Molecular biology

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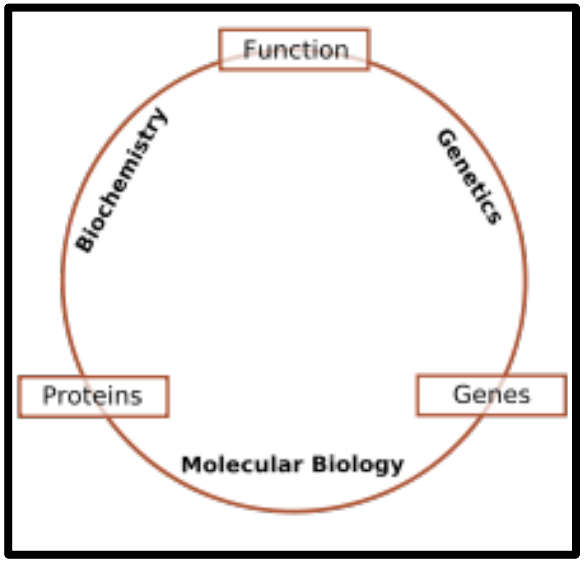
- **Molecular biology** is a branch of biology that concerns the molecular basis of biological activity between biomolecules in the various systems of a cell, including the interactions between DNA, RNA, proteins and their biosynthesis, as well as the regulation of these interactions.

Relationship to other biological sciences



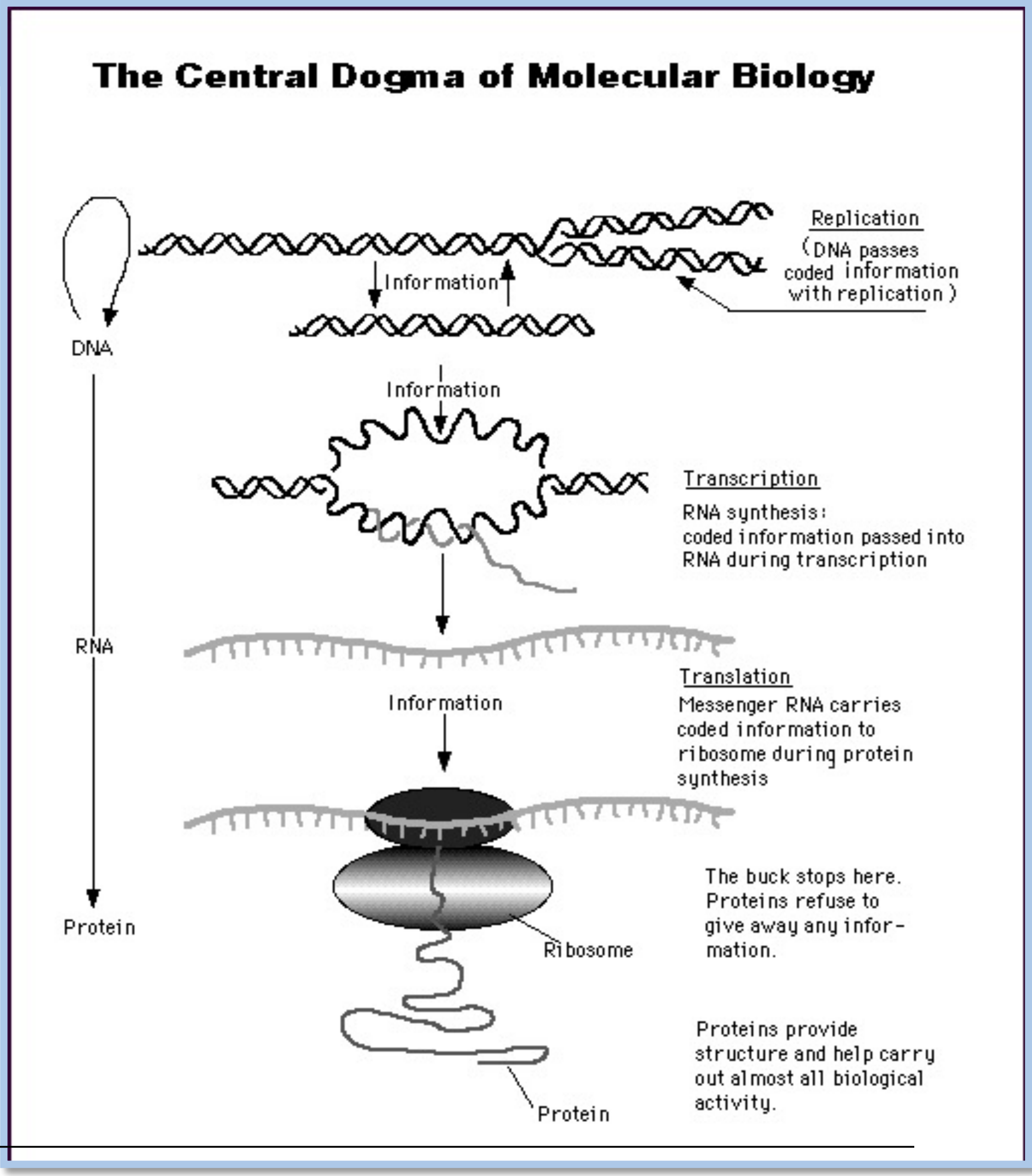
- Schematic relationship between biochemistry, genetics and molecular biology
- Researchers in molecular biology use specific techniques native to molecular biology but increasingly combine these with techniques and ideas from genetics and biochemistry. There is not a defined line between these disciplines.

