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The Neuropsychology of Sigmund Freud

KARL H. PRIBRAM

The experimental foundations of clinical psychology deal, for the most
part, with investigations of psychopathology. There is found another,
somewhat less prevalent theme, however, characterized by an em-
phasis on basic, theory-directed questions. Clinical material is used
as a caricature of the theoretical problem, and the hope is that better
theory will be attained when the clinical phenomenon is related to
laboratory experience. There is one branch of clinical endeavor that
consistently uses this method: clinical neurology.* Pathological ma-
terial is used to gain a better understanding not only of the abnormali-
ties in question but also of the fundamental workings of the brain and
its regulation of behavior. John Hughlings Jackson, Henry Head, Otto
Foerster, Harvey Cushing, Percival Bailey, Wilder Penfield, D. Denny-
Brown and F. M. R. Walshe are only a few names that attest to this
tradition.

Much of clinical psychology today either takes for granted or makes
actual investigations of notions which can be directly traced back to
Sigmund Freud. Many of the chapters in this book detail experimental

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* As I indicated in a recent paper on the interrelations between psychology
and the neurological sciences (1962), clinical neurology is, to a large extent,
a neuropsychological discipline; namely, the investigation of neurological proc-
esses—normal and pathological—by *behavioral* techniques. Perhaps partly be-
cause of the poor prognosis attached to diseases of the central nervous system,
and partly because of the difficulties in the mastery of neurological knowledge in
the first place, clinical neurologists have invariably used clinical material to
pose basic, i.e., theory-directed questions.

analyses of problems discussed extensively in psychoanalytic literature. This is an appropriate place, therefore, to look at one of the earlier of Freud's works from today's vantage.

Forgotten, for the most part, is the fact that Freud was an internationally respected and competent neurologist deeply steeped in his tradition. He coined the term *agnosia* which is used today in the neurological clinic. His work on aphasia is still one of the best statements of the problems encountered when language is disrupted by brain damage. Freud was also an excellent observer in the field of behavioral science, even though behavioral science then was, of course, rudimentary. In his attempt to objectify his observations of behavior, Freud turned first to neurology, as did many others of the period—Sechenov, Bechterev, and Pavlov, for example. Consequently, the results of behavioral observations as well as the inferences drawn from them were often couched in neurological terms. These confusions between the behavioral and neurological levels of discourse made these early attempts so "difficult" that Freud finally abandoned the explicit neuropsychological approach.[*]

My curiosity was piqued by a reference to the "Project for a Scientific Psychology" in Jones's biography (1953). I fully expected the Project (13) to be of historical interest—but if this were all, there would be little use in preparing a chapter such as this. I found rather, that the Project contains a detailed neurological model which is, by today's standards, sophisticated. The special points of interest center on Freud's conceptions of the neurological processes presumed to underlie "pain," "pleasure," "memory," "motive," "learning," and "thinking," conceptions often considerably different from those current today. These differences can be stated explicitly so that they can be tested in the laboratory. The Project is therefore very much alive and not just of historical significance. An added dividend accrues as definitions, in biologically relevant operational terms, of concepts that are household words in the worlds of clinical psychology, psychiatry, the social sciences, and humanities.

There are important deficiencies in the Project. Some of these were recognized by Freud and probably led to its abandonment before publication. In an attempt to remedy these deficiencies I shall here use the device of referring to neurological data and the inferences made from such data with one set of terms, and to use another set when the notions to be described arise from observations of behavior. This makes exposition (though not content) a bit different from the original, but prevents the escape into psycho-physical dualism to which Freud resorted in later years.

THE BEHAVIOR OF ORGANISMS AND
OF NEURONAL AGGREGATES

Inertia

Freud begins with a first postulate. He calls this inertia, which in many respects is similar to what we today know as homeostasis. Inertia is homeostasis in its baldest form: an organism, when stimulated, attempts to get rid of that stimulation, i.e., to return to the unstimulated condition. By invoking the principle of inertia, Freud feels that he can begin to quantify behavioral phenomena. He adduces behavioral evidence to support the postulate: for example, the escape from injurious excitation results in the cessation of stimulation.

He adds, however, a modification; the postulate does not cover all circumstances. Whenever an organism is sufficiently complex it can stimulate itself, as with endogenous physiological substances. From these, the organism cannot withdraw itself as it does from external stimuli. Endogenous stimuli cease only when certain definite conditions are realized in the external world. His example—the need for nourishment. Relief from endogenous stimulation requires an effort which is independent of this endogenous stimulation. The organism is consequently obliged to abandon the original trend toward a reduction of its level of excitation to zero. Organisms must, therefore, learn to tolerate a store of excitation sufficient to meet the demands of the specific actions necessary to relieve endogenous stimulation. The trend toward a reduction of excitation persists in modified form in which there is a tendency to keep the level of tension down and constant.

When the organism reacts so as to maximally reduce excitation, this is called a *primary process*. When the level of excitation is maintained relatively constant through a complex set of interactions with the environment (see below) this is called a *secondary process.*

The "excitation" involved in homeostasis is defined in neurophysiological terms. Neural impulses are conceived as measures of "quantities of excitation in flow." In other words, the nerve impulse as measured electrically is considered an index of the excitatory state of the neural tissue from which the record is made. But note clearly that this index defines only *transmitted* excitations.

Neurons

The second postulate Freud proposes is the neuron theory. Freud develops the neuron theory very briefly in only two paragraphs. This is essentially a statement of the "modern neurohistology" of 1895 (Waldeyer, 1891) and is in no way as detailed and beautiful a development of neuron theory as that presented by Foster and Sherring-

ton (1897) a few years later or in Sherrington's *Integrative Action of the Nervous System* (1906). Nonetheless, with one exception of emphasis, neuron theory *à la* Freud is very similar to neuron theory as we know it today.

That exception stems from Freud's attempt to relate his first postulate to the facts of neuron theory. The electrical recording of neural potential changes measures *only* "quantities of excitation *in flow.*" Freud takes cognizance of the fact known since du Bois-Reymond's *Untersuchungen* of 1845 and Pflüger's (1859) comprehensive work on the subject, that quantity of "electrotonic" excitation may increase or decrease in neural tissue without necessarily initiating transmitted impulses. For Freud, a neuron may "fill"—i.e., become *cathected*—with excitation even though no transmitted activity results. In his words "we arrive at the idea of a cathected neuron filled with a certain quantity, though at other times it may be empty."

This emphasis on cathexis is one of those strokes of luck or genius which in retrospect appears uncanny, for only in the past decade have neurophysiologists recognized the importance of the graded nonimpulsive activities of neural tissue—graded mechanisms such as those of dendritic networks whose functions are considerably different from those of the transmitted impulsive activity of axons (Bullock, 1958; Bishop, 1956; Pribram, 1960).

