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of the skin, known as café-au-lait spots, are the abnormalities most important in establishing the diagnosis of neurofibromatosis. Both first appear in childhood but increase in number with advancing age. The soft, flesh-colored skin tumors arise anywhere along the paths of the nerves that supply the skin, and they may number in the thousands. They tend to be most numerous on the trunk of the body and occur infrequently on the palms or soles. They may coalesce to form large masses, producing a grotesque appearance, similar to that seen in the "elephant man." Bone lesions occur in up to half of individuals with neurofibromatosis, sometimes causing disfiguring curvature of the spine. Forty percent are either mentally retarded or have a learning disability.

Treatment of neurofibromatosis is limited chiefly to surgery. Sometimes it is necessary to remove tumors encroaching upon vital structures. In addition, attempts have been made to perform reconstructive surgery in people with the more disfiguring forms of the disease.

The outlook for people with neurofibromatosis is highly variable. Some who are severely afflicted may succumb from one of the complications of the disease, such as the development of cancer in the tumors. Individuals who have a minor form of the disease, however, have a normal life expectancy. KENNETH E. GREER

NEUROPSYCHOLOGY, the study of how the brain organizes experience. Observations and experiments are carried out in the clinic and in the experimental laboratory. Brain tissue is electrically stimulated, electrical recordings are made from various sites in the brain, and/or parts of the brain are resected. Observations of verbal and nonverbal behavior serve as indicators of the subject's experience. Studies of the effects of drugs on brain function and on behavior are also often included in neuropsychological experiments.

In the clinic, electrical recordings from the scalp of patients are regularly undertaken to determine whether any abnormality in the brain function exists. On the basis of the work done in experimental laboratories, it would seem that such recordings ought to be done while the patient is performing behavioral tasks, which place a "processing load" on function—that is, the recordings ought to reflect a specific mode of functioning of the brain. So far, however, this sort of testing is not standard procedure. Recordings are ordinarily made while the patient is daydreaming or resting or even asleep.

A major area of clinical neuropsychology concerns the behavioral competence of patients who have suffered brain damage. Chemical tracers using radioactive substances injected into the arteries that feed blood to the brain are used to determine the degree of brain damage that has occurred after a stroke or head injury. Recordings (computerized tomography, or CT scans) made with such tracers take from 15 minutes to a half hour, during which the patient is asked to perform some prolonged activity such as reading, reciting, listening to music, or solving mathematical problems. The results of these investigations have shown that the brain is made up of many systems, which differ from one another in function. The systems are defined by the influence they exert on experience and behavior, and they are delineated anatomically and by their chemical differences.

History. As a science, neuropsychology is a branch of both experimental psychology and clinical neurology. Psychology became a science when, toward the end of the 19th century, it was realized that mental experience could be gauged by studying behavior. In humans, behavior is one of two kinds: instrumental, based on gestures and the manipulation of objects; and linguistic, based on the production of symbols, such as those constituting verbal propositions. Other cultural forms of communication, such as music, cannot be as readily classified but can, on occasion, also be used as indicators of the nature of human experience.

During the 19th century, clinical neurology made important advances in relating the location of brain damage to changes in the reported and observed mental life of patients. At the beginning of the century Franz Joseph Gall started this line of investigation and came to the correct conclusion that the brain was composed of systems, each of which could be related to one or another mental process. By the end of the century such eminent thinkers as Sigmund Freud and William James formulated ideas that still motivate the science of neuropsychology and proposed solutions to problems that continue to remain viable a century later. There is, however, a major difference in the approach of 19th- and 20th-century neuropsychology. During the 19th century, man was the focus of scientific interest and therefore the prime question that needed to be answered was, "In what way is man's brain different from those of other animals?" Verbal reports of introspection and reports of bizarre behavior were the main resource available for making the connection between the damaged brain and the damaged person. In the 20th century the focus shifted to an experimental analysis of behavior and the influence of brain resections and stimulations on this analysis. As a result, quantifiable records of instrumental behavior rather than imprecise verbal reports became the dominant mode of investigation.

