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# TEXTBOOK OF MEDICAL PHYSIOLOGY

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forth information that has been stored in the memory of the computer or to call forth information that is given to the computer at its input, information that is comparable to sensory information in the human being.

2. The programming unit can "find information" when its exact locus is not known. In the computer, this is achieved by dictating certain qualities required of the information and then searching through hundreds or thousands of stored bits of information until the appropriate information is found, a function called *scanning*. We know from psychological tests that our own brain can perform this same function, though we do not know how it does so. Yet, since the thalamus perhaps plays a role in directing our attention to stored information in specific areas of the cortex, it is reasonable to postulate that the thalamus, probably operating in conjunction with other basal areas of the brain, plays a major role in this scanning operation.

3. The programming unit of a computer determines the sequence of processing of information. Our brain can also control its thoughts in orderly sequence. Here again, mainly on the basis of anatomical considerations and on the basis of the fact that the reticular activating system is the primary controller of cerebral activity, it can be surmised, until we know more about the subject, that the reticular activating system is the primary controller of our orderly sequence of thoughts.

It is obviously premature to suggest an anatomical locus for the scanning function of the brain; indeed, this function probably requires complex circuitry that involves several loci. However, good candidates for this function are the centrum medianum and the medial dorsal nucleus of the thalamus, both of which are located in the middle of each half of the thalamus. They are large nuclei surrounded on all sides by the diffuse thalamic system, and they make multiple bidirectional connections with essentially all parts of the thalamus. Obviously, they are propitiously located for playing major roles in determining attention, drive, and so forth.

### *EFFECT OF BARBITURATE ANESTHESIA ON THE RETICULAR ACTIVATING SYSTEM*

The barbiturates have a specific depressant effect on the brain stem portion of the reticular activating system. Therefore, barbiturates obviously can either depress brain activity or even cause sleep. Yet it is especially interesting that barbiturate anesthesia does not block transmission in most of the specific sensory systems and also does not entirely block function of the thalamic portion of the reticular activating system. It is probable that many other clinically used anesthetics also have specific depressant effects on the brain stem portion of the reticular activating system and in this way cause general anesthesia.

## BRAIN WAVES

Electrical recordings from the surface of the brain or from the outer surface of the head demonstrate continuous electrical activity in the brain. Both the intensity and patterns of this electrical activity are determined to a great extent by the overall level of excitation of the brain resulting from functions in the reticular activating system. The undulations in the recorded electrical potentials, shown in Figure 54–3, are called *brain waves*, and the entire record is called an *electroencephalogram* (EEG).

The intensities of the brain waves on the surface of the scalp range from zero to 300 microvolts, and their frequencies range from once every few seconds to 50 or more per second. The character of the waves is highly dependent on the degree of activity of the cerebral cortex, and the waves change markedly between the states of wakefulness and sleep.

Much of the time, the brain waves are irregular, and no general pattern can be discerned in the EEG. However, at other times, distinct patterns do appear. Some of these are characteristic of specific abnormalities of the brain, such as epilepsy, which is discussed later. Others occur even in normal persons and can be classified into *alpha*, *beta*, *theta*, and *delta waves*, which are all illustrated in Figure 54–3.

*Alpha waves* are rhythmic waves occurring at a frequency between 8 and 13 per second and are found in the EEG's of almost all normal persons when they are awake in a quiet, resting state of cerebration. These waves occur most intensely in the occipital region but can also be recorded at times from the parietal and frontal regions of the scalp. Their voltage usually is about 50 microvolts. During sleep the alpha waves disappear entirely, and when the awake person's attention is directed to some specific type of mental activity, the alpha waves are replaced by asynchronous, higher frequency but lower voltage waves. Figure 54–4 illustrates the effect on the alpha waves of simply opening the eyes in bright light and

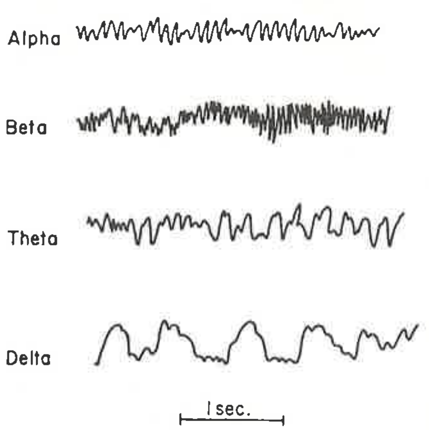

**Figure 54–3.** Different types of normal electroencephalographic waves.

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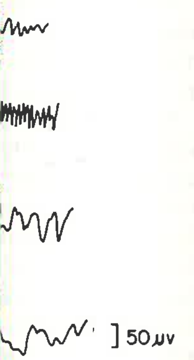

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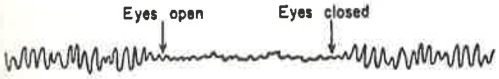

**Figure 54–4.** Replacement of the alpha rhythm by an asynchronous discharge on opening the eyes.

then closing the eyes again. Note that the visual sensations cause immediate cessation of the alpha waves and that these are replaced by low voltage, asynchronous waves.

