8

Intimations of Personality

Children use the fist
Until they are of age to use the brain.
ELIZABETH BARRETT BROWNING

THE physiologist of a generation ago, baffled by the complexity of brain mechanisms, would have been doubly reluctant to enter the territory now reached in the study of them. Those were the days when the specialist was in the ascendant and won golden opinions precisely by keeping to his own field, days before physician and psychologist put their Jovian heads together to produce the psychiatrist. The physiologist of that period was a shy fellow, having indeed little to contribute to the Minervan synthesis. He was more concerned to retain and advance the claims of physiology as an exact science, content to be the servant of the practitioner rather than his partner. Consequently his public repute remained similar to that of the physicist in the days when physics only came into the school curriculum as a stray half-hour of 'Heat, Light, and Sound'.

So far this account of the brain has been traditional in scope if not in matter; that is, brain has been considered in general terms, as might have been heart or liver or any other organ, as if it were anybody's brain, apart from some passing references to typical variations. This common character of an organ and its functions is a natural assumption of the physiologist, whose business it primarily is to establish a norm for the pathologist rather than explore idiosyncrasies. But brain is the organ of personality, and enough has been said in connexion with the individuality of the alpha rhythms and the variable experiences of the subject in the flicker test, to indicate that at some point we should have to begin to examine phenomena of the living brain as elements or at least intimations of personality.

The more we learn about the brain, the more clearly we see

that it can only be studied profitably as a complex of mechanisms; and to study all the mechanisms of the brain implies reference to all its functions, including phenomena which are the physical counterparts of mental events. Thus if the brain physiologist today passes across an old scientific frontier, it is not to join – though still serving – the practitioners, but as an entirely fresh approach to the study of the everyday working of the human mind in so far as it is capable of quantitative observation. To some psychologists this appears to be undermining their position; by others it is welcomed as possibly providing some elements of a more secure material basis for a science that has neither units nor axioms.

Still more consequential in time may be the arrival of the brain physiologist in the social field. He is already providing a certain amount of public service, but not one thousandth part of the assistance he is likely to be called upon to give when 'prevention is better than cure' becomes the watchword in mental as well as physical health policy.

It was in fact in connexion with clinical service that the first information of specific importance concerning mechanistic intimations of personality was discovered. This was during the war period in the EEG laboratory of the Burden Neurological Institute. It will be recalled that one of the first curiosities which had been noticed about the alpha rhythms by early electroencephalographers had been that in no two people are they the same. Not even identical or uniovular twins have quite identical alpha patterns. But in any one person the pattern is remarkably constant from year to year, once cerebral maturity has been reached at the age of fourteen or so. It was noted that the differences between individuals are very great. Early speculations did not go beyond that; the differences were regarded as otherwise meaningless.

The individuality of EEG records, brainprints, seemed to be similar to that of fingerprints, giving simple identification. This in itself was a physiological novelty. The skin is individualist also to the point of rejecting a graft of any other person's skin, but no organ was known to furnish positive identification by its behaviour. And later observations in a

wider field showed there was more in it than that. When the correlation between certain phases of rhythmic activity and certain features of personality was first demonstrated, it was as surprising as if the loops and whorls of fingerprints had acquired meaning. The main facts which have since been verified in this connexion can now conveniently be presented in sequence of age.

Among the first papers published by Berger was one on the relation between age and the EEG. The observations he had made with his too simple equipment suggested that little electrical activity of any sort was present up to the age of one month, and from this age, up to a few years old, amplitude and frequency increased steadily. His observations were generally and broadly confirmed. It soon became evident, however, that some activity is present from birth, and that its increase is not simply a function of age. It has now been found that even before birth some electrical activity can be detected.

If electrodes are attached to the belly of a pregnant woman in the eighth month of gestation, whenever the head of the child moves in the region near them, slow irregular delta waves can be recorded. Sometimes the delta activity is interrupted by larger and more rhythmic discharges similar to the wave-and-spike patterns usually associated with epileptic attacks. It is unlikely that all the babes in whom these patterns have been detected before birth will turn out to be epileptic; rather we may suppose that, while nestling in its private pool within the womb, the child approaching full term is outgrowing the resources of that haven. The convulsive twitching and stretching of the unborn child is evidence that its oxygen supply is lagging behind its needs; with growth the deficit increases, and with it the petty seizures; until, at the appointed phase of some maternal tide, half suffocated, the baby thrashes its way to freedom or disaster. So, too, the pulsations of a jellyfish, augmented in the breathless oily calm of a summer sea, drive it toward regeneration in the foam of breakers.

At birth, and for some months after, the main feature of the EEG is still irregular delta rhythms. The more passive and somnolent the infant, the more prominent are the delta

rhythms. Even in the first few days of life there is a marked difference between the sleeping and waking patterns of EEG. Changes of frequency are correlated best with brain weight, changes of amplitude with the number of active neurones in the first few months and with skull thickness thereafter.

For some time it was thought that the alpha rhythms of adult life are rarely found in children less than eight years old; later analytical technique was more revealing, and a much greater number and variety of childhood rhythms have been identified. (Figure 13.) We can now say that no records of children below the age of three are found which could be accepted as normal by adult standards. From that age, however, the typical features of the normal adult record appear more and more frequently, and even below the three–four years age-group some alpha components are found – small, diffuse, unresponsive, and usually masked in the primary traces of the record. Rhythms of the alpha type then begin to appear in short bursts, often at considerable amplitude. In some children of four they are even the dominant feature of the record, although the typically infantile rhythms, both delta and theta, are still clearly visible.

In most children the records vacillate between the theta and alpha types for some years, at least until the age of ten or eleven. It is noteworthy that a record with no alpha activity at all – common enough in adults – is extremely rare in children below the age of twelve. When the alpha rhythms first appear in very early childhood, they are scarcely responsive even to arresting visual stimulation; they begin to show an unmistakable connexion with vision only after the age of three–four years. The effect of mental activity or non-visual stimuli cannot be very accurately tested in infants, but the classical blocking reaction appears clearly at the age of six–seven in some children. Statistically adult responsiveness is not found before the age of ten–eleven, when also some children show a very low amplitude rhythm even with the eyes shut, and others a persistent one, as in the adult population.

