Gene Concept

Gene, unit of hereditary information that occupies a fixed position (locus) on a chromosome. Genes achieve their effects by directing the synthesis of proteins.

In eukaryotes (such as animals, plants, and fungi), genes are contained within the cell nucleus. The mitochondria (in animals) and the chloroplasts (in plants) also contain small subsets of genes distinct from the genes found in the nucleus. In prokaryotes (organisms lacking a distinct nucleus, such as bacteria), genes are contained in a single chromosome that is free-floating in the cell cytoplasm. Many bacteria also contain plasmids—extrachromosomal genetic elements with a small number of genes.

Chemical structure of genes

Genes are composed of deoxyribonucleic acid (DNA), except in some viruses, which have genes consisting of a closely related compound called ribonucleic acid (RNA). A DNA molecule is composed of two chains of nucleotides that wind about each other to resemble a twisted ladder. The sides of the ladder are made up of sugars and phosphates, and the rungs are formed by bonded pairs of nitrogenous bases. These bases are adenine (A), guanine (G), cytosine (C), and thymine (T). An A on one chain bonds to a T on the other (thus forming an A–T ladder rung); similarly, a C on one chain bonds to a G on the other. If the bonds between the bases are broken, the two chains unwind, and free nucleotides within the cell attach themselves to the exposed bases of the now-separated chains. The free nucleotides line up along each chain according to the base-pairing rule—A bonds to T, C bonds to G. This process results in the creation of two identical DNA molecules from one original and is the method by which hereditary information is passed from one generation of cells to the next.

Gene Action:

The expression of genes by genetic transcription into complimentary RNA sequences and subsequent translation of hereditary information contained in mRNA into polypeptide chain which forms the ultimate product of gene action is called primary gene action.

The analysis beyond primary action of gene is greatly complicated by the integrated state of cellular and developmental metabolism, by the remoteness of the phenotype from the primary gene action and the number of intervening steps influenced by other genes (gene interaction) and by environmental factors (gene activation).

In prokaryotes the transcription and translation of genetic information occurs in one cell compartment whereas in eukaryotes the two processes are accomplished into two separate compartments of a cell, i.e., nucleus and cytoplasm. In addition, some genetic information (organelle DNA) is also present and utilized within certain cytoplasmic organelles particularly plastids and mitochondria.

One Gene One Polypeptide Concept

It is a fact that hereditary characters are maintained and transmitted from one generation to another through DNA molecules, because DNA can duplicate itself and duplicated molecules can be passed on to the off springs. The general activity of genes brings about expression of hereditary traits in the organism.

Now the main questions are as to how the genes (DNA molecules) govern the biosynthetic processes of the cells and how these genes control the phenotypic properties of the organisms. The answers to these basic questions were sought in the relationship between genes and specific biochemical reactions.

The heritable changes that geneticists first studied were necessarily those which could most easily be observed. An English physician, Sir Archibald Garrod, made penetrating study of some rare hereditary diseases in human and recognised that certain biochemical deficiencies were caused by enzymatic abnormalities. On the basis of his studies on congenital (existing from the birth) diseases of human.

Sir Garrod safely suggested relationship between genes and enzymes. The idea that the action of a gene is concerned with the formation of particular enzyme was ignored by most geneticists for some thirty years.

James B. Summer of Cornel University and John H. North Rop of Rockefeller Institute between 1926 and 1930 showed that enzymes are proteins. The idea about gene and enzyme relationship was revived by George W. Beadle and Edward L. Tatum (1941).

From the studies on heritable metabolic abnormalities of the fungus, *Neurospora crassa*, they concluded that all the intermediary biosynthetic steps of a metabolic process were governed by distinct genes. Beadle and Tatum formulated the one gene -one enzyme concept in 1944. The theory states that a gene exerts its influence on the phenotype through its role in the production of an enzyme.