*Beta waves* occur at frequencies of more than 14 cycles per second and as high as 25 and rarely 50 cycles per second. These are most frequently recorded from the parietal and frontal regions of the scalp, and they can be divided into two major types, *beta I* and *beta II*. The beta I waves, which are illustrated in Figure 54–3, have a frequency about twice that of the alpha waves, and these are affected by mental activity in very much the same way as the alpha waves—that is, they disappear and in their place appears an asynchronous but low voltage recording. The beta II waves, on the contrary, appear during *intense* activation of the central nervous system or during tension. Thus, one type of beta wave is inhibited by cerebral activity while the other is elicited.

*Theta waves* have frequencies between 4 and 7 cycles per second. These occur mainly in the parietal and temporal regions in children, but they also occur during emotional stress in some adults, particularly during disappointment and frustration. They can often be brought out in the EEG of a frustrated person by allowing him to enjoy some pleasant experience and then suddenly removing this element of pleasure; this causes approximately 20 seconds of theta waves. These same waves also occur in many brain disorders.

*Delta waves* include all the waves of the EEG below 3½ cycles per second and sometimes as low as 1 cycle every 2 to 3 seconds. These occur in deep sleep, in infancy, and in very serious organic brain disease. And they occur in the cortex of animals that have had subcortical transections separating the cerebral cortex from the thalamus. Therefore, delta waves can occur strictly in the cortex independently of activities in lower regions of the brain.

## *ORIGIN OF THE DIFFERENT TYPES OF BRAIN WAVES*

The discharge of a single neuron or single nerve fiber in the brain cannot be recorded from the surface of the head. Instead, for an electrical potential to be recorded all the way through the skull, large portions of nervous tissue must emit electrical current simultaneously. There are two ways in which this can occur. First, tremendous numbers of nerve fibers can discharge in synchrony with each other, thereby generating very strong electrical currents. Second, large numbers of neurons can partially discharge,

scalp

though not emit action potentials; furthermore, these partially discharged neurons can give prolonged periods of current flow that can undulate slowly with changing degrees of excitability of the neurons. Simultaneous electrical measurements within the brain while recording brain waves from the scalp indicate that it is the second of these that causes the usual brain waves.

To be more specific, the surface of the cerebral cortex is composed almost entirely of a mat of dendrites from neuronal cells in the lower layers of the cortex. When signals impinge on these dendrites, they become partially discharged, emitting negative potentials characteristic of excitatory postsynaptic potentials, as discussed in Chapter 46. This partially discharged state makes the neurons of the cortex highly excitable, and the negative potential is simultaneously recorded from the surface of the scalp, indicating this high degree of excitability.

One of the important sources of signals to excite the outer dendritic layer of the cerebral cortex is the ascending reticular activating system. Therefore, brain wave intensity is closely related to the degree of activity in either the brain stem or the thalamic portions of the reticular activating system.

**Origin of Delta Waves.** Transection of the fiber tracts from the thalamus to the cortex, which blocks the reticular activating system fibers, causes delta waves in the cortex. This indicates that some synchronizing mechanism can occur in the cortical neurons themselves—entirely independently of lower structures in the brain—to cause the delta waves.

Delta waves also occur in very deep "slow wave" sleep; and this suggests that the cortex is then released from the activating influences of the reticular activating system, as was explained earlier in the chapter.

**Origin of the Alpha Waves.** Alpha waves will *not* occur in the cortex without connections with the thalamus. Also, stimulation in the diffuse thalamic nuclei often sets up waves in the diffuse thalamocortical system at a frequency of between 8 and 13 per second, the natural frequency of the alpha waves. Therefore, it is assumed that the alpha waves result from spontaneous activity in the diffuse thalamocortical system, which causes both the periodicity of the alpha waves and the synchronous activation of literally millions of cortical neurons during each wave.