- ***Biochemistry*** is the study of the chemical substances and vital processes occurring in live organisms.
- ***Genetics*** is the study of the effect of genetic differences in organisms. This can often be inferred by the absence of a normal component (e.g. one gene). The study of "mutants" – organisms which lack one or more functional components with respect to the so-called "wild type" or normal phenotype.
- ***Molecular biology*** is the study of molecular foundations of the processes of replication, transcription, translation, and cell function. The central dogma of molecular biology where genetic material is transcribed into RNA and then translated into protein,

DNA:
information store

RNA:
information store and catalyst

Protein:
superior catalyst



- **Discovery of discrete inherited units:-**
- The presence of isolated inheritable units was first suggested by Gregor Mendel (1822–1884). From 1857 to 1864, he studied inheritance patterns in 8000 common edible pea plants, tracking distinct traits from parent to offspring.
- Although he did not use the term gene, he explained his results in terms of discrete inherited units that give rise to observable physical characteristics.
- This description suggested the difference between genotype (the genetic material of an organism) and phenotype (the visible characters of that organism).

- **Nucleic acids** are the biopolymers, or small biomolecules, essential to all known forms of life.
- The term *nucleic acid* is the overall name for DNA and RNA.
- They are composed of nucleotides, which are the monomers made of three components: a 5-carbon sugar, a phosphate group and a nitrogenous base.
- If the sugar is a compound ribose, the polymer is RNA (ribonucleic acid);
- if the sugar is derived from ribose as deoxyribose, the polymer is DNA (deoxyribonucleic acid).

- **History:-**
- Nuclein were discovered by Friedrich Miescher in 1869.
- In the early 1880s Albrecht Kossel further purifies the substance and discovers its highly acidic properties. He later also identifies the nucleobases.
- In **1889** Richard Altmann creates the term nucleic acid
- In **1938** Astbury and Bell published the first X-ray diffraction pattern of DNA.
- In **1953** Watson and Crick determined the structure of DNA.
- Experimental studies of nucleic acids constitute a major part of modern biological and medical research, and form a foundation for genome and forensic science, and the biotechnology and pharmaceutical industries.

