A Synapse-State Theory of Mental Life

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As an alternative to Hebb's theory, mental life is described in terms of Sherrington's synapses, habits, and William James's notion of the stream of thought. The theory accounts for the major organic states, such as waking, sleep, and hypnotic trance; for states of general sensitivity; and for the following aspects of the stream of thought: thought objects with their fringes; acquainting (conception); knowing about; substantive and transitive parts; attention; association; the specious present; remembered recall (memory); sensation; and perception.

What is proposed below is a description or theory of mental life in terms of neural activity. In its ambition it is similar to the theory proposed by Hebb (1949). But it rejects both Hebb's behaviorist view of mental life and his proposed neurophysiological mechanism. Instead mental life is viewed, with William James (1890), as a matter of habits and the stream of thought, in terms of the states of the neural synapses discovered by Sherrington (1906). The theory builds upon insight that was fully available empirically in 1906, but it was not formulated until November 2003 by the present writer.

Hebb's theory (1949) is prominent in recent literature of the neural aspects of mental life (e.g. Greenough and Black (2000) and literature cited there).

Hebb (1949) presented his theory in his Introduction: 'The problem of understanding behavior is the problem of understanding the total action of the nervous system, and *vice versa.* … The central problem with which we must find a way to deal can be put in two different ways. Psychologically, it is the problem of thought: some sort of process that is not fully controlled by environmental stimulation and yet cooperates closely with that stimulation. From another point of view, physiologically, the problem is that of the transmission of excitation from sensory to motor cortex. … In the chapters that follow this introduction I have tried to lay a foundation for such a theory. … In outline, the conceptual structure is as follows: Any frequently repeated, particular stimulation will lead to the slow development of a "cell-assembly," a diffuse structure comprising cells in the cortex and diencephalon (and also, perhaps, in the basal ganglia of the cerebrum), capable of acting briefly as a closed system, delivering facilitation to other such systems and usually having a specific motor facilitation. A series of such events constitutes a "phase sequence"—the thought process. Each assembly action may be aroused by a preceding assembly, by a sensory event, or—normally—by both. The central facilitation from one of these activities on the next is the prototype of "attention." …'

This theory is unsatisfactory in that it fails to deliver what it sets out to do. Even if physiological justification for the assumption of 'the slow development of a "cell-assembly,"' is found, this in no manner contributes to establishing the understanding of the principles of behavior, or the total action of the nervous system.

Further areas of inadequacy of his theory are stated explicitly by Hebb himself when he writes in Chapter 8: '… the sensation of eating, must have some rather direct action in restoring the normal time relations in the firing of central neural cells. Some such possibility has actually been envisaged in supposing that sensory processes may actively support and direct a given cerebral organization. This of course is in extremely general terms, and no details relevant to the present problem can be proposed.'

Another inadequacy of his theory, related to temporary changes in the state of sensitivity of the organism such as sexual arousal, is mentioned by Hebb on page 216: '… It has already been said that it would be very desirable for psychological theory to be able to postulate an inhibition or fatigue in such cases to explain the transient disappearance of responsiveness. But there are difficulties about doing so, as we have seen, and for the present there is no advantage in postulating a special inhibition in sexual behavior—as we understood the excitation but not its absence. Really, we do not understand either…'

It seems fairly obvious that the reason why Hebb's approach fails to account for these several aspects of mental life is that it starts from a behaviorist notion of human beings as stimulus-response mechanisms. It makes the incessant activity of mental life an incidental matter and consequently fails to account for it.

DESCRIBING HABIT IN TERMS OF THE STATES OF SYNAPSES

In what follows an alternative theory of mental life will be sketched. The starting point is a rejection of the behaviorist notion of human beings as stimulus-response mechanisms. Instead the description of mental life presented by William James (1890) in his *Principles of Psychology* is taken as what has to be accounted for. Instead of as stimulus-response mechanisms, James describes human beings thus (James 1890, vol. I, p. 104): 'When we look at living creatures from an outward point of view, one of the first things that strike us is that they are bundles of habits.'

In addition to describing the manifestations of habits over a broad field of human activities, William James also discusses assumptions about what is the physiological ground of habits. He does not hesitate to join in the understanding that at his time had already been stated by a number of his psychological predecessors (James (1890), vol. I, p. 105): '*the phenomena of habit in living beings are due to the plasticity* of the organic materials of which their bodies are composed.* *Note: In the sense above explained, which applies to inner structure as well as to outer form.'

