individual, and that is the drives. These would manifest themselves as intense urges, as intense needs and desires demanding gratification in a most compelling way. It is felt by many neonatal researchers that individuals show considerable variation in the strength of their drives even at birth. There have been many efforts to relate such behaviors as the frequency and the intensity of crying, the intensity of sucking, and various activity patterns to different strengths of drives in the neonate. Furthermore, the individual may enter the world with a given strength to these drives, and yet then have them modified by a variety of factors throughout the rest of his or her life.

Thus, there are a large number of more or less fixed factors, the irreducible minimum with which a person enters the world. These are the constitutional factors, and while substantial work is necessary in order to delineate all of them, they are clearly related to personality development and in some instances to the development of mental illness. And while our understanding of the genetic etiology in mental illness obviously is not elaborate, it is steadily increasing. Work by David Rosenthal, Seymour Kety, and many others has started to fill in some of the gaps. However, this remains a largely unchartered and fascinating area for further research and exploration.

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BRAIN AND BEHAVIOR: A BIOLOGICAL APPROACH

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Although man has been the subject of scholarly inquiry for centuries, as yet we know little about the nature of human behavior. The behavior of man and other animals is caused by a myriad of complex and intertwined, simultaneously occurring processes. Because all animals are biological beings, it is clear that a complete understanding of the nature and causes of behavior will require that behavior also be viewed from a biological perspective.

In recent years there has been a dramatic surge of interest in various interdisciplinary approaches to the study of behavior. Psychologists have rediscovered the brain and disciplines such as neurophysiology, neuroendocrinology, and neurochemistry. Other disciplines, including neuroanatomy, pharmacology, genetics, biophysics, and cybernetics, have also begun to contribute significantly to our understanding of behavior. It is now quite obvious that the study of behavior is not the private franchise of any single discipline. An interdisci-

plinary approach is not only to be tolerated, it is essential for a complete understanding of all the complexities of behavior.

For centuries philosophers have concerned themselves with how "mind" arises in man. For some time, the difficulties encountered in the experimental study of the brain sustained the "mind-brain dualism." Whatever we have come to know of the brain as a marvelous mechanism, it has remained difficult to understand how "mind" arises from brain. The relationship between the physical properties and characteristics of the human brain and the mental processes of integration and association is perhaps the most challenging of all the problems facing behavioral scientists today. It is astonishing to reflect on the fact that these mental processes, which we accept as a natural part of everyday life, are the products of delicate and complex electrical and chemical events in the myriad of cells which constitute the brain. The way in which the context and continuity of personal experience arise from the interplay of these minute and delicate elements is still unfathomed.

However, in recent years we have indeed experienced a renaissance of interdisciplinary research which has provided some rather exciting insights into our understanding of human behavior. It is no longer possible to write a chapter or a book containing all existing facts and theories concerning the biology of behavior, and no attempt has been made to do so in this chapter. Rather, this chapter attempts to approach several scientific disciplines from a biological perspective and to present a concise overview of some of the essential features. As the earlier chapter on the physiology of the sexual response assumed a basic knowledge of the anatomy of the sexual organs, so also do this chapter and the next assume some familiarity with the basic principles of neurochemistry and electrophysiology.

NEUROCHEMISTRY

In the last decade there has been a growing interest in the neurochemical basis of behavior. This interest has been primarily focused on the role of *neurotransmitters* in the central nervous system (CNS). Since the evidence for chemical transmission is virtually conclusive, a vigorous search for specific transmitter substances is currently in progress. A number of criteria must be met in order to prove beyond question that a given chemical is in fact the excitatory or inhibitory transmitter substance at a particular synapse (connection) between neurons (nerve cells). These criteria may be stated as follows:

1. The presynaptic terminals must contain the substance or precursor to the substance.
2. Electrical stimulation of presynaptic terminals must cause release of the substance.
3. Introduction of low concentrations of the substance must cause activation of the postsynaptic membranes.
4. An enzyme that activates or destroys the substance must be found in the vicinity of the synapse.

Acetylcholine (Ach) is one such transmitter substance, and it is localized largely in nerve endings and synaptic vesicles of the brain stem and motor cortex. It is synthesized from choline and acetyl coenzyme *A* by choline-acetylase. Rapid destruction of acetylcholine is essential for the restitution of the resting potential of the excitable membrane. It is now generally accepted that acetylcholine acts as the chemical transmitter at preganglionic and postganglionic parasympathetic nerve endings, at preganglionic sympathetic nerve endings, and in neuromuscular junctions. Acetylcholine is quite essential as a stimulant of neural activity. When injected intravenously or topically applied to the cortex of the brain, Ach increases the activation pattern of the electroencephalogram (EEG). On the other hand, anticholinergic drugs such as atropine and scopolamine impair cortical arousal without any effect on behavior. This is a case of dissociation between brain and behavior. During periods of time when the brain is electrically very active (e.g. during convulsions), brain levels of Ach decrease, presumably due to the metabolism of Ach released during the multiple synaptic transmissions.