Occurrence and nomenclature

- The term **nucleic acid** is the overall name for DNA and RNA, members of a family of biopolymers, and is synonymous with polynucleotide.
- Nucleic acids were named for their initial discovery within the **nucleus**, and for the presence of **phosphate groups** (related to **phosphoric acid**).
- Although first discovered within the nucleus of eukaryotic cells, nucleic acids are now known to be found in all life forms including within bacteria, archaea, mitochondria, chloroplasts, viruses, and viroids.
- All living cells contain both DNA and RNA (except some cells such as mature red blood cells), while viruses contain either DNA or RNA, but usually not both.

- The basic component of biological nucleic acids is the nucleotide, each of which contains a pentose sugar (ribose or deoxyribose), a phosphate group, and a nucleobase.
- Nucleic acids are also generated within the laboratory, through the use of **enzymes** (DNA and RNA polymerases) and by **solid-phase chemical** synthesis.
- The chemical methods also enable the generation of altered nucleic acids that are not found in nature, for example peptide nucleic acids.
- A **gene** is a length of DNA that codes for a protein.
- **Genome** = The entire DNA sequence within the nucleus.
- Chromosomes are composed of two types of large molecules (macromolecules) called **proteins** and **nucleic acids**.

- Inside the nucleus, DNA and proteins associate to form a network of threads called **chromatin**.
- The chromatin becomes fundamental or very important at the time of **cell division** as it becomes tightly condensed thus forming the rod like chromosome with the tangled DNA. The chromatin can not easily observed under light microscope but chromosomes become easily visible under the light microscope.

- DNA is bound to histone proteins in cell– complex called a chromosome diploid-- 2 copies of each homologous (very similar) **chromatid** each chromatid duplicates and separates during cell division.

- The majority of eukaryotic genes are stored on a set of large, **linear** chromosomes.
- The chromosomes are packed within the nucleus in complex with storage proteins called histones to form a unit called a nucleosome.
- DNA packaged and condensed in this way is called Prokaryotes (bacteria and others) typically store their genomes on a single large, **circular chromosome**.

- DNA composition (what are the components of DNA)?

Molecular composition and size

- Nucleic acids are generally **very large** molecules.
- Actually, DNA molecules are probably the **largest** individual molecules known.
- Well-studied biological nucleic acid molecules range in size from 21 nucleotides (small interfering RNA) to large chromosomes (human chromosome 1 is a single molecule that contains 247 million base pairs).
- In most cases, naturally occurring DNA molecules are double-stranded and RNA molecules are single-stranded.
- There are numerous exceptions, however—some viruses have genomes made of **double-stranded RNA** and other viruses have **single-stranded DNA** genomes, and, in some circumstances, nucleic acid structures with **three** or **four** strands can form.

Nucleic acids (DNA and RNA)

- Form the genetic material of all living organisms.
- Found mainly in the **nucleus** of a cell (hence "nucleic")
- Contain phosphoric **acid** as a component (hence "acid")
- They are made up of **nucleotides**.
- **Nucleosides (sugar and nitrogen bases)**

