THE
ELECTRICAL ACTIVITY
OF THE
NERVOUS SYSTEM

A Textbook for Students

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The Electroencephalogram of Man

The recording of the brain potentials of man lagged for many years behind their demonstration in animals, partly because in recording through the skull both electrodes lie at a distance from active brain tissue and the potentials are consequently attenuated. The string galvanometer, which came into general use about 1906, introduced a new era in electrical recording and more confirmations of Caton’s original finding were made, including Neminski’s demonstration in 1925 that recordings could be made through the intact skull.

The first recordings from the human brain were made by Hans Berger in Jena in 1924 and published by him in 1929. Between that date and 1938 Berger published twenty papers on this subject, nearly all bearing the same title: *Über das Elektrenkephalogramm des Menschen*. It is in the first of these that he makes his historic claim, ‘Ich glaube also in der Tat, das Elektrenkephalogramm des Menschen gefunden und hier zum ersten Male veröffentlicht zu haben.’ This was, indeed, the first demonstration of brain potentials in man and the first use of the word ‘electroencephalogram’ to describe them. In these papers he laid the foundation for a great part of our knowledge of electroencephalography. He explored many aspects of the use of the electroencephalogram, including its physiological, neurological, psychiatric and psychological applications. He confirmed Caton’s finding, made in animals, that the electrical beats originate in neuronal tissue, and established that they change with age, with sensory stimuli, and with physicochemical changes in the body. He was the first to record during a major epileptic seizure in man. That the electrical discharges of the brain were abnormal in experimental epilepsy had been demonstrated in animals more than fifteen years earlier, both by Kauffinan in Russia and Cybulski in Poland. Berger was
primarily a psychiatrist and was led to search for correlations between electroencephalography and psychiatric observations. Unfortunately he framed a theory before he gathered his data and this coloured the interpretations he made of his findings; the result is that very few of his hypotheses have stood up to the test of time, though his major observations have been abundantly confirmed.

After the date of Berger’s first publication many laboratories in many countries took up this work and knowledge of this field grew rapidly. A great deal of information was being gained from animal experiments in such laboratories as Bremer’s, Bishop’s, and ten Cate’s, but many workers went ahead at this time with the study of the human electroencephalogram: Kreindler in Romania, Dietsch and Kornmüller in Germany, Adrian and Walter in England, Baudouin and Fessard in France, and Jasper, Schwab, and the team of Gibbs, Davis and Lennox in America.

All workers were able to confirm the essential claims of Berger’s work, and the various centres began to specialise in different problems; Gibbs and Lennox in epilepsy, the Davises in the study of normal subjects, Adrian, Hoagland and Jasper in the basic physiological mechanisms, and Walter in the electroencephalogram in brain lesions. Since these beginnings the spread of interest, observation and experiment has been very great. The historical development since 1936 will emerge as the different aspects of electroencephalography are described.

The growth of electroencephalography has really paralleled that of its instrumentation, for when measured through the skull from electrodes on the unshaven scalp these potentials commonly show a voltage difference between the leads of only about 50 millionths of a volt (50 μV), sometimes more, sometimes less, but rarely, in normal man, do they exceed 200 μV. They are usually, therefore, about 1/10 or less of the magnitude of electrocardiographic potentials. Consequently they need considerable amplification before they can be recorded. The development of the modern thermionic valve made possible an amplification not available to the earlier workers and is responsible for the surge in growth of this field in the last thirty years.

The invention of the transistor in 1948 has now replaced
The Electroencephalogram of Man

Electronic circuits in many of the modern electroencephalog- graphs. Instruments have now been designed which take into account the necessity for adequate linearity of response of the recording to the varying voltages led off from the head, and for faithful reproduction of frequencies in a range of from 1 to 500 c/s or more, as well as for direct current recordings. The modern electroencephalographs are shielded in such a way as to avoid radiated interference.