Absence of alpha rhythms in adults is normally a sign of vivid visual imagination; in babies and young children this seems an unlikely explanation. Judged from their behaviour,

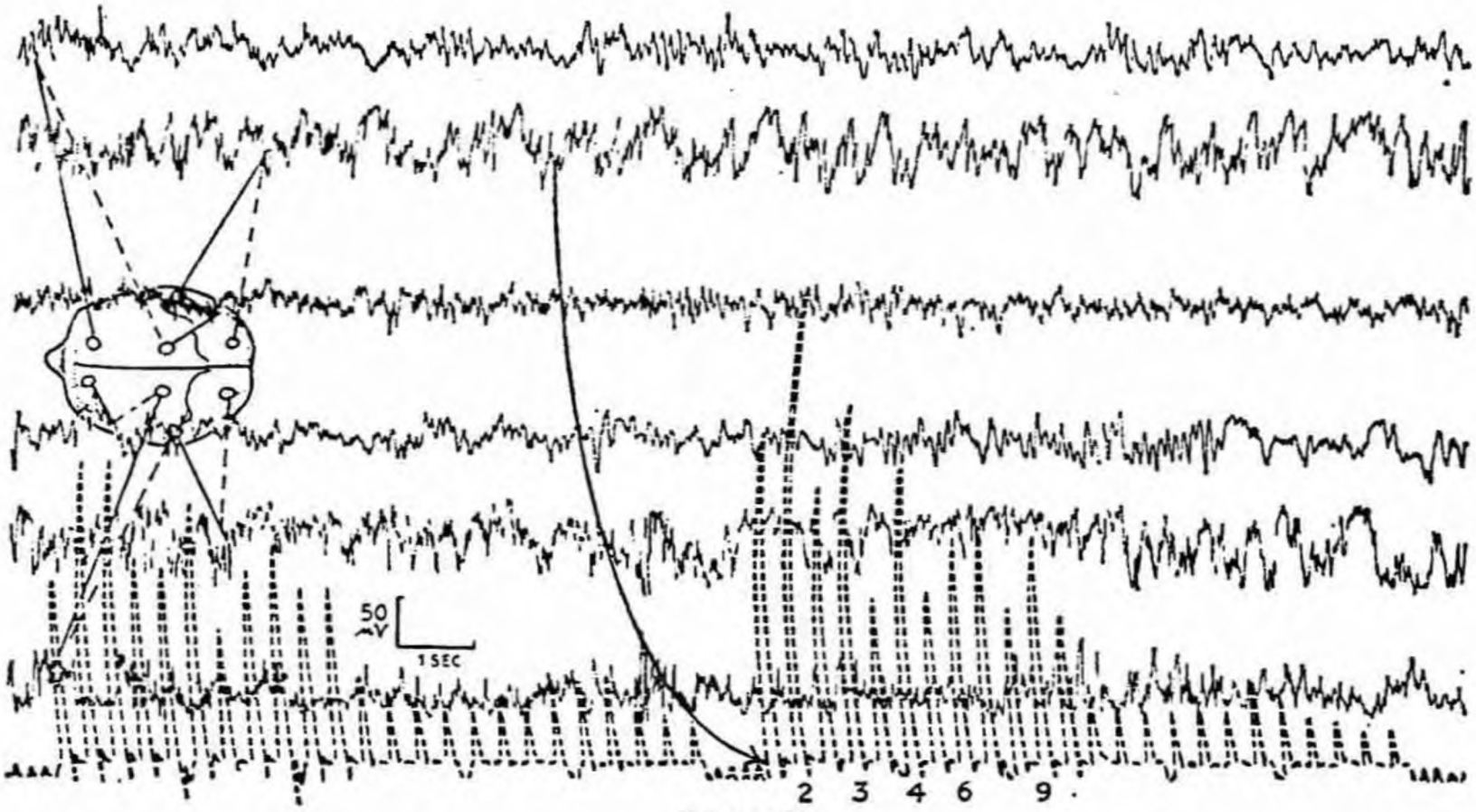

Figure 13

'. . . a much greater number and variety of childhood rhythms have been identified.'

EEG from a child aged two and a half years showing delta, theta, and alpha components.

children are relatively unimaginative below the age of three or four. So the later appearance of alpha rhythms and their relative unresponsiveness may be a sign of the maturing faculty of visual imagination and the lack of practice in its use.

There will be more to say about delta later, essentially the billowy rhythm of sleep; nor is it surprising to find that in their electrical behaviour the brains of infants and adults resemble one another only in sleep. Sleeping like a child, we say. But also, behaving like a child. In the first case our brain is rocking gently on the delta waves of the cradle; the other is not so simple, though the saying is equally apposite.

Apart from the lowest frequencies in the juvenile spectrum, probably associated with the earliest and most vulnerable stages of cortical development, the most arresting feature in the analysis of children's records is the activity at frequencies between four and seven cycles per second. These rhythms were still regarded as merely transitional between the very slow rhythms of the infant and the faster alpha activity of the adult, when chance observation of the subject's change of mood directed our attention to the possibility of a more significant psychological correlation. With further observation, the following points among others were noted. Theta activity is usually dominant in records of the two–five years age-groups; it is approximately equal to alpha activity at five–six years; it is smaller above six years, and very small or intermittent at ten. With other technical observations, a case was thus made for regarding this group of rhythms as specific; they were named 'theta' because they were first identified in clinical studies as arising in or near the thalamus, the antique bridal chamber of the brain, considered by some as the factory of feeling, the seat of emotional display.

Once mechanically distinguished in this way, there was little difficulty in enlarging upon the first indication that theta activity was connected with the mood of the subject. No marked response was shown to ordinary visual stimulation, as with alpha activity, but it soon became clear that theta is associated in some delicate fashion with pleasure and pain. It is easily evoked in a young child, for instance, by frustration, by

snatching away a proffered sweet. But the change may be objectively apparent as pleasure (cooing or smiling) as well as annoyance (whimpering and kicking).

Even in earliest days, and throughout childhood, individual differences are striking. In some children the theta activity is clearly associated with affective changes of any sort; in some it is linked only with pleasant feelings; in others only with unpleasant ones. It is a truism that in a child below the age of ten years or so the show of feelings is more exuberant and less intellectual than in older people. It may well be that this characteristic is associated with the late development of certain of the cortico-thalamic connexions and the consequent relative dominance of thalamic activity (with which the theta rhythms are indirectly associated) over behaviour during the first years of life. Such relationship, easier to assume than to establish, unless a Slaughter of the Innocents is contemplated, is at least a useful hypothesis.

The connexion between the changing of the rhythms from age to age and the anatomical maturing of the brain is evidently complex. The extent and nature of these changes, we may assume, will depend upon which of the innumerable areas and connexions of the brain are mature; and the dependence will not be a simple one; for the changes will be affected not only by the development of the nervous system but also by the presence of a complex private system of acquired responses and conditioned reflexes. Young children live in a world which few of them can describe and few adults remember; it is the special features of this world which, as much as anything else, determine the theta patterns of the young.

The notion of anatomical connexion with the theta rhythms is still more suggestive when we come to consider what is known of the phenomenon in conditions other than childhood. For some time 'slowing of the alpha rhythm', or 'deceleration of the dominant', had been regarded as an empirically pathological sign associated with organic lesions and psychiatric disorders. Its real significance appeared only when analytical unmasking showed that the appearance of 'slowing' was due to the presence of a separate, slower rhythm, masked by or

masking the alpha rhythms according to its relative amplitude.

The resulting correlation of the theta rhythm with the thalamus and structures around the third ventricle has been elaborated by Denis Hill in connexion with aggressive psychopathy. This led him in the course of further observations to recognize the existence of a group of psychopaths with a special characteristic unilateral slow theta discharge, which he termed 'dysrhythmic aggressive behaviour' cases, or DAB. The type of behaviour characteristic of this group involved violent attacks on living creatures in the attempt, as Freud put it, to turn living matter back into the inorganic state. These destructive and murderous episodes were often almost or completely unmotivated by ordinary standards; they recall irresistibly the purposeless destruction tolerated but deprecated in young children when frustrated, or, to readers of St Augustine, his angry baby whose 'weakness of infant limbs, not its will, is its innocence'.