## *EFFECT OF VARYING DEGREES OF CEREBRAL ACTIVITY ON THE BASIC RHYTHM OF THE ELECTROENCEPHALOGRAM*

There is a general relationship between the degree of cerebral activity and the average frequency of the electroencephalographic rhythm, the frequency increasing progressively with higher and higher degrees of activity. This is illustrated in Figure 54–5, which shows the existence of delta waves in stupor, ScALP

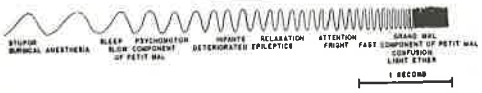

**Figure 54–5.** Effect of varying degrees of cerebral activity on the basic rhythm of the EEG. (From Gibbs and Gibbs: Atlas of Electroencephalography. Addison-Wesley, 1974.)

surgical anesthesia, and sleep; theta waves in psychomotor states and in infants; alpha waves during relaxed states; and beta waves during periods of intense mental activity. However, during periods of mental activity the waves usually become asynchronous rather than synchronous so that the voltage falls considerably, despite increased cortical activity, as illustrated in Figure 54–4.

## *CLINICAL USE OF THE ELECTROENCEPHALOGRAM*

One of the most important uses of the EEG is to diagnose different types of epilepsy and to find the focus in the brain causing the epilepsy. This is discussed further below. But, in addition, the EEG can be used to localize brain tumors or other space-occupying lesions of the brain and to diagnose certain types of psychopathic disturbances.

There are two means by which brain tumors can be localized. Some brain tumors are so large that they block electrical activity from a given portion of the cerebral cortex, and when this occurs the voltage of the brain waves is considerably reduced in the region of the tumor. However, more frequently a brain tumor compresses the surrounding neuronal tissue and thereby causes abnormal electrical excitation of these surrounding areas; this in turn leads to synchronous discharges of very high voltage waves in the EEG, as shown in the middle two records of Figure 54–6. Localization of the origin of these spikes on the surface of the scalp is a valuable means for locating the brain tumor.

The upper part of Figure 54–6 shows the placement of 16 different electrodes on the scalp, and the lower part of the figure shows the brain waves from four of these electrodes marked in the figure by X's. Note that in two of these, intense brain waves are recorded and, furthermore, that the two waves are essentially of reverse polarity to each other. This reverse polarity means that the origin of the spikes is somewhere in the area *between* the two respective electrodes. Thus, the excessively excitable area of the brain has been located, and this is a lead to the location of the brain tumor.

Use of brain waves in diagnosing psychopathic abnormalities is generally not very satisfactory because only a few of these cause distinct brain wave patterns. Yet by observing combinations of different types of basic rhythms, reactions of the rhythms to attention, changes of the rhythms with forced breathing to cause alkalosis, the appearance of particular characteristics in the brain waves (such as "spindles" of alpha waves), and so forth, an experienced electroencephalographer can detect at least certain types of psychopathic disturbances. For instance, it was pointed out above that theta waves are frequently found in persons with brain abnormalities.

## EPILEPSY

Epilepsy is characterized by uncontrolled excessive activity of either a part of the central nervous system or all of it. A person who is predisposed to epilepsy has attacks when the basal level of excitability of his nervous system (or of the part that is susceptible to the epileptic state) rises above a certain critical threshold. But as long as the degree of excitability is held below this threshold, no attack occurs.

Basically, the two different types of epilepsy are: *generalized epilepsy* and *focal epilepsy*. Generalized epilepsy involves essentially all parts of the brain at once, whereas focal epilepsy involves only a portion—sometimes only a minute focal spot and other times a moderate portion of the brain.

### *GENERALIZED EPILEPSY*

**Grand Mal.** Grand mal epilepsy is characterized by extreme neuronal discharges originating in the brain stem portion of the reticular activating system. These then spread throughout the entire central nervous system, to the cortex, to the deeper parts of the brain, and even into the spinal cord to cause generalized *tonic convulsions* of the entire body followed toward the end of the attack by alternating muscular contractions called *clonic convulsions*. The

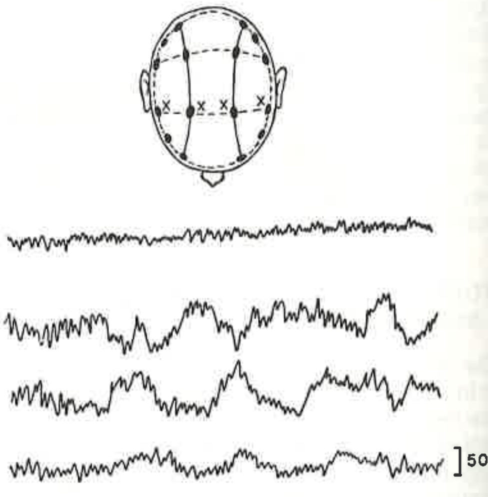

**Figure 54–6.** Localization of a brain tumor by means of the EEG, illustrating (above) the placement of electrodes and (below) the records from the four electrodes designated by X's.

**Figure 54–7.** Electroence
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