While acetylcholine does not appear to be directly involved in the organization of the sleep-waking cycle, it has been implicated as a possible chemical mediator for a number of behaviors. It has been proposed that anticholinergic drugs may block normal behavioral inhibition. After the administration of an anticholinergic compound, animals are quite unable to

perform a task which requires inhibiting a previously learned response. Other researchers have implicated cholinergic mechanisms in the regulation of water intake. It has also been demonstrated that the administration of Ach into the corpus striatum of the brain can induce tremors which will then disappear if Ach synthesis is inhibited. Therefore, it has been suggested that Parkinsonian tremors may be caused by overactivity in the cholinergic neurons of the corpus striatum, and it has been demonstrated that anticholinergic compounds can be effective in reducing these tremors.

Dopamine (DA) is the chemical precursor of norepinephrine, which is found in nerve endings in the brain with its highest concentration in the corpus striatum, tuberculum olfactorium, and the nucleus accumbens of the basal ganglia. The idea that dopamine acts as a transmitter in its own right with specific behavioral effects is supported by experimental results which show that the stereotyped motor activity observed in rats injected with amphetamine remains unchanged when the synthesis of norepinephrine from DA is inhibited. This activity therefore seems to depend entirely on dopamine. When the synthesis of DA is also inhibited, the stereotyped behavior is prevented but can be restored by the injection of DA into the corpus striatum. There is a wealth of evidence which suggests that this agent may have an important role in extrapyramidal function. It has been reported that blockade of dopamine receptors results in abnormal extrapyramidal activities. L-dopa is a precursor for DA synthesis and has been found to be quite effective in the treatment of Parkinson's disease by increasing the missing amine of the corpus striatum. Therefore, it is now well known that endogenous dopamine appears to play an important role in normal motor control in man. It has been demonstrated that blockade of dopamine receptors by specific drug antagonists results in impairment of normal motor control. In fact, extrapyramidal symptoms constitute the most undesirable side effect in the administration of phenothiazines and butyrophenones for the treatment of psychosis.

Norepinephrine (NE) is stored in granules within the synaptic vesicles. Brain NE derives from tyrosine which is initially hydroxylated to dopa. Dopa is then decarboxylated to dopamine (DA) and then with the use of an enzyme known as dopamine-β-hydroxylase, NE is formed. NE is found particularly in the pons, medulla, and locus ceruleus of the brain stem. Other brain areas which have a high concentration of NE include the hypothalamus, basal forebrain, the medial forebrain bundle, and parts of the limbic system. NE neurons seem to be involved in many generalized CNS functions such as sleep and wakefulness, emotion, neuroendocrine function, and possibly temperature regulation. When brain levels of NE are elevated by drugs such as amphetamine, the organism is usually in a state of excitation. Drugs that decrease levels of brain NE, such as large amounts of alcohol, produce sedation.

Traumatic experiences such as electrical foot shocks and electroconvulsive treatment increase NE turnover in the brains of animals. A drop in the NE level in the brain has indeed been found in conditions of severe stress, indicating an increased rate of discharge. A decrease in the tissue levels of NE may be due to a decrease of synthesis or an acceleration of utilization. Since stresses are known to lead to an increased excretion of catecholamines and their metabolites, it is safe to conclude that the drop in the level of brain NE found after stress is due to increased discharge. In order to produce a measurable depletion of NE in the brain, stress has to be both severe and prolonged.

In general, it would be quite erroneous to imply that the effects of stress on brain NE are clear. The paradoxical findings of administered brain NE can possibly be explained by the use of unusual dosage, by an action on brain centers different from those reached by the endogenous transmitter, or by a combination of these factors.

5-hydroxytryptamine (5-HT) commonly called *serotonin* has been implicated as a synaptic transmitter in the brain. It is an indoleamine, deriving from the essential amino acid L-tryptophan. In accordance with its probable function as a transmitter, the greater part of serotonin in a brain homogenate is particle-bound and associated with the nerve endings. The serotonergic neurons of the central nervous system arise from cell bodies located mainly in the raphe nuclei of the medulla, pons, and the upper brain stem. High concentrations of 5-HT are also found in the pineal gland. Stimulation

of the midbrain raphe in vivo has been shown to produce increase in serotonin catabolism in the forebrain.

Unfortunately, in the mammalian CNS, specific connections have not yet been discovered at which the effects of neurally released 5-HT can be compared with the effects of 5-HT applied directly to postsynaptic receptors, with regard to certain inhibitory effects of serotonin. The suggestion has often been made that it is not due to a direct action of serotonin on the postsynaptic membrane, but to a presynaptic inhibition, perhaps a prevention of acetylcholine release.

One of the most interesting aspects in considering the possible role of serotonin in the brain is that serotonin contains the indole nucleus as part of its chemical structure. The very same indole nucleus is present in a number of behaviorally active drugs including reserpine and LSD. This raises the exciting possibility that these drugs might exert their effects by mimicking or antagonizing serotonin's effect on CNS synapses.

