

THE BODY ELECTRIC

Engineers Dream of Electric Implants

The dream of using electrotechnologies to control human physiology is an old one, as this ad from June 1967 attests. Written in the style of a research report only broadly related to the advertiser's business—a popular format in *IEEE Spectrum's* early years—this ad identifies the brain, heart, diaphragm, bladder, and limbs as fruitful areas for electrical stimulation. It also predicts increased experimentation and exploration of ways to technologically better our bodies. As this month's special issue of *Spectrum* shows, it wasn't wrong. —STEPHEN CASS

ated with...
of application...
holds so many pos...
muscles, and nerves that...
suggest the breadth of current...
throughout the world.

Experiments In The Control Of Physiological Function By Radio-Frequency Transmission Across The Intact Skin Boundary

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energy across the intact skin boundary,
lation of a variety of internal organs,
ment Head, has written this article to
ing carried out by medical investigators

The background for chronic electrical stimulation of nerves, muscles, and internal organs was established over 30 years ago when Light and Chaffee implanted a coil and electrodes in an experimental animal. The animal was placed in a cage surrounded by a primary coil. Stimulation was elicited by electromagnetic induction—a spectacular beginning. Shortly thereafter a series of workers¹ who replaced the induction link by a modulated RF carrier resulting in greatly increased efficiency of energy transfer, and improved control of signal waveforms. Radio-frequencies varying from 0.5 to 200 MHZ have been used successfully.

Today, the embodiment of this method is the implantation of a small receiving coil, and a detector feeding the stimulating electrodes. The pulse generator and its battery are external and transmit their energy to the implant across the intact skin boundary. The stimulus pulses may be from 1 msec to 10 msec in duration, and may be delivered at a pulse repetition frequency of one per second to hundreds per second depending on the type of tissue. The pulse energy is of the order of micro-coulombs.

The human figure at the right shows the major sites that are being electrically stimulated today. In the head is shown a portion of the central nervous system including the thalamus, basal ganglion, and the hypothalamus (atop the pons and medulla) where reside the areas for the transmission or control of such fundamental functions as sensation, muscular control, and homeostatic

mechanisms of temperature, appetite, and water balance, to mention a few. At a point along the carotid artery in the neck there is the nervous center, which is part of the blood pressure control network. The stimulation of this nervous center in dogs has produced dramatic reduction of induced hypertension.

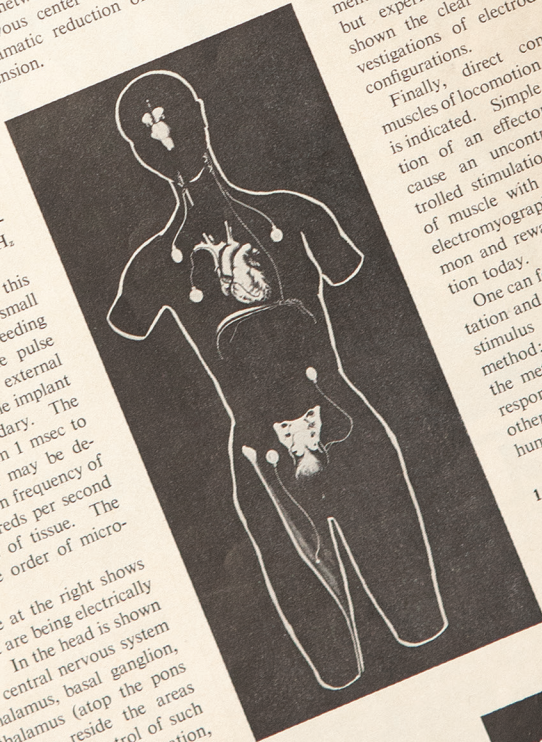
Below the heart, with its pacemaker indicated, is the diaphragm. If it is inactivated by anesthetics, disease, or injury it can be brought into forceful action by electrical stimulation of the muscle itself, or by stimulation of the phrenic nerve.

Incompetence of the urinary bladder is an important medical problem because of the high degree of incidence and of the severity of the disease state. Experiments on animals have been rewarding, but experiments with humans have shown the clear need for further investigations of electrode and control configurations.

Finally, direct control of major muscles of locomotion and manipulation is indicated. Simple command stimulation of an effector muscle will only cause an uncontrolled twitch. Controlled stimulation of antagonist pairs of muscle with feedback provided by electromyographic potentials is a common and rewarding mode of investigation today.

One can forecast increased experimentation and exploration with this type of stimulus system; elaboration of the method; and increased sophistication of the methods of stimulating, measuring response, and establishing control of otherwise inactivated sensory, motor, humoral, and neural systems.

1. Light, R. U. and Chaffee, E. L., "Electrical excitation of the nervous system introducing a new principle: Remote control," *Science*, Vol. 19, 1934, pp 299-300.
2. Glenn, W. W. L., et al., "Remote stimulation of the heart by radio-frequency transmission," *New England J. Med.*, Vol. 261, 1959, pp 948-951.



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