We now have at hand a method for representing every kind of information object, from raw numeric data to complex images, digitally in a computer-like environment. That method consists of identifying and dealing with the universals that are represented in the information and the way it is presented.

We also now have at hand tools [the gates] that enable us to manage and manipulate those digital representations as we see fit.

The task of the next several Sections is to see how operations with those digital representations of universals produce the principle attributes of a mind:

Concepts, Thoughts, Thinking and Memory.

HOW THE MIND ARISES FROM THE BRAIN

SECTION 6

Concepts, Thoughts, Thinking and Memory

UNIVERSALS AND CONCEPTS

As this discussion has developed so far, the neural system has been dealing with inputs from the external world. Such an input is specific, material and has characteristics that are, in their combination, peculiar to it, alone. Each of those characteristics is an example of some universal in which the characteristic participates. The distinction among a specific input example and a universal and a characteristic of an input example that is a sample of that universal is important.

The universal does not exist external to the neural system in the sense that it has no representation other than there. (It is, of course, the commonality among all possible input examples with regard to the characteristic that the universal represents.) It exists in the neural system as a configuration of neurons and their thresholds that is able to discriminate between the presence or absence of that universal in an input example that is presented to it.

The input example exists in the world external to the neural system. It does not exist within the neural system except as a representation in terms of the universals that it participates in. That representation is temporary, pending the next input example. It consists of a temporary state that is some subset of neural *1's*, neural *firings* by the appropriate neurons. [The term "subset" hereafter refers to some number of neurons, part of the total available neurons, having something in common that makes them a "set" of neurons having that shared something.]

The universal is relatively permanent in the neural system being the "wiring" configuration of interconnections among the neurons with their threshold settings which do not change rapidly in amount except in the early learning phase of the system's operation.

A *concept* is a *mental universal*; that is, not only the universal but also any specific examples of circumstances that have characteristics fitting it, can only exist and act in a neural system, a rational mechanism such as a brain. This is as distinguished from *material universals*, characteristics of descriptions of material things having specific examples external to the neural system. See Figure 6-1, below.

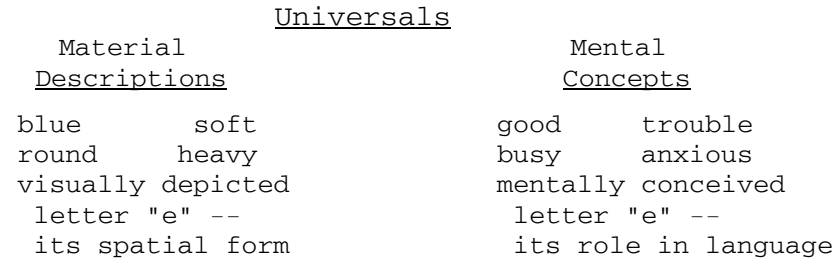

Figure 6-1

A universal, whether material or mental potentially exists whenever a subset of examples have something in common. The universal is overtly expressed only by and in a functioning mechanism that is capable of abstracting the universal from a group of real samples. The universal, itself, has no tangible existence other than that. But, the specific examples of a material universal, a description, are material.

Concepts are purely mental. They arise and exist only in a functioning neural mechanism, a brain. Both the universal that is the *concept*, and specific examples of circumstances fitting the *concept* are mental actions, only.

A *thought* is such a specific example fitting a *concept*. Just as is the case with a specific example of a material universal, a *thought*, which is a specific example of a mental universal, is represented in the neural system only by the firing of the appropriate neurons, the ones whose output firing means that the universals of which the *thought* is a specific example are indeed present in the *thought.* Those “firings of the appropriate neurons” in effect *are* the *thought*.

THOUGHTS AND THINKING

A *thought* can also be of, about, a specific example fitting a material universal rather than a mental one (thinking about blue or soft objects, for example). A *thought* can also be of, about, the universal itself rather than of a specific case that fits the universal (even as in reading this our thoughts are about universals). Such a *thought* is still only a *thought*, not the functioning universal, even though such a *thought* is our only way of consciously, overtly, being aware of the universal.