Beadle and Tatum studied the genie action in *Neurospora crassa*. Normally the fungus can grow on minimal culture medium containing agar, sucrose, nitrate, inorganic minerals and the only vitamin biotin. This means that this organism can synthesize all other vitamins and amino-acids which are required in its metabolism.

When the conidia of this fungus are treated with mutagenic agents (say. X-ray), some of them become unable to grow on minimal medium.

These mutant spores are then tested systematically by adding particular vitamins, amino-acids, etc. to the minimal medium to determine what substance or substances they are unable to synthesize. The mutants can be crossed with normal or wild type and their products of meiosis, the 8 ascospores, may be individually tested for their nutritional requirements.

If an arginine requiring strain (a -) is crossed with normal strain (a +), all the 8 ascospores can grow in a medium containing arginine, but only 4 ascospores can grow in a medium lacking arginine. This indicates that a single gene has mutated.

The arginine requiring mutant may be more complex because, as shown in the following chain, arginine synthesis involves a chain of intermediate steps; each reaction is controlled by one gene. Three steps have been noted in the conversion of glutamic acid to arginine and each of them has been found to be controlled by one gene.

The mutation of a single gene leads to the suppression of one step. This can be demonstrated by growing mutant on minimal medium with that substance which cannot be synthesized. In

several biochemical studies, the extracts of neurospora have shown that tryptophan like arginine is synthesized in a sequence of chemical reactions.

Mutations in tryptophan require strains map at several genetic locations. Each mutant is defective in one of the steps in biosynthetic sequence. The mutation in a specific chromosomal region is reflected by the loss of activity of one enzyme. Thus, basic gene enzyme relationship is clear.

Recent researches have verified the basic conclusion about gene-enzyme relationship. Currently the Beadle and Tatum's concept of one gene-one enzyme has been revised to one gene-one polypeptide chain (protein) in view of the complexity in the structures and the functions of enzymes. The modem researches have proved that gene is DNA which is directly concerned with the synthesis of particular protein.

The operation of nuclear and extra-nuclear genomes is coordinated by some mechanism which is not yet fully understood. The genetic regulation of primary gene action in strict sense of the term occurs only at the level of transcription.

The whole series of biochemical processes which lead from a gene to the phenotypic expression by which it is recognised is referred to as gene action system (Waddington, 1962).

Gene has two essential functions:

(i) Replication or self-reproduction; and

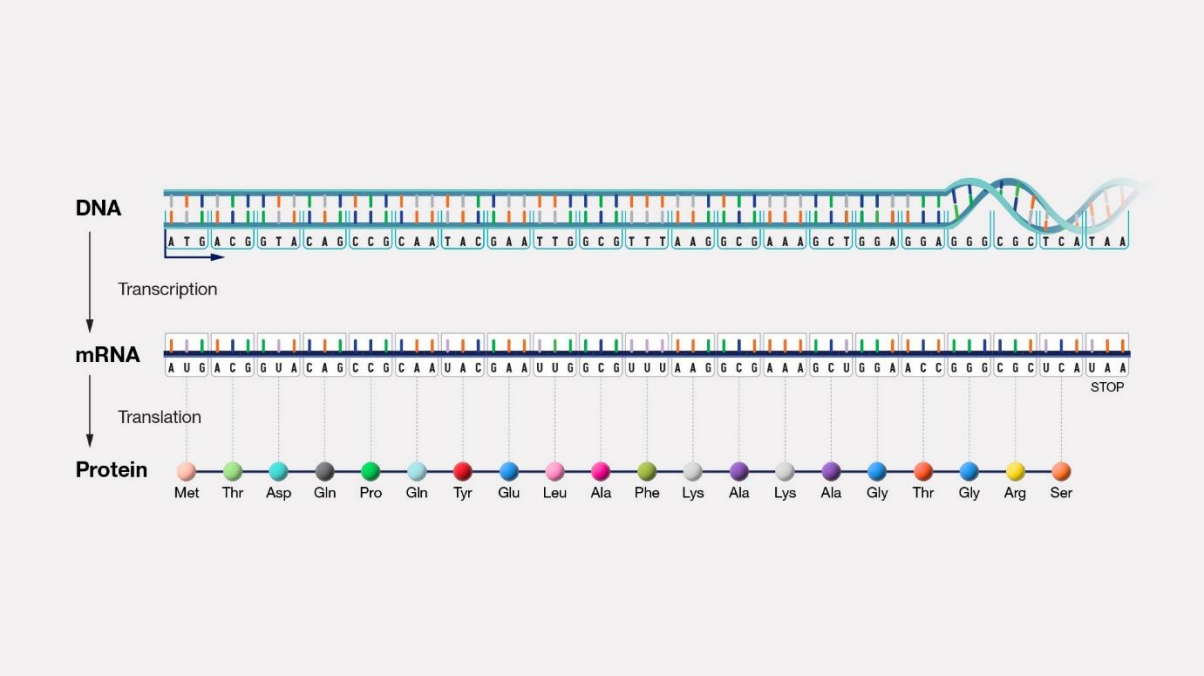
(ii) Intervention in mechanism by which the phenotype of organism is produced in a given environment (phenogenesis).

