PHYSIOLOGY
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Dr. STANLEY KRIPPNER
Dr. ELEANOR CRISWELL

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Physiology of Consciousness

AUTHORS

DR. STANLEY KRIPPNER is president of Humanistic Psychology Institute San Francisco, California (U.S.A) and Author of "*The Measurement of Behaviour*", "*Psychology of Societies*", "*Cognitive Functions of Intentionality.*" and contributed a good number of articles in different Journals published around the Globe.

DR. ELEANOR CRISWELL is an Associate Professor of Psychology, California State College, Sonoma (U S.A.) and faculty member of the Humanistic Psychology Institute, San Francisco. (U.S A.).

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INTRODUCTION

In the physiological approach to consciousness, we consider the relationship between the public world of objects and the private world of Perception of those objects There are a series of transformations that mediate between an object and the perception of that object. The various forms of physical energy to which our nervous system is sensitive are transformed at the appropriate receptor into a pattern of nerve impulses, which are in turn transformed at the appropriate projection area of the cortex into perceptions. So it is that the physiological world of nerve impulses mediates between the physical world of objects and the psychological world of perceptions. These nerve impulses are the only messages accepted by the nervous system. Our perception of light cannot be produced by shining a flashlight directly on to the cortex Further more, these nerve impulses are qualitatively the same for all modalities Different qualitative experiences, such as sights, sounds, smells, tastes and touches, are produced from the same nerve impulses at the appropriate projection area of the cortex. Psychologists do not have all the answers to the puzzle of consciousness But this monograph presents some of the facts that are known as well as some ideas about what still needs to be understood.

All the world's a stage,
And all the men and women merely players.
They have their exits and their entrances,
And one man in his time plays many parts,
His acts being seven ages. At first, the infant,
Mewling and puking in the nurse's arms.
Then the whining schoolboy, with his satchel
And shining morning face, creeping like a snail
Unwillingly to school. And then the lover,
Sighing like a furnace, with a woeful ballad
Made to his mistress' eyebrow. Then a soldier,
Full of strange oaths and bearded like the pard,
Jealous in honour, sudden and quick in quarrel,
Seeking the bubble reputation
Even in the cannon's mouth. And then the justice,
In fair round belly with good capon lin'd,
With eyes severe and beard of formal cut,
Full of wise saws and modern instances;
And so he plays his part. The sixth age shifts
Into the lean and slipper'd pantaloon,
With spectacles on nose and pouch on side;
His youthful hose, well sav'd, a world to wide
For his shrunk shank, and his big manly voice,
Turning again toward childish treble, pipes
And whistles in his sound Last scene of all,
That ends this strange eventful history,
Is second childishness and mere obilvion,
Sans teeth, sans eyes, sans taste, sans everything.

William Shakespeare

Shakespeare demonstrates, as do other great artists, acute observations and insights into the nature of human behavior and the physiological contributions to behaviour. Their greatness depends on the accuracy of their portrayal of the breadth and depth of human existence and our recognition of it through the medium of our own experience. That is physiological psychology as an art.

Physiological psychology as a science began with the rise of scientific psychology in Germany and has continued until the present time within the general purview of experimental psychology. Physiological psychology is the study of the physiological correlates of behavior, the relationship between physiology and behaviour. It makes use of the research findings from a number of sciences including anatomy, biochemistry, physics, electronics, engineering, physiology, and of course, psychology.

How can one use a knowledge of physiological psychology ? Generally a study of physiological psychology is done from a third person perspective in which a scientist gathers information about the physiological processes of another organism. Rarely do physiological psychologists get around to using this information in a first person manner. *i.e.*, using the increased insights to understand their own personal behavior. However humanistic psychologists genenrally encourage students to become increasingly familiar with the basic concepts of physiological psychology and then gradually to begin to increase their awareness of these processes as they occur. The resulting increased awareness and appreciation of one's own physiological processes will enhance personal experience and the effectiveness of the processes themselves, This development is due to the fact that physiological psychology is fundamentally the psychology of consciousness; as one learns about the structures and functions of one's body, one can also learn how to modify and control many of those functions.

Becoming aware of one's physiological state can ultimately enable one to decide how well that state matches the needs of the present situation and whether one would like to change that physiological state or change that situation. In most technological cultures, people have a tendency to become increasingly unconscious as they grow older, of how they are feeling during certain situations because they are expected to behave as though nothing is happening within them......an assumption which may run counter to the needs of the situation. Increased awareness of one's internal states often enables a person to begin to control one's own response to a situation.

·Increasing this level of awareness through an increased knowledge and understanding of the factors occurring within oneself is important in view of T. Hanna's (1970 : 291-292) bleak description of Western culture's effects on the bodies, or somas, of its people :

> Within the space of about three hundred years, the human soma, by virtue of this intensely conscious rational perception and behavior, had accomplished two things : it had triumphed over its environment by its knowledge and use of technological controls and it had repressed its sensual-accommodative drives to the point that it had become somatically oblivious to the accommodative techniques of adaptation.

By planting itself firmly in an assimilative, aggressive stance, the physiological structure of the civilized person has beaten its environment at the expense of having lost much of the somatic abilities. This does not mean that a person, in redeeming the body, will behave like the thousand legged centipede that, upon being asked which leg it began on, could proceed no farther due to the confusion occasioned by the question. It means simply that for a time one becomes deliberately aware of as many of the physiological processes as possible, and after this period of awareness one returns to a natural relationship of oneself and one's responses within situations.

This data of physiological psychology is fascinating due to its familiarity; it is also interesting because it illustrates beautifully the ebb and flow of scientific research findings. What is considered the research insight about a particular physiological event may be upset by new findings at any moment. In fact, between the time that this chapter was written and the time at which a reader began to read it, someone, somewhere made a break through in our understanding of physiological processes. Therefore, all articles and books in this area should be read with a grain of salt, holding in abeyance the notion that a definitive chapter has been written on that particular topic.

Maps of the Body

Physiological psychologists have attempted to draw maps which correspond accurately to the territory of the human body. Among the first to make attempts along these lines were the practitioners of Chinese medicine who based their map of the body on Taoist writings. Health, according to this viewpoint, depended on the free circulation of vital energy ("chi") through a network of meridians that "irrigate" the body and "nourish" its organs. Illness is caused by an imbalance of "yin" and "yang" forces in the "chi" energy system. To restore balance, the skin is pricked or massaged at one or a number of the 824 acupuncture points distributed over the body, most of them along the meridians. A diagnosis can be made by taking the six pulses in the radial artery of each wrist. A careful reading tells which organs are affected, and a knowledge of the meridians tells which points to puncture.

Although dismissed as superstition by Western medicine for centuries, recent research has validated some of the concepts of Chinese medicine. Soviet biophysicists such as V. G. Adamenko have observed, through the use of high voltage electrophotography and various electrical measurement devices, that acupuncture points represent body areas where the skin resistance is very low (Krippner, Davidson, and

Peterson 1973). This work was expanded upon by R. O. Becker (1974) who found acupuncture points to be sources of direct current (D.C.) ; Becker also identified two "electro-chemical limbs" in the body which influence growth, healing, and biological cycles.

Research by Adamenko, Becker, and others has presented psychology with a new map of the body which may combine Western scientific expertise with Eastern Philosophical insight. This map was constructed by investigators who measured the D. C. potentials on skin surfaces, finding a complex field pattern that is spatially related to the anatomical arrangement of the nervous system. These surface potentials appear to be directly associated with the nervous system and can be measured directly on peripheral nerves where they demonstrate polarity differences depending upon whether the nerve is primarily motor or sensory in function.

The existence of electrical potentials in a conducting medium implies the existence of a steady current flow and experiments have indeed demonstrated that such a current exists. These potentials reflect, by means of their amplitude and polarity, the level of neural activity in sleep vs. wakefulness, anesthesia vs. full consciousness, etc. Further, the D.C. potentials appear to determine the level of neural activity, an observation which provides a logical basis for many of acupuncture's effects. For example, the meridians may be thought of as "transmission lines" and the acupunct re points as "spaced generating sources" the stimulation of which produces compensation for various electrical "resistances" and "losses." In fact, Soviet physicians report that electrical stimulation of the acupuncture points produces results more quickly than does the use of needles.

From the standpoint of traditional Western physiology, the nervous system may be sub-divided into the *central nervous system* FIG. 1 and the peripheral nervous system. The *peripheral nervous system* consists of the organism's receptors.

The brain and spinal cord make up the central nervous system. These cells are in the most protected parts of the body, being covered by the bones of the skull and in the vertebral column of the spine.

The nerves leading to the central nervous system are called the *afferent nerves* and those coming from it are called *efferent nerves*. Afferent nerves keep the central nervous system in contact with the outside world and with the body itself. They make connections with the sensory organs called receptors. Efferent nerves allow an organism—such as the human being—to respond to the world by connecting with the muscles or glands.

There are many kinds of receptors, Some receptors are specialized cells connected to afferent nerve fibers, others are modified nerve fibers, and still others are actual nerve fibers freely ending in the skin or in the deeper tissues of the body. All receptors transduce the stimulus they receive into nerve impulses. Each receptor is especially sensitive to the particular sort of energy it evolved to deal with. Reports to the central nervous system have already been partially *sorted* and *selected* by the specific receptors of the various sense organs. This sorting, selecting, and arranging is then continued throughout the central nervous system itself.

Receptors are usually classified into *exteroceptive receptors* that sample the environment and bring information to the central nervous system, *interoceptive receptors* that sample what is going on in the body itself, and *proprioceptive receptors* that sample stimulation from muscles, tendons, and joints. The exteroceptive receptors are the receptors of the specialized senses of vision, hearing, taste, smell, and the touch senses. The interoceptive receptors bring information regarding the stomach, the bladder, and other organs; of the pressure that the blood exerts against the walls of the heart, the blood vessels, and within the brain itself; of the amount of oxygen, carbon dioxide, and glucose in the blood; of the osmotic pressure of the blood; and of the temperature of the circulating blood. The proprioceptive receptors are the receptors within the inner ear that report the position of the body in space and the receptors in the muscles, tendons, and joints that sample information concerning the position and movements of the head, the limbs, and parts of the limbs.

There are receptors throughout most of the body that are sensitive to stimulation that causes pain. But there are no receptors sensitive to painful stimulation in the brain itself.

STIMULATION

To understand the receptors, one must understand the concept of *stimulation.* This process involves the activation of sense organs or nervous tissue by various forms of energy-electrical, mechanical, chemical, acoustical, electromagnetic, etc. All organisms live in an ocean of stimulation, constantly being bombarded by stimulation from many forms of energy.

As this energy hits the surface of the organism, it is transduced by a receptor, which is designed to receive that particular form of energy, into small electrochemical impulses which are propagated through the organism via nerve cells. These impulses are eventually conducted to the brain which is responsible for processing the electrochemical impulses as information, *i.e.*, perceiving them. At the same time the brain is alerted to the stimulation, if it is a novel stimulus or a change in the ongoing stimulation.

The ongoing stimulation which makes up the environment is limited to certain ranges for each organism. In fact, the environment can be conceived as a box which is reality. The boundaries of that reality are made up of the limitations of an organism's senses. For example, humans can only see within a certain visual spectrum that is somehow like the rainbow. However, a few individuals can see beyond that range as well as can those animals with more specialized visual systems.

Humans can hear sounds in the range of 20 to 20,000 cycles per second (cps). They can touch and discriminate textures only to a limited fineness of grain and not larger than a certain size They can tolerate temperatures only within a certain range and can smell only certain chemicals and combinations of chemicals. Proprioceptively, there are limitations to the trustworthiness of human's capacities to sense their bodies positioned in space; the pilot who doesn't learn to trust his instruments can find it confusing to the senses.

Actually, however, the amount of stimulation which impinges on humans in the natural course of a day is quite adequate to keep the organism functioning. Although there are certain drives and rhythms which characterize the human organism, external stimulation and change in stimulation is necessary for healthy functioning.

Examples of what happens without adequate stimulation can be found in the reports from prisoners of war and the results of sensory deprivation experiments. Sensory deprivation occurs when a person is placed in an environment which is devoid of the usual sources of stimulation. The original experiments in this area indicated that some research subjets found the resulting upsets and hallucinations intolerable. Thus, external stimulation has been considered the "food" of the nervous system, the "stuff" of higher mental activity.

Arousal

What happens when the nervous system receives stimulation? When the central nervous system receives the *afferent stimulus* or *stimulus input* (a computer term), its first response is *arousal*. This term refers to excitation of the nervous system. Another term sometimes used interchangeable with arousal is *activation*.

How does one know an organism is aroused? With most organisms one cannot ask directly, and one must not anthropomorphize (interpret in human terms). In the case of an *intact* (*i.e.*, non-surgically prepared) *organism*, researchers use various measures such as change in brain waves (*e.g.*, increased frequency/decreased amplitude), and an increase in heart rate, blood pressure, pupilary dilation, and galvanic skin response. In a sense, the physiological processes have been accelerated to prepare the organism for whatever behavioral or other responses may be necessary for survival.

Acceleration of the organism can be placed on a hypothetical continuum. This hypothetical continuum would begin with coma, go through sleep, through the hypnagogic and hypnopompic states present while entering or emerging from sleep, drowsiness, and wakefulness. The waking end of the continuum would go from awake to alert, very alert, and manic. These delineations do not deal at all with the phenomenology or content of consciousness, nor various dimensions of consciousnes; they deal only with levels and intensity.

During each day, one fluctuates from level to level, depending on external and internal stimulation, as well as other factors such as biological rhythms. This is not simply a passive process. There are a number of activities which one does, sometimes consciously and sometimes unconsciously, to change the level of activation.