We are aware of our thoughts. Our overt awareness of our universals, of the "wiring" and set of thresholds in our neural system, are much less.

For example, if something seems to us to be honest or dishonest the distinction is seemingly automatically made by our mind at an unconscious level. We instinctively and automatically have the opinion without any overt thinking having gone on. That is the operation of the universal concept "honest" or any other universal.

If we, in fact, think about the issue trying to decide if it is honest or dishonest that process takes place because the specific example is sufficiently borderline or so complex that our universal extraction and identification system yields a "no decision" output.

Of course, just as with the words here written on this page, the purely mental *concept*s and *thought*s can be recorded in writing or other media of communications. But, the recorded form, as this page, is merely a code that causes the *concept*s and *thought*s to arise in a rational system able to read the writing, able to decode the record. The concepts and thoughts themselves exist only in that rational system, a mind. They exist there only in the combination of that mind's "hard wiring" and its developed, learned, thresholds.

Yet, a mind starts existence with nothing and what the mind develops, learns, comes from interpreting sensory input from the material world, that is from the extracting of material universals from sensory data. Then, how do concepts, mental universals, arise at all ?

Thinking is associations and sequences of *thought*s, that is associations and sequences of specific examples of, *i.e.* specific examples fitting, certain universals. Each (momentary) thought is a particular subset of (momentary) neuron firings that are a set of universals. Thinking is sequences of such firings of particular subsets of neurons, the content of the set [the universals the set constitutes] changing somewhat from firing to firing. Such sequential firings, such thoughts, associate, that is form a succession, become a sequence, develop the trend of the thinking, by having in common parts of the logic for their universals.

> For example, and greatly simplified, suppose that thought *#1* consists of universals `[a, b, d]` out of the *26 [a … z]* total universals available in this simple example. The next following thought, thought #2, consists of the prior *[a, b, d]* plus *[k]*. The third thought consists of the set comprising the second thought less *[d]*. The three such thoughts in that sequence, and because of those changes in the included universals, are "a line of thought", *thinking*, about the subject of the common universals *[a, b, k]*.

In the preceding section it was pointed out that a specific neuron is usually involved in a number of universals rather than being dedicated to just a single one. It was pointed out that the result was a drawback in that the thresholds must be attempted optimum compromises among the family of universals in which the neuron participates.

But, it was also presented that this was a tremendous advantage in that it made thinking possible. Thinking is associations and sequences of thoughts. A thought is the firing of a particular subset of neurons. Those neurons as a subset, collectively represent that thought. But individually, each neuron also represents a part, a component, of a number of other possible thoughts. At the moment of the current thought those other thoughts are not active because their exact complete subset of component neuron firings is not active; only some parts or pieces of them are active.

However, the activation of the current thought could, with only a little additional help, result in the activation of one or more of those other thoughts that share a significant proportion of their neurons with the current thought. That "little help" would

be something that has the effect of activating some other related neurons and/or deactivating some of the currently active neurons. And, because of the sharing of neurons, of universals, in common between the two thoughts, the successive thoughts will be related; they will tend to follow logically in terms of rational thinking.

While neurons participate in more than one universal they clearly cannot participate in contradictory universals because it would be impossible to achieve a compromise threshold that yet worked for both of the contradictory universals. In general the subset of universals in which a neuron participates must be a somewhat related family not totally unrelated. That is part of the nature of universals, their condensation of the characteristic's various appearances into a commonality.

The neural network in which this process of thinking takes place is not the type that is relatively simple and to a fair degree a layered type structure as encountered where sensory input occurs. Rather it is the most complex and sophisticated form of neural network, that which has a very large amount of interconnections with relatively little layering and involving a very large number of neurons overall and in each thought.