St Augustine would have been interested in the measure in which EEG records confirm the connexion between the sinful mood of infant and adult. Few of us indeed escape unscathed from the test. We are all miserable sinners. In ordinary circumstances the theta rhythms are scarcely visible in good-tempered adults, but they may be evoked even in them by a really disagreeable stimulus. It is difficult to arrange this in a laboratory, where its artificiality is as obvious to the subject as it is embarrassing to the experimenter. The subject must feel himself really deeply offended by some personal affront; one's enemies are not likely to yield themselves so conveniently into one's hands; of strangers one cannot know enough to be sufficiently offensive; and a friend one may not, by definition, offend.

For some years research itself was frustrated by this situation; our hypothesis predicted that theta rhythm should be evoked by suitable emotional stress in any normal adult person, but we could not bring ourselves to jeopardize impersonal relations with experimental subjects. We then had the notion of testing the effects of pleasant instead of unpleasant stimuli. In one of the earliest experiments, records were taken and analysed from a French student while his head was being

stroked by a young lady from Wales. The stroking had no detectable effect upon the analysis, but we noticed that whenever the stroking was interrupted, a few seconds later the analyser indicated a sudden transient outburst of theta rhythms at six cycles per second. This suggested that the withdrawal of a mildly pleasant sensation was more upsetting than the administration of mildly unpleasant ones such as we had tried with this subject. Animal psychologists also have noticed the startling effects of mild pleasure ending. Hebb describes how a chimpanzee may be quite content to stare quietly for hours at an attractive female some cages away, then break down in a paroxysm of rage and exasperation when she retires to her sleeping-chamber.

Short of strip-tease, we proceeded to tantalize a number of normal and clinical subjects by various innocuous devices. The responses varied with the subjects; but we discovered in many of them a remarkable property of theta activity – an extreme constancy of distribution and development of it in certain subjects throughout a whole series of experimental frustrations. In individuals of this constant sensitivity, whenever a pleasant situation comes to an end, a theta rhythm begins to appear regularly a few seconds later and culminates in about ten seconds, when it abruptly disappears. This crescendo, with its sudden finale, is so stereotyped that half a dozen such records, taken in a series of individual tests, can be superimposed on one another and even the details of the rhythmic discharge can be seen to coincide time after time. (See Figure 14.)

Why, in contrast to all other functions of the normal brain, should this particular response to cessation or lack of pleasure be so invariable? This still perplexes; it can only be conjectured that perhaps adjustment to frustration and disappointment is one of the first and firmest foundations of personality. Just as, in learning, many possible ideas must be jettisoned in the search for significance, so there may be more unpleasant ideas than pleasant ones, and most pleasures are indeed but fleeting.

In an earlier chapter some evidence that the alpha rhythms provide a scanning mechanism for visual signals was considered. If the alpha rhythms scan for pattern, we may perhaps

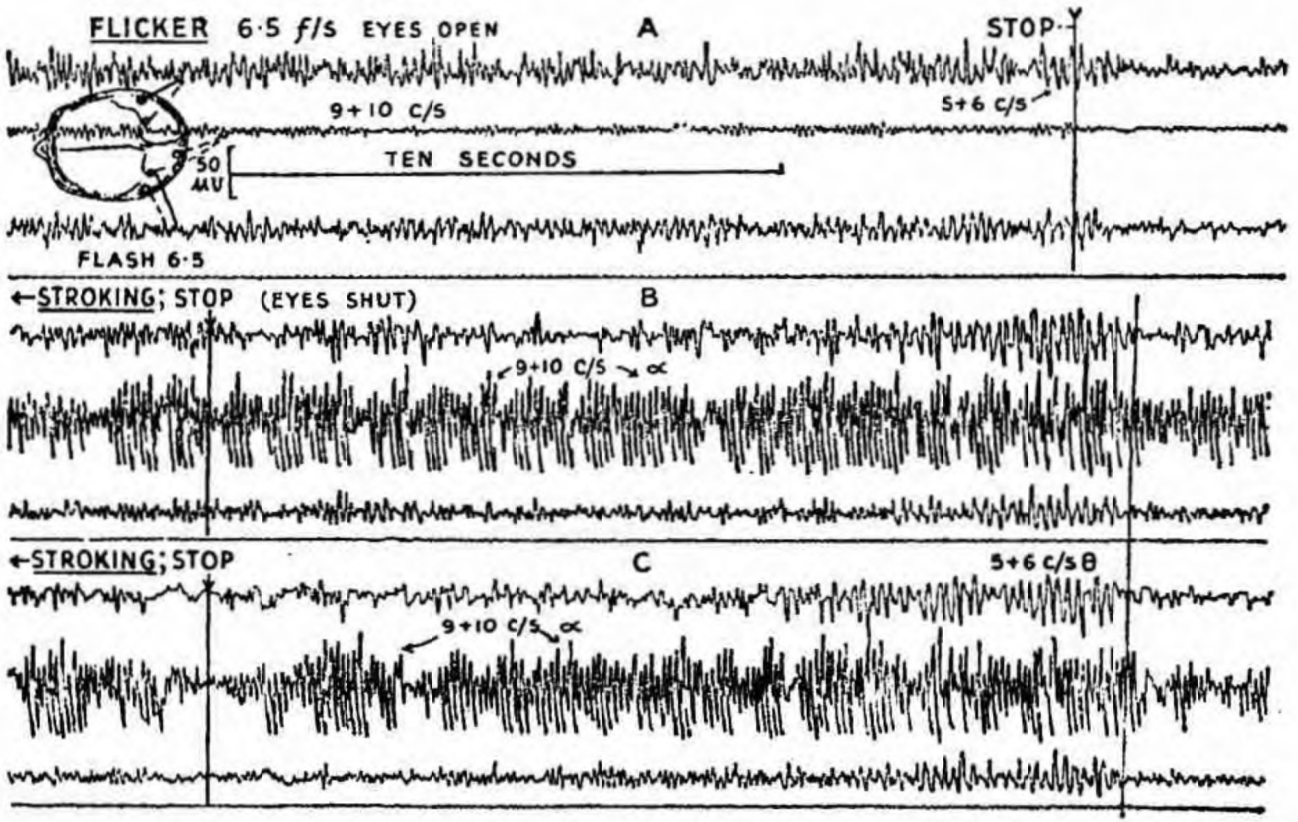

Figure 14

'Are we then at the mercy of the theta rhythms?'

(*a*) Theta rhythm evoked by flicker in a temperamental subject during which he reported feelings of intense irritation.
(*b*) Theta rhythm evoked by termination of a mildly agreeable stimulus in the same subject. Note the slow crescendo and abrupt termination seventeen seconds after the end of stimulation.
(*c*) A record taken a few minutes later in similar circumstances. Note the coincidence of details with those of (*b*).

consider the theta rhythms as scanning for pleasure. On this basis the uniform swell of theta rhythms, as pleasure fades, would represent the renewed search for other pleasures, while its abrupt snuffing-out is a measure of the individual's habit of stoical acceptance and resignation, an admirable and hard-won fortification against vain regret. As a corollary, the persistence of theta rhythms in children and ill-humoured adults may be a simple sign of inexperience in the first, of intemperance in the second.

