ACUPUNCTURE AND NEUROPHYSIOLOGY*

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ACUPUNCTURE, although viewed with scepticism by the medical profession, nevertheless has been making inroads into medical practice, partly because of popular demand and partly because the method is useful in certain morbid states. The policy of rejection is giving way to conditional acceptance. Yet we are still at the experimental and investigative stage because we want to find the elusive answer to the question: how does acupuncture work? Five thousand years of application by an ancient civilization are not enough for us. We want to know the mechanism in terms of our Western concepts of disease, our Western physiology and neurophysiology.

There is a great upsurge of research on the subject. Most of this is clinical. It often consists of trials in which the needle is inserted into various parts of the human body and a record is made of the effects of such application upon the symptoms presented and disorders "cured." This is the wrong way to conduct research. It obliges us to depend entirely on the testimonials of persons treated, without our gaining any insight into the mode of operation. We must therefore set up programs of research which involve a so-called acupuncture point along with the peripheral and central nervous systems if we want to obtain answers that we can respect. Much knowledge is extant which is relevant to our quest, and refined means of recording and interpreting are at our disposal.

There is a general consensus among those interested in acupuncture that whatever is done by the needle locally involves a transmission of impulses from the peripheral nervous system to centers capable of integrating and interpretating the information received.

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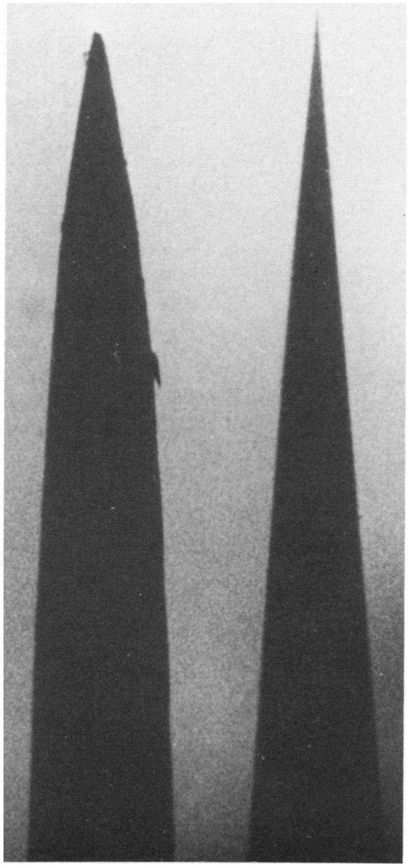

Fig. 1. Dimensions of an acupuncture needle (left) and a microelectrode (right).

The procedure of acupuncture by itself is nothing more than the introduction of a fine piece of metal, usually stainless steel, into the skin, subcutaneous tissue, or muscle. At its tip, this needle-like piece of metal has a diameter of about 50μ; the shaft has a diameter of 300μ or more. This contrasts sharply with the dimensions of a tungsten microelectrode, the tip of which has a diameter of about 8μ (Figure 1).

Skin not only covers and protects an organism, but subserves also such functions as breathing, elimination, heat exchange, and transduction of impinging external forces. It is the latter function which is of greatest interest to us when we study the relation of acupuncture to the skin, for we are introducing an instrument of macroscopic di-

