InstaDeep™

Introduction to Immunology: Unveiling the Body's Defense System

Plan

I. Immunology

II. Immune System

III. Homeostasis

IV. Lymphatic System

V. Types of Pathogens

VI. Protein, DNA & Viruses

VII. Immunology Buzzwords

VIII. Types of Immune Systems

IX. Dysfunctions of the Immune System

Immunology

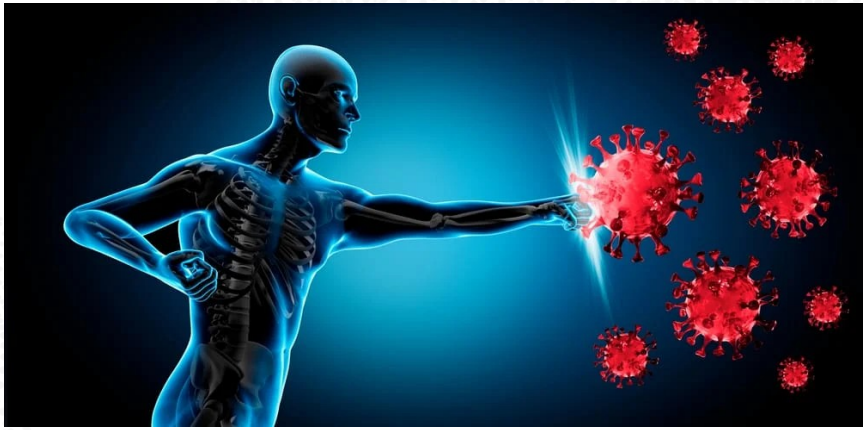
Immunology

- Immunology is the scientific study of the immune system and its functions.
- It explores how the body defends itself against pathogens, foreign substances, and abnormal cells.
- Immunology investigates the structure, function, and regulation of the immune system.
- Immunology is crucial for understanding mechanisms of immune responses, developing vaccines, immunotherapies, and treating immune-related diseases such as autoimmune disorders, allergies, and cancer treatment.

Immune system

Immune system

The immune system is a complex network of cells, tissues, and organs that work together to protect the body from infections and maintain health.



The different **functions** of the immune system:

- **Defense Against Pathogens:**
  It recognizes and eliminates them to prevent infections and disease.

- **Immune Surveillance:**
  The immune system constantly monitors the body for abnormal cells.

Immune system

- **Immune Memory:**
  Following exposure to pathogens or vaccines, the immune system can develop immunological memory.
  This memory allows the immune system to mount faster and more effective responses upon re-exposure

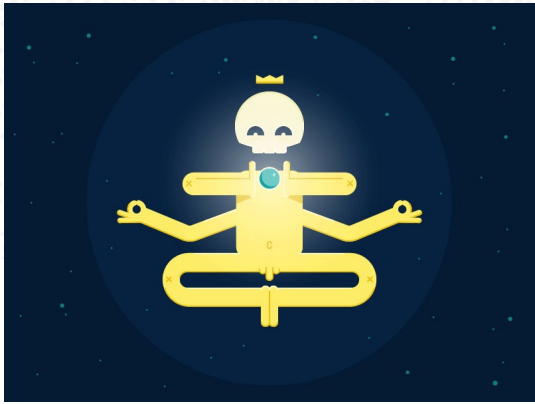
- **Tissue Repair and Healing:**
  In response to tissue damage or injury, the immune system initiates inflammatory responses that promote tissue repair and healing

- **Maintenance of Homeostasis:**
  The immune system plays a crucial role in maintaining homeostasis.

Homeostasis

Homeostasis

Homeostasis refers to the maintenance of a balanced and regulated immune system.
It involves the delicate control of immune responses to ensure that they effectively protect the body from pathogens while avoiding excessive inflammation, tissue damage, or autoimmune reactions.



Homeostasis encompasses several **key aspects**:

- **Immune Cell Balance:**
  The immune system maintains an appropriate balance of different types of immune cells

- **Tolerance to Self-Antigens**
  is the maintenance of tolerance to self-antigens, ensuring that the immune system does not attack the body's own tissues and prevent autoimmune reactions

Homeostasis

- **Control of Inflammation**

- **Microbiota Balance:**
  The gut microbiota and other commensal microorganisms play crucial roles in immune homeostasis by regulating immune development, function, and tolerance.

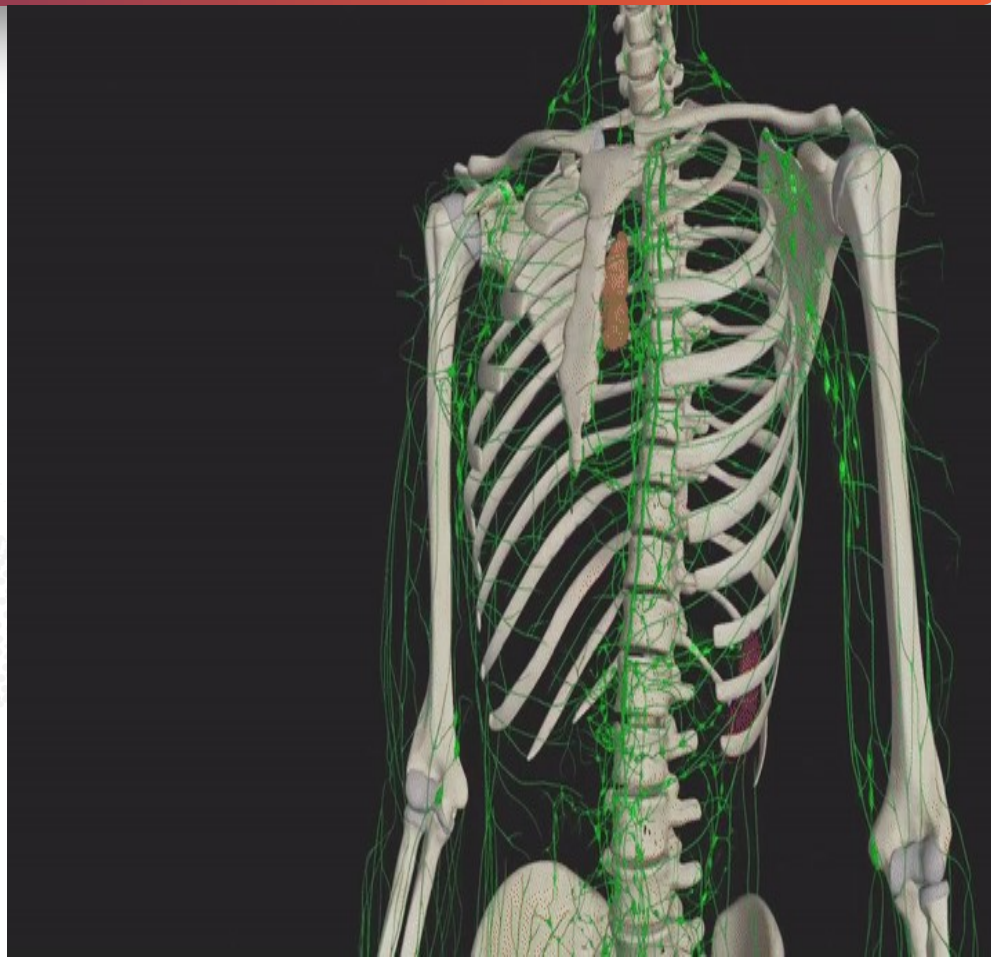
=> Immune **homeostasis** is essential for the proper functioning of the immune system, ensuring effective **protection** against pathogens while preventing **inappropriate immune responses** that could lead to autoimmune diseases, chronic inflammation, or tissue damage.

Lymphatic system

Lymphatic system

- The lymphatic system is a network of **vessels**, **tissues**, and **organs** that work together to maintain fluid balance, remove waste products from tissues, and mount immune responses against infections.