The electrodes used can introduce distortion from extraneous potentials such as those of the skin, bimetallic contacts, and, in the case of chlorided silver electrodes, of photo-electric effects; most electroencephalographs are, however, capacitor-coupled at the input stage, so that these effects become attenuated and they are, in any case, easily recognisable by the experienced worker. As a general rule a relatively non-polarisable electrode (such as silver-silver chloride) is desirable, but many other types of electrode prove roughly adequate for general use. The resistance between any pair of scalp electrodes should preferably be below 3,000 ohms when used with most of the commercially-available instruments. There is a variety of techniques for recording these potentials in the form of graphs of voltage against time. These may be electromagnetically driven ink-writing oscillographs, thermal or crystal type recorders, cathode-ray oscilloscopes or toposcopes.

In the usual designs of recording instruments the potentials from several pairs of electrodes are led in, each through a differential input stage, and are registered simultaneously, each pair having its independent matched amplifying system and recording unit. Recordings between members of a pair of electrodes may be bipolar, i.e. from two electrodes each of which is over active brain, or so-called ‘unipolar’, where one of the pair is over active tissue and the other on a far distant relatively inactive point. Such an inactive point cannot be found anywhere on the head, and although the mastoid process, the bridge of the nose and the lobe of ear are frequently used as locations for reference electrodes, they are not truly indifferent and actually contribute potentials from the brain region nearest to which they lie. Many errors of interpretation are unfortunately to be found in the EEG literature caused by regarding the earlobe or mastoid process as an ‘indifferent’ reference,
negative spiking from the temporal lobe or temporal muscle being picked up by the reference and being interpreted as 'positive' spikes occurring at a distant scalp electrode.

The fact is that no location on the head is indifferent to the electrical activity inside it and no placement will give a truly indifferent reference. Attempts to use non-cephalic references include the use of an electrode on the skin over the spinous process of the 6th or 7th cervical vertebra. An electrode even farther out on the body is satisfactorily indifferent as regards brain potentials although it may introduce muscle and heart potentials. However, these are not easily confused with true electroencephalographic potentials though they distort the record. Other types of reference leads in common use include a circuit in which two electrodes, one on the neck and one on the chest, have a potentiometer between them for balancing out the electrocardiographic potentials. Yet another brings all the electrodes on the head through appropriate resistors to a common point, in this way giving an average of the brain's potentials against which to measure focal changes under any one exploring electrode. In some circuits the exploring electrode itself is omitted from the average against which it is plotted. As knowledge of the sources of electrical activity within the brain has grown, the use of an average electrode as the reference for unipolar recordings is the method that receives most general acceptance.

Both bipolar and 'unipolar' systems of recording contribute information. The unipolar system, in which is noted the potential difference between each of many scalp electrodes and the relatively indifferent average electrode, allows easier plotting of the electrical field of voltage gradients in a manner consistent with physical theory. That electrode which lies nearest to the focus of activity will show the greatest difference in potential in respect to the average of the other electrodes. The potential difference decreases rapidly as the distance from the source increases. Thus, the maximum height of the pen deflection can be used as a localising sign. It is as though the height above sea-level of every peak in a landscape were being measured.

Bipolar recording on the other hand gives one, as it were, the relative heights of the hills and mountains of the landscape without knowledge of the sea-level. Localisation by this method
The Electroencephalogram of Man

depends on a comparison of the directions of the pen deflections in the several channels when the electrodes are connected to the inputs in such a way that activity at any one electrode common to two of the channels will cause opposite deflections of the two pens. This method of phase reversal was originally used by Adrian and his co-workers in their search for the source of the alpha rhythm, and was adopted by Walter for the localisation of abnormal waves. In practice, use is made of both bipolar and unipolar methods, especially when localisation of activity is the primary interest.

Other types of electrode have been developed for special purposes, including those designed for insertion into the nasopharynx for sampling activity at the base of the brain, and into the external auditory canal for recording from the lateral aspect of the temporal lobe, and a 'sphenoidal' electrode for recording from the temporal tip. Several types of electrode with appropriate holders have been designed for use in the operating room on the exposed brain for investigation of both cortical and subcortical areas. Electrodes for insertion into deep structures, in which they may remain for some days or weeks, are now being widely used for diagnostic purposes. They have the advantage that the patient may be studied in the unanaesthetised state and in more normal conditions of behaviour and environment than the operating room permits.