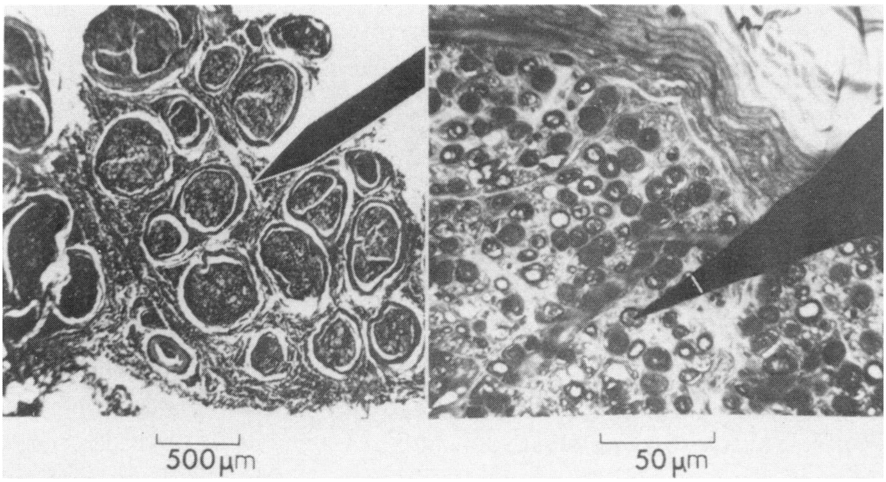

Fig. 2. Microphotographs of tranverse sections of a human median nerve at the wrist level with the silhouette of a microelectrode superimposed. Nerve shrinkage estimated to be about 20%. Note the perineural sheaths surrounding the fascicles and the relatively wide clefts of interstitial tissues (left). Note also the relation between the fascicular diameters and the approximate length of the bare electrode tip (30 m.) as indicated in the high-magnification picture (right). Reproduced by permission from Vallbo, A. B. and Habarth, K. E.: Micro-Electrode Recordings from Human Peripheral Nerves. In: *New Developments in Electromyography and Clinical Neurophysiology.* New York, Karger, 1973, vol. 2, p. 68.

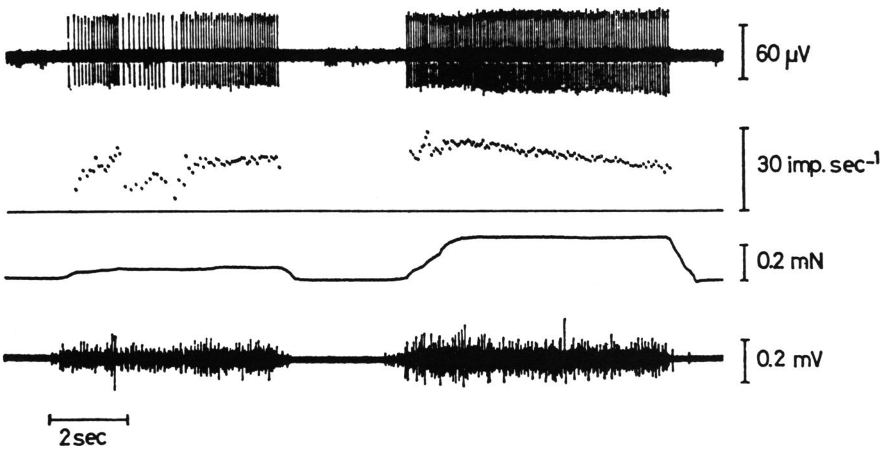

Fig. 3. Afferent unitary discharge associated with two successive voluntary contractions without external shortening of the flexor muscles acting on the index. From above are shown the unitary nerve impulses, the instantaneous impulse frequency, the torque due to the muscle contractions, and the electromyographic activity recorded with surface electrodes over the flexor muscles 10 cm. distally to the medial epicondylus of the humerus. Straight line indicates zero impulse frequency. The torque is given in meters-Newton (mN). Reproduced by permission from Vallbo, A. B. and Habarth, K. E.: Micro-Electrode Recordings from Human Peripheral Nerves. In: *New Developments in Electromyography and Clinical Neurophysiology.* New York, Karger, 1973, vol. 2, p. 78.

mensions into a territory rich in microscopic nerve structures. The procedure is traumatic—even if the patient is unaware of it—and must have profound consequences.

The sensory nerve supply of the skin is derived from many sources and varies from thickly myelinated sensory fibers with large diameters to nonmyelinated sensory and antonomic fibers with extremely small diameters. It must be remembered, moreover, that the myelinated fibers eventually lose their sheaths and terminate in naked axons which end freely or form a variety of end organs, such as Merkel's disks, Golgi's tendon organs, neuromuscular spindles, and lanceolate terminals of hair follicles, and corpuscles of Ruffini, Meissner, Golgi-Manzoni, and Pacini. There naked terminal axons are in close relation either to cells, such as Merkel's cells and epidermal cells—with which they form synapse-like structures—or to collagen fibers. The terminals act as transducers through deformation, giving rise to receptor potentials which eventually reach threshold at the first myelinated portion of the axon. In this way a generator potential is born. Type I and II myelinated fibers (6 to 17μ in diameter) supply the hairs, the glabrous skin, and the Pacinian and paciniform corpuscles. Type III myelinated fibers (1 to 5μ in diameter) supply the hairs and the mechanical and thermal nociceptors.

