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THOUGHTS ABOUT THOUGHTS ABOUT THOUGHTS: THE EMOTIONAL-PERCEPTIVE CYCLE THEORY

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A new model of mental process is presented which helps to explain many seemingly mysterious aspects of creative thought formation: its gestative period, spontaneity, suddenness of emergence, and its ability to create new information out of subconscious feelings. The model, which is shown to be supported by recent neurophysiological findings, postulates a self-referential relationship between limbic emotive processes and cortical perceptive processes. A cognitive event is envisioned as a self-organizing, birth process in which a particular combination of unconscious feeling tones becomes amplified through emotional perceptive cycling into a state of high intensity. It is suggested that these feeling structures, or "emotional-cognitive structures," emerge from the unconscious field in a manner similar to the way spatially ordered concentration patterns emerge from a homogeneous concentration field in certain nonequilibrium chemical systems. Thus, cognition may be understood within the framework of nonequilibrium thermodynamics as an instance of "order-through-fluctuation." The proposed model leads to a new conception of the mind/brain relationship, offers an explanation for the evolutionary emergence of intelligence, and points the way to the achievement of a humanistic social existence.

PART I. THEORETICAL DEVELOPMENT

Emotion, Cognition, Symbolism, these are words with which we are familiar, and which refer to our everyday life experience. Indeed, a lot of emotion, cognition, and symbolism went into writing this paper. But how are these basic concepts related? If we can answer this question, perhaps we will have made a significant step toward being able to understand the nature of man's intrapsychic experience and the way in which it relates to his outer environment or Umwelt. Perhaps it will lead us to a better understanding of the relation between the conscious and the subconscious, between thinking and feeling.

At present there is the widespread belief that cognition and emotion are separate functions of the human mind and, in fact, that they bear a competitive relationship to one another. In this simplified view, thought is believed to be solely the product of the cognitive faculties normally associated with the cerebral cortex. This portion of the brain, also known as the neencephalon, or "new brain," is accredited with the function of consciousness, perception, feeling, and voluntary control. Emotions, on the other hand, are believed to originate subcortically in the limbic system which is part of the palencephalon, the "old brain," or "organ of primitive function." While cognition is viewed as being structural or organizational in character, emotions are viewed (according to the energy theory of the personality) as being unorganized and transient, primarily motivational in character.

THE EMOTIONAL COGNITIVE STRUCTURE THEORY

However, this fragmented picture is rapidly changing today as the theorists strive toward more wholistic conceptions of the human mind. One approach recently developed by William Gray, the *emotional-cognitive structure theory* (16), posits an integrating relationship between emotion and cognition. This theory suggests that the basic global emotions, such as pleasure, anger, fear, love, hate, and possibly others, differentiate during child development into a large number of ever finer less intense emotional nuances, or feeling tones, of precise, sharply defined quality. These differentiated emotional nuances then become combined to form modulated emotional patterns much the same way that musical notes combine to form chords or the way that discrete light frequencies combine in different intensities to form shades of color. A finite array of distinct emotional nuances may become patterned in a nearly infinite number of ways forming a rich emotional language which acts as a counterpart to the vast array of cognitive experience. Emotionally tagged cognitive fragments (or "cognitions," to use Gray's terminology) then form structural ensembles called *emotional-cognitive structures*, or thoughts. These units may then be stored in memory to become a lasting part of the personality structure (16, p. 5). Thus, Gray regards emotional nuances as the *coding elements* of thought and experience.

If one stops to think about it, even unfamiliar sensory data must necessarily be interpreted within a feeling-laden context. The camera theory of sensory perception (the theory of emaculate perception) has long since been abandoned. It is well known, now, that sensory perception is a creative model-building process. Sensory data are automatically oriented within familiar categories before they are stored in memory. For example, suppose that you walk into a friend's house for the first time. Without consciously realizing it, you are coding all of your sensory experience of that house in terms of feelings you have for your friend, for the contents of the house, and for your geographical and temporal location. Perhaps even your mood at the time plays an important role.

Gray views emotional nuances not only as coding elements, but also as the integrating devices and *organizers* of thought. Emotional nuances issuing from cognitions are viewed as tributary flows which combine, or associate with one another, to form a river-like emotional theme (see Figure 1). This emotional theme organizes a collection of initially disparate cognitions into a structural form. Thus, just as a river acts as an organizing focus for the growth and development of an urban constellation consisting of homes, factories, and warehouses, so too, emotional nuances in an emotional theme trigger association with nuance-tagged cognitive fragments, forming a growing emotional-cognitive structure (ECS). This ECS would eventually develop sufficient integration to become organizationally closed. At this stage it would achieve autonomy as a thought, and would have its own emergent emotional tag to identify it.

During the incubation period when a thought is "system forming" an ECS could be

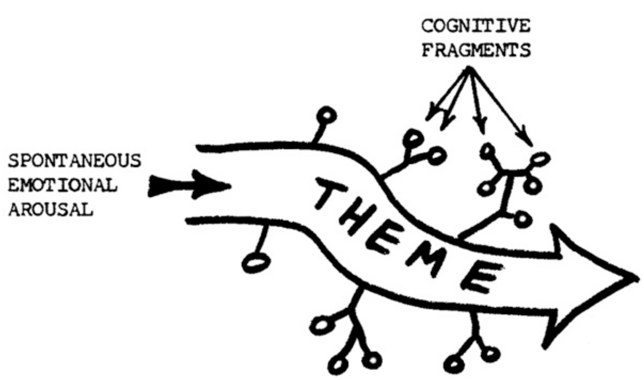


Figure 1. An evolving emotional-cognitive structure.

regarded as a *Fliessgleichgewicht*, a general systems term introduced by Ludwig von Bertalanffy to describe the character of open-system, dynamic structures (71). Thus, a forming thought might be visualized as a persisting pattern of emotional flow, possessing both homeostatic, form-stabilizing qualities, and morphogenetic, form-evolving qualities. Hence, in their formative state emotional-cognitive structures would attain quasi-stable states of equilibrium that are always subject to change.

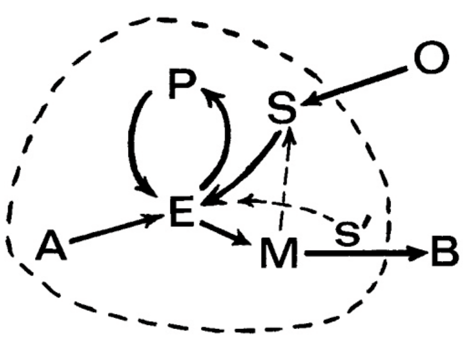
Gray's ECS theory was developed to explain the psychodynamics of creative thought and personality formation. It was refined within a systems theoretic framework with the conviction that since thinking is an evolutionary process, thought must develop in a manner generally characteristic of dynamic systems. It is important to realize that Gray's point of departure was not neurophysiological or psychological, i.e., was not involved in the explanation of psychological experiments. Rather, he was concerned with mental processes, i.e., consciousness, memory, feeling, and creativity, elements belonging to the experiential world rather than the physical. The theory he has proposed offers an excellent framework in which to understand these otherwise mysterious phenomena.

Further support for his theory is to be found in his development of emotional-cognitive structure therapy, an outgrowth of the ECS theory, and which has been applied in the successful treatment of the mentally disturbed. Moreover, a recent survey of neurophysiological literature has turned up evidence that supports many of Gray's claims. This evidence will be discussed in Part II.

THE EMOTIONAL-PERCEPTIVE CYCLE THEORY

At this point, I would like to discuss some of my own ideas which were stimulated by William Gray's work on ECS theory (16), Ilya Prigogine's work on the self-organizing behavior of non-equilibrium systems (42), (53), Ludwig von Bertalanffy's writings on symbolism (73), and my own work on self-organizing systems. These ideas have taken shape in a new theory of the psychophysical organism which, for lack of a better name, I have come to call the *emotional-perceptive cycle theory*.

At the foundation of the theory is the supposition that emotive processes ($\overline{EP}$) and perceptual processes ($\overline{PE}$) are mutually interrelated in a circular causal, self-reflexive process (pictured in Figure 2). That is, emotional nuances from the limbic region would become communicated to the cerebral cortex ($\overline{EP}$) where they would be reemitted in abstracted form and communicated back to the limbic region ($\overline{PE}$) where they would reenter the emotional



$\overline{OS}$ environmental stimulus
$\overline{SE}$ coding of environmental sensation
$\overline{MS}$ efferent sensory modification
$\overline{AE}$ spontaneous emotional arousal
$\overline{EM}$ emotional drive decoded into motoric drive
$\overline{MB}$ expressive behavior
$\overline{SE}$ afferent behavioral monitoring
$\overline{EP}$ cerebral perception of emotion
$\overline{PE}$ emotion elicited by perception

Fiqure 2. A schematic representation of mental processes.

stream, and again recycle themselves. Point E represents a region where nuances from various sources become mixed into the emotional stream, while point P represents a region where nuances become *selectively abstracted* or filtered from the emotional stream. I will refer to this abstraction process with the term "perception."

The abstractive nature of perception has been known for some time as a result of psychological experiments conducted on visual pattern recognition. This topic has also been discussed by Whitehead in such writings as *Process and Reality*:

> "Objectification relegates into irrelevance or into subordinate relevance, the full constitution of the objectified entity.† Some real component in the objectified entity assumes the role of being how that particular entity is a datum in the experience of the subject.
>
> A feeling (X) is the appropriation of some elements in the universe to be components in the real internal constitution of its subject (B) [refer to Figure 3]. The elements are the initial data; they are what the feeling feels. But they are felt under an abstraction. The process of the feeling involves negative prehensions (Y, Z) which effect elimination. There is a transition from the initial data to the objective datum effected by the elimination. The objective datum is the perspective of the initial datum. Thus the initial data (A) are felt under a 'perspective' which is the objective datum (N) of the feeling (X)." (61, pp. 10-11)

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† N is the objectification of feeling X felt by subject B with regard to subject A (author's comment).

A: entity prehended or perceived
B: entity prehending or perceiving
N: objective datum
X: simple physical feeling

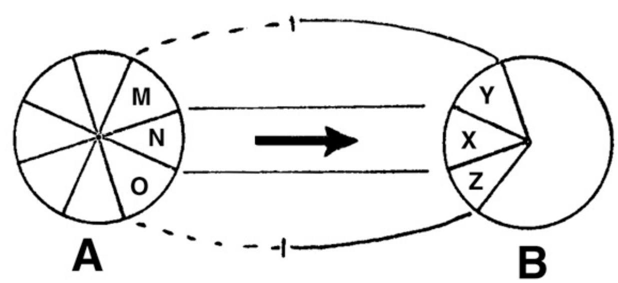

Figure 3. A simple physical feeling as described by Alfred North Whitehead.

The mental behavior of a typical psychophysical organism, as illustrated in Figure 2, is conceived to be primarily active, as opposed to reactive. That is, an emotional nuance arises spontaneously from within the organism A → E from an active "idling cycle," to use Gray's term (16, p. 7), or from an internally activated memory trace. Subsequently, this feeling tone may be expressed by the organism as exploratory or testing behavior in the environment E → M → B. This thesis of autonomy of the psychophysical organism has been repeatedly emphasized by von Bertalanffy (71, 73) and is upheld by leaders of modern psychiatric thought (1, 4, 19, 21, 41, 59, 76). Although, in addition to input from within the system, there is also input from the environment (i.e., from external stimuli) in the form of sensory inputs O → S → E.

Those accustomed to the all too prevalent mechanistic, computer-like models of mental process should take care to understand that Figure 2 *is not a cybernetic diagram*, i.e., the arrows do not indicate pathways of control or effect. Rather, they represent pathways of flow, transformations performed on a stream of subunit entities, i.e., emotional nuances. This model, therefore, represents an open system in the sense that it is open to the flow of information across its boundaries.* For a review of the difference between cybernetic and open systems models see von Bertalanffy (72, pp. 156-163).

THE EMERGENCE OF COGNITION

We will adopt Gray's concept that, in the subconscious, emotionally-coded cognitive fragments (associations) contribute tributary emotional nuances to form an emotional theme, and that this theme in turn organizes these cognitive fragments. We may suppose that in the course of emotional theme formation different nuances constantly surface, become momentarily more emphatic in theme, and then disappear as a result of the continuous making and breaking of associative connections. Thus, the composition of the theme is constantly changing. It can be said to be in a state of *thematic fluctuation*.

Now, the effect of perception ($E \circlearrowright P$) is to abstract certain emotional nuances from the emotional theme. In particular, those nuances having the greater intensity will be captured to the exclusion of other, less emphatic nuances. Alternatively, a biased selection process may be involved in which a particular nuance pattern is sought for, other nuances being selectively screened out. This informationally biased perceptive process may occur when a question is posed and an answer sought.

We might imagine that these abstracted nuances are communicated back to the emotional stream, possibly in amplified form such that $\overline{PE}$ flux > $\overline{EP}$ flux. In effect, what we have here is a built-in vicious circle, a positive feedback, self- reinforcing loop. A set of abstracted nuances fed back to E will become reabstracted. Thus, even though they might initially constitute a minor component of the emotional theme, after several successful loopings they would become amplified and so would come to constitute a dominant part of the emotional theme. Using Magoroh Maruyama 's terminology, we may classify this as a "deviation-amplifying mutual causal process" (36; 26, pp. 38, 89). The deviation referred to here would be a thematic fluctuation of relatively high intensity which would constitute a *deviation* from the homogeneous thematic state — a state characterized by many nuances all having relatively the same intensity.

Now, if a particular fluctuation ("nuance-intensity-deviation") is of the same order of magnitude as other fluctuations randomly arising in the theme, then the composition of the abstracted nuance stream will vary randomly. Consequently, there will be no one particular set of nuances that becomes amplified. Under these circumstances, the ongoing emotional-perceptive cycling would not noticeably change the content, or state of order, of the theme. But, if a fluctuation persists long enough in the theme, or is particularly emphatic, it would have a better chance of becoming amplified through successive reinforcements from the inputted thematic abstractions. Consequently, it would grow rapidly to the point where it

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* The *forming/feeling model* developed by Milton Bennett (3), although not an open systems representation, in many ways resembles the emotional- perceptive cycle model. Feeling, in his model, represents passive feeling for the whole of a boundary system, while forming represents the active creation of conceptual boundaries. Bennett identifies the feeling mode with *perception* and the forming mode with *communication*. Referring to Figure 2, "feeling" would correspond to the perception of the unconscious emotional stream $\overline{EP}$, while "forming" would correspond to the selective elicitation of emotion $\overline{PE}$. Bennett conceives of each mode as continually deriving from the other in an ongoing interactive process in which forming is felt and feeling is formed.

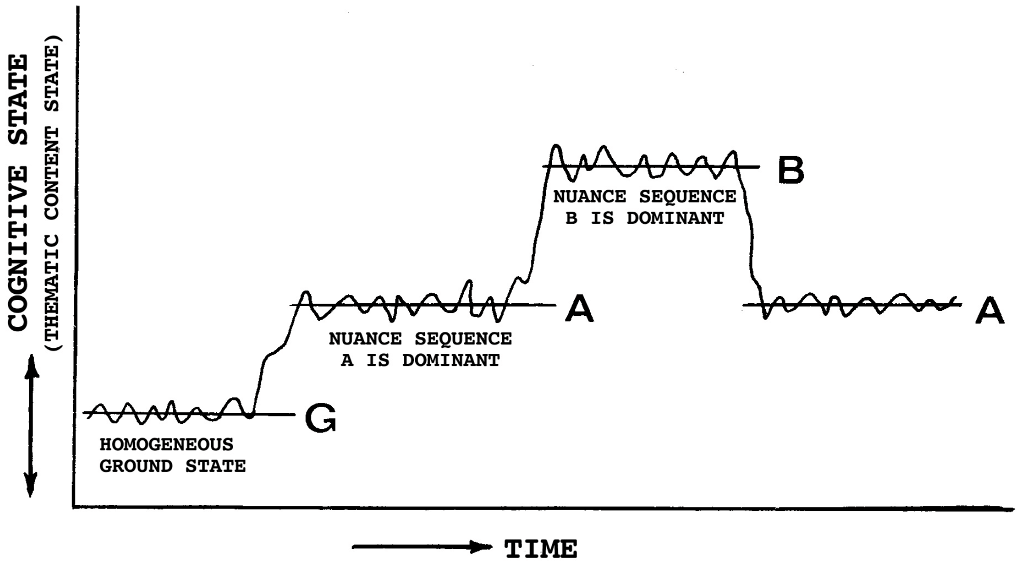

Figure 4. Discontinuous changes in cognitive state resulting from the selective amplification of emotional thematic fluctuations.

would massively transform the content of the theme and become a major "organizing focus."

