Genes

*The set of instructions, or code, that is responsible for all the inherited traits of an organism is held in **genetic material** called **DNA**.*

*A **gene** can be defined as a basic unit of hereditary information. It refers to a specific segment of DNA that influences a particular trait or group of traits.*

Inherited Traits & Genes

All of your inherited traits are the result of your genes. You received half of your genes from your mother and half from your father. In many other species, genes are passed to an offspring from one parent only.

The reason that half of the genetic information contained within a human comes from each parent is because of chromosome recombination during meiosis and fertilization. When a sperm cell fertilizes an egg cell, their nuclei fuse, and the 23 sets of chromosomes pair up. The resulting zygote has a new, full DNA sequence that is half from the mother and half from the father.

So, what is a gene? In general, a gene refers to a specific segment of an organism's DNA. The unique DNA code in that segment influences one or more traits of the organism.

Sometimes, a single gene can control a single trait. Sometimes, multiple genes work together to control a single trait. Sometimes, a single gene can influence many traits.

Organization of Genetic Material

It is important to know how genetic material is organized. A gene is one "piece" of a DNA molecule. A molecule of DNA is "packaged" and carried by a larger structure called a **chromosome**. The **genome** of an organism refers to its complete genetic makeup and includes the organism's entire set of chromosomes. A human has a total of 46 chromosomes: 23 chromosomes come from the mother and 23 come from the father.

Homologous Pairs

In the cells of a sexually-reproducing organism, a pair of similar chromosomes with the same genes in the same locations is known as a homologous pair. This means that every normal human body cell contains a 22 homologous pairs of **autosomal chromosomes** and 1 pair of sex chromosomes.

Homologous pairs are found in diploid cells. Each member of the pair was received from one of the organism's parents.

The genes on a pair of homologous chromosomes often have alternate forms, or alleles, which influence the organism's traits.

Sex Determination

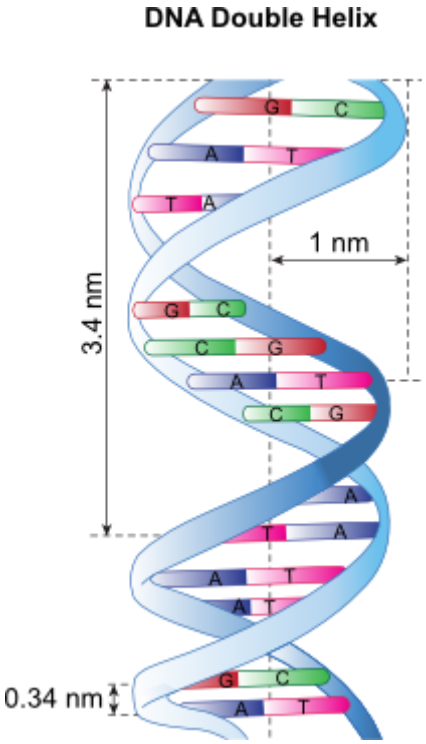
An individual's sex is determined by its combination of sex chromosomes. Females have two X chromosomes (XX), and males have an X chromosome and a Y chromosome (XY).

DNA

*DNA, or **deoxyribonucleic acid**, is a type of nucleic acid that contains genetic information. This information provides instructions for an organism's development and growth, and it is passed from generation to generation.*

DNA Structure

DNA is composed of two nucleotide chains wound together into a double helix.



Each nucleotide consists of:

- a five carbon sugar (deoxyribose)
- a nitrogenous base (adenine, cytosine, guanine, or thymine)
- a phosphate group

The two DNA strands are held together by hydrogen bonds between specific pairs of nucleic acids. Adenine (A) only bonds with thymine (T), and cytosine (C) only bonds with guanine (G). These pairings are known as complementary bases.

DNA molecules are different from one another because they contain a unique sequence of nucleotides. Even though there are only four nitrogenous bases, these bases can be ordered in innumerable ways. In fact, no two organisms possess the exact same DNA sequences in their cells.

DNA can be divided into small segments known as **genes**. Genes can influence a single trait or multiple traits. DNA, along with its associated proteins, can also be organized into larger molecules known as **chromosomes**. An organism's complete genetic makeup, including its entire set of chromosomes, is known as its **genome**.

