Specimen A 0.4000g gave 0.0471g $BaSO_4$ = 7.5 per cent. methionine
Specimen B 0.4018g gave 0.0573g $BaSO_4$ = 9.2 per cent. methionine
Specimen C 0.4000g gave 0.0179g $BaSO_4$ = 2.7 per cent. methionine

These three specimens were further examined as to their effect on the growth of a strain of diphtheria bacillus which requires methionine for optimal development. A control solution,[1] containing all the ingredients for growth except methionine, was prepared and additions to equal amounts were made as indicated in the table. The solutions were made up to a volume of 10 cc, adjusted to pH 7.6, and sterilized. Total nitrogens, taken as a comparative measure of the amount of growth, were made on the centrifuged and washed diphtheria bacilli growing at 35° in 60 hours on these media. The results are shown in the last column of Table I.

TABLE I

	Media			Mg N in bacterial growth
1	Control + l-leucine	A	10 mg	0.83
2	" + "	B	10 mg	1.44
3	" + "	C	10 mg	0.48
4	" + dl "	(synthetic)	10 mg	0.30
5	" + dl methionine		1.0 mg	1.80
6	"			0.35

It is therefore evident that methionine in considerable amounts may be present in commercial leucine preparations and that failure to recognize this fact may lead to complications where such material is used in biological experiment.

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SPECIAL ARTICLES

ELECTRICAL POTENTIALS FROM THE INTACT HUMAN BRAIN[1]

DR. HANS BERGER, of Jena, has published a series of papers in which he reports that changes in electrical potential which are correlated with human brain activity may be magnified and recorded by the use of a suitable vacuum-tube amplifying system and an oscillograph.[2] These potential changes are obtained from needle or surface electrodes placed on different points of the head. His most typical electrode arrangement is one in which needle electrodes are inserted through the skin to the periosteum, one in the back of the head to the right of the median plane and the other high on the forehead to the left of the median plane. He reports, however, that electrodes placed on the surface of the skin give results comparable to those secured by the use of needle electrodes. He holds that the records secured by the use of this general technique show, among other phenomena, two characteristic forms of rhythmic electrical oscillations. The waves of greatest magnitude he calls alpha waves. Smaller oscillations which are sometimes observed alone and sometimes as superimposed upon the alpha waves he calls beta waves. The alpha waves occur with varying frequency in normal adults, but about 10 cycles per second may be taken as a typical value. These waves may show a potential of as much as 100 to 200 microvolts when needle electrodes are used. The beta waves have a frequency of about 25 cycles per second and have a magnitude much less than that of typical alpha waves.

Berger has carried out control experiments intended to demonstrate that the electrical phenomena which he is studying are functions of brain activity and not of some other organic process. Simultaneous electroencephalograms (as he calls the records of the electrical phenomena which he considers to be correlated with brain activity) and electrocardiograms have been taken. These records demonstrate the fact that there is no direct relationship between the so-called brain waves and the pulse. Moreover, even a momentary arrest of both breathing and heart beat had no marked effect on the brain potentials. In the course of human brain surgery it has been possible for him to place electrodes directly on the brain through trephine openings. The records so taken are similar to those secured by the use of the surface electrodes. Prawdicz Neminski[3] has secured similar action potentials from electrodes on the brain of dogs, that is, waves of large magnitude at a frequency of 10 to 15 per second and smaller waves 20 to 32 per second. Adrian and Mathews[4] have recently observed similar phenomena originating in the cortex of the rabbit.

Dr. Berger has shown in these experiments that the alpha waves diminish in magnitude under certain types of anesthesia, during an epileptic seizure and, it may seem at first sight paradoxically, when the

[1] The control solution is fully described in an article now in press (*Jour. Bact.*).

[1] This research has been made possible by a grant from the Rockefeller Foundation.

[2] H. Berger, *Arch. f. Psychiat.*, 87: 527, 1929; 94: 16, 1931; 97: 6, 1932; 98: 231, 1933; 99: 555, 1933; 100: 301, 1933.

[3] P. Neminski, *Pflüg. Arch. f. d. ges. Physiol.*, 209: 362, 1925.