Thus, a fluctuation arising from within the emotional theme, upon amplification drives the theme to a new state of order. As shown in Figure 4, this transition is made in a stepwise manner, as from, for example, the homogeneous uncognized ground state G to the ordered cognized state A, in which the nuance-set-A is dominant.*

Viewing such a transition from a macrolevel viewpoint, it will have appeared that the emotional theme spontaneously changed its emotional state (or nuance composition), from being a highly complex pattern of emotional nuances to being a relatively simple characterization. It is this spontaneous self-simplifying process which, I believe, constitutes *cognition* and which accounts for the emergence of *creative thought* in man.

Once a cognitive event has taken place, the emotional nuance combination representing the emergent emotional-cognitive structure would continue to circulate for a period of time in the E/P cycle. Such recursive cycling would serve the function of *short term memory*. Thus, short term memory is understood to follow as a consequence of cognitive process!
This is probably an appropriate point to define some of the terms used. I will use "cognition" to refer to this thematic self-organizing event, i.e., the stage in the process of creative thought formation which corresponds to the moment of illumination, or grasping, following incubation. Often the term "cognition" is used to refer to the resulting product of creative thought, i.e., the thought itself. However, to emphasize the belief that emotion is one of the primary components of thought, we will adopt Gray's terminology and refer to

* The vertical axis shown in Figure 4 should not be misconstrued as representing a numerical variable, but should be interpreted as a classification dimension for cognitive states. Fluctuation magnitudes, therefore, might be referenced with respect to each level, i.e., with respect to G, A, and B.

such cognitive products as *emotional-cognitive structures*. Gray uses the term "cognition," or "cognitive fragment," to refer to sensory Gestalts and experiences which have not been organized into thoughts, but which form the raw material out of which thoughts are made. To avoid confusion, I will simply refer to these as sense data, or sensory experience, since they are not formed by cognitive process. Rather, sensory experiences are shaped by a sculpturing process in which raw sensory data are operated on by certain image-forming procedures. Some of these procedures are inborn ("hardwired"), while others are discovered in later life, such as the boundary forming operation learned in early infancy, i.e., the feeling of mother as being an entity separate from self.

The process of cognition proposed here may be better understood by reference to a few analogic examples. We may compare the process of mental conception to the *lasing* phenomenon in optics (*laser* meaning: light amplification by stimulated emission of radiation). In a laser, a light wave traveling down the length of a gas discharge tube is continuously reflected from one end to the other. As it travels, it bumps into ionized gas molecules and triggers the emission of additional light waves. Thus, after a series of reflections, the initial photon has grown into a whole battalion of photons all traveling in the same direction with their wave oscillations locked in phase. We are reminded of Alexander the Great's strategy of continuously recruiting mercenaries as his forces swept across the East.

To put it in other terms, lasing involves the production of *coherent behavior*. Whereas light waves from a light bulb tend to travel in different directions in a randomly phased manner, light emerging from a laser is coherent, i.e., the waves travel in a bundle as if they were one photon. Cognition may be viewed similarly as the emergence of coherent behavior. That is, at the moment of insight, when an idea is born, a state of *thematic coherence* is achieved.

Another way of picturing the process of conception is to listen to the musical piece *The Sorcerer's Apprentice*. In the beginning, the sorcerer's apprentice unwittingly activates a floor broom which starts carrying pails full of water to fill a tub. This activity appears in the music as a secondary theme. But, as time goes on, the brooms multiply, and the activity intensifies. What was once a minor melody eventually becomes a major theme, dominating the rest of the music.

The process by which a combination of emotional nuances emerge at the top of the heap may also be compared to the process of social revolution. For example, a political faction holding views opposed to the established political system always starts out as a minority group. However, if this group is able to grow sufficiently to a critical size, in the presence of an adequate relevant nurturing environment (social dissatisfaction), its growth will be able to accelerate relative to other political views. This "fluctuation" emerging from within the political system may then grow to the point where the established regime is overthrown. However, in so doing, the insurgent faction becomes the new establishment, and therefore risks overthrow from imminent political opposition in the system.

Just as political systems evolve to new states, or platforms, through revolution or election, so too emotional themes are always changing. They do not remain in the simplified cognized form for very long. Subliminal association processes continue, threatening to change the nuance composition of the emotional theme. And eventually an "insurgent" set of nuances may arise from within the theme and "overthrow" the established order. As seen in Figure 4, the theme could switch from cognitive state A to cognitive state B in which nuance set B is dominant.

A clear example of how two different thematic fluctuations can compete for control in organizing a theme is illustrated by viewing the classic face/vase picture in Figure 5. At one

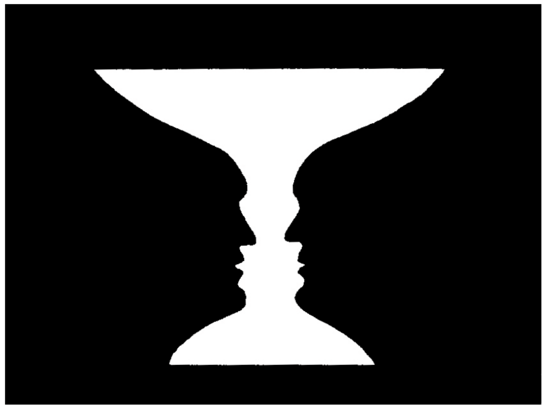

Figure 5. A multistable diagram.

instant the viewer tips the balance in favor of perceiving a vase by including in the evolving theme the nuance of a "vase" cognition. If in the next instance the viewer includes a "human profile" cognition, the balance will tip in favor of perceiving faces. But, both possibilities are equally valid. So, if the observer views the picture with the knowledge that it could be either a vase or faces, the mental image will alternate from one cognitive state to the other in an erratic switch-like manner as each emotional nuance combination alternately gains dominance. This multistable pattern recognition phenomenon is found to occur also in conceptualization, i.e., where a certain situation or set of ideas may be viewed or "punctuated" in two or more different ways.

The emotional-perceptive cycle theory sheds light on the relation of the conscious to the subconscious mind (terms invented by Sigmund Freud). For example, the subconscious would be representative of the subliminal processes such as emotional nuance association and theme formation. It is continuous contiguous, entangled and complex. On the other hand, conscious experience involves focused awareness, the ability to "light up" specific nuances through the transmission of "hypercathexis" (16, p. 10). A bit of mental experience passes from the subconscious to the conscious when a particular thematic fluctuation (i.e., a spontaneous intensification of the nuance representing this subconscious experience) is nurtured, or amplified by conscious, awareness-heightening functions (emotional-perceptive looping) and is eventually born as a full-blown theme.

Emotional-perceptive cycling in conjunction with the subconscious acts as a sort of womb for the birth of ideas. In contrast to subconscious experience, conscious experience is a discrete event or a series of discrete events, an occasion of birth, or a series of births. The phenomenon of consciousness and subconsciousness is closely related to the understanding of how the discontinuous emerges from the continuous, how the simple emerges from the complex.

The cognition of an emotional theme is not a deterministic process; the particular emotional nuances in a theme do not determine exactly what the final mental cognition will be. It is basically incorrect to view the cognitive apparatus as a photographer taking camera shots of fleeting emotions or as a telephone operator making appropriate associative connections. In hierarchical terms, cognition is *not* a top-down process; it is a bottom-up process. It is a *phenomenon of emergence*, of microlevel phenomena producing macrolevel effects.

So, cognition is inherently stochastic. It depends on the detailed whims of the emotional nuance undercurrents at the microlevel. Hence, this accounts for the long gestation period which usually precedes the birth of an idea or concept. This period of incubation must be closely associated with the feeling of *wondering* about something. Gray suggests,

> "...wondering is an essential aspect of emotional nuances, emotional themes, and higher order affects as they seek out cognitions to organize. There is always a questioning, a wondering, an incompleteness, as opposed to an emotional cognitive structure itself which has the type of closure one associates with gestalts." (16, p. 99)

One cannot force a concept any more than one can force the birth of a child. One can only wait in anticipation. When it finally comes it does so in a flash, from apparently nowhere. This dawning of the light, the "ah-ha!" experience may be attributed to the fact that when a thematic fluctuation reaches critical size it experiences a rapid transition to system dominance. The concretization of thought is in effect a set-to-superset transition so often described in the study of hierarchical organization. It is a quantum jump. Regarding the emergence of higher order sets, Clifford Grobstein states the following:

> "Therefore, the emergence of new properties in hierarchical systems is closely linked to what we may call the set-superset transition. In both the developmental and in the functional sense, important new properties arise at the transition between a given set and its next higher order set." (17, p. 45)

The emergent emotional nuance or idea, therefore, is not simply the sum of the individual emotional nuances that originally composed the emotional theme. It represents something more (64). Included are the process of association among emotional nuances, which has a tentative and exploratory quality, and the process of competition between nuances elicited by the amplification process, both processes occurring over an extended period of time. Thus, cognition is not just a structure-relational "snapshot;" it is infused with time — it has *history* as well.* Moreover, there is an element of chance involved as to which nuances will become associated into a theme and which of several predominant nuances will become amplified with the greatest rapidity. Thus, an emergent concept contains more information than just the sum of the information in each of its organized elements. New information is created.

PROBLEM SOLVING

Anyone who has tried to solve a difficult problem knows that before the answer there is a period of transition, or what one may call *pre-cognitive dissonance*. During this time, judgment is suspended; different thoughts and emotional nuances are brought into the picture. When the proper set of nuances become amplified and insight finally comes, there is relief, for now the emotional pressure for exploration (conducted at a subconscious level) may be relaxed. Thus, problem solving, like creativity, is an emotional process.

Of course, in problem solving, as in conceptualization, an element of discrimination must be involved. Thus, if a nuance pattern that does not organize the entire theme emerges, thematic discordance will be perceived and the search continued. In such a situation this rejected trial may unwantedly linger in consciousness and continue to function as a thematic organizer thus reducing the chances for an alternate pattern to emerge. This form

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* It is interesting to note that many modern group-decision making techniques (such as SYNCON) bear a resemblance to the cognitive process described above.

of "conceptual blocking" may be avoided by backing off from the problem and taking a break. This allows the emotional theme to return to its ground state, so that a fresh outlook on the problem may be gained, unbiased by previously attempted solutions.

CONCEPT BUILDING

The emotional nuance which emerges in the theme at the moment of cognition serves as a tag or label, being representative of the emotional theme as a whole. Thus, the original complexity of the emotional theme has become summarized as an emergent emotional nuance which can be manipulated easily for incorporation into higher order associations, or stored in memory for later use.*

This is compatible with Gray's views regarding the hierarchical ordering of emotional cognitive structures. He suggests that "higher level" emotional nuances encode and integrate lower level nuances, and that these higher level nuances, being unique to the particular emotional-cognitive structure formed, have the advantage of simplicity, allowing easy reference and recall (16, p. 9). However, Gray did not elucidate the particular mechanism by which these higher level nuances are selected and "attached" to their emotional-cognitive packages. Such a mechanism, however, is proposed by the emotional-perceptive cycle theory which demonstrates how conceptual labels arise in a natural manner, and in a meaningful way, within the emotional theme. That is, emotional nuances are not arbitrarily assigned to their structured theme, but grow out of the theme as the result of structuration. Thus, these emergent nuance-tags have *value*.

The self-organizing process depicted in Figure 1 (16, p. 8) might be redrawn, in light of the proposed EPC mechanism, as the schema shown in Figure 6a. There, the overall emotional theme is perceived in perspective, whereupon the emotional nuance abstractions elicited by these perceptions enter the thematic mainstream to drive or trigger emotional nuances, with which they harmonize therein.

Once cognized, a prototypical thought may take off to form a new emotional theme, since, as Gray remarks "all thoughts have the potential of again becoming questions." Whereas

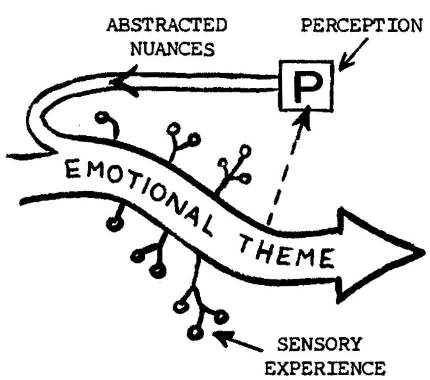

Figure 6a. An emotional-cognitive structure.

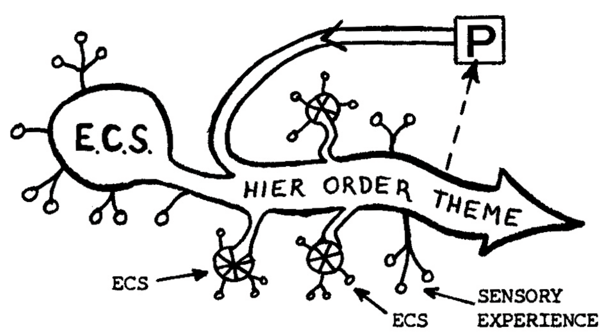

Figure 6b. A coarse structure ECS.

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* Long term memory is implied here. As was mentioned earlier, short term memory is assumed to consist essentially of the circulating emotional stream itself.

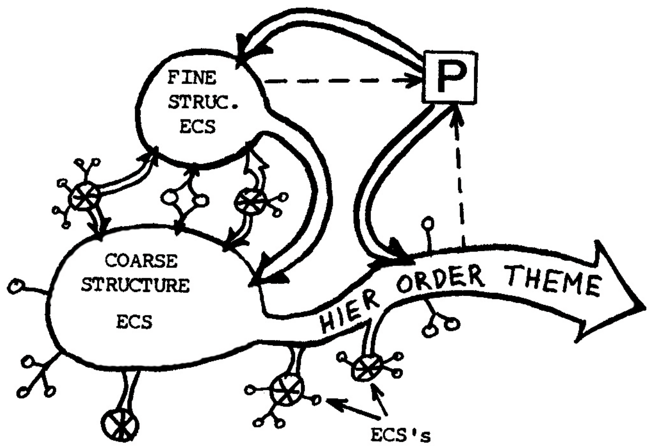

Figure 6c. A core structure ECS.

Figure 6a depicts the process of formation of a simple ECS through the organization of sense data or sensory experience, the higher order structure, or *coarse structure ECS* (16, p. 9), shown in Figure 6b, organizes not only sensory experiences, but also other emotional-cognitive structures. With further development, a coarse structure gives rise to *fine structure ECSs,* "detailed thoughts" which Gray believes serve the main function of revising the more broadly outlined coarse structure thoughts, as can be seen in Figure 6c. Together the fine and coarse structures would be said to constitute a core structure which would constitute a more lasting part of behavior, personality and idea formation (16, p. 9).

THOUGHT: ESSENCE OR SUBSTANCE

Philosophers as far back as ancient Greece have regarded thought as insubstantial, as belonging to the world of ideas. With the advent of Gray's emotional-cognitive structure theory, and with the distinction between conscious and subconscious process offered by the emotional-perceptive cycle theory, a new perspective may be gained. Thoughts become just as "concrete" as atoms, tornadoes, or biological organisms: they can be viewed as stabilized patterns of flow. By pinning thoughts down in this "concrete" fashion, we can begin to deal with the world of the psyche just as effectively as we have dealt with the phenomenal world. In so doing, we should not negate the possibility that there is a noumenal world of ideas having essence, but no substance. Emotional-cognitive structures may be regarded as materializations of these imminent noumenal possibilities into physical reality.

ON THE RELATION OF THOUGHT AND SYMBOLISM

As was mentioned earlier, the emergence of a prototypical thought or emotional-cognitive structure (ECS) constitutes the creation of new information. An ECS, although arising from sublevel cognitions and emotional nuances, is not determined causally by them. Instead, an ECS may be described more adequately as constituting a historical record of the evolution of processes that contributed to producing that thought; i.e., the way in which the associations grew among nuances, and the way in which the tournament unfolded between them.