At a low level of awareness, one's arousal level needs to match the energy demands of a particular task. Some tasks such as football or track require a high level or activation in order to carry out movements which need a great deal of energy output. Others require a moderate level of activation, as well as sustained attention, patience, and capacity to follow intricate details such as in writing and mathematical computation. Each task requires a careful match of the activation of the organism to the requirements of the task.

One theory as to why some individuals report they feel more effective after one or two cocktails has to do with the fact that some overly-tense individuals, a central nervous system depressant such as alcohol compensates for their overly-activated state and its lowering of effectiveness. But other individuals who begin the cocktail party at a different basal level of activation, might have their activation level so reduced that they are very inefficient, befuddled, and even drowsy.

Many organisms adapt to the level of environmental stimulation. That adaptation is studied by *adaptation level* theorists. Adaptation level theory recognizes that when one changes from one environmental stimulation to another, one must a apt to the new level, whether it is more or less stimulating. If the difference is too great, the discrepancy is experienced as painful and/or emotion-provoking, regardless of whether it is in a position (more stimulating) or negative (less stimulating) direction. Even when it is toward something ideally suited to one's desires—such as eagerly anticipated vacations—if it is too intense, the ecstasy will veer into painful areas. People who claim to have "mystical experiences" frequently report this "too much" aspect of extreme ecstasy and the wear and tear on their physical beings, even though they deem it worth the price.

When one moves into a less stimulating environment or away from a companion, one can actually experience withdrawal symptoms as one's body feels the fall from the accustomed stimulation levels (*i.e.*, fall in the level of adrenalin present within the system). Thus the level of arousal/activation determines how effectively one learns and remembers, how responsive is one's behavior, and how keenly one perceives.

VISION

Perception involves the interaction of the peripheral and central nervous systems. In the case of vision, one experiences a certain portion of electromagnetic radiation as light by means of the receptors in the eyes FIG. 2. Light enters the eye through the *cornea*, which is a modified portion of the sclerotic coating of the eye. The light then passes through the anterior chamber of the eye, which is filled with a fluid called the *aqueous humor*, of the interior chamber of the eye and reaches the *retina.*

The *lens* of the human eye is biconvex and elastic ; its curvature can be modified to focus on objects at different distances. To focus on near objects the dioptric power of the lens must be increased by accommodation. In accommodation, the curvature of the lens is increased by the contraction of the ciliary muscles in the eyeball. When we relax these muscles, the lens returns to its more spherical shape for viewing distant objects (objects at infinity). The mammalian lens is slightly yellow, and thereby acts as a yellow filter shutting out some of the violet light. As a person gets older, the lens becomes less elastic. It also becomes more yellow, and blue light is not seen so well. Colors then appear more orange. It has been suggested that the famous English landscape painter, Joseph Mallord William Turner painted his later pictures with an orange tone and lacking in blues because of this change in his lens, of which he himself would not have been aware.

The retina of the human eye has been found to be amazingly sensitive to light. According to S. Hecht, S. Shlaer, and M. H. Pirenne (1942) as little as $5{\cdot}7 \times 10^{-10}$ ergs of energy can be detected at the cornea. This is from 58 to 148 quanta of blue-green light. Taking into account that 90 per cent of these quanta are lost in the eye before reaching the retina, they conclude that only between 5 and 14 quanta are necessary *at the retina* for vision. In everyday experience, we can see a single candle at night five miles away. The range of light intensity to which the retina can respond—between the smallest amount of light just visible in the dark and the brightest sunlight—involves a difference in intensity of about 10,000,000,000 to 1.

The human retina is a complex multi-layered structure.

The photoreceptors in the retina have been named according to their approximate shape—*rods* and *cones*. The rods are for achromatic or black and white vision while the cones are for chromatic or color vision. In the human, there are approximately 120 million rods and seven million cones in each eye. In order for light to reach the rods and cones, it must travel through the whole retinal layer of neural cells because the rods and cones are behind them and point to the back of the eye. The *fovea* centralis in the macula lutea or yellow spot contains only cones and is the most specialized part of the retina for distinct vision.

The primary neurons of the visual system are the *bipolar cells* of the retina, which synapse with the rods are cones. On the same level, *horizontal cells* interconnect many rods and cones. The second-order neurons are also located in the retina ; these are the *ganglion cells* which synapse with the bipolar cells. The ganglion cells are interconnected by amacrine cells. In some cases single cones are connected, instead, to midget bipolar cells which are connected to midget ganglion cells. From the ganglion cells arise the long nerve fibers or axons that make up the *optic nerves*, one for each eye.

In humans, the optic nerve fibers from the temporal halves of the retina project homolaterally, whereas the nasal halves cross and project contralaterally. This means that the left visual field of the environment is projected to the right half of the brain, and vice versa. The point where the inner halves of the two optic nerves cross is the *optic chiasma*. The resulting two optic tracts terminate in the *lateral geniculate nuclei* in the thalamus. Some of the optic tract fibers go to the *superior colliculi* or to the pretectum. The third-order neurons arise in the two lateral geniculate nuclei and each of them sends their axons to the striate cortex of the occipital lobe on the same side (also called the visual projection area and Brodmann area 17). The striate cortex has a granular cytoarchitecture, and has on its surface a rather accurate topographic or retinotopic representation of the visual field. From here, some fibers go to the prestriate area, to the frontal eyefield, and to the infratemporal cortex on the same side. These areas have to do with the feedback processes involved in actively "looking".

The rods and cones are the transducer elements of the eye. They contain pigments which are affected by light. The rods contain a pigment called *rhodopsin* or visual purple. This substance is a protein containing a chemical called *retinene,* which is a form of Vitamin A. If Vitamin A is lacking in a person's diet, that person develops night blindness and other visual disturbances. When light is absorbed by retinene, the shape of the molecule of this substance is modified, and this change sends off a nerve impulse. The rods absorb only blue green light and cannot be used for seeing colour. They are used when the light is poor. At twilight, one cannot see colours and everything appears more or less gray. At night, when it is very dark, only rods are used.

In the human eye, there are three types of cones, each containing a specific pigment for seeing one of the three primary colours. One of the pigments is most sensitive to yellow-red light, another to green, and the third to blue-violet. All the other colours we see are mixtures which affect these three types of receptors to various degrees. There are no separate receptors for yellow. The sensation of yellow results from excitation of the receptors most sensitive to green and to red.

The human being has only a moderately wide field of vision ; when one holds the head still, one can see about two-fifths of the field. Because the visual field of each eye is largely overlapping, one can see stereoscopically. Retinal disparity due to these two slightly different overlapping views of the same scene makes depth perception possible.

The eyes are used not only for seeing but for actively looking. Seeing takes place by means of nerve fibers going from the retina to the visual areas of the cerebral cortex of the brain and by means of other fibers going from the retina to other regions of the brain. These other regions provide a self regulating mechanism for coordinating the movements of the head and neck and trunk in relation to the eyes, for moving the eyes in the direction of sounds that are heard, and for controlling the size of the pupils and the convexity of the lens. When something moves in the visual field, these parts of the brain provide reflexes which bring both eyes around toward the thing seen to be moving in order to get its image onto the most sensitive part of the retina for detailed vision. Audio-visual reflexes turn the eyes in the direction from which sound comes.

The optical apparatus of the eye, the correa and the lens, also have to be adjusted so that rays of light from a point on an object focus on appropriately corresponding parts of the two retinas. If the light did not fall properly on the two retinas, we might see double instead of stereoscopically.

The size of the pupils is adjusted by the muscles of the iris. When the light is poor, the pupils are dilated to let more light into the eyes. If the light is very bright, the pupils are contracted to pinpoint size. The light stimulating the retina sends nerve impulses to a regulating center of the brain from which nerve impulses run along other nerve fibers to muscles in the eye that make the iris contract. This control system can be understood in terms of a mechanism in which a part of the output is fed back to the input by means of a feedback loop. The amount of light falling on the retina is the output that has to be automatically controlled. The error is the difference between this amount of light and what would be the most suitable amount of light, which is the reference input. The error measuring device is the retina. The iris of the eye contracts or dilates to bring the output as near as possible to the reference input, reducing the difference between them to zero. The controlled output is this corrected amount of light reaching the retina.

The pioneering work of recording from single retinal fibers in the horseshoe crab and the frog was accomplished in 1938 by H.K. Hartline. Hartline found *on-fibers* in the frog that responded when light was turned on and discharged steadily during illumination. He also found *on-off fibers* that discharged briefly when light was turned on, then became inactive, and finally gave a new burst when the light was turned off. Finally, he found *off-fibers* that discharged only when the light was discontinued.

The nature of these discharging units was further clarified by S.W. Kuffler (1953) who used small spots of reflected light to explore the response properties of single retinal cells. With this technique he showed that single units respond to illumination of a circumscribed area in the visual environment called the *receptive field*, and that two major types of units can be distinguished—*on-center units* and *off-center units*. The on-center units discharge more spikes when the center of the receptive field is illuminated (on-response) and show an inhibition of discharge when the periphery of the receptive field is illuminated (off-response). The opposite holds for off-center units. These findings seem to suggest a complex organization in the retina where receptors and neurons interact both synergistically and antagonistically.

AUDITION

The auditory or hearing sense depends on the ear FIG. 3 for the reception and detection of *sound waves*. Sound waves consist of rapidly alternating pressures spreading out like ripples on a pond from a source such as a chiming bell, which can be conducted in air, water, and solids, but not in a vacuum. They are conducted faster and more effectively in solids than in liquids, and in liquids faster and more effectively than in gases. For this reason, people used to put their ears to the ground to listen for galloping horses, knowing that they would hear them in this way before they could hear them in the air.

Physicists describe all aspects of a single tone in terms of frequency and intensity of sound. The human experience of a single musical tone, however, has all these characteristics : *loudness*, *pitch*, *timbre*, *growth*, *duration*, and *decay* of the tone, *slide* or portamento, and *vibrato*. Loudness is almost but not quite the same as intensity; our hearing is more sensitive to some frequencies than to others and so we hear these frequencies louder than others although they have the same intensity. Pitch is almost the same as frequency, but it also includes some degree of loudness. Bass notes need more intensity than treble. The timbre or quality of a sound or tone depends partly on the frequency of the fundamental, partly on the overtones that accompany it, partly on the intensity of the different overtones, and partly on the envelope of the sound. Slide or portamento is the passing or gliding from one pitch or tone to another with a smooth progression. Vibrato is a tremor-like variation in the intensity of a note (called loudness vibrato) or a tremor like variation in the frequencies above and below the true note that is sandwiched between them.

The human ear is sensitive to frequencies approximately between 20 and 20,000 cps. To hear speech, the necessary range is between 500 and 2,500 cps. As people get older, they lose some of their sensitivity to hear high tones.

The human ear consists of three parts : the *outer*, *middle*, and *inner ear*. The *outer ear* is the part of the ear one can see. The sound waves travel down the passage of the outer ear and vibrate the *eardrum* or *tympanic membrane*. Behind the tympanic membrane is the *middle ear*, an air-filled space in the temporal bone.

The middle ear contains the three small bones or ossicles that are hinged together to form a system of levers. These *auditory ossicles* are the *malleus* (hammer), the *incus* (anvil), and the *stapes* (stirrup). They provide a mechanical link between the eardrum and the *oval window*. The function of the middle ear is to provide efficient transmission of the sound energy that strikes the eardrum.

The pressure at the oval window sets into motion the fluid inside the cochlea, the auditory portion of the *inner ear.* Small movements at the eardrum are condensed into a magnified pressure on the oval window, an increase in pressure per unit area of about 30 to 1. Pressure at the oval window is relieved at the *round window* that also lies between the cochlea and the inner ear, at the other end of the fluid-filled channel through the cochlea. The pressure on the fluid in the cochlea stimulates the auditory receptors lying in the *orgon of Corti*; the tips of these nerve cells form the aud.tory portion of the eighth nerve. The tips of the primary auditory neurons enter the medul a, and their collaterals end in the *dorsal* and *ventral cochlear nuclei.*

Some of the fibers of the second-order neurons that originate in the cochlear nuclei end in the contralateral superior olivary nuclei, but the main bulk of fibers cross near the midline and form the lateral lemniscus on each side. Some of these fibers terminate in the lateral lemniscus in which they occur but most go on to the *inferior colliculus* on the same side. Most of the second-order auditory fibers terminate there but a few continue to the two *medial geniculate bodies* Only a few of the fibers reaching the medial geniculate nuclei are still second-order afferents: the majority are third or higher-order fibers. The axons of cell bodies located in each of the two medial geniculate nuclei give rise to thalamocortical fibers which project to the auditory cortex in the temporal lobe on the same side.

When one hears, one not only receives and tries to understand the message of a sound, one also tries to detect the direction from which the sound is coming and the distance of the source of the sound. One learns early in childhood that loud and clear sounds come from nearby sources and that softer and l ss clear sounds usually come from farther away. The best position of the head for localizing a sound is to have the sound source coming straight towards one ear. When this happens, the further ear will be in the very worst position for hearing that sound. If a sound strikes both ears at exactly the same time, the person will localize it somewhere in the middle. Another mechanism used for localizing sound is based on the experience that as a sound gets nearer, the bass notes get relatively louder than the treble. Thus, the whistle of a train coming toward you sounds higher pitched than it sounds when the train is moving away from you This is the *Doppler Effect* regarding sound.

SMELL AND TASTE

The olfactory or smell sense in vertebrates involves the *olfactory membrane* at the top of the nose which is the part of the nasal mucous membrane that contains the olfactory receptors. The odors of the outside world are experienced mainly through the nostrils, but the smells of the food we chew reach the membrane by going up the back of the nose.