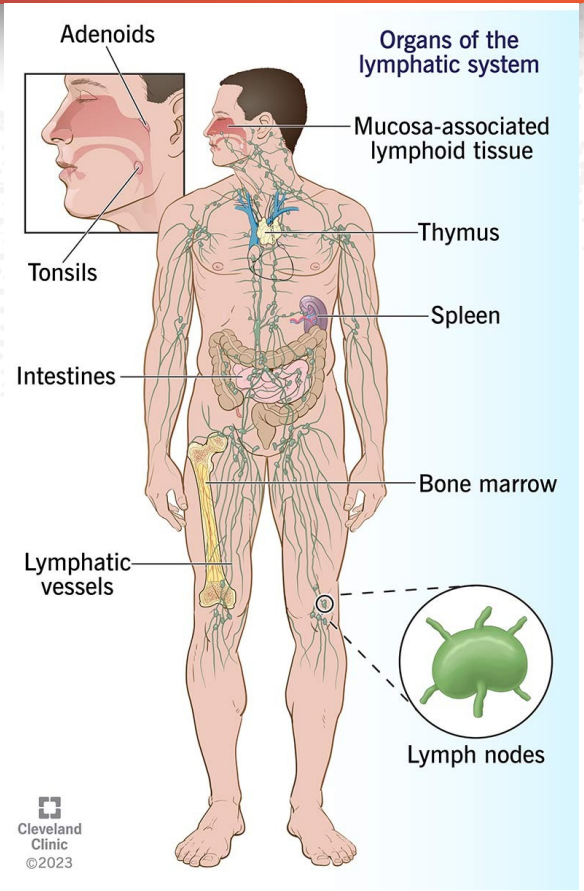
- It plays a crucial role in the body's immune system, serving as a conduit for the **transport** of **immune cells, antigens and lymphatic fluid** throughout the body



Lymphatic system

Key components of the lymphatic system:

- Lymphatic Vessels
- Lymph Nodes
- Spleen
- Thymus (maturation of **T cells)**
- Bone Marrow (maturation of **B cells)**
- Mucosa-Associated Lymphoid Tissues (MALT):
  located in mucosal surfaces throughout the body, such as the gastrointestinal tract, respiratory tract and genitourinary tract.It plays a crucial role in mucosal immunity.



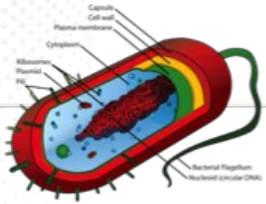
Types of Pathogens

Types of Pathogens

Pathogens that can attack the immune system include:

- **Fungi:** Microorganisms such as yeasts and molds that can cause fungal infections (mycoses) in humans such as Candida albicans
- **Parasites:** Organisms that live on or inside a host organism and obtain nutrients at the host's expense.
- **Prions:** Abnormal, misfolded proteins that can cause infectious diseases
- **Bacteria:** Single-celled microorganisms that can cause infections by invading tissues and releasing toxins such as E-coli.
- **Viruses:** Infectious agents consisting of genetic material (DNA or RNA) enclosed in a protein coat.
  Viruses replicate inside host cells and can cause a wide range of diseases, including the common cold, influenza, HIV/AIDS, and COVID-19.

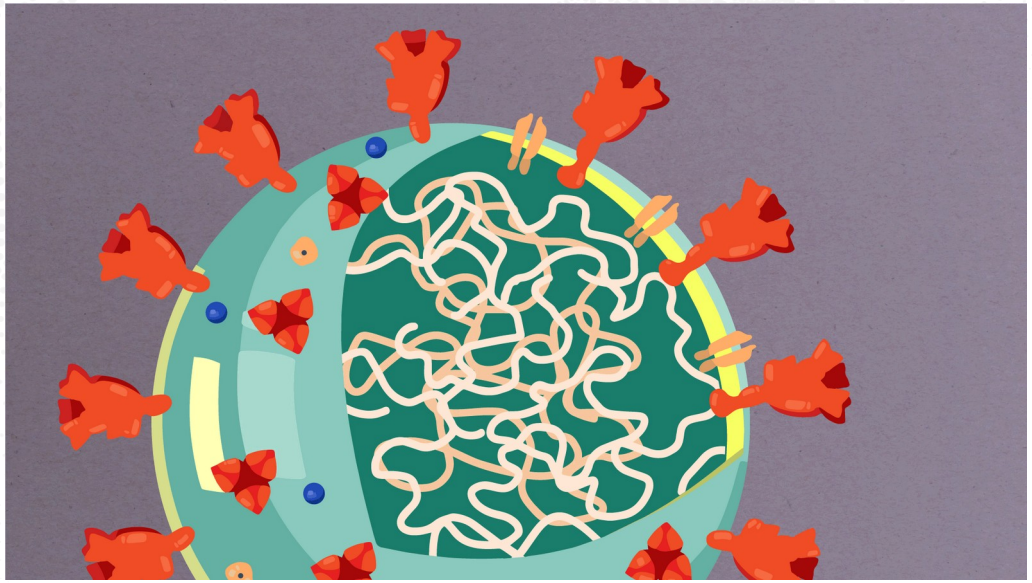
Types of Pathogens

	BACTERIA	VIRUSES
LIVING?	Living organism	Nonliving
NUMBER OF CELLS	Unicellular; one cell	No cells; not living
TREATMENT	Antibiotics	Vaccines prevent the spread and antiviral medications help to slow reproduction but cannot stop it completely.
INFECTION	Localized area of body	Systemic - can affect entire body
BENEFITS	Some bacteria are beneficial (e.g. certain bacteria are required in the gut)	Viruses are NOT beneficial. However, a particular virus may be able to destroy brain tumors (see references). Viruses can be useful in genetic engineering.
REPRODUCTION	Splits into 2 	Invades a host cell and takes over the cell causing it to make copies of the viral DNA/RNA. Destroys the host cell releasing new viruses.
SIZE	Larger	Super tiny 

Proteins & DNA & Viruses

ProteinS & DNA & Viruses

As proteins are the building blocks of DNA and amino acids are the building blocks of protein, we better start understanding the amino acids then the proteins and finally the DNA and how the viruses do manipulate it to mess with our immunity



ProteinS & DNA & Viruses

1. Amino acids
2. Proteins
3. Genetic Information
4. Viruses

Amino Acids

Amino Acids

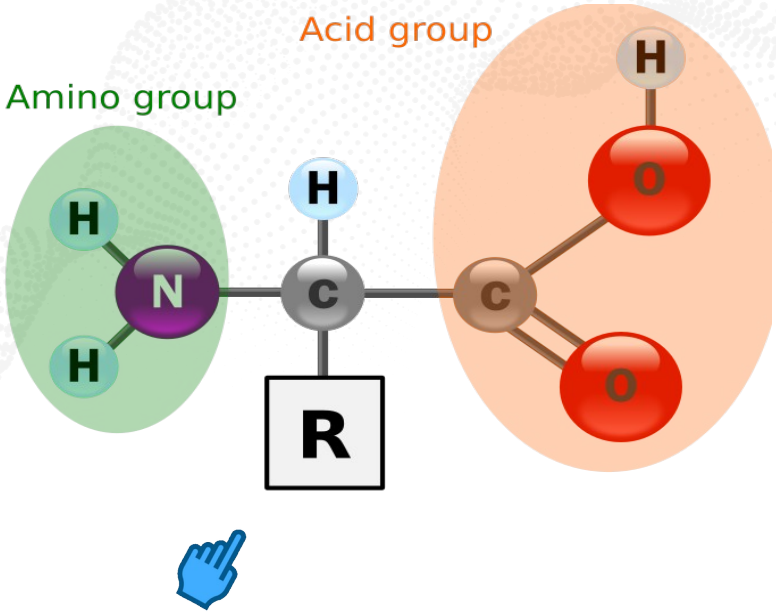
1. Amino Acid Structure

2. How Amino Acids are linked together

Amino Acids

1. Amino Acid Structure

- Amino acids are the monomers (building blocks of proteins)
- Are composed of:
  - The amino group (−NH2)
  - The acidic group (—COOH),
  - The alpha carbon (central carbon)
  - There's the variable group, also known as the **R group**, which varies among different amino acids.

