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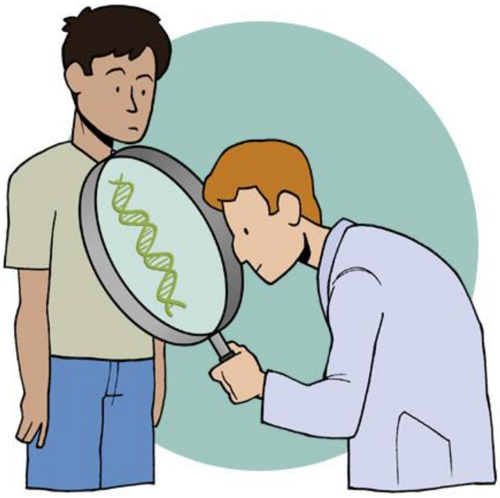
Basic of genetics



Introduction to Genetics

- **Definition: Genetics** is the study of heredity and variation in living organisms.
- Importance: Explains how traits are inherited, basis of evolution, medical
- genetics, agriculture, and biotechnology.

Historical Background

- Gregor Mendel – Father of Genetics (pea plant experiments).
- Discovery of DNA (Watson & Crick, 1953).
- Human Genome Project (2003).

3. Key Concepts in Genetics

- **Gene**: The basic unit of heredity passed from parent to child. Genes are made up of sequences of DNA and are arranged, one after another, at specific locations on chromosomes in the nucleus of cells.
- **DNA**: (deoxyribonucleic acid) is the hereditary material in humans and most other organisms. It is composed of four chemical bases/letters called adenine (A), guanine (G), cytosine (C) and thymine (T). The human genome is made of over 3 million letters of DNA. These letters are arranged in various sequences and length to make up genes.

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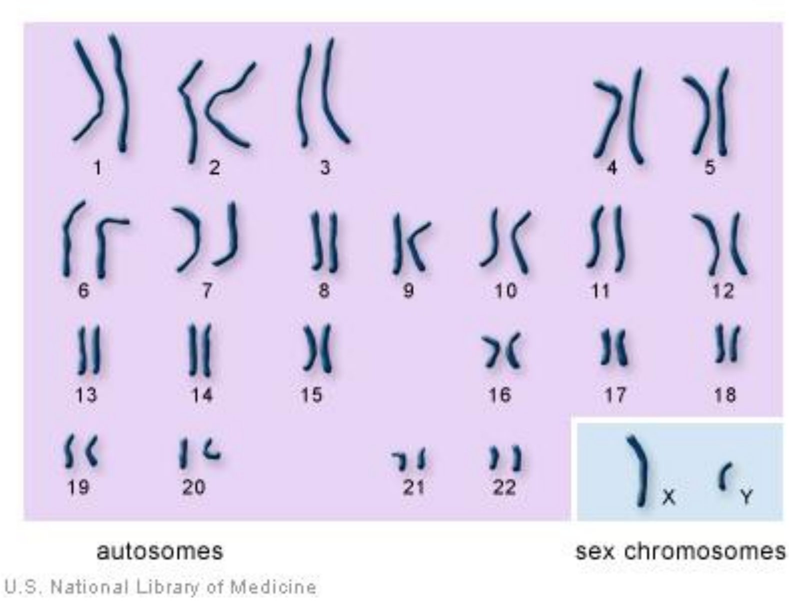

- **Chromosome**: the center of each cell is the nucleus—the control center of each cell. Within the nucleus, you'll find structures called chromosomes. Our chromosomes are made up of proteins and DNA (deoxyribonucleic acid).[1] Except for sperm and egg cells, every cell in a human body normally has 23 pairs of chromosomes (for a total of 46). You inherit one set of 23 chromosomes from your mother and the other 23 from your father.

a compact, thread-like structure of DNA and proteins found in the nucleus of cells, carrying genes that determine an organism's traits. These long DNA molecules are tightly coiled around proteins, like histones, to fit within the cell. During cell division, this packed structure becomes visible and ensures that the genetic information is accurately copied and passed on to new cells

- **Proteins** are large, complex molecules that play many critical roles in the body. They do most of the work in cells and are required for the structure, function, and regulation of the body's tissues and organs.
- **Proteins** are made up of hundreds or thousands of smaller units called amino acids, which are attached to one another in long chains. There are 20 different types of amino acids that can be combined to make a protein. The sequence of amino acids determines each protein's unique 3-dimensional structure and its specific function. Amino acids are coded by combinations of three DNA building blocks (nucleotides), determined by the sequence of genes.

