THE RELATIONSHIP OF ELECTROENCEPHALOGRAPHY TO PSYCHIATRY.*

By DENIS HILL, M.B., M.R.C.P., D.P.M.,
Sutton Emergency Hospital, Surrey.

INTRODUCTION.

THE technique of electroencephalography has become to neurophysiology what the microscope is to histology. It is probable that by this technique neurophysiologists will achieve a comprehensive knowledge of the functional organization of the brain. While the EEG has been used most successfully for this type of research, it has also been applied with no less enthusiasm to clinical problems of neurology and psychiatry. In certain cerebral disorders, for example epilepsy, where knowledge had already made considerable advance, the EEG technique was immediately found to have application. But in what may be called " the problems of function " provided by the main psychiatric reactions of schizophrenia and manic-depression, and in relation to individual differences of temperament, intelligence and personality, in all these the EEG has so far proved of little value.

Hans Berger, himself a psychiatrist, developed theories about cerebral function based on the belief that the rhythms which he recorded from widely separated electrodes were an expression of the total function of the brain. Evidence that this global EEG is made up of numerous discrete rhythms arising from different cortical areas is provided by the finding that certain areas show rhythms peculiar to themselves—the alpha rhythm in relation to the visual association areas and the beta rhythm to the precentral areas being the best known examples.

Although many have recognized that the global EEG is a heterogeneous mixture of rhythms, yet the outstanding character of the alpha rhythm, which in many records seems to the unaided eye to be the only rhythm, has drawn attention to itself to the exclusion of other features. The alpha rhythm has therefore been subjected to careful and repeated scrutiny, and in fact has been regarded as if it alone constituted the total phenomenon to be observed.

It is my task to-day to review the position of electroencephalography and, while emphasizing the limitations for psychiatric research which are apparent in the technique, to point perhaps to one enormously important function which the method may aspire to fill. In the backrooms of psychiatry, neuropathologists, biochemists, endocrinologists and psychologists have long been busy forging chains of data, which, while they may have a tenuous relation to one another, rarely bear any obvious relation to the observed facts of behaviour, and even less to the subjective experiences of thought and feeling. In this respect the EEG certainly does not claim anything, yet it seems probable that the technique will form a bridge on which the several sciences can meet.

The record of electrical changes which is obtained from the brain is composed of a large number of rhythms, with frequencies varying from ½ to at least 30 waves per second. Some of these are discrete rhythms which stand out clearly for the eye to see and can be counted with no great difficulty. Others are not visible as separate rhythms, and their presence can only be judged by the manner in which they alter the shape of the visible waves. In addition, harmonics—the multiples of lower frequencies—occur in the EEG. Thus a fundamental rhythm of 2 waves per sec. may have its character altered by its harmonics, at 4, 6, 8, 10, etc., waves per second. These are some of the difficulties which confront the electroencephalographer who is making a naked-eye investigation of an EEG, and it illustrates a

* A paper read at the Quarterly Meeting of the Royal Medico-Psychological Association in London on February 7, 1945.

fact which is becoming increasingly apparent—that the more we know about the EEG the more difficult the phenomena are to interpret by the naked eye. It is to be recalled that among those who first recorded the EEG, surprise was felt that so complex an organ as the brain should produce so simple and apparently unchangeable an expression of its vital activity. No doubt, out of the present confusion of isolated facts and observations, laws will emerge ultimately, relating the mathematical data to the physiological functions.

Visual interpretation of the record has proved inadequate, and it is only when large, well-defined rhythms, or rhythms of peculiar character, stand out from the background, that they can be identified.

The significance which should be attached to these rhythms with their varying incidence cannot always be judged from observing the record alone. The completed data for such interpretation includes a knowledge of the physio-chemical environment of the brain. The distribution of energy at different frequencies, both in the normal and abnormal brain, is only constant while the chemical environment is constant. Attention to visual stimuli or the utilization of visual imagery for thinking brings about changed conditions, with rearrangement of energy in the cortical rhythms. Age, the psychological state of the individual and the concentrations in the cerebral blood of O_2 and sugar, the acid-base situation and the metabolic rate are among the determinants of the EEG picture. This field is still growing larger and only a beginning has been made in its exploration, though the results are not difficult to obtain and have wide application.