In bad-tempered adults, especially in those with an unusual tendency to aggressive behaviour, the theta rhythms are often prominent and may sweep through quite a large area of the brain. Their childish intolerance, selfishness, impatience, and suspicion are mirrored in the juvenile appearance of their brain patterns. Are they still children at heart? The coincidence is so obvious that we are tempted to jump to the conclusion that the theta rhythm of childhood is qualitatively and functionally identical with – as it is quantitatively similar to – the theta rhythm of adult pathology, sign of relative immaturity of the mechanisms linking cortex, thalamus, and hypothalamus. How convenient it would be, and socially how useful, if one could classify the whole population morally by examining their theta rhythms! But the case is not so simple. It seldom is. As so often in scientific research, when a goal seems to be in sight, you find something quite unexpected round the corner. In this case it was, instead of theta rhythms, delta.

With the assistance of a public authority it was possible to examine a considerable number of intellectually normal delinquent children and to relate the features of their EEGs with an assessment of personal and social backgrounds. The odds seemed to be heavily in favour of finding pronounced theta activity as a sign-manual of mischief. One might have expected to be able to pick out the really 'bad boys' by their theta signatures. Actually eighty-five per cent of the records were 'abnormal' or at least peculiar, but no significant correspondence was found between the presence of theta rhythms and particularly bad behaviour records. The whole research seemed to be otherwise negative until, after tedious statistical tests of

the association between other features of behaviour and the results of automatic analysis of the EEG records, it was found that the significant rhythms in seventy per cent of the children were not theta but the slower delta activity, hitherto associated only with pathological conditions, with infants, and, as will be discussed in more detail later, with sleep. The only characteristic of behaviour which was significantly correlated with the presence of delta activity in these children was not aggressiveness, but a relatively *promising* reaction to their mothers, to leisure, and to their fellows, as estimated by the authorities responsible for classifying them.

Consideration of what these estimates imply has suggested that the common factor related statistically to delta rhythms is a comparatively docile attitude to suggestions from others. The terms 'malleable', 'easily helped', 'easily led' were used, and the word that seems most apt and free from irrelevant or misleading associations is 'ductile'. The significant delta activity in these boys was small and hard to measure, even with the best analytical equipment; it was often masked completely in the primary records by alpha or theta rhythms; but the suggestion of something infantile is hard to escape. The ages ranged from ten to seventeen and due allowance was made for the normal differences between juvenile and adult records. There was no correlation with age, so arrested or delayed maturity seems an adequate explanation. The delta distribution was not the same as in babies; it was mainly in the temporal, parietal, and occipital lobes, but usually diffusely located; and in only a few boys could it be compared directly with a baby's record. There is doubtless more to be learned from this observation and particularly its relation to the various contingencies of education and social rehabilitation.

Evidence that the condition of the electrical activities – alpha, delta, and theta – are closely connected with the maturing of the personality is plentiful. We should expect therefore to find signs of mechanistic immaturity in cases of disturbed behaviour. By watching the decline or development of brain rhythms in a child it is possible to follow to some extent the formation and growth of character, and so be guided in or

warned against correction or encouragement.

The correlation between deep feelings, the wells of personality, and the apparently simple electrical discharges which we record and analyse, may seem remote to those who have never witnessed the connexion between them either as the result of statistical investigation or in the course of a laboratory experiment. A few minutes of theta flicker would probably be convincing. Visual stimulation at the frequency of the theta rhythm evokes, even in a normal subject, a feeling of annoyance and frustration. If you are an irascible type it may make you very angry. The mood changes completely without any external emotional stimulus. If, however, during visual stimulation, an emotional stimulus is added – if the subject is told something really disturbing or annoying to him – the effect of this double stimulus is a summation of the two effects of flicker and emotional stimulus when given separately. (See Figure 14.)

Are we then at the mercy of these theta rhythms? Do they provide an excuse for outbursts of uncontrollable bad temper in young and old? By no means. Laboratory experiments confirm most of the admonitions about learning to keep our temper, which we heed when young or wish we had in later years. The characteristic sign of those who have learned to do so can be recognized in the laboratory. When the theta rhythm recedes, after its first evocation by flicker, we are getting a quantitative description of the subject's efforts to suppress the bad feelings that accompany it. These coded messages from his brain can be deciphered, following the ups and downs of the conflict, as he struggles to keep his temper or to dissipate feelings of annoyance or frustration.

There is a simple proof of the validity of this decoding: if the flicker stimulus is given in equable emotional conditions and the subject is encouraged to control the feeling of annoyance aroused by it, the evoked electrical disturbance is quenched - he suppresses his bad feelings, and with them their material associates, the theta rhythms. In this experiment, easily repeated in any laboratory equipped for flicker and analysis recording, there can be no doubt that we are witnessing the physical counterparts of mental events.

Here, for once, when the coded signal is deciphered, the message turns out to be a very personal one; also the information it contains can be verified through other channels, by the subject's account of his experience. We still do not know enough about the delta and theta rhythms to say much more than this; but, given a wider field of observation and a more varied correlation of the rhythms with personal characteristics, there is promise of much information of potential social value. Already, as indicated, some public use is being made of the assessment of character which statistical and analytical correlation of the recorded rhythms can contribute to the general picture; and the forensic use of EEG is now orthodox in criminal procedure.

Discussion here has been limited to aspects of the rhythms dominant in childhood about which interpretation could be offered with some degree of confidence. There are plenty of hints of other significant correlations to be discovered by patient work in this field, not only in the characteristic rhythms of the child but in the development of the adult alpha rhythms and their relation to the maturing character of the brain. An index of special aptitudes and ineptitudes, of temperamental maturity, tendencies of self-indulgence and self-control, as shown by the mechanistic responses of the brain, for which there can be no coaching, will be possible in the near future. It may prove to be a useful supplement to, or substitute for, the conventional IQ and personality tests.

The alpha rhythms, as might be expected, are a source of more general information about personality than those of childhood. The irregularity of their first appearance has been noted – they emerge sporadically, even below the age of three and become dominant in rare cases at the age of four, although typically adult responsiveness is not generally found until about the eleventh year. The differences are so wide as to seem random, but after our experience with first impressions of 'the Berger rhythm' we must hesitate to conclude that they are meaningless. About the brain it would be better to assume that nothing means nothing. Some of the records of children being made today will be interesting reading when examined in con-

nexion with the adult achievements of those children. Meanwhile there is much to be learnt today from the variations of mature alpha rhythms.

Meaning began to emerge from what had seemed random differences of personal rhythms as soon as a sufficient number of records had been taken to show that there is a natural grouping of differentiated responses to the normal blocking by mental effort. It has already been mentioned as one of the earliest observations of EEG, that in most people the alpha rhythms, prominent when the eyes are shut and the mind is at rest, disappear whenever the eyes are opened or when the subject makes a mental effort – for example, while doing a sum in mental arithmetic. Exceptions had of course been noticed; entire absence of rhythms in some cases. But it was only in the course of war services at the Burden Neurological Institute that we were able to designate some of these exceptions as a stable group with definite characteristics. It was shown in 1943 that individuals with persistent alpha rhythms which are hard to block with mental effort, tend to auditory, kinaesthetic, or tactile perceptions rather than visual imagery. In this group of persons the alpha rhythms continue even when the eyes are open and the mind is active or alert.