This change in direction was consistent with the "behaviorist" orientation of psychology during the middle of the century. Neuropsychologists, however, realized that by ignoring verbal behavior, scientists were neglecting a fruitful source of information. Neuropsychological observation showed that instrumental and verbal behavior reflect different psychological processes and in this difference lies the key [illegible] understanding much of what we call "mental." This [illegible] exemplified by "blindsight," a condition that results from injury to the back end of one of the brain's hemispheres. Most body parts are connected to the brain hemisphere [illegible] the opposite side—the connecting nerve fiber tracts [illegible] From the eyes the connections are so arranged that dam[illegible] to their terminus in the back end of the brain leaves [illegible] patient blind on the side opposite to the damage. Paradoxic[illegible] however, when asked to guess, such patients can point corre[illegible] to the location of objects and can even identify their [illegible] and color. When asked how they have done this, they [illegible] in surprise that they were merely guessing as asked. *Objec*[illegible] speaking they can see, but *subjectively* they are "blind." [illegible] behaviorists have great difficulty in accepting these ob[illegible] tions. After all, were nonhuman animals being tested [illegible] having them press a panel with object forms displayed [illegible] as observers, would (incorrectly) infer from their instrum[illegible] behavior that the animals could, *from their point of* [illegible]

Another instance of the importance of attending [illegible] verbal reports of patients comes from studies with [illegible] who have had the hemispheres of the brain [illegible] separated for treatment of severe epilepsy. When ob[illegible] shown to their right, these patients properly descri[illegible] objects verbally, since in most adults raised in [illegible] culture, speech is controlled by the left hemisphere. [illegible] however, the objects are shown on the left, these [illegible] cannot describe the objects verbally but can match [illegible] an appropriate picture also shown on the left. The [illegible] states that he did not "see" the object on the left.

Neuropsychology became recognized as a separate discipline [illegible] second half of the 20th century. The early history that [illegible] this recognition can be told in terms of a handful of [illegible]gators whose work defined both the essential core and [illegible] boundaries of the discipline. Donald Hebb, Henri Hecaen, [illegible]ndr Luria, Brenda Milner, Karl Lashley, Hans-Lukas [illegible] Karl Pribram, Roger Sperry, and Oliver Zangwill [illegible] its principal architects. All of them were devoted to 1) [illegible]ful quantitative recording and description of the changes [illegible]ght about in the brain either by disease or by experimental [illegible]ulation and 2) precise analysis of the resulting changes [illegible] behavior (verbal and nonverbal) by a variety of formal [illegible] informal testing procedures.

Lashley, originally a zoologist, applied the behavioral research procedures developed by John B. Watson. He was joined by Donald Hebb, Roger Sperry, and Karl Pribram during the most formative years of the discipline.

In the Soviet Union the clinical tradition was developed by Aleksandr Luria. After World War I, Luria initiated, together with Lev S. Vygotskii and Aleksei N. Leontiev, a new psychological theory based on the concept that as children develop, their behavior comes more and more under the control of internalized speech. He and Teuber later showed that the frontal lobes of the brain had much to do with the development and execution of such controls.

Karl Pribram, a neurosurgeon, turned to investigative work during the peak years of psychosurgery. Each year thousands of patients were being subjected to the procedure known as frontal lobotomy. In a lobotomy, a blunt instrument is inserted into the front part of the brain and the fibers connecting its frontal parts at the rear are severed from the rest of the brain. Pribram explored changes in behavior and experience resulting from lobotomy. He focused on nonhuman primate research, establishing an experimental psychosurgery laboratory at Yale University. Pribram discovered that the psychosurgical effect of lobotomy was due to the close connection of the far frontal cortex with the hypothalamus and the limbic systems of the forebrain. Further research revealed that the limbic systems (so-called because they lie at the medial edge (*limbus* in Latin) of the cerebral hemispheres) as well as the hypothalamus regulated visceral and endocrine functions, findings which went a long way toward explaining some of the effects of lobotomy on personality. These experiments led Pribram to investigate not only the functions of the frontal lobes and the related limbic formations of the forebrain, but also other systems of the brain that had until then been overlooked. In the process Pribram and his students firmly established neuropsychology as an experimental science.