These elements of various provenance intertwine in the skin to form an extensive, but not fused, network. The various sensory end organs, in particular the hairs with their lanceolate terminals, derive their nerve supply from many different axons. In the external ear, one root axon may supply as many as 80 individual hairs. The receptive fields, therefore, are extensive and overlap. Excitation by an external force large enough to be in close approximation to any or all neighboring terminal nerve fibers will send showers of discharges to the integrative centers of the spinal cord through a number of open pathways.

Since the acupuncture needle is a body with a large volume, its mere presence in this network will exert an excitatory force. If perchance such a needle is twirled, first in one and then in the opposite direction, it produces not only excitation by pressure and distortion but also excitation by injury, since the tip of the needle then moves in an arc or circle and tears the delicate nerve terminals, depolarizing them either directly or through the release of histamine or similar substances.

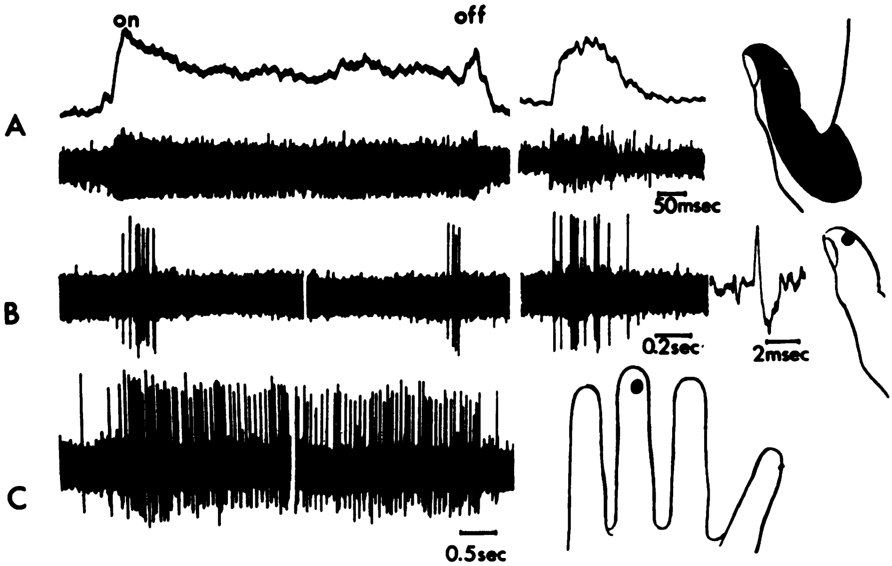

Fig. 4. Comparison between a multiple-unit recording from a glabrous skin fascicle (A) and recordings from rapidly adapting (B) and slowly adapting units (C) sampled in such a fascicle. Reproduced by permission from Vallbo, A. B. and Habarth, K. E.: Micro-Electrode Recordings from Human Peripheral Nerves. In: *New Developments in Electromyography and Clinical Neurophysiology*. New York, Karger, 1973, vol. 2, p. 71.

In order to register discharges from the receptive fields, the neurophysiologic technique formerly employed required dissection of cutaneous nerves and recording from single axons. Since 1968 new ways of studying afferent impulses have become established, microelectrodes being employed to impale the median or other nerves (Figure 2). With such a procedure it is possible to study discharges that originate in contracting muscle (Figure 3), glabrous skin (Figure 4), hairy skin, and C fibers. In addition, it is possible to record directly from the skin (Figure 5) by means of a microelectrode pressed into it; from the hair follicle by means of a semimicroelectrode inserted into the follicle (Figure 6), the hair being subsequently pulled; from muscle by means of a coaxial electrode (Figure 7); and from the subcutis, also by a coaxial electrode (Figure 8).

Common to all these procedures is the experience that the electrode must be moved and that the discharges appear after an interval of from three to five minutes. One might speculate that injury is indeed the sine qua non for the appearance of generator potentials and conducted