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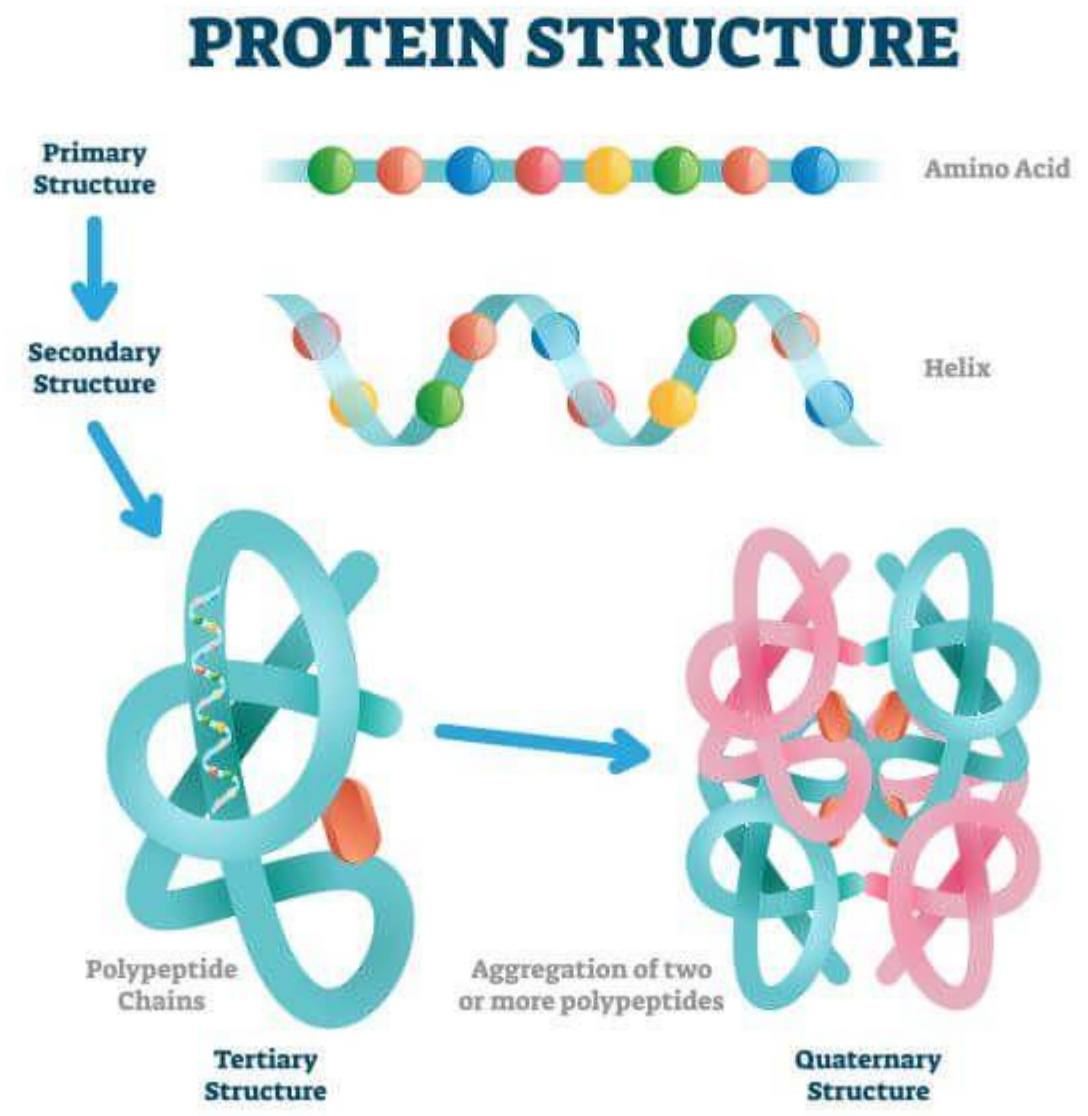