In his original paper Berger described the normal electroencephalogram as consisting essentially of the two types of rhythm, first observed by Neminski, which he named the alpha and the beta bands. Alpha is usually regarded as activity in the frequency range from 1 to 13 c/s, which is prominent in the parieto-occipital regions and disappears with visual attention, and beta as the low-voltage activity between 18 and 30 c/s. To be more exact, the waveform recorded by the electroencephalograph is a complex composed of waves of many frequencies with shifting phase relationships and varying amplitudes. In the great majority of normal records, probably owing to a considerable degree of synchronisation of cell groups, the presenting rhythm generally shows the two frequency bands, originally described by Berger. One of the first recordings from a human subject is reproduced in Fig. 134, which Berger made from his young son; this shows mostly the alpha type of waves.

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It has been suggested by several workers that the beta activity may be due to some neuronal groups beating in the second harmonic (i.e. at twice the rate) of the fundamental alpha frequency; accordingly, if such groups were to have greater voltage than those oscillating at alpha frequencies they would dominate the picture, and the tracing would be that of a beta type, whereas if they were of only low amplitude their presence in the tracing would merely be as an asymmetry of the alpha waves which would then appear jagged. In the absence of these faster waves the tracing would appear as a more or less purely sinusoidal alpha rhythm. On the other hand, as the physiological studies detailed in the previous section have shown, there is every reason to regard some of the beta rhythms of man as analogous to those fast rhythms of the animal cortex which have been proved to be the result of activity in the ascending reticular system.

In the normal brain when the subject is awake and relaxed, but not alerted, the type of rhythm differs in recordings from different areas. The beta type of rhythm is more commonly found in the frontal part of the brain and the strongest centres of alpha activity are usually located, as Adrian found, in the parieto-occipital regions, although their fields may be spread over other parts of the head as well. However, almost all variations are met with and the above statement applies only to the great majority of normal records. The early hypothesis that the alpha rhythm is generated solely in the occipital poles is no longer so rigidly maintained, the incidence of alpha foci having been demonstrated in other parts of the brain, although they are rare in the frontal regions. The approximate relationship of these major brain areas to certain bony landmarks can be seen in Fig. 135 and a typical recording from a normal subject, when awake and relaxed, is shown in Fig. 136.
The Electroencephalogram of Man

In most normal records one frequency stands out more clearly than all others. This is usually described as the dominant frequency which, in more exact terms, is defined as the wave-frequency in c/s which occupies the greater part of the record. Analysis reveals that more than one frequency in the alpha band is present in most records. Measurement of large numbers of records in many laboratories indicates that 95 per cent of normal adults have, in the occiput, dominant frequencies in the alpha range, that is, between 8 and 13 c/s. This is also the average dominant frequency recordable from the parietal lobes where, however, it may be in some cases a spread by field effect from the occipital alpha centres. No comparable data have been published for the frontal lobes, but, as mentioned before, the rhythms in these regions are very frequently of the fast

FIG. 135. DIAGRAM OF THE BRAIN TO INDICATE ITS RELATIONSHIP TO CERTAIN BONY LANDMARKS ON THE SKULL FOR PLACEMENT OF SCALP ELECTRODES

This shows the gross divisions into occipital (O), parietal (P), temporal (T) and frontal (F) regions.
beta type, and a simple multiple of the occipital frequency is a common finding. The rhythms of the temporal lobes are in general slower (by 1 or 2 c/s) than those of the occiput.