Central Dogma

The 'Central Dogma' is the process by which the instructions in DNA are converted into a functional product. It was first proposed in 1958 by Francis Crick, discoverer of the structure of DNA.

The concept of a sequence of interaction can be understood through the framework. The most common includes biopolymers. The major category of biopolymers include Proteins, RNA and DNA that are further divided into general transfers, unknown transfers, and special transfers.

Special transfers occur in an exceptional case in the laboratory. General transfer occurs in almost all cells. It describes the regular flow of information through transcription and translation. Unknown transfers are said never to occur.

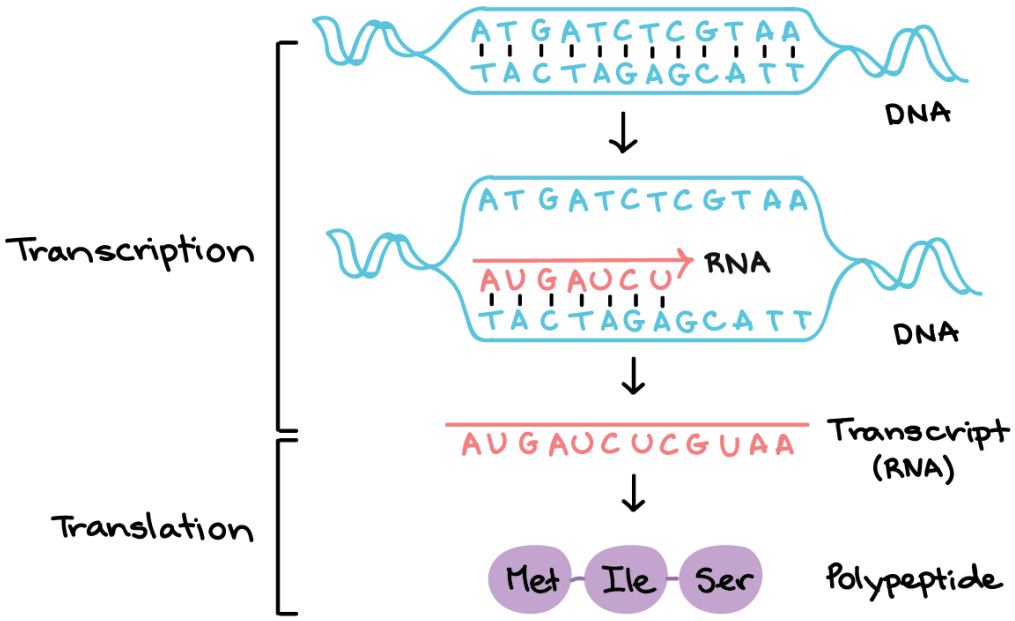


Creator: Darryl Leja

Transcription

Transcription, as related to genomics, is the process of making an RNA copy of a gene's DNA sequence. This copy, called messenger RNA (mRNA), carries the gene's protein information encoded in DNA. In humans and other complex organisms, mRNA moves from the cell nucleus to the cell cytoplasm (watery interior), where it is used for synthesizing the encoded protein.