In other respects, there are many similarities between Sherrington's model and Freud's. Sherrington attributed to the synapse the properties of the reflex that could not be accounted for by the properties of nerve conduction. He inferred that synapses were endowed with a dual set of properties which he named "central inhibitory and central excitatory states." Freud talked of synapses as *contact barriers* (the term synapses was introduced by Foster and Sherrington two years after Freud wrote the Project; the term neuron had become current only a few years earlier through Waldeyer's neuroanatomical contributions). Freud attributed the single property of *resistance* to contact barriers. "Resistance opposes the discharge of excitation from one neuron to another."

ADAPTIVE PROCESSES: NEURAL AND BEHAVIORAL

Freud poses the issue that an organism must remain sensitive to new excitations, yet at the same time develop the stabilities necessary to retain traces of prior stimulation. As those who have tried to stimulate neuronal networks have found out, design of this dual system characteristic is beset with difficulties. If the receptive aspects of such a stimulated network are emphasized, then the behavior of the net

is continually modified—i.e., the net is stimulus bound—and it retains little. If, on the other hand, the retentive capacities of the network are overemphasized, "one-trial learning" and inability to allow subsequent modification characterizes the behavior of the system.

Freud examines the retentive process. He abandons the then current and not as yet completely abandoned view, that sensory and memory mechanisms are separable on a gross anatomical basis. He adopts the now well-worn, though still unsupported, idea that receptor excitation repeatedly transmitted through the nervous system lowers synaptic resistance (Gerard, 1949, 1950, 1960). Memory is, according to this notion, a grooving or *bahnung* of transmission pathways in the nervous system.

But even here Freud adds his own peculiar twist. He states that every neuron must in general be presumed to have several paths of connections with other neurons, i.e., several contact barriers. He details explicitly the conditions under which transmission of excitation takes place and under what conditions it does not take place. (For these, see below, under Functional Localization.) Thus he shows that the possibility exists for a choice among paths. This being so, he adduces that the condition of facilitation of each contact barrier *must* be independent of that of all others in the same neuron. Otherwise, transmission would be random. Organisms do not behave as if all paths were equally likely—they are *motivated,* their behavior is directed, often on the basis of prior experience.

Motive, for Freud, does not initiate behavior; motive directs ongoing processes. Motivation is selection and selection is to a large degree a result of experience. In this fashion, Freud calls attention to the inexorable linkage of motive and memory. David Rapaport considers this the third great step in the study of memory processes (1950). According to Rapaport, the first of these steps was the experimental study of rote memory by Ebinghaus, the second was the demonstration by the Gestalt investigators that remembering is lawfully organized, and the third is the notion that motive and memory are so intimately interwoven.

Freud goes on to point out that facilitation cannot be based solely upon the excitation transmitted to a single neuron, nor on the cathexis of excitation that is retained in that neuron, for this would not produce differences of facilitation between contact barriers of the same neuron. Here, again, Freud is ahead of his time in posing the important problem. It is only recently that neurophysiology has attained the techniques to study simultaneously what goes on in different portions of a neuron (Bullock, 1957; Bullock and Terzuolo, 1957, 1958). It has been conclusively demonstrated, at least for the nervous system of lower organisms, that graded response mechanisms in different parts

of the neuron can vary independently of one another, and that transmitted activity results only under very special and as yet incompletely understood circumstances. The techniques are now available, therefore, to take into the laboratory the question of how neural impulses are directed through a net, and under what conditions such selective direction leads to an adapted repetition of the neuronal pattern.

In summary of this portion of the Project, comparison with Sherrington's treatment of similar problems in *The Integrative Action of the Nervous System* is profitable. Sherrington takes as his paradigm an idealized spinal reflex. He points out that the known characteristics of the reflex and those of neurotransmission are not in consonance. He therefore turns to the neuron theory and suggests that reflex behavior can be explained in terms of the inferred properties of the synaptic junctions between neurons. Sherrington builds upon the notion of a final common path through which reflex action must discharge: "The resultant singleness of action from moment to moment is a keystone in the construction of the individual whose unity it is the specific office of the nervous system to perfect." In order to account for the phenomena to which he addresses himself, he infers central excitatory and inhibitory states, simultaneous and successive spinal induction and comes to classify integrative action as based on two sorts of interactions among reflexes: antagonistic (differentiative) and allied (combinatorial).

Freud also begins with observed behavior—his paradigm is escape from noxious stimulation. He addresses himself not to the reflex, but to homeostatic aspects of the situation. He also invokes the neuron doctrine to interpret discrepancies between observed behavior and the behavior to be expected if the sole property of nervous tissue were the conducting of excitation. However, Freud places the locus of the resolution of his problem only in part at the synaptic contact between neurons. He makes use as well of the other known graded nonconducted excitations of neural tissue. He calls attention to the fact that transmitted excitations are not the whole story. Excitation can build up within a neuron and this increase need not necessarily lead to conducted impulsive activity.

Sherrington uses the single behavioral conception "reflex" to compose the coordinated behavior of the organism by the addition of a considerable number of neurologically derived constructs. Freud, on the other hand, analyzes a variety of behaviorally derived concepts (such as motive and memory) and attempts to find explanatory reductive correlations among a relatively few well substantiated neuroanatomical and neurophysiological concepts. It is obvious that Freud found his task the more difficult one, since the presentation of the Project is not nearly so well worked out as that in *The Integra-*

tive Action of the Nervous System. Nonetheless, in the long run, Freud's approach may prove to be equally fruitful, since it tackles problems that can only be handled with great difficulty by the building block approach.

FUNCTIONAL LOCALIZATION IN THE CENTRAL NERVOUS SYSTEM

Projection and nuclear systems

For Freud, the problem demands that there be at least two differently organized systems of neurons. Neural tissue has to receive and to discharge excitations both of exogenous and of endogenous origin; also, neural tissue has both to retain receptivity and to remain receptive.

He suggests the hypothesis that there are two neural systems. The first consists of permeable tissues and the latter consists of impermeable ones. "The suspicion now arises that each system may serve two of the four functions under consideration. If that were so, we should not have invented them. We should have discovered them. It would only remain to identify them with what is already known. And, in fact, we know from anatomy that there is a system of neurons which is alone in contact with the external world and a superimposed system which has no direct peripheral contacts, but which is responsible for the progressive development of psychological complexities."