Levels of protein structure

1-2 Basics of molecular biology

Introduction

- Molecular genetics: study of the structure and function of genes at a molecular level.
- Combines **molecular biology** + **genetics**.
- Explains how genetic information is stored, replicated, expressed, and regulated.

Structure of DNA

- Double helix model (Watson & Crick, 1953).
- Components: sugar-phosphate backbone + nitrogenous bases (A, T, G, C).
- Base-pairing rule: A–T, G–C.
- Antiparallel strands, complementary base pairing.

Gene and Genetic Code

- Gene: sequence of DNA coding for RNA/protein.
- Central Dogma (Francis Crick, 1958):
  DNA → RNA → Protein.
- Genetic code: triplet codons, universal, degenerate, non-overlapping.

Transcription (DNA → RNA)

- RNA polymerase synthesizes RNA from DNA template.
- Stages: Initiation, elongation, termination.
- Types of RNA: mRNA, tRNA, rRNA, snRNA, miRNA.

Translation (RNA → Protein)

- mRNA carries codons, tRNA brings amino acids.
- Ribosome catalyzes peptide bond formation.
- Initiation, elongation, termination phases.

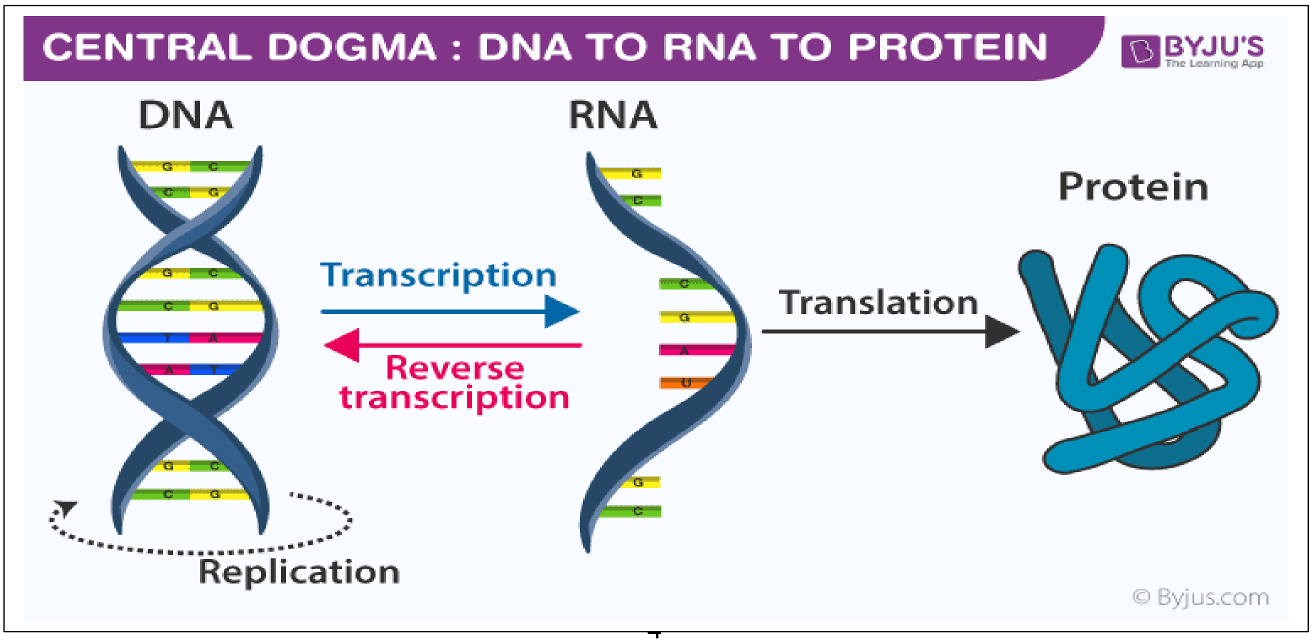

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Figure 1.2. (The central dogma of molecular biology).