Roger Sperry capped these developments by the research that earned him a Nobel Prize in 1981. Sperry exposed unsuspected differences in the functions of the two hemispheres of the brain. The most dramatic effects of disconnection were those mediated by verbal reports. Often, two mentalities could be shown to coexist; sometimes the two were at odds. These observations led directly to inquiries on the nature of consciousness.

Consciousness. Blindsight is just one of the disturbances of consciousness that results from brain damage. Disturbances of "reflective self-consciousness" result from injury to the region of the brain just behind the top of the head. Patients "neglect" a part of their body on the side opposite to the brain damage. One such patient repeatedly tried to sit up in bed only to be caught in the sheets. When her arm was shown to be the cause of the obstructed movement, she exclaimed, "Oh, an arm!" And when shown that the arm was attached to her body she was surprised and flustered. The arm just did not seem to belong to her. If it were a speechless animal being observed, we would be unable to note that anything had gone awry. The behavior of the animal toward its environment would be essentially unimpaired. Its behavior is guided by the contents of a more elementary form of consciousness. A cat running across the coffee table is certainly judged conscious. If, however, one's neighbor suddenly did the same thing and you asked him why, he might well reply that he did not know, that he just had the urge to climb on the table. Only later would it be discovered that he had been hypnotized and given the suggestion to climb onto the coffee table. Like the cat the neighbor had acted without reflective self-consciousness, except that he had the verbal capacity to say so!

Hypnosis induces an alternate state of consciousness. Ordinarily we experience such alternate states when we fall asleep. Dreams that occur during sleep are difficult or impossible to recall when we awaken. Alternate states of consciousness are often exclusive: what we experience in one state becomes inaccessible when we are in another. When we are depressed everything seems hopeless; when we are elated, we cannot but wonder that we could ever feel anything but optimism. Drugs that act on the brain are known to change states of consciousness. That is why they are called "psychoactive." A practical offshoot of neuropsychology, neuropsychopharmacology, is making great strides in relating various chemical brain states to various mood states, states of consciousness.

Not only are the contents of consciousness determined by states, but the converse is true: pass a bakery and the smells quickly induce an appetitive state. The connections between state and content are studied by experimental and neuropsychologists as the processes of attention. The states and the contents of consciousness, and the attentional processes that connect them, provide animals with sufficient awareness to adapt successfully to the events experienced by them during their lifetime. What is the role, then, of reflective self-consciousness in the economy of being? With reflective consciousness comes the search for identity, the separation of a perceiving self from that which is perceived. With reflective consciousness comes the search for communion, communion that allows consciousness to transcend self. With reflection comes conscience (in French no distinction is made between "consciousness" and "conscience"). These aspects of consciousness are hallmarks of human existence. But, as properties of a physical system that is not that different in appearance from that of certain other animals, their emergence and development is less explicable in evolutionary terms than more strictly "biological" traits.

Learning and Memory. There is considerable memory stored in the body: muscles become larger with practice; immune systems protect against recurrent onslaughts of microorganisms; respiratory, heart rate, and digestive cycles become established and entrained by experience. But in order to remember grandmother, the high school prom, multiplication tables, and the first date, a normally functioning brain is required.