The group with persistent activity is known as P for short, while the larger group, whose alpha rhythms are responsive, are known as R. A third group was further definable as those people in whose EEG's no significant alpha rhythms are found, even when taken with the eyes shut and the mind idle. This group is known as M, for minus, and consists of persons whose thinking processes are conducted almost entirely in terms of visual imagery. (See Figure 15.)

Several surveys have been made to find out how these types are distributed in the population; groups comprising more than 600 persons have been studied for this purpose. The proportions vary a good deal according to occupation but, in general, about two thirds of an ordinary normal group of people selected at random are found to be of the R type, and the remaining third are about evenly M and P. The proportion of M types is usually rather higher in science students than in arts students.

Here is a simple test by which you may be able to tell to which group you or your friends belong:

Shut your eyes. Think of a cube like a child's block. It is painted. Now imagine that you cut it in halves across one side, then cut these halves in halves, and then cut them a third time at right angles. Now. think of the little cubes you have made. How many of their sides will be unpainted?

Did you work it out or did you 'see' it? Then what else did you see? What colour was the cube? Did you see the sawdust falling as you cut it?

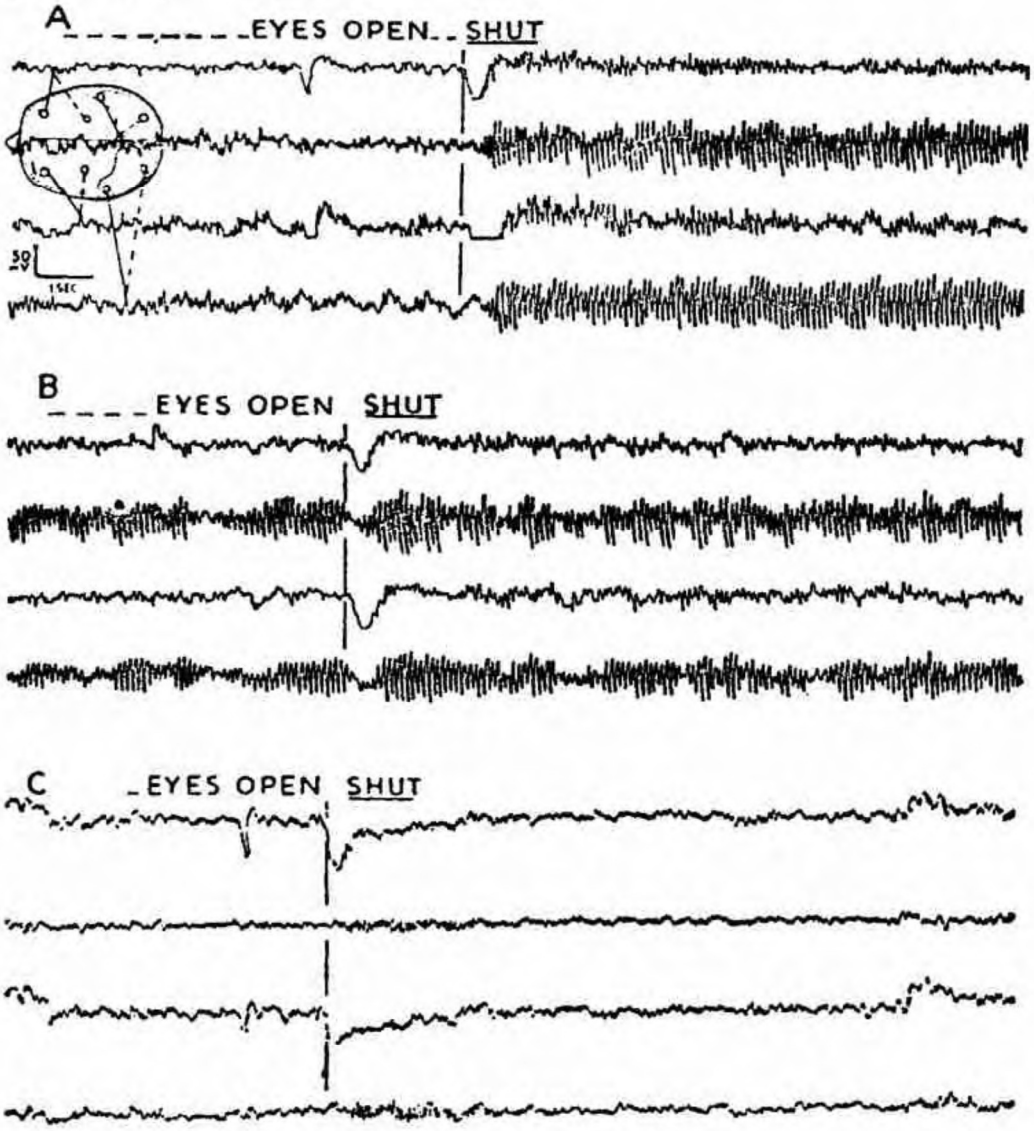

Figure 15

'... a discrepancy in their ways of thinking.'

Alpha type records: (*a*) R Type (*b*) P Type (*c*) M Type

Note particularly the question about colour. Quite often, when you have put the test to someone precisely as above, the reply will be red or green or whatnot; and if you then ask, why red or green or whatever the colour mentioned, you will very likely be told that you had said it was that colour! If the picture visualized had such details as this, more details than are really necessary, the subject may be one of the M type, a visualist with few if any alpha rhythms; if he saw no picture at all, he is likely to be a non-visualist with persistent alpha activity, a P type. If he had a picture that was just clear enough for the purpose but no more, he is probably a mixed type, mostly R, with a responsive alpha rhythm.

When a solution or decision of any kind can be reached by visualizing it, the performance of the M type of people is rapid and precise; but when they are faced with a problem of an abstract kind, or one in which the mental pictures required are too elaborate for them, they become sluggish and confused. On the other hand, at the other extreme, the smaller P group, people whose alpha rhythms persist even with the eyes open and doing a sum, do not use visual images in their thinking unless they are obliged to do so. Even then, their mind's eye is almost blind; they think in abstract terms, or in sounds, or movements; they may even have to 'feel' their way out of an imaginary maze. The R group, the responsives, whose alpha rhythms disappear when they do a sum or open their eyes, are intermediate between the other two groups; while they do not habitually use private pictures for their everyday thinking, they can evoke satisfactory visual patterns when necessary. Moreover, they can combine data from the various sense organs more readily than can either the M or P types. So even if you did the cube test just now by visualization, it is possible you belong to the more adaptable and versatile R group. The test of the cubes is valid as far as it goes, but only a recording and analysis of your EEG could give you your standing in your class.

There is still a great deal to be learnt about these groups. For instance, the origin of the differences between them. When and how does the differentiation become so clearly defined?

Why are the alpha rhythms so persistent when they first appear in childhood? We must be cautious about jumping to any such conclusion as that children only learn later to think in visual terms, although this is suggested by the extreme rarity of M type children. If, as seems likely, imaginative thinking becomes habitual at about the age when alpha rhythms appear, the startling differences between children, and the critical influence of age on the effects of deprivation, may find an explanation in the tardy and variable development of these physiological mechanisms, which in the adult provide the consolation in exile so conspicuously lacking in the very young. We have not yet had time to follow the development of a large enough population from birth to maturity to discover how soon and how permanently these differences are established.

