

From DNA to RNA to Protein

Why do we need to store the genetic code in the polymer DNA?

After a cell divides, the offspring cells should have the same ability to produce the right proteins as the parent cell. A skin cell should be able to produce skin proteins, a hair follicle cell hair proteins. The linear polymer DNA with all the information about proteins can be easily duplicated in cell division.

How does it work?

To make new proteins, the living cell uses the genetic code of the macromolecule DNA, which stores all the information about the sequence of amino acids in the cell's proteins. The identity and position of each amino acid in the protein chain is coded by three consecutive nucleotides on the DNA, called **codons**. (DNA is made of four nucleotides, adenine, thymine, guanine and cytosine, abbreviated with letters A, T, G, C - the first letters of their names). Three nucleotides make a codon for an amino acid. A codon in the genetic code can be compared with a single letter in our human alphabet. These letters are combined in separate "words" - genes, each "remembering" the sequence of a specific protein.

A Dilemma For a long time scientists could not understand how it could happen that, after a cell divides, new cells end up with the same set of proteins, and therefore has also the same appearance and the same functions. They considered two possible scenarios:

1. Each protein copies itself, serving as a mold for its own copying.
2. There is a single genetic code (a blueprint) storing information about all cell's proteins. Before a cell divides, the code copies itself, and each offspring gets an exact copy of the code.

They argued a great deal about which scenario was correct. The first scenario assumes that protein molecules are copying themselves. This can happen if every amino acid in a protein chain can attract exactly the same amino acid, and then these attracted amino acids will connect into a new chain, a copy of the old one. But chemical analysis did not support this theory although positively charged amino acids can attract negatively charged (polar attract polar and non-polar attract non-polar), these attractions are not specific enough: a negatively charged amino acid, for example, can attract any positively charged amino acid.

Only recently have scientists finally proven that DNA in the cell nucleus carries all the information necessary to build all of the cell's proteins (about 70-80,000 in number!). The second scenario is correct. Before a cell divides into two, it makes two exact copies of DNA, one for each offspring. Then the DNA controls what proteins, in what amount, and when the cells must produce. The cell does it by opening for copying (i.e. reading the code) or closing a specific part of the DNA that controls a given protein. There are special proteins that do the "closing-opening" job. Therefore DNA in the cell nuclei, together with the regulatory proteins that open or close specific parts of it, serve as a kind of command and control center, responding to a cell's needs and to different outside signals brought by hormones or nervous impulses.

The genetic code is translated into a protein sequence with the help of several types of

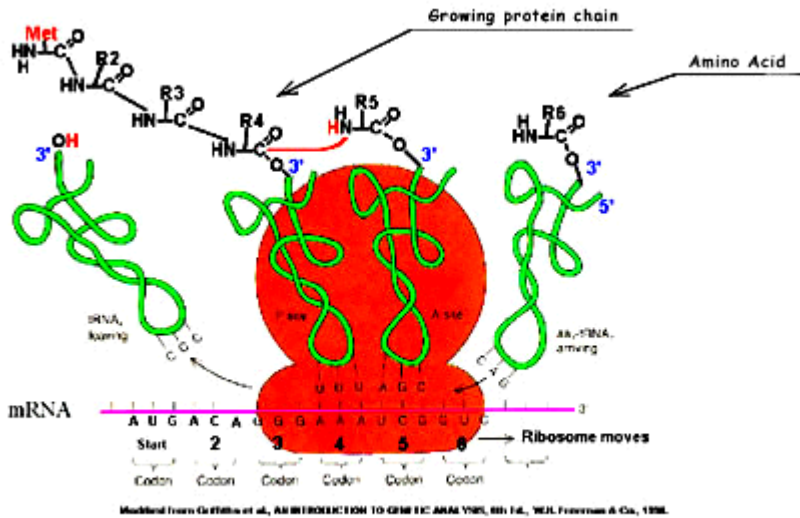


Fig. 1 Assembly of a protein on a ribosome

protein will be made. Such copy of a gene is another type of nucleic acid, called messenger RNA (mRNA).

The active gene is copied into mRNA with the help from an enzyme that works as a copying molecular machine. Then mRNA moves from the nucleus to the cytoplasm to work with the protein-assembling machine, called ribosome. The ribosome uses a blueprint of a protein, the mRNA (messenger RNA). (Think of this as if you need to make only one part of a car. There is no need to carry the entire blueprint of the whole car to the machine shop. Similarly, the entire DNA does not move from the nucleus; mRNA brings to the protein-making machine (ribosome) information about one particular protein that cell needs at that moment.)

Following the instruction brought by the mRNA, a ribosome assembles a protein. It works as an assembly line, moving along the mRNA, from codon to codon, requesting just one amino acid at a time from the pool of amino acids in the cell's cytoplasm, according to the codon that was "read" at that moment. Special carriers, called tRNA (transfer RNA), respond to the ribosome's request, adding the necessary part (amino acid) to the protein chain growing on the ribosome's assembly line (Fig. 1).

molecular machines working within the cell's nucleus and cytoplasm. First, DNA gets a signal, for example, from a hormone, that a cell needs a protein. Then the part of the DNA that controls this protein, called a gene, becomes active. Proteins that had been "hiding" the gene now allow the gene to be copied (transcribed) onto a messenger that carries information to the cytoplasm where the