From equations *6-1* and *6-2*, further on below, the number of different possible thoughts that can appear in only one percent of the total human brain's number of neurons is the immense-beyond-comprehension number: *1,000,000 ... (30,000,000 zeros or about 10,000 pages of zeros) ... 000*.

With the extensive interconnection of neurons, including the feed-back or recirculation of output firings as inputs elsewhere in the network, and with the essentially continuous sensory input constantly delivering new data, the "little additional help" necessary to progress to a next, related, thought is constantly present. Inevitably, then, the existence of a current thought results in an immediately following next thought and that next thought is inevitably related to, but not identical to, the former thought.

Each of those thoughts is a specific subset of characteristics fitting, calling, their related mental universals, a subset of mental concepts. A thought is usually a mélange of a large number of concepts. Each *concept*, and specific examples of circumstances fitting the *concept* are mental actions, only. A *thought* is a mélange of such a number of various specific examples fitting various *concept*s.

The associations and consequent transitions from thought to thought are then progressive changes of one, usually some, and perhaps rarely all, of the specific individual universals, mental concepts, that comprise the current thought. In the complex neural thinking structure with thoughts involving inconceivably large numbers of universals the opportunities for a variety of associations are quite large.

This overall process is what we call *thinking* (but not, yet, purposive thinking). It is a process that can take place in neural systems over a wide range of size and complexity. Certainly man does this kind of thinking. But such thinking is also performed by dogs, birds, snakes and beetles. In each of the cases as the size and sophistication of the neural system is smaller and simpler then the complexity of the thoughts is reduced. But, some form of thinking takes place.

The sequence of thoughts, which thought comes next, which specific mental example fitting what universals is the next to appear, is determined by the interaction and

relative significance of the universals of the current and the prior thought(s) plus the "little additional help", the effect of new sensory input and of the feed-back of current firings to recirculate in the network.

At the same time each thought can modify the then existing universals. Since the universal is an abstraction of a common element from a family of samples, then if the thought is a new sample added to the family, the thought must produce at least a small change in the pertinent universals. Each neuron's firing reduces its threshold leaving it more easily fired after, and each failure to fire allows its threshold to increase making future firing less likely. That is because the neuron's firing is electro-chemical and involves, requires energy. Firing depletes energy, depletes threshold. Non-firing increases rest time for metabolism to restore energy, restore threshold.

The result is an iterative process of evolving universals and sequences of specific examples where the examples modify the universals and the universals determine what the various available directions that the sequence of examples may take is.

- Early thinking, learning, operates with material universals, only, and produces some relatively simple concepts.
- Most thinking operates with material universals and existing concepts and produces changed and new concepts.
- Abstract thinking operates purely with concepts and produces more and changed concepts.

Thoughts, thinking, inherently involve the developing of new concepts from the interaction of existing material universals and concepts. That is accomplished by the changes in the thresholds which results in the formation of the ability to perceive new associations, relationships, among the existing material universals and concepts. Those new associations and relationships become new concepts.

MEMORY

A *memory*, that is a thing remembered, is a *thinking pattern*. It is a short or long sequence of thoughts, simple or complex. To the extent that the memory is mentally repeated (the thinking through the sequence of thoughts again) to that extent its thresholds become more firmly set; the memory becomes more permanent. To the extent that the memory is not repeated, to that extent other thoughts that use some of the same logic as is used in that particular memory, produce threshold changes that degrade that particular memorization.

Memories reside in a diffused, distributed manner over a large number of neurons. They are not in some separate "library" or "memory file cabinet" of the brain. They are "right out there" intermixed with and inter-operating with the brain's overall activity. The only difference between a *remembering* and a *thinking* is whether the active sequence of thoughts, its successive neural firings, is new, that is original, or is it the retracing of its earlier, original sequence.

Thus thoughts are new memories, ones that result from the interaction among preceding thoughts and may include sensory inputs. In effect thinking takes place in memory, not in some separate "thinking place".

What with the vast amount of information that we remember and the complexity of our thinking, one wonders how our neural system can contain it all. Of even more concern could be that, with thresholds being constantly affected by current mental activity how can things learned and things remembered last a long time ?

