Electronics World

MARCH, 1963
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BIONIC COMPUTERS—*Machines That "Think"*

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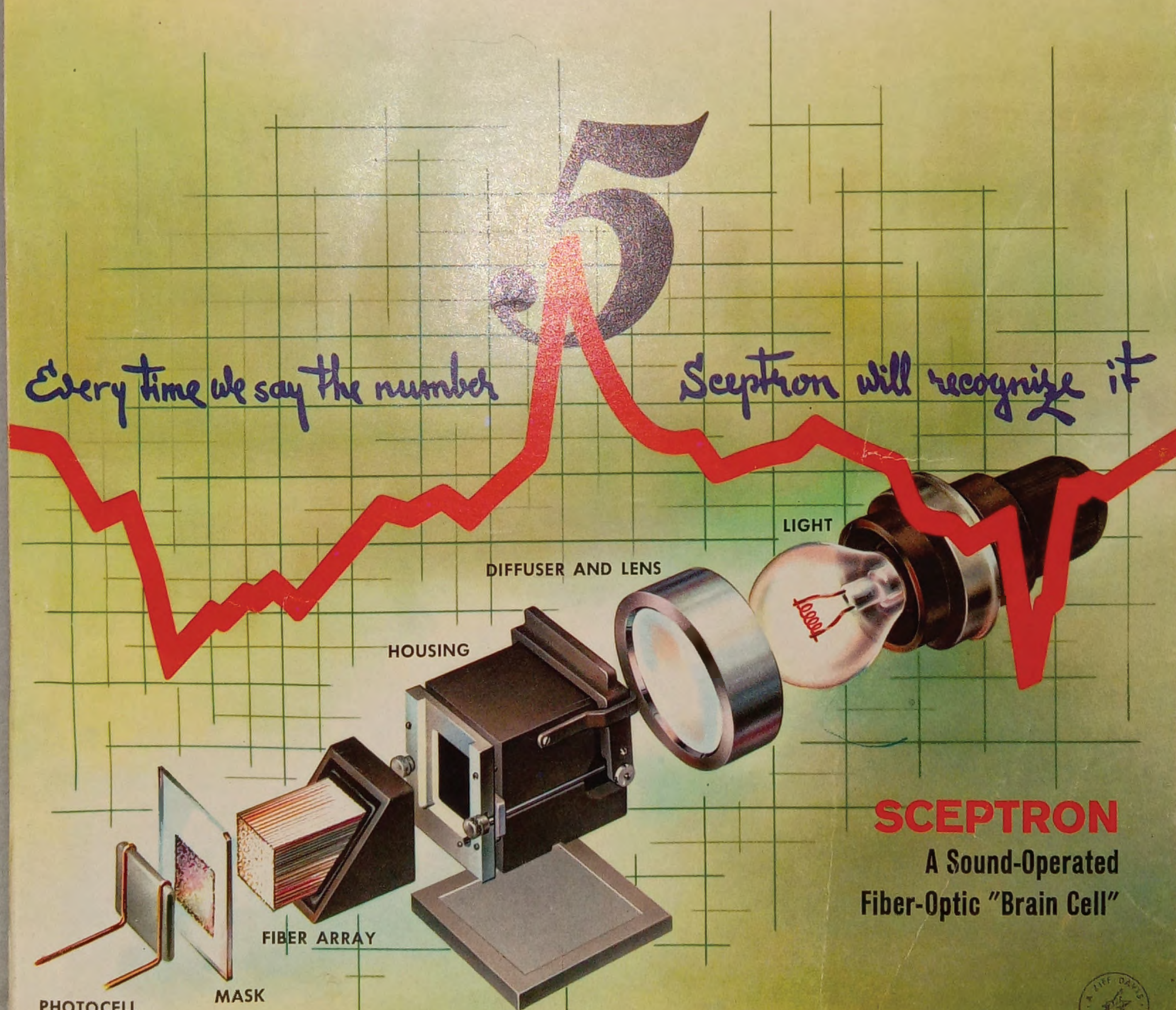

SCEPTRON

A Sound-Operated Fiber-Optic "Brain Cell"

A ZIFF-DAVIS PUBLICATION

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or else if another input signal comes along, it fires again.

Neural Networks

The complexity of the human brain is almost incomprehensible. It contains on the order of ten billion neurons, each with hundreds or thousands of dendrites. The neurons are connected in semi-random patterns, with each one receiving signals from and sending signals to hundreds or thousands of others. Signals from eyes, ears, and scores of other sensors all over the body are fed into this complex network, where they set billions of patterns of currents swirling through trillions of interconnections.

Somehow, this fantastic data-handling system, which dwarfs to insignificance our most advanced electronic computers, generates all human and animal actions and reactions. Also produced in ways only dimly understood are qualities we have come to know as intelligence, learning ability, and emotion.