1-3 Some characteristics of the human DNA

The proteins coded by the DNA in our cells determine the structures and functions of the cells. If there is a mutation in the DNA, it can change the structure and function of the protein, which can have consequences on the function of the cell and can lead to diseases. Let's see the structure of the DNA in our cells. The backbone of the DNA strand is made from alternating phosphate and sugar residues (Figure 1.3). The sugar in DNA is 2-deoxyribose, which is a pentose (five-carbon) sugar. The sugars are joined together by phosphate groups that form phosphodiester bonds between the third and fifth carbon atoms of adjacent sugar rings. These asymmetric bonds mean a strand of DNA has a direction. In a double helix the direction of the nucleotides in one strand is opposite to their direction in the other strand: the strands are antiparallel.

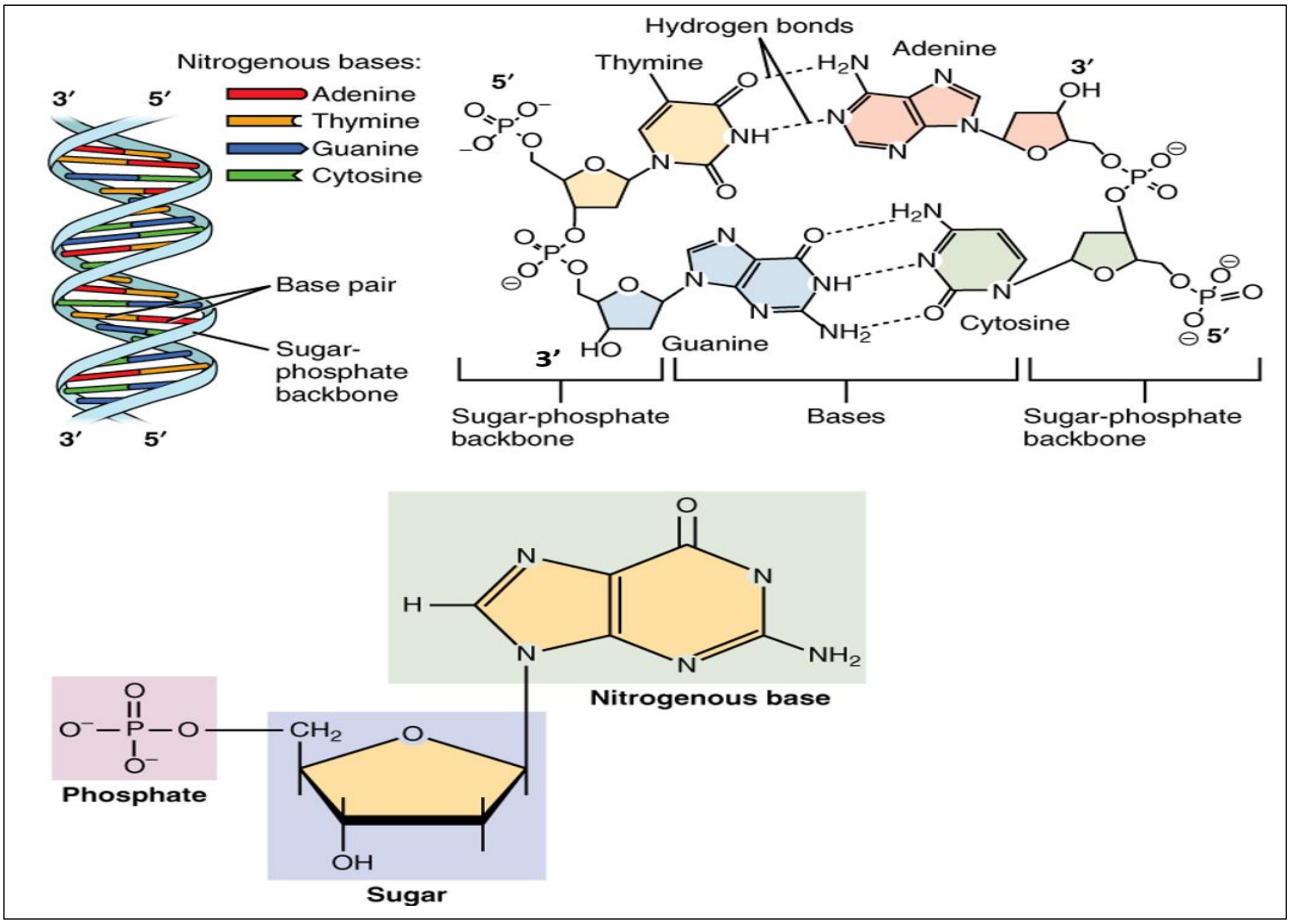

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Figure 1.3 (The backbone of the DNA structure)

The asymmetric ends of DNA strands are called the 5′ (five prime) and 3′ (three prime) ends, with the 5′ end having a terminal phosphate group and the 3′ end a terminal hydroxyl group. One major difference between DNA and RNA is the sugar, with the 2-deoxyribose in DNA being replaced