DNA Replication

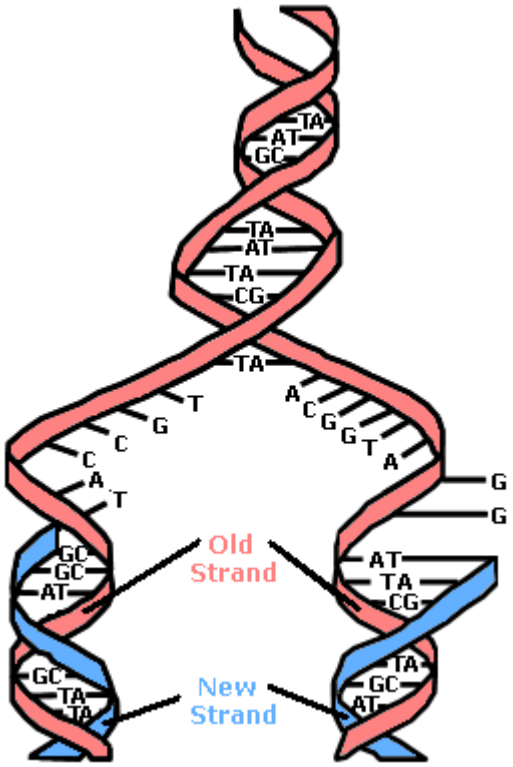
DNA replication *begins when enzymes unwind and separate the two strands of the molecule. Each strand serves as a template for polymerases to add complementary nucleotides (A-T and C-G). The process results in two identical DNA molecules.*

During DNA replication...

- The two original strands of DNA are separated with the help of enzymes known as *DNA helicases*. Helicases work by breaking the hydrogen bonds holding the nucleotide bases together.

- Enzymes known as *DNA polymerases* add complementary nucleotides to each strand. Adenine bonds with thymine, and cytosine bonds with guanine.

- Two DNA molecules, which are identical to the original DNA molecule, form. Each newly formed DNA molecule consists of two strands of DNA, one from the parent molecule and one built from scratch using the parent molecule as a template.



DNA Replication is said to be *semi-conservative*. Each copy contains one newly-replicated strand and one strand from the original molecule.

The process of DNA replication is biologically significant because it allows the cells of living organisms to copy their DNA before cell division.

Gene Expression

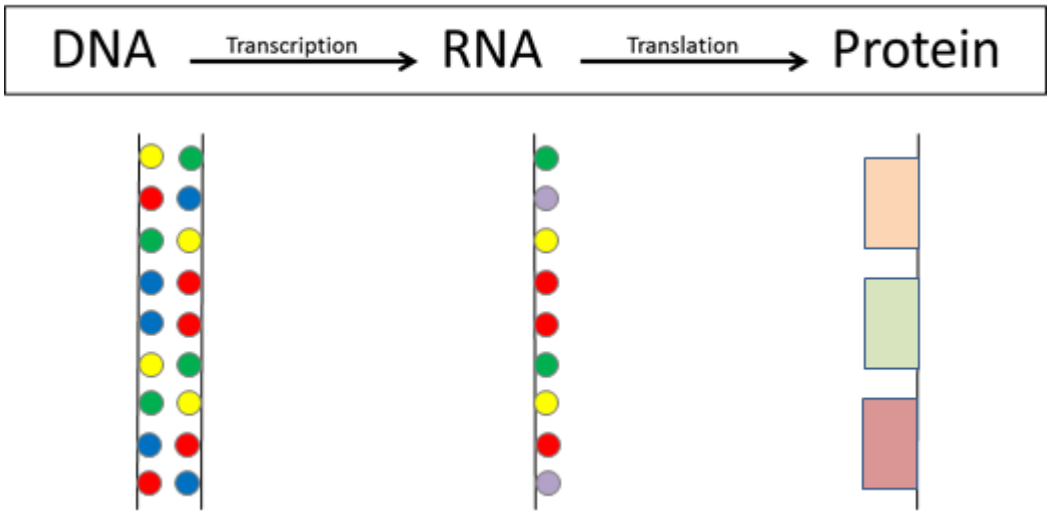
*The genetic information that is passed from a parent to its offspring is found in **DNA** molecules. Segments of DNA known as **genes** code for the production of **proteins**. These proteins cause specific **traits** to be expressed.*

Two main processes are involved in gene expression - transcription and translation.

- During **transcription**, DNA in the nucleus of a cell is copied into messenger RNA, or mRNA, molecules.