The olfactory receptors are packed among columnar supporting cells. Each receptor cell ends in hair—like processes called *cilia*, which move about spontaneously. About 50 million nerve fibers leave the olfactory mucosa of each side of the nose. These connect with other neurons, and from these 50,000 nerve fibers go to the brain.

The odor particles have to be transferred from the air to the lipid-water interface of the membrane of the cilia. Therefore, any substance that can be smelled has to be volatile, Molecules must leave the substance and pass into the surrounding air. The substance must be soluble in water and in lipid (fats or oil). The substance must have molecules of certain sizes (not too large to enter the pores of the membrane of the receptors) and must have certain shapes, For example, substances whose molecules are disk-shaped have a musky smell. An appropriate molecule can enter the receptor and trigger off a nerve impulse.

In mammals, the gustatory or taste receptors are situated along the surface and edges of the tongue, over the epiglottis, on the soft palate, and in scattered areas around the throat.

The taste receptors are grouped together in goblet-like structures called *taste-buds*. These receptors synapse with nerve fibers that go to the brain.

The human being's sense of taste is even less developed than the sense of smell, since a larger number of molecules of a substance must be dissolved in fluid to be tasted than to be smelled, There are four primary tastes : sweet, bitter, sour, and salt. It is likely that they are detected by four different receptors. We are most sensitive to the taste of bitter substances since it takes far fewer molecules of a bitter substance to give us a taste than it takes molecules of sweet, sour or salt substances to give us a taste.

THE CRANIAL NERVES

The brain itself is the source of twelve pairs of cranial nerves, whose names and actions are as follows : (1) *olfactory nerve*, subserving smell ; (2) *optic nerve*, subserving vision ; (3) *oculomotor nerve*, supplying most of the muscles which move the eyeball and the muscles which contract the pupil ; (4) *trochlear nerve*, supplying the muscle which turns the eyeballs downward and outward ; (5) *trigeminal nerve*, supplying sensation to the face, etc., and to the muscles of mastication ; (6) *abducens nerve*, supplying the muscles which turns the eyeball outwards ; (7) *facial nerve*, supplying the muscles of the face ; (8) *auditory nerve*, a part of which subserves hearing and the other part is involved in maintaining equilibrium ; (9) *glossopharyngeal nerve*, subserving taste but also supplying sensation to the inside of the throat and activating some muscl s there ; (10) *vagus nerve*, ("wandering nerve"), supplying the heart, lungs, stomach, and other viscera ; (11) *spinal accessory nerve*, supplying muscles in the neck ; and (12) *hypog.ossal nerve*, supplying the muscles that move the tongue. A mnemonic device may be used to remember these nerves, each inital letter representing, in order, one of the cranial nerves. *O*n *O*ld *O*lympus' *T*owering *T*ops *A* *F*at *A*rmed *G*irl *V*iews *S*nowy *H*ops.

The olfactory nerve (first cranial nerve) connects with the olfactory lobe of the cerebrum. All the other cranial nerves connect with various portions of the brain stem FIG. 4.

TOUCH, MOVEMENT AND EQUILIBRIUM

The skin is not only the covering of the body which separates a person physically from the outside world, but it also contains the cutaneous or "touch" receptors which continuously examine the world and sent information to the person's brain. This infcrmatton is used for making automatic adjustments of the body, most of which are made without conscious awareness. There are three different ways in which nerve fibers end in the skin : (1) as freely ending nerve fibers, (2) as complex endings, and (3) as encapsulated endings. The *hair-follicle* is one kind of encapsulated nerve ending. When a hair is bent, it exerts a level-like pressure on the skin near its root, and touch receptors near the root then send impulses to the spinal cord. The cutaneous (touch) sensations are *pressure*, *heat*, *cold* and *pain*—each originating from the stimulation of different type of nerve endings. The free nerve endings are pain receptors. The skin possesses about 200,000 nerve endings for temperature (heat and cold), 500,000 for pressure, and 3,000,000 for pain.

The touch receptors are found most densely strewn on the tongue and fingertips, which are the parts of the body most likely to be used in exploration. For example, at the fingertip two touches must be separated by 2·3 millimeters before being experienced separately. The tip of the nose eequires a separation of 6·6 milimeters before a person can detect a double touch. And the middle of the back requires a separation of 67 millimeters.

In the deeper levels of the skin, the various nerve fibers come together to form the *afferent nerves* which enter the *posterior roots* of the spinal cord. The unipolar cell bodies of the afferent nerve fibers are located in the dorsal root ganglia outside the spinal cord. Some of the fibers of these afferent nerves pass up the spinal cord to different parts of the somesthetic sensory area of the cerebral cortex of the brain. Because of this, we can tell where the skin has been touched. Thus, when the big toe on the right foot is touched impulses go predominantly to one part of the cortex.

Nerves leaving the spinal cord from the *anterior roots* go to muscles, blood vessels, and the sweat glands of the skin. These are the *efferent nerves.* These nerves are involved in most of our reflex and voluntary activities.

The spinal nerves are segmentally arranged, the sensory fibers of each nerve supplying a distinct area of the skin and the motor fibers supplying a separte myotome of a muscle. There are 31 pairs of spinal nerves which are conventionally divided into eight pairs of cervical nerves, 12 pairs of thoracis nerves, five pairs of lumbar nerves, five pairs of sacral nerves, and one pair of coccygeal nerves FIG. 5.

If a cross section through the spinal cord is made at some point, the gray matter may be seen in the central region in the form of the letter H, surrounded by white matter FIG. 6. The upper arms of this gray matter are the right and left *dorsalhorns,* into which funnel the dorsal or posterior afferent nerves. The lower arms are the right and left *ventral horns*, which contain large motor cells. The middle gray matter linking the two wings across the midline is the gray commissural region that associates the two lateral halves of the spinal gray matter.

The motor area of the cerebral cortex contains *pyramidal nerve cells* or *Betz cells* that are essential to the initiation of voluntary movements The terminations of their axons come into contact with other neurons in the anterior horn of the gray matter in the spinal cord, and the axons of these neurons come into contact with the muscles. The pyramidal cells are called the *upper motor neurons*; the *lower motor neurons* are part of the spiral cord. An impulse in the upper neuron can be transmitted to the lower and result in muscular action, or it can partially or completely inhibit the activity of the lower neuron.

The simplest type of nervous activity is *reflex action.* If the sole of the foot of a sleeping person is scratched with a pin the foot is drawn away even though the person may be unaware either of the pain or of drawing the foot away. This happens because impulses travel along an afferent nerve from the foot to motor cells in the spinal cord with which the fibers of the nerve are in communication by synapses. The motor cells in the spinal cord are thereby activated and cause the movements of the muscles that draw away the foot. This reflex movement is coordinated and purposive. It withdraws the foot from what is hurting it, but it is not voluntary. If the person were awake he would be aware of what is taking place, but would probably still withdraw his foot, though he could will not to do so.

Many actions on the reflex level, such as the blinking of the eyes, the changes in the size of the pupils, the secretion of saliva, and the movements of the intestines, are always going on more or less. In many instances chains or patterns of reflexes set each other in motion. Inhibition may also be reflex, as when the muscles that bend an arm are at work, it is necessary that the muscles which straighten it should be relaxed. This is brought about by reflex action.

As will be seen later, the body's nerves can be grouped into those belonging to the *somatic nervous system* (which effects skeletal control and bodily voluntary processes) and the *autonomic nervous system* (which controls the glands and the smooth muscles). The autonomic nervous system is also involved in reflex action as well as emotional and instinctive activity.

As stated earlier, the proprioceptive receptors give information about stimulation that arises in the muscles, tendons, and joints. For example, the stretching or contracting of muscle fibers produce impulses in the nerve endings attached to muscles. These impulses travel to the spinal cord and through ascending tracts they travel to the brain stem.

A person attains normal equilibrium in an upright position—with the head above the neck and the neck straight above the trunk—mainly by using the eyes. But second in importance for maintaining equilibrium are the proprioceptors of the neck, the proprioceptors in the joints, and the exteroceptors in the skin. The third important receptors for equilibrium are in the labyrinths of the inner ear and in the cerebellum. All of these receptors play a role in maintaining equilibrium, but there are many individual differences concerning the extent to which individuals rely on their eyes, on proprioceptors and exteroceptors from their joints and skin, and on their labyrinths and cerebellum. And all this normally goes on with little awareness. If a person does become aware of labyrinthine events, it is usually an unpleasant experience such as occurs in vertigo and sea-sickness.

The inner ear contains labyrinthine hair-cell receptors which are sensitive to movement, to acceleration and deceleration, to rotation and to vibration. The part of the inner ear that is concerned with posture and balance is called the *vestibule.* In each inner ear the vestibule consists of three structures : the *utricle*, the *saccule*, and the three *semicircular canals* which are in the three planes of space. The utricle and saccule are sensitive to linear acceleration, including gravity. The semicircular canals are sensitive to rotational acceleration.

Internal Receptors

Finally, there are the sensory receptors that bring information to the central nervous system about what is happening in the internal environment or the inside world of the person's body. These are the interoceptor receptors which inform a person of conditions in the body such as hunger, thirst, and tiredness. They also help to control many internal processes that maintain physical homeostasis. Many of these receptors are in the medulla oblongata or in the hypothalamus of the brain.

Breathing is automatic, but one can pay attention to and voluntarily influence it. Automatic breathing is controlled by *stretch receptors* in the bronchial tree and lungs, by *feed-back mechanisms* and reflexes that are used for the control of muscles, by the *chemoreceptors* in the medulla oblongata that are sensitive to carbon dioxide and blood chemistry, and by the *baroreceptors* in the large blood vessels and heart.

There are *osmoreceptors* in the hypothalamus and the medulla oblongata which are sensitive to osmotic pressure, and which are used to keep this value constant. The salts and proteins in solution in the liquid part of the blood (or plasma) cause an osmotic pressure. If the blood gets too concentrated, these osmoreceptors cause certain neurons in the hypothalamus to secrete anti-diuretic hormone which acts on the kidneys to make them reabsorb fluid. In this way, less urine is formed and more fluid is retained in the body. This maintains the blood at the correct osmotic pressure.

There are chemoreceptors in the hypothalamus which record the amount of glucose that circulates in the blood. The hypothalamus also has chemoreceptors that are sensitive to the amount of hormone secreted by the adrenal gland medulla. Baroreceptors or pressure receptors in the walls of the large blood vessels and in the heart signal changes in blood pressure to the central nervous system by firing more or fewer impulses as the pressure rises or falls. When the firing is rapid, the brain slows down the heart to allow the blood vessels to dilate and thereby offer less resistance to the flowing blood. Slowing the heart also leads to slower respiration. If firing is too slow because blood pressure falls, impulses are sent to the sympathetic nervous system to make the adrenal glands secrete adrenalin into the blood. This makes the heart beat more forcefully to increase the blood pressure.

The autonomic nervous system contrasts to the *somatic nervous system*, a portion of the peripheral and central nervous system that effects skeletal control and voluntary processes of the body. The autonomic nervous system is important for an organism's relating to its environment. It has two parts : the *sympathetic nervous system* that prepares one for action such as fleeing or fighting, and the *parasympathetic nervous system* which regulates quiet activities such as relaxing, digesting, excreting waste matter, and sleeping FIG. 7.

The sympathetic nervous system makes it possible for a person to be alert when danger threatens or when an interesting event is likely to happen. Fight and flight behavior, and the emotions of rage and fear, activate the sympathetic nervous system. Even a sudden noise activates the sympathetic system and causes the blood vessels of the skin to contract within one or two seconds, and the heart to speed up and beat more forcefully. If the stimulus is very startling, the pupils dilate, the eyelids become retracted, the bronchi dilate, and the hair stands on end. Internally, glucose is released from the liver and enters the blood circulation to be available to the muscles for increased activity.

The parasympathetic nervous system is active when the person is relatively inactive in the world and feels secure. The parasympathetic nerves activate the glands in the alimentary canal that secrete enzymes and lubricants for digesting food. At other times, when the person is active in the world, the sympathetic nervous system not only prepares the person for activity but also has a quieting effect on the alimentary canal. Normally, both the sympathetic and parasympathetic systems work together as a whole, their activities being harmoniously balanced to meet the organism's needs.

The neurochemical activity of the autonomic nervous system is highly complex. The sympathetic system is mainly a monaminergic transmitter system. And the parasympathetic system is mainly a cholinergic transmitter system. The sympathetic nerves liberate *noradrenalin* from their endings, whereas the parasympathetic nerves liberate *acetylcholine* from their endings. The sympathetic nervous system also has a large depot of adrenalin and noradrenalin in the central part of the adrenal glands which are poured into the bloodstream when stress is experienced and there is a need for physical exertion. Anger causes the release of noradrenalin, and anxiety causes the release of adrenalin.

The sympathetic nervous system consists of a chain of nerve gangila containing nerve cells and is located on either side of the spinal cord ; three pairs of sympathetic ganglia are in the neck region, 10 pairs in the thoracic region, and several in the lumbar region. Thus, the sympathetic nervous system is called sometimes the *thoracico-lumbar* system. These ganglia are connected by fibers to the spinal cord and to other ganglia which lie further out, some of them being in the walls of the intestines. The parasympathetic nervous system's ganglia are usually located near the organs innervated. It is sometimes called the *cranio-sacral system*. Both parts of the autonomic nervous system are controlled by the hypothalamus.

