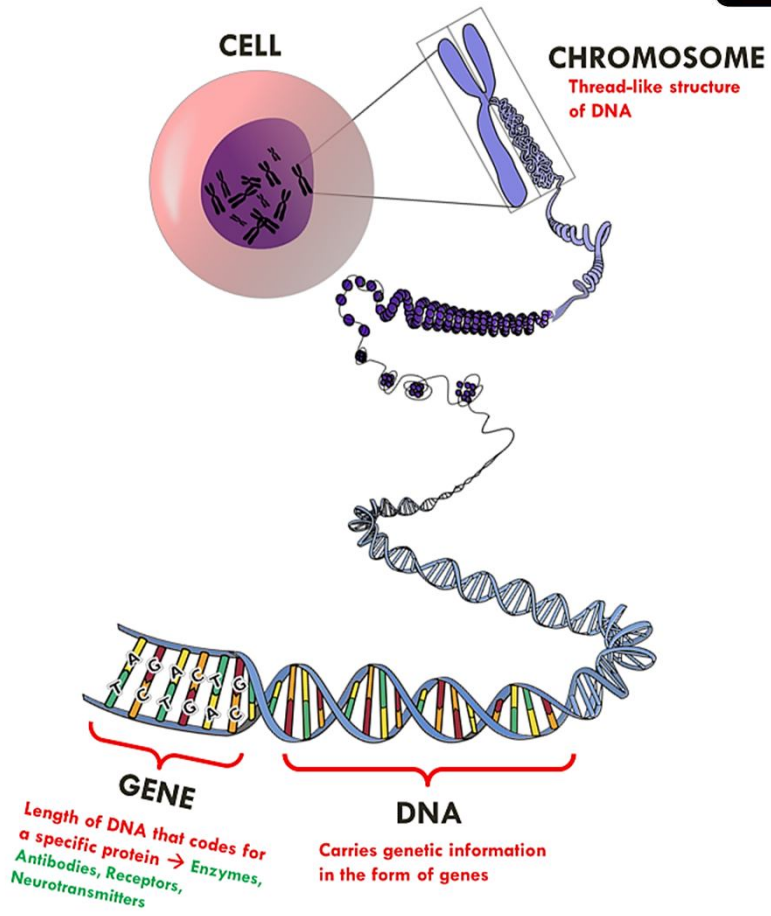
University of Duhok
College of Sciences
Department of Biology
4th Year Class

Lecture3. DNA and Gene

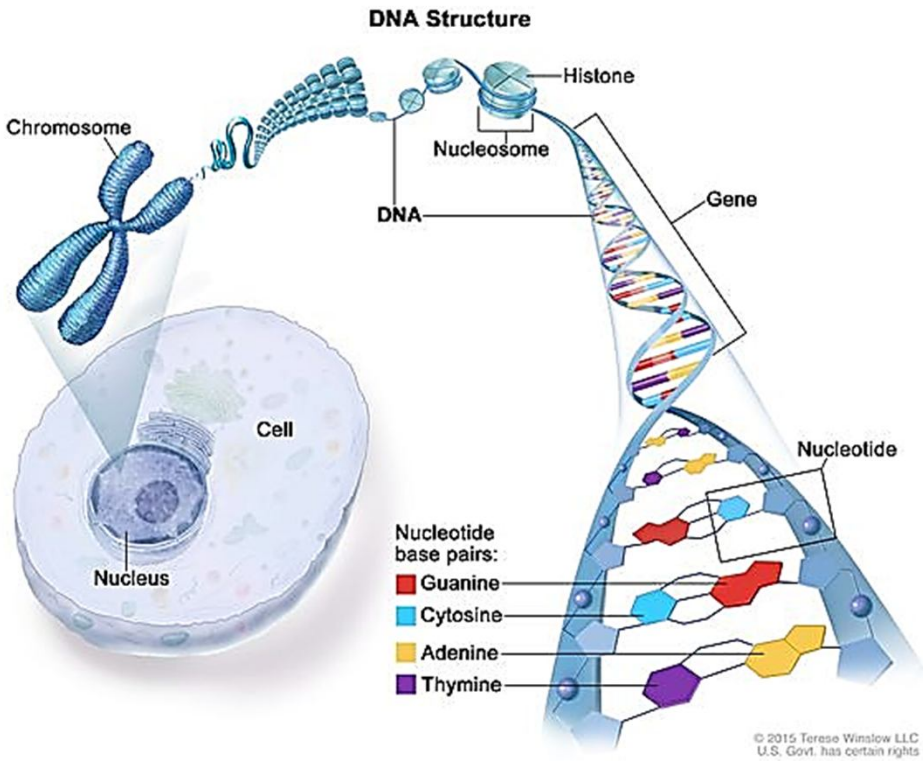
- Introduction
- What is a gene?
- Types of gene according to their expression
- Regulation of gene expression
- Types of gene regulation
- Nucleic Acids, DNA, and RNA Structures.