by the alternative pentose sugar ribose in RNA. The four bases found in DNA are adenine (abbreviated A), cytosine(C), guanine (G) and thymine (T). These four bases are attached to the sugar/phosphate to form the complete nucleotide, as shown for adenosine monophosphate. The nucleobases are classified into two types: the purines, A and G, being fused five- and six-membered heterocyclic compounds, and the pyrimidines, the six-membered rings C and T. A fifth pyrimidine nucleobase, uracil (U), usually takes the place of thymine in RNA and differs from thymine by lacking a methyl group on its ring. Uracil is not usually found in DNA, occurring only as a breakdown product of cytosine.

Mitochondrial DNA (mtDNA)

Introduction

- Mitochondria = “powerhouse of the cell.”
- Contain their own DNA separate from nuclear DNA.
- mtDNA plays a vital role in energy production and heredity

i3. Unique Features of mtDNA

- **Maternal inheritance** (passed from mother to offspring).
- High copy number per cell (hundreds to thousands).
- Lacks protective histones.
- Limited DNA repair → higher mutation rate compared to nuclear DNA.

Functions of mtDNA

- Encodes proteins essential for **oxidative phosphorylation (OXPHOS)**.
- Works with nuclear DNA to produce ATP.
- Involved in apoptosis (programmed cell death).