Constitution.

When we consider the relationships which the EEG characters have to the more complex phenomena of human behaviour and personality types, the findings have been discouraging. Superficially, some relationship might have been expected. The EEG records the developing patterns of cerebral activity from birth to adult life, and when a cerebral injury is suffered, the EEG provides the most sensitive indicator known of the process of repair and recovery. Indeed the EEG has been called the " ever-moving shadow " of the brain's activity. Some variation with the basic qualities of constitution, such as physique, intelligence and temperament, would not have been unusual. In the case of temperament, the introversion-extraversion scale which is known to have physical correlates again shows little relation with the EEG type. For extraverts a large amplitude alpha rhythm was claimed (Gottlober, 1938), and in a nearly related investigation the same was claimed for the cycloid personality, whereas the schizoid had a poor alpha rhythm (Lemere, 1936). But as Walter has recently pointed out (1944), this would suggest that extraverts use very little visual activity for their thinking, while introverts are largely dependent upon it. In these investigations, as in others related to schizophrenia, insufficient significance appears to have been attached to the state of tension or relaxation of the subject. It may be that the introvert shows little alpha rhythm because he responds to the novel situation of the test by an increased alertness, possibly coloured by anxiety, while the extravert is much less disturbed by the same situation. It seems unlikely at the present time that the main characters of two such complex series of phenomena—the one at the level of human behaviour and the other at an electrical level, should show such a simple relationship. At the physiological level, however, positive results are to be found. Golla, Hutton and Walter (1943) have shown a relationship between the type of alpha rhythm and the type of habitual imagery used in solving problems. Those dependent for their thinking on intense visual imagery tend to have least alpha rhythm, while those unaccustomed to visual imagery have a persistent alpha rhythm.

The last component of constitution with which I shall deal is heredity. The EEGs of identical twins have identical characters, whether they be normal or abnormal. The Harvard studies recorded the presence of EEG abnormality in 60 per cent. of the total relatives in a group of epileptics, and in one or other parent in 95 per cent. of epileptic children. On the basis of these investigations, it was suggested that the main characters of the cerebral rhythms were determined by genetic factors, and that epileptics were predisposed to fits by reason of a hereditary cerebral dysrhythmia. Various attempts to particularize the genetic influence have been made, the Harvard studies suggesting that it is a single dominant gene.

Further research will, however, be required before this matter can be settled. But the conception has been extended further. In view of the high incidence of abnormal EEGs among psychiatric material generally, Williams (1941) has stated that its possession predisposes the individual not only to epilepsy, but also to psychosis, neurosis and psychopathy. We are faced, however, with the fact that this " non-specific EEG abnormality," which comprises by far the largest group among psychiatric cases, is not a homogeneous abnormality. As I have already indicated, its heterogeneity cannot be identified by the naked eye. The surprising results which occur when one deals with the " non-specifically abnormal EEG " as if it were a single entity is illustrated by some recent work relating to the prognosis of war neuroses (Heppenstall, Hill and Slater). The presence of an abnormal EEG in 300 soldiers passing through a neurosis rehabilitation centre bore no relation to whether they were subsequently invalided, subsequently only able to do light duties, or continued in their units free from symptoms. Yet when a single abnormal component was considered—abnormally fast rhythms—it proved of bad prognostic omen.