At the time of James's *Principles*, 1890, the biological ground of the plasticity of the organic materials was unknown, but only few years later the plasticity was established, largely through the researches of Charles S. Sherrington (1857-1952), as reported in the following quotations from *The Integrative Action of the Nervous System* (1906), page 13-14:

'Nervous conduction has been studied chiefly in nerve-trunks. Conduction in reflexes is of course for its spatially greater part conduction along nerve-trunks, yet reflex conduction *in toto* differs widely from nerve-trunk conduction. - Salient among the characteristic differences between conduction in nerve-trunks and in reflex-arcs respectively are the following: Conduction in reflex-arcs exhibits: (1) slower speed as measured by the latent period between application of stimulus and appearance of end-effect, this difference being greater for weak stimuli than for strong; (2) less close correspondence between the moment of cessation of stimulus and the moment of cessation of end-effect, i.e. there is a marked 'after-discharge'; (3) less close correspondence between rhythm of stimulus and rhythm of end-effect; (4) less close correspondence between the grading of intensity of the stimulus and the grading of intensity of the end-effect; (5) considerable resistance to passage of a single nerve-impulse, but a resistance easily forced by a succession of impulses (temporal summation); (6) irreversibility of direction instead of reversibility as in nerve-trunks; (7) fatigability in contrast with comparative unfatigability of nerve-trunks; (8) much greater variability of the threshold value of stimulus than in nerve-trunks; (9) refractory period, 'bahnung', inhibition, and shock, in degrees unknown for nerve-trunks; (10) much greater dependence on blood-circulation, oxygen (Verworn, Winterstein, v. Baeyer, etc.); (11) much greater susceptibility to various drugs—anaesthetics.'

Of these properties, (3), (5), (7), and (9) are matters of plasticity in the conduction in reflex-arcs.

Sherrington (1906) discusses at length the evidence on what part of the organic material gives rise to the difference between conduction in reflex-arcs and nerve-trunks. Through this discussion his attention is drawn to (p. 15-17): 'the existence at the confines of the cells composing the organism of "surfaces of separation" between adjacent cells. … … The characters distinguishing reflex-arc conduction from nerve-trunk conduction may therefore be largely due to intercellular barriers, delicate transverse membranes, in the former. - In view, therefore, of the probable importance physiologically of this mode of nexus between neurone and neurone it is convenient to have a term for it. The term introduced has been *synapse.*'

This in particular means that the most likely location of the plasticity of the organic material will be the synapses.

Sherrington (1906) further says (p. 157): 'There is abundant evidence that different synapses differ from one another.'

THE SYNAPSE-STATE DESCRIPTION OF THE TOTAL ORGANISM

On the basis of the description of the nervous system established by Sherrington (1906) it is possible to formulate the following picture of the neural properties of the total organism:

With the plasticity of the organic material located in the synapses, it will be distributed throughout the body. The number of synapses in the body is of the same order as the number of the neurons they connect, which in the human organism is about 10,000,000,000. These synapses are not all biochemically identical. The way they increase their efficiency upon activation, and the rate of their regression upon inactivation, undoubtedly is different from one synapse to another. At any moment each synapse will be in a certain state of efficiency. The mental state of the organism is then given by the momentary state of efficiency of each of the synapses.

Being alive then means that the organism is in continual change in which at any moment a certain part of the neurons and the synapses transmit impulses, which are distributed into the network of neurons according to the current state of efficiency of the synapses, each synaptic efficiency in its turn being changed by the transmission intensity it is subjected to, typically increasing when the intensity is high, decreasing when it is low.

THE GENERAL STATES OF THE ORGANISM

This overall activity presumably is maintained by impulses circulating in certain neuron/synapse paths that form closed circles. At any time a number of such circulations, each supported by a neuron/synapse circle at some place in the organism, may be supposed to be active.

Each different major state of consciousness, such as waking, sleep, and hypnotic trance, may correspond to some particular circulation taking place. A cursory inspection of typical electroencephalographic records suggests that the number of circulations per second of such a major-state-controlling circle in each of certain general states of the organism is approximately as follows: excited: 17; relaxed: 10; drowsy: 5; asleep: 1; deep sleep: 2; coma: 0.8.

Transitions between the major states happen when one or several of certain neuron/synapse circles change from being active to passive or *vice versa*. Such transitions will be influenced by other synapses. The daily wake-sleep transition may be influenced by a neuron/synapse circle making one circulation per day.