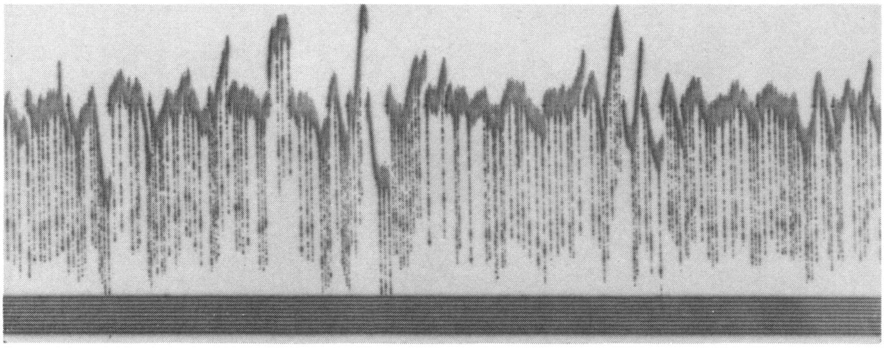

Fig. 5. Recording from skin with microelectrode. Reproduced by permission from Fleck, H. and Spring, M.: The acupuncture point. *New York J. Med. 74*:1061, 1974.

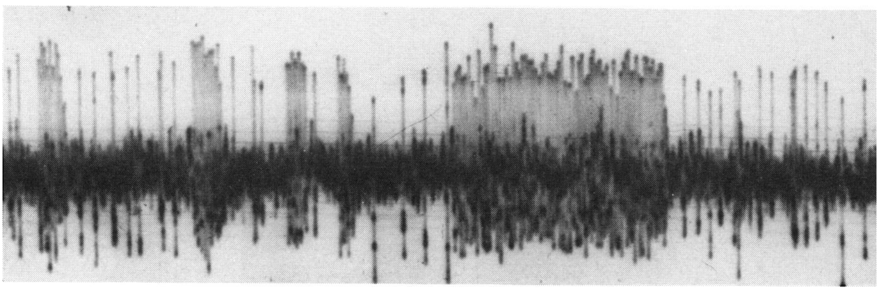

Fig. 6. Recording from a hair follicle. Reproduced by permission from Fleck, H. and Spring, M.: The acupuncture point. *New York J. Med. 74*:1061, 1974.

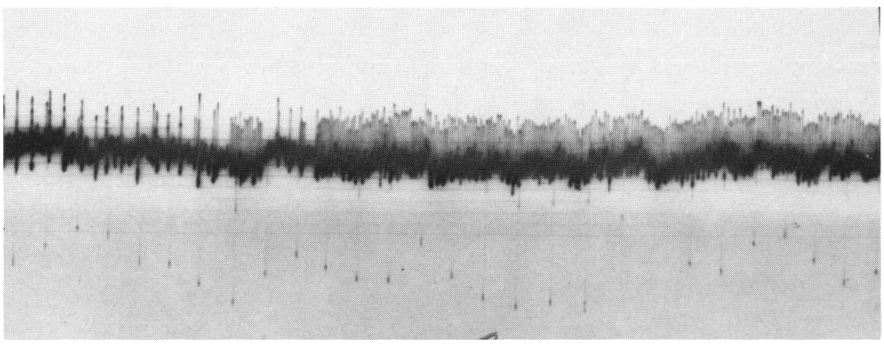

Fig. 7. Recording from muscle with coaxial electrode. Reproduced by permission from Fleck, H. and Spring, M.: The acupuncture point. *New York J. Med. 74*:1061, 1974.