Freud goes on to identify one system as composed of the spinal tracts leading up to the brain, and the other system as the gray nuclear masses of the brain stem and forebrain. The difference between the functions of the two systems is attributed to their permeability, i.e., the permeability of their synapses. But this difference is ascribed not to any intrinsic dissimilarity between the neurons of the two systems, but to a distinction of their connections. The spinal projection system handles the greater quantity of excitation since it is in direct contact with peripheral receptors and therefore is continually stimulated by the environment. The neurons in the nuclear system, in contact with the spinal system and some "internal" neuroreceptors (see below), are reached only by quantities of excitation of the same order of magnitude as the resistances of the synapses. Thus neurons are neurons irrespective of their location; the only distinction is in the milieu to which they happen to be allocated.

"Now, however, we must examine the assumption that the quantities of excitation reaching the neurons from the external periphery of the body are of a higher order than those from the internal periphery." Freud deals with this problem for several pages and brings to bear some "recent" neurohistologic findings, but these are of little

use today. Though much work has been done since the turn of the century to prove the existence of osmoreceptors, glucostats, and other neuroreceptors in the midline regions of the brain stem (Pribram, 1960), the quantitative data necessary to support Freud's argument are still unavailable.

Nonetheless, the distinction Freud makes is in many respects similar to that current today between the modally specific projection systems and the nonmodally specific, more diffusely organized core systems of the cephalic portion of the neuraxis. The classical sensory-motor projection systems, with their rapid conduction of neural impulses over long fiber tracts interspersed with few synapses, fulfill the descriptions of Freud's projection system. The nonspecific systems, on the other hand, are made up of many branching neurons usually shorter than those of the projection systems. They received stimulation from the external world only through collaterals from the projection systems. Further, these nonspecific systems lie close to the midline neuroreceptors of the brain stem. Propagation of excitation takes place only under certain, yet to be determined, circumstances in the nonspecific systems. The work of Gloor (1955), for instance, has demonstrated that (in the forebrain portion of these systems) an electrical stimulus in one location will increase the excitation in the dendritic layer of an adjacent structure, but that this increase in graded dendritic potentials fails to be transmitted immediately as impulsive discharge in the tract that leads from this structure. So the notion—oversimplified though it is—that the central nervous system consists of two types of neural systems is at least as tenable today as it was at the turn of the century.

The commonly ignored, nontransmissive, graded response characteristics of neural tissue are conceived by Freud as important properties of the nuclear system. The process of cathexis, i.e., of increase in the nontransmitted "bound" excitation of nervous tissue must take place mainly in this system. So must the differential decrease in synaptic resistance that makes possible motive and memory. Freud spells out his own views in detail:

Each neuron in the system is in contact with many others, not just one; connections are diffuse, not discrete. In fact, a drawing of a neural net appears in the Project and Freud refers to the nuclear system in several places as a network of neurons. Freud postulates that, when in adjoining neurons excitation builds up simultaneously, a temporary facilitation of the synapses between them results and thus modifies the course of any transmitted excitation that might be initiated in peripheral receptors. The build-up of excitation in the system can accrue as a residual excitation from prior stimulation of peripheral receptors; as endogenous stimulation through internal neu-

roreceptors; and, of course, as intrinsic activity of the nervous tissue it-self. In today's language, the conception is that of (1) an originally more or less randomly connected net into which only a few initial con-straints are built; (2) these constraints together with momentary peripheral and endogenous inputs progressively direct the essentially stochastic processes of propagation of excitation through the net; until (3) in the motivated adult, neural transmission is no longer random but selectively directed.

The cortical system

There is another problem, however, which is not handled by the division of the nervous system into (1) a reception and transmission system and (2) another that is closely related to the internal environ-ment of the organism and in which excitations build up more or less gradually before discharge. Freud needs a third system of neurons because he wants to deal with the problem of the qualities of sensa-tion: "We may ask how qualities originate and where qualities origi-nate. Where do qualities originate? Not in the external world, for 'out there' there are only masses in motion and nothing else. In the projection system perhaps? This would tally with the fact that the qualities are connected with sensation but it is contradicted by every-thing that rightly speaks in favor of the involvement of higher levels of the nervous system. In the nuclear system then? There is an im-portant objection to this. The nuclear system is primarily involved in the reproductive processes that underlie memory and motive. Thus we must summon up enough courage to assume that there is a third system of neurons, 'perceptual' neurons they might be called, which are excited along with the others during perception but not during reproduction, and whose states of excitation give rise to the different qualities, that is to say, 'conscious sensations.' "

Freud must now reconcile some difficulties. The projection system is conducting because it has been recurrently subject to large amounts of excitation. The nuclear system is retentive because these large amounts of excitation rarely occur. Freud is in trouble if his third system were to receive its excitations from the projection *through* the nuclear systems. "Perception is characterized by its immediateness, mutability, transitoriness, and the easy combination of simultaneously perceived qualities. All of these characteristics would tally only with complete permeability of the third system coupled with a full return to a prior state."

Again, Freud finds an ingenious solution. Hitherto he had regarded only quantities of neural excitation and their transmission. But excita-tion has another attribute, a temporal characteristic—frequency. "Thus I shall assume that the resistance of the contact barriers

applies *only* to the *transmission* of the *quantity* of excitation but that
the pattern of its *frequency is transmitted without inhibition in every
direction as though it were a process of induction*. Much remains to
be done here in the way of neurophysiological clarification. . . . Where
do these differences in frequency pattern originate? Everything points
to the sense organs where "qualities" of receptor stimulation must
be represented by different frequencies. These sense organs operate
not only as screens against quantity like every nerve-ending apparatus
but as sieves, for they only let through stimuli of a particular fre-
quency. They probably transfer the specific frequencies directly to the
projection system and from there to the nuclear system which in turn,
after considerable modification—especially in the quantity of excita-
tion that accompanies the process—pass them on to the third sys-
tem." The transmission of frequency that leads to the perception of
"quality" is not durable—it leaves no traces, and therefore cannot be
reproduced.

This is not the final solution for Freud of the relation of the third
system to the others. The problem continued to plague him. Further
along in the Project he states that the third and the nuclear systems
"function to some extent like intercommunicating pipes." A year
later—in a letter written in January, 1896—he has another view of
the matter: "In my new scheme I insert the perceptual neurons be-
tween the projection and the nuclear neurons, so that the projection
system transfers 'quality,' but merely excites the nuclear system."

This "new scheme" is maintained in Chapter VII of *The Interpreta-
tion of Dreams,* and is an unfortunate modification. For, what does
"excite" mean other than the transmission of the intensity or fre-
quency of neural activity? By intercalating processes important to
"perception" between those that transmit sensory input and those
involved in memory and motive, Freud loses a great deal of richness
of *interaction* between motive, memory, and percept that the earlier
model allows. And all this only to gain a false simplicity that will
allow some unitary central process (in the nuclear system) to "par-
allel" and therefore culminate in the psychic! Dualism has taken its
toll; for the later Freud, the black box that is the brain can safely
be assumed to give forth the essence that is mind.