Transcription is the first step in gene expression, in which information from a gene is used to construct a functional product such as a protein. The goal of transcription is to make a RNA copy of a gene's DNA sequence. For a protein-coding gene, the RNA copy, or **transcript**, carries the information needed to build a polypeptide (protein or protein subunit). Eukaryotic transcripts need to go through some processing steps before translation into proteins.



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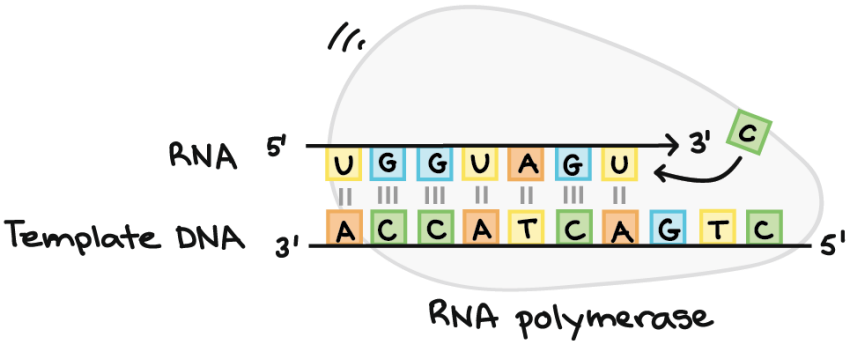
RNA polymerase

The main enzyme involved in transcription is **RNA polymerase**, which uses a single-stranded DNA template to synthesize a complementary strand of RNA. Specifically, RNA polymerase builds an RNA strand in the 5' to 3' direction, adding each new nucleotide to the 3' end of the strand.



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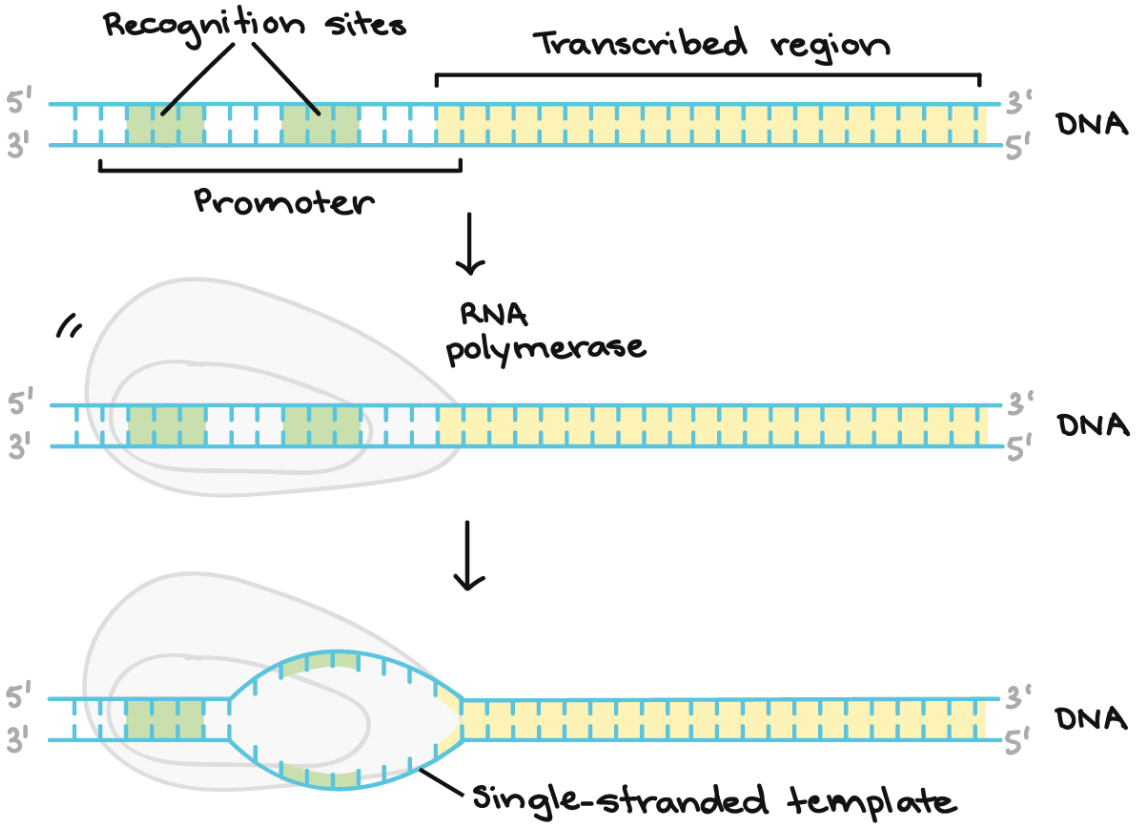
Stages of transcription