Inhibition of 5-HT synthesis brings about a drastic reduction in the duration of sleep in cats. It has been demonstrated that lesions of the raphe nuclei which contain numerous 5-HT neurons can easily disrupt sleeping patterns in cats. The reduction of sleep is highly correlated with the loss of 5-HT from the forebrain. It is quite possible that 5-HT and NE interact in the forebrain to initiate and organize sleep-waking patterns. Lesions of the raphe nuclei in rats result in a decreased level of serotonin in the forebrain and are manifested by increased spontaneous motor activity and an arousal pattern in the frontal cortical EEG activity. Serotonin appears to be critical in the induction of slow wave sleep. Levels of serotonin are usually high during the hours of sleep and low during waking hours. Insomnia can easily be produced in cats by the destruction of serotonergic neurons of the raphe nuclei or by inhibition of serotonin biosynthesis with the aid of *p*-chlorophenylalanine.

ELECTROPHYSIOLOGY

Sleep and Dreaming

Awareness and the state of sleep are two phases of human existence present from birth. Sleep, an intricate phase of life, is equal to waking in importance. Sleep may be defined as a natural, temporary, and periodic state of rest, characterized by a diminution of activity and consciousness with a partial loss of response to environmental stimuli. The causes and nature of sleep and dreaming have been a source of speculation and fascination since ancient times, but the attempt to understand dreams scientifically only began with the publication of Freud's masterpiece, *The Interpretation of Dreams*, in 1900.

Sleep usually occurs in a cyclic fashion so that a sleep-wakefulness cycle may be observed. Reduction of sensory stimuli such as auditory, visual, and proprioceptive stimuli is particularly conducive to sleep. Assumption of the reclining, horizontal position, an outstanding characteristic of sleep in man and many animals, permits relaxation of many of the body muscles including the muscles of the jaw, soft palate, and uvula. However, complete muscle relaxation does not occur during sleep; special muscle groups may remain contracted except during very deep sleep. The anal sphincter and the muscles around the eyes and eyelids are contracted during sleep. Position is frequently changed during sleep so that different muscles are temporarily used. This may occur as often as 20 to 40 times a night for a total of three to four minutes every night. It involves a pseudo awakening which is usually not recalled.

In 1953 Aserinsky and Kleitman discovered that rapid eye movements occur in subjects who are sleeping. It was later learned that these rapid eye movements occur during a specific state of sleep, designated by the term *rapid eye movement* (REM) *sleep*. It is during REM sleep that dreams occur. The remainder of sleep has been designated as *non-rapid eye movement* (NREM) *sleep*.

By and large, NREM sleep is defined by the electroencephalogram (EEG), and is characterized by a continuously changing flux of strikingly different electroencephalographic (EEG) patterns. NREM sleep is best classified by four discrete, discontinuous categories of EEG states or stages, as illustrated in Figure 48.1.

Stage 1 occurs primarily in the transition from wakefulness to the other sleep stages. During this period rapid eye movements (REM)

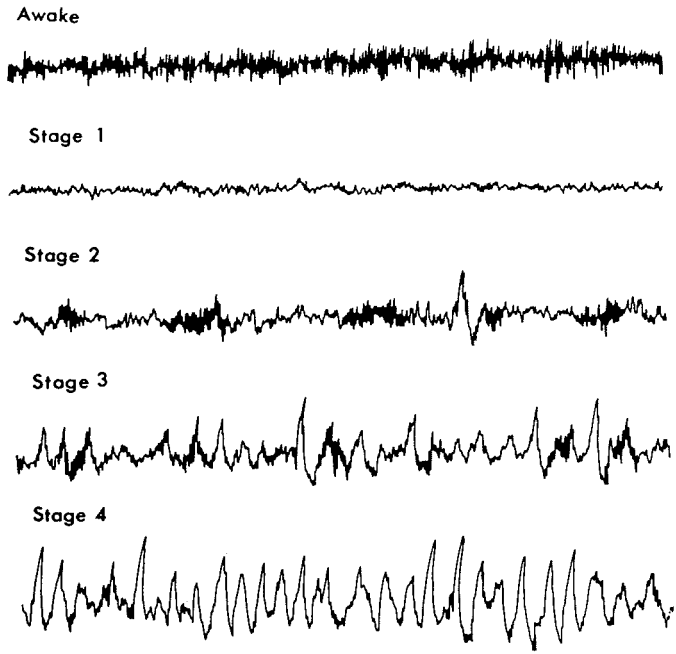

Figure 48.1 EEG tracings of sleep stages. These sample tracings of a subject's brain waves were made during a single night. The recording paper was moving under the pens at one-third the standard speed, which means that the waves are somewhat pushed together. The top line shows the 10-per-second alpha waves characteristic of the "awake" EEG. Their mean amplitude is about 50 microvolts. The *stage 1* tracing shows a mixture of low voltage, irregular, relatively fast waves. The *stage 2* tracing shows the characteristic waxing-waning bursts of regular waves (sleep spindles) lasting one to two seconds. The frequency of the spindle waves is about 12 to 14 per second, which causes them to be somewhat blurred at this paper speed. Nonetheless they stand out sharply from the low voltage, irregular background rhythms. A moderate amount of high voltage, slow activity waves is seen in the *stage 3* tracing. *Stage 4* is characterized by continuous high voltage, slow activity waves. Their frequency is about one per second. (From Dement, W. C. An essay on dreams. In *New Directions in Psychology,* vol. 2. Holt, Rinehart and Winston, New York, 1965).

are absent and tonic electromyographic (EMG) levels are usually below those of relaxed wakefulness. The EEG shows a mixture of low voltage, irregular, relatively fast waves.