By Dr. Shaymaa Hadi Ali
Assistant Professor of Molecular Biology

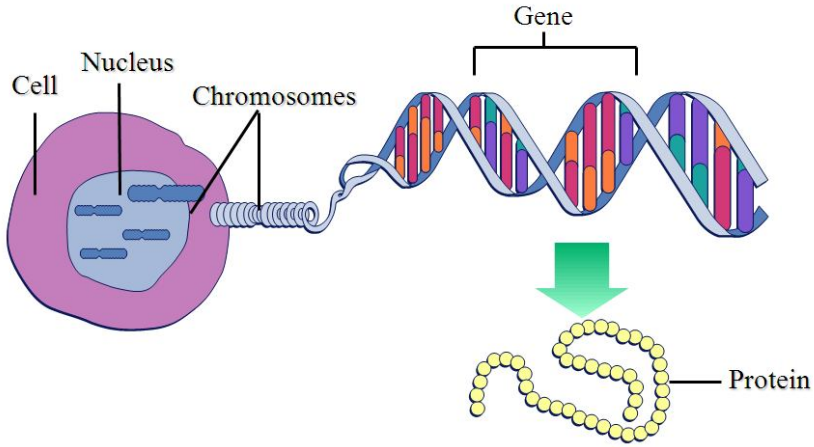
Introduction

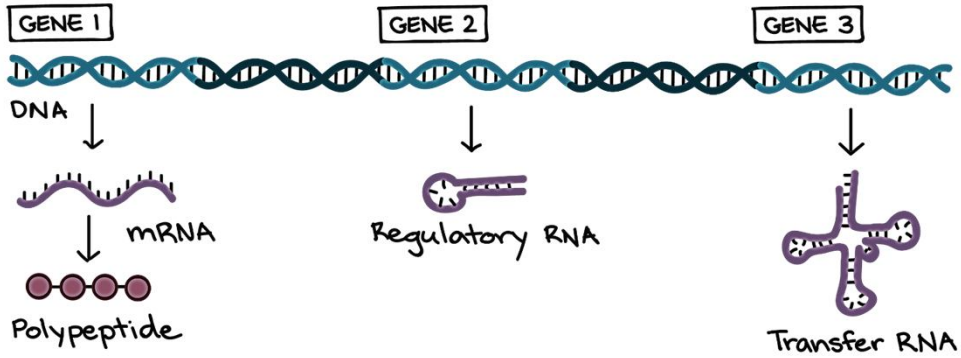
- In most organisms, the hereditary material is DNA (deoxyribonucleic acid) or more correctly nucleic acids. However, a number of viruses use RNA (ribonucleic acid) as the building block for their genome.
- DNA and RNA made up of linear chains of subunits called nucleotides.
- DNA molecule contains numerous separate pieces of information, each coding for the structure of a particular protein or functional RNA.

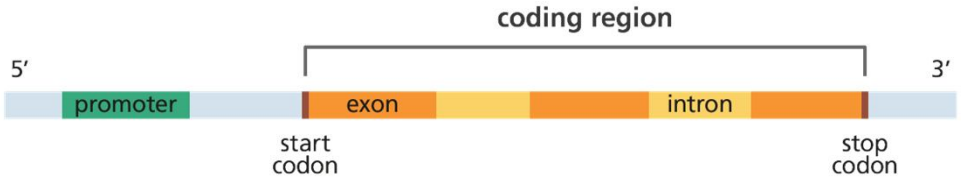


What is a gene?