In considering the influence of genetic factors, yet a further difficulty confronts us. It is well known that the cortical rhythms change throughout the period of physical growth of the brain. The process may not be complete until the last association tracts are myelinated, for it is certainly not always so at puberty. The delta rhythm which appears dominant at birth gives way to the dominance of faster rhythms, and the general trend is for more energy to appear in faster rhythms until the adult type alpha rhythm is dominant. In the " normal " individual at 18 the slower rhythms have disappeared to naked-eye examination. While this account is certainly an over simplification, there is evidence pointing to a maturation process in the brain, of which the stability of the EEG characters is one of the outward and visible signs. Evidence for this was found by Walter and Dovey, who demonstrated that in epilepsy there is a decline in the percentage of abnormal records with age. Similar findings for the incidence of abnormal EEGs considering the age at which a head injury is suffered have also been demonstrated (Heppenstall and Hill). Again, voluntary hyperventilation, which will produce delta rhythm in 40 per cent. of normal children aged 14–17, only does so in 30 per cent. of adult controls under the age of 50, and in our experience is extremely rare over 50. There is then a process which can be called " maturation," and this makes the problem of investigating the influence of genetic factors even more difficult. Where a gene exerts its influence at a single time and its effects are present thereafter, as for example in the case of the gene determining the blood group, it can be recognized readily. But when its influence is potential, or when its action is spread out over a period of many years, influencing the normal developmental process—as indeed, according to J. S. Huxley, many genes do—then its presence can only be recognized if the developmental process is fully understood. Since from EEG data there are at present no sure landmarks in the brain's maturation process, the whole problem will not, I think, be elucidated yet. While discussing this matter, reference may be made to the EEG abnormality in psychopathic personalities of the aggressive type. In a high percentage of EEGs in patients of this class an abnormal amount of energy is seen in the theta band—usually at 4–6c/sec. in the parietal and temporal areas on both hemispheres. By automatic frequency analysis Walter has recently found theta rhythm to be a normal characteristic of the parieto-temporal areas, although in the normal EEG the rhythm is of such low voltage that it is barely apparent to visual observation. With the exception of the clinically severer cases in which a temporal slow focus is seen, the EEGs in the psychopaths would pass for normal in children of 12–15. Yet it is interesting that theta rhythm, the abnormality in the adult psychopath, is also found *in excess* in the behaviour problem child of the same type. A cortical immaturity has been postulated in these cases—a failure to reach the adult types of rhythm—but we are no nearer to knowing whether this is the result of a genetic factor whose action is spread out over a considerable period of time, or due to one of a great number of other possible acquired factors. The relationship which these cases bear to epilepsy gives slight support perhaps to the genetic theory.

The question of genetic determination is, of course, directly associated with the problems of maturation, to which I have referred. Maturation may be related not only to the dominance of any one frequency in any one area for a given age,

but also to the dominance of one hemisphere over the other. Mrs. Gibb has recently made a very careful study of the characters of the alpha foci. She finds that the focus on the left side shifts more frequently than that on the right and is more responsive to arousal stimuli. The greater stability of frequency, the greater amplitude and the relative inactivity of the alpha focus on the right side indicates, as Mrs. Gibb points out, that this focus is less susceptible to the influence of external stimuli than that in the dominant hemisphere. In the severest forms of aggressive psychopathy asymmetry of rhythm is frequently present, and the temporal lobe theta rhythm focus is most commonly found on the right side. The presence of asymmetry of pyramidal function and the association of lesions of the right hemisphere with mental symptoms was recently reviewed by Fleischhacker. The observation was first made by Hughlings Jackson, who called the left hemisphere the more objective and voluntary, and the right the more automatic, but what connection the EEG data have with cerebral dominance is not at present clear.

To the electroencephalographer the realization soon comes that his findings can only be interpreted clinically if the history is known. A local focus of abnormality may itself strongly suggest an acquired cerebral lesion, even though the lesion is the result of prolonged functional change in, say, the blood supply. The history of trauma or encephalitis or symptoms suggesting a neoplasm puts the EEG finding into its clinical setting. Although it is true that special wave forms tend to be associated with tumour or atrophy, yet by no wave form alone can a tumour or atrophy be diagnosed. Experience may in time correct this, but since, even with an abnormal focus present in an EEG, the problem of whether it is of acquired or constitutional origin is still in doubt, how much greater is that doubt where the EEG shows generalized abnormality and no focus can be found. This question, frequently asked, may be incorrect. Possibly we should restrain ourselves to asking whether a focus, if present, is associated with a structural or only a local functional change in the brain. Unfortunately even this cannot always be answered with certainty. But it would be unwise to assume that structural changes, extremely small as Penfield has shown they may be, are always the result of an exogenous factor.