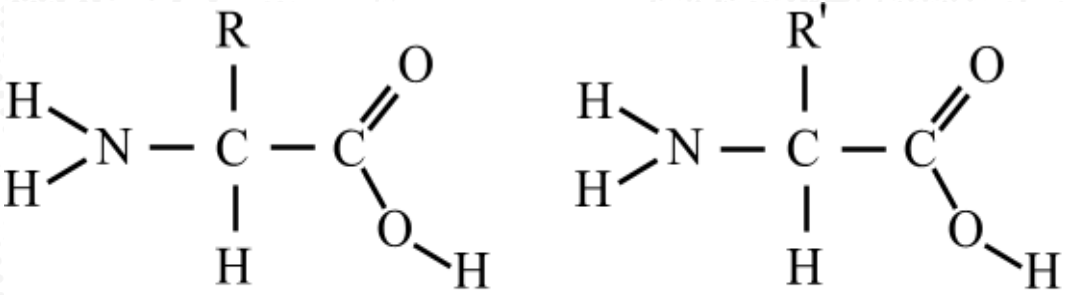


The variable group **determines the function and properties of the amino acid**.

Amino Acids

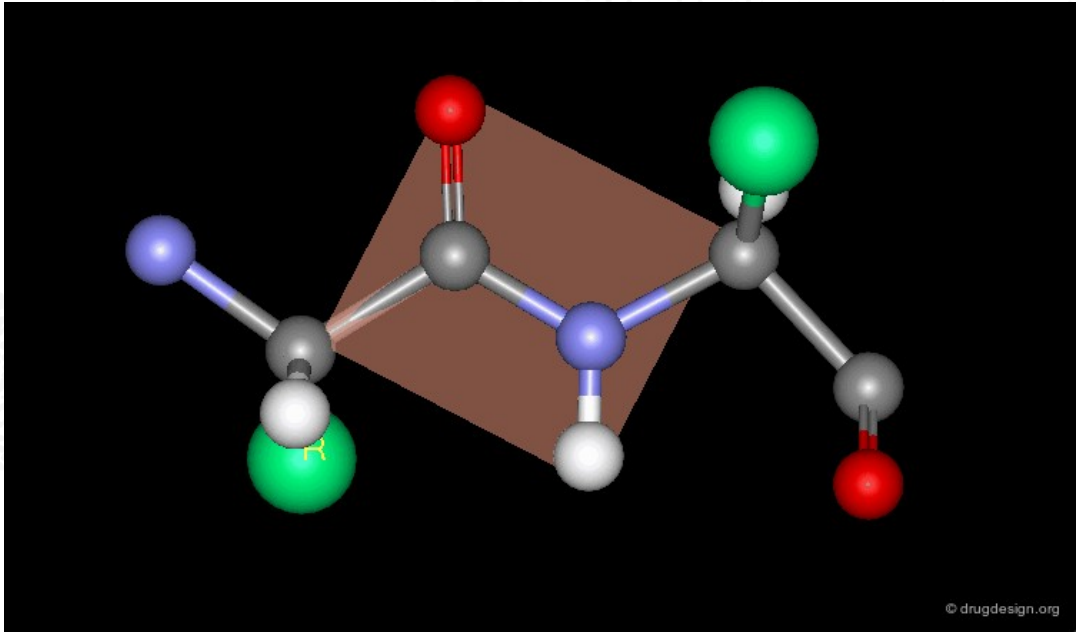
2. How amino acids are linked together

- Amino acids can be linked together to create a polypeptide or protein through a **condensation reaction**
- This reaction **removes a molecule of water** in the making of a bond, **creating a peptide bond**



Amino Acids

- **The peptide bond** is essentially planar. All the atoms in the central amide bond lie in the **same plane**



Proteins

Proteins

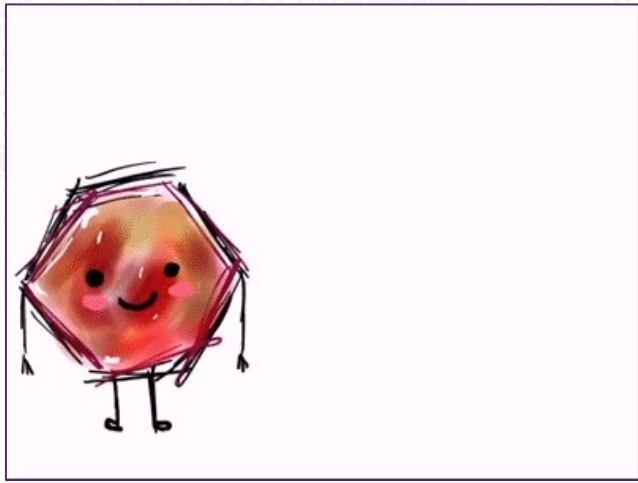
1. Protein Functions
2. Protein Structure
3. Polypeptide VS Protein
4. Levels of Protein structure
5. The relationship between protein structure and function
6. Computational modeling

Proteins

1. Protein functions

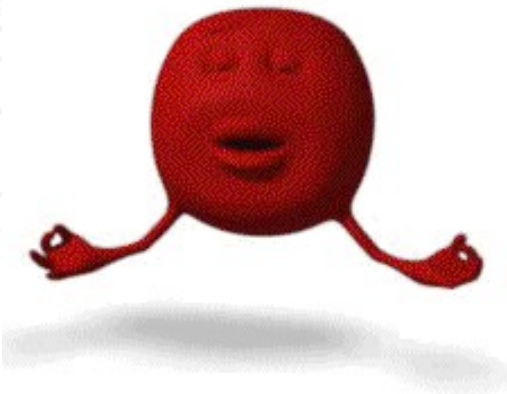
- **Structural support:** Proteins such as collagen and keratin provide structural support to cells, tissues, and organs like hair and skin.

- **Enzymes:** Many proteins act as enzymes, which are biological catalysts that facilitate chemical reactions within cells. Enzymes are involved in processes such as digestion, metabolism, and DNA replication.



Proteins

- **Transport:** Certain proteins, such as hemoglobin, transport molecules like oxygen and nutrients throughout the body.
- **Defense:** Antibodies are proteins that play a key role in the immune system by recognizing and neutralizing foreign invaders such as bacteria and viruses.
- **Regulation:** Proteins are involved in regulating various cellular processes, including gene expression, cell signaling, and metabolism.

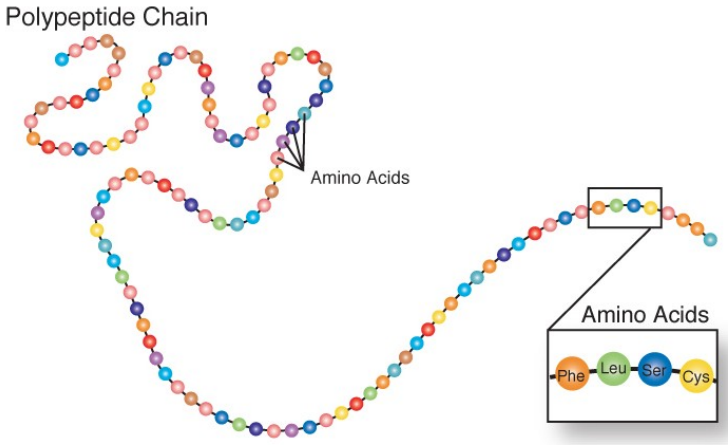


Proteins

2. Protein structure

- Proteins are molecules called polymers, which are made up of amino acids **linked together** in repeating units.
- Proteins are constructed with the same basic set of **20 amino acids** that can be combined in various ways to form a wide variety of proteins.
- These amino acids are also **monomers**
- Each amino acid is represented by a little individual circle, and when they are linked together into a polymer, that is called either a **polypeptide/protein.**