There are considerable differences in electroencephalograms from person to person, but under standard conditions of rest and relaxation there is little variation in the electroencephalogram of a normal adult individual, either from hour to hour or over a period of several months. It is this fact which has led workers to feel that the electroencephalogram is a reasonably constant measure of basic physiological significance. Identical twins frequently show superficially similar electroencephalographic patterns, but the evidence is not sufficiently direct to warrant the conclusion that a factor is carried by the genes. More direct information from animal breeding is still lacking.

The frequency characteristics just described for the brain potentials in normal man were originally established by various
methods of manual measurement of the tracing. The development of several means of automatic analysis such as those used by Grass, Cohn, Walter, Brazier and Casby, and others, to reveal components hidden to the eye, give a great deal more information.

These early pioneer efforts to quantify the electrical activity of the brain have now been surpassed by the tremendous power of the modern computers for which electroencephalographers have developed many programmes, not only for frequency analysis but for several other aspects of the brain’s activity.

In Chapters 16 and 17, the close relationship between thalamic and cortical activity was documented. There is now some evidence that this also holds in man. Records are, of course, unavailable from normal subjects, but in patients with indwelling electrodes implanted for diagnostic and therapeutic purposes, records have been obtained which show the close correlation between thalamic nuclei and their projection cortices, a correlation which does not exist between the neocortex of the convexity and the limbic structures which have no direct projections to it (Fig. 137). These relationships, suggested by visual inspection of the record, have been substantiated by computer correlation analysis.

The electroencephalogram in the awake subject at rest and relaxed is independent of respiration and of heart rate. Over-breathing, on the other hand, with its resultant alkalosis, will eventually break up the normal rhythm of any electroencephalogram. Individuals vary a great deal in the amount of over-breathing they can undertake without affecting their rhythm, but in general most normal adults show no significant change after three minutes of deep breathing, provided their blood sugar level is adequate (that is, not lower than about 130 mg/100 cm³). Children have less stable rhythms than adults, and those epileptic patients who have a low threshold to alkalosis also have labile records, a factor which may be used with caution in the diagnosis of this condition.

As mentioned above, rhythmicity of the electrical activity in the parieto-occipital region usually disappears when the eyes are opened, though it tends to return if the eyes are persistently illuminated. This early observation led to a definition of the alpha rhythm as rhythmic activity with a frequency in the
range between 8 and 13/sec which disappears when the eyes are opened. Berger's early suggestion was that loss of alpha rhythm results from concentrated attention to the stimulus. In fact, if the subject opens his eyes in a pitch dark room and tries very hard to see, the alpha rhythm will be suppressed. Conversely, if in a bright light he wears frosted glasses which blur his vision, the alpha rhythm will persist. It is the attempt to attend to form perception, rather than the light in the eye, which has this effect on the rhythm. The findings are consistent with the clear relationship between electroencephalographic changes and levels of consciousness, in this case an augmentation of consciousness, and they received their explanation when the underlying physiological mechanisms were revealed by
The Electroencephalogram of Man

Moruzzi and Magoun's classic work on the influence of the reticular core of the brain stem on electrocortical activity and on vigilance (see Chapter 17).

A more comprehensive definition of the alpha rhythm than that given above would, therefore, be: rhythmic activity with a frequency in the range between 8 and 13/sec which is desynchronised by visual activity and alert attention. This rhythm

![Graphs showing EEG responses to flickering light.](image)

**FIG. 138. AN EXAMPLE OF EEG RESPONSES IN A NORMAL SUBJECT TO FLICKERING LIGHT OF TWO DIFFERENT FREQUENCIES**

The large slow wave seen in the leads from the front of the head (left F-P, mid F-P, right F-P) are blink potentials at the onset of the flash.

is most commonly found (though not uniquely) in the parieto-occipital regions.