Aetiological Problems.

In certain aetiological problems of the constitutional psychoses electroencephalography has made a contribution. While it is generally conceded that no specific EEG disorder is associated either with the manic depressive or schizophrenic reaction types, the EEG has been profitably applied to the old problem of the relationship of schizophrenia to epilepsy. The Harvard workers found a type of organized theta discharge commonly among schizophrenics. This suggested that similar abnormalities were to be encountered in epilepsy and schizophrenia, indicating a similar disorder of function. Lennox has since stated that this was an erroneous conclusion, and now believes that schizophrenics who demonstrate such EEG abnormalities are atypical and may be called symptomatic schizophrenics, analogous it may be thought to those states commonly encountered in young children with organic brain disease, and not uncommonly in adults with acute G.P.I.

It can be argued that the study of epilepsy by the EEG, as indeed the study of the various clinical pictures seen in neuro-syphilis or encephalitis has already done, has shown us that the main reaction types have a varying aetiology. Symptomatic schizophrenia associated with cerebral dysrhythmia probably bears little relation to the schizophrenic process originally called dementia praecox, nor indeed does symptomatic schizophrenia seen in G.P.I. This will probably find general agreement, yet it was little appreciated by those who hoped to find diagnostic criteria for the major psychoses from a study of the dominant pattern of the cortical rhythms. It would only seem justifiable to relate the characters of the EEG to the physiological substratum of the mind. The same physiological stress—hypoglycaemia for example—will in one produce irritable aggressiveness, in another amorous cheerfulness, and in yet a third anxious silence, yet the qualitative electrical changes *when they occur* may be much the same in all three.

The following cases illustrate the association of cerebral dysrhythmia with first a symptomatic schizophrenic state, secondly a symptomatic depressive state, and thirdly a depressive state of unknown aetiology.

CASE 1.—A young merchant seaman, aged 20, was admitted from a Seamen's Convalescent Home. He was there because he had been anxious and depressed while at sea. After a few days he had developed an attack during breakfast in which he left the room and was found staggering in a corridor. He was put to bed and given chloral and bromide and slept until the afternoon, when he attempted on two occasions to leave his bed. He was then very restless and excited, and was regarded by lay observers as hysterical. Morphine, gr. ¼, and further doses of chloral and bromide failed to control his behaviour, but two hours after an injection of luminal, gr. 3, he became rational for over an hour, only to relapse again and remain " excited " for most of the night. By 8 a.m. the following morning he had fully recovered.

On admission the patient admitted previous attacks over a period of two years. In one hospital chorea had been diagnosed, but the movements which he again showed were not choreiform, but quasi-purposive. They were particularly severe in the left shoulder and arm, and were much worse when attention was drawn to them. He said that associated with his attacks was an abdominal pain and occasionally he would feel giddy, and once had fallen with brief loss of consciousness. He had experienced considerable stress at sea and had lost his brother in the service. He said he longed to avenge the latter's death, and in addition, having no home to go to, felt that he must return to sea, which he dreaded. At first the illness was regarded as of psychogenic determination—a superficial hysterical escape from his anxiety. He was told that he would be recommended for discharge from the service and was put on modified insulin therapy. Thereafter his attacks became more frequent, due, as was subsequently inferred, to the hypoglycaemic trend. These attacks were observed, and further investigation revealed that the acute behaviour disorder was preceded by a change of personality. He was normally cheerful, friendly and sociable, but he became seclusive, irritable and suspicious. After the attack was over he could discuss it freely. He said that sometimes he felt giddy at the start. For a few hours he would observe other patients watching him, would feel they were talking about him and were unfriendly. During this stage he could control his thoughts and behaviour, but later he would hear voices telling him to commit suicide and then he would not have charge of his own thoughts or actions. He would be impelled to walk off and to seek his own destruction. He was seen on two occasions while in hospital making for a railway line, and had to be restrained once and could be persuaded back to his ward on the other occasion. It was difficult to assess accurately the quality of what appeared to be a primary thought disorder, the patient only replying that during the attack his thoughts were not his own and that he was controlled by his single suicidal impulse. He found the hallucination very distressing. In these attacks he was acutely antisocial, seclusive, paranoid, hallucinated and impulsive. The thought disorder bore resemblance to schizophrenic disorder. Consciousness in the two attacks observed remained normal for orientation throughout and there was no subsequent amnesia.