Amino Acid = Monomer
Polymer = Polypeptide/Protein



Proteins

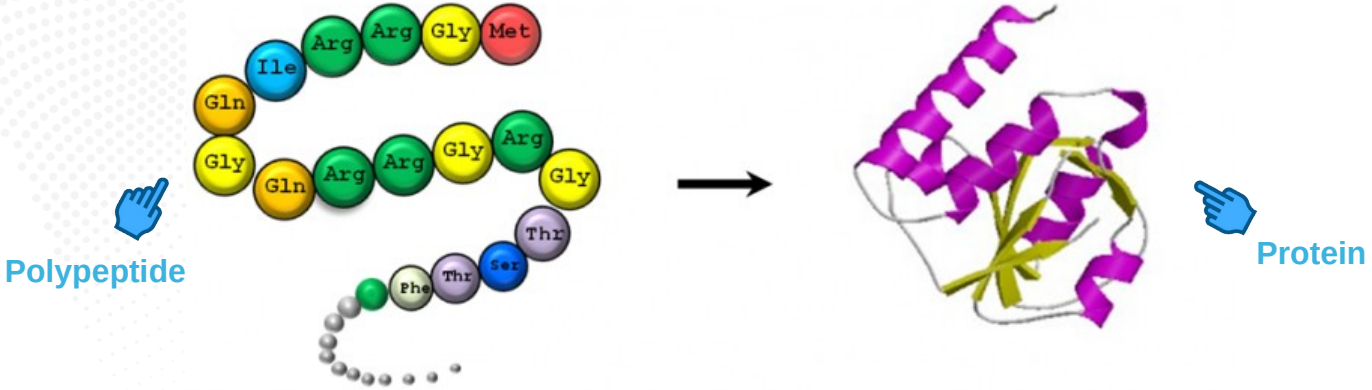
3. Polypeptide VS Protein

A Polypeptide:

- Polypeptide consists of a sequence of amino acids
- Once three or more amino acids are linked together, it is considered a **polypeptide**

A Protein:

- Can consist of **one or more** polypeptide chains
- Adopts a unique **three-dimensional structure** through **folding**
- Exhibits **specific biological functions** due to its folded structure

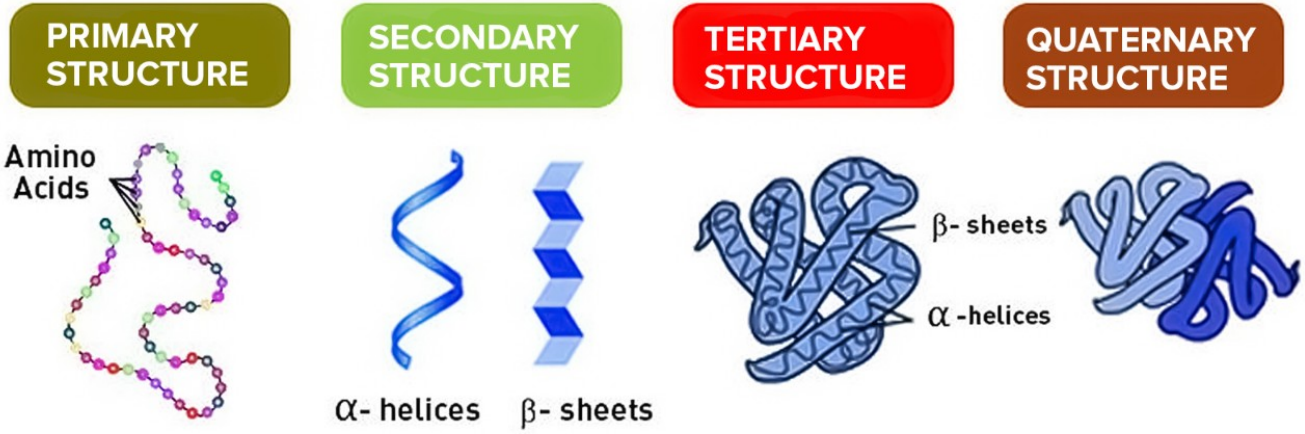


Proteins

4. Levels of Protein structure

- As more amino acids are added and linked together, the polypeptide chain takes on a complex shape to become a protein.

- To describe this complexity there are four levels of protein structure.
  - **The primary structure** is the sequence of amino acids in the polypeptide chain.
  - **The secondary structure** refers to the particular shape that a segment of the chain takes on(alpha helix or beta pleated sheet)
  - **The tertiary structure** is the 3D shape of the entire polypeptide chain
  - **The quaternary structure** is when multiple polypeptide chains interact to form a functional protein.

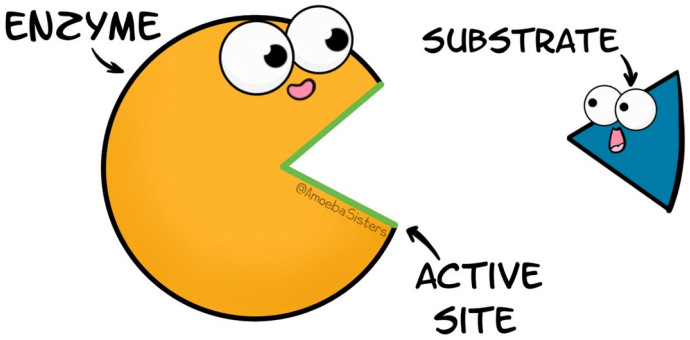


Proteins

5. The relationship between protein structure and function:

- **Structure Determines Function:**
  - The precise folding pattern of a protein dictates its function

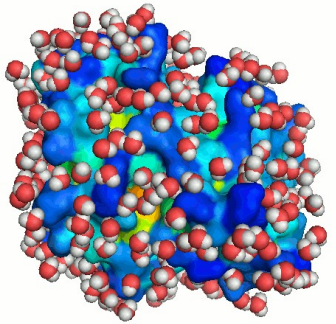
- **Active Sites and Binding Sites:**
  - Protein structure often features pockets, clefts, or grooves known as **active sites** or **binding sites**
  - These regions provide a precisely shaped surface where other molecules, such as ligands can bind with high specificity
  - The chemical interactions between the protein and its binding partners are **essential for the protein's function**



Proteins

- **Conformational Changes:**
  - Proteins can undergo conformational changes in response to environmental cues or interactions with other molecules
  - These changes can alter the protein's shape and activity
  - For example, allosteric proteins can switch between active and inactive conformations in response to binding events at distant sites.

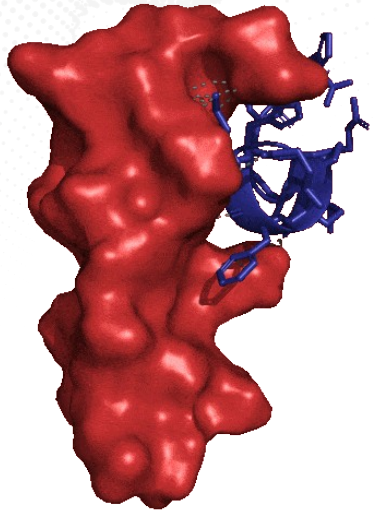
- **Structure-Function Relationships in Disease:**
  - Mutations or structural alterations in proteins can disrupt their normal function and
    diseases
  - For instance neurodegenerative disorders like Alzheimer's disease and Parkinsor



Proteins

6. Computational Modeling

- Computational modeling of proteins involves using computer algorithms and simulations to predict the structure, function, and dynamics of proteins and facilitating the development of novel therapeutics
- It plays a crucial role in modern molecular biology and drug discovery



. Here's an overview of the process:

Protein Structure Prediction:
Computational methods are used to predict the three-dimensional structure of proteins based on their amino acid sequence

Molecular Dynamics Simulations:
Molecular dynamics simulations involve modeling the movements and interactions of atoms and molecules over time.

