SPECULATIONS ON THE EVOLUTION OF THE GENETIC CODE

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Abstract. An evolutionary scheme is postulated in which the bases enter the genetic code in a definite temporal sequence and the correlated amino acids are assigned definite functions in the evolving system.

The scheme requires a singlet code (guanine coding for glycine) evolving into a doublet code (guanine-cytosine doublet coding for gly (GG), ala (GC), arg (CG), pro (CC)). The doublet code evolves into a triplet code. Polymerization of nucleotides is thought to have been by block polymerization rather than by a template mechanism. The proteins formed at first were simple structural peptides. No direct nucleotide-amino acid stereo-chemical interaction was required. Rather an adaptor-type indirect mechanism is thought to have been functioning since the origin.

In considering the evolution of a complex system it is useful to adopt an idea expressed by Bernal: "In general the pattern... is one of stages of increasing inner complexity, following one another in order of time, each one including in itself structures and processes evolved at the lower levels" (Bernal, 1960). I like to call this the 'onion heuristic'. Complex systems evolve by adding layers to a simple system. The problems of the origin and evolution of the code depend therefore on the complexity of the biosphere postulated when the coupling of nucleic acid and protein occurred.

If one adopts the view of Cairns-Smith (1965) that life evolved through natural selection from inorganic crystals in particular clays, then one would conclude that the genetic code is a later invention and that the origin of life must be separated from the origin and evolution of the code. In recent years the experiments by Paecht-Horowitz, Berger and Katchalsky (1970) have given evidence of the importance of clays in the polymerization of activated amino acids. The hypothesis that clays were the original living systems which evolved is the view which I adopt in this paper.

The protein synthesis 'read-out' system as we know it today involves four interdependent subsystems: (1) Enzymes for the polymerization of nucleotides; (2) Ribosomes and enzymes for the polymerization of the activated amino acids; (3) Transfer RNA; and (4) activating enzymes.

The search for inorganic catalysts which will polymerize either nucleotides or amino acids is a very active field of research. However, the combination of tRNA and activating enzymes implies that today there is no specific physical-chemical interaction between the tRNA and the amino acid. Two views of a more primitive system can be presented. The first view presumes that the present system evolved from one in which a specific interaction existed between a tRNA and an amino acid. In other words there was no need for an activating enzyme. The second theory assumes that the existence of a primitive activating system was a necessity at the beginning. In other words there was no specific physical-chemical interaction between the amino acid and the tRNA.
I propose to adopt this second hypothesis and assume that a primitive activating enzyme was necessary.

If the original living systems were clays, then the introduction of nucleic acids and proteins might have been solely for the additional structure which they provided to the clays (Cairns-Smith, 1971). The origin of the code would then lie in the interaction between nucleic acids, polypeptides and clays. Since these interactions have as yet received only preliminary study, much experimental work is needed.

A pattern inferring the evolution of the code and compatible with the above assumptions is proposed here which suggests how the various amino acids came into the coding system and correlates this entry with their function.

![Pattern](image)

If the code table is written in the form of Figure 1, a pattern is discerned which can be summarized as follows:

1. The code originated as the polymerization of glycine which was specified by polyguanine. (Figure 2)

   ![Glycine Polymerization](image)

2. The code evolved to a doublet code specifying four amino acids by the addition of cytosine. (Figure 3)

   ![Cytosine Addition](image)