Nucleotides

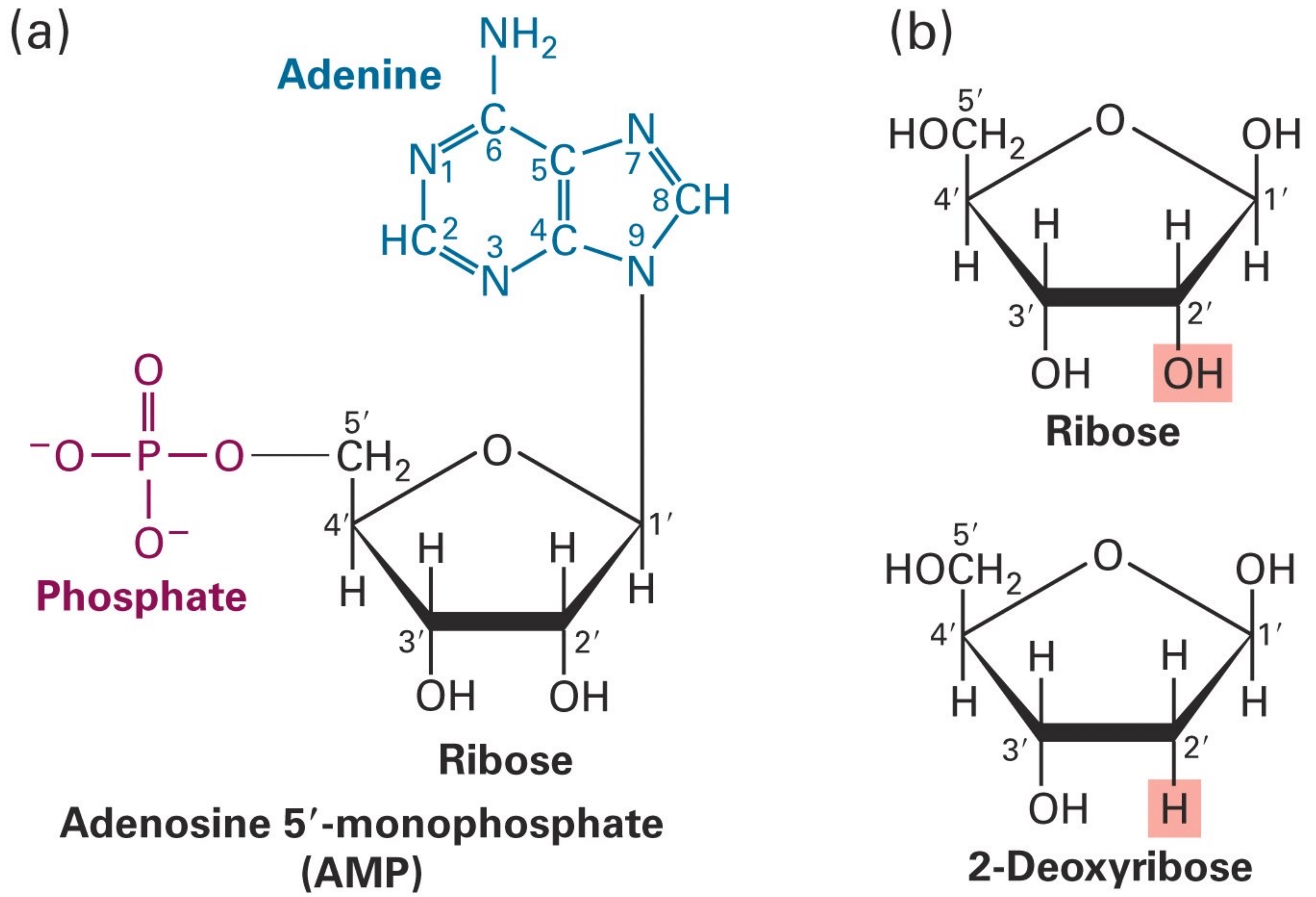
- A nucleotide has 3 components
  - Sugar (ribose in RNA, deoxyribose in DNA)
  - Phosphoric acid
  - Nitrogen base
    - Adenine (A)
    - Guanine (G)
    - Cytosine (C)
    - Thymine (T) or Uracil (U)

Monomers of DNA

- A deoxyribonucleotide has 3 components
  - Sugar - Deoxyribose
  - Phosphoric acid
  - Nitrogen base
    - Adenine (A)
    - Guanine (G)
    - Cytosine (C)
    - Thymine (T)

Monomers of RNA

- A ribonucleotide has 3 components
  - Sugar - Ribose
  - Phosphoric acid
  - Nitrogen base
    - Adenine (A)
    - Guanine (G)
    - Cytosine (C)
    - Uracil (U)