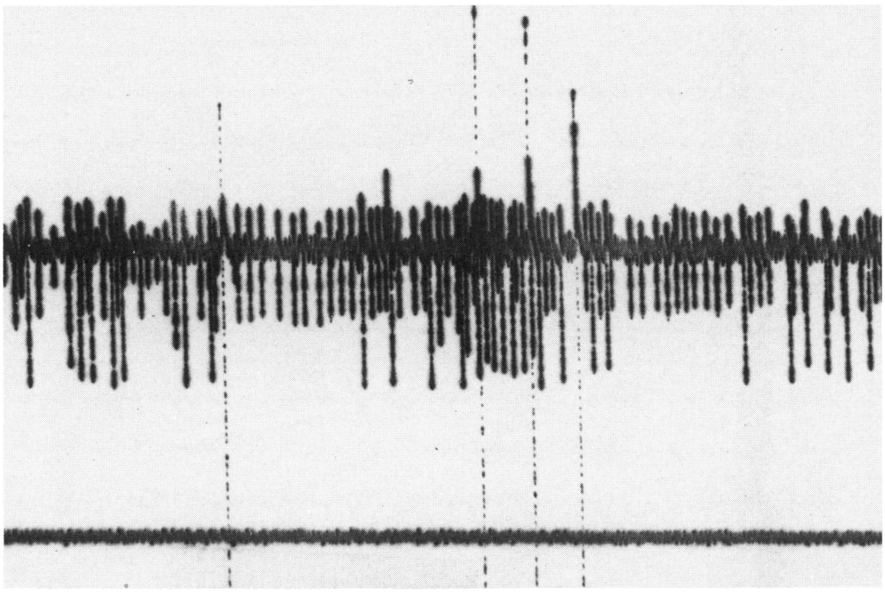

Fig. 8. Recording from the subcutis with coaxial electrode. Reproduced by permission from Fleck, H. and Spring, M.: The acupuncture point. *New York J. Med. 74*:1061, 1974.

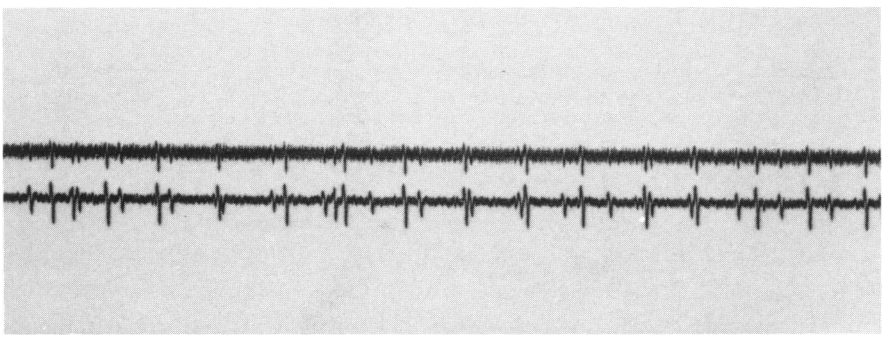

Fig. 9. Recording from a median nerve with microelectrode (upper trace). Recording from acupuncture point "lung 10," with coaxial electrode (lower trace). Note the one-to-one relation of recorded discharges.

trains of action potentials. The discharges are sustained; there is neither adaptation nor fatigue.

To confirm that the evoked discharges, in this case from acupuncture point "lung 10" in the abductor pollicis brevis, i.e., from this muscle, are sensory, the median nerve above the wrist was impaled with a free-standing tungsten microelectrode and the muscle was ex-

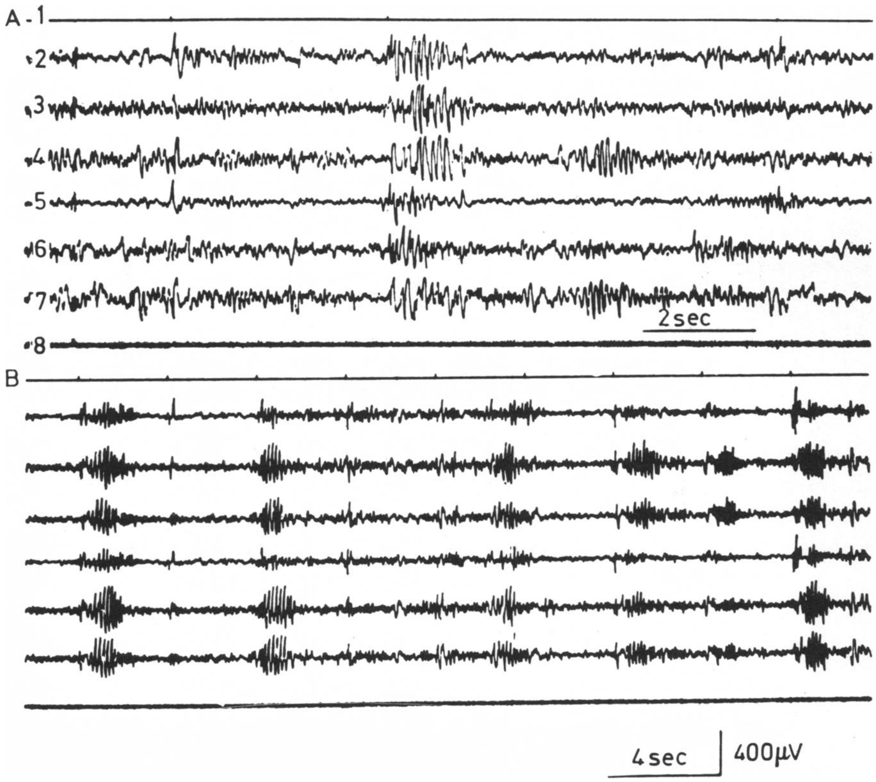

Fig. 10. Synchronization of electroencephalogram through low-frequency stimulation. Reproduced by permission from Pompeiano, O.: *Handbook of Sensory Physiology*. New York, Springer, 1973, chap. 12, p. 397.