- DNA is divided up into functional units called genes, which may specify either polypeptides (proteins and protein subunits) or functional RNAs (such as tRNAs, rRNAs and snRNA).
- Every genes have three main regions or components:
  1. **Promoter:** is a sequence of DNA needed to turn a gene on or off. It is a sequence of DNA where transcription of a gene is initiated.
  2. **Coding region:** has the protein building information and start with **initiation** or **start** codon, triplet of DNA bases (ATG).
  3. **Termination sequence:** which contain **termination** or **stop** codon (TGA, TAA or TAG) that indicates the end of a gene.







Types of gene according to their expression

1. Constitutive (house keeping) genes:

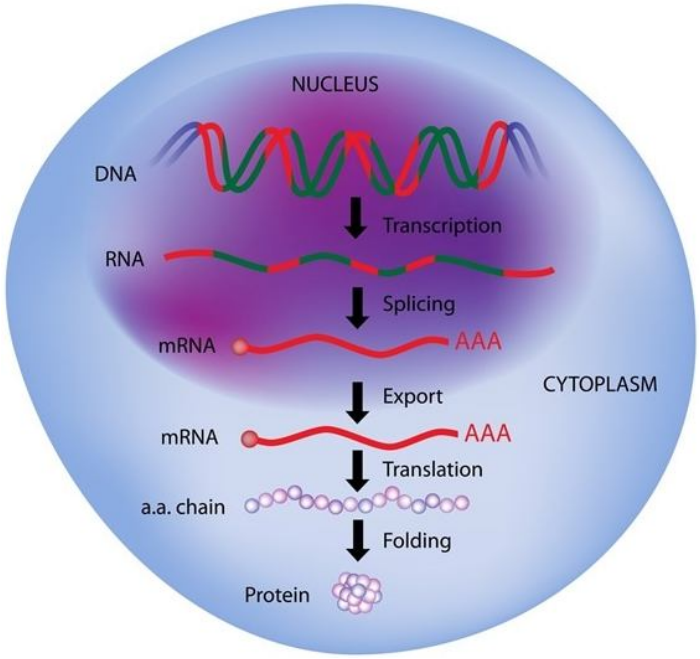
- Constitutive genes refer to genes whose expression is not regulated.
- They are actively expressed all the time at a fixed rate, and their products (proteins/RNA) are constantly present in the cell.
- Their structure is simpler.

2. Inducible (Controllable) genes:

- They are expressed only when their proteins are needed by the cell.
- They are expressed only when a specific positive regulatory substance (Transcription factors), i.e. an inducer or activator is present, e.g. insulin is an inducer of the gene glucokinase of glycolysis in human being.
- Their structure is relatively complicated.

Regulation of gene expression

- Regulation of gene expression includes a wide range of mechanisms that are used by cells to increase or decrease the production of specific gene products (protein or RNA).
- Gene regulation is essential for prokaryotes and eukaryotes as it increases the versatility and adaptability of an organism by allowing the cell to express protein when needed.
- Although a functional gene product may be an RNA or a protein, the majority of known mechanisms regulate protein coding genes.



- Any step of the gene's expression may be modulated, from DNA-RNA transcription to the post-translational modification of a protein.
- Gene regulation drives the processes of cellular differentiation and morphogenesis, leading to the creation of different cell types in multicellular organisms where the different types of cells may possess different gene expression profile.

Types of gene regulation

1. Positive regulation

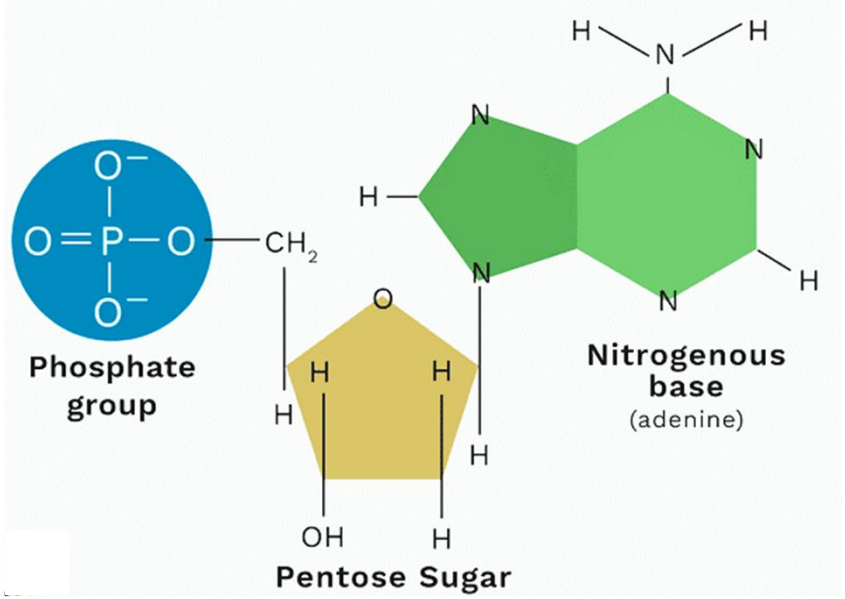
- If a particular protein or compound puts a gene into operation and the expression of genetic information is quantitatively increased then that protein is called stimulatory protein or compound and the process is called positive regulation.
- The element modulating positive regulation is known as activator or positive regulator.