Thus, if any of the sublevel emotional nuance complexes are determined instinctually, this

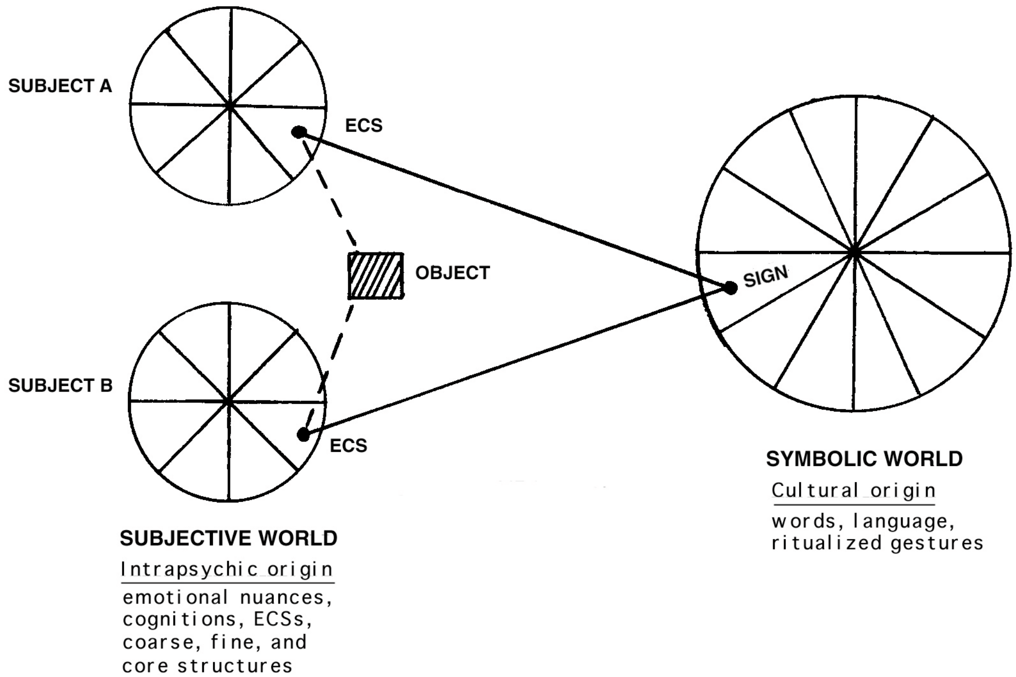

Figure 7. The correspondence of thoughts and symbols.

inherited determinism will not likely shackle the cognitive level. ECSs fulfill two of the basic criteria used by Bertalanffy (73) to define a *symbol*: 1) they are freely created (not biologically determined), and 2) they are representative of some meaningful content (this being the emotional nuances and cognitions composing the underlying ECS and the history of evolution of the concept). Only the third criterion is lacking, that being the communicability of symbols, their capability of being transmitted among individuals by tradition.

However, by somehow establishing among individuals the sublevel cognitions (assuming, for example, that these cognitions are perceptions of objects in the common environment) and by establishing their relation, it should be possible to duplicate in the mind of each individual essentially the same form of ECS. Nevertheless, each individual's concept cannot be expected to be identical; and sometimes, due to poor communication, the ECS may be too different, resulting in a *misunderstanding*. However, granted that, with proper communication, similar ECSs may be generated separately in people's minds, it should be possible for the individuals involved to agree by popular consensus that a particular verbal or visual sign be mentally associated with this concept, as shown in Figure 7. At this point, the concept has achieved symbolhood. It fulfills all the characteristics of being a symbol, because now, through the use of language (a set of verbal or visual associations) it can be transmitted by tradition, a process known as *education*.

It is interesting to note that the particular coding or emotional nuance label which emerges in each person's mind for a given concept may be different, as self-organizing systems, as information *creating* systems, each of us builds his own internally consistent emotional nuance coding system. *That is why human beings are individuals. Why each of us is different.* Differences in IQ, therefore, would not be expected to be linked genetically. Genetically determined IQ makes sense only with mechanistic analogies which have been demonstrated to be inadequate in describing mental phenomena. Man viewed as a self-organizing psychophysical system must assume responsibility for his own level of IQ, or mental state of mind; however, social influences and what a person learns will also figure strongly in the picture.

Concepts cannot be transmitted from one person's mind to another's like TV signals. They cannot be replicated, code and all, from the top-down as in programming a computer. They must be learned from the bottom-up. They must by *freely created*. Thus, symbolism serves as a means of translating from one's own internally developed code to a commonly agreed upon code, much the same way that an international language (i.e., telegraphy) would mediate between people speaking French, Greek, Chinese, and Swahili.

Building concepts from the bottom-up (learning) often can be excruciating, as we all know. But, it is a fortunate circumstance, since it allows each individual the freedom to mentally do "their own thing." Your boss does not care how you drive to work as long as you get there on time. The same is true of learning: you may include your own, personal embellishments in a concept, as long as your version contains the agreed upon essence of the cognized material. Thus, there is an element of freedom in the creation of ideas, and in the learning of concepts.

Humans, not functioning as programmable computers, must pay for this freedom: they run the risk of making a mistake, of misunderstanding a teacher, of coming up with an idea that is totally off base. By understanding the microcosm, the nature of thought, we come to a better understanding of the macrocosm, the history of ideas, and the socio-technical world in which we live. The tentativeness of thought, the possibility of being wrong, produces the *tentativeness of knowledge* as the history of science has demonstrated.

A "THERMODYNAMICS" OF THOUGHT: AN ANALOGY TO THE BRUSSELATOR MODEL

Cognition, like photo lasing and social revolution, is a self-organizing type of phenomenon. In all of these examples a fluctuation arising from within the system grows, due to the existence of prevailing nonlinear conditions and eventually changes the state of the system. This may be described as "order-through-fluctuation," a term introduced by Ilya Prigogine (53) to describe the process of self-organization in certain kinds of nonequilibrium chemical reaction systems.

The self-organizing behavior of one particular chemical system, the *Brusselator* (alternatively known as the Trimolecular Model), has been extensively analyzed mathematically by Prigogine and his coworkers (42, 53). Since the Brusselator played a central role in the development of the emotional-perceptive cycle theory, I would like to present a brief description of it here. If anything, this should demonstrate further the interdisciplinary nature of the principles presently under discussion.

The Brusselator essentially consists of a set of nonequilibrium reactions, i.e., steps (i) through (iv), which proceed irreversibly over time in the direction indicated by the arrows (Fig. 8). These are sometimes called *state equations*, in that constituent elements of the system exist sequentially in different states, i.e., elements in state A will eventually transform at rate k_1 to state X (equation (i)), elements in state X in combination with elements in state B will transform at rate k2 into a combination of states Y and D (equation (ii)), and so on.The structural interrelation of these reactions is depicted in Figure 8. Note the similarity with the proposed emotional-perceptive model pictured in Figure 2. In both models, sublevel constituents (molecules/emotional nuances) are transformed or conducted in a self-closing

$$
\begin{array}{rcll}
A & \xrightarrow{k_1} & X & \text{(i)} \\
2X+Y & \xrightarrow{k_2} & 3X & \text{(ii)} \\
B+X & \xrightarrow{k_3} & Y+D & \text{(iii)} \\
X & \xrightarrow{k_4} & E & \text{(iv)}
\end{array}
$$

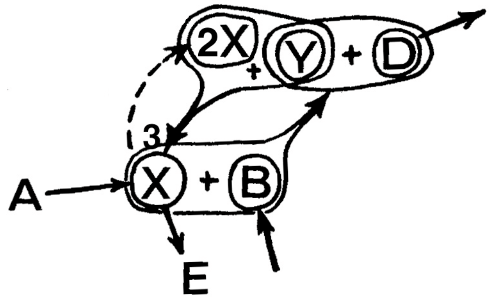

Figure 8. A schematic representation of the reaction kinetics of the Brusselator.

loop (X $\curvearrowleft$ Y vs. E $\curvearrowleft$ P). Hence, they are both open systems. The Brusselator being open to the flow of matter A → X → E and B → D, and the emotional-perceptive cycle model being open to the flow of information A → E → M → B and O → S → E → B.

Now, suppose we have a reaction vessel which contains all of these transforming chemical species in a *homogeneous* mixture. As these chemicals proceed to transform, fluctuations in chemical concentration will develop from place to place. For example, if reaction intermediates X and Y are assumed to have low diffusion coefficients, some regions of space will develop more X and less Y, and other regions more Y and less X. However, these

random fluctuations will tend to dampen one another through mutual competition. This homogeneous state will persist only as long as the global reaction B → D takes place at a low rate with respect to global reaction A → X → E. That is, as long as very little Y is produced in step (iii), the autocatalytic X/Y cycle (steps ii and iii) will not be able to amplify a prominent concentration fluctuation at a fast enough rate before it is destroyed by competitive diffusive effects.

However, if the concentration of B is increased such that reaction B → D moves further from equilibrium, a critical threshold will be reached where the effects of steps (ii) and (iii) become significant. If a fluctuation of sufficient size develops, it may grow at a rate fast enough to dominate the homeostatic effects of other random fluctuations. Consequently, a critical fluctuation could drive the entire reaction systems to the inhomogeneous steady state in which the concentrations of X and Y vary macroscopically with spatial location in a periodic manner similar to a standing wave pattern. Such a pattern is termed a *dissipative space structure*. Hence, the ordering which was imminent in the initial fluctuation (or precursor) will have become amplified by nonlinear effects and propagated throughout the reaction medium. The original symmetry of the system becomes broken as the microlevel behavioral complexity (random molecular order) is superseded by a simple pattern of spatially periodic order (coherent molecular order).

There are a few differences, however, between the Brusselator and the model I am suggesting to describe the emergence of thought. For example, the chemical model is bivalent; ordered patterns emerge depending on the relative concentrations of intermediates X and Y. On the other hand, the EPC model is multivalent, it is a veritable "alphabet soup" of emotional nuances, any combination of which could be amplified to thematic dominance. If steady-state dissipative space structures emerge in the cerebrum, they would be of a more complex nature, with a variety of nuance combinations dominant in different regions of the brain. Finally, because the EPC model is multivalent, its amplification cycle must make use of an abstraction operation to select from the abundant variety. Such an abstraction step is not required to produce ordering in the simple Brusselator model.

Although there are differences between the two models, the similarities offer intriguing possibilities. For example, nonequilibrium thermodynamic principles and terminology, which Prigogine and others have applied to chemical reaction systems, might be translated to describe mental processes. Thus, thoughts might be regarded as dissipative space structures. The nuance flux involved in emotional-perceptive cycling might be represented in terms of *entropy production*, and used as a measure of the distance from "thermodynamic" equilibrium. The "near-thermodynamic-equilibrium" regime in the emotional- perceptive cycle model would be a state where emotional nuances circulated at a very slow rate, a state of mental relaxation, as during sleep or deep meditation. On the other hand, the "far-from-thermodynamic equilibrium" regime would correspond to a state of emotional arousal, or mental attentiveness. The threshold intensity which an emotional nuance must achieve in order to become spontaneously amplified into a thought may be termed *critical nucleation threshold*.

Considering cognition as a self-organizing phenomenon opens many opportunities for making interdisciplinary correlations and may offer a point of departure for developing a "thermodynamics" of thought.*

THE ORIGIN OF THOUGHT

As was mentioned in the last section, the appearance of a cognitive event may be compared to the spontaneous emergence of inhomogeneity in a nonequilibrium chemical system. Thus, just as a chemical reaction dissipative space structure is seen to emerge only past a certain critical threshold of tranmutational flow, so too, we may suppose that the ability to produce thought emerges only past a certain threshold of self-reflexive emotional flux.

Evolutionary changes in the neural system, such as increases in cerebral mass and in cerebral-limbic integration, may have allowed this threshold to be more easily achieved in hominids than in lower animal forms. We may hypothetically represent the "facility" with which thought is produced at various stages of brain development by means of the stability diagram shown in Figure 9.** Animals with less developed brains, such as cats, lie to the left of the critical threshold k_c. That is, when aroused, they are able to induce a nuance amplification capability which reaches as high as k_1. However, at this amplification level $k_1 < k_c$, thematic fluctuations (emotional nuances) of even large intensity will not be able to grow fast enough to dominate the diffusing effect of competing fluctuations. Hence, even with intense emotional effort (e.g., arousal induced by an incentive such as food), high intensity fluctuations are not able to cross the critical threshold where they might become

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* John Nicolis and Marianna Benrubi (43, 44), independent of the present work, have applied nonequilibrium thermodynamic concepts to mental process. However, their work deals specifically with interpersonal communication. Based on neurophysical findings and on principles describing the behavior of self-organizing systems, they have postulated the existence of affective/ cognitive oscillatory cycles in communicative transactions. Their assumptions regarding mental process, though, are fundamentally different from those set forth in this paper.

** Stability diagrams similar to this are used to describe the ordering behavior of nonequilibrium chemical systems, where the vertical axis represents the size of a concentration fluctuation and the horizontal axis represents the distance from equilibrium, i.e., the potential form amplification.

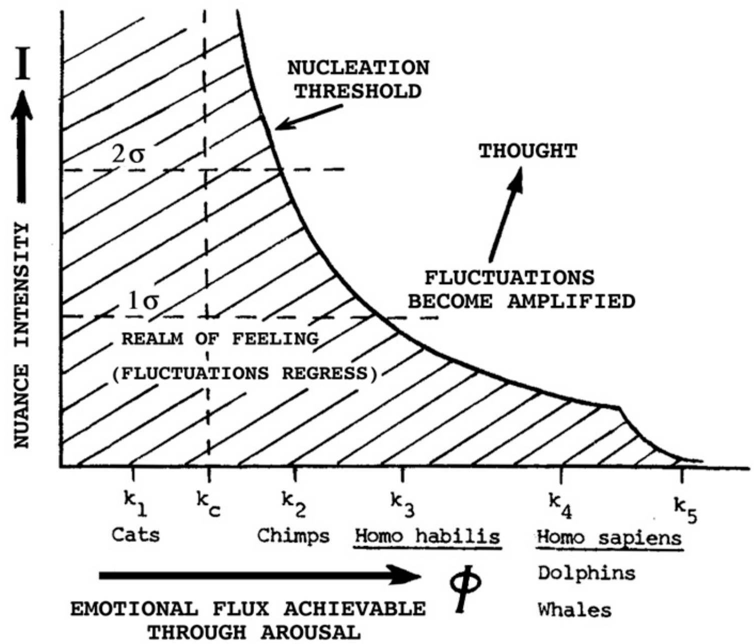


Figure 9. Hypothetical stability diagram showing, for different values of emotional flux Φ, the critical threshold intensity, I, which nuances must achieve in order to become spontaneously amplified into thoughts. Also shown are hypothetical "standard" deviation levels indicating the probability of achieving fluctuations of that corresponding intensity.

spontaneously amplified into thoughts. While such animals have the capability of synthesizing emotional nuance patterns, they do not have the capability of precipitating thought, i.e., of simplifying complex emotional theme patterns into graspable entities.

We might assume that many of the lower animals have feelings composed of differentiated and textured emotional tones, and that these constitute their intrapsychic language. While the emotional nuances may not be as highly developed in animals as in man it is reasonable to assume that sufficient complexity is present to permit intrapsychic coding of instinct and sensory experience. We might suppose that as in man so too in the lower animals there is a natural tendency for emotional nuances to trigger one another through association and to form emotional tributaries and finally emotional themes. Of course, with animals there would be no emotional-cognitive structures for nuances to organize, only sense data. It is emotional theme formation, i.e., the association of diverse emotional states or sensations not instinctively coded, that allows animals to become conditioned to stimuli. Hence, a dog may be trained. While animals are capable of perceiving their own emotions via E $\rightleftharpoons$ P cycling, their predominant pathways for information handling extend via A $\rightarrow$ E $\rightarrow$ M $\rightarrow$ B and O $\rightarrow$ S $\rightarrow$ E $\rightarrow$ M $\rightarrow$ B shown in Figure 2.

Chimpanzees may be considered to lie the right of critical threshold k_c, their brains being more highly developed than those of the gorillas, or other lower forms of life. Experiments have shown that they are capable of "insight learning" under conditions of inducement, such as reward of food (8, p. 218). We might imagine that in such states of arousal chimps are able to stimulate a level of emotional flux k_2, and that at this level there is a finite probability (say P ~ 3%) that a fluctuation of sufficient magnitude will arise and be capable of amplification into a thought. As shown in Figure 10, it may be assumed that emotional

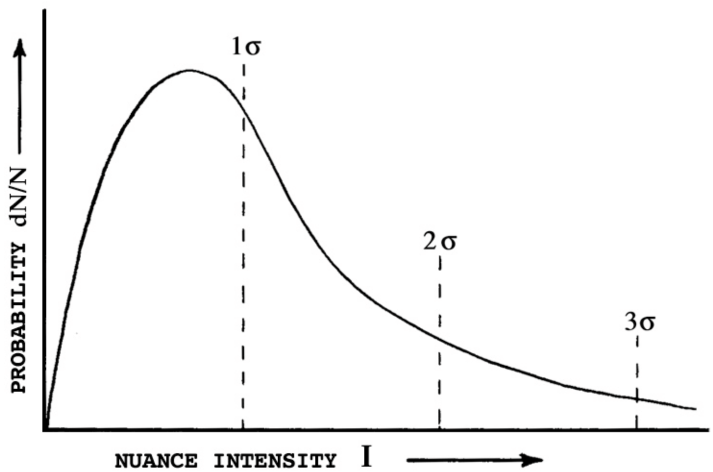


Figure 10. Poisson distribution for nuance intensity fluctuations around the homogeneous steady state level (uncognized ground state). The vertical axis plots the probability dN/N that a given nuance fluctuation will flare up with an intensity between I and I + dI, where N is the total number of fluctuations considered statistically. Also shown are the corresponding "standard" deviation thresholds.

nuance fluctuations around the homogeneous state are distributed according to a Poisson distribution. Thus, there is a much lower probability that a large fluctuation will emerge as compared to a small or medium size fluctuation.