Brain Function, Pleasure and Punishment

The hypothalamus, in addition to controlling the autonomic nervous system, has eating centers, drinking centers, pleasure centers, and pain centers FIG. 8. The central region of the hypothalamus appears to have two parts of an eating center, one that turns appetite on and one that turns it off. Its existence was first discovered when it was observed that animals ate voraciously and became very obese when one of these areas of the hypothalamus was destroyed, and tended to starve to death when the other part was destroyed. It seems that one part of the hypothalamus tests the blood passing through for glucose content, and when glucose drops below a certain key level, appetite is turned on. When the person eats, one's normal glucose level is restored, and another part of the hypothalamus turns appetite off. The hypothalamus also has two thirst centers, one which initiates and one which stops drinking activity. As was mentioned earlier, the hypothalamus is also concerned with emotional behavior such as fear rage. This is consistent with the fact that the hypothalamus is at the upper end of the reticular formation of the brainstem which—together with the sensory systems—aids in maintaining the cerebral cortex at a level of activity consistent with consciousness.

The *pituitary body* (an endocrine gland) is attached to the middl part of the hypothalamus FIG. 9. There is evidence that some of the neurons of the hypothalamus produce substances that regulate the secretory activities of the *anterior pituitary*, and also produce the anti-diuretic and oxytocic (childbirthhastenirg) hormones of the *posterior pituitary* FIG. 10.

It has recently been found that the hypothalamus has pleasure centers. J. Olds and P. Milner (1963) studied rats placed in a modified version of the Skinner box in which experimental animals learn to obtain a reward (such as food or water) by pressing a bar inside the box. In their experiment, Olds and Milner arranged the apparatus so that each time the rat pressed the bar in the box, a small burst of electric current passed into its brain through a wire connected to an electrode which was fixed into its skull. With some electrode placements, this type of stimulation had no influence on the animal's bar-pressing. The animals just continued to press the bar infrequently as they moved about and explored the box. The number of spontaneous bar-presses which a rat makes randomly during a specified time is called the "operant level" of responding. When the electrode is placed in certain other parts of the brain, however, the rats pressed the bar very rapidly and soon reached a continuous high rate of bar-pressing far above the operant response level. In this latter type of case, the intracranial stimulation acts as a positive reinforcement.

In all species thus far studied, the areas in which stimulation produces positive reinforcement belong to the phylogenetically older parts of the brain or to areas closely connected with them. Purely positive reinforcement occurs along a nearly cylindrical path of tissue on each side of the brain, extending from the base of the forebrain down through the lateral hypothalamus into the ventral midbrain. The portion of this reward zone that is in the lateral hypothalamus is a particularly potent area for positive reinforcement. When electrodes are placed there, rats will stimulate themselves at rates as high as 8,000 bar-presses per hour and continue to do so for 24 hours or more until they finally drop from exhaustion. The rat will stimulate itself to the exclusion of food, sex, and sleep.

There are also ambivalent areas and negative reinforcement or punishment areas. With electrodes implanted in a purely negative reinforcement area, experimental animals never attempt to turn the current on although, if the current is turned on by the experimenter, the animal quickly learns to press a bar in order to turn off the intracranial stimulation and escape from the punishment. Rats will also learn to press a bar after a warning tone is sounded in order to interrupt the stimulating circuit before their brain is stimulated. The largest punishment areas in the rat are in the midbrain, within the reticular formation and the central gray substance which surrounds the medially placed aqueduct, and in the ventromedial portions of the thalamus.

Exploring the Black Box

The experiments conducted with the brain's pleasure centers are only one example of physiological psychology's attempts to explore the variables that intervene between an incoming stimulus and an outgoing response. As physiological psychologists attempt to enter and explore the "black box" of responding organism, a variety of techniques are used :

1. *Neuroanatomical methods* involve inspecting the relationships of the organism's structures to their functions

One method is *extirpation*—the process of removing select areas of an animal's brain, then determining the effects of these changes on the animal's behavior. *Surgical intervention* can create brain lesions in order to explore the resulting behavior change; in *acute* preparations, the animal is studied and then "sacrificed" to more fully study the procedures' effects, while in *chronic* preparations, the animal is studied over an extended period of time. In *chemical intervention*, various drugs are used to study behavior with the animal generally recovering its ordinary functioning in time.

2. *Electrical recordings* include those ways in which electrical changes can be picked up from the organism and amplified for observation. Depth electrodes can be implanted for ongoing monitoring of deep brain electrical activity; this activity can be correlated with recordings made on the surface of the skin. Information can be obtained about electrical activity of the brain by fastening electrodes to the surface of the head; the resulting recording is an *electroencephalogram* (EEG), a record of *brain potentials*—the volrage differences between regions of the brain consisting of *brain waves*, an oscillating pattern of various magnitudes and frequencies. To secure information about electrical activity of the muscles, one can obtain an *electromyogram* (EMG), for eye movements an *electrooculogram* (EMG), for the heart, an *electrocardiogram* (ECG), etc. Researchers have found certain electrical changes that correspond with higher nervous system activity such as scores on mental ability scales and perceptual tests; these changes are called *evoked potentials* or *average evoked responses* (AERs) because the electrical recording is evoked by having the subject perform a task, and an average of several such trials is computed.

3. *Stimulation methods* include the activities sometimes carried out during surgical procedures with humans in order to map the brain more adequately. While the subject is awake, various areas of the brain's outer layer, or *cortex*, is electrically stimulated while the subject reports the resulting experiences. W. Penfield and L. Roberts (1959) found that

stimulating the visual cortex of the brain's occipital lobe produced the experience of diffuse lights. Stimulation of the auditory cortex of the temporal lobe yielded soft sounds while stimulation of the touch cortex of the parietal lobe resulted in pleasurable body sensations. This work has resulted in a more accurate location of the motor and sensory areas of the brain's cortex FIG 11.

4. *Hormonal and biochemical methods* include the removal of glands in other animals to measure the effects of glandular-related behavior. The procedure is often followed by the replacement of natural or synthesized hormones to determine at what course in the organism's development replacement can be benefical. The body's glandular system is slower to exert its effects than the nervous system, but its impact upon behavior is profound and often long-lasting. The endocrine glands include the thyroid, parathyroid, adrenal cortex, adrenal medulla, pancreas, anterior pituitary, posterior pituitary, gonads, thymus, and pineal. A related way of studying the organism is to administer chemicals to the intact organism and measure the results, or to apply chemicals to tissue cultures or isolated portions of the whole organism.

5. *Natural observation* includes the ethological process of trying to catalogue behavior sequences performed by the organism within its habitat. The physiological processes occurring during these sequences of behavior are either inferred or measured directly through long distance monitoring of electrodes implanted in the organism.

Topology of the Brain

Investigative techniques in physiological psychology demand a set of directional terms, physiologists deal with humans as if they were still on all fours and never evolved to an upright posture FIG. 12. This has been done so that the same directional terminology can be used in a cross-comparison with other organisms. In addition to *upper*, *higher*, and *lower*. these are the terms in most common use which indicate the relative position of a particular brain structure :

1. rostral (toward the nose or beak)
2. cranial (toward the cranium)
3. caudal (toward the coccyx or tail)
4. anterior (toward the front)
5. posterior (toward the back)
6. ventral (toward the belly)
7. dorsal (toward the back)
8. superior (above)
9. inferior (below)
10. lateral (outward from the central plane)
11. medial (inward from the central plane)
12. distal (away from the central plane)
13. proximal (toward the central plane)
14. contralateral (the opposite side of)
15. ipsalateral (the same side as).

Two Hemispheres

The largest part of the human brain is the *cerebrum*, which has *left* and *right hemisphere* joined together by the *corpus callosum*. The corpus callosum makes possible inter-hemispheric transfer of memory traces. Experiments by R.E. Myers (1955) and R.W. Sperry (1964) have been shown that a cat or monkey with a split optic chiasma (by sectioning the crossed optic fibers) develops a functional is conflict between the two hemispheres when the animal conditioned to make two opposite visual discriminations, but that this conflict disappears when the corpus callosum is sectioned. This indicates the importance of the corpus callosum or 'great cerebral commissure' for mental unity.

J. Bogen and P. Vogel (1962) described two human patients with severe epileptic seizures who were given split brain operations that sectioned the corpus callosum and the anterior and hippocampal commissures plus the messa inter-media in one case. In the other case the messa intermedia was judged to be absent in the course of the operation. It was expected that the operation would prevent the seizures from spreading from one hemisphere to the other. To their surprise the seizures were almost entirely eliminated.

The convoluted layer of gray matter of the cerebral cortex that covers the cerebral hemispheres plays a large part in controlling d stinctly human behavior. The cortex of each hemisphere is divided into areas called the frontal lobe, temporal lobe, parietal lobe, and occipital lobe FIG. 13. The Fissure of Rolando begins somewhat behind the top of the head andruns obliquely downwards and forwards; it is between the frontal and parietal lobes. The Fissure of Sylvius is between the frontal and temporal lobes. The occipital lobe is behind the parietal lobe on top and behind the temporal lobe below. The longitudinal fissure divides the cerebrum into its right and left hemispheres. In front of the Fissure of Rolando (in the frontal lobe) is the area concerned with initiating voluntary movements. This "motor" area is subdivided into parts that are essential for moving the toes, legs, arms, fingers, neck, face, and larynx, in this order, from the top downwards. The nerves to these surface areas cross so that the left side of the brain moves the right side of the body, and vice versa. The somesthetic areas behind the Fissure of Rolando, in the parietal lobes, serve the cutaneous sensations of warmth, cold, and pressure from these same corresponding parts of the body. These motor and somesthetic sensory areas on each hemisphere that represent the body upside down, from the toes to the face, are sometimes called "the homunculus" in the brain.

The occipital lobes contain the visual areas. Large areas of the cortex do not have localized functions; these are called the association areas. They are involved in the complex processes of memory, learning, and thinking.

The speech and language areas appear to be located in the lower frontal and parietal lobes in the left hemisphere. These are called Broca's Wernicke's areas. These areas are appropriately right by the facial motor and somesthetic sensory areas of the so-called "homunculus", respectively. Penfield found that when a patient on the operating table is fully conscious while his brain's left hemisphere is exposed, a weak electrical current applied to the speech area produces immediate interference in his speech process. But if the electrode is applied to the corresponding area of the other hemisphere, no such effect results.

At exciting area of research which sprang from the splitbrain preparations of Sperry and others includes the differentiation of hemispheres as to certain categories of function. A growing number of findings indicate that the right hemisphere is more prone to dominance during creative, non-verbal, and spatial behavior as well as body movements, musical activities, perception of designs and pictures, and related orientations. The left hemisphere on the contrary, is more scientific, logical, linear, verbal, and mathematical. These findings have the potential for opening up areas of a person's capacities which may have been over-ridden by the dominant hemisphere. And it has possible applications to education and other developmental activities.

In addition to the brain's division into the *cerebrum*, the *cerebellum*, and the *brainstem*, it can also be divided into three primary embryonic subdivisions : the *hindbrain, mid-brain*, and *forebrain*. These three parts are then further differentiated into five secondary subdivisions. The hindbrain consists of the *metencephalon* which contains the pons Varoli (a bridge of nerve fibres connecting the lobes of the cerebellum as well as the medulla and cerebrum) and the *myelencephalon*, which contains the *medulla oblongata*. The medulla oblongata joins ths spinal cord and is anatomically the lowest and most essential part of the brain because it contains the centers that maintain the vital functions of breathing, the beating of the heart, blood pressure, sucking and swallowing. The cerebellum originally developed from the roof of the metencephalon. The cerebellum, along with the labyrinths of the inner ear, are important for maintaining balance and for coordinating movements.

The midbrain is also called the mesencephalon. The mesencephalon, metencephalon, and myelencephalon (with the exception of the cerebellum) are sometimes collectively called the brainstem. This is the same as saying that the hindbrain and midbrain, without the cerebellum, is also called the brainstem, cerebellum and, cerebrum.

The forebrain is the largest part of the human brain. It can be subdivided into the diencephalon (which contains the thalamus and hypothalamus) and the *telencephalon* which consists of the two cerebral hemispheres. In all higher vertebrates such as the cat and man, a layer of neocortex is also present as the outer shell of the adult telencephalon, covering the more primitive cerebral hemispheres. The right and left hemispheres of the cerebrum are connected by a broad band of fibers running transversely (the corpus callosum). The surface of the cerebrum (and also of the cerebellum) consists of layers of gray matter which is infolded, forming convolutions that increase the area of the brain surface.

The brain is covered by three membranes : the *pia matter* (in close contact with the brain substance), then the *arachnoid,* and the *dura matter* on the outside. The space beneath the arachnoid is filled with *cerebrospinal fluid* which is in communication with the fluid in the *ventricles* of the brain through openings at the back of the medulla oblongata FIG 15.

There are four ventricles, namely, the *right* and *left lateral ventricles* which are contained in the cerebral hemispheres and which are connected to the *third ventricle* beneath them; the third ventricle which is connected with the fourth by the aquaduct of Sylvius in the midbrain; and the *fourth ventricle* which is in the hindbrain and connects with the canal that runs down the center of the spinal cord. All of these cavities contain cerebrospinal fluid.

The blood supply of the brain is derived from the internal carotid and the vertebral arteries. The venous blood and cerebrospinal fluid drain into the large venous channels known as *sinuses*. These sinuses, in turn, pour their contents mainly into the jugular vein. These sinuses are also connected with external veins at various points on the surface of the skull.

The Reticular Activating System

The thalamus acts as a reception center for the somesthetic sensations—touch, pain, heat, cold—and the muscle senses. It is also an important part of the reticular activating system (RAS). The thalamus receives the impulses representing the incoming sensory data and passes the impulses of the milder sensatians from the muscles, the gentle touches, and moderate temperatures, on to the somesthetic sensory areas of the cerebral cortex which are posterior to the Fissure of Rolando at the side of each hemisphere. The mild sensations can be entrusted to the cerebral cortex where they can be given prolonged judicious consideration before being responded to. The more violent sensations—such as pain, extreme heat and cold, rough touch—must be dealt with rapidly and so are handled more or less automatically by the thalamus itself. Because of this, the cerebral cortex tends to be regarded as the center of reason and the thalamus as one of the centers of emotion.