2. Negative regulation

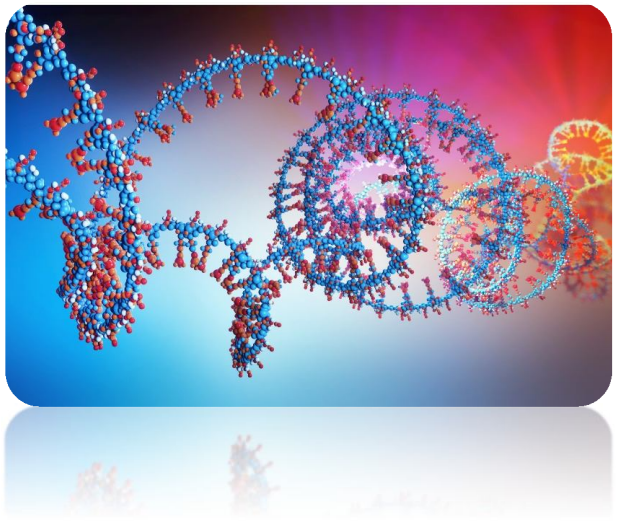
- If a protein or compound stops the operation of a gene and the expression of genetic information is diminished this process is referred to as negative regulation by the presence of specific regulatory element.
- The element or molecule mediating the negative regulation is said to be repressor protein or compound.
- Activators and repressors are transcription factors.

Nucleotide structure

- A molecule of DNA is made up of millions of tiny subunits called Nucleotides.
- Nucleotides are the unit structure of nucleic acids.
- Each nucleotide consists of 3 components:
    1. **Phosphate group.**
    2. **Pentose sugar called deoxyribose.**
    3. **Nitrogenous base (A, C, G, T or U).**



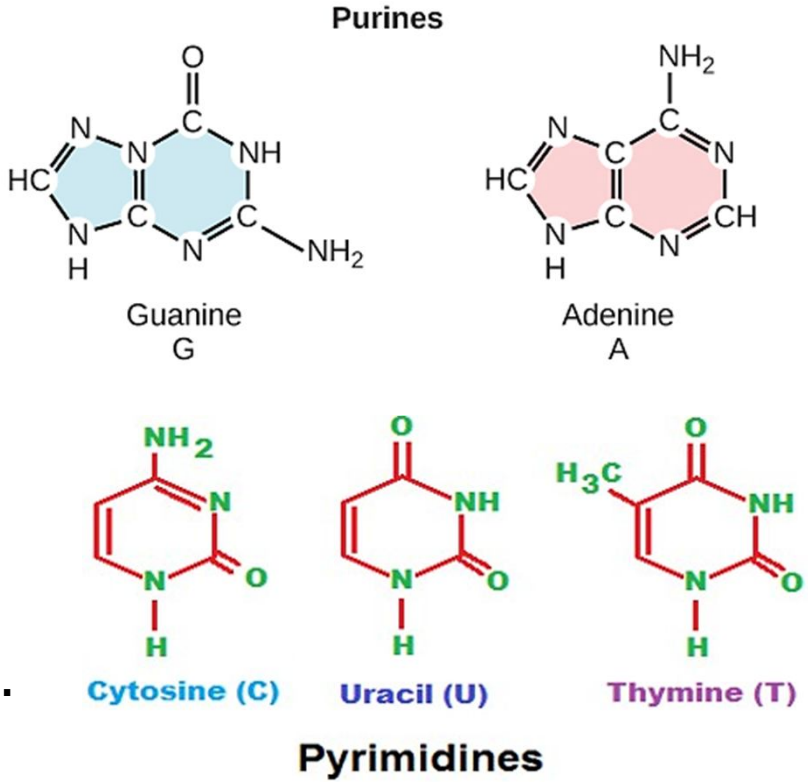
Functions of nucleic acids



1. Storage of genetic information.
2. Storage of chemical energy e.g. ATP.
3. Form part of coenzymes e.g. NAD^+, $NADP^+$, FAD and coenzyme A
4. Act as second messengers in signal transduction e.g. cAMP.