Homo habilis (~2 million years BP) and *Homo sapiens* (emerging ~200,000 years BP), having more developed brains, have been placed successively further to the right in terms of nuance amplification ability, as can be seen in Figure 9. The downward sloping threshold curve for thought formation indicates that at higher levels of self-reflexive emotional flux, spontaneously emerging emotional nuances need not achieve as high an intensity to become amplified into thoughts. Thus, the effort required to produce thought becomes less for the more evolved life forms. For primitive man, conceptual awareness might have come only during moments of substantial arousal, e.g., during moments of danger or during periods of goal directed behavior as when hunting a quarry. Primates capable of achieving the thought threshold at such times would have possessed a trump card in the game of natural selection. Thus, increases in cerebral mass and integration of the frontal-lobe-limbic system, allowing increased levels of self-reflexive emotional flux, would have been positively selected for. In modern man, thought formation appears to be spontaneous. No significant extreme state of arousal is required, merely wakefulness.

We may list *cetacea* such as dolphins and whales along with *Homo sapiens*, see Figure 9. Dolphins have a brain weight which is above that of humans both in absolute and relative terms. Also, observations of *cetacea* indicate that they are capable of intelligent communication among themselves via a sonic language which has yet to be decoded.

Finally, we might imagine certain individuals whose brains are such that they are able to easily achieve extremely high levels of emotional flux, up to point k_5. At such high levels of self-sensibility, the critical nucleation threshold would be so low that just about any minor thematic fluctuation could become amplified into a thought. Such individuals would have difficulty trying not to think all of the time. Their minds would constantly be spinning off thoughts. Moreover, since almost all thematic fluctuations would have an opportunity to become amplified, these individuals would have difficulty attending selectively to particular nuances and weeding out inappropriate thoughts. Consequently, their train of thought would tend to lack coherence or logical structure.

These conclusions, which have been reached by considering the possible behavior of the EPC model under particular circumstances (high nuance flux), are corroborated by recent studies of schizophrenic patients. There has been growing support for the observation that at least one type of the "group of schizophrenias" primarily involves the impairment of the normal inhibitory functions of attention. In contrast to previous conceptions, the schizophrenic is seen, not as an individual who has effectively shut out external reality, but as one who is *overwhelmed* by too much contact with the environment (39, p. 88). For example, the following extracts, taken from several studies, are introspective experiences reported by a number of schizophrenic patients (quoted in 39):

> "I can't concentrate... It's diversion of attention that troubles me... the sounds are coming through to me but I feel my mind cannot cope with everything... it is difficult to concentrate on any one sound... it's like trying to do two or three things at the one time..." (40)
>
> "Everything seems to grip my attention although I am not particularly interested in anything. I am speaking to you now but I can hear noises going on next door and in the corridor. I find it difficult for me to concentrate on what I am saying to you." (40)
>
> "It has to do with what is going on around me... taking in too much of my surroundings... vital not to miss anything... I can't shut things out of my mind and everything closes in on me..." (6)
>
> "Each of us is capable of coping with a large number of stimuli, invading our being through any of the senses... It's obvious that we would be incapable of carrying on any of our daily activities if even one hundredth of all these available stimuli invaded us at once. So the mind must have a filter which functions without our conscious thought, sorting stimuli and allowing only those which are relevant to the situation in hand to disturb consciousness. What happened to me was a breakdown of the filter, and a hodge-podge of unrelated stimuli were distracting me from things that should have held my undivided attention... I had very little ability to sort the relevant from the irrelevant... Completely unrelated events became intricately connected in my mind." (38)

It is interesting to note that post mortem examinations of some schizophrenics have revealed that their brains have an inordinately large number of fiber connections in the medial forebrain bundle connecting the frontal lobe of the cerebrum and the limbic region of the brain with the reticular activating system. Such excess in brain integration might be responsible for producing an overly active emotional-perceptive cycle. (More will be said in Part II about the neurophysiology of such pathways of integration). Further evidence that schizophrenia results from an overactive mind is the fact that tranquilizers, acting to reduce the degree of arousal, also tend to alleviate the symptoms of schizophrenia.

At the other end of the spectrum is the catatonic, or extremely depressed individual, whose mind is in such a reduced state of mental activity that hardly any thoughts at all can be amplified. This is true even when the individual is awake. Such conditions are generally alleviated by the administration of stimulant drugs such as amphetamines which, we might imagine, act to raise the cerebral-limbic emotional flux to a more appropriate level.

Intelligence, it appears, operates within narrow limits, the healthy mind being characterized by the Epicurean motto of moderation: neither too much nor too little input. While a healthy individual is capable of producing thought, he is not condemned to continuous mentation. Indeed, individuals spend much of their time in subthreshold levels of neural activity. With sufficient relaxation of inattention, the conceptualization process subsides. The need to concentrate in order to think, to be free of distraction, may actually be an effort to generate a sufficient level of sustained, focused emotional-perceptive interaction.

COEVOLUTION: THE UNFOLDING OF MAN-ENVIRONMENT RELATEDNESS

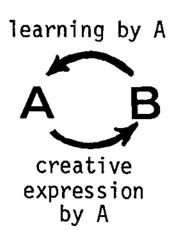
The English word "man" comes from the Sanskrit *manu*, meaning "to think." The ability to think, to engage in extended periods of conceptualization, might be regarded as a distinguishing characteristic of man. The ability to use tools or manipulate symbols cannot be considered as distinguishing factors since these abilities are observed in many animals (18, 73). However, experiments with chimpanzees have shown that even with regard to thought it is difficult to draw a clear-cut dividing line. Intelligence appears to be a matter of degree.

It is reasonable to assume that there was a time in human evolution when man was capable of cognition and rudimentary thought, but as yet incapable of symbolic expression. Then, as time went on, man learned to express socially cognitions of external events, i.e., develop symbols for these cognitions. The development of language, or interpersonal communication, was simply the expression of these cognition-object, thought-action connections. Whereas man had formerly vocalized only feelings and emotions, he now began to vocalize symbols. The ensuing transition from *homo-emotional-cognare* to *animal symbolicum* was a natural one, man being a social animal. Indeed, modern experiments with deaf children at play indicate that humans have the innate ability to spontaneously develop their own structured communication system in a manual. mode without the benefit of learning an explicit, conventional language model (13).

The development of man's I-thou awareness, or ego boundary came still later, unfolding as a corollary of symbolic thought. The self-awareness experience in which the symbolized "self" became understood as being separate from the symbolized "other" required that man develop a significant level of philosophic insight. Self-awareness is another trait often inappropriately claimed to be a basic characteristic distinguishing man from animal. As we see here, self-awareness is not the cause of intelligence, but a product of intelligence.

As symbolism and environmental relatedness unfolded, man's thoughts, or emotional-cognitive framework, of course, evolved too. Man's thoughts, originally rooted in an emotional-feeling context, with the advent of symbolism evolved toward a conceptual context or emotional-cognitive context. An iterative or self-referential dialectic process most likely took place between man's thoughts and his social symbolic framework, see Figure 11.

<u>Individual level</u>
(I)
subjective realm
realm of personal values
realm of creativity



<u>Social level</u>
(thou)
formal symbolic universe
realm of social values
realm of logic
realm of knowledge

Figure 11. Pathways of information exchange between the personal self and the social symbolic framework, a process of coevolution.

The evolution of man's symbolic "universe" was and is a social phenomenon. In child rearing, the role of society, B, is taken by the parent who teaches the child, A, a subset of the socially developed framework, i.e., the rules of proper behavior. The child is not usually asked to understand these rules, merely accept them. And, they are backed by punishment if they are disobeyed. Taking time to explain is often a long, tedious, and sometimes futile process which most parents are not willing to undertake. Thus, from an early age, children learn to accept cognitive relations from their social environment and commit them to memory. The comprehension of these categories usually involves a minimum of feelingful thought, since they are delivered in a simplistic way, for example, simple relationships of logic such as A plus B causes C, i.e. "Johnny, if you play with matches, you will get spanked":

These emotionally impoverished cognitions contrast strongly with the child's own creative insights and self discoveries which spring from great intuitive depths and result in the development of rich textured patterns of cognitions and emotional nuances. Thus, from early childhood people learn two kinds of thought: feelingless thought (digestive, receptive) and feelingful thought (creative, expressive). There is also a third kind of thinking which should be mentioned to cover all three of Gray's thought classifications, and this is emotionally driven thought. This refers to the situation in which too much feeling, usually emotionally undifferentiated, floods an individual organizing theme. Such would be the case in a temper tantrum.

As the child grows up and becomes socially responsible, he internalizes the *parent role* which becomes associated with his rational, thought processes, whereas the *child role* (originally present) remains as the wondering, exploratory, freedom-loving side, the feelingful thinking side. Experimental evidence indicates that these two activities of the mind are allocated to separate hemispheres of the cortex. The left hemisphere in most people underlies analytic, sequential, and rational thought— particularly language — while the right hemisphere underlies holistic or associative thought (i.e., thought processes characteristic of the dreamer, the artist, craftsman, or the mystic). Thus, the roles of parent and child may be correlated with the left and right hemispheric distinction. What would be regarded in transactional analysis as the adult state would be a balance or equal emphasis between these two modes of thought.

Thus, a person with an overly active parent would overemphasize left hemispheric activity and would place much emphasis on proper social behavior, conformism and rules (anal personality), whereas a person with an overly active child would emphasize right hemispheric activity, placing much emphasis on personal values, breaking rules, and eccentric behavior (oral personality). Finally, the case where proper balance has been achieved between the personal and social realms would be characteristic of the adult state of mind.

The two modes of thought discussed earlier (feelingless and feelingful, left brain and right brain hemispheres) constitute two different ways in which the mind fabricates thought structures. Left-brain processing involves the sequential arrangement of bits of information into logical forms, the rules of arrangement being socially (or personally) learned. Left-brain processing is active, verbal, conscious, volitional, and generally takes a short time to accomplish its operations. On the other hand, right-brain processing, which fosters the spontaneous birth of ideas, is passive, unconscious, avolitional, and generally takes a considerable length of time. Effective thought involves striking a proper balance between both modes. Thus, newly emergent ECSs (right brain) are stabilized through left-brain processes, and established ECSs (left brain) are changed through right-brain processes. Recall Gray's ECS revision process where coarse emotional cognitive structures are continuously refined through the reflexive action of fine emotional cognitive structures. This interplay between intuitive and rational modes is also described in terms of "second cybernetics" as a shifting between morphogenetic, form-creating processes (right brain) and morphostatic, form-stabilizing processes (left brain) (26, 36).

Most of the discussion until now has centered on the creative process, however left-hemispheric processes may also be understood in terms of the EPC model (cf. Part II of this paper). We might imagine that the emotional-perceptive cycling underlies both right and left hemispheric brain processes. In the creative mode E/P cycling is relatively undirected and free-wheeling, while in the analytical mode it is consciously directed and constrained. Thus, the EPC model really constitutes an integrated approach to understanding mental process.

THE SICK SOCIETY

Ideally speaking, a humanistic society should try to encourage both the rational and intuitive modes of thought. Unfortunately, our modern Western society does not. In the name of technological progress, left-brain, analytical thought has been increasingly emphasized at the expense of right-brain holistic perception. According to Hazel Henderson (20):

> "Today we see our culture suffering from an overdose of left-brain hemisphere Cartesian cognition. It has led to compulsive dichotomizing and the Tower of Babel of academic disciplines that now fractionate reality. Accordingly we reward analysis and punish synthesis, while the interesting problems exist at the interfaces between the disciplines."

Aristide Esser (10) states:

> "Modern man is in motion so continually that he has no possibility to relax, to experience emotion. Our contemporary ways of human relating increasingly proceduralize change, i.e., they try to make us learn through the intellectual process and without emotion, without the feelings that originally accompanied learning in a social context. As a mammal, our first pleasant learning experiences were those of smell, warmth, intimate touch, and sound.... Formal learning experience is directed toward replacing such intimate motivations with ulterior motives based on intellectual functions needed to live a human-like existence."

Also William Gray warns that when thoughts have come to be "drained" of their feeling element, people have a tendency to "carry out actions based purely on logical connectedness, without regard as to whether the results are destructive to society." (16, p. 11)

To what do we owe this modern day predicament that thinking has become feelingless? I would say that the root cause is of social origin. Basically, it arises from our fast pace of life and tendency to cut corners for the sake of "efficiency." As mentioned in the last section, in Western society children are exposed to the left brain bias at a very early age, feelingless thought patterns being implanted by parents who do not have the time to explain things properly. Yet this learning paradigm extends beyond child rearing. It has permeated the very essence of society.

It is not surprising that students today find school subjects dull and uninteresting. Because of the fast pace of life, lessons are often taught in rote fashion with emphasis placed on learning at a bare minimum. For example, in teaching physics more time is spent mastering techniques for manipulating equations and less pondering theoretical underpinnings and the history and philosophy of physical science. The result is that students lack *feeling for their subject*. They can spit back equations in a mechanical way and maybe even apply them in a limited range of examples, but when it comes to their understanding of the subject one finds that it is really superficial.

Modern society, which worships the efficiency of the computer, expects the same performance from its human beings. But, by demanding efficiency, it gets only shallowness in return; for, learning any concept well requires a period of gestation, a period of pregnancy for emotional nuance connections of the proper depth to develop. This truly takes time. By trying to speed up things our society only creates mental abortions and miscarriages. While educators intuitively know this to be true, the mechanistic ontology is so ingrained in our culture that these faint callings are often drowned in the din. It is ironic that *by trying to get ahead more rapidly than we should, our society is actually getting behind conceptually.*

What is true of our educational system is also true of our working world and interpersonal relations. The fast pace of life leads people to deal superficially with one another. Management often falls into the trap of dispensing directives in a *cold, mechanical* way,* and of expecting unquestioning obedience. After all, understanding the purpose behind an instruction, developing a feeling for it, takes too much time.

Efficiency takes its toll in the commercial world too. In order to give the impression that they care about their customers, checkout clerks in some supermarkets are instructed to ask: "Did you find everything you needed?" But the monotonous tone of their voices exposes their true sentiments. After all, there are ten more people next in line, waiting to be checked. It is the artful clerk who can really ask you "How are you?" and actually mean it, because the pace of modern life stacks the odds against relating with feeling.

Comprehension, being a process of system formation, requires a certain length of time to occur. Without taking time to contemplate and to let feelings organize cognitions into structured and meaningful forms, one is left basically with just a *collection* of cognitions. Being bombarded with information from every side, people naturally tend to get in the habit of just accepting what others tell them without trying to understand for themselves. Thus, if they are told that A causes B causes C, and they do not take the time to understand why, to understand what is assumed, what has been left out, they may instead take the short cut and accept this statement as is, i.e., $A \rightarrow B \rightarrow C$. It is this bad habit of accepting statements at face value, and our institutionalization of this habit, that allows the advertising industry to manipulate consumers.

When we accept conclusions without understanding how they are reached, just memorize relations, and when we go on doing this day after day, fairly soon we have succeeded in building a hierarchy of one unexamined fact on top of another. We have therefore in effect created a system of cognitions interconnected with precious little feeling. To properly flesh out this system of logic, to put meat on its bones, great time and care would have to be taken to understand each fact as we go. But, many jet setters today do not take the time to do this.

While our pace of life has increased in the last century, our mental capacity to assimilate concepts has not, it has remained about the same for the last one hundred thousand years or

* It is interesting to note that "cold" and "mechanical" have become closely associated terms. The theory of concept formation presented here provides an insight as to why mechanical ways are cold (or emotionless).

so. Consequently, the amount of time allotted to emotionally organize each new set of cognitions becomes less and less. Information overload has resulted in shallow understandings (and TV has not been much help in this regard either).

Thus the frenetic pace of life has produced the Brave New World, the meaninglessness of life, and the modern neuroses of nihilism (cf. 73). At last we can find comfort that the ailment of emotionless thought does not find its root cause as an outgrowth of the cognitive process, but, rather, is imposed upon us unwittingly by a society gone berserk. Hopefully, through a better understanding of what it means to be human, and through a more enlightened view of the world provided by humanistic general system theorists, better prospects are in store for the human race.