There are a sufficient number of brain cells to store prodigious amounts of experience. More important, each brain cell is endowed with many branching nerve fibers. Most neuropsychologists believe the experience becomes stored in the junctions between the nerve fiber branches, although this has not been firmly established. What is known is that in the brains of newborns there are myriads of such connections. During the lifelong learning process, some of these connections atrophy and disappear, others show a thickening of their active membranes. This indicates that connectivity becomes more selective: when a previously experienced event recurs, it triggers a network of interconnected brain cells in the same fashion as it did originally. Thus, the original experience is "remembered." One would expect that such a system of connectivities could become damaged or even cleanly excised in the experimental laboratory. But this is not the case. When individuals have strokes or when neuropsychologists take out chunks of brain tissue, no single isolated memory trace is removed. A woman who has had a stroke yet still recognizes her children does not then turn to her husband to ask who he might be. Memory is more of a whole and this has posed a serious problem to understanding.

Two discoveries enabled neuropsychologists at least to begin an explanation. The first was the mathematical formulation that led to holography. A hologram stores events in a peculiar fashion. Instead of making an image on a photographic film, as in ordinary photography, a hologram is composed of the nodes of intersection of various wave forms of light reflected from a scene. In such nodes the intersecting waves either reinforce or cancel each other. Mathematically the photographic image and the hologram are invertible transforms of each other, which means that an image can be transformed into a hologram and a hologram into an image.

The second discovery is more of an invention than a discovery. Scientists have found ways to mimic the connectivities of brain cells in computer programs. Techniques have been developed allowing the programs to learn anything from phrases of music to language. What is of special interest is that when the programs are examined, the memory for a musical phrase or of a particular word cannot be located in any particular part of the network of connections. Storage is distributed. The events to be remembered are first dismembered and stored in a nonlocal fashion. Mathematically, these computer programs are derived from the same invertible transformations that also spawned holography. By recording from single brain cells located in the visual system of monkeys and cats, scientists established that visual processing can be described by the same mathematical formulations that characterize holography and "parallel distributed processing" (PDP), as the computer simulations are called. The brain processes responsible for a distributed memory store can, therefore, be described by these formulations.

Experimental psychologists and neuropsychologists have distinguished several different sorts of learning and memory. One is sensory memory, tied closely to a sensory system and lasting from a few seconds to minutes and occasionally hours. Another is skill learning and memory, which become disturbed when the motor systems of the brain are damaged. Reference (also called semantic) memory is the kind of memory stored in a dictionary . The posterior systems of the brain construct this sort of memory store. By contrast, the frontal and limbic parts of the forebrain process episodes. Memory of this sort hangs together because it was experienced as a unit marked at its beginning and end by an orienting reaction. This sort of memory is closely related to what is called working memory, the type of memory used in everyday life to keep track of what needs to be done.

Language. Humans are distinguished by their ability to communicate via a bevy of signals that reference their own experience and evoke similar experiences in others. The natural languages, mathematics, and music are signals of this sort. In most humans raised in Western cultures the functions of the hemispheres of their brains have specialized the processing of such signals. Basic to the specialization of the functions of the hemispheres of the brain is the precedence of language development given to the left hemisphere. The discover of hemispheric specialization goes back to the ancient Greeks. Hippocrates and Galen knew that damage to the left side of the brain resulted in disturbances of speech. In modern times this fact was rediscovered by Paul Broca, although the brain region which, when damaged, is responsible for speech disorders lies somewhat behind the area Broca thought to be critical. This region was better defined by Carl Wernicke, who also distinguished two types of speech disturbance. One type, named Broca's aphasia because it results from damage to the front of the entire region near to where Broca had placed it, is a disturbance of expression. This type of aphasia (speech disturbance due to brain injury) is often characterized by telegraphic speech: only "content words," which refer to events and objects, are used. The other type of aphasia, now called Wernicke's aphasia, is a receptive disturbance. Patients with Wernicke's aphasia are often fluent, creating a great number of seemingly meaningful sentences with many function words. When one listens closely, however, it becomes apparent that the aphasic is putting together a meaningless set of sentence-like words that fail to signify anything.