Transcription of a gene takes place in three stages: initiation, elongation, and termination. Here, we will briefly see how these steps happen in bacteria. You can learn more about the details of each stage (and about how eukaryotic transcription is different) in the stages of transcription article.

1. **Initiation.** RNA polymerase binds to a sequence of DNA called the **promoter**, found near the beginning of a gene. Each gene (or group of co-transcribed genes, in bacteria)

has its own promoter. Once bound, RNA polymerase separates the DNA strands, providing the single-stranded template needed for transcription.



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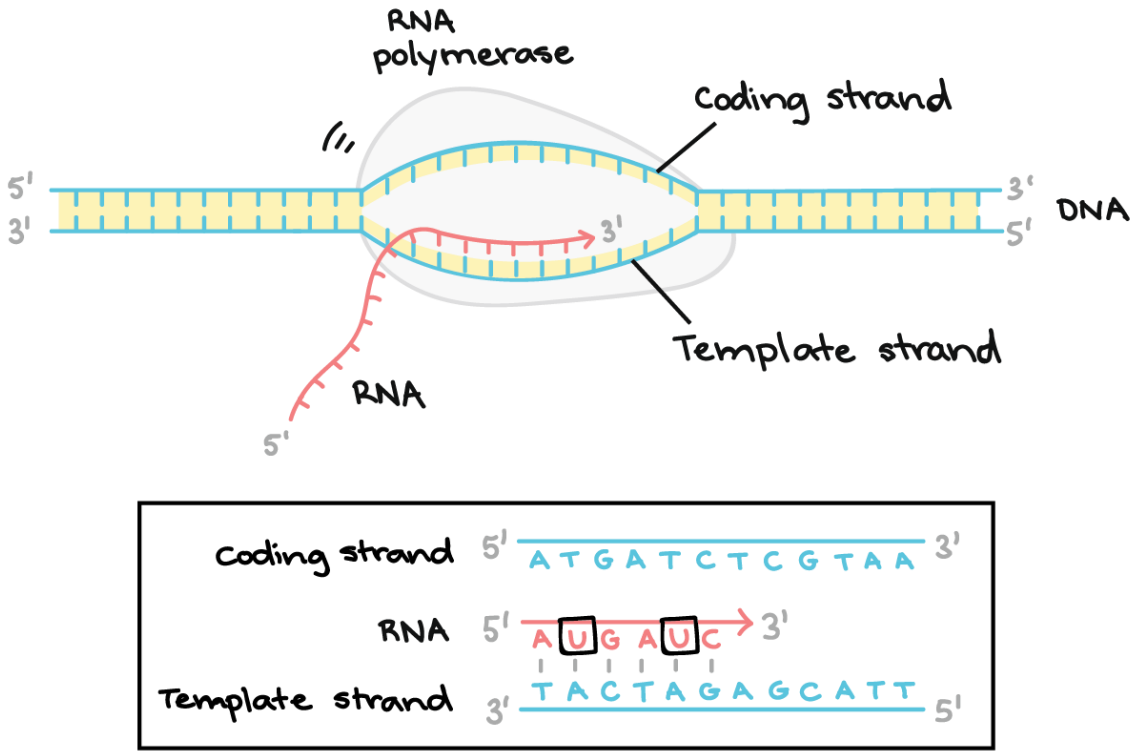
2. **Elongation.** One strand of DNA, the **template strand**, acts as a template for RNA polymerase. As it "reads" this template one base at a time, the polymerase builds an RNA molecule out of complementary nucleotides, making a chain that grows from 5' to 3'. The RNA transcript carries the same information as the non-template (**coding**) strand of DNA, but it contains the base uracil (U) instead of thymine (T).