The strong effect of visual stimuli on the synchrony of the beat led Adrian to examine the effect of a rhythmically flickering light. He found, as many workers have since confirmed, that rhythmic potentials can be evoked in the brain which correspond in frequency to that of the flicker within a limited range, from about 6-60 c/s in the normal subject, a wider range in pathological cases (Fig. 138). The two processes, the imposed flicker and the inherent alpha rhythm, compete for the response of the cortical neurones, and it does not seem correct to say that the flicker drives the alpha rhythm, for both can exist together
at different frequencies. If the flickering light is diffuse and uniform over the whole visual field, all receptors are equally stimulated at the same moment in time and they consequently respond in unison. This response is in some subjects very clearly seen in the electroencephalogram; in others it is of such low voltage that it is difficult to identify. However, with the added technique of automatic analysis, full descriptions of which appear in the publications of Walter, or by the more modern computer techniques, the evoked response is clearly defined. These techniques are being used in the analysis of flicker rhythms in many widely-distributed laboratories.

One of the details of the response which emerges in the automatic analysis of the flicker response is that with great intensity of light there is not only a response within a given range at the fundamental frequency of the flickering light, but also at twice that frequency (the second harmonic). In man this response at the second harmonic of the flash rate is much more closely localised to the occipital pole than the response at the fundamental frequency, and is less easily disrupted by concentrated mental effort. This finding suggests that the second harmonic may be a response of the primary receiving areas and that the fundamental may be the recruited response of cells whose inherent rhythmicity is closer to the flicker frequency than to the second harmonic.

As a matter of fact in some people the EEG appears to make a differentiation between what one may perhaps call ‘vision’ and ‘gaze’. When the subject is called on to execute certain types of visual task, a typical wave pattern of sharp-peaked 4 to 5 c/s waves appears in the occipital leads. This pattern, first described by Evans in 1952, has been given the name of lambda waves.

In those persons exhibiting this phenomenon, the lambda waves are evoked only when the eyes are open in the light and when the subject is looking at a patterned stimulus which requires searching, scanning movements, for fixation of the gaze immediately blocks the lambda waves. The percentage of people exhibiting lambda waves is so small that it is not surprising that the suggestion has been made that this is an abnormal phenomenon, though its relation to any known disease state has not been established.
The Electroencephalogram of Man

Many agents are known to alter the electroencephalogram, those that affect nerve cell metabolism being among the most potent. Among these may be mentioned anoxia, hypoglycaemia and alcohol, all of which result in slow rhythms and eventual suppression of voltage. The effect of drugs, especially the anti-convulsant drug, has been very widely studied and an extensive bibliography on the subject is being built up. Anaesthetics have varying effects depending on the drug used, but here again the close relationship between electroencephalographic changes and levels of consciousness becomes apparent.

In a previous section the optimal conditions for detecting a response of the cortex to sensory stimulation were shown to be those of deep barbiturate narcosis, the effect of barbiturates being to suppress most of the electroencephalographic potentials before those of the afferent sensory impulses (see page 254). Ether has a different effect, for it blocks activity in the afferent tracts before that in the cortex. Bishop has shown that the action potential of the afferent radiation to the cortex is the last activity to be abolished by ether.

In the human subject the successive stages of slowly induced barbiturate narcosis are very marked, with a close relationship between change in level of consciousness and change in electroencephalographic pattern. In the early stage of thiopental anaesthesia when the subject has not lost consciousness, but is usually, on the other hand, euphoric or confused, the cortical potentials are consistently fast in frequency and generally of high voltage. This type of activity is seen again as the subject emerges from anaesthesia. This change in the electroencephalogram appears first in the leads from the front of the head and persists there longest when the drug wears off. At the moment when the patient loses consciousness the record is immediately dominated by high-voltage slow waves and is strikingly similar to recordings made on patients in a coma or during a faint. If the anaesthesia is deepened a stage may be reached where long isopotential periods are interposed between bursts of irregular waves. This latter stage is not so frequently seen in man as it borders on a very deep level of anaesthesia, but its comparison with the records of Morison and Dempsey at the level used to reveal the spontaneous burst activity in cats is highly suggestive. These successive changes in the electroencephalogram in man
during the slow administration of thiopental are illustrated in Fig. 139.