PART II. NEUROPHYSIOLOGICAL EVIDENCE

The emotional-perceptive cycle (EPC) model presented in the first part of this paper predicts that certain neuroanatomical and neurophysiological features should be observed in the architecture and operation of the brain. Namely, one should observe bi-directional connections between the cerebrum and limbic region, such that the perceptive/abstractive function of the cerebrum is involved in self-reflexive interaction with the receptive/emotive function of the limbic region. Moreover, the brain's arousal mechanism should be found to make connection with that part of the limbic region which makes efferent connection to the cerebrum and should be found to act as a regulator of the intensity of the nuance flux propagating cyclically between the old and new brains. These predictions and others were originally formulated before a survey of the neurophysiological literature had been made. Consequently, the details brought to light in the following section may be regarded as a test of the EPC model. As will be seen, there is a close correspondence between theoretical prediction and observation.

Before investigating the predictions suggested above, a few sections will be spent exploring the neurophysiological evidence supporting some of the assumptions underlying the EPC model which were borrowed from Gray's ECS theory. In particular, we will begin by examining evidence supporting the contentions: 1) that emotions may combine to form a spectrum of emotional nuances, 2) that these nuances might be the information carriers of mental experience, rather than the physical structure of the brain, itself, 3) that thoughts and memories are affectively coded, and 4) that the cerebral and limbic regions of the brain do not function independently of one another, but in an integrated fashion.

NEUROPHYSIOLOGICAL EVIDENCE OF AN EMOTIONAL LANGUAGE

The assumption that the basic emotions might combine to produce a vast spectrum of emotional nuances, or feeling tones, appears to be reasonable in view of neurophysiological evidence. For example, different emotional and behavioral responses may be elicited by stimulating different limbic structures (i.e., the amygdala, hypothalamus, septal region) and different regions within each of these structures (22). Moreover these structures are integrated both internally and among one another by a rich network of fiber connections allowing these spatially separated emotional loci, if simultaneously stimulated, to produce a variety of blended emotional tones.

It is conceivable that if an emotional nuance coding system indeed exists, it might physically manifest itself as a spectrum of neuroelectric waveforms, having varying shapes, frequencies, and amplitudes. Indeed, experiments in which limbic structures have been electrically stimulated indicate that the elicitation of a particular emotion or physiological response is contingent not only on the precise location of the electrode, but also on the *nature* of the stimulation, i.e., its voltage, amperage, frequency, waveform, or duration (37, p. 114-119; 2, p. 266).

More direct evidence that not only feelings, but intentions and visual images as well, are coded in a waveform context comes from experiments conducted with monkeys (48, 50, 52). A monkey was trained to perform a visual discrimination test in which either a circle or pattern of vertical stripes was flashed on a translucent panel in front of him. The apparatus into which he was strapped would reward him with a peanut if he pressed the right half of the panel when the circle was presented and the left half when the stripes were presented. Electrodes implanted in the monkey's primary visual cortex recorded a variety of distinct reproducible waveforms correlated with specific mental events such as the monkey's visual observation of one or another illuminated stimulus, its intention to respond by pressing one or the other side of a panel for reward, and its anticipation of reward or disappointment when no reward was forthcoming, see Figure 12.

These experiments strongly suggest that mental events, whether of external origin (sense perceptions) or of internal origin (motivational intents or experiential states) are in a similar manner physically manifested as waveforms. This evidence strongly supports the hypothesis that mental events are experienced in a *coded form*, since physical waveforms may be regarded as encoding sensory, motor, or emotional information in their shape and amplitude. It is a relatively small step from this to imagine that subtle feeling states, or "emotional nuances," might each possess unique reproducible waveform patterns and that

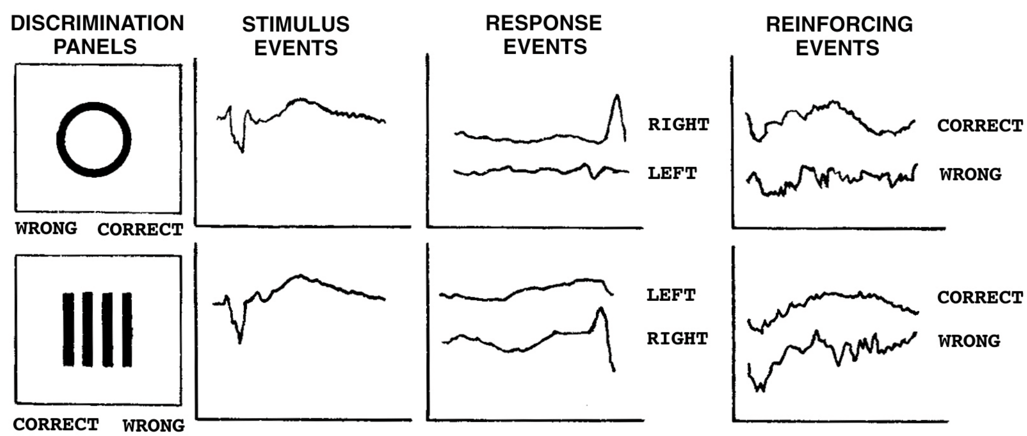


Figure 12. Results of monkey visual discrimination experiment. A slight difference in the "stimulus" waveforms indicates whether the monkey has seen a circle or stripes. The records under "Response Events" were those generated just prior to the moment when the monkey actually responded by pressing either the left or the right half of the panel. Only after he has learned his task, do the response waveforms show differences in pattern. These differences appear regardless whether he has seen a circle or stripes. Thus the waveforms reflect his intention to press a particular half of the panel and do not indicate whether his response is going to be right or wrong. However, a third difference in waveforms does indicate whether a reward has been obtained: a slow shift in baseline following the movement of response indicates anticipation of reward and a 25-30 Hertz waveform indicates disappointment (48, p. 76; 50, p. 123).

thoughts coded in terms of emotional nuances (and possibly also incorporating sensory and motor waveform data) are similarly manifested as waveforms, or "thought waves."

This evidence, that mental experience is coded in a waveform context, strongly undermines the classical "association-by-fiber-tracts" view. Those who hold this view believe that mental functions such as thinking, learning, and remembering at least for the higher animals and man, are somehow localized exclusively in the nerve cell network that makes up the cortex. That is, a particular thought would be determined by a particular firing pattern of particular nerve fiber pathways in the cortical neural reticulum. Thus, the "association-by-fiber-tracts" view essentially regards mental experience as being hard-wired, the reticulum being compared to the complex circuits of a digital computer.

However, recent evidence that sensory experience and perhaps thoughts are coded as waveforms strongly undermines this contention. Neurophysiologists are now rapidly shifting from a "hardware" to a "software" approach in viewing brain functioning. The neuroelectric impulses, rather than the fiber tracts which transport them, are now being regarded as the informational locus of thought. That is, the information content of thought is now viewed as being ingrained in the waveform, rather than being bound to a particular physical location or sequence of physical pathways traversed.

Thus, waveform information is self-contained and portable. It may be neurally transmitted to different parts of the brain without change in content. Thoughts may be projected via nonspecific paths to different regions of the cerebrum and still retain their meaning. Direct evidence that information becomes distributed in the brain has been demonstrated in experiments on cats (25) where it was found that a particular neuroelectric waveform relating to a particular visual stimulus occurred simultaneously in many brain structures. These results indicate, in accordance with the EPC theory, that the particular fiber pathways traveled are not as informationally important as is the wave structure (or emotional nuance).

LIMBIC CYCLING AND AFFECTIVE MEMORY

The emotional-cognitive structure theory suggests that cognitions in memory elicit emotional nuances which form river-like confluences and that these emotional themes evolve over time, eventually developing closure to form a thought, or emotional-cognitive structure. For such a model of mental process to be valid, we should expect to find evidence of closed-loop connectivity in the brain closely associated with limbic structures (the source of emotion) and with memory storage. That is, the transmission of emotional nuances and sensory waveforms in a closed loop would allow these informational units to persist over time. The informational content of such a set of cycling units could, therefore, be represented in the time-dimension as a river-like emotional theme. Provided that this circuit continually received inputs of new informational units, i.e., from the senses or from memory, and provided that existing units in the informational stream diminished in intensity with each passage around the closed loop, the informational content in this loop would continuously evolve as suggested by Gray's "idling cycle" (16, p. 7).

Probably the best candidate for such a self-closing pathway is the *Papez circuit* in the limbic system. This was first described in 1937 by the anatomist James Papez (46) who suggested that the activity in this circuit might provide the neural basis for emotional experience. We may trace its limbic structure connectivity as follows, (see Figure 13):

Fiber connections from the *mammillary bodies* (M) of the *hypothalamus* (Hyp.) lead to the anterior thalamic nuclei (AN, VA) which project bi-directionally onto the *cingulate gyrus*

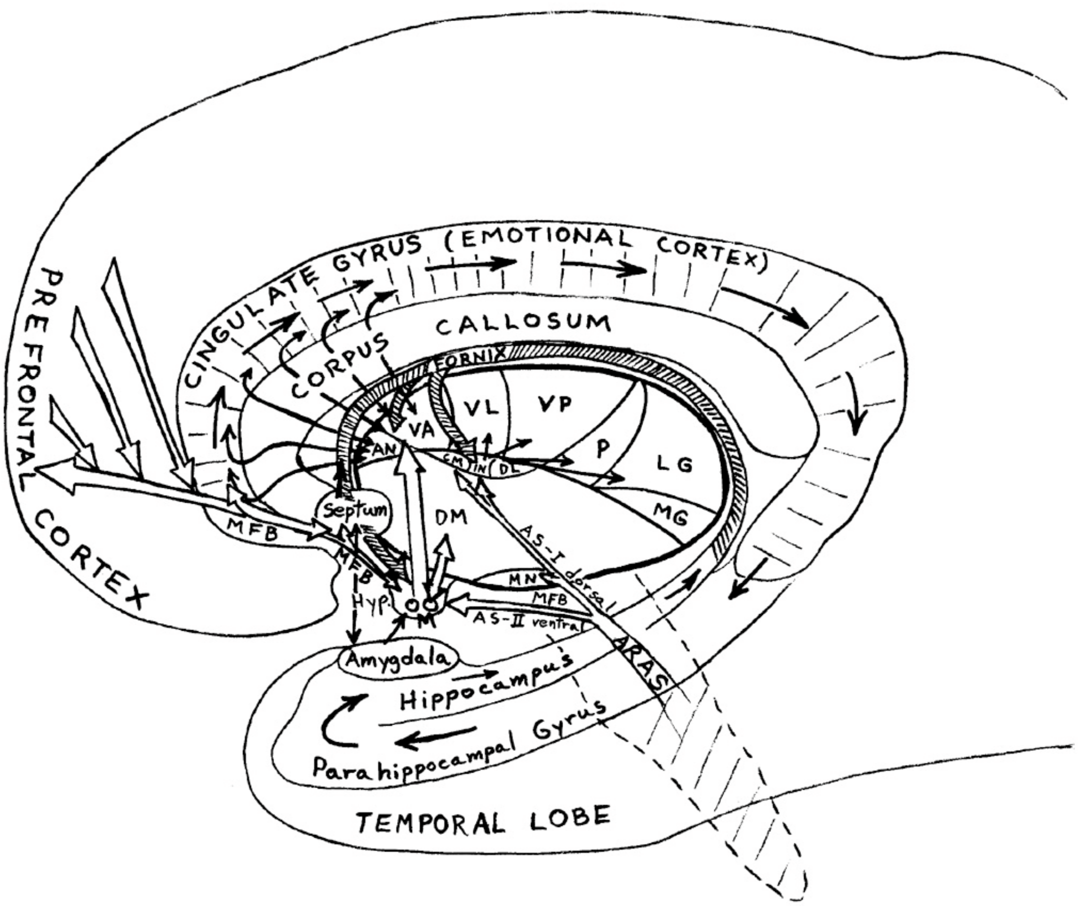


Figure 13. Pathways of connectivity in the limbic system including Papez' circuit. Abbreviations of specific thalamic nuclei: ventral anterior (VA), ventrolateral (VL), ventroposterior (VP), lateral geniculate (LG), medial geniculate (MG). Abbreviations of nonspecific thalamic association nuclei-: anterior (AN), centromedian (CM), intralaminar (IN), dorsolateral (DL), dorsomedian (DMO, pulvinar (P), midline (MN). Hypothalamus (HYP); Mammillary bodies (M); Median Forebrain bundle (MFB); Ascending reticular activating systems (ARAS); Arousal Systems I and II (AS-1, AS-II).

(also known as the "emotional cortex"), the pathway then leads around the cingulate gyrus and *parahippocampal gyrus*, through the *entorhinal cortex* (EC) and into the *hippocampus*, which, via the fornix nerve bundle, connects back to the mammillary bodies. Thus we might imagine a "stream of feeling" coursing repetitively around this loop. Regarding this MacLean (32) has noted that discharges electrically stimulated in the hippocampus have a tendency to spread throughout and be confined to the limbic system. He compares these cycling neural impulses to "stampeding bulls which do not jump the fence and leave the corral of the limbic system."

All of the structures encompassed by the Papez circuit, as well as others such as the amygdala and septal region, have been shown to be involved in a variety of somatic and autonomic phenomena closely related to behavioral activities which are usually associated with emotional expression. The hypothalamus appears to be a key structure in the Papez circuit. It receives afferent connections from almost all subcortical structures and may be

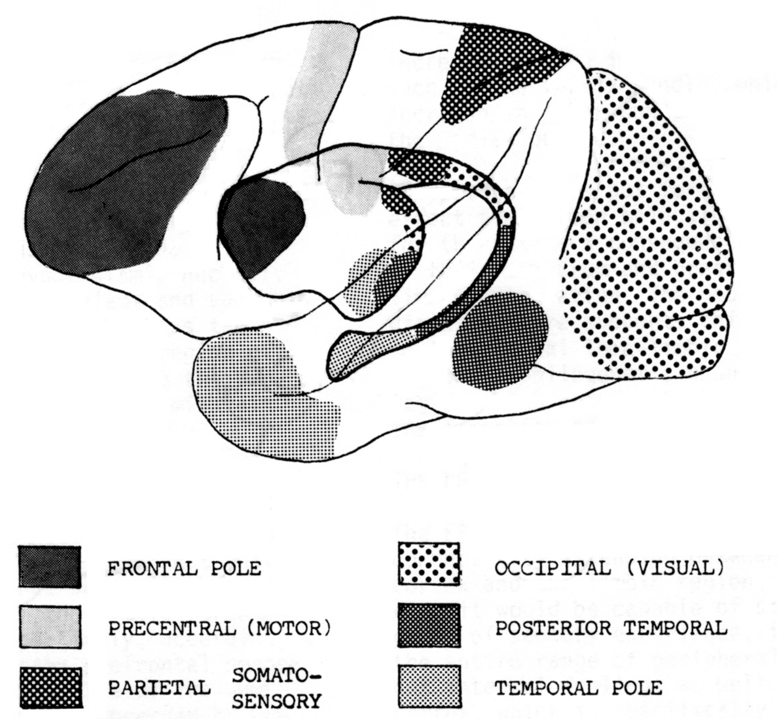


Figure 14. Projections of the cerebral cortex onto the caudate nucleus and putamen, members of the basal ganglia (Pribram, 1971) (50). There is considerable overlap not shown in the diagram.

regarded as a major entrance into this limbic loop. As a center concerned with motivation (appetites or drives) and emotion (affects), it receives fibers from the amygdala which is concerned with emotional feelings and behaviors that insure self-preservation, i.e., selfish demands such as feeding, fighting, and self-protection (31; 33, pp. 14-15), and from the septal area, which is concerned with sexual drives and sociability (31; 33, pp. 15-16). Thus there is ample opportunity for basic emotions generated in these drive centers to become blended in the hypothalamus to form a wide variety of feeling tones. Connectivity between the hypothalamus and the *dorsomedial thalamic nucleus* might be a main corridor for the entrance of sensory and thought waveforms. The dorsomedial nucleus, an important center, receives nonspecific sensory inputs from other regions of the thalamus (the brain's sensory center) and is also connected with the prefrontal cortex (prefrontal-cortex-dorsomedial-thalamic loop) whose role in creative thought formation and short term memory will be discussed shortly. Finally, the hypothalamus may serve as an entrance for sensory waveforms originating in the posterior cortical regions and for thought waveforms passing through the prefrontal cortical region. As seen in Figure 14 (50, p. 320), these cortical regions project to various portions of the basal ganglia, which, in turn, project to the hypothalamus (55, p. 42).