Evidence already available, however, both statistical and experimental, strongly suggests that the alpha rhythm characters are inborn and probably hereditary. We are also beginning to get some notion of the distribution of rhythm characteristics in the population. Alpha rhythms vary in frequency, as we have seen, from eight to thirteen cycles per second. The distribution of these frequencies in the population seems to be as normal as the variations of stature; so that, like stature, it may well depend on many factors, some hereditary and some environmental. But the way the alpha rhythms respond to mental effort, and the consequent grouping which has been described, is less straightforward in its distribution. It may be more like eye-colour or blood-group in its dependence on heredity – complicated, however, by the effects of individual experience and impressions.

Differentiation by experience can be most clearly traced in the case of identical twins. The resemblance between the alpha rhythms of uniovular twins is as close as that of their fingerprints; the resemblance of the unstimulated rhythms persists through the years. Differences soon begin to appear, however, in the details of their responses to stimulation. The similarity of their brain mechanisms may continue to be as close as their physical resemblance when they mature, but their conditioning experience will not have been precisely alike. The differences

of these imposed patterns show not in the records of their resting rhythms but in those of their responses to stimulation. They may seem identical to casual acquaintances, as much alike as ever in form and feature; but the experimental responses of their EEGs will indicate slight differences of character which possibly only their intimates will have noticed. When we find such evidence in our records, we seem to be justified in saying that we not only detect but are also able to measure acquired differences of personality.

An appreciation of theta activity has various applications and possible uses. In what way could this information about alpha rhythms be of service? There is no doubt that the different characters of the three personality groups – P, R, M – and the effects of their different ways of thinking, are constantly intruding in our daily life. Everyone is familiar with the unaccountable nature of (other people's) family squabbles and perhaps even our own lovers' quarrels. Apart from arithmetical problems, in which nobody is much concerned about how they are done as long as the answer is correct, the three different ways of dealing with any question may, and often do, lead us far apart before we reach a common destination. Here is a simple example.

Supposing Peggy and Michael at breakfast receive an invitation to a party and have to decide whether they shall go to it; and supposing Peggy is an extreme P type and Michael an extreme M type. Michael will have a whole series of vivid pictures about it all in his mind; he will see them going to the party, the party itself, the people they will meet, and so forth; and he will compare it all with alternative pictures of what they will be doing if they do not go, perhaps a vision of somebody awkwardly asking him the day after it why they weren't there. That is the way M types literally figure things out for themselves. He will come to his decision that way very quickly, and in discussing the pros and cons with Peggy he will try to make her figure it out that way, too. But Peggy, being a P type who does not use visual images in this quick and easy way, has a more abstract method of thought, and will be considering the advantages and disadvantages of going, balancing duty and

other obligations against the pleasure of an outing, the convenience of going against the effort, the number of times 'we've been there without asking them here', and so on. She will be irritated by Michael's efforts to make her see his pictures, while he will be equally annoyed by her attempts to make him appreciate her heartfelt abstractions. It is not that one of them is more self-centred than the other, though if the reader happens to be of either type he may already have decided that the other one is. Worse than any adjustable blinkers of that kind, their language, their mental accents, so to say, are incompatible. Through nothing but the differences of their ways of thinking, before they can come to agreement, things may get to such a pitch that neither will give the other credit for clarity, consistency, or good taste.

Fortunately extreme types are rare; but when two people display unreasonable and irreconcilable differences of approach to a question, before concluding that this is due to innate antagonism or incompatibility of purpose, a discrepancy in their ways of thinking may be worth looking into. Communication between them, meanwhile, might be easier through an intermediary of the R type – who on occasion can use both ways of thinking. (See Figure 16.)

Suggestions for other applications of this knowledge about the mechanisms of the thinking brain will occur to the reader. One is obvious in these days of protracted international wrangling. How many negotiations may be frustrated simply by the fact that one of the negotiators is an extreme P type and the other an extreme M type! Like Peggy and Michael they want to agree and eventually may come to agreement, but meanwhile the peace of the world is in jeopardy through mischance of alpha grouping, just as a man's life may be imperilled by a mistake in blood-groups. Academic examinations are designed to discover character as well as capacity, but these basic mechanisms of mental behaviour, the characteristic operations of a person's way of thinking, are masked by all manner of social and intellectual tricks. Competitive examination does not reveal them; it is not a question of one type being superior to another. Even the most extreme types are undesirable only, like matter,

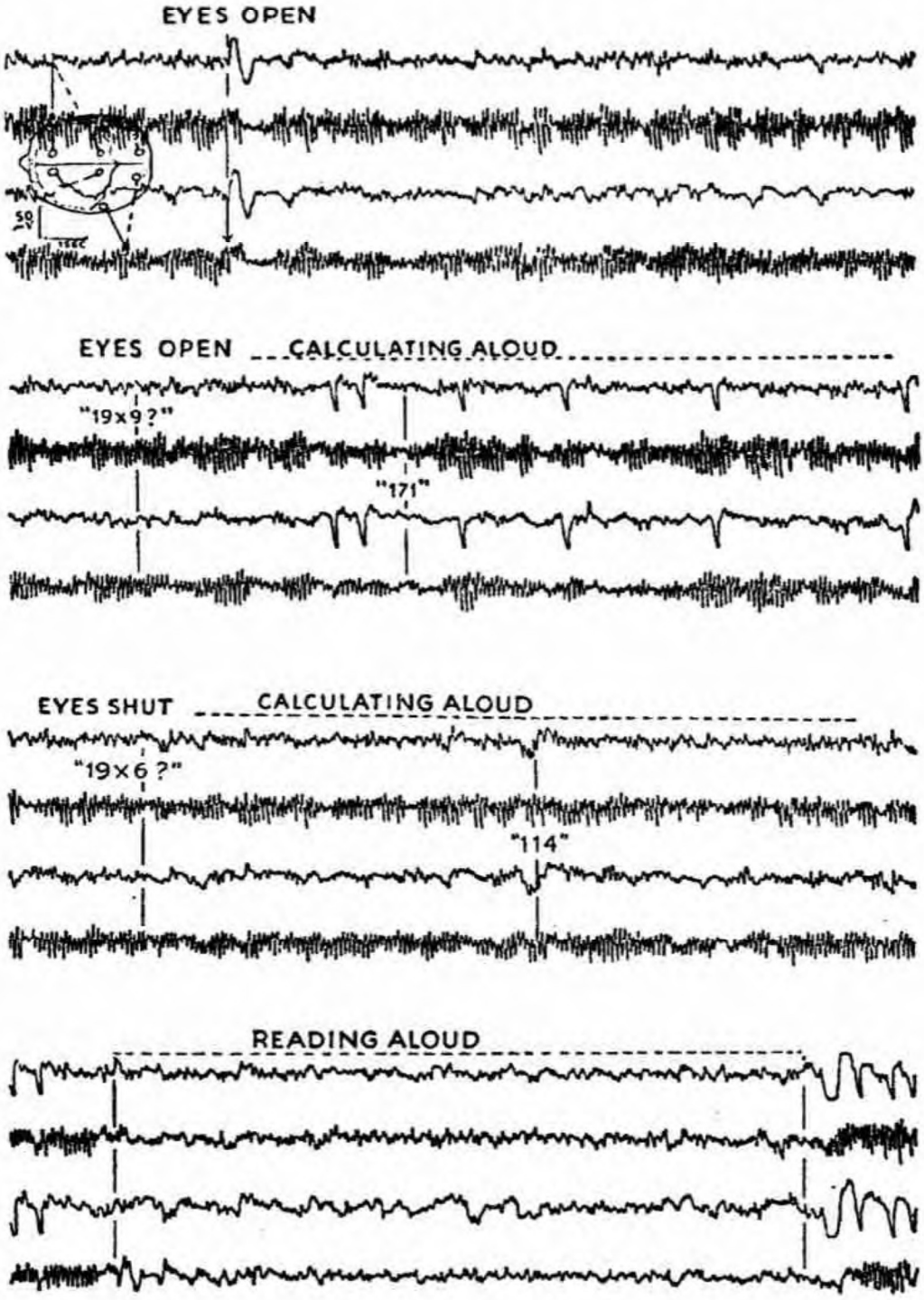

Figure 16

'Fortunately, extreme types are rare.'