Bremer, in his work on cats, drew attention to the similarity between the electroencephalogram he found in sleeping animals and that found during barbiturate narcosis. The common denominator was revealed by the demonstration of French, Verzecano and Magoun that the principal site of action of the barbiturate drugs is in the reticular formation of the brain stem. In man the change in the electroencephalogram in natural sleep is a profound one.

In the first drowsy stage the usual alpha frequencies are replaced by rather low voltage potentials. The drowsy stage is one in which the subject can very easily be brought back, just by the spoken word, to the fully awake condition. Frequency analysis (Fig. 140) shows that drowsiness has brought with it a shift of the frequencies present from those clustering around 10 c/s to 7 and 8 c/s. Later, in deeper sleep, the frequencies are replaced by slow potential changes of great amplitude and little regularity (see Fig. 141). These are often as long as 1 sec

**Fig. 139. Changes in the Electroencephalogram of a Human Subject at Deepening Levels of Thiopental Narcosis**

*Lower right:* The horizontal line represents duration of 1 sec; vertical line the deflection for 100 μV. Only samples from the occipital region are shown.
FIG. 140. AROUSAL FROM THE DROWSY STATE
Scalp recording with automatic frequency analysis of the EEG of a normal subject who was drowsy. Note changes of dominant activity from 7 and 8 cycles per second to 10 and 11 when aroused by a verbal command. The second strip is continuous with the first recording.
in duration and are frequently interspersed with trains of faster waves in a frequency range between 14 and 16/sec. These spindles in the records of sleeping man seem analogous to the 'bursts' described by Morison and Dempsey.

This stage usually lasts for only the first one or two hours of sleep and is more rarely seen in the later part of the night when long periods of low amplitude fast activity occur. When recordings are made with amplifiers with suitable time-constants, this activity is found to be riding on slow waves, also of low amplitude. Another feature which differentiates this activity from that of the alert stage is the distribution of the fast frequencies as revealed by computer analysis.

Interest, especially in psychological and psychiatric circles, was stirred when reports began to appear linking dreaming to the stage of sleep when the EEG shows low voltage fast activity, and rapid eye movements are recordable. As rapid eye movements are also seen in sleeping animals this led to the occasional unfortunate description of 'dreaming cats'. However, it has now been demonstrated in many laboratories that dreaming, as reported by human subjects, may often take place during the slow-wave stage of sleep, although this type of mental activity is apparently rather more common when the EEG is in the fast low-voltage stage.

Motor activity other than eye movements and superficial twitches, i.e. discharges from Betz cells, apparently requires a 'waking' cortex, for in man there is usually a return to alpha activity in both thalamus and cortex just before a body movement is made. The slowest components of the sleep records are not equally distributed over the whole head but have two very common foci, one lying precentrally, approximately over Brodmann's area 6 (Fig. 142), and the other farther forward in the frontal region, approximately over area 9. The typical electroencephalographic response to a sensory stimulus during sleep has been described in a previous chapter (see page 218).

There have been some tenuously supported claims that there is a relationship between 'personality' and the alpha rhythm, but the only well-controlled objective study could establish no statistically valid basis for these statements (Henry and Knott). It seems possible that the disturbance of importance in cases that are interpretatively described as 'personality disorders' may
FIG. 141. CHANGES IN THE NORMAL ELECTROENCEPHALOGRAM DURING ALERTNESS, RELAXATION, DROWSINESS AND NOCTURNAL SLEEP

The delta activity is usually seen in the early part of the night. The 'spindling' superimposed on the slow waves is characteristic of this stage. As the duration of sleep lengthens these features tend to drop out as shown in the lowest strip.
be a change in the steering or a re-routing of activity rather than a lesion of structure, and a search for abnormal patterns of distribution may prove more fruitful than has the search for abnormal frequencies as such. If this were so the search for anomalous responses to stimulation might be expected to yield more results than the search for abnormal characteristics in the resting record. That this approach may hold some promise is already suggested by work on the EEG in relation to behaviour, as operationally defined (for example, in controlled experiments on conditional reflexes).