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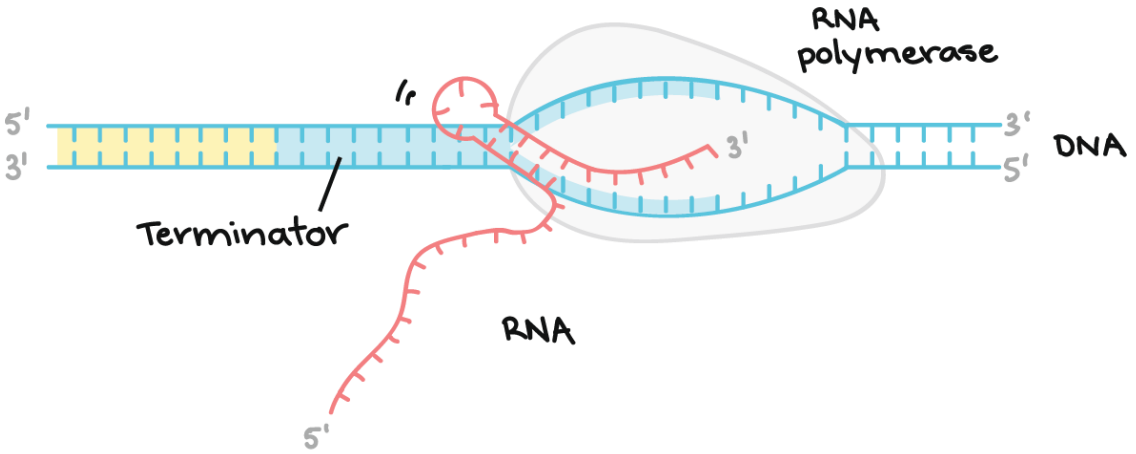
Termination. Sequences called **terminators** signal that the RNA transcript is complete. Once they are transcribed, they cause the transcript to be released from the RNA polymerase. An example of a termination mechanism involving formation of a hairpin in the RNA is shown below.



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Eukaryotic RNA modifications

In bacteria, RNA transcripts can act as **messenger RNAs** (**mRNAs**) right away. In eukaryotes, the transcript of a protein-coding gene is called a **pre-mRNA** and must go through extra processing before it can direct translation.

- Eukaryotic pre-mRNAs must have their ends modified, by addition of a **5' cap** (at the beginning) and **3' poly-A tail** (at the end).
- Many eukaryotic pre-mRNAs undergo **splicing**. In this process, parts of the pre-mRNA (called **introns**) are chopped out, and the remaining pieces (called **exons**) are stuck back together.
- End modifications increase the stability of the mRNA, while splicing gives the mRNA its correct sequence. (If the introns are not removed, they'll be translated along with the exons, producing a "gibberish" polypeptide.)