Record of extreme P type. So persistent were the alpha rhythms in this subject (Peggy in the fable) that the only way to stop them was to make her read aloud.

in the wrong place, in the wrong company. It might be well to index all politicians, and his alpha designation should certainly be on the passport of every diplomat.

Occasionally disorders of thought are found associated with wildly exaggerated alpha characteristics, but mental illness is usually accompanied only by the most subtle and evanescent changes in the EEG. An alpha rhythm which persists when the eyes are open and the subject is apparently fully occupied – reading aloud for instance – is usually suggestive of some isolation from reality. In a few cases absurdly persistent alpha rhythms have been the first clear indication of something wrong, that what seemed unintelligible or eccentric brilliance was really lunatic delusion.

Rhythmic activity in the alpha range of frequency at nine to ten cycles per second is sometimes found in the front rather than the back of the head, with the activity in the two hemispheres seemingly quite dissociated. In such cases the 'alphoid' rhythm, as Sessions Hodge has dubbed it, is not reduced by visual or mental activity. A significant proportion of such subjects are referred for examination because they have suddenly committed some offence in an acute confusion of lust and frustration. In some cases, when the confused episode is over, the alphoid rhythm disappears and a normal occipital alpha rhythm may be found – at a different frequency from the frontal one. These are truly miserable sinners, as compared with the insane with persistent occipital alpha rhythms, who often seem quite content in the private circle of their intractable fantasies.

Generally, then, the electrical signs of brain function correlate better with 'how' than with 'how much'. The superficial EEG differences are linked more closely with personality than with intelligence. There is one measure, however, which seems to vary with extremes of dullness and brilliance. Soon after we started making regular frequency analyses of records it was realized that the results depended to some variable extent on the length of time over which the analysis was made. In the standard instrument the analysis 'epoch' was ten seconds; if we added up the readings over six such epochs and divided each of the 144 readings by six we obtained an average frequency

spectrum of one minute. This average sometimes looked very like the separate analyses from which it was made up; sometimes it was quite different. The greatest variance we found in our more brilliant colleagues or friends, the least in our duller patients. Revolting at the prospect of so much arithmetic, we devised a computing circuit to do the job automatically; nearly all analysers are now fitted with this 'averager' and various lengths of period can be averaged. With this device it is possible to extract a measure of what one may call the 'versatility' of the brain.

The more original types, verging towards genius, seem to have a high versatility in this sense; to obtain a set of average results similar to one another, one has to average over a very long time – several minutes, at least. In 'dull' brains half a dozen ten-second analyses may be indistinguishable from one another.

This may seem a difficult statistic to understand, but in fact one uses similar judgements every day – without arithmetic. A 'brilliant' driver, for example, is one who goes very fast when speed is safe, very slowly when caution is indicated, who accelerates briskly and slows down quickly, matching his performance to the conditions of the road. The average speed of such a driver, taken over periods of, say, one minute, would show great variations, and only his lap times would be constant. But a dull driver creeps round at a low steady average; his speeds on bends and on the straight are not very different, and they compare with his lap speed, too. So the brain seems to vary in the span of its variance, matching in the brighter ones the scale of its effort to the quality of the task.

In an ageing population, attention naturally veers toward the art of growing old. The brain is not, in general, the limiting factor in determining the length of our days. Disorders of the heart and circulation, the appearance of malignant growth, accidents, and social isolation, are responsible for the greater proportion of the 'old age woes'. There are of course certain brain diseases characteristic of the last few decades of the extending normal span, but these are relatively rare and specific disorders. The EEG changes little with advancing years; apart from truly senile states, it may have the same features at eighty

as at sixty. Gerontology, the science of old age, has so far gained from electrophysiology only the assurance that most brains could outlast the other organs.

The dying brain is calm; as the blood reaching it brings less and less oxygen, a few slow waves appear with failing awareness; these rise in amplitude, then slowly wane, and with them fades the organization of personality. Strangely, the brain and its subordinate ganglia are ill-armed against oxygen lack. A man dying of coal-gas poisoning or exposure to a rarefied atmosphere rarely feels acute distress; when the oxygen in his blood is about half normal, he faints quietly and his brain may show a few minor electrical disturbances, but often none. Yet, if recovery occurs, the period of oxygen lack may leave traces for many days or for life.

This is the Achilles heel of the brain. Its need of oxygen and sugar is perpetual and exacting. Lack of sugar it can signal, but not lack of oxygen. The agony of suffocation, the gasping and craze for air, is in fact due to the accumulation of carbon dioxide in the blood from the burning of the body fuel; and this the brain does feel, choked as it were by its own smoke, even though it cannot detect when the dampers are closing down.

No one has yet succeeded in relating the electrical features of the living brain with the now classical but still disputed categories of mental disorder – schizophrenia, manic-depressive psychosis – or with the symptom groups: paranoia, delusion, hallucination, obsession, compulsion, depression, agitation, and the like. This has been a sad disappointment, but we may be comforted to recall the unexpected complexity of the analysis of the simplest form of learning. The electrical signs of mental disturbance could well be a minor aberration in one or other of the operations leading to the formation of ideas. We should not detect such differences in a passive patient. Studies of the brain responses to various types of stimulation in cases of mental disorder are now in progress in many laboratories, and first results suggest that such experiments will clarify much of the inherent weaknesses and self-restoring powers of individual brains. The difficulty is that the more refined the method of study, the more striking is the individuality of each subject and

of each instant in the subject's life. We are still lost in admiration of the cerebral universe and have scarcely begun to name the constellations and trace the course of individual planets in the electrical firmament.

Willingness to ascribe mental differences and disorders to brain characters and diseases varies from generation to generation. There are physicians now living who remember the time when general paralysis of the insane was the commonest form of serious mental disorder, and was ascribed to the effects of excessive travelling, since it was most common in sailors, salesmen, and locomotive drivers. When it was shown to be due to the spirochaete of syphilis, prevention and cure became a matter of pharmacology and common sense. At the present time, many disorders that seem essentially mental are being attacked by physical means; there is less prejudice against this today than there has been for several hundred years.