plored with a one-inch coaxial electrode. After some probing of the muscle and an interval of several minutes, a compound discharge was recorded with the coaxial electrode (Figure 9, upper trace), and the same discharge in the median nerve (Figure 9, lower trace). The discharges have amplitudes of about 50μ v. The speed of the paper was 20 cm. per second, the discharge frequency between 15 and 20 per second.

Discharges of this kind are usually and wrongly labeled bizarre and more often than not are thought to originate at the end-plate region as miniature end-plate potentials. They can be found at the acupuncture point if one has the patience to explore and wait. They can be found in normal individuals, but are recovered in great profusion in the initial stages of neuropathy because the nerve fiber has been made unstable by disease and therefore is unusually excitable.

Some of these discharges attain a frequency of about 800 to 1,000 per second; this is compatible with the performance capabilities of Type I and II myelinated sensory fibers. This is in sharp contrast to motor fibers, in which the repetition rate rarely exceeds 100 per second and the absolute and relative refractory periods prevent an increase in frequency.

Sensory fibers may have extremely short refractory states. Their membrane potentials oscillate rapidly near threshold value and discharges may persist after the stimulus has ceased. This property of sensory fibers may account for the prolonged effects of stimulation by acupuncture, as does the fact that traumatized nerve fibers discharge for a long time after trauma.

I believe it now has been established satisfactorily that acupuncture needles can provoke high frequency discharges which last for a long time without decrease, adaptation, or fatigue, and that such discharges in all probability involve all types of sensory fibers: I to IV, myelinated to nonmyelinated.

Melzack and Wall's 1965 pain-suppression hypothesis, as modified by Wall in 1973, implicates the small cells in lamina five of the substantia gelatinosa as being receptive to stimuli from skin and small myelinated and nonmyelinated fibers, and as responding with intense discharge to noxious forces and with lesser frequencies to blunt mechanical stimuli. The cells of lamina five have complex receptive fields which respond to large-fiber input with inhibition and to small-fiber input with facilitation.

It may well be that stimulation by acupuncture involves preferential excitation of large-diameter fibers and that this blocks the noxious effect of input from small fibers and nonmyelinated fibers. This may be particularly true with the nondestructive use of the electrical stimulus which would excite the low-threshold, fast conducting fibers of Type I and II before the Type III and IV fibers.

In the gate-control hypothesis it is postulated that much of the incoming information from the periphery is filtered through a set of intermediate cells which, under given conditions, modify further transmission to higher centers. Some of the information from the periphery undoubtedly is conveyed directly to these centers for integration and interpretation, bypassing the intermediate cells.

