DNA TRANSCRIPTION

The process in which the hereditary code carried by DNA is used by the cell to control protein synthesis has turned out to be quite complex. It involves three different types of a slightly different nucleic acid, called RNA, and two sequential processes known as transcription and translation.

Color the headings DNA and RNA and titles and structures D, T, R, and U. Use the D and T colors from the previous plates and light colors for R and U.

RNA (ribonucleic acid) is made up of numerous nucleotides assembled in exactly the same way as in DNA except that RNA is mostly single-stranded and mostly not in the form of a helix. It differs in composition in that the sugar component is ribose, rather than deoxyribose, and that the base thymine is replaced by uracil, a different, though quite similar, molecule. The other three bases are the same as in DNA: adenine, cytosine, and guanine.

The first step in utilizing the DNA code is the process of transcription. In transcription, the DNA unzips, just as if it were going to be replicated (Plate 83), except that instead of DNA polymerase attaching to it, a different enzyme, called RNA polymerase, attaches, synthesizing a molecule of RNA instead of a molecule of DNA. Only one side of the DNA molecule is transcribed. This is assured by the fact that RNA polymerase is not attracted to just any stretch of DNA but only to certain DNA base sequences, called “promoters.” Promoters are sequences of bases that do not determine protein structure but serve only to convey the message “RNA polymerase, start here.”

The transcription process is essentially identical to replication. The differences are that the complementary daughter strand is being assembled with ribonucleotides instead of deoxyribonucleotides and that the RNA daughter strand does not remain attached to the parent DNA strand. Instead it separates from the DNA, and the DNA then zips back together. The RNA migrates out of the nucleus of the cell to the cytoplasm.

Three different classes of RNA are made in this way. The most abundant class is called messenger RNA (abbreviated mRNA) because it carries the message of what amino acids are to be put together in what sequence to make the cell’s proteins. The second class is ribosomal RNA (rRNA), which is an important component of the ribosomes, the organelles that actually accomplish the synthesis of the cell’s proteins. The third class is called transfer RNA (tRNA) because it transfers the amino acids to the ribosome for assembly into proteins. The RNA molecule being synthesized in the center of this plate could belong to any of the three classes of RNA. They are all alike except in length and the sequence of bases. Messenger RNA varies in length according to the number of amino acids in the protein for which it carries the code, but it is typically from 900 to 1500 nucleotides in length. It is mostly linear, although it can fold back on itself, and a few short sections may form a helix where the bases are complementary.

Ribosomal RNA takes only certain specific lengths, approximately 120, 1500, and 3000 nucleotides in prokaryotic cells and approximately 120, 160, 2000, and 5000 in eukaryotic cells. It is extensively folded back and forth upon itself, because it forms a framework for the attachment of a number of protein molecules to form the somewhat globular ribosome, which is slightly more than half rRNA by weight and slightly less than half protein.

Transfer RNA deserves some special attention because of its peculiar structure. There must be at least one different kind for each amino acid (actually a few more than that), all are about 80 nucleotides in length, all end in the sequence CCA (cytosine, cytosine, adenine) on their 3' ends, that end always serves as the attachment point of the amino acid to be transferred, and all tRNAs are folded into a complex "hairpin" structure with most of the molecule in helix form but three loops of unpaired bases.

The center loop has a set of three unpaired bases known as the "anticodon" (see next plate), which serves as a "recognition code" and assures that that particular tRNA is attracted only to a particular complementary set of three bases on the mRNA, known as a "codon." The unpaired bases on one of the other loops serve to attach the tRNA to the ribosome, and the bases on the third loop serve as a recognition code for the specific aminoaeryl-tRNA synthetase enzyme that attaches a particular amino acid to a particular tRNA molecule. The correct protein will be synthesized only if each of these recognition codes is correct.