The hippocampus, another important structure of the Papez circuit, is believed to play an important role in long term memory (70, pp. 5-6). For example, patients suffering bilateral damage to the hippocampus as a result of either surgery or disease have difficulty in storing memory records of new events as they occur. In addition, retrograde amnesia has been observed extending back in time for a period prior to the occurrence of hippocampal damage (37, pp. 131-132).

Olds (45, pp. 257-299) has compared the hippocampus to the random access memory unit of a computer, suggesting that memory might be stored in *coded form*. Spinelli (63, p. 235) suggests that the memory system used by the brain is *content addressable*, rather than *location addressable*. He suggests that memory networks are addressed in parallel by any stimulus entering the nervous system, and that to retrieve a chunk of information all that is necessary is that the system be provided with a fraction of that chunk, the remainder being played back. Thus, we see that Spinelli's model is quite similar to Gray's (16) in which an emotional nuance transmitted to memory was supposed to reactivate those memory traces with which it was "tuned," and would elicit the retransmission of these associated traces in the form in which they were originally recorded.

This view is supported by experiments conducted by John and Killam (24), in which a cat was trained to press a bar to avoid shock whenever a visual stimulus was presented. A light flickering at 4 cycles per second (cps) was used as the stimulus and was found to produce a 4 cps neuroelectric waveform in the cat's visual cortex whenever presented. After the cat had learned the task, a 10 cps light stimulus was presented and the same avoidance response was evoked, but records from the visual cortex now showed what looked like a mixture of 10 cps and 4 cps activity. Spinelli has suggested that this is an indication that the cat is generalizing the trained 4 cps response to the 10 cps stimulus, and that the observed 4 cps waveform was a memory playback trace. This and other experiments have led him to the conclusion that all experience is stored in memory in a waveform context (63, p. 294).

We might represent the Papez circuit schematically as shown in Figure 15. Thus, the limbic stream of emotional and sensory experience continually passes through a memory storage/retrieval region (the hippocampus). This hippocampal memory processing region is, in effect, continually "bathed" in the stream of consciousness, hence allowing ready access for storage of new experience or retrieval of past memories. Direct evidence that this sensory/emotional circulation is closely involved in memory processing is indicated by the fact that bilateral, nonsymmetric damage to any portion of the Papez circuit impeding this circulation produces a memory deficiency known as *Korsakoff's syndrome* (5, p. 560-561).

For Gray's model of subconscious process to be completely vindicated, we should expect to find a mechanism for the admission of bipolar affects, i.e., feelings of pain or pleasure, into this limbic-memory circuit. A study of the neurophysiological evidence reveals the hypothalamus to be the receptive center for such affects. For example, the medial nucleus of the hypothalamus and the *periventricular fiber system* extending up from the brainstem

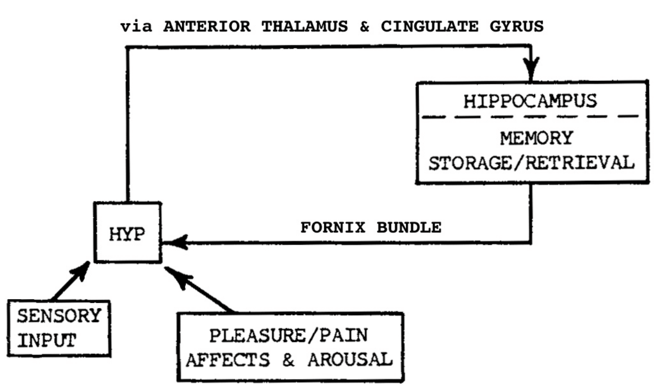


Figure 15. A schematic representation of the Papez circuit.

to the hypothalamus have been shown to produce strong aversive reactions (22, p. 65). Moreover, pleasurable affects have been produced by stimulation of the *median forebrain bundle* (MFB), also known as the "reward system" of the brain. This fiber tract arises from the anterior portion of the midbrain and passes through the lateral hypothalamus and mammillary bodies. Via this nerve bundle, the hypothalamus may receive pleasure

stimulation either from the frontal cortex via descending fibers passing through the caudate nucleus, or from deep within the brain stem via ascending fibers. Routtenberg (57) has suggested that the MFB constitutes a limbic arousal system concerned with incentive or reward. The core brain receptors from which the medial forebrain bundle originates give rise to feelings that may be classified generally as "moods," depression and elation, sleepiness and alertness, and assertiveness (50, p. 183).

Vinogradova (70, pp. 60-63) has suggested that the limbic system consists of two large interconnected circuits, see Figure 16. The main limbic circuit to the left is essentially the Papez circuit and is primarily concerned with information processing. This interfaces with a second circuit, the hippocamporeticular circuit, which performs regulatory functions. Parts of this regulatory circuit are made up from the ascending and descending portions of the MFB. In particular, it is believed that the portion of the MFB descending from the prefrontal cortex via the caudate nucleus to the hypothalamus is concerned with modulating drives and affective behavior in the limbic system. Such a view is compatible with Gray's model, which views bipolar affects and their possible modulation as indispensable to the coding of memory and mental experience.

The importance of pleasure/pain affects in the emotional coding of memory has been demonstrated by Routtenberg (58). He reports that if the pleasure center in the entorhinal cortex (a limbic structure in the Papez circuit which feeds into the hippocampus) is artificially stimulated immediately after the learning of a task, memory will be impaired. Moreover, Magda Arnold (2) points out the importance of having a limbic system

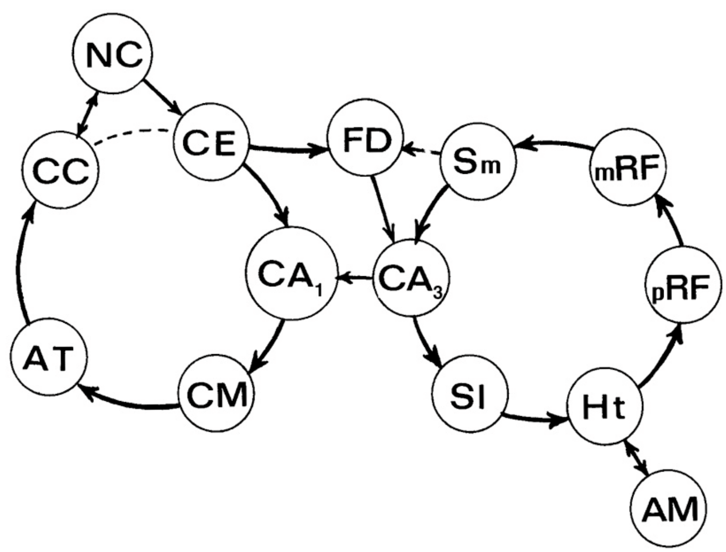


Figure 16. A schematic representation of the main interactions between the limbic structures. Abbreviations refer to: hippocampal fields (CA_1, CA_3) ; dentate fascia (FD) ; medial and lateral septal nuclei (SM, Sl) ; mesencephalic and pontobulbar reticular formation (mRf, pRf); hypothalamus (Ht); amygdala (Am); mammillary bodies (CM); anterior thalamic nuclei (AT); cingulate and entorhinal limbic cortex (CC, CE); neocortex (NC).

mechanism which affectively codes memories. What she calls "affective memory" would not only store pure sensory experiences, but also appraisals of these experiences as well. She states:

> "Whatever is experienced, in any sensory modality, arouses not only a memory of things seen, heard, or otherwise known (modality specific memory) but also revives the corresponding affect. The liking or dislike once felt toward a person or a thing is felt again as soon as we encounter doing something similar. In the same way, what we have once enjoyed doing, or what we have once done successfully, will leave an inclination to the same action. These positive or negative feelings about an object or an action are affective memories. They represent a reliving of past appraisals, though they are experienced neither as 'past' nor as 'appraisals' but merely as an immediate positive or negative attitude which obviously cannot be produced by something seen for the first time. Most of the things we see, hear, or read about are prejudged in this way, a fact of which we usually are completely unaware. It is 'affective memory' that accounts for this inclination to judge the present in terms of the past, to expect what our imagination and emotion predispose us to expect. Such emotional attitudes stemming from past appraisals have to be corrected by deliberate design to safeguard our judgment, just as our memory of facts has to be checked by comparison with objective data" (2, pp. 264 - 265).

Reviewing this section, we find that the limbic system has all of the features necessary to generate the kind of subliminal activity required by Gray's ECS theory: closed-loop limbic connectivity permitting the recursive propagation of sensory and emotional waveforms, input of external experience from the peripheral senses (i.e., O $\rightarrow$ S $\rightarrow$ E in Figure 2), cognitive inputs from short term memory — the prefrontal-cortex-dorsomedial-thalamic loop (i.e., E $\circlearrowright$ P), cognitive and sensory inputs from long term memory (i.e., A $\rightarrow$ E), and affective appraisal of both current sensory inputs and past experience.

CORTICAL-SUBCORTICAL INTEGRATION

Gray's ECS model which postulates an integrative, organizing relationship between emotions and cognitions, counters the classical association-by-fiber tracts model which assumes the higher mental processes to be conducted exclusively in the cerebral cortex. According to this classical view, the cortex is specialized into distinct regions (i.e., of vision, audition, touch sensation, motor control, memory, etc.), these being linked up by transcortical connections to permit the execution of various mental functions. Thus, for example, it was believed that a particular visual stimulus processed in the occipital cortex must elicit, via transcortical connections, a particular motor response from the motor cortex.

However, this corticocentric view has been dealt a severe blow by recent neurological experiments which have shown that the critical fiber connections are not transcortical, but instead extend primarily from the cortex to the subcortex. That is, neural pathways interconnecting cortical sensory and motor areas appear to be organized *vertically*, rather than *horizontally* (37, pp. 8 - 12). For example, Robert Doty (9) and his coworkers attached electrodes to the skulls of cats such that one electrode was placed in the visual and the other in the motor cortex. They repeatedly fired the visual area electrode (conditioned stimulus) together with the motor electrode (unconditioned response) which produced a leg flexion, and were able eventually to condition the cat to flex its leg solely by firing the visual electrode. To find the neural route taken by the impulse stimulating the visual cortex, they made two kinds of surgical cuts in the vicinity of this electrode. They found that a cut circumscribing the electrode (cutting any transcortical paths) did not impair the leg flexion response to visual stimulation, while undercutting the electrode (severing pathways to the subcortex) totally impaired the leg flexion response (37).

Other evidence against the associationist view comes from experiments by Pribram, Blehart and Spinelli (51), in which they surgically operated on the inferior temporal lobes (the "association" cortex) of the monkeys. They found that simply disconnecting the transcortical pathways which join this area with the primary cortex (seat of visual perception) had no effect on learning and recognition abilities. On the other hand, cutting the neural pathways which connect this part of the cortex with subcortical structures produced learning and recognition deficiencies as sever as if the cortical tissue itself had been removed.

Even stronger support for the ECS and EPC theories comes from the finding that the prefrontal cortex (the nonmotor region of the frontal lobe), a region specifically responsible for the *creative formation of thought*, is unique among cortical regions in its profuse connectivity with limbic structures. In a summary of anatomical investigations, Walle Nauta (41) notes that: efferent fibers extend from the prefrontal cortex to the presubiculum and entorhinal area (which feed directly into the hippocampus); to the cingulate gyrus and gyrus fornicatus (which feed indirectly into the hippocampus); to the caudate nucleus, putamen, and claustrum of the basal ganglia; to a variety of hypothalamic nuclei; to the dorsomedial thalamic nucleus and various nonspecific thalamic structures such as the nucleus reticularis and the midline region of the intralaminar thalamic complex; to the subthalamic nucleus; and to the rostral midbrain tegmentum.

Nauta concludes that the "prefrontal cortex appears as a neocortical mechanism closely associated with the organization of limbic forebrain structures" (41, p. 405). The fact that there is a close resemblance between subcortical projections emanating from the limbic forebrain and prefrontal cortex respectively, according to Nauta, may indicate that "the prefrontal cortex is the isocortical representative of the same category of functions that is subserved by the limbic forebrain" (41, p. 405). Thus, the prefrontal cortex may be regarded as the isocortical superstructure of limbic and visceral activities in the same sense that the motor cortex may be regarded as the superstructure to motoric functions organized at the subcortical levels.

The ability to solve complex problems, to voluntarily attend to specific internal or external stimuli, to form stable plans and intentions capable of controlling subsequent conscious behavior, to carry out context-sensitive social interactions, and, in general, the ability to organize the higher forms of conscious activity, all depend on an intact prefrontal cortex (30, pp. 187 - 224; 7; 11; 49). The evidence of fronto-limbic integration cited by Nauta, therefore, strongly suggests that emotions are intimately involved in the creative formation of thought, a basic assumption underlying both the ECS and EPC theories. It is worth noting that Gray's proposal that emotions are intimately involved in the thought formation process was made from the introspective point of view of a psychiatrist and without prior knowledge of these recent neurophysiological findings.

Frontal lobe-limbic integration takes on an even greater significance when we consider the philogeny of the mammalian brain. With the evolution of mammals to primates and eventually to man, there is a continual increase in the size of the prefrontal cortex in relation to other cerebral regions, in man reaching as much as ¼ of the total brain mass. At the same time, there is a corresponding increase in the size of the thalamus, i.e., the lateral and medial nuclei and the pulvinar (29, pp. 149, 154) and particularly the dorsomedial nucleus. As will be discussed in the next section, the prefrontal cortex and dorsomedial thalamus are bi-

directionally connected and intimately involved in context sensitive behavior and problem solving. Thus, it is not surprising to see the coevolution of these parts of the brain. In addition, there is an increase in size in other limbic structures, such as the fornix bundle, which has a 20:1 increase in fiber content from rat to man, and the median bundle.
A hypothesis was put forth in Part I to the effect that human beings have a greater facility for thought as a consequence of the greater mass of their cerebrum and greater degree of cerebral-limbic integration. The neuroanatomical evidence discussed here supports this hypothesis, pointing to the frontal lobe-limbic system as the chief region of philogenetic change in the brain, a region which appears to be uniquely involved in the formation of creative thought.

THE PREFRONTAL-CORTEX-DORSOMEDIAL-THALAMIC LOOP

The EPC model postulated the existence of looped connectivity extending between the cerebral cortex and the limbic region, and that this circuit would be capable of sampling the entire gamut of sensory experience, including not only the entire range of peripheral sensory stimuli, but internal feelings as well. The prefrontal cortex, which is specifically concerned with thinking, might be considered to be the cortical component of the postulated $E \frown P$ loop. Although this cerebral region connects with many parts of the limbic system, as already discussed, the subcortical structure which seems to fit most closely as the complement to the prefrontal cortex is not part of the limbic loop, but is closely associated with it. This is the dorsomedial nucleus of the thalamus. It is intimately connected with the Papez circuit via the hypothalamus, and, therefore, should be capable of receiving limbic inputs such as feelings, emotions, and affective memories, i.e., experience of the "world-within." Moreover, through its diffuse connectivity with the cortical relay nuclei of the thalamus and through efferents from the basal ganglia, it receives a mixture of mode-specific sensory inputs, i.e., experience of the "world-without."

The thalamus might be regarded as the "third eye" of the brain. Its activities are believed to be associated with the maintenance of conscious awareness (55, p. 238). It has become apparent that some thalamic nuclei play the dominant role in the coordination, maintenance, and regulation of the state of "consciousness," alertness, attention through widespread "nonspecific" functional influences upon activities of the cerebral cortex, a subject to be discussed in the next section. Also, it is known that the thalamus participates both in afferent and efferent systems, and that sensory data passing through its structures may be relayed simply to the cortex as well as integrated and elaborated. The dorsomedial nucleus together with the dorsolateral nucleus, the posterior lateral nucleus, and the pulvinar, which projects to the parietal association areas of the cortex, are known as the "association nuclei" of the thalamus. They may be activated by sensory stimuli in any modality, i.e., they have nonspecific irritabilities.

In particular, the dorsomedial nucleus is known to have extensive *bi-directional* connectivity with the prefrontal cortex (12, p. 157). This *prefrontal cortex-dorsomedial-thalamic loop* (PCDT loop) is believed to be associated with the appraisal of emotional events (55, p. 243), and hence, serves as a likely candidate to represent the E/P cycle pathway. In terms of the EPC model, the PCDT loop would be involved in sustaining emotions in an amplified state through recursive processes, whether those emotions were global and undifferentiated, or differentiated as feeling tones. Within this theoretical framework, excessive frontal lobe connectivity to the dorsomedial thalamic nucleus, increasing the level of self-sensibility, may be responsible for certain kinds of psychoses or psychoneuroses. Indeed, Riklan and Levita

(55, p. 232) mention that "psychotic" patients who underwent bilateral dorsomedial thalamic surgery experienced decreases in introversion, in fearfulness of emotionally charged situations, in uncertainty, and in depression. This emotional recursion/amplification hypothesis regarding the functioning of the PCDT loop is further supported by experiments in which lesions were placed in the thalamus of patients suffering from the advanced stages of cancer in an attempt to relieve pain (35). It was found that bilateral destruction specifically of the dorsomedial and anterior thalamic nuclei, although leaving cutaneous sensitivity and the perception of pain intact, removed its emotional component, i.e., the patients, although feeling pain, did not pay much attention to it. Removal of the prefrontal cortex is also found to reduce the emotional aspects of pain perception. Moreover, Pribram (50, p. 342) notes that frontal lobe damage reduces the *duration* of emotion in frustrating situations, *not its occurrence*, again evidence of amplification through recursion, most probably taking place in the PCDT loop.