The thalamus also controls the muscle movements involved in the facial expressions of emotions: when cortical control of the facial muscles is destroyed, the facial expression is mask-like in calm states but can still assume distorted expressions in response to strong emotions.

The *limbic system* consists of the protovertebrate components of the forebrain, including such subcortical structures as the hippocampus, amygdala, septal nuclei, and some olfactory areas; such allocortical structures as the cingulate gyrus, hippocampal gyrus, and uncus; and possibly also such justallocortical structures as the orbitofrontal, insular, and temporal pole cortices FIG. 16. This system is sometimes called the 'rhinencephalon' because in many lower vertebrates the olfactory areas in it are predominant.

Some physiologists also include the hypothalamus and the midbrain tegmentum in the limbic system. It has been demonstrated that an intact hypothalamus is necessary for the occurrence of rage in a cat. The limbic system mediates need-gratifying and emotional activities. In lower vertebrates, where the olfactory areas predominate, the need-gratifying activities (inter relations with prey, enemies, and sex partners) depend to a large extent on olfaction.

Since the limbic system plays an important role in need-gratifying activities with strong emotional concomitants, J.W. Papez (1937) postulated that *some* of its component parts and their interconnections—the cingulate gyrus, hippocampus, and parts of the thalamus and hypothalamus—form the neural basis for emotional experience. These have since become known as *Papez' circuit*.

The RAS, along with the sensory areas of the cerebral cortex, appear to play the predominant role in controlling the state of arousal of an organism, in changing from sleep to waking, and from diffuse awareness to alert attention. When something interesting happens, the central nervous system is alerted and the receptors are adjusted to examine the various types of stimuli. Thus, for example, a sudden sound not only increases the sensitivity of the cochlear receptors of the inner ear, but also the photoreceptors of the retina. In this way the whole brain is activated and the person becomes vigilant. An unexpected visual stimulus can also bring about increased activation of the cerebral cortex.

Arousal takes place because a sudden visual, auditory, or other stimulus causes many nervous impulses to travel rapidly down the *descending pathways* or tracts of the RAS, and from there impulses are sent up to the sensory and motor cortex along the *ascending pathways*.

The RAS runs through the entire brainstem and extends anteriorly into the hypothalamus and the central part of the thalamus. When a person is awake, many nervous impulses stream up from the ascending pathways to the sensory areas of the cerebral cortex. RAS was first described by G. Moruzzi and H.W. Magoun (1949).

R. Hernandez-Peon (1965) performed experiments with human subjects in which he showed that the nervous impulses coming from the eyes are greatly reduced when the person is engaged in conversation, when he is asked to remember something, or when he is working on an arithmetic problem. Hernandez-Peon also found that the inflow arriving at the primary tactile area or primary auditory area can be reduced by getting the subject to solve mathematical problems or by engaging him in conversation.

When Hernandez-Peon suggested to the person that the flashing light is being made brighter, the action potentials he was recording from the brain increased; and when he suggested that the intensity of the light is being reduced, the action potentials became less. The intensity of the light itself was actually not changed.

He also found that the number of nervous impulses arriving at the higher centers of the brain diminishes when the stimulus is continued and becomes monotonous. This phenomenon is referred to as *habituation*.

Living Neurons

The units of the nervous system are the nerve cells or *neurons*, each of which consists of a mass of protoplasm made up of carbohydrate, fat, protein, salts, and fluid. The nerve cell is surrounded by a semipermeable membrane. The main portion of a neuron is the *cell body* which contains a nucleus and cytoplasm. The nucleus within the cell body contains chromosomes and genes. Long, thin, threadlike branching fibers from the cell body called *dendrites* transmit nervous impulses toward the cell body. At one point of the cell body is a long fiber that usually does not branch although it is often several feet long. This is the axon and it conducts nervous impulses away from the cell body.

The potential initiated at the dendrites, called *generator potentials*, can be recorded from the dendritic processes of the neuron, but, being decremental in nature, they do not spread to the axon unless the current flow reaches a certain critical magnitude of 20 microvolts or more below the resting value. When such an increase in potential takes place, the permeability of the axon membrane increases, and the generator potentials spread to the axon.

In a living neuron, sodium ions are found almost entirely on the outside of the fibers and potassium ions are almost entirely within the fibers. Therefore, relative to each other, the interior of a neuron has a negative and the outside has a positive charge. This separation of charges is called *polarization.*

When a neuron is sufficiently stimulated, a reaction occurs in the axon membrane between acetic acid and choline. resulting in the formation of *acetylcholine.* This increases the permeability of the axon membrane to sodium ions; sodium ions then enter the fiber and potassium ions inside the fiber leave it. This equalizes the charge on each side of the membrane and is called *depolarization.* When depolarization takes place at one point of the fiber, it initiates an action potential or spike potential that travels along the entire axon fiber in a wave of depolarization. This is the *nervous impulse.*

The portion of the fiber behind the impulse becomes repolarized because cholinesterase in the neuron breaks down acetylcholine into acetic acid and choline again. The sodium ions are pushed outside of the fiber again by a process called the "sodium pump." The outside of the membrane thereby becomes positively charged again. During the time between depolarization and repolarization, the neuron will not respond to stimulation. This is the *absolute refractory period*. It is followed by the *relative refractory period* during which a second impulse can be evoked, but only by a stimulus which is stronger than normal.

Generator potentials in dendrites can be of two types, producing *hypopolarization* and *hyperpolarization*. Hypopolarization is a partial depolarization that reduces the normal resting potential. This action is excitatory or facilitatory because it makes further depolarization and eventual spike generation easier. Hyperpolarization involves an increase in the normal polarization of the membrane, an event regarded as inhibitory because it makes subsequent spike generation by other potentials more difficult.

All neurons conduct impulses in one direction only, from the dendrites to the cell body and down the axon to the nerve-endings. The nerve impulse does not travel at the same rate in all neurons. Its rate of travel along an axon varies approximately with the width of the axon; the wider the axon, the more rapid the rate of propagation.

Nerve impulses also travel faster in myelinated neurons. Many neurons have axons that are covered with a white lipoid substance called *myelin*; this myelin sheath is interrupted at regular intervals along the axon called nodes of Ranvier. In a myelinated neuron, the nervous impulse travels at a velocity of about 100 meters per second, or 225 miles per hour. All axons of the peripheral nervous system, whether they have a myelin sheath or not, are surrounded by a thin sheath called the *neurilemma*.

The process of myelination is not complete at birth, and therefore various functions do not develop until the appropriate neurons become myelinated. For example, the nerves connecting the muscles of the legs are not completely myelinated until a boby is more than a year old; hence, walking is delayed until then.

The gap between the axon of one neuron and a dendrite or cell body of another neuron is called the *synapse.* Acetylcholine liberated at the end of the axon of one neuron affects the dendrites or cell body of the next neuron and initiates a new impulse there. The neuromuscular junction (the gap between a neuron and a muscle cell) is crossed by the impulse in the same way.

The neurons in the central nervous system have no neurilemma sheaths. Instead, the central nervous system has supporting cells called *neuroglia* or *glial cells*, which provide neurons with food and energy. These cells differ in size and shape; nearly all have processes that weave around nerve cells and fibers. They are often attached to the wall of blood vessels.

Evoked Memories

Memory involves learning (retention) and remembering (recall and recognition); in the central nervous system this involves storage and retrieval of memory-traces. There is short-term memory that lasts for a few seconds or at most, a few minutes. One example of this is the ability to repeat sequences of numbers that one hears. After a few seconds or minutes, this memory is lost beyond recall. D.O. Hebb (1949) and R.W. Gerard (1949) have postulated that this kind of memory is dynamically maintained and can be retrieved as long as its spatio-temporal pattern is preserved by reverberating impulses. Hebb writes (1949 : 19) : "Any frequently repeated, particular stimulation will lead to the slow development of the 'cell assembly.' A diffuse structure...capable of acting briefly as a closed system."

The second type of memory—long-term memory—is distinguished by its enduring character, often lasting for a lifetime. Long-term memory has been experimentally shown to survive even when the central nervous system is reduced to a quiescent state, as by coma, deep anesthesia, or extreme cooling. These memories must therefore lay down "memory traces" based on enduring changes in the nervous syst m. These structural changes are usually hypothesized to occur at the synapses.

W. Penfield (1966) found that in humans, bilateral lesions of the hippocampal formation or the mesial portion of the diencephalon, without involvement of specific sensory pathways, results in an incapacity for long-term memory storage. This does not imply that memory-traces are localized in these structures since recall of already established memories is preserved. These individuals appear alert and intelligent, often substituting old memories for more recent memories which they have already forgotten. New experiences they can recall for only a few minutes, or a little longer by deliberate repetition.

Synaptic changes that are strengthened by repetitive activity, however, cannot entirely explain long-term memories for they are as selective as the processes of conscious awareness. The establishment of long-term memories, according to H.H. Jasper (1966), seems to depend on an interaction between subcortical structures and selective on-going neuronal processes in the cerebral cortex where essential components of the permanent memory traces are laid down.

As stated earlier, Penfield (1966) found that when a patient on the operating table is fully conscious and a small electrical current is applied to the temporal area of the cortex, that patient may experience an alteration of present experience so that what is seen and heard may seem familiar. The person may have a "flashback" of a previous experience in full detail so that music is heard again as it was heard at a concert, or in a cafe, or in a church. If asked, the patient can hum an accompaniment to the music. The flashback may be an experience of laughing with friends, or watching circus wagons coming to town many years ago in childhood. Penfield regards the function of the temporal cortex to be "interpretive" and so has called this area from which these responses are obtained the "interpretive cortex."

The interpration of a present experience and flashbacks of past experiences seem to be parts of a scanning mechanism that normally enables an individual to compare present experience with similar past experiences automatically. This may be the anatomical physiologicel correlate of W. James' stream of consciousness. In their exaggerated form, as induced in Penfield's experiments, these experiences are often like some of the experiences produced by psychedelic drugs such as mescaline and LSD, or even like psychotic experiences.

The cerebrum appears to be involved in most types of conditioning and learning, and as the mass and complexity of the cerebrum increases in different organisms up to man, so does the complexity and intricacy of conditioned responses increase. Thus, more and more neurons can be used for "hooking up" with various circuits that represent different combinations of conditioning. And as more and more memory storage units are established, there is greater probability that trial-and-error can take place among the storage units themselves rather than having to take place in direct interaction with the physical world itself by means of overt responses. This increases the scope of thought processes.

In connection with conditioning, behavioral scientists have done research to answer this question : whether neural pathways that connect cortical sensory areas with cortical motor areas are organized horizontally or vertically. The older and more traditional viewpoint is that the organization is horizontal; that sensory information from the outside world arrives at the appropriate sensory area in the cortex, from where nerve impulses then pass across the cortex (in so-called transcortical paths) to the motor area of the cortex Neural activity in this motor area then produces an appropriate response via t e *pyramidal tracts* that eventually coı nect the motor cortex with the peripheral muscles.

The more recent viewpoint emphasizes the *vertical organization* of the brain which involves up-and-down pathways or loops between lower centers and the cortex. Experiments by R.W. Doty and his associates (1961) support this latter view-point. They attached electrodes to the skulls of cats in such a way that one electrode was in the visual cortex and a second in the motor cortex. The motor electrode was placed so that when it was used to apply electrical stimulation to the cortex, a discrete peripheral movement of one of the limbs occurred. These cortically-induced movements were used in the experiment as the unconditioned response (UR). Electrical stimulation from the electrode in the *visual area* was used as the conditioned stimulus (CS) In the Pavlovian conditioning experiment, the UR is a response that occurs automatically when a particular stimulus is used. For example, when an animal's foot is shocked, the UR is a fle ion of that leg. The CS would then be a stimulus other than the shock—such as a buzzer—that comes to produce the leg flexion after it is presented a number of times just prior to the shock to the foot. Analogous to the pavlovian conditioning experiment, Doty hoped that by repeatedly stimulating the visual electrode and then the motor electrode, it would eventually be possible to produce the movement of the leg when only the visual electrode was activated. Conditioning (learning) of this type turned out to be possible.

After conditioning their cats in this manner, Doty and his associates surgically sectioned the cortex near the sensory electrode and retested the cats for the conditioned response to find out what neural path was used for the newly established sensory-motor connections. They used two types of surgical cut. Some cats received a circular cut through the cortex that completely circumscribed the sensory electrode while other cats received an undercut beneath the visual cortex where the CS electrode was located. It turned out that when the electrode in the visual cortex was surgically circumscribed, severing the direct *transcortical connections* with the motor cortex, the "conditioned" response could still be produced when the CS electrode was *undercut* so that its downward connections were lost, stimulation with the CS electrode no longer resulted in the performance of the conditioned or learned response. This appears to indicate that conditioning depends on vertical neural organization.

Emotion

Having understood to an extent the nervous system of the organism, the physiological psychologist uses that understanding to try to understand behavior from that perspective. The areas of greatest interest include motivation (sex, hunger, thirst, etc.) with its hypothalamic involvement; emotion and moods with their relation to the limbic svstem; learning and memory in which the hippocampus is implicated, and unusual states of consciousness.

Shakespeare commented upon emotion in these celebrated lines :

> To leave his wife, to leave his babes
> His mansion, and his titles, in a place
> From whence himself does fly ? He loves us not,
> He wants the natural touch. For the poor wren
> (The most diminutive of birds) will fight,
> Her young ones in her nest, against the owl.
> All is the fear, and nothing the love,
> As little is the wisdom, where the flight
> So runs against reason.