A circular neuron/synapse path may include an organ other than a synapse that undergoes a change upon activation by a nerve impulse, such as a muscle. Circles of this kind are well known from their control of such organic functions as the heart beat and peristaltic movements.

Many more secondary circulations may be assumed to be in play, depending on the state of activity of the organism. Such characteristic phenomena as the ‘warming up’ of the organism which is an important part of the activity of any kind of performers such as athletes and musicians, may be understood as the starting up of particular circulations. Relaxation and rest may then be understood to give rise to a corresponding closing down of certain circulations.

Other circulations may account for such a phenomenon as sexual arousal. All the various aspects of male sexual arousal may in fact be understood in terms of one or a few circulations that account for the feeling of sexual excitement, one circulation that stimulates the muscles that control the erection, and one circulation that when released stimulates the muscles that give rise to the orgasm.

A synaptic circle comes into being when all the synapses of the circle come into such a state that the circle will support the circulation. This does not have to happen at the same time for all the synapses of the circle. Once the synapses along the circle have all come into an appropriate state, the circle will, as long as the states of its synapses have not decayed through inactivity, support the circulation of an impulse for a certain length of time whenever the circle is triggered by an impulse at a suitable point.

Thus the pattern of potential neuron/synapse circulations in the organism, that is which neuron/synapse paths would become active in a circulation if the organism were influenced by some particular stimulus, is a matter of steady change, reflecting the development and exercise of habits in the organism.

The participation of a particular neuron/synapse path in a particular circulation at a certain moment does not exclude that the same neuron/synapse path is activated in a different way, perhaps in a different circulation, a moment later.

Instincts would come about from such circles that develop in the organism so as to be ready to be activated without prior training.

This description of the major mental/organic states further suggests a mechanism of how mental life is influenced by conditions that influence the chemical constituents of the blood stream, such as hunger, thirst, or drugs. The description assumes that the synapses belong to a number of different kinds, differing in their plastic properties, the different kinds of synapses being distributed throughout the nervous system in a definite way. Each different condition may then give rise to a specific reaction in the nervous system by the blood stream influencing the plastic properties of just one kind of synapse in a particular way. As mentioned above, the influence upon synapses of drugs has already been reported by Sherrington (1906).

THE ACTIVITY OF THE STREAM OF THOUGHT

The properties of the stream of thought are described by William James in his *Principles* (1890). Already in this description many features are expressed directly in terms of neural activity that make direct sense as expressions of the synapse-state theory. In the following account it has therefore been convenient to present first James's description in his own words, without interruption, and only after that the account of the way the stream of thought can be accounted for in terms of the synapse-state theory. James's description is given as his description of a series of key issues, in extreme abbreviation, with replacement everywhere of James's term 'conception' by 'acquainting'. James (1890) writes (volume and page no.s given within square brackets):

States of consciousness

[I 185] The word introspection … means … the looking into our own minds and reporting what we there discover. *Every one agrees that we there discover states of consciousness.* … All people unhesitatingly believe that they feel themselves thinking, and that they distinguish the mental state as an inward activity or passion, from all the objects with which it may cognitively deal.

Knowledge of acquaintance and knowledge-about

[I 221] *There are two kinds of knowledge* broadly and practically distinguishable: we may call them respectively *knowledge of acquaintance* and *knowledge-about*.…[I 221] I am acquainted with many people and things, which I know very little about, except their presence in the places where I have met them. I know the color blue when I see it … ; but *about* the inner nature of these facts or what makes them what they are, I can say nothing at all. I cannot impart acquaintance with them to any one who has not already made it himself.

Thinking goes on

[I 224] *The first fact for us, then, as psychologists, is that thinking of some sort goes on.*

Thought is in constant change

[I 230] … *no state once gone can recur and be identical with what it was before.* … [I 231] *there is no proof that the same bodily sensation is ever got by us twice. What is got twice is the same* OBJECT. We hear the same *note* over and over again;

The stream of thought

[I 237] *Within each personal consciousness, thought is sensibly continuous.* … [I 239] Consciousness … A 'river' or a 'stream' are the metaphors by which it is most naturally described.… *let us call it the stream of thought, of consciousness, or of subjective life*.