Stage 2 includes a number of sleep spindles in the EEG, which are slow negative waves followed by a positive component. The sleep spindles are quite sporadic, and last from one to two seconds.

Stage 3 is defined by the occurrence of slow wave, high voltage activity (2 cycles per second and 75 microvolts) occurring between 20 and 50% of the total sleep time.

Stage 4 is quite similar to stage 3. However, the slow wave, high voltage activity is continuous and occurs more than 50% of the total sleep time.

As compared to wakefulness, NREM sleep is characterized generally by an overall lower level of activity, with slower respiration, slower heart rate, lower blood pressure, and lower body temperature.

REM sleep is characterized by an EEG pattern similar to that of Stage 1 NREM sleep, namely a low voltage, relatively fast, mixed frequency pattern. However, the REM EEG pattern includes sawtooth waves that are unique to these periods, as illustrated in Figure 48.2. In addition to the rapid eye movements, an important feature of REM sleep is the tonic inhibition of motor output. During REM sleep nearly all of the muscles are flaccid and relaxed, and the tonic electromyograph (EMG) almost always reaches its lowest levels during REM sleep.

During REM sleep blood pressure rises and

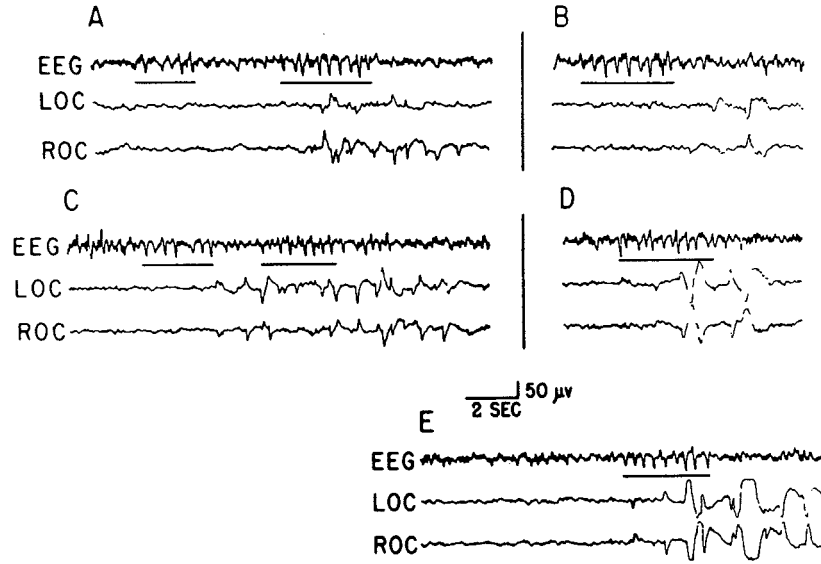

Figure 48.2 Rapid eye movement (REM) sleep electroencephalogram (EEG) patterns. These sample tracings show the sawtooth waves that precede bursts of rapid eye movement. EEG is monopolar from the central electrode; *LOC,* left outer canthus to ears; *ROC,* right outer canthus to ears. (From Dement, W. C. Eye movements in sleep. In *The Oculomotor System,* edited by M. Bender. Hoeber Medical Division, Harper & Row, New York, 1964.)

the heart rate shows some acceleration. In addition respiration accelerates and there is an increase in oxygen consumption. The REM period is characterized by a marked increase in neuronal firing, a rise in brain temperature, and, as noted, a tonic inhibition of motor output. Recent studies have demonstrated that in man penile erection takes place during the REM period. One interesting characteristic of REM sleep is the occurrence of limb movements and changes in facial muscles.

REM sleep takes place approximately every 90 minutes during the total sleep in one night, lasts for about 15 to 20 minutes, and accounts for approximately 20 to 25% of the total sleep time in young adults. In the neonate, REM sleep accounts for 50% or more of the total sleep time, and this percentage may even be higher in premature infants. This relationship of age to dream cycle has been investigated rather extensively. A two year old dreams about 30 to 40% of his sleeping time. At age five dreaming decreases to 19% of sleep and stays at that level through adolescence. The proportion of dreaming increases to 25% at about age 20. Dream time averages 18% between ages 30 and 40 and a little less by age 50.