This quotation illustrates one dimension of emotionality : the *flight* or *fight polarity* of fear and anger. This dimension has received psychophysiological research attention because it is simple to create in the laboratory and the effects are physiologically dramatic.

How can an understanding of the physiological correlates of emotion be helpful to one ? Another quotation from Shakespeare dramatizes the problem :

> ...cruel are the times, when we are traitors
> And do not know ourselves; when we hold rumour

From what we fear, yet know not what we fear,
But float upon a wild and violent sea
Each way and none...

People are frequently at the mercy of their emotions. But with a greater understanding of their emotions, they can be more aware during emotional situations. Being more aware of emotional reactions, one can make certain decisions, *i.e.,* a decision to alter one's own emotional state, or the emotional state of others by one's behavior toward them, thus, changing the situation or leaving the situation for a more favorable one. With a greater self awareness in such situations, a person has a greater range of possible responses.

But what are emotions? Being such a universal experience, it would seem simple to define emotions, but it is not. The *American Collegiate Dictionary* defines emotion as "An affective state of consciousness in which joy, sorrow, fear, hate, or the like, is experienced (distinguished from congnitive and volitional states of consciousness)."

Emotions can be viewed from various perspectives : the emotional experience itself, dealing with the subjective feelings of the one experiencing the emotion; the observable emotional behavior which includes body movements, facial expressions, vocalizations, somatic nervous system responses, etc.; the knowledge of internal physiological responses and the changes which deal primarily with the autonomic nervous system. It is from these perspectives that emotional research and theories have arisen.

The psychophysiological theories of emotion can be divided into those done from the standpoint of different parts of the nervous system. Some theories concern seeing the emotion as being created by the changes in the body by changes in the somatic and autonomic nervous systems, and other theories concern changes in structures within the central nervous system and their mediation of emotions. In either theory, the goal was to find the specific emotional states and their physiological correlates.

The former theory of emotion is characterized by the James-Lange theory (developed in 1884 and 1885 respectively). The classic illustration of James' theory was that upon seeing a bear, one flees. One's running activity signaled the central nervous system that a state of fear was present, therefore, it was the perception of the visceral and skeletal muscle feedback that "created" the emotion. Lange independently added that feedback from the circulatory system was also included in the creation of an emotional state.

S. Schacter's and J. Singer's (1969) research extended the James-Lange theory to include the influence of autonomic states on the degree of arousal of the organism. He felt that it was the level of arousal related to the environmental situation that created specific emotions. In other words, it is the set (nervous system tuning) and setting (environment) which interact to give the arousal meaning in the situation.

The autonomic correlates of emotion are particularly interesting if one attempts to obtain phenomenological picture of emotional states. The autonomic nervous system, as stated earlier, is divided into the parasympathetic and sympathetic divisions. The parasympathetic division deals mainly with maintenance functions and maintaining the organism's homeostasis. The sympathetic system deals mainly with emergency situations. In general, the parasympathetic nervous system is dominant during pleasurable emotions and situations (the exceptions being the parasympathetic role in crying, nausea, etc.). The sympathetic nervous system is dominant during emotions such as anger, fear, or stress responses. At all times, both divisions are operative.

The efforts to get a phenomenological profile of an emotional state have been only partially successful. It has been found that noradrenalin (a hormone secreted at the synapses of the sympathetic nervous system which raises the blood pressure via constricting he peripheral blood vessels) levels increase during the anger response, and adrenalin (a hormone secreted by the adrenal medulla and circulating throughout the body which raises the blood pressure through increase in heart rate) levels increase during fear responses.

The work of W.B. Cannon and P. Bard illustrates the central nervous system theory of emotion. Their attention centered on the thalamus, and th y felt that behavior was dependent on brain activity. The thalamus, they asserted, added the emotional tor ing to the sensory input which came into the brain via the afferent, primary sensory system. W.R. Hess, on the other hand, later shifted the focus from the thalamus to the hypothalamus as the locus of the generation of emotional states.

The central nervous system structures explored for their impact emotions include the hypothalamus, limbic system, amygdala, hippocampus, septal region, cingulate gyrus, certain portions of the neocortex, and the reticular activating system. In the following section, we will look at several of these structures beginning with the hypothalamus.

Two areas of the hypothalamus implicated in emotional tuning include the anterior and posterior hypothalamus. If one stimulates the anterior hypothalamus, one obtains responses characteristic of the parasympathetic nervous system. If one stimulates the posterior hypothalamus, one gets flight or fight behaviors characteristic of the sympathetic nervous system. (Lesions in these two areas have an opposite effect.) Hess recognized this functional dichotomy, and heuristically delineated a trophotropic system (that is, a system concerned with the anterior hypothalamus and controlling the parasympathetic activity, centrally and peripherally) as well as an ergotropic system (that is, a system which activated the sympathetic nervous system responses characterized by intensification of behavior and the stronger emotions and located in the posterior hypothalamus).

The limbic system, it will be recalled, is a series of structures ringing the thalamus and hypothalamus. The limbic structures form an emotional circuit as innervation flows from structure to structure around again. For example, have you ever had something emotional on your mind just as you were trying to go to sleeep ? Each time you tried to put it out of your mind, a new aspect of the problem would assert itself, sometimes making a full circuit in reasoning, apparent even to you, the worrier. That is the emotional circuit or limbic system in operation. The limbic system mediates the hypothalamus and the emotions and motivations which flow from it. The limbic system also appears to be concerned with the preservation of the flight or fight polarity and preservation behavior.

The amygdala and septal region seem to have some sort of reciprocal relationship to each other. Lesions in the septal region induce attack and rage responses in the organism as though the amygdala is able to discharge, unabated by the influences of the septal region. Lesions in the amygdala have the reverse effect.

There are interconnections between portions of the prefrontal lobe and the limbic system structures which have led to the use of *psychosurgery* to relieve intense anxiety and obsessional behavior. Mounting evidence of the side effects which outweighed the positive gain led to the reduction in usage of that surgical procedure, especially with the advent of alternative types of therapy.

Most contemporary views see emotions as being the result of internal changes, as well as external behaviors that may occur in a particular stimulus-environment. Within the central nervous system, the hypothalamus, limbic system, and related cortical areas are activated: this activation finds its expression in the autonomic nervous system changes. The perception and, therefore, interpretation of meaning of the emotional state is primarily a cortical activity. However, it is the autonomic mechanisms which make the emotional experience possible. In addition, a number of issues in emotion research remain unresolved.

Motivation

Shakespeare described motivation quite well in three lines:

My falcon now is sharp, and passing empty,
And till she stoop she must not be full-gorg'd,
For then she never looks upon her lure.

Regardless of the particular aspect of motivation one is concerned with, (hunger, thirst, sex, etc.) there is a state of need exemplified by the hungry falcon. This state of need increases the keenness of perception with regard to the particular need state. . There is also the possibility of satiety which decreases the need state and heightened perceptions.

What is meant by motivations? Motivations are *need states* which propel the organism toward satisfaction of the need. These needs can stem from the maintenance of the organism (in hunger and thirst) or the survival of the species (in sexual, reproductive, or parenting behavior).

A.H. Maslow outlined a need hierarchy which included physiological needs (hunger, thirst, rest, etc.), safety and security, belonging and understanding, love, attention, esteem, curiosity, the need for beauty, and self-actualization. As the basic needs are solved the person moves on to fulfill higher order needs. There is a close relationship between motivation and emotion; indeed, some of the same brain areas are involved.

The autonomic factors present in *hunger* include blood composition, digestive phase, amount of nutrition present, state of mouth receptors, etc. The central factors include the state of the lateral hypothalamus and limbic regions.

A great deal of research has been done about what stops eating behavior or what signals satiety. Once the stomach has been maximally distended by ingestion, the proper amount of calories has been ingested, or the oral receptors have been sated, signals are sent to the amygdala, then to the ventromedial nucleus, and feeding ceases.

Thirst follows the same general format as hunger, *i.e.*, autonomic factors (such as dry mouth) and central factors as cholinergic state of the lateral hypothalamus) produce the need for liquid ingestion. There are additional physiological signals which initiate and stop drinking behavior.

Like eating and drinking, *sexual behavior* has autonomic and central factors involved. Unlike hunger and thirst, in the sexual experience both the sympathetic and parasympathetic nervous systems are activated during the entire behavioral sequence. During the initial excitation and need state there is a sympathetic nervous system dominance. The parasympathetic nervous system becomes dominant during the physiological preparation for the sexual experience. The sympathetic nervous system again becomes ascendent during the orgastic discharge, followed by the parasympathetic post-orgasm phase.

Stimulation of the erogenous zones increases sexual arousal which is a centrally mediated response as seen by recordings from the hypothalamus. (The critical area may be the anterior hypothalamus.) Hormonal control of sexuality is more the case for lower animals than for primates where experience and learning play a greater role.

There is an obvious need on the part of organisms for *activity* and *exploration*. This need can be observed and measured in a laboratory situation such as quantifying the search pattern of a rat in a new environment. Monkeys can be given a visual reward for completing behavioral tasks. The need for activity and exploration can be understood as related to the organism's continuous need for novel stimulation, environmental change, and arousal. At the human level, it is expressed as curiosity about both the self and the environment.

LEARNING

Shakespeare wrote :

> Will I with wine and wassail so convince
> That memory, the warder of the brain,
> Shall be a fume, and the receipt of reason
> A limbeck only.

This quotation indicates the capacity of alcohol to combine biochemically with the biochemistry of the brain so as to interfere both with learning and memory. It also underlines the fact that it is far easier to explore the biochemistry of memory through chemicals which block or neutralize memory than it is to enhance memory.

Most psychological definitions of learning include change in behavior as the primary criteria for whether learning has occurred. This change in behavior can mean new additions to the organism's behavioral repertoire or an improvement in old behaviors.

Again there are numerous learning theories depending on one's psychological orientation. Some of these theories are complex and philosophical and others are more simple and concrete.

The general approach to the study of physiological correlates of learning is to provide a learning situation in the laboratory according to one of several types of learning. The types of learning include : *classical conditioning* - presentation of a conditioned stimulus repeatedly until it becomes paired with an unconditioned stimulus; *operant conditioning* a—gradual shaping of behavior by reinforcing parts of the ongoing behavior to increase the probability that it will recur; *discrimination learning*—training the subject to discriminate between stimuli; and *complex learning*—teaching more complicated behavioral sequences. If the learning experience occurs in the laboratory where its physiological correlates can be measured before, after, and during learning, it can be studied to determine the effects of various experimental treatments.

The electrical correlates of learning show an interesting pattern. Upon presentation of a novel stimulus the organism shows a general arousal of the cortex as seen by the shift toward beta waves throughout the cortex. (This is called the *orienting reflex.*) Gradually the area of arousal decreases until only the area of the brain involved in this behavior remains activated. And finally, the brain may show no arousal at all during particularly habituated learnings when alpha brain waves may be present.

It seems that memory is a two part process; there is a *short term memory* which can be disrupted and may be largely a reverberating of electrochemical circuits; and *long term memory* which is less easily disturbed and may be biochemical or even related to the electron-microscopic particles within the DNA genetic code. Short term memory may be stored in the hippocampus and long term memory in the temporal lobe region. However, it is more likely that virtually the entire cortex and many subcortical regions are involved in memory. Perhaps different aspects of memory are stored in different places; visual aspects may be processed by the visual cortex, auditory aspects of the auditory cortex, etc. Perhaps recent memories are processed by the hippocampus and the final storage of memory is carried out by the association cortex (Isaacson, et at, 1971).

Biofeedback Training

One area of learning research is the use of technological aids to change physiological processes with information returning to the organism. This area, termed *biofeedback training*, validates the centuries-old claim of yogis that they could control autonomic processes. The physiological parameters being used in biofeedback training include EEG (brain wave feedback), EMG (muscle tone feedback), EKG (heart rate feedback), and GSR (Galvanic Skin Response feedback).

M. A. Wenger, B. K. Bagchi, and B. K. Anand (1961) studied four subjects who claimed that they could stop or slow their hearts. None of the subjects could stop their heart, but one subject could slow down his heart. The authors explained that the subjects employed strong abdominal contraction and breath arrest with closed glottis which produced intrathoracic pressure to the point where venous return to the heart was markedly reduced.

M. E. Miller (1969) pointed out that studies like this one cannot rule out the possibility that the *entire* effect is due, not to the direct learning of a visceral response, but to the subject having learned a skeletal response the performance of which causes the visceral changes. Thus, Miller and his associates designed a series of studies to overcome this problem. J.A. Trowill (1967) used deep curarization (because it paralizes the skeletal-muscular system) combined with electrical stimulation of the pleasure center of the brain as a reinforcer. His subjects were rats, half of which were rewarded for heart rates above the average and half for rates below average. Trowill's results were that 15 of 19 rats rewarded for fast heart rates increased their rates and that 15 of 17 rats rewarded for slow rates decreased their rates. These changes were statistically significant but small.

Subsequently, N.E. Miller and L. DiCara (1967) replicated Trowill's experiment but produced larger heart rate changes by "shaping" the responses. After the rats attained the easy criterion of a small change, they were required to meet progressively more difficult criteria for reward. In this way, different groups of rats increased and decreased their heart rates by approximately 100 beats per minute. The rats also were able to learn to respond discriminatively to stimuli that signalled that cardiac changes would be rewarded.