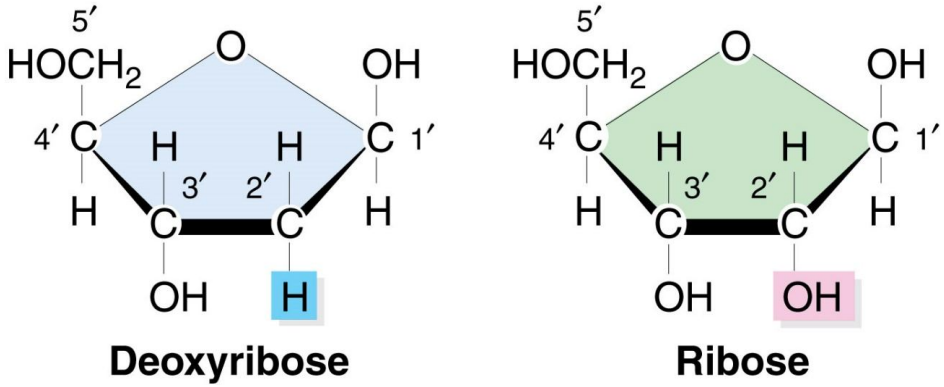
Types of nitrogenous bases

- **There are two types:**
  1. **Purines:**
     - **Two ring structure**
     - **Adenine (A) and Guanine (G)**
  2. **Pyrimidines:**
     - **Single ring structure**
     - **Cytosine (C) and Thymine (T) or Uracil (U).**



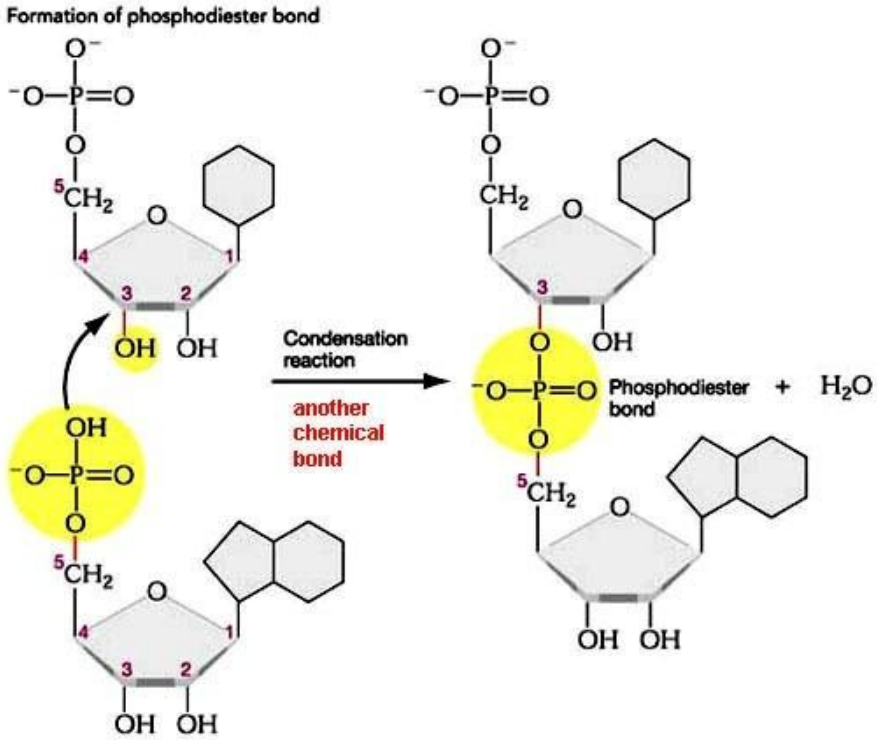
The Sugars: Ribose and Deoxyribose

- **Ribose** is a sugar, like glucose, but with only five carbon atoms in its molecule.
- **Deoxyribose** is almost the same but lacks one oxygen atom. Both molecules may be represented by the symbol



Sugar backbone and phosphodiester linkage

- Phosphodiester bonds link successive nucleotides in nucleic acids.
- The successive nucleotides of both DNA and RNA are covalently linked through phosphate group “bridges” in which the 5’- phosphate group of one nucleotide unit is joined to the 3’- hydroxyl group of the next nucleotide, creating a phosphodiester linkage .