According to the EPC model, abstracted emotional nuance sets, or thoughts, held in an amplified state through cortical-subcortical circulation, serve the function of short-term memory. Short-term memory may be tested by the *delayed response test*. In one form of this test, the animal is restrained while food is placed under one or the other of two boxes, after which restraint is continued for a delay period, and then the animal is set free to choose between the two boxes. Bilateral ablations of either the prefrontal cortex (23) or bilateral lesions of the dorsomedial thalamic nucleus (60) have been shown to totally abolish or severely impair performance of the delayed response test, evidence which strongly supports the choice of the prefrontal cortex-dorsomedial-thalamic loop as representing the emotional-perceptive circuit of the brain. Moreover, Foster (12), working with monkeys, has observed that during the food-presentation phase of this test, the firing rate in the cells of the dorsomedial thalamic nucleus became considerably augmented and that this elevated firing rate often persisted into the 1-minute delay period. He offers these results as further indication that the dorsomedial nucleus not only participates in the acquisition of sensory information, but also in the retention of this information in short-term storage (12, p. 162).

The EPC model suggests that if emotional-perceptive cycling were impaired, relevant nuances could not be abstracted from the fluctuating emotional theme of mental experience leaving the organism at the mercy of momentary feeling states. Perhaps this might throw some light on Pribram's observation that frontal lobe damage impairs the ability to carry out context-sensitive decisions:

> "Viewed prospectively, the defect shows in problem solving: the organism is not able to regulate his behavior on the basis of the perturbing events that signal changes in context. Viewed retrospectively, the defect shows in emotional expression: the organism has failed to monitor, register, and evaluate perturbations that continuously complicate context and so add to the troubling present. In the temporal domain this loss of context-sensitive operations is reflected in the fact that the stream of happenings is not segmented and so runs together in a present which is forever, without past or future. The organism becomes completely a monitor at the mercy of his momentary states, instead of an actor on them." (50, pp. 347 - 348)

The inability to stabilize relevant information in consciousness would be a serious disadvantage in the performance of the delayed response test provided that the emotional theme in the organism's stream of consciousness was subject to erratic change. However, if thematic fluctuation were to be minimized, i.e., by minimizing disturbing sensory inputs, the stability of the emotional theme (circulating in the Papez circuit) would be improved, and hence performance on the delayed response test should be improved. In fact, this is what is actually observed. Malmo (34) has shown that monkeys having bilateral ablations of the frontal association areas successfully performed the delayed response test in darkness, but failed in light because of the distracting affects of extraneous visual stimuli.

Goal-directed behavior in a novel situation arises from the ability to assign *importance* to a certain set of sensory stimuli or concepts and to stabilize these in consciousness such that they may direct the organism's future course of behavior. The inability to stabilize novel unhabituated inputs in consciousness has been observed in patients having frontal lobe disturbances. Luria reports:

> "Very frequently actions required by a spoken command are not retained by the patient and are replaced by more habitual and more firmly established actions. One such patient, for instance, when asked to light a candle, struck a match correctly but instead of putting it to a candle which he held in his hand, he put the candle in his mouth and started to 'smoke' it like a cigarette. The new and relatively unstabilized action was thus replaced by the more firmly established inert stereotype. I have observed such disturbances of a complex action programme and its replacement by elementary, basic behavior in many patients with a clearly defined 'frontal syndrome.' ... Another such patient, who had been given permission to leave the consulting room of the physician examining him, got up and, when he saw the open door of a cupboard, went into the cupboard, thus showing the same type of impulsive, stereotyped behavior. A third patient with a similarly well-marked frontal syndrome, whom I sent into the ward to fetch his cigarettes, began to carry out this instruction but when he met a group of patients coming towards him, turned round and then followed them, although he still clearly remembered the instruction which he had been given." (30, pp. 199 - 200)

As with the monkeys tested by Malmo, extraneous environmental stimuli contributed to distract the patients from their initial task.

SELECTIVE ATTENTION THROUGH PHASIC AROUSAL

The EPC theory presented in Part I of this paper dealt primarily with spontaneous mental processes, i.e., the spontaneous emergence of a creative thought (right-hemispheric processing). Now, how might this theory be extended, so as to come to grips with *volitional* processes (left-hemispheric processing), i.e., processes of discrimination, of determining whether an emerging fluctuation is desirable to have as a thought, or undesirable? We might venture that discrimination among alternative thematic fluctuations might involve a mechanism of selective amplification. Thus, referring to Figure 9, suppose that the emotional-perceptive cycle is operating at point k_4 and that an undesirable thematic fluctuation of sufficient intensity arises and crosses the critical threshold. This nuance may be damped, rather than amplified, simply by reducing the intensity of the emotional-perceptive flux, i.e., by shifting to the left of k_4. Since the intensity of emotional flux was postulated earlier to be affected by the state of mental arousal, we might expect that selective perception involves some sort of selective arousal mechanism. Consequently, if this extension of the EPC model is correct, we might expect to find that the problem solving region of the brain, the prefrontal cortex, has the capability to rapidly modulate the cerebral arousal mechanism.

In fact, this is exactly what we find. Arousal in the brain is administered by way of the ascending reticular activating system (ARAS) which extends up from the core of the

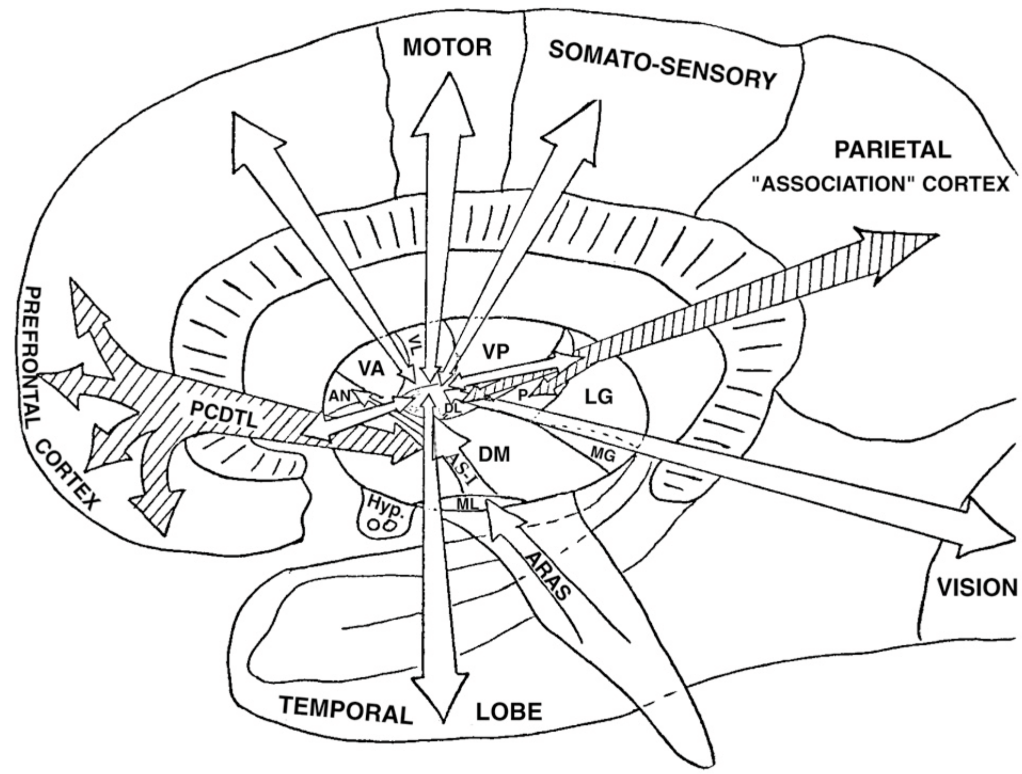


Figure 17. Thalamocortical projections of the association nuclei (striped arrows) and of the diffuse thalamocortical projection system (DTPS) (white arrows radiating from the intralaminar thalamic nucleus). More white arrows could be drawn since these symbolize diffuse fiber projection, however, visual clarity of the diagram would be sacrificed. Abbreviations: prefrontal cortex-dorsomedial-thalamic loop (PCDTL). For other abbreviations please see Figure 13.

brainstem to the subthalamus, hypothalamus, and the midline and intralaminar nuclei of the thalamus (37, pp. 74, 83). The intralaminar cells are believed to be part of an intrathalamic association system, connecting various specific nuclei within the thalamus. From this region of the thalamus, the cephalic portion of the reticular system, fibers project out diffusely to all parts of the cerebral cortex, to the hypothalamus, basal ganglia, and amygdaloid complex, see Figure 17. This portion of the ARAS has been termed the *thalamic reticular system* or the *Diffuse (nonspecific) Thalamocortical Projection System* (DTPS).

Neurophysiologists have isolated two arousal mechanisms in the ARAS. One is involved in maintaining a state of wakefulness, or cortical arousal for prolonged periods of time. This tonic arousal mechanism is mediated by control sites in the brain stem. On the other hand, the midline and intralaminar thalamic nuclei part of the DTPS appear to be the controlling center for a *phasic* arousal mechanism which produces sudden transitory changes in arousal (55, p. 58). By way of comparison, when the tonic system is electrically stimulated, arousal may persist for some minutes, whereas, when the phasic system is stimulated, arousal lasts for only a few seconds (37, p. 84). Thus, we might imagine that tonic arousal brings the emotional flux of the E/P cycle up to a certain point (say, k_4 on Figure 9) producing an *optimal level of cortical tone* essential for the organized course of mental activity (cf. 30, pp. 44-45), while phasic arousal modulates this level around this optimal point to engender orienting effects.

Whereas the tonic activation system equally affects all sensory modalities, the phasic system is capable of selective arousal, and hence, of orienting consciousness specifically to one of several sensory stimuli. Indeed, carefully controlled local stimulation within different parts of the intralaminar system reveals that arousal is topographically organized with respect to different areas of the cortex (55, pp. 55, 58 - 59).

Both tonic and phasic arousal systems are controlled from the prefrontal cortex. Bi-directional pathways between the prefrontal cortex and the brain stem are responsible for regulation of the tonic system, while the caudate nucleus, which receives efferent influences from the "suppressor" regions of the prefrontal cortex and from the central medial nucleus of the thalamus, projects to the intralaminar nuclei of the thalamus to modulate the phasic system (55, pp. 41-43,46,59,262-263; 56, p. 11).*

Although controlling fibers originate from the prefrontal cortex, it is important to realize that it may not be the prefrontal cortex itself which controls the arousal mechanism. Rather, *waveform information* conducted to the prefrontal cortex may be in the driver's seat. For example, low, slow stimulation in the intralaminar thalamic nuclei result in cortical synchrony (nonactivation) and produce inattention, drowsiness and sleep, while high-frequency, or stronger stimulation will produce desynchronization or arousal (62, p. 186 - 187; 55, p. 238). The fact that these information-bearing waveforms are modulated by arousal and that arousal is modulated by these waveforms constitutes an interesting self-reflexive process, the consequences of which will be discussed more fully at the end of this paper.

The basal ganglia, and in particular the caudate nucleus, are important not only in regulating motor activity, but also in modulating the activity of thought and perception (55, p. 63 - 64, 161). Patients with Parkinson's disease (disease of the basal ganglia) not only exhibit motoric disability, but show cognitive impairment as well. For example, Parkinsonians sometimes demonstrate cognitive deficits on standardized tests (37, p. 81). Rosvold and Szwarcbart (56, pp. 3 - 5) point out that electrical stimulation or damage to the head of the caudate nucleus impairs performance on the delayed alternation test. Also, as the size of the electrolytic lesion is increased, the severity of the deficit increases approaching complete loss when large ablations are made. Pribram (50, pp. 334, 337) notes that lesions of the caudate nucleus as well as ablations of all parts of the limbic system, or resection of the frontal pole of the brain, impair the performance of monkeys on delayed response tests.

Luria states that in problem solving patients with lesions of the frontal lobes never start by subjecting the conditions of the problem to a preliminary analysis and do not confront its separate parts, but instead, as a rule, single out random fragments of the conditions and begin to perform partial logical operations (30, pp. 15, 21). He concludes that injury to the frontal lobes disables the "orienting basis of action," i.e., the phase of problem solving concerned with singling out the most informative points and thereby reducing the search for data. As has been suggested in this section, the volitional aspects of the thinking process, such as discrimination, are monitored via the frontal cortex and involve the operation of the frontal portion of the DTPS. This hypothesis is strongly supported by Luria's experiments which indicate that patients with frontal lobe injury suffer disturbance to their *discriminative faculties*.

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* The central medial nucleus appears to integrate sensorimotor information from all modalities as well as from cerebellar and reticular afferents.

THE RECRUITING RESPONSE AND EXPECTANCY WAVES

The thalamus produces a spontaneous electrical rhythm predominant ly at the alpha wave frequency (~ 6 - 12 cps). Repetitive stimulation of the midline intralaminar thalamic nuclei at close to this frequency generates a steady negative electric potential shift in the frontal lobe of the cerebrum and incrementing waves of positive and negative potential specifically in the prefrontal cortex (orbitofrontal granular cortex). This phenomenon is called the *cortical recruiting response* because cortical excitability is observed to increase in a stepwise manner as though more and more neurons were being recruited into activity (37, p. 85). When the recruiting response occurs, certain cortical cells become more excitable and easier to stimulate, and when the response reaches its peak, neurons that were not previously firing at all are observed to begin to send out nerve impulses in rhythm with the thalamic stimulation.

The fact that cortical activity increases in a stepwise manner, in step with the dominant thalamic rhythm strongly indicates that cortical recruitment is brought about through recursive thalamocortical wavefront circulation. That is let us suppose that the alpha rhythm is generated by impulses circulating continuously with a certain frequency f_o, or period $\tau = 1/f_o$. If impulses are administered to the thalamus at this same frequency with the proper phase relationship, each descending wavefront, or impulse, from the previous beat will reach the thalamus in time to be joined and reinforced by the next stimulating pulse from the electric probe. Thus, the combined output transmitted to the prefrontal cortex should exhibit a stepwise increase in strength with each cycle.

Thus, the recruiting response is essentially a resonance phenomenon, and may be compared to the phenomenon of electromagnetic resonance observed in an L-C oscillator circuit. For example, a coil and condenser coupled, as shown in Figure 18, will have a characteristic resonant frequency $f_o = 1/2\pi\sqrt{LC}$, where L is the inductance of the coil and C the capacitance of the capacitor. When the driving frequency F of the AC generator is made equal to the natural frequency of oscillation f_o, the amplitude, or peak voltage, of the L-C circuit will increase exponentially.

Direct evidence of thalamocortical waveform circulation is reported by Verzeano and Negish; (67, 69). They have shown with microelectrode measurements that this circulation follows a curvilinear path and is progressively displaced through the neuronal networks such that a helical wave propagation is produced. They estimate this circulation velocity to

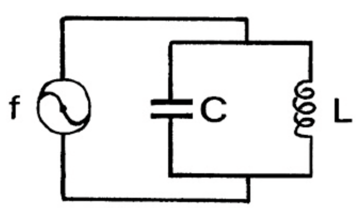

Figure 18. An electrical L-C oscillator circuit having a generator frequency f, capacitance C and inductance L.

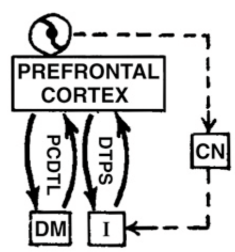

Figure 19. A possible resonance mechanism for modulating the arousal of the diffuse thalamic projection system. Abbreviations: caudate nucleus (CN); dorsomedial thalamic nucleus (DM); intralaminar thalamic nucleus (I); prefrontal-cortex-dorsomedial-thalamic loop (PCDTL); diffuse thalamocortical projection system (DTPS).

be on the order of 0.5 - 9 mm/sec (68, 69), which would yield for one looping a circulation period of between 15 seconds and 5 minutes. However, this is way too long to explain the cortical recruiting response. Perhaps, then, this slow wave circulation is a supplementary phenomenon generated by more rapid thalamocortical wave circulation activity. Indeed, Riklan and Levita (55, p. 55) report that a single electrical stimulation of brief duration administered to the central portion of the intralaminar system (the same region where the recruiting response is evoked) may induce bursts of rhythmic waves in the frontal cortex after only a few milliseconds of delay and in the more posterior areas of the cortex with delays of up to several hundred milliseconds.