But Freud was also driven to his modifications by neuroanatomical
fact. The projection systems terminate in the cerebral cortex (albeit
after an interrupted passage through the dorsal thalamus). Are these
"projection areas" then to be part of the nuclear system—or are they
the location of the cells of the third system? Freud vacillates even
in the Project. In places he divides the nuclear systems into two com-
ponents—one of which is pallial (i.e., cortical). Yet, for the most part,
the characteristics he ascribes to the nuclear system are unitary and

noncortical, while those he ascribes to the third system he identifies with the properties he believes to be cortical.

Here, I shall assume that Freud is correct on all counts (provided there is no conflict). The third system according to this view which is characteristic of the latter part of the Project both receives excitations from the nuclear system and *at the same time* is intercalated between the projection and nuclear systems. Thus, the third, i.e., the cortical, and the nuclear systems are considered related as by "intercommunicating pipes"; the direction of transmission to be dependent on the particular parameters operating on the systems at any moment.

To summarize: There is a direct projection system. This is connected with exteroceptors which act as "sieves that let through" certain quantities of excitation with specific frequency characteristics. Because of repeated bombardment, the synapses between projection system neurons have a low resistance. This system acts essentially as a conduction pathway for the transmission of neural impulses. Both the quantity and the patterns of frequency of excitation are transmitted.

The connections of the projection system are both with a nuclear system and with a cortical system. The nuclear system is directly influenced as well by the internal environment of the organism through centrally located neuroreceptors. This nuclear system, since it is bombarded by smaller quantities of excitation, does not transmit indiscriminately. Synaptic resistance is lowered selectively by convergent excitations from various sources. The selectivity is the basis of memory and motive. Because of the relatively diffuse interconnections of the nuclear system, quantities of excitation are transmitted from the projection to the nuclear system "as from a trunk of a tree to its branches." Thus, what is quantity in the projection system is expressed as complexity in the nuclear system. Quantity of excitation in the projection system can be recorded in the form of neural impulses—in the nuclear system this same neural activity becomes cathected, i.e., bound, nontransmitted excitation, and is recordable as a graded potential change.

Primarily, although not exclusively, only the frequency characteristics of the excitation in the nuclear systems affect the cortical system. Thus the activity in the cortical system is a resultant of exteroceptive excitation transmitted both directly and in modulated form. The modulations are imposed in a matrix of the traces left in the nuclear system by the effects of prior similar excitations. According to this model, perceptions result from an interaction between current external stimulation and the residuals of prior experience with similar situations, an interaction modified by concurrent prior and present endogenous excitations. The now well-known experimental demonstrations by Bruner and Postman (1949) on the attainment of veridical perception are certainly more easily handled by this than by any other

neurological model of the perceptual process current today. And what better view of the functions of the central nervous system have we that accounts for Lindsley's (1957) facilitation of tachistoscopically presented discriminations by electrical stimulation of the mesencephalic reticular formation?

PSYCHOLOGICAL DERIVATIVES OF BASIC NEURAL PROCESSES

The model which Freud presents of the consequences of noxious excitations is thus not a simple one The operation of the model in psychological processes is still more complicated. There is in the Project no assumption similar to the "pain and pleasure centers" of the brain (Olds, 1959). Nor is there any oversimplified notion of some "optimal" level of over-all neural excitation which is rewarding (Hebb, 1955; Lindsley, 1957). Yet Freud's model is explicit and sophisticated, on both the neurological and on the behavioral level. Three sets of concepts are distinguished; each set deals with a different order of the complexity of events. The first refers to the *locus of origin* of the excitations that give rise to the awareness of *pain* and of *strain*. The second set of terms deals with affects—these are based on *memory traces* left in the nervous system when the organism has been subjected to pain or strain: *negative affects* on episodes of pain and strain; *positive affects* on relief from strain. Finally, a third set is used to describe a still more complex set of processes: *defense* and *satisfaction* involve the interactions between the memory traces that underlie affects and current excitations.

Pain, strain, and pleasure

Pain is defined on the basis of attempted escape from intense stimulation. Whenever the organism is subjected to noxious stimulation that originates outside, it attempts to escape. Therefore, pain—the result of excitation of the somatic receptors—is transmitted through the projection systems to the nuclear systems where, "like a stroke of lightning," transmission is facilitated. This facilitation makes it possible for the cortical system to receive in addition to the frequency the quantitative aspects of the stimulus. Another way of stating this is to say that the cathexis in the cortical system is suddenly and dramatically increased. The awareness of pain, for Freud, is a function of this sudden marked increase in cathexis in the cortical system. Pain ceases abruptly when the organism has removed itself from the noxious stimulation, because the "high permeability" of the cortical system allows it to get rid of excitation rapidly through efferent discharge.

Strain results from an entirely different mode of excitation. Strain is

produced when the receptors internal to the nervous system, the neuro-receptors, are stimulated. Here the organism has no simple mode of removing himself from such excitation. Strain must be handled in a different fashion, i.e., by changing the physicochemical environment of these receptors through more complicated actions. The excitation of the internal neuroreceptors also produces an increase in the cathexis of the nuclear system which can be transmitted to the cortical system. The awareness of strain is dependent on this increase of cathexis in the cortical system; this increase is neither as sudden nor as great as that which characterizes pain. The awareness of the relief from strain, i.e., of *pleasure*, is dependent on a diminution, which is also gradual, of this cortical cathexis.

The affects

The excitations that initiate and relieve pain and strain intimately involve the nuclear system. Traces of these excitations are left in this system, and these traces facilitate conduction paths so that on future occasions they will be selectively activated. As already noted, these selectively activated neural networks are the basis of memory and motive. Minimal cathexis of the cortical system derived from the excitations in these networks of the nuclear system is the neural con-comitant of the affects.