[4] E. D. Adrian and B. H. C. Mathews, *Jour. Physiol.*, 81: 440, 1934.

subject is given sensory stimulation or does a "mental" problem. The waves indeed appear at a maximum amplitude when the subject is relaxed. He has studied a variety of pathological cases and finds that marked changes in alpha waves are characteristic of certain abnormal brain conditions. The beta waves, however, seem, according to the report of this investigator, to remain very constant in most conditions of the organism. Dr. Berger presents an elaborate and interesting psychological discussion, couched largely in terms of an inhibition theory of attention, as an explanation for the results which he has secured. Adrian and Mathews, from their work on animals, are of the opinion that the low frequency waves are due to the summation of many smaller higher frequency potentials.

A brief statement of the technique and results of our present investigation, which has in some respects confirmed and amplified Berger's results, is given in the following paragraphs.

In most of our experiments electrodes made of silver disks 1 to 2 c in diameter, covered with flannel soaked in salt solution, are used. These electrodes are placed on the skin surface and usually at opposite poles of the head. For example, one may be placed high on the forehead and the other at the back of the head just above the inion. The electrical potentials appearing at these electrodes, when fed into a suitable amplifier-oscillograph system, confirm Berger's general observations. Notably our records show large rhythmic oscillations (alpha waves) which vary in magnitude from about 20 to 80 microvolts and in frequency from about 8 to 12 cycles per second in a normal adult during a favorable condition of relaxation and quiet. In one experiment simultaneous records were taken from a pair of needle electrodes inserted through the skin to the periosteum and from a pair of surface electrodes on the skin directly above. Using a pair of matched non-interfering amplifiers and oscillographs the two records were practically identical in form, although the potentials picked up by the needle electrodes were slightly greater.

Smaller oscillations (beta waves) are also observed at magnitudes of about 15 to 30 microvolts and with frequencies varying from 25 to 50 cycles per second. These small oscillations are quite variable in frequency and different in form from the larger alpha waves.

In addition to these potentials, which appear to be present across almost any part of the head during a quiet, relaxed state, what seems to be a different type of potential has been recorded when the subject is presented with a sensory stimulation such as a light or sound. In several instances electrodes seem to have been so placed on the head that following a given stimulation a complex series of waves appear which may possibly be thought of as the positive excitatory effect of the stimulus. Further experimentation may make it possible to identify these as excitation waves, since they resemble somewhat the action potentials taken from visual centers of animal brains following photic stimulation.

In addition to the potentials which have just been described, incidental potential shifts such as those caused by movement of the skin beneath the electrodes and short "spiked" waves of muscular action currents (about 10 σ duration) are at times recorded in the course of our experiments. These secondary phenomena are most noticeable when the subject is in a state of heightened muscular tonus or restlessness. These phenomena seem not to be present in a completely relaxed and cooperative subject who is comfortably placed in a quiet, dark room. It seems, however, that the skin and muscle potentials may be readily distinguished by their form and frequency from those potential changes which, according to Berger's theory, are to be considered as of brain origin. Similar potential changes observed by several investigators in carefully controlled experiments on animals suggest that these changes are of cortical origin.

Separate rooms for the subject and the apparatus, both well shielded against electrical disturbances, have been used in our experiments.

Fig. 1 illustrates the type of record which we have obtained from a relaxed and cooperative subject.

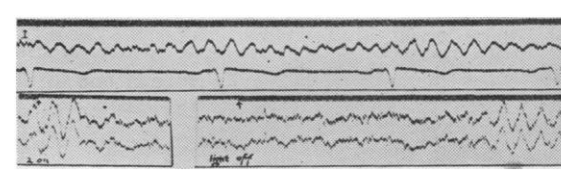

FIG. 1

The first record of Fig. 1 shows the alpha waves in the upper line and in the second line a record taken, as a control, simultaneously from electrodes placed across the left leg above the knee. A record of the pulse only is obtained in this latter curve and no relation is seen between the pulse and the simultaneously recorded alpha and beta waves.

"Spontaneous" fluctuations in magnitude of the alpha oscillations are present in all our records. When the subject is undisturbed by extraneous stimulation these fluctuations appear quite regularly at 1 to 2 second intervals. This rhythm may be seen in the sample record No. 1. We have been unable to correlate these fluctuations with any other organic rhythm. They are the type of modulations that would be produced by the interference of different component frequencies, the total effect of which we obtain

in our records. This provides indirect evidence in support of the hypothesis of Adrian and Mathews, namely, that the large oscillations are the end result of potentials built up by several smaller oscillations at different frequencies.

