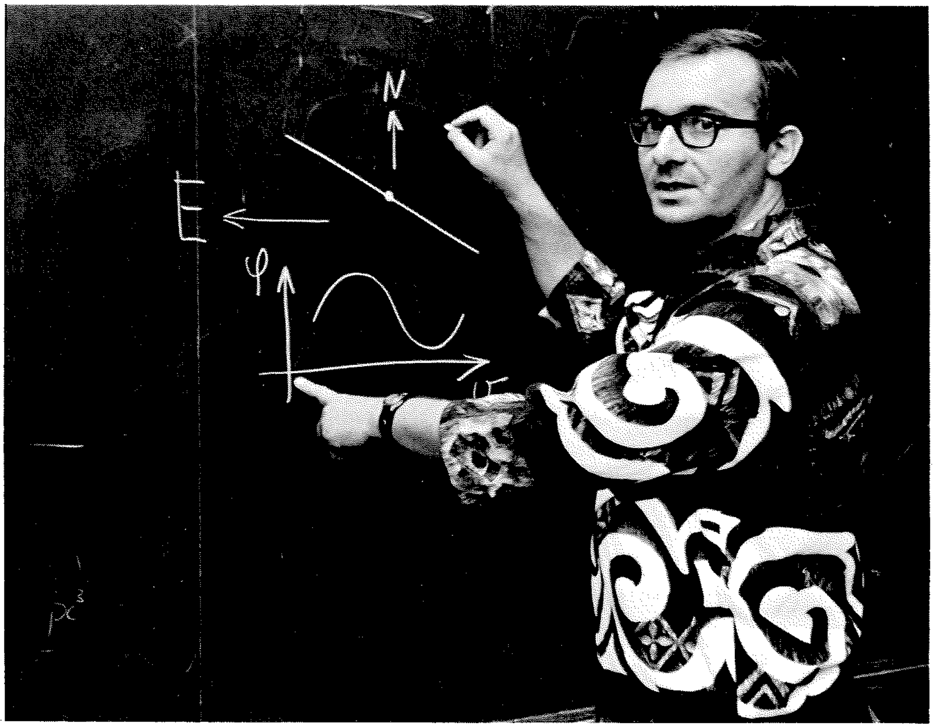
The fact that some of these are the precursors of amino acids, the building blocks of living things, was fascinating for the theoreticians in the field. Even more fascinating was the probability that their existence in our galaxy strongly suggested their existence in others. Weliachew says he simply designed an experiment to test that assumption.

His success had none of the serendipity of which great scientific legends are made. It resulted from a deliberate search, backed up by careful planning. One of the first tasks was to identify the galaxies that would be the most suitable candidates for the study. Weliachew's interest was in those about 10 million light years (6×10^{19} miles) from earth, which have an apparent size that is most suitable for study with the Caltech interferometer.

M-82 and NGC-253 emerged as the most promising targets for the search, because both emit strong radio signals from their centers and contain galactic dust clouds which are needed to shield the OH molecules from destructive ultraviolet radiation. Detection is possible only while the molecules are floating freely in space, in an equilibrium between one of several formation processes and eventual destruction. Once attached to a dust particle, they defy observation.

Weliachew knew it would take hypersensitive instrumentation to achieve the signal-to-noise ratio required to elevate his findings beyond the realm of pure chance and make them scientifically acceptable. Such a sensitivity edge should allow him to succeed where radio astronomers at Meudon, Green Bank, and other observatories had so far failed in the quest for extragalactic OH.

He was confident that a new instrumentation configuration at Caltech's Owens Valley Radio Observatory would supply the answer and made arrangements to use the equipment. His experiment, supported by the National Science Foundation and the Office of Naval Research, would be the first since the big dish antennas at the facility were beefed up by the addition of two delicately sensitive parametric



Leonid Weliachew diagrams motions in the inner regions of M-82, an irregular exploding galaxy and one of two galaxies in which he detected the presence of OH.

amplifiers. By October 1970, Weliachew and the equipment were ready.

With their receivers turned to the 18-centimeter wavelength at which OH is "visible," he simultaneously directed two big dishes first toward one galaxy, then toward the other. This synchronized use, called interferometry, can give two or more antennas the resolving power of one giant dish with a diameter equal to the distances between them.

Weliachew returned to Owens Valley in February 1971 to complete the experiment. There were four observations in all, each eight to ten hours long. Three were with the twin 90-foot dishes 1,600 feet apart, and one employed a 90-footer and the 130-foot dish, 3,500 feet away.

Weliachew's efforts produced just what he expected they would. The telltale spectral fingerprint of OH showed up twice in each galaxy, its signature readily identifiable as faint absorption dips against the brightness generated by radio signals emanating from deep within M-82 and NGC-253. This indicated that as the signals passed through clouds containing OH, the molecules absorbed their characteristic OH wavelengths from the signal pattern.

By finding OH in "nearby" M-82 and NGC-253, Weliachew has strengthened the case that it probably exists in a great many other galaxies as well. This suggests that natural laws operable in our own cosmic neighborhood are also at work elsewhere in space and contributes a new plank for theoreticians in the discipline to build on.

His findings also show that M-82, NGC-253, and our own Milky Way contain roughly one OH molecule for every million atoms of hydrogen, the most abundant and widely distributed interstellar element. In our galaxy, molecules that absorb radio waves should be detectable at concentrations well below one molecule per cubic yard. A much greater concentration would be required to detect a molecular fingerprint in other galaxies.

Weliachew has a busy schedule ahead of him when he returns to Meudon in December. In addition to studies on hydrogen line emission and absorption in external galaxies, and formaldehyde absorption in our own galaxy, he will be writing up the results of two years of research at Caltech. And he'll probably have to get used to being called Vell'-ya-chef again after finally adjusting to the Americanized Well'-ee-uh-chu.

Scientific detachment notwithstanding, he is "happy over-all" about his well-reported first. A few years ago when he was commuting between an engineering job at Meudon and doctoral studies in physics at the University of Paris, a career in radio astronomy wasn't the uppermost thing in his mind. ("Nothing about it attracted me.") But colleagues won him over by emphasizing the ideal fit of his electronics background and experience at Meudon. A positivist, Weliachew has been content to accept the symbiosis and make the best of it.