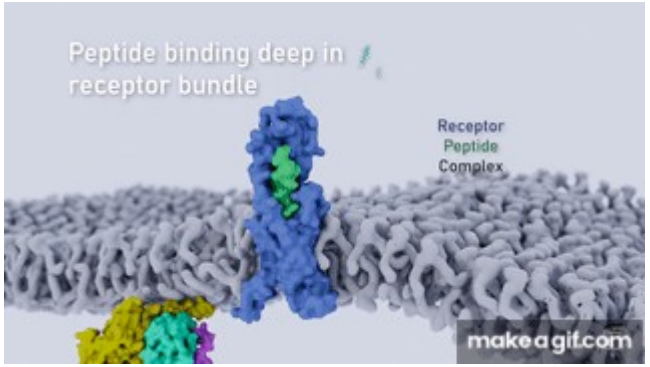
Proteins

Docking and Binding Studies:

- Computational docking techniques are used to predict the binding interactions between proteins and other molecules, such as drugs or substrates.
- These methods can help identify potential binding sites, predict binding affinities, and guide the design of novel therapeutics.

Protein-Protein Interactions:

- Computational methods can be used to study the interactions between different proteins within a biological system.



Proteins

Deep learning-based models have shown promising results in predicting protein structures such as:

AlphaFold:

- Developed by DeepMind, AlphaFold is one of the most well-known deep learning-based models for protein structure prediction.
- It uses a deep neural network architecture (CNNs) combined with attention mechanisms to predict the distances between pairs of amino acids in a protein sequence.
- These distance predictions are then used to reconstruct the 3D structure of the protein.
- AlphaFold has demonstrated remarkable accuracy and won the CASP (Critical Assessment of Structure Prediction) competition in 2020.

Other models:

- RoseTTAFold
- CASP14
- TrRosetta
- RaptorX-Property
- DeepCNF

Genetic Information

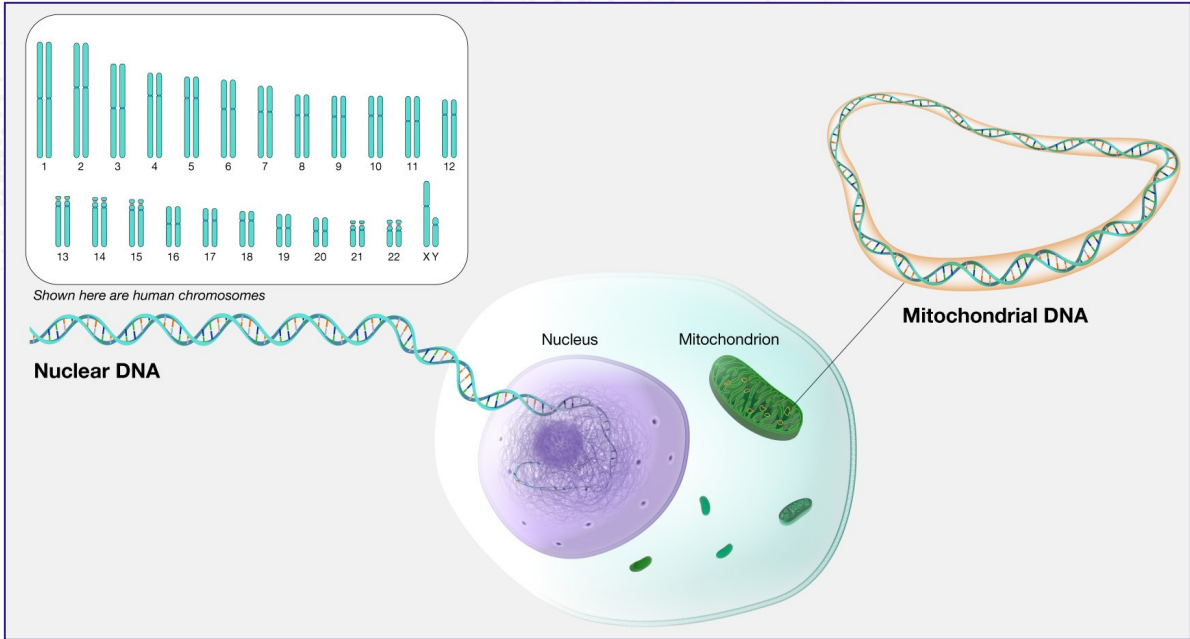
Genetic Information

1. The Genome
2. The Chromosome
3. The Gene
4. The DNA
5. The Gene Expression
6. The Gene Regulation

Genetic Information

1. The Genome

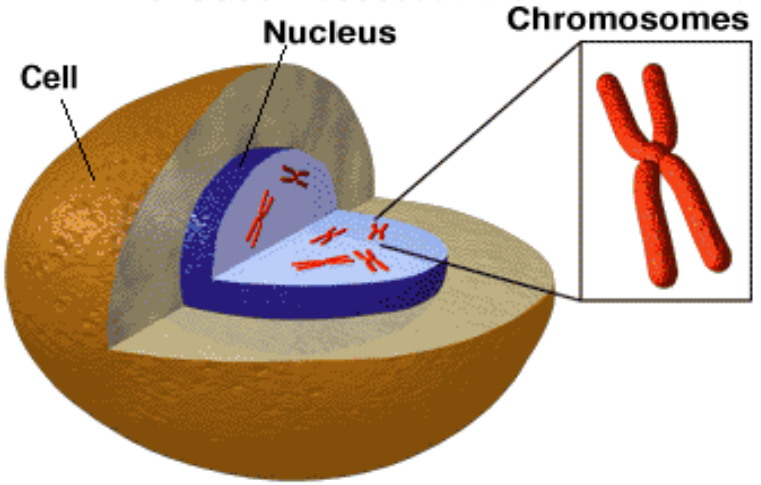
- An organism's complete set of genetic material
- Genome **=** Nuclear DNA (which contains all 23 pairs of chromosomes) **+** Mitochondrial DNA



Genetic Information

2. The Chromosome

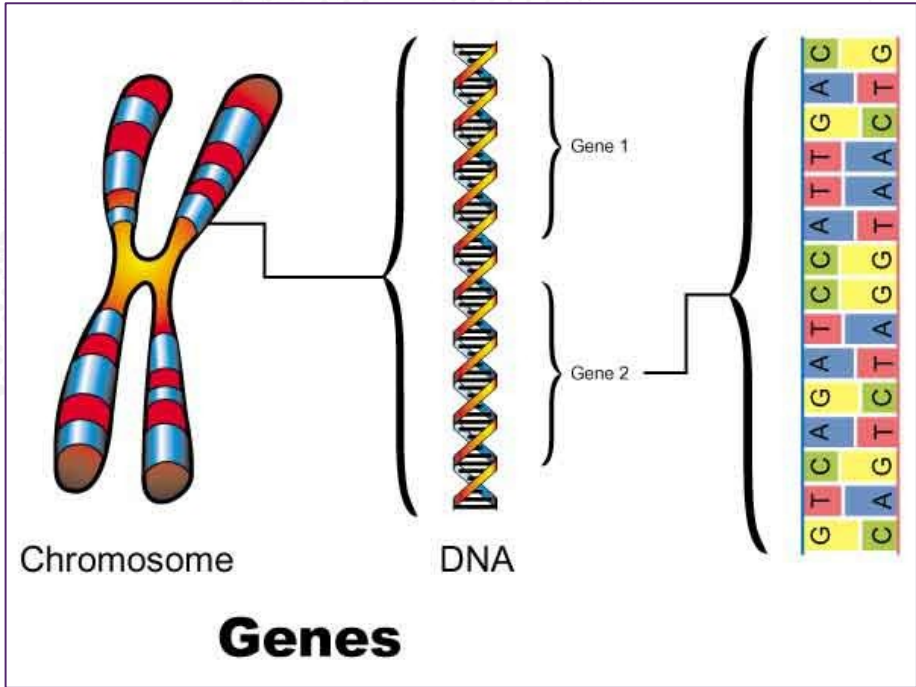
- A chromosome is a condensed, thread-like structure found in the nucleus of a cell, containing the genetic material
- Humans have 23 pairs of chromosomes