- The mRNA then moves into the cell's cytoplasm and attaches to a ribosome, where it is **translated** into proteins.

Central Dogma



Once DNA is transcribed into mRNA and translated into a protein, the process cannot be reversed. That is, information cannot be transferred from the protein back to the nucleic acid. This is known as the central dogma of molecular biology.

Transcription

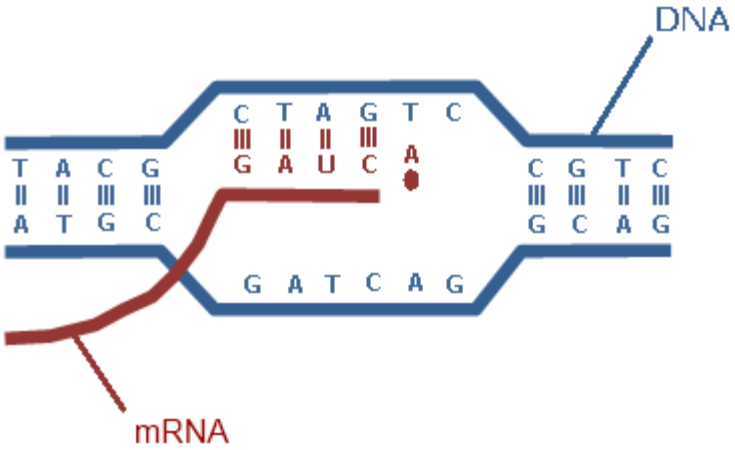
The sequence of the nucleotides within a strand of DNA provides the genetic instructions needed to construct proteins. In order to express these proteins, a segment of DNA must first be transcribed, or copied, to a complementary strand of messenger RNA (mRNA).

Three processes occur during transcription:

- **Initiation** - Enzymes bind to a DNA sequence and unzip the molecule.

- **Elongation** - As the molecule unzips, RNA nucleotides pair to complementary DNA nucleotides on one of the DNA strands. For example, if the DNA strand reads AGT, the new RNA strand would read UCA.

- **Termination** - Once base pairing is complete, the new RNA molecule (mRNA) breaks away from the DNA strands and the DNA strands re-attach.



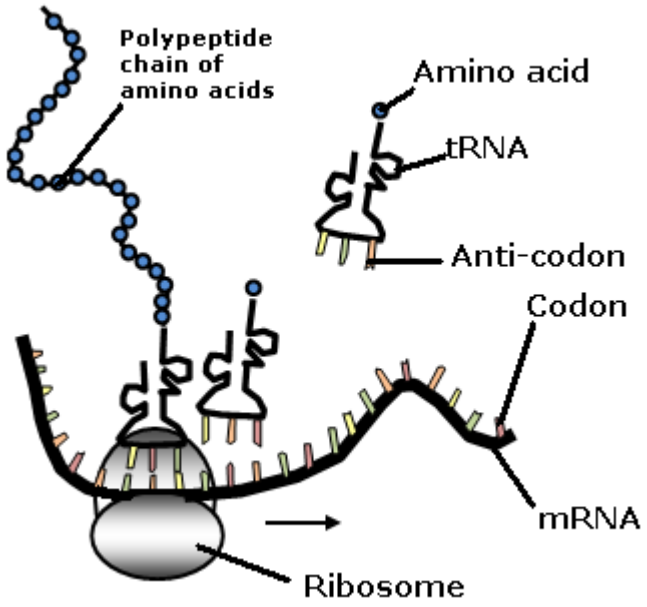
The process of transcription occurs in the nucleus of a cell, but the mRNA that is created travels into the cytoplasm once it is made.

Translation

During transcription, segments of DNA are copied to a complementary strand of messenger RNA, or mRNA. ***Translation*** *is the process through which amino acids that correspond to codons, or triplet nucleotide sequences, in the mRNA molecules are joined together to form functional proteins.*

During translation...

- A codon on the mRNA molecule attaches to a ribosome.
- Then, transfer RNA, or tRNA, molecules, carrying specific amino acids, approach the ribosome.
- The tRNA molecule that corresponds to the codon (called the tRNA anticodon) attaches to the mRNA codon.
- The ribosome slides to the next codon on the mRNA molecule and repeats the process.
- As amino acids are added next to each other, peptide bonds link the amino acids together.
- The chain of amino acids continues to grow until the ribosome reaches a stop codon on the mRNA strand. This signals that no more amino acids should be added, and the protein is complete.