REM sleep is usually thought of as the period of dreaming. It has been reported that the greatest number of dream reports take place when subjects are awakened from REM sleep. Furthermore, the length of the dream is commensurate with the duration of the REM period. However, dreams are not necessarily or always visual. For example, blind persons do not have visual dreams or rapid eye movements. Dreams in which talking, music, or voices are the only remembered elements are common in persons who have strong auditory interests. Tactile elements also appear in dreams.

The consensus is that everybody dreams repeatedly every night, though most of the dream content is never recalled. Researchers commonly speak not of dreamers and non-dreamers, but of "recallers" and "non-recallers." Several differences between recallers and non-recallers of dreams have been suggested tentatively by some investigators. Persons who say they seldom or never dream have about the same four or five nightly dreaming periods as oth s, but spend less time in them. They seem to g t into and out of their dreams faster, and to do about one-fifth less dreaming than proficient dream-recallers.

Irresistible pressures to dream suggest that

dreaming has some biological purpose. There are indeed a plethora of theories about the "purpose" of dreams. Some have speculated that dreams help us to wipe out a thousand useless memories of the day, whereas others have conjectured that dreams help to consolidate memories. Freud held that dreams protect sleep. Occurrence of dreams during the light stage of sleep when the brain is nearly as alert as in the waking state, may be an ancient evolutionary pattern of protection to guard against possible danger. However, it may be erroneous to impute any vital biological function to dreams. Dreaming might be an acquired habit to which we return unfearingly every night.

Evoked Potential

Only quite recently has it become technically possible to record the electrical activity of the intact human brain in response to specific sensory stimuli. This development offers exciting new opportunities for the observation of brain responses to sensory stimulation. The relationship between brain-evoked potentials and psychological processes is perhaps one of the most challenging problems facing neuroscientists and psychophysiologists today.

While the term EEG (electroencephalography) pertains to all the ongoing electrical activity in the brain, the *evoked potential (EP)* refers to only a specific part of these background rhythms (Figure 48.3). The evoked potential is the specific detectable electrical change of any part of the brain in response to the stimulation of a peripheral sense organ, sensory nerve, point on a sensory pathway, or any related structure of the sensory system. This stimulation can be photic (e.g. light flash), auditory (e.g. distinct click), electric (e.g. pulses), olfactory, or any other stimulus that can be sensed by the nervous system.

The emergence of computer techniques has enabled neuroscientists to extract electrical responses to specific sensory stimuli from the total ongoing EEG. In order to separate out the signal (EP) from the noise (background EEG), it is necessary to stimulate the organism repetitively and record the neuroelectric potential immediately following each stimulus. This process is called *signal averaging*, and the principle on which it is based is that time-locked neuroelectric potentials will summate, while random fluctuations will cancel each other out.

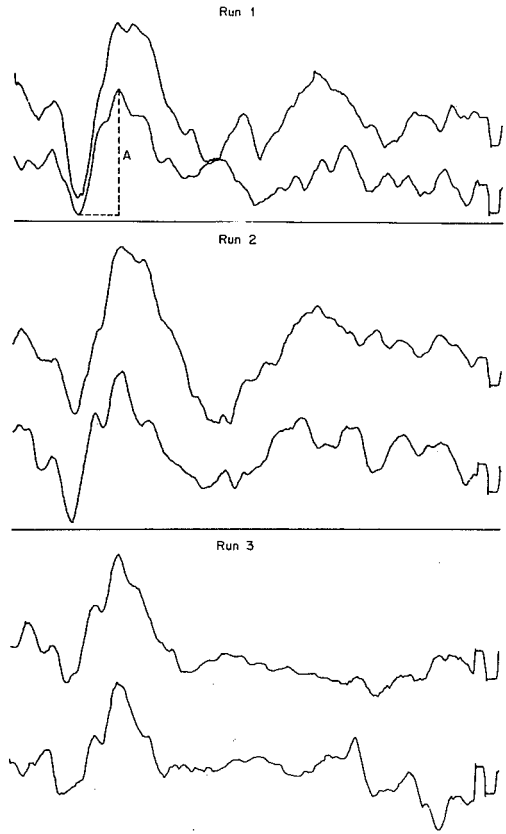

Figure 48.3 Visual evoked potentials obtained at Cz for one typical subject. In *Run #1* the top potential was evoked by a bright flash and the bottom one by a dim flash. In *Run #2* and *Run #3* all the potentials were evoked by a stimulus of medium intensity. The top traces were obtained with a medium stimulus preceded by a signal indicating the onset of a bright stimulus. The bottom traces represent the potentials evoked by the same medium stimulus, but preceded by a tone signaling the onset of a dim stimulus. Negative deflections are up; the time base is 500 milliseconds. The calibration pulse at the end of each wave form is equal to 5 microvolts; *A*, amplitude.