Under what conditions, asks Freud, do affects occur, and what are their components? Negative affects cannot be differentiated on the basis of whether the irritant was external or internal, for there is in the nuclear system considerable convergence of the pathways initiated by the somatic and by the internal neuroreceptors. In fact, Freud points out that the nuclear system is endowed in its midline portion with secretory mechanisms and these are activated whenever the quantities of excitation in the system reach a certain level. This is one reason why strain cannot be simply relieved: stimulation of the internal neuroreceptors activates the nuclear system, and when a certain level of excitation has been reached, the neurosecretory cells are discharged. This, in turn, results in the production of more of the chemical sub-stances that stimulate the internal receptors. The cycle can be inter-rupted only through external intervention designed to diminish abruptly the chemical stimulation, e.g., by feeding or by sexual re-lease. So also, when a noxious external stimulus results in marked increase in the quantity of excitation in the nuclear system, chances are that this will activate the neurosecretory elements to pour out the chemical subsances that stimulate the internal neuroreceptors. As an example, should one burn one's hand and withdraw it ever so quickly, there is nonetheless a temporary increase in the adrenalin circulation in the blood. Freud postulates a neurosecretory, i.e., a neurochemical

stimulation of the adrenal rather than (or in addition to) the direct neural stimulation of this gland.

Thus, the neural traces left by stimulation initiated either externally or internally come to include the effects of internal excitation. Negative affects, therefore, are based on more than a one-to-one reproduction of the initiating experience. The neural concomitants of the negative affects, i.e., minimal patterned increases in cortical cathexis, are the results of the interactions of the effects of the initiating experiences with those of the organism's internal reactions to the experience.

Positive affects are based on an additional complication. Whenever stimuli excite the nuclear systems, they activate not only the paths associated with an increase but also those that on prior occasions had led to a decrease in excitation. The effects from these trace excitations are to activate efferent motor discharge and so to minimally diminish cathexis in the cortical system; thus the organism experiences a positive affect. Should circumstances be similar to those that relieved the strain on prior occasions, positive affect accompanies actions that lead to pleasure. Should circumstance have changed significantly, however, then strain will not be relieved by these actions. And here it is necessary to invoke yet a third level of complexity.

Defenses and satisfactions

Prolonged and intense excitation can be initiated by an affect, i.e., by awareness of a memory of pain and strain and the situations that led to their alleviation. Such remembrances can stimulate the neurosecretory cells of the nuclear system—and thus start the accruing strain spiral anew. The normal organism is not continually strained. Freud postulates, therefore, that the individual develops a *defense* against this release of neurosecretions. The defense mechanism is conceived as a lateral distribution of excitation in the neural network of the nuclear system, i.e., a distribution in a direction other than the transmission of excitation to the neurosecretory and cortical cells. The defense consists therefore of a diffusion of excitation that brings into functional contact an increasingly larger pool of neurons in the nuclear system and so delays and often prevents the transmissions of excitation to the neurosecretory and cortical cells. Defense mechanisms so conceived prevent the build-up and maintenance of excessive strain.

The emphasis throughout the Project is on the interpersonal as well as on the neurological bases of the intrapsychic process. Freud therefore takes this opportunity to define as hostile those people whose actions could induce affects that would lead to strain. Defense in this context deals with hostilities. More of this in a moment.

Just as defenses develop to prevent affect from producing prolonged or overly intense strain, so satisfactions develop when affects

result in pleasureable actions. The characteristics of satisfactions are rather different from those of defenses. The neural mechanisms of defense involve primarily the nuclear system, the neural mechanisms of satisfactions involve primarily the cortical system. When the organism repeatedly experiences pleasure—that is, the relief of strain—memory traces of the experience are built up in the nuclear system. When these traces are activated for whatever reason, and the excitations are transmitted to the cortical system, the person becomes aware of positive affects.

When the actions he undertakes on the basis of these positive affects are in concordance with the current situation, they lead to an experience of satisfaction. "As we showed in the beginning of the discussion, no discharge can bring about any permanent relief of tension as long as endogenous stimulations continue to be initiated and, in the nuclear system, excitation continues to be reestablished. The removal of these stimulations can only be effected by actions which will more or less stop the release of chemical substances in the interior of the body."

Again the emphasis is on the interpersonal:

> The excitation of the cortical system thus acquires an extremely important secondary function—that of bringing about an understanding with other people. The infant is so constituted that an extraneous helper must carry out specific actions in the external world on its behalf. Only when these are accomplished is the infant in a position by means of reflex contrivances to perform what is necessary in the interior of his body in order to remove the endogenous stimulus. This total series of events constitutes the basis of an experience of satisfaction: persons become a prime source of satisfactory (and unsatisfactory) experience; further, the actions undertaken to obtain satisfaction usually involve other persons—thus moral motives are built up. But these are only some of the momentous consequences in the functional development of the individual.

Before we go on to other momentous consequences, a brief review of this section is in order: At the simplest level Freud differentially defines pain and strain. Pain is consequent upon excitation of somatic receptors, and strain ensues from excitation of the neuroreceptors in the center of the brain. Pain can usually be escaped by removing the receptor from the excitant. Strain cannot be so easily done away with, especially since the neural mechanism into which the excitation feeds (the nuclear system) contains neurosecretory elements whose secretions directly regulate the chemical substances that presumably excited the neuroreceptors in the first place. The vicious spiral of accruing excitation that results in prolonged and excessive strain can be

prevented only by the intervention of a complex series of actions undertaken by the organism or by others on his behalf.

The excitations that accompany experiences of pain and strain and their alleviation leave traces in the nuclear system. These traces, when they minimally change cathexis in the cortical system, are the basis of the affects. Affects may be set off by the current situation or they may be internally triggered. Affects are based on experience and they motivate (i.e., give direction to) behavior.

Accumulating excitation that could accompany affects has to be defended against. Neural defense mechanisms are conceived in terms of the development of lateral pathways in the nuclear system which act to diffuse excitation and so prevent, or at least delay, its transmission to neurosecretory and to cortical cells. Thus the organism is relatively protected against the prolonged unremitting strain that would otherwise be initiated by hostility, pain, and the stimulations of neuroreceptors that recur in the ordinary course of events.

Satisfactions are obtained when positive affects are congruent with reality, i.e., when the inputs to the cortical system from the projection and the nuclear systems are comparable, so that actions undertaken on the basis of positive affects lead to the relief from current strain. Pleasure can occur by happenstance; satisfaction depends always on achieving a match between the record of experience and stimulations produced in the current situation.

PSYCHOLOGICAL DERIVATIVES OF ADAPTIVE PROCESSES

Learning

Freud contends that learning results through the experience of satisfaction. When learning takes place, interconnections must be facilitated between trace and new neuronal excitations in the nuclear system; thus, the initial network is functionally extended so that subsequent excitation will cathect this larger network. Freud notes that this conception of the learning process assumes a fundamental "law of association by simultaneity." His mechanism of learning is also a physiological-drive-reduction theory of reinforcement.