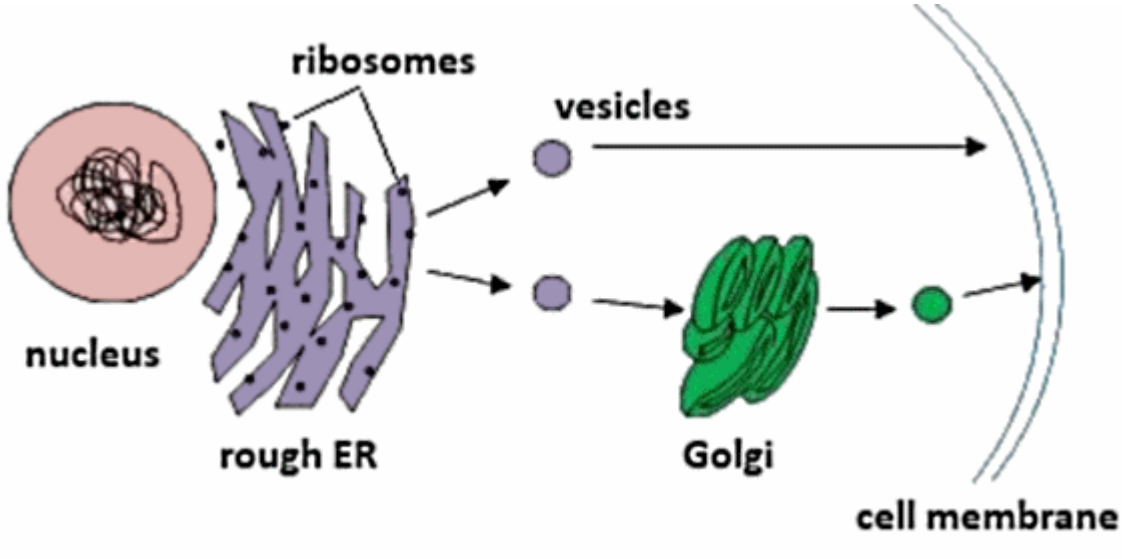


Protein Synthesis - Organelles

Protein synthesis starts with the transcription of mRNA from DNA in the nucleus.

Organelle Interactions During Protein Synthesis

Beginning with the transcription of messenger RNA in the nucleus, protein synthesis involves many cellular structures, including: ribosomes, the endoplasmic reticulum, and the Golgi apparatus.



Many proteins are synthesized by ribosomes located on the rough ER. Some of these proteins continue to the Golgi apparatus where they are packaged and sorted.

Some proteins also involve other organelles. For example, the heme portion of hemoglobin is manufactured in mitochondria.

Ribosomes and Protein Synthesis

The translation of mRNA to a polypeptide chain takes place on ribosomes.

The nucleus is the location where the portion of DNA that codes for a specific protein is transcribed into messenger RNA. After the mRNA leaves the nucleus, it is delivered to a ribosome in the cytoplasm.

Translation of the protein takes place on the ribosome. At the end of translation, the protein has completed the primary structure, which is simply a polypeptide chain that will still undergo folding and other possible modifications.

Endoplasmic Reticulum and Protein Synthesis

The endoplasmic reticulum aids in transporting proteins out of the cell or to other organelles within the cell.

Some proteins are synthesized by ribosomes found on the *rough* portion of the endoplasmic reticulum. The term rough refers to its appearance due to the attachment of ribosomes. The proteins made here are destined for other organelles or to be secreted by the cell.

The endoplasmic reticulum also plays a part in the folding and modification of some proteins. The ER aids in the creation of disulfide bonds, which provide stability to the structure of the protein, and glycosolation, which attaches carbohydrates to proteins.

Golgi Apparatus and Protein Synthesis

The Golgi apparatus is responsible for sorting, modifying, and packaging proteins.

The Golgi apparatus works closely with the rough ER. It receives proteins synthesized by ribosomes on the endoplasmic reticulum. These proteins sometimes undergo further modifications. Phosphorylation, or the addition of phosphates, to some proteins occurs here. Glycosolation also continues in the Golgi.

The Golgi plays an important role in sorting and tagging proteins which aid in their transportation to the correct location.