This is accomplished by introducing a timing pulse, coincident with the stimulus onset, which triggers the computer to begin sampling electrical brain activity for a predetermined amount of time. Thereafter, each occurrence of the timing pulse signals the computer to sample electrical activity for the same time span, and add it algebraically to the previously accumulated responses. Those components of the time function which are phase-locked to the

timing pulses reinforce themselves with each successive summation, while those components which are random and therefore not time-locked will tend to cancel each other out to zero.

The computerized evoked potential that emerges from the brain's background electrical activity is a rather complex pattern of wave components, with specific polarity, amplitude, and duration that lasts a total of 200 to 300 milliseconds. The time of occurrence (latency) and magnitude (amplitude) of each component can be accurately measured, and varies according to recording site, stimulus, and response parameters, as well as psychological states and processes. Characteristics of these electrical cerebral patterns indicate that they represent activity initiated by sense organs of the cortical and subcortical brain areas. The evoked response is multiphasic, and can be readily divided into two major components: the early components are often considered to indicate sensory input, while the late components reflect the more cognitive aspects of perception.

Research efforts in the area of evoked potentials have attempted to discover the means by which the brain first processes incoming sensory information, then forms internal representations of the external world, and finally makes a behavioral response. Animal data is of great scientific value in determining more rudimentary information about the exact nature of neural correlates underlying specific sensation, as for example the activity in a particular cell or population of nerve cells and the identification of a specific neuroanatomical site. However, electrophysiological studies of those more complex brain functions which are unique in man must necessarily be investigated solely in human subjects. The quantitative and qualitative descriptions of sensations and experience which can be provided by human subjects are obviously much more detailed than any corresponding behavioral data attainable from animals.

The study of evoked potentials of different brain structures is a powerful tool for obtaining increased insight into the functioning and communication of the brain. Evoked potentials spread and travel from one part of the brain to another. By means of several, simultaneous recording electrodes, the way in which the evoked potential travels can be mapped. This spread and transformation of evoked potentials in brain space constitutes an important measure which can be related to perceptual processes. Modifications in evoked potentials occur in conjunction with known subjective perceptual changes that accompany stimulus modifications.

Numerous psychophysical experiments have been performed, modifying physical stimulus parameters while monitoring the resultant perceptual experiences and concomitant evoked potential characteristics. Studies dealing with brightness perception, for example, have found that as perceived brightness increases, so too does the evoked potential amplitude. With the use of psychophysical techniques, evoked potentials can serve as indices of subjective perception, thus bridging the gap between clearly measurable stimulus parameters (input) and the resultant perceptual change (output). While the relationship between man's evoked potential and the physical attributes of his environment are of great interest, the most fascinating aspect of evoked potential research for the psychologist is the sensitivity of the evoked potential to subtle psychological variables.

Since the human organism is constantly being bombarded with sensory stimulation, his nervous system acts to cope expediently with signals impinging on him—selectively focusing his attention on certain significant aspects of his environment, while excluding other non-significant stimuli. When a stimulus is successively and monotonously repeated, the amplitude of the averaged evoked response to that stimulus becomes concomitantly reduced in amplitude. This phenomenon is known as *habituation*, and can be considered as a form of adaptive behavior or learning (learning not to attend). Evoked potential studies of habituation have determined that late waves beginning approximately 150 milliseconds after the stimulus, are more susceptible to habituation than early components, which are fairly resistant to repetitive stimulation. In addition, the phenomenon of habituation is more readily observed at central scalp locations than in primary receiving areas, suggesting that the late components, particularly in the vicinity of higher cortical centers, are most reflective of the psychological aspects of perception.

Late components of the evoked potential are also sensitive to other attentional phenomena (e.g. vigilance, distraction). Numerous experi-

ments dealing with tasks directing attention toward and away from the evoking stimulus have concluded that increased attention toward a stimulus is paralleled by increased average evoked potential amplitude, and similarly, decreased attention toward a stimulus results in decreased average evoked potential amplitude.

In recent years, we have conducted an integrated, long-range program of research in our laboratory in which we have demonstrated that the evoked brain potentials recorded from the scalp of humans are reliably sensitive and lawfully related to manipulations of psychological variables. Our research efforts have been concerned with an investigation of the relationship between various aspects of "meaning" and "stimulus significance," and the cerebral evoked potential.

The way in which a stimulus acquires meaning (via learning processes) and its evoked potential concomitants was the focus of one such program of research, which relied on conditioning techniques to accomplish this end. We found that modifications in the late component amplitude of the visual evoked potential systematically paralleled the acquisition and extinction phases of the learning process, suggesting that these late components reflect the release of neuronal patterned activity influenced by both the present and past relevant experience of the organism.

Numerous studies have investigated various aspects of *stimulus significance* phenomena and evoked potentials. Late components of the visual evoked potential are sensitive to factors such as the degree of certainty of stimulus occurrence, and correctness of guess. The higher the probability of a stimulus occurring, the less the amount of information delivered by the stimulus, and consequently the lower the evoked potential amplitude. Furthermore, the latency (time of occurrence) of this large late positive deflection (which occurs around 300 milliseconds after the stimulus and is known as P300) is dependent on the time of the reduction of uncertainty. Other data have shown that an electrical brain event even occurs to an expected, but physically absent stimulus. These so-called *emitted potentials* resemble those evoked by real stimuli when they are actually presented.