The electrical neural activity also accounts for memory, although there is some doubt as to how. Some physiologists and bionicists feel that a certain pathway set up for processing a certain signal tends to "wire" the neurons so that they are more likely to conduct a similar signal along the same pathway the next time. If you solve a problem, for example, the neural currents tend to "bias" the neurons involved in a certain pattern. The next time you face the same problem, the biased neurons would tend to conduct currents along the same pathways, or to put it another way, to "remember" the previous solution and repeat it. Continued exposure tends to reinforce the "biasing" or "wiring" and thus makes the memory firmer.

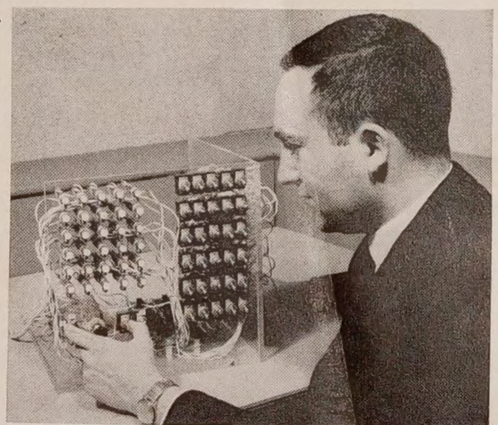
Imitating the Neuron

Although our understanding of the operation of complex biological neuron nets is extremely limited, the operation of single neurons is fairly well understood. Consequently, scientists have been able to construct artificial neurons—electronic circuits that duplicate closely the electrical activity of the biological neuron.

At least twenty companies are working on such a project, and have come up with many different kinds of circuits. Fig. 3 shows one such neuron designed at *Bell Laboratories.* It has six inputs—five excitory and one inhibitory. Its operational characteristics closely approximate those of the biological neuron, except that its input and output signals are on the order of one volt, rather than in the millivolt range as is the case with the biological model.

The *Aeronutronic Division* of *Ford Motor Company* has built an artificial neuron called "MIND" (Magnetic Integrator Neuron Duplicator), which is simpler but does not imitate the behavior of the neuron as closely as the *Bell* model. *General Electric, Melpar,* and many other companies

A



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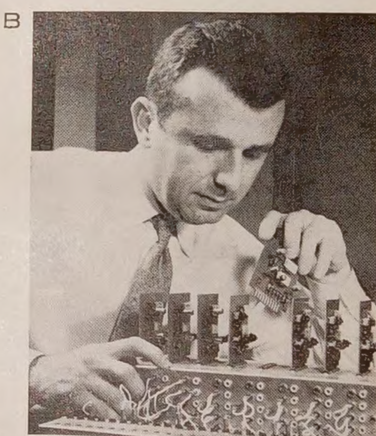

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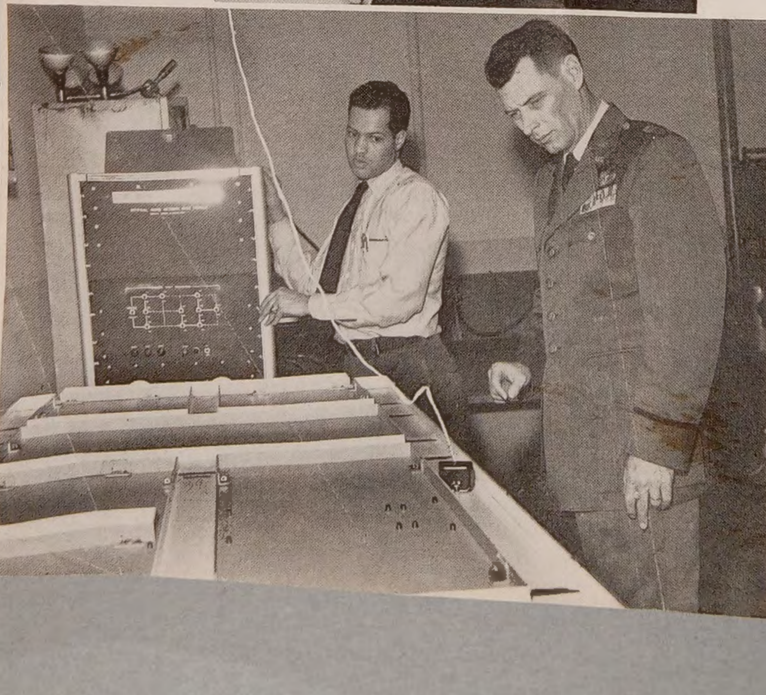
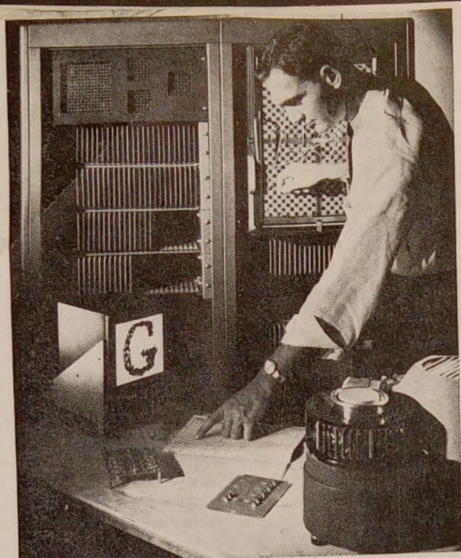