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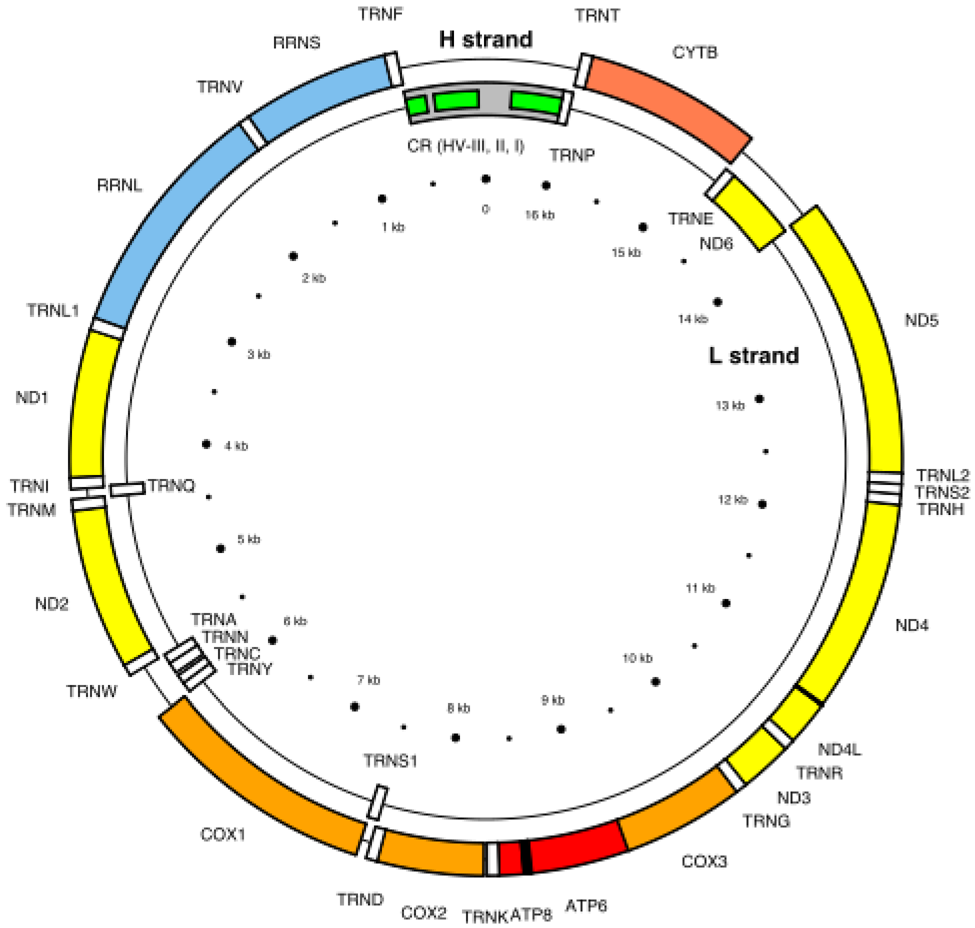
Mitochondrial vs. Nuclear DNA



Similar to the nuclear genome, the mitochondrial genome is built of double-stranded DNA, and it encodes genes). However,

the mitochondrial genome differs from the nuclear genome in several ways (Taylor & Turnbull, 2005). Many interesting features distinguish human mitochondrial DNA from its nuclear counterpart, including the following:

- The mitochondrial genome is circular, whereas the nuclear genome is linear (Figure
- The mitochondrial genome is built of 16,569 DNA base pairs, whereas the nuclear genome is made of 3.3 billion DNA base pairs.
- The mitochondrial genome contains 37 genes that encode 13 proteins, 22 tRNAs, and 2 rRNAs.
- The 13 mitochondrial gene-encoded proteins all instruct cells to produce protein subunits of the enzyme complexes of the oxidative phosphorylation system, which enables mitochondria to act as the powerhouses of our cells.

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- The small mitochondrial genome is not able to independently produce all of the proteins needed for functionality; thus, mitochondria rely heavily on imported nuclear gene products.
- One mitochondrion contains dozens of copies of its mitochondrial genome. In addition, each cell contains numerous mitochondria. Therefore, a given cell can contain several thousand copies of its mitochondrial genome, but only one copy of its nuclear genome.

Feature	Mitochondrial DNA (mtDNA)	Nuclear DNA (nDNA)
Location	Inside mitochondria	Inside nucleus
Structure	Circular, double-stranded	Linear, double-stranded
Size	Small (~16,500 base pairs in humans)	Very large (~3.2 billion base pairs in humans)
Gene content	Encodes 37 genes (13 for proteins, 22 tRNAs, 2 rRNAs)	Encodes ~20,000–25,000 genes
Inheritance	Maternal (passed from mother only)	Biparental (inherited from both parents)
Copy number per cell	Many copies (hundreds–thousands per cell)	Typically 2 copies per cell (diploid, except sex chromosomes)
Histones	No histones (DNA is not packaged with histone proteins)	Wrapped around histones to form chromatin
Mutation rate	Higher (due to exposure to reactive oxygen species and less efficient repair)	Lower (better repair mechanisms)
Function of genes	Mainly code for proteins involved in oxidative phosphorylation (energy production)	Code for nearly all proteins needed by the cell (structural, enzymatic, regulatory, etc.)
Replication & Transcription	Independent of cell cycle (replicates continuously)	Replication and transcription tightly regulated with cell cycle