The four by four array examined earlier contained only sixteen discrete elements - in effect neurons. Yet that array is capable of representing $2^{16} = 65,536$ different patterns. The human brain contains on the order of *one hundred billion* neurons, about 10^{11}. Let us arbitrarily assign 10% of those to sensory, motor, automatic (for example heart beat) and intercommunication activities within the body and brain. (That is quite generous. A *Tyrannosaurus Rex* had a brain of fewer than 10% of a human's number of neurons for all purposes yet it did a pretty good job of functioning.)

Let us then recognize that the complex human brain has a number of regions of specialization. One local region interprets vision; another deals with language, another handles emotion, and so forth. Let us provide for one hundred such sub-systems. Then any one such sub-system would have as presented earlier.

$$(6\text{-}1) \quad 10^{(11-1-2)} = 10^{8} \text{ neurons}$$

which could represent

$$(6\text{-}2) \quad 2^{10^{8}} = (2^{10})^{10^{7}} = (1000)^{10^{7}} = (10^{3})^{10^{7}} = 10^{21} =$$
$$= 1,000,000, \ldots \text{[30 million zeros]} \ldots ,000.$$

different patterns per each such sub-system.

Even our neural system, having that great capacity, is not able to really appreciate what an immense number that is. At the rate of a page being able to contain about 3,000 zeros it would take 10,000 pages of zeros just to write out the number -- to write it down not to express the value of the number. (It takes four digits to write down "1000" but it has the numerical value $1,000$.) That vast capability certainly suffices for our neural system, our brain, to readily learn and retain everything that we give it over a lifetime.

Yes, a certain amount of memory loss occurs because of disuse of some memories or learnings and the consequent blurring of their thresholds. And yes, a brain cell dies here and there regularly and takes its participation in the logic with it when it goes. But those degradations are negligible in the overall system. The number of neurons involved in any single thought or memory is so large that a problem with, or a failure of, a single neuron here or there, now and then, is of no importance.

On the other hand, a popular saying that is valid in its context is that "we are what we eat". It is likewise true that our mind (which, after all, is our selves) is what we think. We tend to become, to think as, to behave as, that which we feed into our neural logic networks and threshold settings. That is something to think about.

At this point it is worth re-calling the following from the preceding section.

> Whenever a neuron "fires", that is delivers a 1 output because a majority of its inputs and its threshold so correspond, then its threshold naturally and automatically must decrease slightly so that a similar "firing"

will be more likely under subsequent similar input conditions. Whenever a neuron "does not fire", that is it effectively delivers a *0* output because a majority of its inputs and its threshold is not present, then its threshold naturally and automatically must increase slightly so that a similar "non-firing" will be more likely to occur under subsequent similar input conditions.

Those slight decreases in threshold due to a firing are due to the firing's consumption of a small portion of the available electro-chemical energy of the neuron. Those slight increases in threshold due to a non-firing are due to that much more time given to the neuron for it's natural metabolism to restore or build up its electro-chemical energy.

In summary:

- Something in memory is a set of universals, a subset of neurons the universals of which, that they implement, being contained, represented in the various thresholds of the neurons of the subset.

Something remembered or re-thought is the re-firing of the same subset of neurons the original firing of which set the thresholds, set the universals of that set.

NEXT

Each memory is stored in a specific population of neurons, that memory's particular subset out of the total available neurons. When a memory is linked with another to generate an associative memory, their neural subsets partially overlap. At the same time, the individual memories maintain their own identities.

With all of the vast number of possible patterns, specific neural subsets, in memory per equation *6-2* the problem arises: how is one particular pattern, a particular memory or thought, to be specifically accessed out of the vast number available ?

Access to the memory, that is the remembering of it, is via the same kind of associations of thought universals as in any thinking. To access the memory we must think of something associated with it, something that will trigger the sequence of thoughts that are the memory.

But how ? That process is developed in the following sections.