Genetic Information

3. The Gene

- Genes are the building blocks of chromosomes
- Humans have 20 000 genes spread across all chromosomes
- Each gene has a specific site on a chromosome
- Genes represent a segment/chunk of a DNA
- Genes encode the instructions necessary for synthesizing proteins and RNA molecules through a process called **gene expression**



Genetic Information

4. The DNA

- Within the cell membrane, we find the nucleus, a vital organelle housing the cell's genetic material which contains chromosomes and these chromosomes contain the DNA

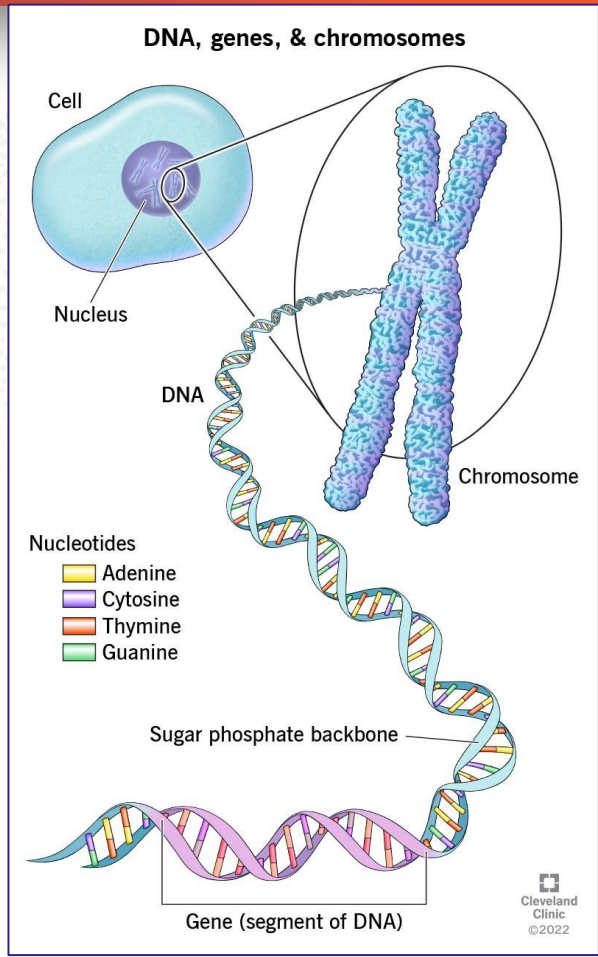
- The DNA determines the genetic code that contains the instructions necessary for an organism's traits and functions

Genetic Information

4. The DNA

- DNA is made up of two long strands of nucleotides arranged in a double helix structure

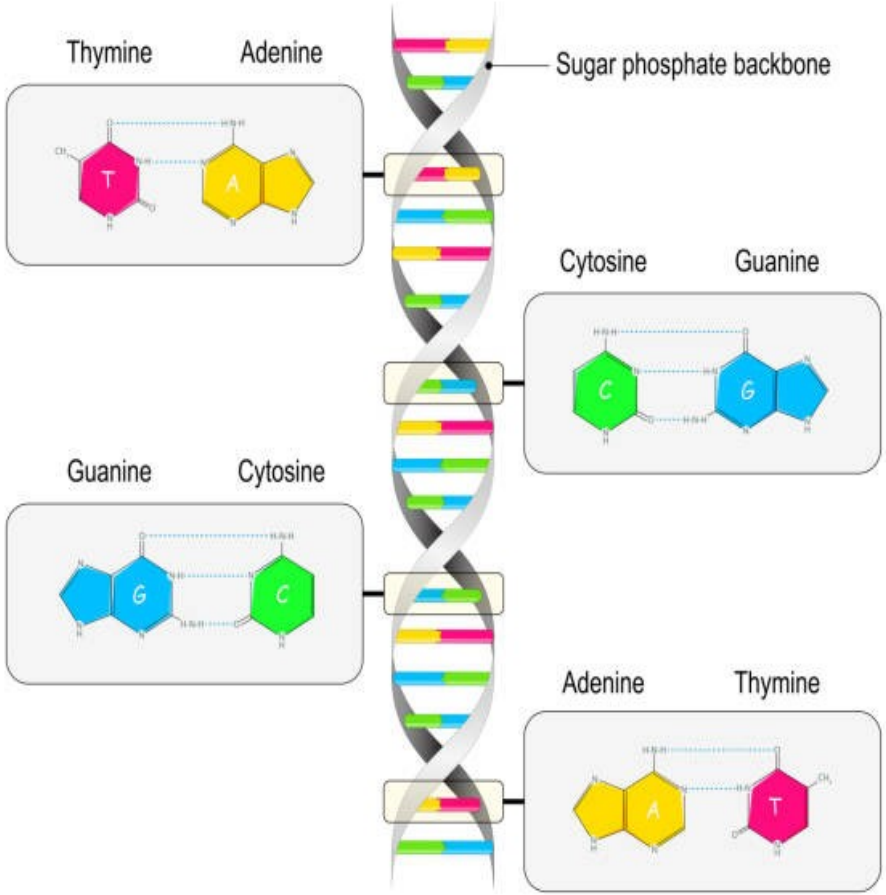
- DNA is the fundamental unit of both genes and chromosomes



Genetic Information

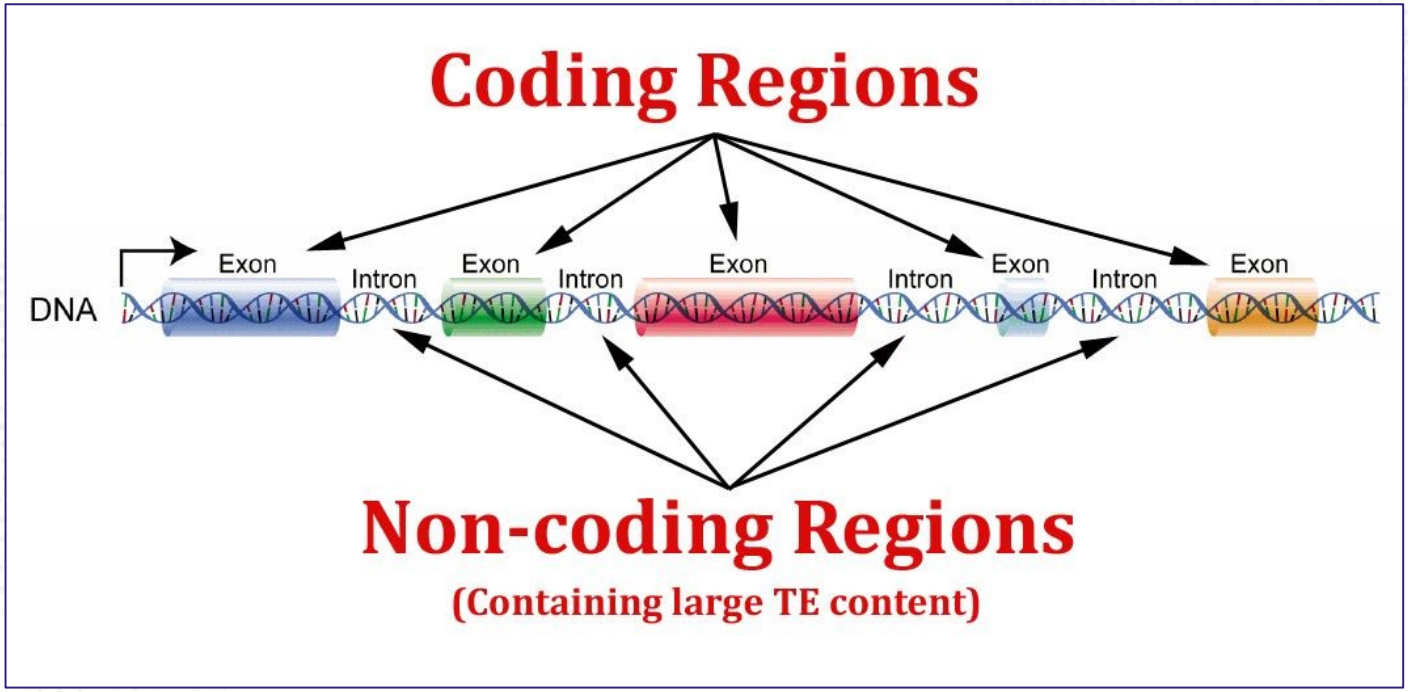
4. The DNA

- The nucleotides in DNA consist of a phosphate group, a sugar molecule (deoxyribose), and one of four nitrogenous bases: adenine (A), thymine (T), cytosine (C), and guanine (G) complemented consecutively by T,A,G and C