The influence of low-frequency stimulation of low-threshold cut-

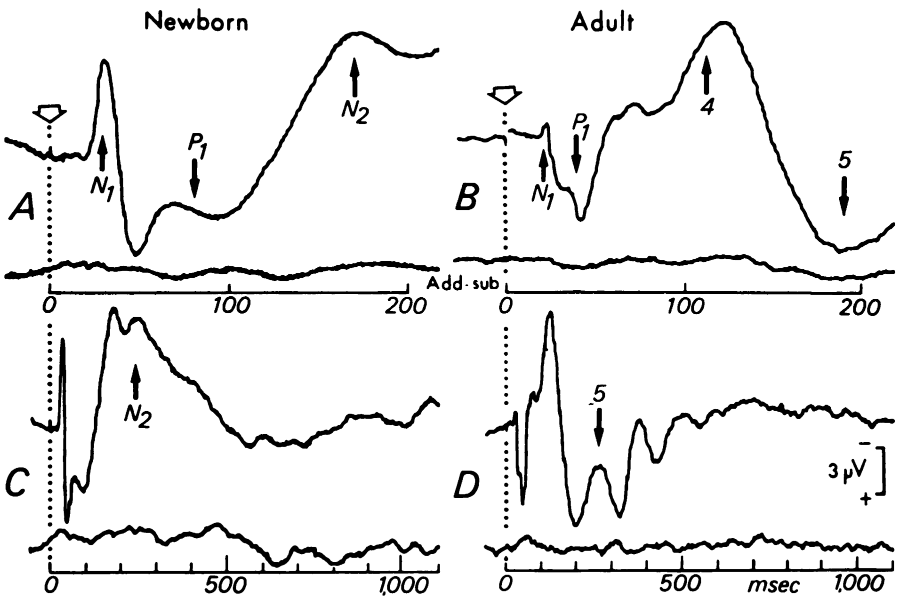

Fig. 11. Average cerebral potentials evoked by a finger stimulus (white arrow) in a normal full-term newborn in REM sleep (A, C) and in a normal adult man (B, D). The nomenclature of response components is indicated. The same data recorded on an FM magnetic recorder have been averaged at two different computer sweep speeds. An add-sub. control of the same data is included for each trace. Reproduced by permission from Desmedt, J. E., Noel, P., Debecker, J., and Nameche, J.: Maturation of Afferent Conduction Velocity as Studied by Sensory Nerve Potentials and by Cerebral Evoked Potentials. In: *New Developments in Electromyography.* New York, Karger, 1973, vol. 2, p. 57.

aneous nerves can be observed in the electroencephalogram (EEG) of the cat as synchronization in all channels, provided the background activity is low (Figure 10). The cat tends to fall asleep. With higher intensities of stimulation, synchronization and sleep give way to desynchronization and arousal. In 1960 Oswald produced sleep in normal humans by intense stimulation of exteroceptors, in spite of the unpleasant quality of the stimulus.

Stimulation of Type I afferent fibers at any frequency does not affect the EEG. Stimulation of Type II fibers at low frequencies causes synchronization. Stimulation of Type II and III fibers at high rates causes arousal. Type II afferent fibers originate in hair and serve as pressure and touch receptors. Type III fibers transmit sensations of temperature and pain, as do Type IV fibers—the C fibers.

Evoked potentials can be recorded by surface or steel needle electrodes placed on the scalp opposite the site where peripheral nerves are stimulated either directly by penetrating electrodes near the nerve or by surface electrodes placed on an appropriate digit (Figure 11). The recording requires sophisticated computers or averaging equipment to determine the evoked potentials and to read out latency as well as parameters.

With all this material on hand, several pertinent questions can be asked:

1) Can pain evoked by a painful electrical stimulus be suppressed by the stimulation of acupuncture?

2) Can pain produced by chemical means be suppressed by acupuncture?

3) Is the choice of the acupuncture point the determinant of the effect or can such an effect be produced anywhere in the territory of a nerve in which pain originates?

4) Since synchronization can be obtained in the cat, can it be produced in man?

5) If this should be possible, can it be suppressed by acupuncture?

6) Can stimulation of the ear induce or suppress synchronization?

7) Can evoked potentials be suppressed by acupuncture?

These are but some of the questions; innumerable projects can be undertaken to elucidate the mechanisms of acupuncture. One thing is certain: we cannot persist in repeating the experience of past generations, which, so far as man is concerned, depended exclusively on the testimony of the individual.

If we really want acupuncture to gain a rightful place in the house of medicine, we must apply the techniques of the present part of the 20th century in order to answer the many questions.

GENERAL REFERENCES

Midana, A.: The skin as a sense organ. *Minerva Med. 52*:2083, 1961.

Hensel, H. and Bowman, K. K. A.: Afferente Impulse in Menschlichen Hautnerven. *Naturwissenschaften 46*:634, 1959.

Vallbro, A. B. and Habarth, K. E.: Micro-Electrode Recordings from Human Peripheral Nerves. In: *New Developments in Electromyography and Clinical Neurophysiology*. New York, Karger, 1973, vol. 2, p. 67.

Pompeiano, O.: *Handbook of Sensory Physiology*. New York, Springer, 1973, vol. 2, p. 397.

Fleck, H.: High frequency discharges in human muscle. *Ann. Phys. Med. 7*:144, 1963.

Fleck, H. and Spring, M.: The acupuncture point. *New York J. Med. 74*:1060, 1974.

Melzack, R. and Wall, P. D.: Pain medianism: A new theory. *Science 150*:971-79, 1965.

Oswald, F.: Falling asleep open-eyed during intense, rhythmic stimulation. *Brit. Med. J. 1*:1450-55, 1960.