Many characters of these attacks obviously suggested an epileptic aetiology, and this was supported by the EEG, which shows a generalized cerebral dysrhythmia of both fast and slow frequencies. No abnormal physical signs were elicited, but the secondary hair was of female distribution. His physique was predominantly athletic. The modified insulin treatment was stopped and anticonvulsants given, after which no further attacks occurred during six weeks and he was discharged to continue treatment.

CASE 2.—In the second case, that of a woman, aged 36, the history of epilepsy is more definite. From 22 until 27 she had brief " absences," and since then has had, periodically, major convulsions which have been witnessed in various hospitals. About eight years ago, when in Maida Vale Hospital for investigation of these fits, a persistent left parietal focus of abnormal potentials was found by Mr. Grey Walter and subsequently the skull was opened, but no abnormality was found in the cortex. Soon after the beginning of the war her major attacks became more frequent, and at this time she began to suffer from psychomotor automatisms, in some of which she lost consciousness; in others she suffered horrible but indescribable physical sensations, and in these would at times laugh immoderately and behave in a hysterical manner. Since the beginning of the war, when she came under my observation, her major fits, absences and severer attacks of automatism have gradually ceased. Routine EEGs have been taken every few months, though less frequently during the last two years, since her clinical condition has improved. During 1941, when she was having major fits, numerous attacks of *petit mal* were seen in the EEG records, but the resting focus, originally found in the left parietal area, was seen to move from one side to the other and had no constant position. Since 1942 she has been seen at monthly intervals and has had no further major convulsions, but on four occasions in 1943 she suffered from attacks of feeling dazed and unreal and in one of these she fell and hurt herself. The attacks which she suffered towards the end of 1944 had, however, a different quality. These started with a marked feeling of depression and she was observed to be quiet and pale. She would just sit at home and cry, apologizing for her incapacity. After 24 hours a new symptom developed. She now felt strange: " I know myself but in the distance. A queer sensation all over. I was sitting in an armchair, and although I was there I was away from myself. I get a heavy head and my eyes droop. I am frightened of myself. I worry over the least thing."

This feeling of unreality relating to herself lasted 2–3 days, and while it was on she could carry on with her work—a routine factory-belt job—but felt very depressed and cried if spoken to. This attack was of some interest, since we were able to record her EEG during and after it. This indicated that the EEG was changing in character at the time. A fast rhythm on the left

side, which had been present for some months, was still apparent during the attack, but was less evident after it.

This patient has never been considered neurotic. She is of a friendly, sociable disposition, and has a record of persistent employment which does her credit, considering her disability.

CASE 3.—The third case, a man, aged 35, had between the ages of 15 and 20 suffered from attacks of falling with self injury, without loss of consciousness, but with aphasia and inability to move. These attacks recommenced two years ago, at the age of 33, and continued until the onset of his present illness, when they ceased. Between 5–6 a.m. one morning in October, 1943, he woke up to feel he was dying—a strange, indescribable sensation. Within a few hours, attacks of vertigo commenced with a feeling that he was falling to the left, each attack lasting 20–30 minutes, and associated with panting for breath and tachycardia. He improved after a few hours, but every night for two weeks had a mild recurrence. He then became depressed, could not sleep, and was very worried by his attacks. In these he became very cold, then broke into a hot sweat. He said that in the attacks he could see people " but not know them." " I don't feel I belong to this world at all. I have a feeling I am actually dying all the time." The attacks of vertigo ceased when he was given luminal, but the unreality feelings did not, and he now experienced strong obsessional compulsions to kill himself and the constant idea that his wife must die too. A little later he felt that he must kill his children. These ideas had a true obsessional quality and were strongly resisted. This patient's EEGs showed a left temporal focus of low voltage theta rhythm. He has been under out-patient treatment for nine months and has gradually improved. His obsessional ideas come and go, he has had no further attacks of vertigo, but occasionally in the evenings still has attacks of what he calls " unawareness." His depression has steadily left him.