Nucleotide pairing

- The bases attract each other because of hydrogen bonds.
- Hydrogen bonds are weak but there are millions and millions of them in a single molecule of DNA.
- The bonds between cytosine and guanine are shown here with dotted lines.
- When making hydrogen bonds, cytosine always pairs up with guanine.
- Adenine always pairs up with thymine.

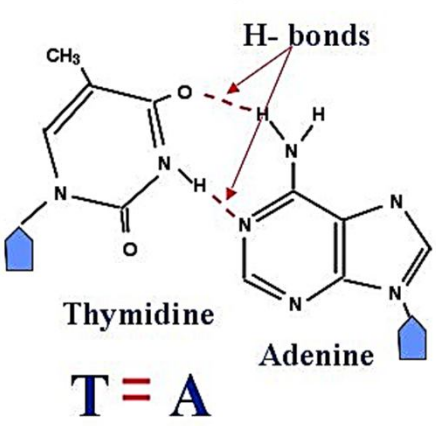
Chargraff's Rule:

- **Adenine and Thymine always join together**

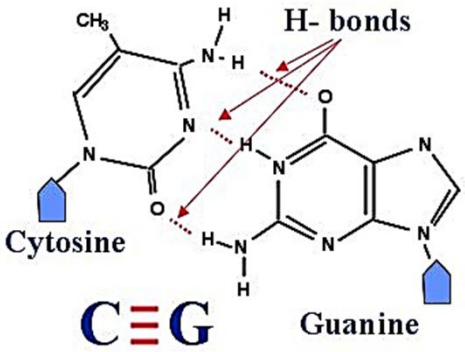
A = T

- **Cytosine and Guanine always join together**

C ≡ G



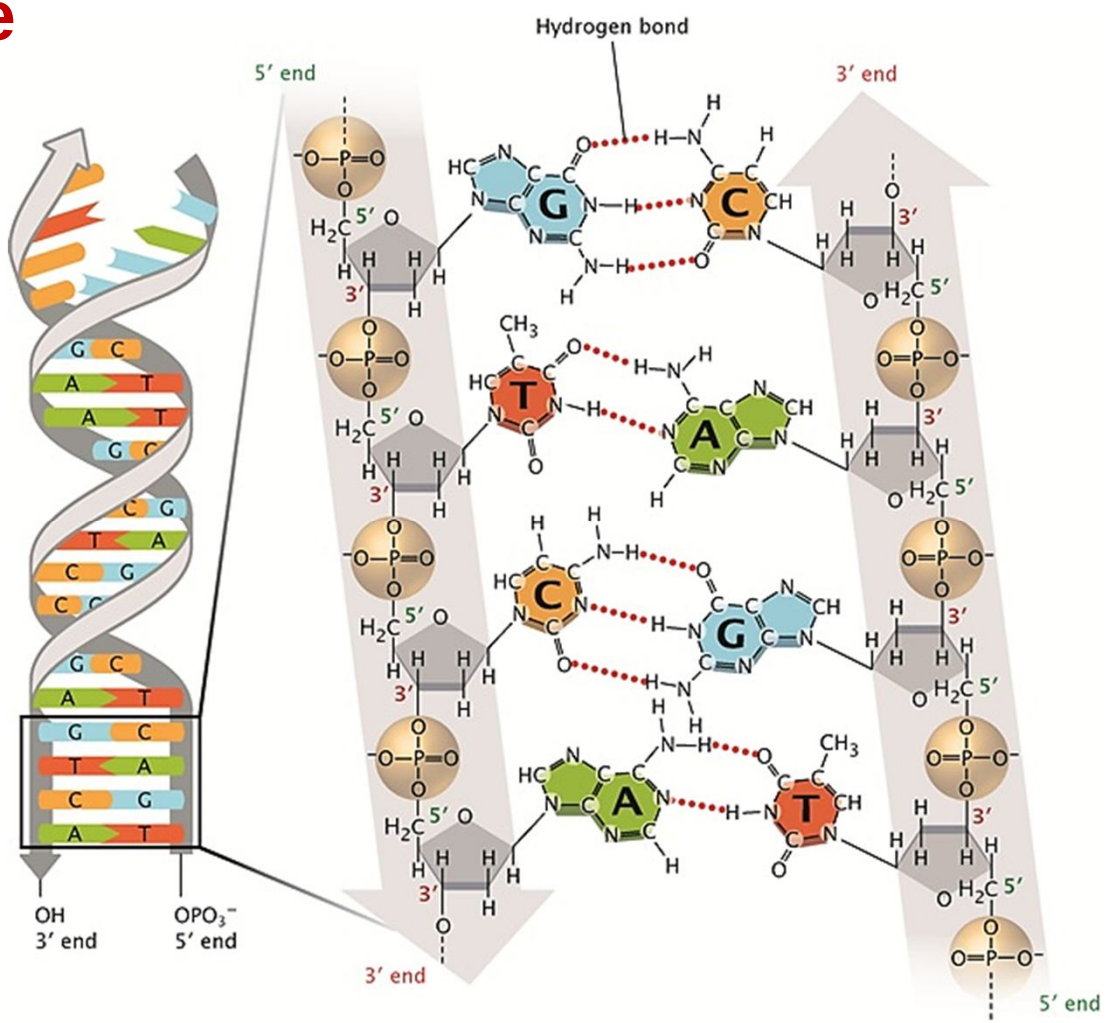
T = A



C ≡ G

DNA Double Helix structure

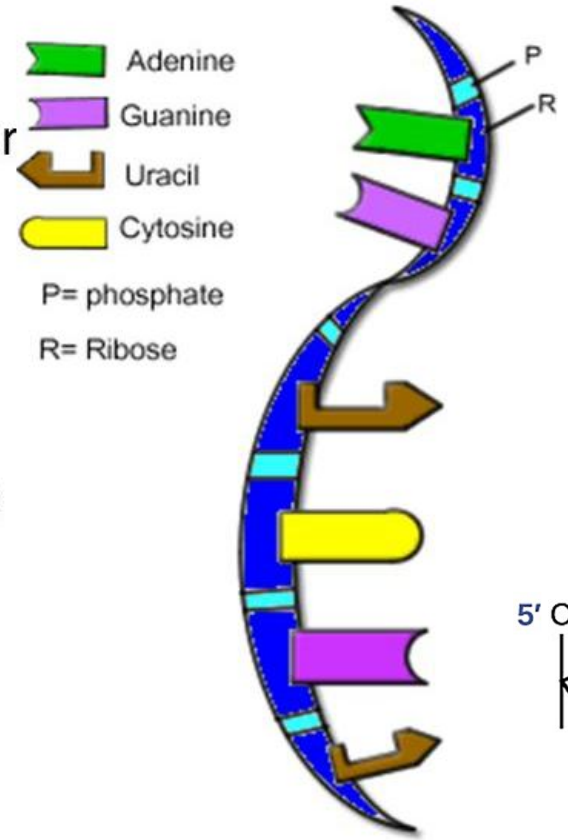
- DNA is a double stranded molecule consists of two antiparallel polynucleotide chains running in opposite directions.
- Both strands are complementary to each other.
- The bases are on the inside of the molecules and the two chains are joined together by double H-bond between A and T and triple H-bond between C and G.
- The base pairing is very specific which make the two strands complementary to each other.
- So each strand contain all the required information for synthesis (replication) of a new copy to its complementary.

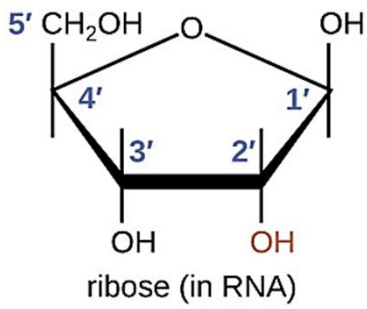


Ribonucleic acid (RNA) Structure

- Made up of a repeating strand of nucleotides, contains all 3 parts similar to DNA (sugar, phosphate, nitrogen base)
- The sugar in RNA is called Ribose
- Contains the nitrogen base Uracil instead of Thymine. Uracil will bind to Adenine (like thymine did)
- RNA is single strand

How does DNA compare to RNA?





ribose (in RNA)


Time for QUESTIONS