We have also investigated the area of "stimulus significance" in a series of studies examining the expectation of specific relevant stimulus characteristics. We have been able to show that potentials evoked by the same physical stimulus are dramatically different depending on what stimulus is expected. Using the intensity dimension of flashes as our relevant stimulus characteristic, we were able to demonstrate that when a stimulus of medium intensity is preceded by a signal indicating the occurrence of a bright flash, the resultant evoked potential is more similar in amplitude to the potential obtained to a "real" bright flash. The potentials evoked by the medium flash when a dim flash was signaled closely resembled the potentials evoked when the dim flash actually was presented. However, this study makes the assumption that the subject's own expectancy is consistent with the one signaled. Thus, in another experiment, no external cue signals were presented, but rather, the subject generated his own stimulus expectancy by requesting the stimulus he wished to see, either bright or dim. Medium flashes were interspersed among the bright and dim flashes, and evoked potentials to these identical medium flashes were compared depending on whether they were expected to be bright or dim. When a bright flash was anticipated, the potentials evoked by a medium stimulus intensity resembled those elicited by an actual bright flash, whereas when a dim flash was expected, potentials evoked by the identical medium flash resembled those to a dim flash. Thus, a subject's internal expectancy of the physical parameters of a stimulus are at least as important in determining the resultant visual evoked potentials as the actual physical features of the stimulus.

In a recent study, we extended our research in the area of "stimulus significance" and "meaning" one step further, and related it to the *decision-making* process; more specifically, we investigated decision making with respect to a particular physical property of the stimulus, in this case intensity. In this experimental design, subjects judged bright, dim, and medium flashes to be either bright or dim, in a forced-choice paradigm. Evoked potentials obtained to medium flashes judged bright resembled those elicited by actual bright flashes, whereas those judged dim resembled actual dim responses. Thus, the decision about the physical properties of a stimulus dictates certain characteristics of the evoked potential to

that stimulus. The evoked potential undergoes a modification leading to a markedly different waveshape which corresponds more with the subsequent behavioral outcome than with the actual physical properties of the stimulus presented.

It can be concluded from our research program in the area of "stimulus significance" and "meaning" that these more psychological aspects of information processing are most important in determining certain evoked potential characteristics, namely, late component amplitude, latency, and wave form.

Another area of interest in the study of "meaning" and evoked potential is *affective loading*. Stimulus significance in these studies refers to the subjective affective reaction the stimulus evokes in the subject, whether pleasant or unpleasant. In one such study, evoked potentials were elicited to focused and unfocused picture slides of pleasant, neutral, and unpleasant contents (e.g. "art," scenic, and leg-ulcer slides, respectively). In another "affect" experiment, we investigated the influence of affective meaning on visual evoked potentials with and without the subject's awareness. Previously meaningless figures (conditioned stimulus) acquired different affective loading with the use of conditioning techniques. The same figure, rotated in three possible orientations, was associated with words of either positive, negative, or neutral affect, respectively. The results indicated that the amplitude of the evoked potential seemed to differ with each affective condition—hardly influencing responses to the neutral stimulus, and producing the most pronounced effect in the response to the negative figure. The late component of the evoked response was found to be most sensitive to affective loading. In another study of affect, we have also examined evoked potentials to visually presented taboo words, neutral words, and blank flashes, with and without the subject's response (saying the word aloud). Taboo words elicited the largest late component visual evoked potentials, particularly when a verbal response was required, while blank flashes produced the smallest visual evoked potentials (although they were brightest).

All of these studies have demonstrated that under some circumstances, *certain aspects of previous experience are reflected in the evoked electrical activity of the human brain*. The waveshape of this electrophysiological response is not solely determined by the physical stimulus itself, but also reflects the activation of endogenous neural processes related to the past experience and present state of the organism. Although at present the precise nature of the neural "codes" underlying the organization of experience and behavior is rather ambiguous, hopefully we will eventually come to understand these "codes" in terms of the complex firing patterns of brain neurons, which are so well reflected in the specific evoked brain potential characteristics.

Biofeedback

Conditioning methods are quite useful for learning to do, or to stop doing, almost anything. However, it should be pointed out that, at the present time, very complex behavior cannot be controlled by just any conditioning methods.