There are other, even more severe, types of aphasia due to more extensive brain damage. Also there are special sorts of speech disturbances due to disconnections of nerve fibers between the various brain systems responsible not only for speech but for what the speech signifies (its reference) and the effect it is to have (its rhetoric). Several brain systems are involved in language, the speech system being only one of them.

By studying the relation between brain and language, neuropsychologists have learned much about the overall organization of the brain. The fact that computer simulations of brain connection networks by PDP computer programs were able to learn to reproduce speech means that brain organization must be a combination of separate systems, each constructed of networks that can operate as parallel distributed processors. The systems are organized by large-scale, long-distance connections, which form nerve trunk-line pathways between senses and brain, brain and muscles, and parts of the brain with one another. The PDP networks are composed of short-distance micro-connections among branching nerve fibers. Network properties underlie learning and memory. System properties account for stability in performance.

To some extent, even system properties can be reorganized after damage, such as that caused by a stroke. When a sufficient number of micro-connections are made (due to training and practice), they overwhelm the previous system organization to allow reorganization to occur. Possibly this also accounts for reorganization of our knowledge and motiva from time to time as we learn more and more—until the framework within which we had organized our experience no longer serves. Reorganization can be gradual or it can be precipitous, as when we are "converted" to a new viewp

Personality. To each of us life has a special meaning. meaning is mediated by processes that make past experience relevant to present experience. It is the limbic systems are involved in processing relevance. These systems are de connected to others that lie within the core of the brain. cells composing the core and limbic portions of the have many chemical affinities. They not only absorb spe chemical compounds but also secrete some.

Brain chemistry is just beginning to uncover the variety of affinities to which the core of the brain and limbic cells heir. But this much is already known: starting from the fi core regulates body temperature; sexual activities (sex hormones); stress (adrenal hormones); thirst (water concentration); appetite (blood sugar concentration); comfort and (endorphin level); sleep and serenity (serotonin); dream- (norepinephrine); and respiratory and circulatory rate blood circulating carbon dioxide). Certain limbic structures modulate these body functions and others regulate the modulators on the basis of sensory input. In turn, the limbic systems influence what is going on in the sensory and motor systems of the convexity of the brain, thus influencing what we experience and how we act.

The far frontal part of the brain has a critical relation to the limbic systems. On the basis of connections with the movement-controlling areas that surround it, and with the convexity of the hemisphere, the far *frontal cortex* extrapolates relevancy. When this area is damaged, the mental capacities of planning, inference, propriety, and priority are all severely impaired (depending on the location of the damage). This kind of correlation—bridging the traditional gap between the material sciences on the one hand and subjective thought, emotion, and aspirations on the other—is what neuropsychology is about. *See also* Artificial Intelligence and Human Intelligence; Consciousness. Karl Pribram

NEUROSIS, or neurotic disorder, a condition of emotional maladjustment manifested by a variety of mental, emotional, physical, and behavioral symptoms. When the condition is mild, organic and mental faculties are essentially intact. In more severe cases, it can develop into an almost incapacitating disturbance of thinking, feeling, and acting.

Origins. The traditional view of psychotherapy, stemming from the work of Sigmund Freud, is that neuroses, or psychoneuroses, arise from certain unconscious inner conflicts. These conflicts may be between opposing wishes or between wishes and the norms of conduct established by society. People who are unable to resolve their conflicts within themselves repress them; that is, they remove them from their consciousness so that they are apparently forgotten. But the "forgotten" material, which consists of repressed mental processes and painful and unpleasant memories, still keeps its dynamic force and nature. It does not remain dormant within the deeper, unconscious layers of the mind, but exerts active pressure from "within," influencing the person's thinking, feeling, and behavior. The term "neurosis" is sometimes used to denote this neurotic process itself as a psychological mechanism that produces symptoms.

A number of psychiatrists reject the Freudian approach to neurosis, however, insisting instead that the problem of neurosis is a behavioral one akin to a bad habit, and subject to cure by conditioning. Others attempt to explain the development of the various neuroses in terms of cognitive, biological, and social learning models.

