DNA Puzzle Kit

With this kit you study the structure and function of DNA and RNA.

MATERIALS

- 24 Deoxyribose Units
- 24 Phosphate Units
- 12 Ribose Units
- 4 Adenine Units
- 8 Cytosine Units
- 8 Guanine Units
- 4 Thymine Units
- 2 Uracil Units
- 6 Alanine Amino Acid Units
- 6 Glycine Amino Acid Units
- 2 Alanine Activating Units
- 2 Glycine Activating Units
- 2 Alanine Specific tRNA Units
- 2 Glycine Specific tRNA Units
- Ribosome Template
- Student Worksheets, DNA: The Genetic Code
- Student Worksheets, RNA: The Code Transcribed
- Student Worksheets, Protein Synthesis: The Code Translated

PROCEDURE

The DNA Puzzle Kit includes three exercises, each of which requires about 20 to 45 minutes for completion. The exercises are cumulative and should always be done in this order: 1. DNA: The Genetic Code; 2. RNA: The Code Transcribed; and 3. Protein Synthesis: The Code Translated. The student should master each exercise before proceeding to the next.

DISCUSSION

A DNA nucleotide, upon analysis, yields three parts: an inorganic phosphate, a molecule of deoxyribose sugar, and one of the organic bases adenine, cytosine, guanine, or thymine. Reactions between the 5’ end of one nucleotide and the 3’ end of another result in the linkage of nucleotides to form chains of DNA. (The designations 5’ and 3’ refer to the numbering of the carbon atoms in the sugar molecule.) These linkages are covalent chemical bonds. However, the bonding between bases of the two complementary chains results from unequal distribution of electrons within the bases. When a hydrogen atom is bonded to an atom of oxygen or nitrogen, its electron tends to drift to the oxygen or nitrogen atom. Hydrogen becomes slightly positive in charge, while oxygen and nitrogen gain in negative charge. Thus, when the complementary bases are brought together, the portions of the molecules having opposite charge attract. This attraction, called hydrogen bonding, is weaker than covalent bonding.

DNA is the repository of the genetic code. Actual protein synthesis is mediated by RNA. At the present time, less is known about ribosomal RNA than is known about either mRNA or tRNA. A ribosome has two parts or subunits: a small or 40 S (S = Svedburg unit) subunit and a large or 60 S subunit. (The subunits of bacterial ribosomes are 30 S and 50 S.) The initial binding of ribosome, mRNA, and tRNA is complex and is not considered in this exercise. Transfer RNA occurs throughout the cytoplasm where it reacts with activated amino acids. Activation consists of an enzyme mediated reaction between an amino acid and ATP. There is a specific activating enzyme for each amino acid. The reaction may be represented as:

\[
\text{Amino Acid} + \text{ATP} \xrightarrow{\text{activating enzyme}} \text{Amino Acid} \cdot \text{AMP} + \text{2P}
\]
The same enzyme then transfers the amino acid from AMP to the appropriate tRNA.

\[
\text{Amino Acid} \cdot \text{AMP} + \text{tRNA} \quad \xrightarrow{\text{activating enzyme}} \quad \text{Amino Acid} \cdot \text{tRNA} + \text{AMP}
\]

The enzyme not only recognizes specific amino acids, it also recognizes specific tRNA molecules. Thus, the activating enzyme for glycine will bind glycine only to glycine specific tRNAs, although occasional errors in binding do occur.

The Amino Acid • tRNA complex reaches a ribosome by diffusion. Each ribosome has two sites, the A or Acyl • tRNA binding site and the P or Peptidyl • tRNA binding Site. A cycle in amino acid chain formation is as follows: a tRNA with a forming chain occupies the P site. A second tRNA with a single amino acid attached enters the A site. If this tRNA’s ant~codon is compatible with the codon of the mRNA in the A site, an interaction occurs and the tRNA is bound within the site. (If the anticodon and codon are not compatible, the tRNA is not bound.) The amino acid chain is cleaved from the tRNA in the P site and transferred to the amino acid of the tRNA in the A site. The chain has now been elongated by one amino acid. The final step of the cycle is the release of tRNA from the P site and the transfer of the tRNA-amino acid chain from the A to the P site. The shapes and relative sizes of the units used in the kit are arbitrary. The pattern printed on the tRNA units is of the clover-leaf model of tRNA. Evidence indicates that the arms of the actual molecule are folded together and the molecule is bent into an "L" shape. The method by which an activating enzyme is able to recognize a specific amino acid and a specific tRNA is unknown at present; therefore, the method used to attach these units in the kit is arbitrary. Similar statements apply to the combination of the ribosome with mRNA and tRNA. None of the simulations in the kit involves initiation or termination.

It is important to remember that the purpose of the kit is to simulate molecular events, not to exactly duplicate them. Several compromises have been necessary because of the limitations of the materials used. Perhaps the most obvious limitation is the use of a two-dimensional model for a three-dimensional system. The primary goal of the exercises is to help the student understand the relationship of DNA to the various RNA's and to protein chain formation. To avoid detracting from this primary goal, most of the details concerning enzyme activity, energy requirements, and other factors associated with replication, transcription, and translation are omitted. A greatly simplified, mechanical presentation is the result.

It is a convention among biochemists to write nucleic acid codons in a 5' to 3'direction. This convention is not consistently followed in most introductory presentations, nor is it followed in this kit. For example, the DNA codon for alanine is given in the kit as 3' CGT 5'. By convention this should be 5' TGC 3'. However, it is difficult for introductory students to associate a DNA codon written TGC with an RNA codon of GCA because they are reversed anti Parallel).