Biofeedback training involves placing an organism in a closed feedback loop where information concerning one or more of its bodily processes is continually made known to it. When the organism possesses this sort of information about a bodily process, it can learn to control this function. Operant control of EEG alpha brain waves (Figure 20) and associated changes in mental activity was first studied by J. Kamiya in 1962. Kamiya's first question was whether human subjects could be trained to discriminate the presence and absence of alpha. The subject was told that from time to time a bell would ring and when it was heard, a guess was to made as to whether or not alpha was being produced. As soon as a response was made, the experimenter told the snbject whether it was correct. The results indicated that after several training sessions most subjects had increased their discrimination accuracy far beyound the 50 per cent chance level. Kamiya then studied the question of whether subjects can exercise control over their alpha and produce it on command. He constructed an automated feedback system consisting of an electronic deviee which would turn on sine-wave tone in the subject's room whenever the alpha rhythm was present. The tone stopped whenever alpha disappeared. Kamiya (1969) found that the subjects who could produce high amounts of alpha described the experience as pleasant, and as involving "some kind of general relaxation of the mental apparatus, not necessarily relaxation in the motor system, but a kind of general calming-down of the mind."

It may also be possible to increase creativity by biofeedback training. E. E. Green, A. M. Green and E. D. Walters (1970) initiated a project in which they attempted to train subjects to voluntarily produce theta brain waves which appear to be associated with hypnagogic-like reverie often found to accompany certain types of creativity. In the meantime, therapeutic applications have been made of biofeedback training. The use of EEG biofeedback can often help shape the individual toward either increased relaxation or alertness. EMG training generally has been used to train for relaxation, using the frontalis (forhead) muscle as an index of the state of relaxation of the organism; it has been especially helpful for work with chronic anxiety patients and those with tension headaches. Temperature feedback has been helpful in migraine patients ; blood pressure feedback has been used for hypertension, gastric acid feedback has been used for ulcer patients, and GSR feedback has been utilized in training for relaxation.

The use of biofeedback for desensitization to conditioned stress responses has been another therapeutic application. The individual is taught to relax while gradually being exposed to habitually anxiety-producing situations. Through biofeedback, the patient learns to regain composure in proximity.

The REM Phenomenon

Neuron activity of the brain at sleep, as measured by the EEG, consists of an oscillating pattern of brain waves of varying magnitude and frequency which vary with the stages of sleep. With the onset of sleep, the beta activity (14 cps and above) of wakeful concentration and rhythmical 8 to 13 cps alpha waves of relaxed wakefulness give way to slower theta (4 to 7 cps) and delta (½ to 3 cps) waves. Stimulation of the RAS in a sleeping person converts the EEG from a sleeping to a wakeful pattern.

E. Aserinsky and N. S. Kleitman (1953) observed rapid, jerky, binocularly symmetrical eye movements under the eyelids of some of their sleeping subjects. These rapid eye movements (REMs) occurred in bursts three to five times during the night. It was found that these REM periods were characterized by a low voltage desynchronized EEG pattern and slightly faster heart and respiration rates. When the subjects were awakened during REM sleep, vivid and detailed dreams were reported in 74 per cent of the instances. Dreams were reported only 7 per cent of the time when subjects were awakened during non-REM periods. REM sleep is sometimes called "activated sleep", "paradoxical sleep," or "desynchronized sleep". Non-REM sleep is sometimes called "synchronized sleep."

Research has demonstrated that REM sleep dreaming is an invariable and universal occurrence of normal sleep and that it takes up about one-fifth of an adult's sleep each night. During infancy and childhood the proportion is higher, while in old age it is somewhat lower.

It was noted by R. J. Berger (1969) that the amount of REM sleep of different species is closely related to the amount of binocular coordinated eye movements they display. This suggests that REM sleep is functionally involved in the establishment and maintenance of binocularly coordinated eye movements needed for accurate binocular depth perception.

There is also some non-REM mentation, as D. Foulkes (1966) has pointed out. Non-REM mentation contain more conceptual thinking, less perceptual material, and less vivid, emotional, and distorted material. These thoughts correspond more to the person's daily life than dreams but are less of an expression of his or her inner life.

During dreaming, a large part of the cerebral cortex of the hemisphere is active. It has been found through animal experiments that when the lowest part of the sleep center in the pons is destroyed, REM sleep with dreaming no longer occurs, but deeper non-REM sleep is unaffected.

M. A. Pessah and H. P. Roffwarg (1972) reported that they detected activity of the stapedius and thensor tympani muscles of the middle ear during REM sleep. In a waking person these muscles generally respond to a loud sound (middle ear reflex). They measured middle ear muscle activity (MEMA) while their five human subjects (two female and theree male, ages 20 to 38) were sleeping. In their study they used controls to discriminate between spontaneous ear activity and ear activity due do changes in air pressure in the middle ear produced by swallowing, snoring, talking and murmuring during sleep. They found spontaneous activity of the middle ear muscles in all their subjects during all the REM periods ; and 80 per cent of all nocturnal middle ear muscle activity occured in the REM periods. They also found that REM dreams seem to contain more auditory images when the middle ear muscles are active.

Psychopharmacological Phenomena

Anyone who has observed an intoxicated person could guess that certain drugs affect the nervous system. W.J. Mc-Keachie and C. L. Doyle (1966) describe how the exhilaration and excitement characteristic of the individual intoxicated by alcohol is due to the removal of inhibitory affects of higher brain centers. Alcohol is a *depressant drug* ; it anesthetizes those parts of the brain that control and suppress thoughts, feelings, and actions. Alcohol also impairs the brain's ability to use oxygen, thus reducing one's efficiency on tasks of learning and memory, causing people to forget to end a sentence, but also produces unusual and sometimes pleasurable effects while listening to music. The chief active ingredient in marijuana, hashish, and other derivatives of the Cannabis sativa plant is tetrahydrocannabinol, a complex molecule whose effects are heavily dependent upon one's expectancy, experience, and psychological setting.

Tranquilizers such as the phenothiazines, are also depressants and have been useful in treating certain forms of schizophrenia and reducing the number of patients occupying beds in mental hospitals. It has been theorized that some types of schizophrenia are associated with abnormal metabolism of dopamine, a body chemical found in the brain. Tranquilizers are effective because they block the receptor sites for dopamine, thereby blocking its effects. (The opposition to this treatment has come from some psychotherapists who argue that drug therapy is superficial and merely treats the symptoms of the condition, and from other psychotherapists who cite untoward side effects of tranquilizers claiming that alternatives such as dietary changes and large doses of vitamins should be used instead.) Barbituparates, hynotics nd other sedatives have been used to treat anxiety and insomnia. These drugs' depressive effect upon the body is not clear, but it is felt that they decrease the activity of the sympathetic nervous system.

On the other hand, *stimulant drugs* are felt to facilitate sympathetic nervous system activity. Caffeine and nicotine are both mild stimulants ; they can decrease fatigue ; increase talkativeness and physical activity, produce a state of alertness, and – for a time—elevate one's mood and enhance certain tyyes of performance. Powerful stimulants such as amphetamines have been used to treat narcolepsy (a rare condition in which a person falls asleep at inappropriate times) and hyperkinesis (a condition which appears to be associated with brain dysfunction and a resultant inattention among school children) ; again, opponents of drug therapy note that alternatives exist, e.g , special education techniques such as operant conditioning and nutrition-vitamin approaches.

Stimulants are not to be confused with *anti-depresssant drugs* such as the mono-amino-oxidase inhibitors and the tricyclic anti-depressants. It is hypothesized that functional differences of noradrenaline in the brain are related to depressive emotional disorders while excesses of noradrenaline are related to mania or overly-excited states. Drugs that increase the availability of noradrenaline in the brain might alleviate depression, and drugs that decrease the availability or block the effects of noradrenalin might alleviate mania. The mono-amino-oxidase inhibitors and tricyclics block destruction of noradrenaline inside the nerve cell, making more of it available for bodily use. On the other hand, the plenothiazines (and other tranquilizers), often effective in controlling manic psychosis, may work by blocking the effects of noradrenaline. The opponents of drug therapy point out that only one out of ten depressed people responds to drugs; as for manic psychosis, a mineral by the name of lithium carbonate was found, by H. Corrodi, S.M. Schanberg, and

R.W. Coldburn (1967), to be effective with none of the side effects often produced by the phenothiazines, although the mechanism might be similar.

One of the most interesting psychopharmacological phenomenon involves the action of *LSD-type drugs* on the nervous system. The perceptual and conceptual changes resulting from the ingestion of these drugs may relate to the role of serotonin in the body. Serotonin is an amine that, like noradrenaline, probably transmits nerve impulses in the brain. This amine is chemically similar to part of the LSD molecule.

LSD has been found to block the effects of serotonin on cell tissue; thus it has been hypothesized that LSD exerts its behavioral effects by blocking serotonin's action in transmitting nerve impulses. In any event, preliminary studies with LSD-type drugs suggest their possible experimental use in studies of cognition and creativity as well their therapeutic use with alcoholics, severe neurotics, disturbed children, terminal cancer patients, and heroin addicts. Clinically, cases have been reported of borderline psychotics who have taken LSD-type drugs illegally only to become severely disturbed during an experience which could not be wisely handled or assimilated. As for the claims that LSD-type drugs are pharmacologically toxic, N. Dishotsky and his associates (1971), after reviewing the literature, concluded that "pure LSD taken in usual small doses ..in the human being...does not damage chromosomes, cause mutations, or cause cancer."

Heroin and other *narcotic drugs* exert depressant effects upon the central nervous system. There is some evidence that potential receptor sites for the narcotics exist on the brain and persons with an abundance of these sites are predisposed to addiction from heroin, opium, or morphine—all of which produce a torpid state of euphoria. Of course, psychological and sociological factors for narcotic addiction (and other types of drug misuse) exist as well, ranging from individual to individual.

At times, various psychologists have tried to dismiss as meaningless such questions as the nature of consciousness and the place that hypnosis, dreams, and other forms of altered awareness have in scientific research. Although difficult to define, the word "consciousness" -can be taken to refer to a self that can reflect on its own processes, its own "goings-on". The term "awareness" can be taken to refer to the quality of experience undergone by such a self. When alterations in awareness are discussed, hypnosis often comes most readily to mind.

A. Mesmer (1734-1815) was a Viennese physician who used hypnosis for various disorders. He treated patients by touching their bodies with a wand, immersing them in a large vat surrounded by magnets, or making "magnetic passes" which presumably affected their bodily fluids in positive ways. J.M. Charcot (1925-1893), a neurologist, was influenced by Mesmer's work and advanced the therapy of treating emotional disorders by applying hypnosis. In 1885, S. Freud (1856-1939) began to study with Charcot and saw the efficacy of hypnotic induction for treating certain neurotic problems.

Freud eventually abandoned hypnosis for free association and other psychoanalytic techniques, however, its use peristed and eventually found a place in psychotherapy, dentistry, medicine, and experimental psychology.

W. James (1892-1910) posited a "dual consciousness" to explain many of the phenomena of hypnosis. He felt that a hypnotized person to perceive it in order to be able notto perceive it. In one of James' examples, a mark was made on a piece of paper fails and the hypnotized person was instructed not to see it. Many additional marks were then made on the paper, and the person acted as if all the marks were visible except the first. James noted that the hypnotized person could discriminate that mark from all the others and could manage not to perceive it while perceiving the other marks.

However, in James' example, how do we know that the subject did not lie ? How can we even be sure that subjects are not merely pretending to be hypnotized ? Or how do we not know not that the subject is sincere but merely playing a role ? T.X. Barber (1970) has been able to demonstrate that all common hypnotic phenomena (hallucinations, post-hypnotic suggestions, post-hypnotic amnesia, increase in muscular strength, etc.) can be brought about by task-motivating instructions—encouraging the subjects to engage in unusual behaviors by increasing their self-confidence and giving them instructions in a firm, yet reassuring tone of voice. Barber has asserted that hypnosis is a phenomenon of social interactions and does not represent an important alteration in awareness.

M. Orne (1959) attempted to investigate this problem by comparing the behavior of subjects who were hypnotized with people who were merely pretending to be hypnotized. The hypnotist did not know which was which. Orne discovered some important differences between the two groups centering on what he termed "trance logic." With trance logic, a person readily perceives hallucinations suggested by the hypnotist and mixes them freely with perceptions based on real objects and events without making any attempt to be logically consistent. For example the hypnotist told a subject, that a third peron, known to the subject,would be seen sitting in a chair that was empty. That individual was, in actuality, standing behind the hypnotized person. The hypnotized person turned around a d seeing the third individual, registered surprise, saying there were two images of the same person. In contrast when the pretenders turned around, they either said that they saw no one or claimed that they saw a person but there was no recognition.

In general, there are no brain wave changes during hypnosis, although a few subjects tested by a Soviet psychiatrist, V. Raikov, demonstrate a slower brain rhythm after several hypnotic sessions. Both Soviet and American researchers have also noted differences between the cold electron emissions from fingers of hypnotized and non-hypnotized subjects following high voltage electrophotography (Krippner & Rubin, 1974). Differences in bodily electrodynamic fields have been reported by investigators using the vacuum-tube voltmeter devised by H.S. Burr (19 3).

E R. Hilgard (1965) has admitted that social roles are an importa-t part of the hypnotics process. However, l e has also described several other characteristics of hypnotized subjects : leaving initiative and planning to other , easily produced fantasies and memories, manipulatable attention, lessened reality testing, less concern for the external environment, and increased susceptibility to suggestion. Indeed, the latter trait may be a focal key to hypnotic phenomena.

Holographic Qualities of the Brain

One might conclude a discussion of consciousness by pointing out that the brain works in a unified manner, largely as a whole. K. Goldstein has theorized that the brain always works as a whole although some more specific localized areas and pathways may be *figural* for different mental activities. The other brain processes then are ground. There are also many unifying brain mechanisms. F. Bremer has recently described three important neurophysiological correlates of the unity of consciousness. These three mechanisms of cerebral synergy are : (*a*) the interhemispheric exchange of sensory information and the transmission of motor decisions by way of cerebral commissures, especially the corpus callosum; (*b*) the unifying influence produced on brain activities by the energizing impulses emitted by brainstem and thalamic reticular structures; and (*c*) the neuronal convergence and interaction in the visual area of impulses from corresponding receptive fields of the two retinas. These unifying brain mechanisms may give unity to our conscious experience and to our behavior.