**THE ELECTROENCEPHALOGRAM IN NORMAL CHILDREN**

The electroencephalogram of the normal child differs from that of the adult. This fact is of significance, not only for the interpretation of records but also, by implication, for the understanding of the brain mechanisms responsible for the electrical activity.

Observation, or measurement by manual methods, fails to
The Electroencephalogram of Man

reveal rhythmic electrical activity in the occiput of the normal infant during the first three months of life, although there is evidence of rhythmic electrical activity from the precentral regions even before birth. The remarkable finding is that these rhythms from the precentral cortex are almost of the same order as in the adult (varying from 7 to 15/sec) even before birth, whereas those from the occiput, when they first appear at about the fourth month of life, are very slow (3 to 4/sec). The occipital rhythms increase in rate, at first rapidly and then more slowly, until at about 13 years the range of frequencies resembles that of the adult (Fig. 143).

The presence of waves in the sensory-motor area of the infant’s brain, before the appearance of any electrical activity in the occiput, parallels to some extent the structural development and maturation of those areas, also the behavioural development of the child. Somatic motor function is evident at birth in the movements and reactions of the child, whereas
perception of visual objects, i.e. functioning of cortical visual mechanisms, does not develop fully until the third month.

A quantitative study of a large series of children, many of whom were examined repeatedly over a period of 5–8 years, was made by Henry, whose monograph on this subject establishes standards for normality. The importance of this study is the emphasis it has brought to criteria for the assessment of abnormality in the records of children. In summary, Henry's work defines the characteristics of the normal child's electroencephalogram as a dominant rhythm slower than the adult's, with slow waves (i.e. slower than 8/sec) always present; these are more prominent in the central areas than they are in the occiput, and decrease as the child's age approaches 13. A chart incorporating Henry's findings is shown in Fig. 144. Walder has used the Greek letter \( \theta \) to designate the band of frequencies between 4 and 7 c/s which in young children's records is a normal feature. An outstanding feature of the records of normal children is their great variability from day to day, in contrast to the comparative stability of the adult's record. It is not surprising that no direct correlation has been found between the electroencephalogram and skeletal maturity, and it is of interest that there is no correlation with the intelligence quotient in normal children.

There have been many reports of abnormal electroencephalograms in children with behaviour disorders. It seems likely that factors such as encephalitis, anoxia at birth, latent epileptic tendencies, and congenital defects of the brain, including failure in completing maturation, may be some of the causes common to both the behavioural and electroencephalographic disorders. The temporal lobe is a suspect region, and again the pattern of distribution of activity may be a clue.

Knott examined the electroencephalograms of a group of normal children with the Grass analyser. The Fourier transforms so obtained showed a relatively high energy peak at 6/sec at one year of age and the gradual emergence of the alpha and beta bands as the age increased. It has been the impression of most workers that occipital alpha frequencies are absent in infants and that the slow waves found in young children gradually accelerate with increasing age until they reach these frequencies. One observer (Dovey) has reported on a group of
normal children whose electroencephalograms were analysed by an automatic electronic analyser. From the analysis she concluded that the alpha band of frequencies was present in the occipital regions of all children, even the youngest tested (6 months old), but that it was masked in the unanalysed trace

![Graph showing the increase of mean occipital alpha frequency in children.](chart)

**FIG. 144. INCREASE OF MEAN OCCIPITAL ALPHA FREQUENCY IN CHILDREN**

The centre curve represents the mean values found at each age, and the grey area the extreme limits encountered in this study of 530 children between the ages of 4 and 19.

(Chart compiled from data published by Henry (1944) *National Research Monograph*, Washington.)

by slower rhythms of higher amplitude. These slower rhythms became less and less prominent as the child's age increased, until at about 10 years of age they were sufficiently insignificant to unmask the alpha band. That this might be the case had been suspected earlier by Smith from observations made without an analyser; he suggested at that time that identification

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of alpha waves was difficult or impossible when the slower waves were simultaneously present.

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The Electroencephalogram of Man