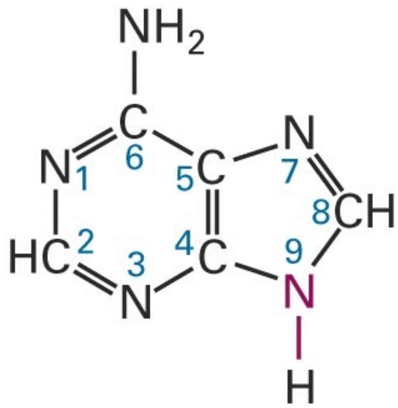

(a)
Adenine
NH2
N
C
6
C
5
N
7
8
CH
1
HC
2
3
N
4
C
9
N
O
O
P
O
O
O
Phosphate
5′
CH2
O
4′
1′
H
H
H
H
3′
2′
OH
OH
Ribose
Adenosine 5′-monophosphate
(AMP)
(b)
5′
HOCH2
O
OH
4′
1′
H
H
H
H
3′
2′
OH
OH
Ribose
5′
HOCH2
O
OH
4′
1′
H
H
H
H
3′
2′
OH
H
2-Deoxyribose

Nitrogen bases

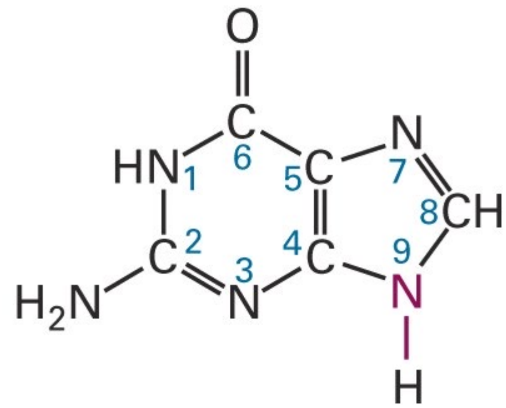
There are two groups of nitrogen bases :-

- Adenine (A) and Guanine (G) are double ring bases called **purines**.
- Cytosine (C) and Thymine (T) or Uracil (U) are single ring bases called **pyrimidines**.
- Both DNA and RNA contain four different subunits or nucleotides two **purines** and two **pyrimidines.**
- **RNA** usually exists as a single stranded polymer that is composed of a long sequence of nucleotides.
- **DNA** usually a double stranded molecules.

PURINES

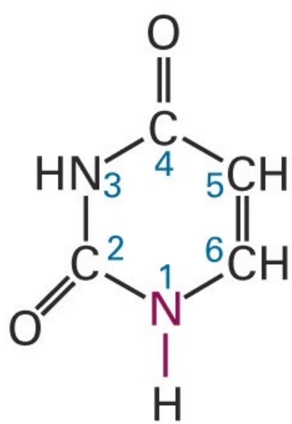


Adenine (A)

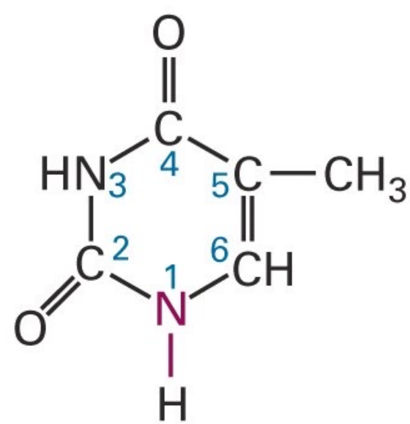


Guanine (G)