A large body of scientific literature shows plainly that conditioning methods can be used to control several types of voluntary and involuntary activity, affective thinking, language, emotion, motivation, habits, and skills. People can be conditioned to blush to meaningless words and to hallucinate to signals; to feel fear or arousal upon demand; to feel cold when they are being warmed or warm when being chilled; to dilate or constrict their blood vessels or the pupils of their eyes; to establish habits and mannerisms they had never known before; and to break free from lifelong patterns of activity they thought would never be forgotten. There are two basic kinds of conditioning methods. *Classical conditioning* was developed by Ivan Pavlov in 1909 and was originally used to control internal, often involuntary, behavioral events like emotion, mood, sensation, and the functioning of smooth muscles in the stomach, blood vessels, and the heart. *Instrumental* or *operant conditioning* was first described by E. L. Thorndike in 1898 and has been fully developed by B. F. Skinner. It was originally used to demonstrate control of voluntary behavior, such as the teaching of social and intellectual skills and of voluntary motor and muscle activity. These two forms of conditioning will be discussed further in a later chapter on learning theory. In essence, classical conditioning re-

quires an antecedent stimulus, whereas in instrumental or operant conditioning the subject acts in response to feedback from his own experience, and no antecedent stimulus is required.

In recent years it has been amply demonstrated that both conditioning methods may be used to control either voluntary or involuntary behavioral or autonomic nervous system events. Broadly speaking, instrumental or operant conditioning is the essence of self-controlled behavior because it involves consciously learning to control many different responses to a problem, so that only the most "useful" one will finally be mastered. The greatest potential of instrumental conditioning for behavior control is to be found in the technique of *biofeedback*. It is the aim of biofeedback training to activate feedback from visceral organs, thus making such organs responsive to conscious control. The therapeutic potential of biofeedback, particularly in the treatment of psychosomatic diseases, is enormous.

Operating entirely with incentives and information feedback, given as the individual acts in ways which approach a particular goal or criterion, a great many changes in various bodily functions can be taught by this technique. The main difficulties in applying operant technology to any human problem are the need of the behavioral engineer to have complete enough control of the environment so that he can reward the individual as he chooses, and his need to have suitable rewards to dispense once he has control.

When instrumental techniques are used, a person's learning ability is sharply increased, especially when information about his own behavior is fed back to him. A Russian scientist, M. I. Lisina, found that she could not easily produce constriction and dilation of blood vessels until her experimental subjects were allowed to observe the recordings of their own vascular responses; upon knowing what the experimenter wanted, they were conditioned very quickly. At the University of California Medical Center, Joe Kamiya has been demonstrating for years that people can be taught to control some of their brain-wave patterns (alpha = 8–12 cps) by hearing a feedback buzzer whenever the desired pattern occurs. Eventually they learn to associate their subjective mental state with the buzzings so that, by reproducing that mental state, they can indeed reproduce the brain-wave pattern whether or not the buzzer is on.

Other researchers have reported similar control over functions such as: heart rate, blood pressure, respiration, various gastrointestinal functions, pupil size, etc. It is worth noting that all of the experiments cited above involve body processes which we usually think of as quite involuntary. To whatever extent someone can manipulate a subject's involuntary processes, or can teach him to manipulate them himself, then the subject is able to control them himself. The biological and psychological implications of these results for the meaning of volition is as important as their practical implications for the technology of control. Evidently some body functions become voluntary in direct proportion to the amount of information feedback the subject obtains. It is as if will and knowledge were reducible to the very same thing.

The range of medical problems to which these feedback training procedures can be fruitfully applied continues to grow at a rapid pace. Bernard Engel has already reported encouraging results in the use of biofeedback training to treat arrhythmias of organic origin. Randt has had some success in training epileptic patients to suppress the abnormal paroxysmal spikes in their electroencephalogram. Neal Miller and his colleagues havee studied the instrumental learning of many visceral responses and are actively pursuing the many possible therapeutic effects of biofeedback training techniques.

Biological Rhythms

Although the concept of *periodicity* in behavior has been an important part of medicine and folk lore since the beginning of time, it has only been very recently that we have begun to investigate scientifically the possible relationships between birthdates, planetary movements, biological rhythms, and behavior.

This new science of *chronopsychophysiology* is based upon the observation that nearly every physiological process has demonstrated a 24 hour periodicity. This inner biological clock that is responsible for our homeostatic physiological functioning has apparently become embedded through evolution. In addition to the major 24 hour day-night cycle, other *biological*

rhythms range from the microseconds of biochemical reactions, to the seconds of the heart cycle, to the 90 minute rapid eye movement cycle of dreaming, to the monthly menstrual cycle. The normal regularity of these various rhythms becomes apparent when there is disruption of the regularity because of disease, stress, or erratic external synchronization, as seen, for example, in *jet fatigue*.

The major 24 hour day-night cycle is referred to as *circadian* (circa: about; dies: a day). Rhythms shorter than 24 hours are defined as *ultradian,* and those longer than 24 hours are *infradian*. We will comment about the possible relationship between biological rhythms and psychopathology in the following chapter.

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NEUROBIOLOGICAL FACTORS IN MENTAL ILLNESS

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For the better part of this century more people have been hospitalized for mental illness than for all other diseases combined. It is important to note that the reduction of patient populations in mental hospitals coincides with the introduction of various psychopharmacological agents such as the tranquilizers and the antidepressants.

PSYCHOPHARMACOLOGY

Psychopharmacology (Figure 48.4) may be defined as the use of drugs in the treatment of