Physical interference with personality by operating on the brain has been accepted with quite extraordinary public equanimity. Psychosurgery has developed through bold and reasonably safe operations by which parts of the brain are removed, destroyed, or isolated, in patients with only mental symptoms. Egaz Moniz of Lisbon, who first demonstrated the practical value of such operations, received a Nobel Prize; his prefrontal leucotomy, the cutting of the nerve fibres that connect the front of the brain with the rest, has been performed on thousands of persons. Very few deaths have been reported, and some astonishing 'cures' have been achieved, even in patients who had been mad as hatters for years. The most promising results appear to be more or less enduring changes of personality. People with silly fixed ideas which stop them doing anything useful, sometimes say after the operation that they still have their obsessions or delusions but do not worry about them any more. Even when the main trouble is intolerable pain – due to whatever cause – leucotomy seems to help the patient not to care so much, though the physical cause of the pain is still there. Many leucotomized people have returned to a full and happy life and indeed are often particularly agreeable and easy to get on with. An American surgeon has said

that the nicest people in his hospital are the ones with the little scars where the horns used to grow.

This is not a refined manner of treating the brain. The operation is sometimes effected through the eye-socket and needs no special tools; it could have been done by a neolithic savage equipped with nothing more than his flint scraper and the conviction that mental diseases can be attacked by physical methods. Some ancient skulls do in fact show trephine holes where there is no evidence of organic disease. In the present trend of thought, until the contrary is proved, it will be assumed that mental processes have physical representation in the brain in some form, and when the mind is disturbed surgical methods will be used where others fail.

Operations such as leucotomy, however, are mainly of symptomatic benefit to the individual; their long-term biological effects on society are hard to assess. It must be remembered that if the symptoms only are relieved, in a disease which is not understood and which may have hereditary factors, the effect may be ultimately to increase the prevalence of the disease. For thousands of years the insane and eccentric have been discouraged from breeding by Church and State; so neither the disapproval of the operation expressed by the Vatican, nor the decree of the Kremlin forbidding it, is surprising. Without considering what part heredity plays in mental disorder, leucotomized mental patients are put back into circulation and, as noted, they can be very pleasant and easy-going. Thus, courageous and inspired surgical invention can raise quite serious problems of the relation between individual welfare and the future of the species.

The effect of leucotomy on the electrical rhythms of the brain is variable and correlates little with the clinical results. Usually there is some increase in alpha activity after the operation, and delta activity may be prominent immediately after it but disappears within a matter of months. What have been described as the personal characteristics in the behaviour of alpha and theta rhythms are not greatly altered by leucotomy; or by electric-shock therapy.

In other respects electric-shock therapy, introduced from

Italy into this country before the war at the Burden Neurological Institute, also alters the personality to the extent of allaying some of the most trying symptoms of mental disorders and psychological distress. It has quite surprisingly won public confidence – one might almost say popularity. But again, though a less drastic procedure than leucotomy, it must be confessed that very little is yet known about its influence on the life history of a brain, beyond what has been empirically demonstrated and clinically observed. When first introduced it was hoped that it would throw some light on epilepsy, with which its convulsive effect is related, but beyond the confirmation of certain therapeutic aspects of epilepsy, mentioned elsewhere, it has not yet brought any major revelation such as those obtained by non-clinical techniques. It is essential, however, that research should continue to follow this and other experiences in psychosurgery.

An axiom demonstrated by the heroic physical treatment of mental disorder is one that has been emphasized in an earlier chapter: only a few brain functions are permanently located in one part of the living structure. A person who has suffered an extensive brain injury, or submitted to prefrontal leucotomy, usually displays some changes in personality; but re-education and discipline can often re-establish a great part of the missing pattern. In the early days of psychosurgery the patients were frequently left to recover without psychiatric or psychological assistance; it is now realized that the good effects of physical intervention can be greatly amplified, and the bad effects diminished, by carefully planned and rigorously maintained personal and social re-education. Even a mutilated brain retains its plasticity and resilience; it can still learn, still adapt to environmental stress. This principle applies in a less welcome fashion to the tendency to relapse after physical treatment. A patient with a characteristic personal symptom complex may obtain great relief from a leucotomy operation, may worry less, return to work, fit in better with the social pattern; then, perhaps, ten years later, the symptoms may return in precisely their original form. We know that in the brain there is no possibility of physical healing – a nerve cell is never replaced. A

brain can no more grow a new frontal lobe or re-establish a severed pathway than the trunk can replace an amputated limb. Recovery of normal function and reversion to pathological disorder are both examples of the principles of tireless search, of parsimony, and of plasticity, discussed earlier in connexion with some simple models.

One aspect of widespread submission to psychosurgery the research worker must welcome unreservedly. The present abundance of subjects with carefully planned, restricted, and reasonably uniform brain injuries, presents a valuable opportunity to study the re-establishment of functional patterns; otherwise the casualties of road and battle were his only material.

The cerebral circumvention of crippling obstacles, the resumption of even pathological behaviour patterns, is a phenomenon of such a personal nature that it should be common ground for students of mind and brain alike. To the latter it already suggests that when the physiological count of the content and structure of personality differences is made, it will be as detailed and important as the description given of them when psychic factors were deemed sufficient to define psychiatric states. Pure and applied psychopathology already has an enormous literature and a powerful tradition; but the material evidence from this field, from the physiological standpoint, is hard to assess, so serious is the conflict of testimony. As yet there is very little common experience on this common ground.

In the realm of normal psychology, the difficulty is just as great, where so many currents are turbid with sectarian strife. Several schools of psychology have set up various schemes of types with which correlation can be sought; some are based on physique, some on results of personal inquiry, some on tendencies to pathological extremes; and the typology devised by the Pavlovians has been outlined here. It would be gratifying if EEG studies could be made to relate to any of these classifications; but so far no precise or even suggestive correspondence has been established with any of them.

For the time being, then, we must be satisfied to summarize the material intimations of personality found in the electrical activities of the living brain, without academic psychological

correlation. They have at least the merit of being not opinions or elements of a theory but facts recorded in experiments which can be repeated. Brainprints, the records of the electrical rhythms, beyond giving personal identification such as that of fingerprints, can be obtained even before the birth of a child, and from then onward they display in various frequencies and amplitudes the maturing characteristics of mental development. This is associated, though not in a simple manner, with the maturing anatomy of the brain. The diversity is so great as to seem random; but refined automatic analysis of the main rhythms reveals in all of them certain features which can be correlated with the mental experiences of the subjects, providing the data for a very diversified classification of types of all ages. Childish behaviour in adults was shown to be related with characteristic rhythms of childhood, and self-control demonstrably measurable. What appears to be a scanning for pleasure was found dominant in childhood until, as the brain matures, the adult scanning of the alpha rhythms takes its place. Study of the alpha rhythms themselves revealed the personal characteristics of three different, and sometimes incompatible, ways of thinking. There was a hint that, in connexion with the unexpected complexity discovered in the simplest form of learning, certain signs of mental disturbance could be related to minor aberrations in one or other of the seven operations. Study of the alterations of personality effected by the physical treatment of mental disorders confirmed some of the principles of organic construction exemplified in working models. The popularity of psychosurgery suggested some cautionary reflections while providing the brain physiologist with an invaluable field of research.

Finally, it must be recalled that these are only the first fruits of this sapling. As recently as 1946 an eminent physiologist could write: 'It remains sadly true that most of our present understanding of mind would remain as valid and useful if, for all we knew, the cranium were stuffed with cotton wadding.' Ten years ago, in fact, there was no precise knowledge about any of the matters discussed in this chapter.