There is a difference, however, between Freud's conception and that which characterizes current drive reduction theories. In much of current learning theory, drive reduction is assumed invariably to *initiate* the association of an environmental stimulus with the organism's response to this stimulus. For Freud, drive reduction is achieved as a *consequence* of an association by contiguity between the input from an environmental stimulus and memory traces left by prior drive-reduc-

ing experiences. Only when these associations lead to adaptive actions
that reduce internal excitation for a fairly prolonged period can learn-
ing be said to have taken place. When, on the other hand, the situation
has changed, and the actions taken are incongruous to the situation,
no learning results. Nonetheless, reinforcement continues to occur by
virtue of a temporarily effective discharge of the cathexis of the nu-
clear system. But this is accomplished only at the price of a rebound
of even greater strain. The initially exciting stimulation is not re-
moved and on each subsequent occasion it cathects a larger network
of nuclear neurons. Thus there is an increasing likelihood that the de-
fense mechanism will be overrun—unless it is simultaneously strength-
ened—and the accruing neurosecretory-neuroreceptor spiral of ex-
citation established. In Freud's scheme, therefore, a nonadaptive
neural process can be reinforced. Again Freud has anticipated the
struggles that learning theorists have had with a problem.

Thinking

Freud now has the basis for making a distinction between two types
of thinking: productive (cognitive) and reproductive (wishful). When
an affect is modified (because a disparity between a memory and the
reality situation is recognized) or, when a new affect replaces the
old, productive thinking is taking place. When, on the other hand,
such a change in affect does not take place, thinking is purely re-
productive.

Reproductive thinking results when the cathexis of the neural net-
works involved in the positive affect overrides that produced by the
current input. Such reproductive or *wishful* thinking carried to the
point of hallucination involves a complete expenditure of the lateral
cathexis (defense) in the nuclear system and is noted by Freud to be
a *primary process*, since excitation is thus completely though tempor-
arily discharged. Moderations of the total discharge of excitation—i.e.,
the maintenance of some cathexis in the nuclear system—is the *sec-
ondary process*. Correct exploitations of the indications of reality are
possible only when there is sufficient lateral cathexis (i.e. defense) in
the nuclear system to delay or prevent the accruing of excitation
through the vicious spiral of neurosecretory-neuroreceptor stimulation.
This defense against excessive discharge by dispersal of excitation
within the nuclear system Freud calls the organism's ego function.

The case of cognitive thinking is the more puzzling one for Freud
from the neurological standpoint. When the thought about a possible
external object is initiated by a positive affect, that is, when a *wish*
has been initiated and this wish and an external object are perceived
to be similar but not identical, a "judgment" is made. There must be
some mechanism to compare the similarities and differences between

the excitation set up by the memory trace and that initiated by the current input. What that mechanism might be was far beyond the scope of nineteenth century neurology and Freud could not even hazard a guess as to its nature.

But recent work on the habituation of orienting reaction, (Sharpless and Jasper, 1956) has begun to fill the gaps in Freud's model of cognitive thinking. An organism is repeatedly exposed to a stimulus which, on the first occasion, was a novel one; electrical activity is comcomitantly recorded from the brain; gradually, the electrical patterns that are characteristically recorded only during the organism's exposure to novelty drop out. That this "habituation" to the novel stimulus is not due to fatigue of nerve cells has been shown. For instance, dishabituation (re-orientation) occurs immediately when, after habituation to a tone of a certain frequency and intensity has been in effect, the intensity of that tone is suddenly diminished. Dishabituation also occurs when the duration of the tone is shortened. The electrical patterns characteristic of orientation begin only at the moment the tone is turned off and persist for the duration of the "expected" length of the tone. Traces representative of the stimuli aroused by the situation must be built up in the nervous system during habituation so that the input of the moment can be matched against these traces. Response depends on this match or "judgment."

Electrical patterns have also been demonstrated to be characteristic of various phases of problem solution (Adey, 1960; Freeman, 1960). Certain electrical patterns recorded from limbic areas of cats during the early stages of training recur during later stages of training only when the animal makes an error. And two very sophisticated analyses of these electrical records have been interpreted to show that a "comparator" must be located in the regions from which the recordings are made!

In summary: For Freud, learning takes place only when the memory traces of initial pleasureable, i.e., strain relieving, experiences are modified by the current situation. On the other hand, reinforcement occurs whenever excitation in the nuclear system is discharged. A rebound from the discharge results when the actions on the basis of the memory trace are inappropriate to the situation—i.e., when affect is inadequately modified or unmodified by the input of the moment. In such instances the thinking that accompanies the discharge is termed wishful or reproductive. Satisfaction results only when the affect is modified sufficiently to take into account the current situation until it becomes conducive to lasting relief from strain. The thinking that accompanies this type of discharge is productive—cognitive— and entails a judgment or comparison between a wish and the reality of the moment. This comparison leads to the modification of the

memory traces that initiated the wish—the modification necessary for learning to take place.

The remainder of the Project is concerned with an amplification of Freud's ideas and observations of normal and clinical behavior, as these are shaped by the neurological model he has developed. But then, the rest of Freud's career was engaged in this spirit. As time went on he tended to leave the neurological model implicit rather than, as in the Project, to detail it explicitly. There was good reason for this. Neurology had gone through a burgeoning period of factual and theoretical growth during the nineteenth century. The first part of the twentieth was involved in settling issues uncovered during the previous ferment and developing new technical tools with which to tackle the nervous system afresh. Freud continued to ferment. From the mid-twentieth century, it sometimes appears as if Freud turned from the "hard" science of the laboratory and the neurological clinic to the "softer" procedures of analysis of verbal behavior. But for Freud, psychological analysis was as rigorously conceived a scientific method as was neurohistological analysis. And in the context of history, Freud's evaluation of his own work may well prove the more accurate. A brief review of the "Zeitgeist" in Vienna around the turn of the century illuminates this view.

Toward the latter part of the last century, empirical analysis of the thought process was the dominant interest that occupied all psychologists. A human subject was given a task, asked to introspect—look inward while he tackled the problem—and to tell the experimenter the steps he took as he went along. Very often, in fact, the experimenter served as his own subject. Though the technique proved to be of limited value due to the differences between people in what their introspections revealed, some unexpected discoveries did result. The most systematic studies were made by a group of investigators at the University of Würzburg in Germany, who pinned down beyond a reasonable doubt the importance of the initial presentation of a task in determining all the subsequent events that take place during problem solution. Provided a problem is adequately accepted, the thought process seems to run itself off automatically when released. Great difficulty was experienced in any attempt to specify the nature of this running off process. Thus, thoughts were distinguished from thinking. Thoughts could be described in detail—and these descriptions were dubbed the "content" of the thought process. Thinking, on the other hand, became the more elusive and therefore the more interesting problem. The activity or act of thinking (Brentano, 1874) demanded an analysis of the antecedents of the content of thought, an analysis which taxed the capabilities of the scientific effort of the time.