The second record shows two recordings of the effect of light stimulation on the large alpha waves. The two records are taken across different parts of the head. It will be noted that these waves are markedly reduced by the light stimulation after a latency of 0.4 seconds. (The time line at the top of the record indicates 1/50 second intervals. The signal indicating the period of stimulation is marked by an upward deflection of the time line). When the light stimulus is turned off, the alpha waves return to normal after a short period. The duration of this after-effect of light stimulation seems to vary with characteristics of the stimulus, such as duration. It may most tentatively be suggested that this latency in the return to normal of the alpha waves is possibly associated with the phenomenon of the visual after-image.

As noted above, it is suggested by Berger that the alpha waves may indicate a fundamental characteristic of brain activity. In our experiments on normal individuals the frequency varies little from day to day when experimental conditions are maintained constant. Characteristic frequency of different normal individuals has varied from about 8 to 12 cycles per second. In 6 individuals from whom repeated records were secured on different days, up to five repetitions, variation of not more than one cycle per second was shown in the same individual on successive measurements. In one or two pathological cases which we have studied a frequency of alpha waves as low as 2 or 3 per second has been observed. We have also demonstrated that in certain normal individuals when the electrodes are placed so as to include part of the right side of the head between one pair and part of the left side of the head between the other pair the same frequency is observed in both records and under these conditions the waves are typically in phase. Other records indicate that some normal individuals, and especially certain pathological cases, show different frequencies or a lack of synchronism between the functioning of one side of the brain and that of the other. For example, in the case of a young girl who suffers from a convulsive disorder and is quite ambidextrous, the alpha-wave frequency was observed on repeated tests to be about 10 per second across the left side of the head and but 6 to 8 cycles across the right side of the head. These records were taken simultaneously by the use of two well-matched, non-interfering amplifier-oscillograph systems.

In conclusion, we may say it has been possible for us to confirm many of Berger's observational findings. With the improvement of recording techniques and with an increased understanding of the functional relationship between the results secured and other processes of the living organism, it may well be that electroencephalograms of the sort described in this note may prove significant in psychology and clinical neurology. It is even possible that this technique may provide information in regard to brain action which will be comparable in significance to the information in regard to heart function which is provided by the electrocardiograph. Further experimental studies of the phenomena described here are in progress.

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THE LONG WAVE-LENGTH LIMIT OF PHOTOLETHAL ACTION IN THE ULTRA-VIOLET

SINCE the earliest observations on the lethal action of sunlight by Downes and Blunt in 1877,[1] the determination of the long wave-length limit of lethal action of light upon cells has been a subject of recurrent interest, as various investigators, failing to use a quantitative technique, claimed different limits. In 1924 Coblentz and Fulton,[2] measuring the incident intensities at different wave-lengths, showed that much less energy is necessary to kill *Bacillus coli communis* at wave-lengths shorter than 3,050A than at longer wave-lengths, although lethal action extended as far as 3,660A when the dosage was exceedingly large. Few studies on the wave-length limit of lethal action have been made upon protozoan cells. Swann and del Rosario[3] report that the wave-length 3,132A is only 1 to 4 per cent. as destructive to Euglena as is the wave-length 2,536A. On the other hand, Weinstein[4] reports that *Paramecium multimicronucleata* is killed about one ninth as readily at 3,130 as at 2,654A and about one half as readily as at 3,025A comparing the lethal action on the basis of the energy incident upon the exposure cell. As this appeared to be an unusually destructive effect for the wave-length 3,130A, it was decided to investigate its effects upon this species of Paramecium as well as upon several other protozoans.

The protozoans were obtained in sufficient numbers by inoculating individuals from a local pond into 0.1

[1] Downes and Blunt, *Proc. Roy. Soc.*, 26: 488, 1877.
[2] Coblentz and Fulton, *Sci. Papers U. S. Bur. Standards*, 19: 641, 1924.
[3] Swann and del Rosario, *Jour. Franklin Inst.*, 213: 549, 1932.
[4] Weinstein, *Jour. Op. Soc. Am.*, 20: 433, 1930.