The continuity of thought comes in the fringe of the thought

[I 240] Into the awareness of the thunder itself the awareness of the previous silence creeps and continues; for what we hear when the thunder crashes is not thunder *pure,* but thunder-breaking-upon-silence-and-contrasting-with-it. … [I 241] the *feeling* of the thunder is also a feeling of the silence as just gone. … [I 241] We name our thoughts simply, each after its thing, as if each knew its own thing and nothing else. What each really knows is clearly the thing it is named for, with dimly perhaps a thousand other things. It ought to be named after all of them, but it never is. Some of them are always things known a moment ago more clearly; others are things to be known more clearly a moment hence. Our own bodily position, attitude, condition, is one of the things of which *some* awareness, however inattentive, invariably accompanies the knowledge of whatever else we know. We think; and as we think we feel our bodily selves as the seat of the thinking. If the thinking be *our* thinking, it must be suffused through all its parts with that peculiar warmth and intimacy that make it come as ours.

Substantive parts and transitive parts of the stream of thought

[I 243] This difference in the rate of change [of our thoughts] lies at the basis of a difference of subjective states of which we ought immediately to speak. When the rate is slow we are aware of the object of our thought in a comparatively restful and stable way. When rapid, we are aware of a passage, a relation, a transition *from* it, or *between* it and something else. … *Let us call the resting-places the 'substantive parts', and the places of flight the 'transitive parts', of the stream of thought.*

The fringe of every thought has feelings and knowledge about

[I 245] If there be such things as feelings at all, *then so surely as relations between objects exist in rerum naturâ, so surely, and more surely, do feelings exist to which these relations are known.* … [I 258] Let us use the words *psychic overtone, suffusion,* or *fringe,* to designate the influence of a faint brain-process upon our thought, as it makes it aware of relations and objects but dimly perceived. If we then consider the *cognitive function* of different states of mind, we may feel assured that the difference between those that are mere 'acquaintance', and those that are 'knowledges-*about'* (see I 221, quoted above) is reducible almost entirely to the absence or presence of psychic fringes or overtones.

The thought object comes as an undivided unity

[I 275] … the *Object* of your thought is really its entire content or deliverance, neither more nor less. … [I 276] The object of every thought, then, is neither more nor less than all that the thought thinks, exactly as the thought thinks it, however complicated the matter, and however symbolic the manner of the thinking may be. [I 276] … *however complex the object may be, the thought of it is one undivided state of consciousness.* … [I 278] *There is no manifold of coexisting ideas;* the notion of such a thing is a chimera. *Whatever things are thought in relation are thought from the outset in a unity, in a single pulse of subjectivity, a single psychosis, feeling, or state of mind.*

Attention chooses in the stream of thought

[I 284] *The stream is always interested more in one part of its object than in another, and welcomes and rejects, or chooses, all the while it thinks* … [I 420] *There is no such thing as voluntary attention sustained for more than a few seconds at a time.* … [I 421] *No one can possibly attend continuously to an object that does not change.*

The mind can always intend, and know when it intends, to think of the Same

[I 459] THE SENSE OF SAMENESS - … two kinds of knowledge of things, bare acquaintance with them and knowledge about them. … '*the principle of constancy of the mind's meanings*', and which may be thus expressed: '*The same matters can be thought of in successive portions of the mental stream, and some of these portions can know that they mean the same matters which the other portions meant*'. One might put it otherwise by saying that '*the mind can always intend, and know when it intends, to think of the Same'*. … [I 461] *The function by which we thus identify a numerically distinct and permanent subject of discourse is called* ACQUAINTING; and the thoughts which are its vehicles are called *acquaintance objects*. … [I 464] ACQUAINTINGS ARE UNCHANGEABLE

The stream of thought contains imagery

[II 44] *Sensations, once experienced, modify the nervous organism, so that copies of them arise again in the mind after the original outward stimulus is gone.* …. [II 44] … Fantasy, or Imagination, are the names given to the faculty of reproducing copies of originals once felt. …. [II 44] … The phenomena ordinarily ascribed to imagination, however, are those mental pictures of possible sensible experiences, to which the ordinary processes of associative thought give rise.