As Edwin G. Boring has succinctly summarized (1950): "Act and content were in Europe the two horns of a dilemma. The empiricist who has his attention always on the nature of his own consciousness is burdened to accept activity as the essence of mind. The experimentalist [on the other hand] accepts content because he can work with it. . . . The empiricist accuses the experimentalist of being prejudiced by his method; the experimentalist replies that casual empirical observation has always failed to yield the truth and that science resorts to experiment for this reason."

The dilemma was temporarily resolved within the Würzburg school: both act and content were accepted and fairly rigorous descriptions were given of the laws that govern each. The result was a short-lived bipartite psychology (Külpe, 1893) which fell under the onslaught of the new approaches. As an example of this onslaught, William James (1950), the outstanding American empiricist, held that psychological processes were just that—processes. The stream of thought is his most eloquent example. He rejected analysis of process into content and act: "Though analysis is the necessary scientific method, analytic descriptions of mind fall short. The real mind is more than an aggregate of elements." The dilemma as stated by James is not between content and function, but between descriptive analysis and process. From today's vantage there is, of course, no such dilemma. Data are analyzed, processes are inferred from the analysis. Today data relevant to the study of the thought process are no longer limited to verbal reports of introspections made during problem solving behavior—all sorts of neurological and behavioral responses are admitted as evidence. But we are ahead of the story. James was not completely wrong in his criticism. The analytic approach of the Germans had served only as a beginning, but an excellent beginning it was.

The Viennese, just as the Americans, were especially concerned with the whole thought process. However, they did not reject identification of the central issue as the determination of what goes on during the *activity* of thinking. But they, as had the Würzburgers before them, came to see that superficial examination of the contents of thought did not directly lead to an understanding of process.

It was within this Zeitgeist that Freud began his studies of mental illness. As already mentioned, he had worked in the best neurological clinics and laboratories on the continent where such advanced (even by today's standards) methods as hypnosis were often used. From this background came a new technique: to allow the patient, by letting him say *anything* that came to mind, to reveal the contents of thoughts usually hidden to himself and to others. Freud seized the importance of his discovery: provided this usually hidden thought content is

thoroughly explored, the activity of thinking *can* be understood. In essence, the technique reveals a whole series of thought contents, and from this series inferences can be made regarding the total process. Freud noted that the great majority of the contents of thought are not immediately accessible to introspection, and he called these contents preconscious and unconscious. Psychoanalytic theory thus became one important answer to the Würzburg dilemma. Act *can* be derived from content, provided the variety of nonreadily accessible content is adequately unveiled. The criticism of William James is met: exposure of contents of different levels of accessibility provides the continuity that an understanding of process demands.

The writings that describe the findings obtained in the psychoanalytic laboratory are many. For the most part, this body of evidence has little relation to the knowledge that comprises the biological and physical sciences. But a relationship should be discernible if a single scientific universe of discourse is to include both biological and social events. For those interested in the development of such a single universe through the formulation and execution of their research, the Project can prove valuable as a psychobiological Rosetta stone. To this end, and as a summary of this paper, a glossary of the neuropsychological concepts to be found in the Project is appended.

Glossary

Affects: Neurologically, the affects result when cathexis in the cortical system minimally increases (negative affects) or decreases (positive affects). Such minimal changes in cortical cathexis accompany the activation of traces laid down in the nuclear system on prior occasions during episodes of pain and strain (the negative affects) and during experiences of the relief from strain. Affects, therefore, "color" current experience with pigments prepared on the palette of past impressions.

Cathexis: The excitation of neural tissue is measured as changes in electrical activity recorded from the tissue. Abrupt potential change —the nerve impulse—is a measure of propagated excitation. Recently the attention of neurophysiologists has again focused (as it had been in the latter half of the nineteenth century) on the nontransmitted electrical activities of neural tissue. The graded, spontaneously waxing and waning mechanisms were characteristically found where synaptic and dendritic fields predominate. These electrotonic manifestations of local neural excitability are measures of the cathexis of the tissue. Cathexis, therefore, refers to the amount of local nonpropagated neural excitation which leads to impulsive, transmitted excitation only under certain special circumstances.

COGNITIVE THINKING: Propagated neural activity has two aspects, a quantitative (number of impulses) and a qualitative (pattern of impulses). The propagation of quantity of excitation results in changes in cathexis; the transmission of quality does not. Perceptions result when patterns of excitation developed in receptors activate the cortex. Thoughts occur when patterns of excitation developed in the nuclear portions of the brain activate the cortex. Cognitive thinking takes place when the patterns of excitation developed in the nuclear systems and those developed in the receptors are matched—i.e., when thought and perception are compared. An incongruity may exist. Thinking is considered productive or cognitive when the incongruity is met by actions that change either the environment directly and thus the percepts, or the experience of the individual in the environment and thus the traces in the nuclear system from which the thoughts take origin. Changes in traces will, of course, also change the cortical cathexis and therefore the affects that accompany the thoughts. Any such change in the direction of congruity between thought and percept is adaptive.

DEFENSE MECHANISM: The nuclear systems have certain characteristics. (1) Their connections from the projection systems are like branches from the trunk of a tree. (2) They contain in their core, midline portion, both chemically sensitive neuroreceptors and neurosecretory cells. These characteristics determine certain consequences. The quantitative aspects of propagated excitation in the projection systems become distributed more or less randomly in the nuclear systems. Because of synaptic resistance propagation is hindered, and transmitted excitation is converted to local graded activation, that is, cathexis. An overwhelming or an oft-repeated excitation can overcome synaptic resistances and in this fashion transmission pathways are established through the nuclear systems. These pathways, though initially random, become structured by a process of selection that occurs at the neuronal level. This selection is the basis of directed behavior—i.e., of motive. The structure of the pathways is the neural memory trace. Excitation can thus be transmitted to the neurosecretory cells and to the cortex. Stimulation of neurosecretory elements results in an increase of the chemical substances to which the neuroreceptors are sensitive. A spiral of accruing excitation within the nuclear system is therefore possible and a mechanism must exist to defend against such accrual. The mechanism of defense is the lateral extension of the nuclear neural network that becomes activated on stimulation. This lateral extension in a direction other than that necessary for transmission of excitation to the neurosecretory cells and to the cortex—serves to disperse the excitation, and thus delays or prevents excessive accrual.

EGO STRUCTURE AND FUNCTION: The manifestations in behavior of the distributions of excitation in the nuclear system constitute an individual's ego characteristics. Ego structure depends on the particular nuclear networks of traces activated; ego function is the defense against a spiral of accruing excess of excitation.

