SOME REMARKS ON ROSEN'S QUANTUM-MECHANICAL APPROACH TO GENETICS

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It has been suggested by Robert Rosen (Bull. Math. Biophysics, 22, 227–255, 1960) that multiple alleles or pseudoalleles correspond to multiple cites of degenerate states of some quantum mechanical observable which acts as a source of primary genetic information. It is pointed out here that if the quantum mechanical states are determined by the different sequences of the purine and pyrimidine bases in the DNA molecule, the expected number of pseudoalleles would be much too large. The expected number is considerably reduced if we assume that a quantum mechanical state determines the coupling between a molecule of transfer RNA and the corresponding amino acid.

In two recent papers Robert Rosen (1960b, 1961) has outlined a novel approach to the problem of primary genetic information. Instead of considering the coding as due to a particular sequence of "molecular letters," he suggests that the instruction which determines the phenotype is characteristic of a state of some quantum variable. This concept leads to a number of interesting conclusions, some of which are compatible with already known facts, others suggesting a search for as yet unobserved phenomena.

Rosen does not define the nature of the quantum-mechanical "observable," the different states of which give rise to different genetic instructions. He points out, however, that this observable need not be energy. In fact, energy is implicitly rejected as such an observable. In a different context N. Rashevsky (1959) also considered the possible role in biology of quantum-mechanical observables other than energy.

In the usual atomic applications of quantum mechanics the number of observables that have definite eigenstates and that therefore commute with the Hamiltonian is rather limited. In addition to energy, the "naturally" occur-
ring observables are the angular momenta and certain of their components. The "parity" is another observable which commutes with the Hamiltonian and has two eigenvalues, +1 and −1 (Landau and Lifshitz, 1958). To the above-mentioned observables there correspond explicitly defined operators, derived from the "classical" counterparts of the observables. Another important observable, the spin, with only two eigenvalues (+1/2 and −1/2) has, strictly speaking, no analytically defined operator. One simply considers that there exists a spin operator with the above eigenvalues and two corresponding eigenfunctions. In field physics (Schweler, Bethe, and de Hoffmann, 1956) annihilation operators are defined essentially by their properties. Thus there is no reason why we could not postulate an observable whose operator may not be analytically defined. Apparently Rosen's "genetic information" observable is of that kind. Rosen's conclusions are independent of the nature of this observable and follow from general relational properties of all quantum-mechanical observables.

One of such general properties of all observables is that the structure of the set of their eigenstates is to a large extent defined by any transformation group with respect to which the system is invariant. Let us look into this somewhat more closely.

Rosen (1960b, p. 251) remarks that a quantum-theoretical interpretation of primary genetic mechanisms is incompatible with the accepted view of coding processes as "molecular sentences" consisting of a sequence of four (or, for that matter, any number) of "molecular characters." On the other hand, the role of the DNA and RNA molecules in the transmission of genetic information cannot be denied, even though the interpretations of their role may differ. That different sequences of a given number of purine and pyrimidine bases may correspond to different states of some as yet undefined quantum-mechanical observable is to be expected.

Whatever the nature of the observable, its value will not be changed by permuting identical bases. Hence if a DNA molecule contains a total of \( N \) bases, of which \( N_A \) is the number of adenine bases, \( N_G \) the number of guanine bases, \( N_T \) the number of thymine bases, and \( N_C \) the number of cytosine bases, so that

\[
N_A + N_G + N_T + N_C = N, \tag{1}
\]

then, whatever the nature of the observable, it must be invariant with respect to the subgroup \( S' \) of the permutation group of order \( N! \), which permutes only identical bases.

The same thing holds about the RNA molecule, except that for \( N_T \) we substitute \( N_U \), the number of uracil bases.