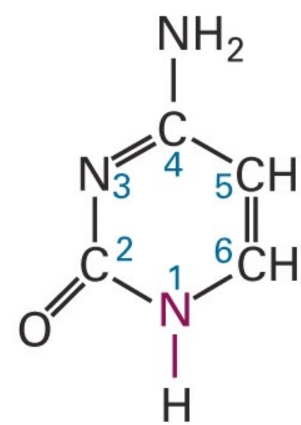
PYRIMIDINES



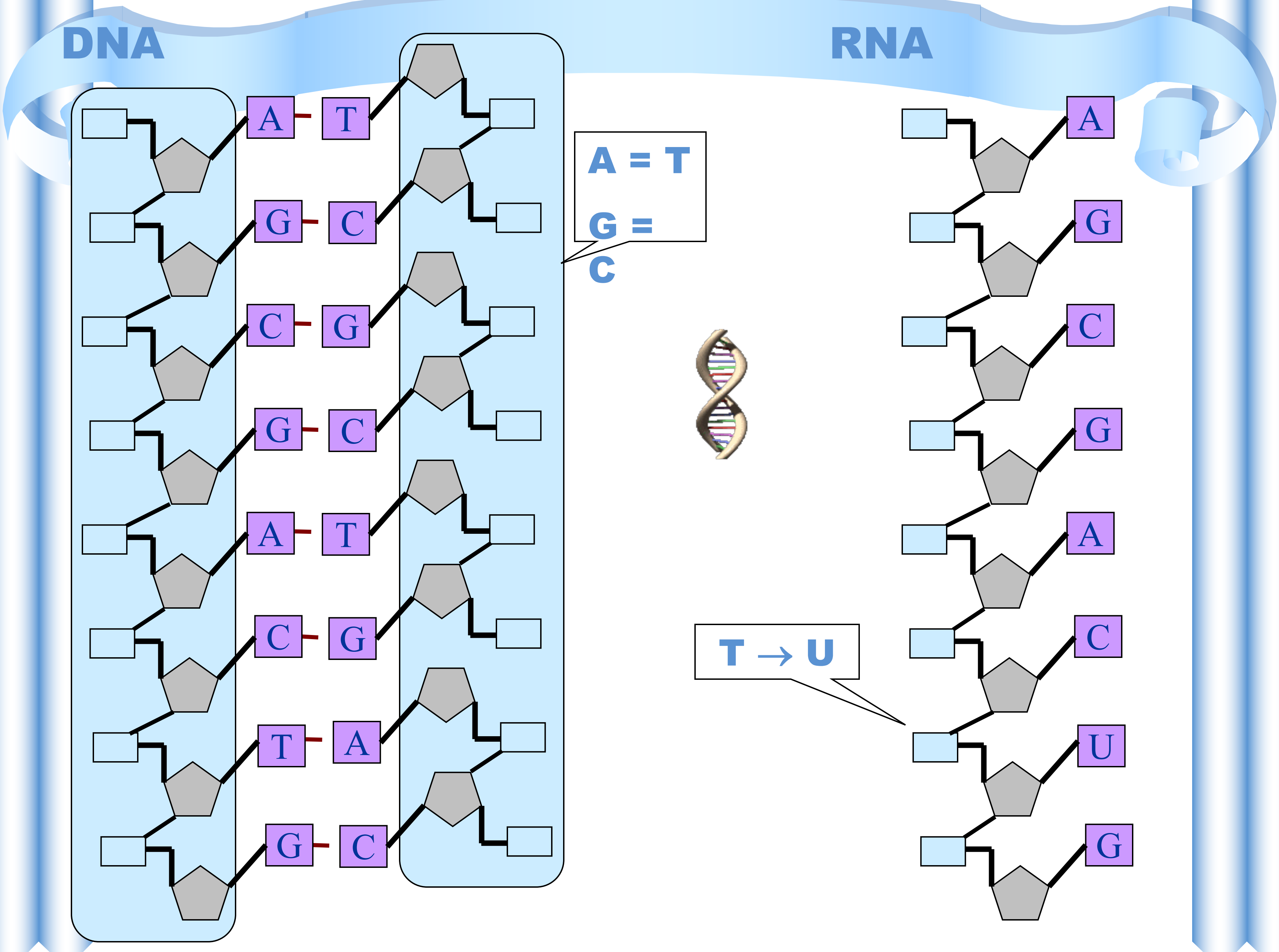
Uracil (U)



Thymine (T)