EXCITATION: Organisms are alive, they therefore make transformations on systems of energy. Metabolic processes are one example of such transformations. Behavioral interactions with chemical and physical stimuli (psychological processes) are another. These interactions must be quantifiable. The problem is what to measure. The nervous system is intimately involved in regulating behavior—why not use indices of neural excitation as measures of the transformations of energy involved in the psychological process? And so, the nerve impulse, recorded electrically, is used as a measure of propagated neural activity. That leaves local, nontransmitted excitation. Electrotonic potential changes (and in today's language, other graded response mechanisms of neural tissues such as dendritic and synaptic potential changes) serve as indices of this type of neural activity. Freud uses the term cathexis to denote this localized neural excitation. The transformations of energy involved in the psychological process are therefore to be understood as changes in the neural processing of the interactions between the organism and its physical and chemical environment.

LEARNING: The adaptive behavioral change that accompanies a change in the structure of the neural traces in the nuclear systems. Learning takes place when a relatively durable relief from strain is achieved consequent to actions that minimize the incongruity between thought and percept. Such actions serve both to alter the situation and to provide new experience in the situation. Learning invariably involves some change in the affects that accompany the thought and percept since these affects result from the same neural trace structure that is undergoing change.

MEMORY: Synapses have only one property—they resist the transmission of quantity of excitation through the neural net. (They do not distort the propagation of frequency patterns, however.) Synaptic resistance is usually overcome only when the quantity of excitation on both sides of the synaptic junction builds up above some threshold. Resistance can also be overridden by excessive excitation. Repeated lowering of resistance at a particular synapse leads to a permanent conduction path through that synapse. Such permanent facilitation is the basis of memory. In the projection and cortical systems synaptic facilitation is relatively complete due to fairly direct contact with an ever exciting environment—their local patterns of excitation are therefore determined for the most part by the inputs to these sys-

tems. The nuclear systems, on the other hand, somewhat more isolated from external stimulation, provide the locus where synaptic facilitation can be selective. Here, therefore, patterns of excitation are dependent as much or more on traces left by previous synaptic facilitations as on those produced by current stimulation. The structure of memory at any moment is thus a function of these nuclear system traces as they are currently activated.

MOTIVE: Each cell within the nuclear system is in multiple contact with its neighbors. If resistance were overcome with equal ease at all of these contacts, transmission would be random. The organism does not behave randomly—his behavior is directed, i.e., motivated. To account for this, the assumption is made that the resistance of the various synaptic contacts of a cell are differentially affected in the nuclear system. All parts of a neuron must therefore not necessarily behave in the same way at any moment. That this is so has been demonstrated conclusively, at least in the invertebrate nervous system. Neurons, therefore, are the selectors of the paths of conduction that build up the memory trace. The function of this selection is to give direction—to motivate—behavior. The pattern of pathways of lowered resistance that are based on the selection form the memory trace.

PAIN: A sudden, dramatic increase in cortical cathexis follows noxious stimulation of somatic receptors. The psychological concomitant of this increase is pain. Not only are the usual frequency patterns of neural impulses transmitted to the cortex through the projection systems but a large quantity of excitation erupts from the nuclear systems because synaptic resistances are overwhelmed. With removal of the stimulus, there is a sudden drop in cortical cathexis, and thus a relief from pain.

PERCEPTION: Propagated neural excitation has two characteristics, quantity, based on the number of impulses, and quality, based on their frequency patterns. Frequency patterns are transmitted throughout the nervous system without modification by synapses. Those cortical frequency patterns that are derived from stimulation of somatic receptors are the basis of percepts. Cortical frequency patterns derived from the nuclear system are the basis of thoughts. There must therefore be in the cortex a mechanism that allows the input from projection and from nuclear systems to be distinguished. In fact, evidence is beginning to accumulate that such a mechanism does exist and that it serves as a comparator that matches the inputs for congruity.

PLEASURE: When the neuroreceptors of the nuclear system are stimulated, cathexis builds up gradually in the system. When this cathexis is transmitted to the cortex, strain is experienced. When stimulation of the neuroreceptors ceases, nuclear and therefore cortical cathexis gradually diminishes. This is felt as pleasure.

REINFORCEMENT: Whenever cathexis is discharged in the nuclear systems, there is lowering of the synaptic resistances involved—thus the particular pathways that are activated become reinforced. *Only* when the discharge (1) extends to new neurons in the network, or when the older pathways are modified, and (2) these changes lead to actions that effectively prevent the excessive accruing of nuclear system excitation, does the reinforcement lead to learning.

RESISTANCE: The property of synapses that counters the propagation of quantity of excitation in a neural net. The transmission of frequency patterns of nerve impulses is not altered by resistance. Synapses have no other property Current neurophysiological knowledge has not been looked at from this viewpoint. The techniques to study the transmission of patterns of frequency are in their infancy.

SATISFACTIONS: Satisfactions result from actions that diminish the incongruity between thought and percept so that further action leads to long lasting relief from strain. Pleasure may come inadvertently; satisfaction involves learning. Both are based on a diminution of cortical cathexis. When pleasure is experienced the nuclear trace systems remain unchanged; therefore the affects of the moment remain unchanged. For example, pleasurable sadomasochistic experiences are thus possible. When satisfactions are obtained, on the other hand, the nuclear trace systems do undergo change because of the experience involved in the attempt to match thought and percept. Thus the affects of the moment may undergo considerable change. The satisfying creative experience is fraught with such changes.

STRAIN: All noxious excitation cannot be escaped: e.g., stimulation of the neuroreceptors in the core of nuclear systems. Such excitation must be held at a minimum by actions on the part of the individual and his environment—for example, actions designed to reduce the amount of the chemical substances that stimulate the neuroreceptors. The gradually increasing cathexis produced by such stimulations, when transmitted to the cortical systems, are experienced as strain.

WISHFUL THINKING: A thought is wishful when the actions initiated by the thought override those that would be initiated by the percept in the situation. Such wishful actions are reinforcing because cathexis is temporarily relieved through efferent discharge. There is danger of rebound, however, since the conditions that led to the thought have remained unchanged and will re-initiate the now-reinforced wish. Should this process get out of hand, hallucinations develop. These are accompanied by the complete breakdown of the defense mechanism in the nuclear system, with the result that a vicious spiral of accruing neurosecretory-neuroreceptor excitation is established. Wishful thinking may occur when a situation changes so suddenly that thought and percept are so disparate that congruity cannot be established. Wishful

thinking is apt to take hold in such circumstance when the thought is accompanied by strong affect—that is, when cortical cathexis is high.

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