Genetic Information

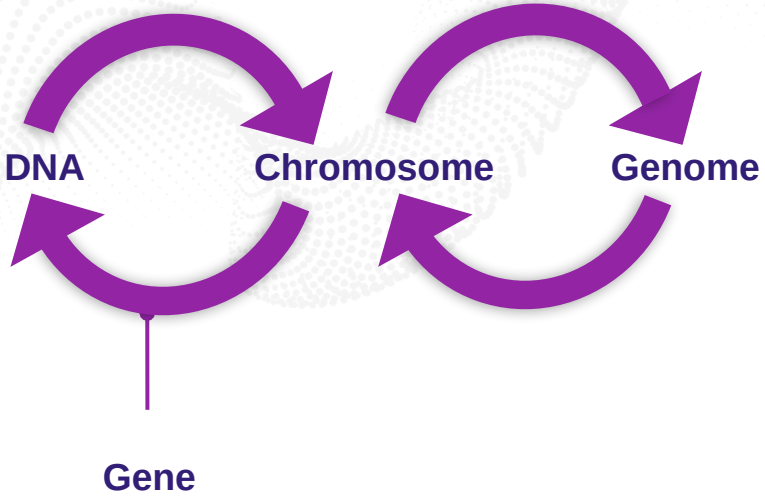
4. The DNA



The DNA = 98% non-coding region + 2% coding region

Genetic Information

=> As a summary we can say that the genome is divided into the mitochondrial DNA and the nuclear DNA which is consisted of 23 pairs of chromosomes and each chromosome is divided into several genes, and the basic of all of this is the DNA



Genetic Information

5. The Gene Expression

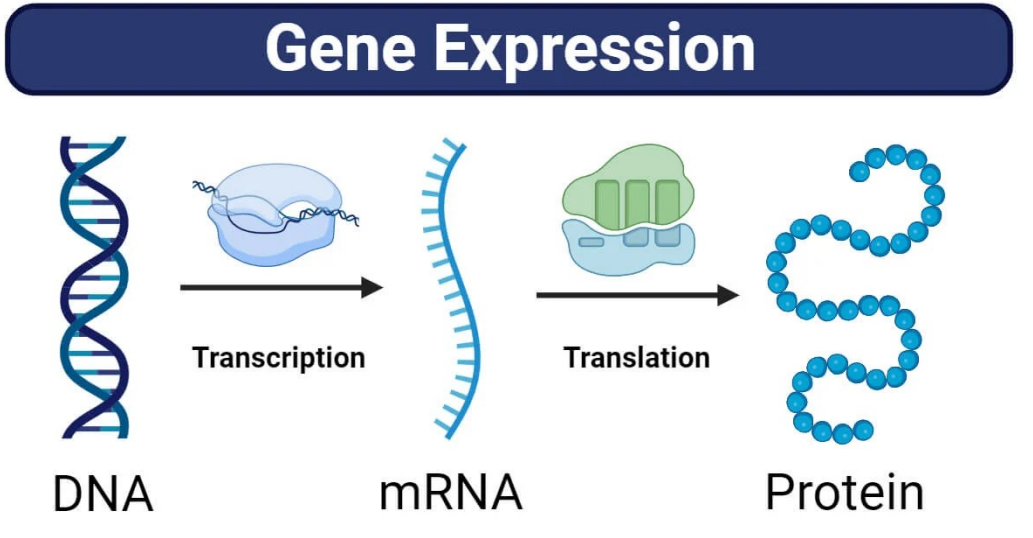
The root cause :

DNA is Not Directly Accessible: DNA is located within the nucleus of the cell and is tightly packed with proteins into chromatin which makes it inaccessible for protein synthesis.

mRNA, on the other hand, can exit the nucleus and travel to the cytoplasm where protein synthesis occurs.

- Gene expression is the process by which the information encoded in a gene is used to direct the synthesis of a functional gene product, typically a protein or a functional RNA molecule.

- This process involves two main steps: **transcription** and **translation**



Genetic Information

5. The Gene Expression: The journey from DNA to cells

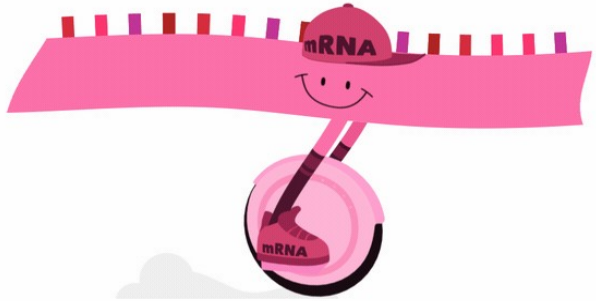
5.1 Transcription:

In the cell nucleus, the DNA strands serve as a template for the synthesis of a complementary RNA molecule called messenger RNA (mRNA).

This process, known as transcription, is catalyzed by an enzyme called RNA Polymerase

Transcription:

RNA Polymerase(DNA) = mRNA



Genetic Information

5. The Gene Expression

5.2 Translation:

- The output of translation of mRNA is the synthesis of proteins.
- Translation is the process by which the sequence of nucleotides in mRNA is decoded into a sequence of amino acids, forming a polypeptide chain.
- This process occurs on ribosomes, with the help of transfer RNA (tRNA) molecules carrying amino acids.

image source : https://www.pfizer.com/news/articles/the_rise_of_rna_the_cellular_workhorse_behind_a_new_class_of_next_gen_therapies

Genetic Information

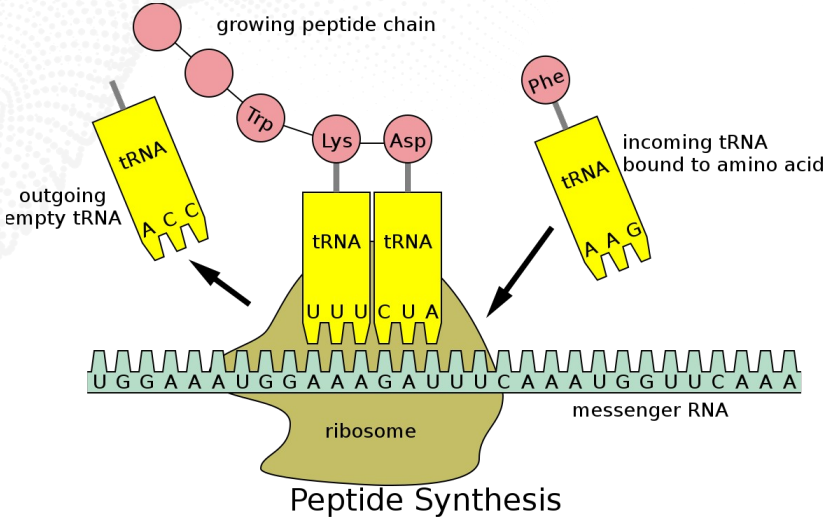
5. The Gene Expression

5.2 Translation:

- As the ribosome moves along the mRNA molecule, it reads the codons (three-nucleotide sequences) and matches them with the appropriate amino acids carried by the tRNA molecules.
- This results in the formation of a specific protein according to the sequence of codons in the mRNA molecule.