Association: how the thought objects change

[I 553] *There are, then, mechanical conditions on which thought depends, and which,* to say the least, *determine the order in which is presented the content or material for her comparisons, selections, and decisions.* … [I 554] *Association,* so far as the word stands for an *effect, is between* THINGS THOUGHT OF—*it is* THINGS, *not ideas, which are associated in the mind.* We ought to talk of the association of *objects,* not of the association of *ideas.* … [I 561] THE LAW OF CONTIGUITY … *objects once experienced together tend to become associated in the imagination, so that when any one of them is thought of, the others are likely to be thought of also, in the same order of sequence or coexistence as before. … the most natural way of accounting for it is to conceive it as a result of the laws of habit in the nervous system;*

How time is perceived: the sensible present has duration: the specious present

[I 606] … *The knowledge of some other part of the stream, past or future, near or remote, is always mixed in with our knowledge of the present thing.* … all our concrete states of mind are representations of objects with some amount of complexity. Part of the complexity is the echo of the objects just past, and, in a less degree, perhaps, the foretaste of those just to arrive. Objects fade out of consciousness slowly. If the present thought is of A B C D E F G, the next one will be of B C D E F G H, and the one after that of C D E F G H I—the lingerings of the past dropping successively away, and the incomings of the future making up the loss. … [I 608] THE SENSIBLE PRESENT HAS DURATION … [I 609] The only fact of our immediate experience is … 'the *specious* present.' … [I 636] *Duration and event together form our intuition of the specious present with its content.*

Remembered recall: memory

[I 653] … the *phenomenon* of memory … [I 655] A simple scheme will now make the whole cause of memory plain. Let *n* be a past event; *o* its 'setting' (concomitants, date, self present, warmth and intimacy, etc., etc., as already set forth); and *m* some present thought or fact which may appropriately become the occasion of its recall. Let the nerve-centres, active in the thought of *m, n,* and *o,* be represented by M, N, and O, respectively; then the existence of the paths M—N and N—O will be the fact indicated by the phrase 'retention of the event *n* in the memory,' and the excitement of the brain along these paths will be the condition of the event *n*'s actual recall. The *retention* of *n,* it will be observed, is no mysterious storing up of an 'idea' in an unconscious state.

Sensation and perception

[II 1] *From the physiological point of view both sensations and perceptions differ from 'thoughts'* (in the narrower sense of the word) *in the fact that nerve-currents coming in from the periphery are involved in their production. In perception these nerve-currents arouse voluminous associative or reproductive processes in the cortex; but when sensation occurs alone, or with a minimum of perception, the accompanying reproductive processes are at a minimum too.*

THE NEURAL ACTIVITY OF THE STREAM OF THOUGHT

By the synapse-state theory, the activity described by James as the stream of thought happens in a particular part of the neuron/synapse network of the organism, a part having a vast number of neurons and synapses. In what follows this part will be called the *thought network.* At any moment the state of the synapses in the thought network will be such that certain of the *neuron/synapse paths in this network have been put in a conductive state.* Being conductive is a matter of degree, being dependent on the momentary plastic state of the synapses along the path. It is assumed that the plastic properties of the synapses generally are such that the passing of impulses through a synapse will increase its conductivity and maintain that increase for a certain duration of time, here called the *plastic time scale*.

The thought network operates as a whole, integrated into the total organism. For purposes of description the thought network will be considered to be divided into five closely interconnected layers, each distinguished by the plastic time scale of its synapses and the aspects of the stream of thought handled by it as follows:

Sense-layer: plastic time scale: a few milliseconds; *makes what is received from sense organs appear in the stream of thought* thus to some extent drowning out what comes in the stream from the item-layer.

Attention-layer: plastic time scale: one second; directs the *changing of attention* between excited parts of the sense-layer, the item-layer, and the motor-layer.

Specious-present-layer: plastic time scale: ten seconds; controls the *progression and overlapping in time of the excited parts of the item-layer and the motor-layer,* according to their *association*.

Item-layer: plastic time scale: months, years. Explained below.

Motor-layer: plastic time scale: months, years. Similar to item-layer, having *motor-networks* rather than item-networks. Whatever is excited leads to *muscular activations* rather than to thinking experienced.

Any such *long term item of mental life that is ready to come present with its fringes (knowledge-about, etc.) as part in the stream of thought*, for example *each item that is retained or remembered* over long periods ready for recall, is held in the item-layer in the form of *those parts of the item- and motor-layers that become excited when one particular node (acquaintance object) is excited*. I shall call such a part of the item- and motor-layers an *item network.* What comes in an item network will depend on the strength of its excitation, and on the state of the synapses that come along the paths that are reached by the excitation. Thus an item network will be different from one excitation to the next, accordingly as the states of the synapses change. These changes reflect the development of the *knowledge about* the acquaintance object. An item network is *not* a fixed subnetwork of the thought network.