This man has a bad family history. His father was treated at the Maudsley Hospital as an out-patient for an involutional depression. His mother, following a pregnancy, developed a nervous illness lasting some months in which she " believed she could not see properly." This symptom is of interest, since the patient himself had a disorder of reality feeling, and since his younger brother also suffered from it. This brother, now doing well as an officer in the R.A.F., was at the age of 17 a patient in the Maudsley for some months. He had anxiety attacks and obsessional preoccupation with his vision. There was a history of attacks of migraine with a right-sided teichopsia and hemianopia, but superimposed were obvious feelings of unreality about the external world. I am quoting from the notes of Dr. Aubrey Lewis, his doctor at that time. The patient said: " To all appearances I am blind, although I can see. I can hear all noise; I can hear myself talking, but it seems I am sitting here without sight, although I can see you. When I look at you I can see, but there's something not there that ought to be."

The first of these cases indicates, I think, the presence of an undoubted epileptic process. Here the EEG was valuable, but the symptoms could be interpreted clinically as epileptic.

The second case had undoubtedly had epileptic fits, and it would seem reasonable to suppose that her short depressive attack was in some way related to her epilepsy. EEGs taken before, during and after this attack did not show a type of rhythm commonly seen during epileptic fits. These records do, however, indicate a process of change occurring in the brain.

I have quoted the third case at some length, since both clinically and from the EEG the diagnosis of an epileptic disorder is not certain, although from both points of view there are suggestive features. The symptoms in this type of case would seem to be related to the epilepsies, but probably not in the sense that a sensory aura is related to the electrical discharge in the brain which accompanies it. The third case showed resemblances to the second in that the symptoms did not appear to be associated with a definite epileptic discharge in the EEG. The aetiology in these three cases, which in greater or lesser degree is related to epilepsy, is still obscure despite the EEG. They demonstrate the caution necessary when associating cause and effect between dysrhythmia and the symptoms in any given case.

CEREBRAL HOMEOSTATIC MECHANISMS.

Another view of the relationship between electroencephalography and psychiatry is provided by the clinical and EEG changes accompanying alterations in the contents of the cerebral blood.

One of the earliest discoveries in electroencephalography was that respiratory alkalosis tended to produce high voltage delta rhythms in susceptible people. While at first this was thought a characteristic of epilepsy, it is now realized that about 70 per cent. of individuals with abnormal EEGs from any cause will exhibit

the phenomenon. It would seem to be a normal character of early childhood, the brain becoming more stable to alkalosis as age increases. The brain's sensitivity to respiratory alkalosis is markedly increased by a low blood sugar, and is less sensitive as the blood-sugar level is raised. It has thus been demonstrated that the stability of the brain to one chemical stress is varied by the presence or absence of another. The effects of alkalosis can in fact be countered by the maintenance of a high blood sugar.