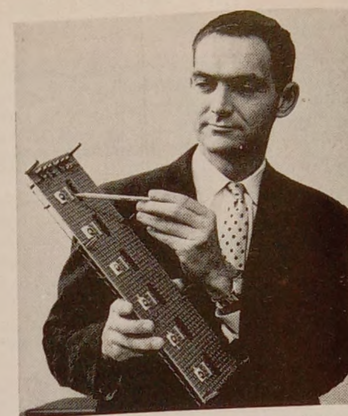
(A) Model of pattern-recognition system, based on array of neuron-like elements. Toggle switches for input sources and lights that display whether the sources are energized are in the two rectangular arrays on the front of the model. Neuron-like translation modules are also employed in similar array on right side of the unit.

(B) Network of electronic neurons is assembled by L. D. Harmon of Bell Telephone Laboratories, who initiated project of simulating the functions of nerve cells with simple transistorized circuit. Array shown imitates some functions of the eye nerves.

(C) The Air Force's "bionic mouse" learns to run maze in much the same way as does its live counterpart. Scientists hope that some day vastly more complex bionic brains may rival the human brain in its ability to think, to reason, and to learn.



Bionic pattern-recognition machine learning to recognize "G."



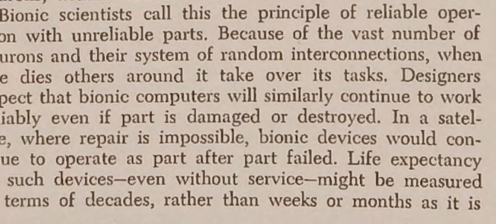
Artificial "nerve network" used to test behavior of Aeronutronic neurons. Transistor circuits are used in conjunction with devices to help them carry out decision-making functions.

This small artificial neuron was developed by Ford Motor Co.'s Aeronutronic Div. as part of its self-organizing machine research work. The MIND (Magnetic Integrator Neuron Duplicator) device duplicates in some ways the functions of live nerve cells. While it cannot imitate a living neuron as closely as can the circuit shown in Fig. 3, it is able to remember and learn from experience when taught by human or mechanical teacher. →

all you will ever have. When a neuron dies, it is not replaced. And about 1000 die every hour of your life. You'll lose 500 million during a normal lifetime, yet you will still operate effectively. As a matter of fact, there is apparently no adverse effect on the system due to the death of individual neurons, within certain limits.

Bionic scientists call this the principle of reliable operation with unreliable parts. Because of the vast number of neurons and their system of random interconnections, when one dies others around it take over its tasks. Designers expect that bionic computers will similarly continue to work reliably even if part is damaged or destroyed. In a satellite, where repair is impossible, bionic devices would continue to operate as part after part failed. Life expectancy of such devices—even without service—might be measured in terms of decades, rather than weeks or months as it is

Fig. 3. Schematic diagram of electronic nerve cell. When the sum of the excitory inputs exceeds a preset level, the circuit "fires" and generates a pulse similar to the one produced by a biological neuron. If a signal appears at the inhibitory input, the firing threshold is raised. Under these conditions, the electronic neuron requires larger excitory signal to fire.



now usually the case with presently available equipment.

Human Beings—Living Computers

The idea which eventually resulted in bionic computers came from the brilliant mathematician, Norbert Weiner, in the late 1940's. His classic book "Cybernetics," published in 1948, pointed out for the first time that man could be considered not only as an animal with certain behavioral patterns, but as a fantastically complex information processor—a flesh and blood digital computer. But far too little was understood about the human mechanism to hope to apply its principles to electronic circuitry at that time. Richard Caton had discovered in 1875 that the brain was essentially an electrical device, but that didn't help much either. Trying to explore the brain's operation by reading electroencephalograms is like figuring out how an *IBM* 7090 works by measuring voltages on the outside of the cabinet.

The breakthrough in the study of the brain's operation came in 1949 when Ling and Gerard invented the intracellular electrode, a glass capillary tube with a conducting salt inside. Its over-all outside diameter was on the order of a few tenths of a micron (more than 10,000 such probes laid side by side wouldn't cover an inch). With the microprobe, it became possible for the first time to measure electrical currents in individual neurons.

In the early 1950's, the need for computer systems orders of magnitude better than those then in existence became obvious. So scientists, while continuing to improve conventional computers as rapidly as possible, also began to look around for new approaches to data processing. They found one clue in the oldest data handling system in existence: the brain. Scientists around the country set to work to wrest useful secrets locked in the brain cells of animals and men.

(*Continued on page* 63)