Symptoms. The average personality is relatively unhampered by mental conflicts, has a satisfactory working capacity, and is able to love someone other than himself. Hardship and suffering are endured without excessive impairment of the individual personality. A neurotic person does not fully answer these requirements and often fails completely in these areas.

Contrary to popular belief, imagination does not play the most important part in neurotic conditions. The frequent somatic and nonsomatic complaints of neurotic individuals, such as anxiety, headache, dizziness, fatigue, indigestion, palpitation, pain, shortness of breath, insomnia, and so on, are not imaginary. Although not caused by any organic disease or lesion, they are present and real. They are usually greatly intensified during periods of emotional upsets or acute nervous tension. Abnormal fatigue, unrelieved by rest and without any physical disorder to account for it, is another frequent neurotic symptom.

The most significant symptom of neurosis is anxiety. Fear of insanity, infection, venereal or heart disease, cancer, death or suicide, people, or animals is found in many neurotic patients. Most of them have no overt cause for their fears, yet they are harassed by them constantly. Anxiety is a state of chronic fear, a distressing uneasiness of the mind over an anticipated ill, that pervades the lives of most neurotic individuals. Attacks of acute anxiety may occur suddenly and be so intense as to develop into severe panic or terror.

Treatment. Psychotherapy is the psychological treatment of emotional maladjustment, personality problems, and other neurotic disorders. Its goal is to make the emotionally disturbed and unstable patient a happier, more mature, and more stable person. Psychoanalysis is an especially intensive form of psychotherapy that employs such specialized techniques as free association, dream analysis, exploration of fantasies, and so forth.

In another form of psychological treatment, group therapy, patients are organized into small therapeutic communities, or groups, with the psychotherapist as leader. A dynamic relationship usually develops quickly, not only between the therapist and the group but among the group members themselves. The various psychodynamic factors (identification, resistances, hostility, competitiveness, escape mechanisms) operative in such a setting come to the fore and can be explored, understood, and ultimately dealt with.

A variety of tranquilizing drugs has been introduced into the treatment of neurotically disturbed patients. Many of these chemicals and "psychotropic" agents have become popular and are widely used because they have helped patients with disturbing symptoms to feel reasonably comfortable, to work, to sleep, or at least to function better than before. The use of chemical compounds is limited, however, not only by the fact that they do not cure the basic disorder but also because they may produce a variety of unwanted side effects.

Conditioning therapy, a relatively recent form of treatment, often depends upon the patient's ability to achieve complete physical relaxation. Conditioning therapy may include negative conditioning, such as electric shock, to eliminate undesirable acts or habits.

Classification. Citing a lack of agreement among mental health professionals concerning the definition of "neurosis;" the *Diagnostic and Statistical Manual of Mental Health Disorders* of the American Psychiatric Association (3rd ed., 1980) omits the class of neuroses as a separate diagnostic category. Instead, these disorders are grouped under the headings affective disorders (depressive neurosis), anxiety disorders (phobias, panic disorder, obsessive-compulsive disorder), somatoform disorders (hysteria, or conversion disorder, hypochondria), dissociative disorders (psychogenic amnesia, multiple personality), and psychosexual disorders. *See also* Amnesia; Anxiety Disorders; Conversion Disorder; Dissociative Disorders; Hypochondria; Multiple Personality; Phobia; Psychoanalysis; Psychology: Abnormal Psychology; Psychosexual Disorders; Psychosis; Psychotherapy; Unconscious.

NEUROTRANSMITTER, a chemical substance produced by nerve cells that transmits nerve impulses across a very narrow space, called a synaptic gap, to other cells. Some neurotransmitters may also inhibit the generation of nerve impulses. After a transmitter has exerted its effect, it is usually destroyed by enzymes.

Approximately 30 different neurotransmitters are known.