Does the occurrence of delta rhythm in response to overbreathing have any practical bearing on psychiatric problems? Probably yes. The hyperventilation syndrome occurs in the anxiety attacks of hysterical persons and frequently in cases of effort syndrome (Sargant). Hyperventilation has been found to be a factor causing giddiness and amnesia during high flying (Rushmer and Bond), and has been suggested as a factor in psychopathic crimes of violence (Hill, Sargant and Heppenstall). It has been known for some years that it is possible for normal people to overbreathe themselves into unconsciousness, but more recently the finer grades of impairment of consciousness have been noted during the appearance of delta waves (Davis and Davis; Davis and Wallace), which in susceptible people appear after 30–60 seconds' deep breathing. This is thought to be due to vasospasm consequent upon CO_2 lack. The delta rhythm first appears in the frontal areas and gradually involves the whole brain, so that finally the rhythm can be obtained from any area. The rhythm is usually of high voltage, and at this stage cannot be distinguished from the discharges seen in physiological and pathological states of quite a different sort. For example, delta rhythm is seen in generalized cerebral oedema consequent upon high C.S.F. pressure and it is seen also in deep anaesthesia. The rhythm can be induced in young patients by many electric fits repeated without due intervals between them.

In the numerous instances, both physiological as well as pathological, in which delta rhythm is dominant in all cortical areas, unconsciousness or dulling of consciousness is the invariable clinical accompaniment. Yet from the appearance of the waves themselves, it is at present impossible to say whether consciousness has not yet fully developed as in infancy, whether consciousness is only dimmed as in the delirium of the post-concussive, or whether consciousness is completely absent as in deep anaesthesia. If a degree of consciousness persists the delta discharge may be accompanied by normal or abnormal behaviour, by subsequent amnesia or by no amnesia. It seems probable that only when delta rhythm is dominant in all cortical areas is any serious degree of change of consciousness present.

Looked at from the point of view of the maintenance of dynamic equilibrium within the organism, respiratory alkalosis is seen as a dangerous threat, which will ultimately result in a breakdown of the controlling mechanisms of cerebral metabolism. These mechanisms and the failure of homeostasis as a result of which delta rhythm appears in the EEG have been the subject of investigation by many workers, but notably by Darrow *et al.* in Chicago and Gibbs *et al.* at Harvard. Their work indicates that when as a result of overbreathing the arterial CO_2 falls the blood pressure also falls, and it is only when this ceases or the fall is not maintained that a CO_2 deficit occurs in the cortex. Until this happens no change is seen in the EEG. Only when the blood pressure stops falling is the CO_2 in the brain necessarily reduced and cerebral vasoconstriction to be assumed. At this point an excessive vasospasm is offset by a reinforcement of the parasympathetic tone, increasing the acetylcholine depleted by the alkalosis; so that on the one hand excessive vasospasm does not occur, and on the other, adequate acetylcholine is conserved for synaptic transmission. But if this parasympathetic reimbursement of cholinergic activity itself fails, local and excessive vasospasm may result, with consequent interference with cerebral oxidation and the development of delta activity in the EEG.

Convincing experimental evidence has been furnished by Darrow and his colleagues by cutting, by stimulating, and by paralysing the recently discovered parasympathetic nerve supply to the cat's frontal lobes. The outcome of this work is that a parasympathetic control of brain waves has been demonstrated, which may have very important significance for psychiatry. Darrow writes: "We would mention a possible implication of these findings. There is here a mechanism by which emotionally induced autonomic changes possibly exert an

influence on the brain. We are provided pathways by which chronic emotional upset, especially when in association with spontaneous hyperventilation, may possibly exert an influence on both electrical activity and cerebral circulation."

The manner in which the autonomic nervous system preserves the dynamic equilibrium of the organism, and the various ways by which emotional upset tends to break down that equilibrium, have resulted in the broad concepts of " vagotonic " and " sympathicotonic " type of individual. It is unfortunate that, through complexity of innervation, very few tests to establish these differences are valid. Darrow has pointed out that tests of autonomic balance are, in general, of two types: firstly, those which examine the reaction of the organism or of some of its organs to a specific autonomic stimulus, and secondly those which, imposing a more or less non-specific though regulated load on the organism, attempt to measure the efficiency of the machinery for maintaining equilibrium. Since in most instances it is impossible to say whether a given result is due to inhibition of the one, or excitation of the other type of autonomic innervation, one must be content to consider only the second group. Such tests are not strictly tests of autonomic activity, but of total effect of a variety of homeostatic mechanisms in handling a new situation—the stress given.

