VIII. Memory, the Brain's Electrochemical Filing System

If memory storage requires alterations in the biochemical structure of neurons, then it follows that when memories are formed, something must be changed within the brain. Virtually all biochemical processes demand energy and energy in the brain comes from burning glucose.

Learning initially produces a brief change in the status of synaptic membrane proteins. But this is only short-term. Although this stage may be necessary if long-term memory is to later occur, it can't be the biochemical change that remains permanent.

According to Stephen Rose in:

Rose, Stephen. The Making of Memory. New York: Anchor Books, 1992, page 253:

Something more permanent is required, something that will in some way produce some lasting remodeling of the synapses. It is this remodeling which must require the synthesis of new proteins. (See Romans 12:2)

A definition for "*synthesis*" is necessary for those of us who did not do well in chemistry. When two or more elements are combined to form a new compound, this is called synthesis, in this case, new proteins.

Proteins are synthesized on the basis of information provided by the DNA, that is, the genes present in the cell's nucleus.

When an engram is to be created, the DNA must be activated in some way, so as to switch on the relevant genes which, in turn, produce the new proteins which then make the new memory trace.

Review: Information is heard through the ears and frequencies are transmitted synaptically to the auditory area. A synaptic transmission is then made to Wernicke's area where vocabulary is referenced to decipher the information. Meaning is determined and the thought is placed into its proper syntax after a trip through Broka's area. At this point the idea is sent to the Association Cortex, the area where all incoming data is processed and then integrated into memory traces. If what is heard and understood is processed into long-term memory, a sequence of chemical changes begins to occur in the nucleus of the pertinent neuron. This nucleus's DNA switches on certain genes which produce the synthesized proteins which create the new memory trace.

These genes are the mechanism by which information arriving at the cell nucleus is translated into instructions for the synthesis of key proteins.

These proteins are eventually inserted into the synaptic membrane so as to change its structure and shape.

It is these synthesized proteins which go about the business of actually modifying brain cells. When these changes occur over a sequence of several million synapses involving thousands of neurons, a memory trace is created.

An engram of long-term memory has been chemically filled into the tissue of the brain and this information may be recalled to the conscious mind when provided the proper stimulus.

The brain has been permanently altered under the principle of plasticity.

(Show four-panel transparencies from): **Restak, Richard M. The Brain. New York: Bantam Books, 1984, pp. 32- 33**:

(a) Artist John Allison's rendering of a look inside the neural network of the cortex. (b) The signal from one neuron is transmitted electrochemically to another. (c) The receiving neuron fires, (d) sending the signal down its axon to the next neuron in the memory trace.

Restak, Richard M. The Brain. New York: Bantam Books, 1984, pp. 36-37:

(a) The artist's rendition of a neuron's axon extending toward a nearby cell, forming a synapse. (b) The neuron fires sending information down the axon. (c) It reaches the end of the axon at the synapse. (d) It triggers the release of neurotransmitters across the synapse. (e) This causes the receiving neuron to fire and the process is repeated at the next synapse in the memory trace (or, wheel-track).

Restak, Richard M. The Brain. New York: Bantam Books, 1984, pp. 38-39:

(a) The artist's illustration of the synaptic (cleft). (b) Chemical neurotransmitters are released by the nerve fiber (axon). (c) The synaptic cleft fills. (d) The receptors on the dendrite are activated. (e) The full signal is received. (f) The full signal continues on its way.

The surface of each of the dendrites which branch out from the neuron's cell body is covered with synapses. There are perhaps as many as 10,000 per neuron. Simply put, a synapse is a contact point between neurons. (See Transparency: Electrical Wiring System) Some of these synapses are on the shafts of the dendrites, others are attached to the spines which branch off of the shafts. (See Transparency: Complete Neuron)

How these synapses are connected between one neuron and another changes when learning occurs. Also, the dendrites increase in length, change their branching patterns, and alter the numbers of their spines.

How effective one given synapse might be in influencing the neuron to which it is attached depends upon several things:

1. How close it is to the cell body of the neuron.
2. Whether its connection is on the shaft of the dendrite or one of its spines.
3. Spine synapses are more effective than shaft synapses in spreading current.
4. However, in any given spine, current flow is dependent upon its shape.

At the synapse, the chemical transmission of data released from the axon's side binds to a receptor on the dendrite's side resulting in a change in the flow of electrical current in the dendritic membrane. The conclusion is that any change in the structure of dendrites and the location of the synapses on them also changes the electrochemical makeup of the neurons involved.

Further, communication between neurons can be altered not only by increasing or decreasing the actual number of synapses between the two but also by altering the size or location of any given synapse. As each repetition in learning occurs, alterations are made in the memory trace, causing it to become more and more efficient. The more you study the subject, the better you understand it, the easier it is to recall, and the more it becomes a part of your lifestyle.

Example: The Bible is the only source of information which may be communicated to a person regarding the gospel of salvation.