Translation :

Ribosome(mRNA) = Protein

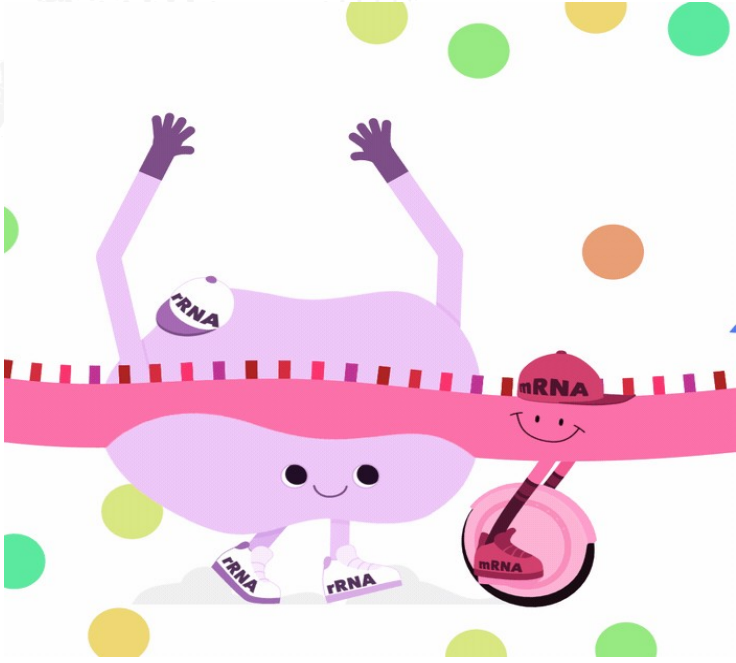


Genetic Information

5. The Gene Expression

5.3 Protein Folding and Modification::

The newly synthesized polypeptide chain undergoes folding and post-translational modifications to adopt its functional three-dimensional structure.



Genetic Information

5. The Gene Expression

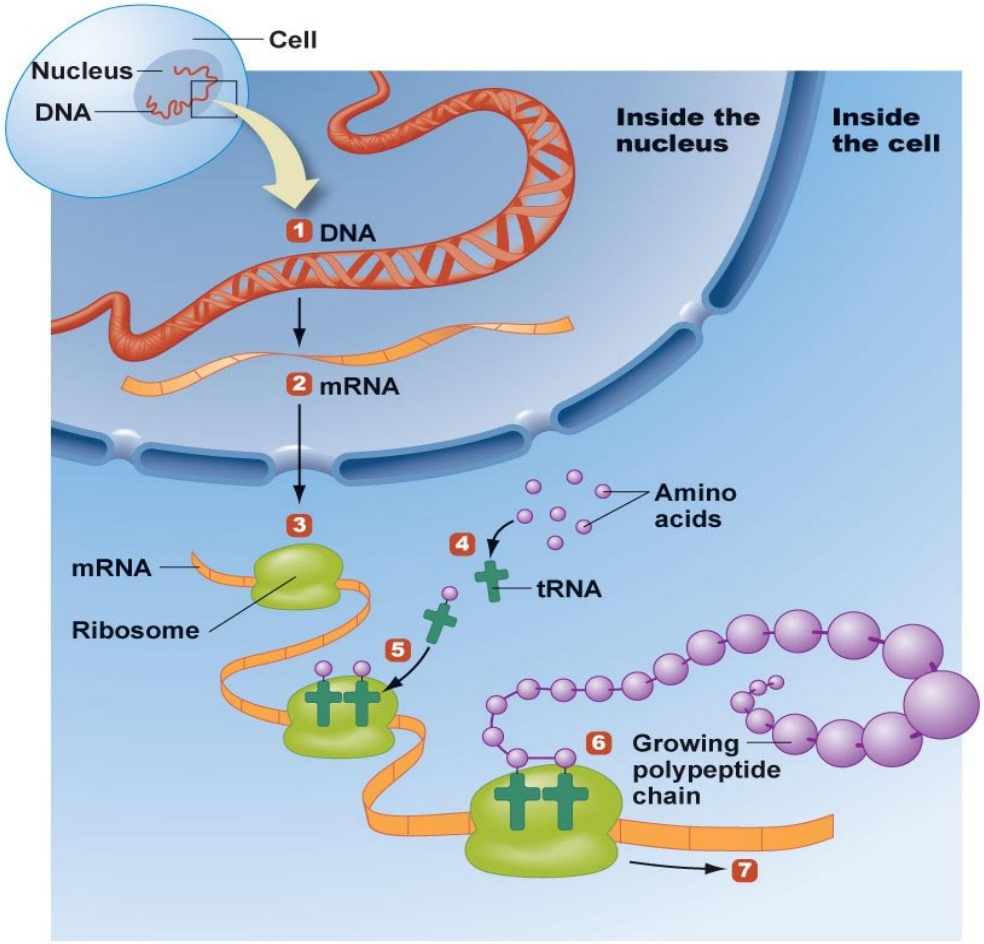
5.4 Cell Division:

Once the necessary proteins are synthesized, the cell proceeds through the cell cycle, which includes phases such as DNA replication, mitosis (nuclear division), and cytokinesis (cytoplasmic division).

These processes ultimately lead to the formation of two daughter cells, each containing a complete set of chromosomes and the necessary cellular machinery to carry out cellular functions.

=> the journey from DNA to new cells involves transcription of DNA into mRNA, translation of mRNA into proteins, protein folding and modification, protein trafficking, and ultimately cell division resulting in the generation of new cells.

Genetic Information



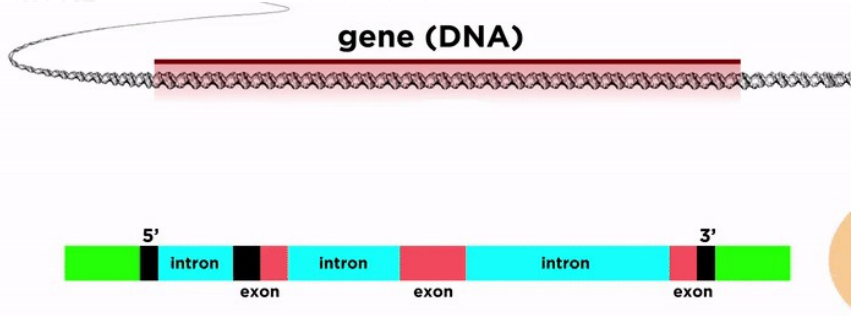
1. Each strand of DNA holds the code to create specific proteins. Because the DNA can't leave the nucleus of the cell, a copy of the code, called messenger RNA (mRNA), is made. This is called transcription.
2. The mRNA takes this information outside the nucleus and brings it to the ribosome.
3. The ribosome moves along the mRNA, reading the code. This is the phase called translation.
4. Another type of RNA called transfer RNA (tRNA) collects the specific amino acids that are needed to make the protein. There are 20 different tRNAs, one for each amino acid.
5. The tRNA brings the amino acid to the ribosome.
6. The ribosome then builds a chain of amino acids (the protein) in the proper sequence, based on the code in the mRNA, called elongation.
7. The ribosome continues to move down the mRNA strand until all the appropriate amino acids are added and the protein is complete.

Genetic Information

6. The Gene Regulation

Since each human has the same DNA but different cells in each organism, how does the body know that it must generate different cells for each organ?

- **Gene Regulation** is the answer:
  - It is the process where specific genes are activated (turned on) or descativated (turned off) in response to internal and external signals
  - This allows which gene are going to produce certain protein, determining cell fate, function and identity



Genetic Information