The waveform amplification model, deduced here from reported observations of the recruiting response, is in line with the EPC model, which suggests that the brain amplifies emotional nuances through a process of repetitive circulation. This process was compared earlier to the laser in which a beam of light waves becomes amplified through the continuous recruitment of photons during its recursive passage through an ionized gas.*

Resonance in a tuned L-C circuit may be damped simply by changing either the *frequency* or *phase* of the generated wave with respect to the resonating wave. Thus, the degree to which the generated wave is amplified through resonance is dependent at any given moment on its frequency and phase. By analogy, perhaps the path from the prefrontal cortex through the caudate nucleus serves as a line for transmitting "generated" frequencies to the thalamus so as to modulate DTPS arousal; see Figure 19. The level of arousal would in turn affect the magnitude of the waveform flux in the prefrontal cortex-dorsomedial-thalamic loop (PCDT loop) which is involved in discriminative thinking. By also directing impulses topographically, cortical-caudal feedback could selectively arouse different regions of the cerebral cortex, thereby allowing the organism to attend selectively to particular stimuli.

The original form of the EPC model presented in Part I implied that the arousal channels (DTPS) and the information channels (PCDT loop) function as a single unit. This is supported by neurophysiological evidence. That is, the fiber connections for both of these channels, although separate from one another, are intricately interwoven. Moreover, both systems of fibers pass through the inferior thalamic peduncle (ITP).

Skinner and Lindsley have found that cryogenic blockage of the ITP totally abolishes the recruiting response (62, p. 203), and that animals with ITP blockage suffer behavioral deficits similar to those produced by lesions in the prefrontal cortex and dorsomedial thalamic nucleus. They concluded that the DTPS plays a crucial role in the performance of these tasks. Moreover, finding that ITP blockage increased the transmission of visual and auditory stimuli to cortical regions, they concluded that the DTPS normally maintains a tonic suppression of evoked potentials elicited by unattended stimuli (62, p. 212). This suppression is most likely mediated via the prefrontal cortex-caudal-thalamic pathway which, as was mentioned earlier, is believed to be involved in the regulation of selective attention. Thus, the system is structured such that activation of the prefrontal cortex, i.e., during problem solving activities automatically suppresses environmental stimuli, in turn allowing attention to become focused more on internal sensations.

The fact that the PCDT loop is structurally interconnected with the DTPS, which is involved both with the recruiting response and with selective attention, and that these same circuits

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* Perhaps we might now coin a new term referring to the brain as a NASER, i.e., a system which is able to effect Neuroelectrical Amplification through Synchronized Emotional-perceptive Recycling.

must be intact for the performance of complex behavioral tasks, strongly supports the notion that selective amplification is basic to the process of discriminative thinking, a concept understandable within the concept of the EPC theory.

Velasco and Lindsley (66) found that successive ablations of the prefrontal cortex effected progressive proportionate reductions in the recruiting response, with the recruiting response disappearing entirely when the orbitofrontal cortex was ablated. This mass action effect of the prefrontal cortex on the magnitude of the recruiting response strongly supports the assumptions of the EPC theory regarding the evolution of intelligence. That is, the philogenetic increase in size of the prefrontal cortex would have increased the amplification capability of the DTPS and the PCDT loop systems of the brain believed to be critically involved in discriminative and creative thought processes. This philogenetic change would have allowed emotional thematic fluctuations (or emergent waveforms) to become more rapidly amplified for a given level of tonic arousal, and hence would have lowered the critical threshold for cognition, i.e., the intensity which a fluctuation must reach to overcome thematic damping effects.

Golding and O'Leary (14) have shown that the positive-negative wave impulses produced by the recruiting response are superimposed upon a steady negative potential shift. Moreover, the duration of the negative potential was shown to outlast that of each impulse by several hundred milliseconds, permitting a sustained steady potential shift to be generated as a result of repetitive stimulation. This monophasic negative component of the recruiting response, it is believed, corresponds to what is called *contingent negative variation* (CNV). This phenomenon involves a steady negative variation in cerebral electrical potential occurring over parts of the frontal and vertex regions of the cortex observed in both man and animals during directed attention or expectancy.

Contingent negative variation may be evoked in an experimental situation by an initial stimulus, the *warning stimulus*, which alerts the organism to respond to a subsequent, expected stimulus, the *imperative stimulus*. When the second stimulus finally takes place, a sharp positive deflection ends the negative variation. In any act of expectancy the magnitude of this "expectancy wave" (CNV) increases in proportion to the degree of motivation exhibited in performing a task. Moreover, CNV magnitude is correlated with the likelihood that a stimulus will materialize.

W. Grey Walter observes the following correlations between the CNV and the accompanying psychological situation in adults responding to paired stimuli:

"(1) The CNV grows slowly over the first few dozen presentations of associated stimuli after instructions to respond to the imperative stimuli.

(2) Once established, the CNV persists indefinitely as long as the subject retains an interest and concern with his response. In some subjects, identical records of the CNV have been obtained day after day over a period of several months.

(3) When the imperative stimuli are withdrawn (extinction trials), the CNV subsides slowly to zero over the first 20-50 trials. When the imperative stimuli are restored, the CNV reappears after about 12 presentations. This process of alternating extinction and restoration can be repeated indefinitely in strong, well-balanced, normal adult subjects.

(4) When the subject is told beforehand that the imperative stimulus is going to be withdrawn or that he need not make the operant response, the CNV subsides at once." (74, p. 118)

The locus of occurrence of the potential change depends upon the type of task. For example, Pribram states that when a monkey or person waits without making an overt response, the CNV occurs maximally in the frontal cortex; when an anticipated motor response is demanded the negativity occurs first in the motor cortex preceding the execution of the movement and terminating with the occurrence of the movement; when a continuing response, such as a prolonged preparatory depression of a lever, is necessary, the negativity occurs maximally in the somatosensory cortex (50, p. 281).

The EPC model offers an interesting framework for assembling the pieces of this not too well understood phenomenon of CNV. We might begin by imagining that the expectancy wave is brought about through: 1) sustained activation of the phasic arousal system, accompanied by 2) inhibition of all incoming stimuli. By analogy to driving a car, this might be compared to stepping on the accelerator and the brakes at the same time, In light of the EPC theory, what the organism is actually doing is "priming," or biasing, the intensity of the emotional theme circulating in the PCDT loop with a waveform (or emotional nuance) corresponding to the expected stimulus such that the intensity of this waveform is a major component of the emotional stream. At the same time, the organism is arousing its E/P cycling flux (DTPS) arousal to some level, say k_4 (refer to Figure 9), such that the intensity of this thematic fluctuation is voluntarily maintained at a level just below the critical threshold of nucleation. In addition, all external sensory and internal emotional stimuli would be inhibited by an equal amount. Because their resulting intensity is so low, all *irrelevant* stimuli will fail to develop sufficient intensity to reach the critical threshold. Only the imperative stimulus will be able to reach the critical threshold, since it is supplemented by the primed stimulus already circulating in the PCDT loop. Thus, even though the externally received, expected stimulus input is damped by an equal amount, its intensity is just enough to make the primed waveform go critical. Whereupon, amplification occurs abruptly with the accompanying generation of a sudden positive potential surge.

Assuming that the mind is able to direct expectancy not only to external but to internal stimuli as well, the same model described above may give useful insights into problem solving and creative thought processes. For example, let us consider the stages in creative thought formation which Gray speaks of (16, pp. 10 - 11): The *preparation* phase (i.e., the forming of the question) may be compared to the priming of the E/P cycle. The *incubation* phase corresponds to the expectancy period during which the organism is open to receiving an assortment of stimuli (Gray's window shopping process). The *illumination* phase corresponds to the moment when the imperative stimulus (answer to the question) is received from the subconscious, driving the PCDT loop supercritical. Finally, the *verification* phase would involve the application of volitional discriminative operations as described in the last section. Incubation and illumination would constitute right-brain processes, while preparation and verification would be left-hemispheric.

PRIMARY AND SECONDARY PROCESS

The thinking process may be conceived as involving the operation of two interrelated self-reflexive loops: the Papez circuit and the prefrontal cortex-dorsomedial-thalamic loop. The Papez circuit would be the more basic of the two and would be involved in: affectively evaluating and associating thoughts and sensory and motor experiences; storing and retrieving sensory, motor, emotional, and emotional-cognitive memory engrams, and in sustaining emotional nuances (including sensory and motor waveforms) in an ongoing recursive process that allows the development of an emotional theme. Together these limbic

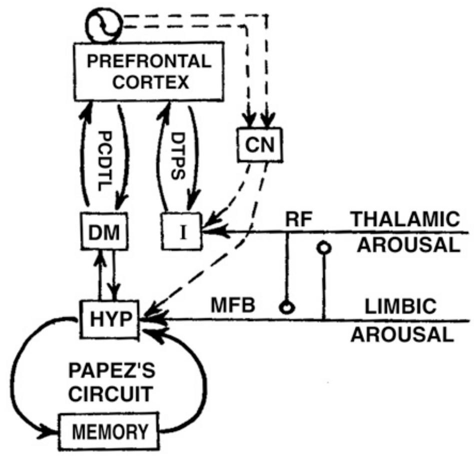

Figure 20. Primary and secondary information processing loops, their arousal systems, and cortical pathways for modulation. Abbreviations: Reticular formation (RF), median forebrain bundle (MFB). For other abbreviations please see Figure 19.

system processes would constitute what Freud referred to as the *primary* process, and may be considered as the domain of the unconscious.

Bi-directional connectivity between the Papez circuit and the medial thalamus, i.e., via the hypothalamus, allows the primary process emotional theme to pass into the PCDT loop. This secondary self-reflexive mechanism would function as a selective attention, or awareness-heightening mechanism operating on the primary process emotional stream so as to selectively amplify specific nuances and produce conscious experience. This "higher" brain process we will call the "*secondary process,*" to borrow Freud's term. Here we echo Gray's view of the conscious, that it constitutes a secondary awareness heightening organ (PCDT loop + DTPS + cerebral-caudate pathways) which focuses in on, or "lights up," emergent patterns of feeling or thought circulating in the unconscious (i.e., circulating in the Papez circuit).

The relationship between primary and secondary process loops is shown in Figure 20. The activity of each loop is aroused via two separate branches of the reticular activating system which Routtenberg (57) has called *Arousal System I*, administering tonic arousal to the thalamus (secondary process), and *Arousal System II* which, via the median forebrain bundle, activates the limbic system (primary process). The prefrontal cortex is able to modulate Arousal System I via cerebral-caudal-thalamic pathways and Arousal System II via the descending cortical fibers of the median forebrain bundle. It is probably no accident that these descending MFB fibers also happen to pass through the caudate nucleus. Thus, the caudate nucleus seems to perform a regulatory function in both primary and secondary thought processes.

Routtenberg suggests that Arousal Systems I and II tend to mutually inhibit one another, with Arousal System I generally overriding Arousal System II at higher levels of ARAS arousal. However, we might imagine that during emotionally charged periods, as during mourning or rage, Arousal System II may become hyperactivated to such an extent that even at high levels of ARAS arousal it is able to maintain dominance, inhibiting the functioning of Arousal System I, hence clouding the secondary thinking process. Observing the behavioral manifestations of such circumstances without knowledge of their underlying neurophysiological connections, one might be led to theorize erroneously (as many psychologists have done) that the primitive, driven emotions bear a competitive disorganizing relationship to the "more evolved" neocortical faculties of rational thought. It is this superficial view that Gray was contesting with the development of his ECS theory. It is hoped that the rationalist perspective will be permanently abandoned in light of the picture conveyed here: namely, that *emotive disruption of the secondary process does not reflect an intrinsic feature of emotion itself, but only the modus operandi of the brain's arousal systems*.

THOUGHTS THAT GO ROUND AND ROUND

The associative nuclei of the thalamus, together with the limbic system, may be thought of as the market place or agora, where sensory waveforms and emotional nuances from memory and the stream of consciousness cross paths and influence one another. Thus, contrary to popular belief, the importance of the cerebral region is not to integrate the diverse mental experiences, but to *separate* them, to give them "breathing room" not possible in the lower brain centers. As mentioned earlier, transcortical connections do not appear to play an important role in thought processes. Moreover, brain wave experiments have demonstrated that the cerebral field is homogeneous only during certain kinds of relaxed states (i.e., diffuse focus alpha wave generation), that in the aroused state, as during problem solving, the brain field is differentiated into several regions having differing EEG patterns. Pribram (50, p. 207) has suggested that this de synchronization or independent functioning of neural regions is evidence of separate information processing channels functioning simultaneously.

Cerebral differentiation allows simultaneous processing of several information modes, while at the same time reducing the amount of "cross-talk" between the information structures evolving in each mode. Thus, one is able to think about a problem while walking, gazing at the scenery, smelling the flowers, and whistling a song all at the same time. All of these processes may be separately monitored in their respective cerebral areas at differing intensities of cortical arousal and simultaneously interwoven in the subcortex to yield the fabric of consciousness.

There are many who hold the belief that consciousness is connected with the generation of particular physical effects at particular sites in the brain. The EPC theory rejects this physicalist view, suggesting instead that the locus of consciousness lies somehow in the *structure and relation evolved between the feelings themselves*. That is, consciousness is *transcendent*. The complexity of thought is not contingent on the physical complexity of the brain, but on the complexity of the emotional coding system in which thought is based.

In one sense, feelings are physically based in that they appear as neuroelectric waveforms, however, in another sense they have an informational aspect which emerges within the context of the fabric of consciousness. The physical waveform simply acts as a substrate or carrier for this information, much the same way that the sound vibrations of musical notes (physical aspect) act as a carrier for the music being played (informational aspect). Thus, the particular waveform configurations which emerge are not contingent on the laws of physics and chemistry, but on events transpiring within the confines of the fabric of consciousness itself.

This approach points out a possible avenue to resolving the mind-body problem. Mind may be regarded as evolving within body (or brain). The physical architecture of the brain and the biochemical behavior of nerve cells serve as a womb in which feelings may differentiate, combine, self-organize, and relationally increase in complexity. The architecture of the brain allows *feelings to feel themselves feel*, or, in other words, permits feelings to *affect* themselves.

It is within this self-reflexive structure that self-reflection or consciousness *emerges*, and (in man) takes account of itself.

The brain, therefore, should be regarded as a relatively simple instrument. Just as a simple handloom enables the weaving of complex tapestries, so too the brain provides conditions such that complex emotional fabrics may weave themselves! The incoming stream of sensory experience, the associations internally elicited from memory, and internally generated affective evaluations would constitute the brain's raw material, i.e., the threads of yarn that are woven. The brain's arousal mechanisms would constitute its "weaving controls." Moreover, as was mentioned earlier, the emotional nuances themselves, manifested as waveforms of differing frequencies and intensities, seem to control both the arousal mechanisms and the kinds of affects and memory experiences generated internally. Metaphorically speaking, the fabric controls the loom and the loom weaves the fabric. The mind, therefore, is self-producing, or, in systems theoretic terminology, the mind is an *autopoietic system* (65). It is a reality system which creates its own form (cf. 75).

Just as biological life required the preexistence of certain environmental conditions in order to emerge on the surface of our planet, so too the mind requires the preexistence of certain sensory-emotional information processing conditions in order to emerge. These conditions are provided by the central nervous systems of biological organisms. The mind, in effect, is an emergent form of life, of informational rather than biochemical constitution. As long as its biological environment, the brain, stays within certain defined limits, it has the opportunity to evolve in complexity and, if fortunate, to maintain a healthy existence.

CONCLUSION

The test for any newly proposed theory often comes when it is able to correctly predict observations or circumstances not initially taken into account at the time of its formulation. The EPC theory initially grew out of considerations in the field of general systems psychology and psychiatry (16), the thermodynamics and structural stability of self-organizing systems (53, 54) and systems philosophical anthropology-encompassing aspects of evolutionary biology and the study of symbolism (73). Although the EPC theory initially avoided consideration of neurophysiological findings, the survey contained in Part II suggests that this theory is, indeed, quite compatible with current neurophysiological observations. Thus, there is reason to believe that the EPC theory is a reasonable model of mental process, and that it may serve as a useful framework for understanding future neurophysiological, psychological, and psychiatric findings.

ACKNOWLEDGMENTS

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