The *thinking experienced* by the person at a particular moment—the *thought object*—is *whatever parts of the item- and motor-layers are excited* at that moment. Any thought object is a very complicated whole, in which it is possible to distinguish a number of *items known by acquaintance* (item-networks), each item coming in the thought object with a *fringe* of feelings, relations to other parts, and knowledge about it. When an item network is excited at its initial node all this comes forth as excitations in the item- and motor-layers, the various parts being excited at different degrees of strength, depending on the conductivity of the neuron/synapse paths through which they receive their excitation.

During periods when an item network is not excited (thought of) the decay of the synaptic efficiencies will gradually weaken its synaptic links. However, any part of an item network may be linked also to other item networks and may have its synapses strengthened through the excitation of these.

Whenever two parts of either layers are excited at the same time, or within the same specious present, the conductivity of a neuron/synapse path that leads from one to the other will be strengthened. This is the mechanism of *association.* Plausibly this mechanism will depend on the action of a kind of neuron/synapse path that allows transmission of an impulse in both directions, in which the plasticity of the synapse is such that the efficiency of transmission is increased whenever the path receives an impulse from both directions simultaneously.

When subsequently one of the two parts becomes excited, impulses exciting the other one will be transmitted.

The neural paths in the item-layer that support the actual remembered recall (memory) have been described accurately by James (1890), as quoted from [I 655] above.

When the person is in a normal waking state a very small, continually changing fraction of the sense-, item-, and motor-layers is excited. These excitations and their changes are brought about by the activity of the attention-layer and the specious-present-layer of the thought network.

The attention-layer, having its plastic time scale of the order of a second, controls the change of the *attention* among the parts excited at any moment and the alternation of what James describes as the *substantive parts* and the *transitive parts* of the stream of thought. Attention plausibly primarily consists in brief increases of the excitation–highlighting–of such parts of items in the sense-, item- and motor-layers that are already weakly excited, passing this highlighting quickly around from one such part to another under the control of a neuron/synapse circulation. Such highlighting will lead to the *formation and strengthening of associations* among parts of all those items that are excited at the moment.

Plausibly this attention-highlighting mechanism, like the association mechanism, will depend on the action of a neuron/synapse path that allows transmission of an impulse in both directions, in which the plasticity of the synapse is such that the efficiency of transmission is increased whenever the path receives an impulse from both directions simultaneously.

The attentive highlighting of a part of the sense-layer will lead to excitation of such parts in the item-layer with which it is linked by association, this being the mechanism of *perception*.

Plausibly the transitive parts of the stream of thought arise from straight excitations of the particular items, while the substantive parts achieve their relative stability by being excited by a fast circulation that maintains its excitation for a duration of about one second. The stream lands in a substantive part whenever a new associative link has been formed.

The specious-present-layer, having time scales of the order of ten seconds, controls the change of the object of the thought–that part of the item-layer which is excited–as induced by the habits of *association of the thought objects.* These changes likewise support the *thinking of time*–the *specious present*–by which each object of the stream of thought lingers during a period of many seconds while the following objects are already becoming excited.

NEURAL TOPOLOGY AND SYNAPSE KINDS

The present theory presupposes a network of neurons connected by synapses of several different kinds. About these given properties only a few suggestions shall be given here. It seems clear that at least two different major kinds of synapses have to be at work, the one kind taking care of items of the thought objects having long term stability, the other kind being at play in the rapid moment to moment changes of the stream of thought. It seems plausible that the topology of the network of the neurons also will come in several different styles in different parts of the thought network, accommodating various kinds of cycles.

The synapse-state description of the nervous system suggests a wide field for empirical neurological studies. One area would be to identify and locate certain of the circulations. As the analysis technique, electroencephalographic analysis suggests itself, at least for such circulations that take place in extended neuron/synapse circles. By their similarity to the scratch-reflex of dogs studied extensively by Sherrington, it seems plausible that the circulations active in male sexual arousal take place in extended neuron/synapse circles that involve synapses in the lower spine, which might reveal themselves by their associated electrical potentials.

Another area is to study the plastic properties of the synapses in various parts of the nervous system. Plausibly each anatomical part of the nervous system accommodates one or only a few kinds of synapses. Plausibly the synapses of the five layers of the thought network are localized in five separate parts of the brain. One may venture the guess that synapses located in the spine have long term plasticity.

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