The electrical reaction of the brain to the stresses of alkalosis, low sugar, low oxygen tension and the like can be estimated even by the naked eye, if only coarse changes are admitted. Delta rhythm does not appear in the EEGs of normal individuals until the blood sugar falls between 40 and 30 mgm. per cent. Using this fact, 80 units of insulin have been given to controls, epileptics, psychopaths with abnormal EEGs and chronic schizophrenics (Heppenstall, Shaw and Hill—unpublished). As a group the epileptics and the dysrhythmic psychopaths could be distinguished from the controls, since delta rhythm appeared in the EEG at sugar levels above 40 mgm. per cent. Of greater interest is the fact that the chronic schizophrenics also could be distinguished as a group, since they either did not produce delta discharge at all, or if they did, it appeared at levels of blood sugar below the range of the controls. The few exceptions among the schizophrenics were those in whose personal or family histories epileptic phenomena had occurred. These tests, with which we have made only a beginning, and which in the case of schizophrenics are complicated by the factor of insulin resistance, require further verification to establish their validity. But they illustrate again the well-known concept of a lack of stability in the epileptic brain, and an increased stability in that of the schizophrenic.

A similar type of stress test has been developed by Heppenstall, using respiratory alkalosis and hypoglycaemia as the chemical variables. Raising the blood-sugar level tends to inhibit the delta rhythm produced by some individuals on voluntary over-breathing. Mention has already been made that one of the indications of a maturation process is the decreasing incidence of this phenomenon as age increases. In children it is very common, whether fasting or not, but the level of the blood sugar is very important in the adult. When fasting, about 70 per cent. of all patients with abnormal EEGs produce delta rhythm on severe overbreathing, but if the blood sugar is raised above 130 mgm. per cent. the phenomenon is inhibited in all but the epileptics and certain psychopaths. It is not at present clear whether the cerebral instability consequent upon a traumatic lesion or that consequent upon other factors can be differentiated by the method, but this test as well as that developed by standardized hypoglycaemia presents us with new data and a new approach. The principles upon which the tests are founded are now a commonplace in medicine. They are analogous to the familiar exercise tolerance, urea clearance, liver detoxication tests and the like, in all of which an organ or system is subjected to a known stress and its reaction measured in a certain way. Like them, however, the way in which the brain deals or fails to deal with the stress is not indicated by the nature of the test.

These two tests of cortical electrical stability once again emphasize the inadequacy of the visual method of interpreting the EEG. When decision as to the " point of change "—the occasion when theta or delta rhythm significantly replaces alpha as the dominant pattern—is made by the naked eye, that decision is necessarily determined in greater or lesser degree by subjective factors. The eye is a poor analyser. These limitations for electroencephalography have been known for some time. An apparatus for analysing the amount of energy at the different

frequencies was developed by Grass in America in 1938, but in practice the device suffered from the fact that lengths of the record were analysed after it was taken. The EEG was not analysed as it was produced. A brilliantly conceived invention of Mr. Grey Walter's has, however, provided an apparatus which produces a continuous analysis of the EEG which proceeds as the EEG is taken, the analysis being recorded over the primary record which it represents. It is clear that the use of this apparatus will not only lead to greater knowledge of the nature of the EEG, but will also obviate the subjective factor in interpretation, and make good the deficiency so apparent in the human eye.

If one may venture a prophecy about the future of the EEG for psychiatry it would be this: The time is past when the consideration of large numbers of EEGs from any clinical type is likely to produce data of significance. While for the neurologist the identification of the space-filling lesion, the epileptic focus and the cerebral atrophy may be assisted by the primary EEG record, in the case of the problems confronting the psychiatrist this is not so. For him the data will be more complex, and the concepts within whose framework the data can be understood will involve such terms as "maturation," "stability to stress" and the like. Of the homeostatic mechanisms involved in this most complex chapter of physiology, knowledge is very incomplete. If at present electroencephalographers can see maturation of the brain in electrical terms as a vague though probable concept, they must translate this process into terms with which the psychiatrist can work.

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