K. Pribram (1971) has suggested that much of brain function resembles that of a hologram. In this process of three dimensional photography, a vast amount of optical information may be stored within and retrieved from a single holographic plate, depending on shifts in angles in the exposure and reconstruction of images. To extend the parallel one step farther, it is interesting to note that any single fragment of the hologram is seen to contain the entire image stored within the complete holographic plate. A challenging model, based on this concept, has been presented by K. Floyd (1974 : 55-56).

Although laboratory evidence is just beginning to accumulate, and introspection remains suspect, it may not be premature to hypothesize that the area of the midbrain immediately posterior to the optic chiasma will be found to be the locus of a neural holographic plate.

Floyd goes on to suggest that the pituitary gland, hypothalamus, thalamus, and pineal body are associated with a "theater of consciousness" awareness. Floyd continues :

> Increasing numbers of neuropsychologists and neurophysiologists are coming to regard higher brain function in terms of an optical system processing a form of bioluminescence (light in the midst of the darkness of the skull)...Let me suggest that brain functions such as perception, memory, imagining, etc., are beginning to appear most clearly explainable on the basis of a holographic model. The "screen" of awareness may turn out to be an-organicform of a holographic plate which processes-three-dimensional perceptions and reconstructed images with equal facility.

Floyd concludes that the "seat of consciousness" may never be found by a neurosurgeon because it involves not so much an organ as it does the interaction of energy fields within the brain.

The study of energy fields and holographic models may eventually teach psychologists more about human consciousness than a study of specific brain mechanisms. If so, psychology will face one of the greatest explorations in its history—an exploration that other disciplines must be invited to join if the new terrain is to be adequately mapped.

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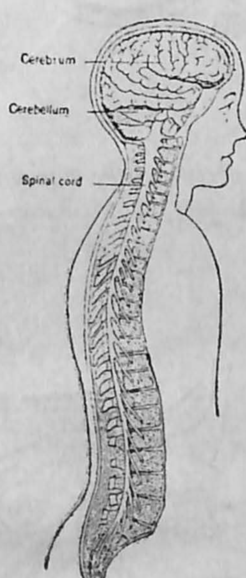
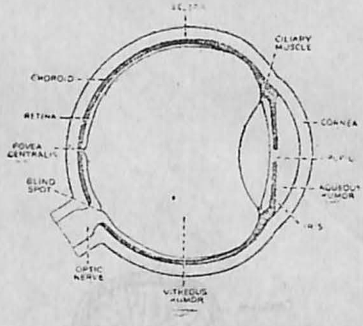
Illustrations



The Central Nervous system as a whole

FIG. 1 PAGE—5



Cross section of the human Eye

FIG. 2 PAGE—10

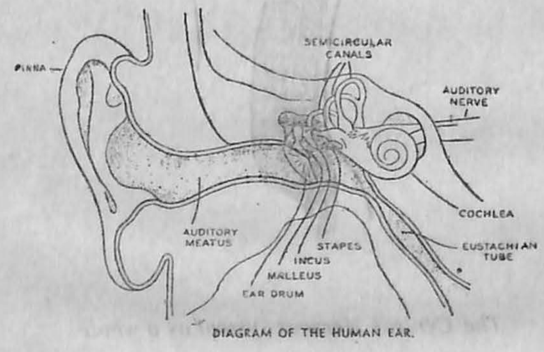
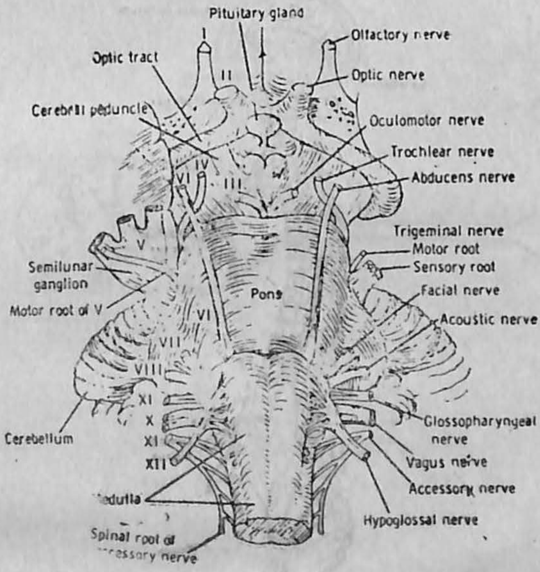


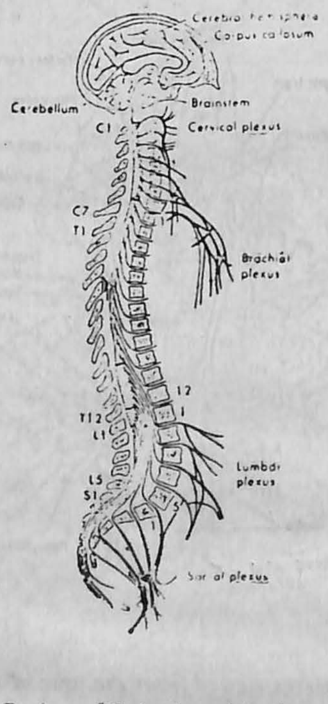
Diagram of the human Ear

FIG. 3 PAGE—15



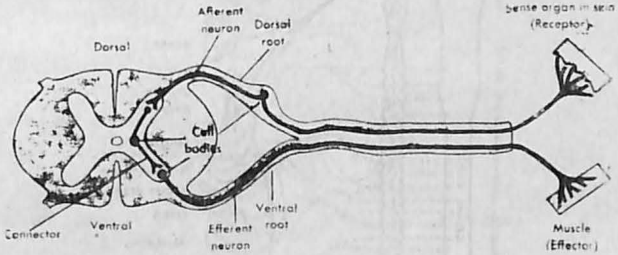
Cranial nerves viewed from the base of the Brain

FIG. 4 PAGE—20



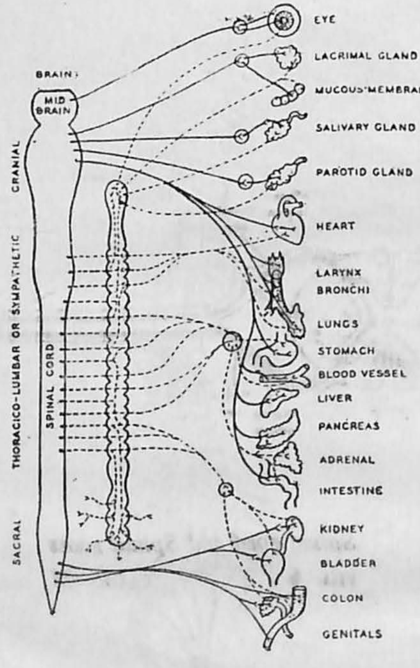
Brain and Spinal cord in situ

FIG. 5 PAGE – 21



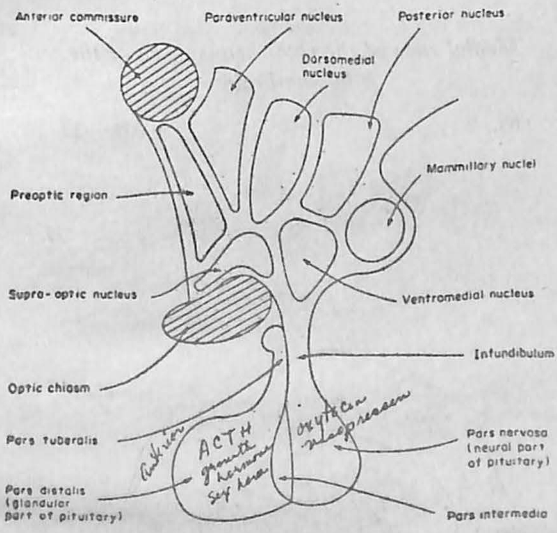
Spinal cord and Spinal roots

FIG. 6 PAGE—21



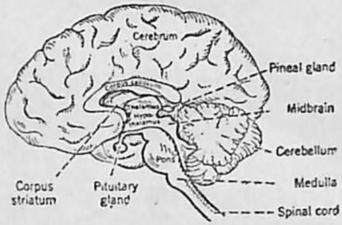
Autonomic Division of the Nervous System

FIG. 7 PAGE—25



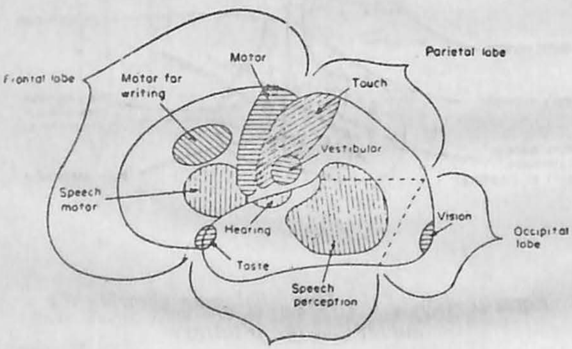
Lateral view of the Hypothalamus showing the nuclei and the pituitary

FIG. 8 PAGE—26



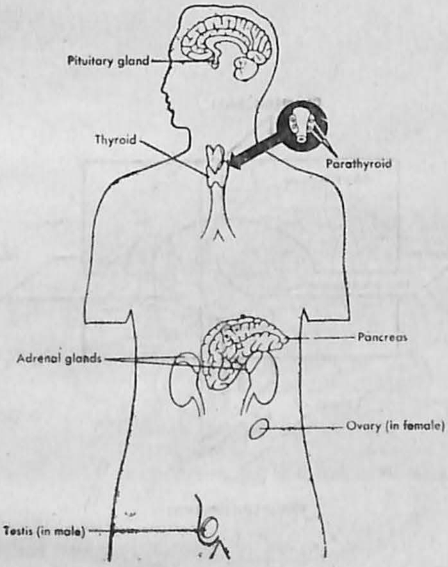
Medial view of the right hemisphere of the human brain

FIG. 9 PAGE—27



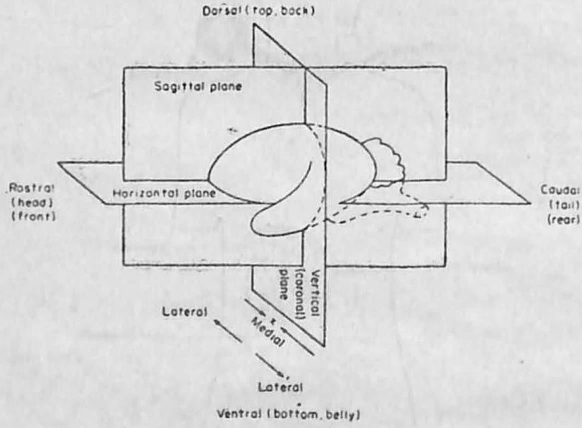
Locations of motor and sensory areas of the human brain within the Lobes of the Brain

FIG. 11 PAGE—30



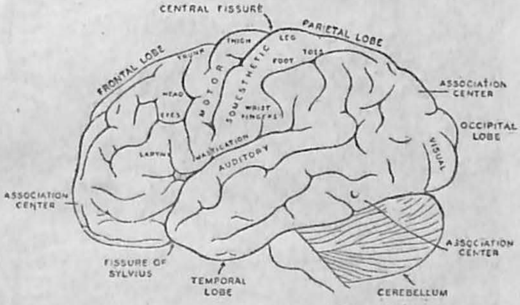
The location of the Endocrine glands in the body

FIG. 10 PAGE—28



Side view of a human brain showing the directional terms commonly used by brain researchers

FIG. 12 PAGE — 30



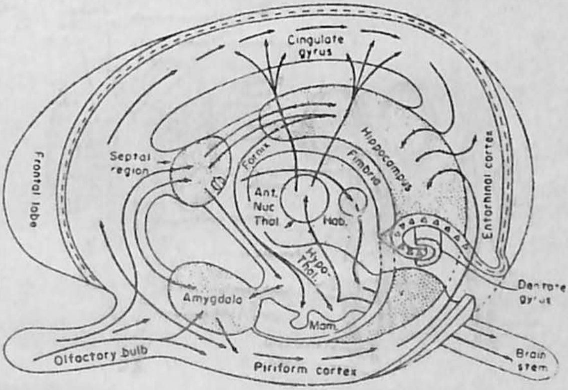
SIDE VIEW OF THE LEFT HEMISPHERE OF THE BRAIN

Side view of the left hemisphere of the brain

FIG. 13 PAGE—32

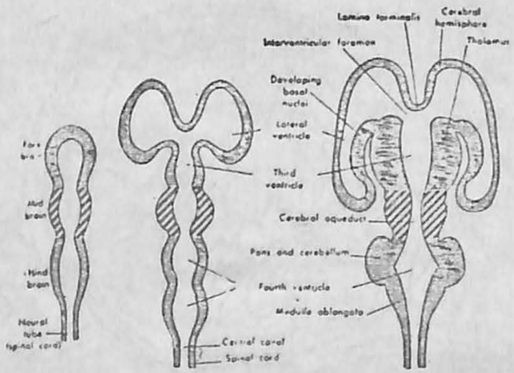
Motor homunculus

FIG. 14 PAGE—25



A Primer of Physiological Psychology

FIG. 15 PAGE—34



Development of the brain from the neural tube

FIG. 16 PAGE—36

PHYSIOLOGY OF CONSCIOUSNESS

AND PRAKASHAN, MEERUT.