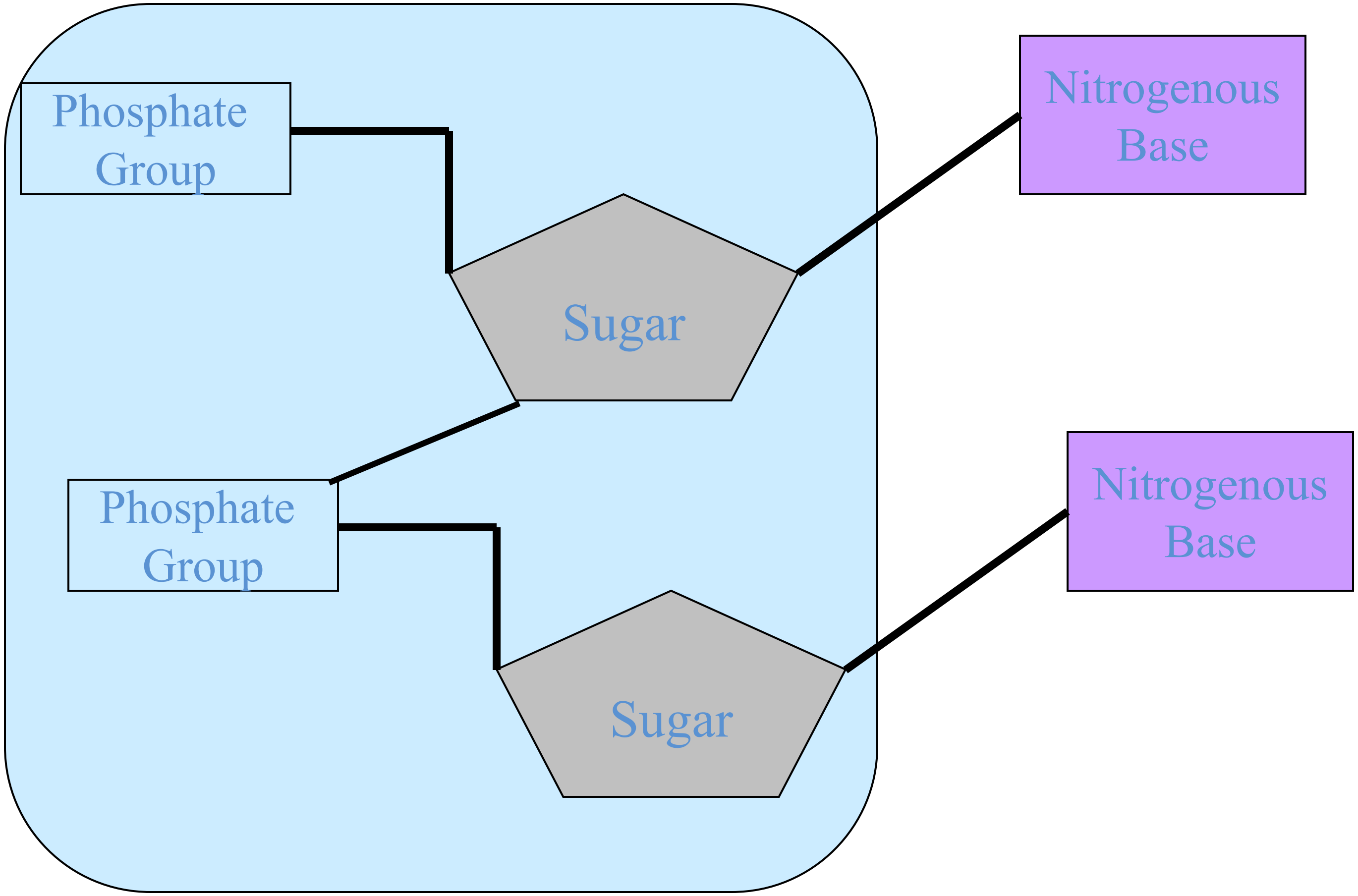
Cytosine (C)


DNA
RNA
A G C G A C T G
T C G C T G A C
A = T
G = C
T → U
A G C G A C U G

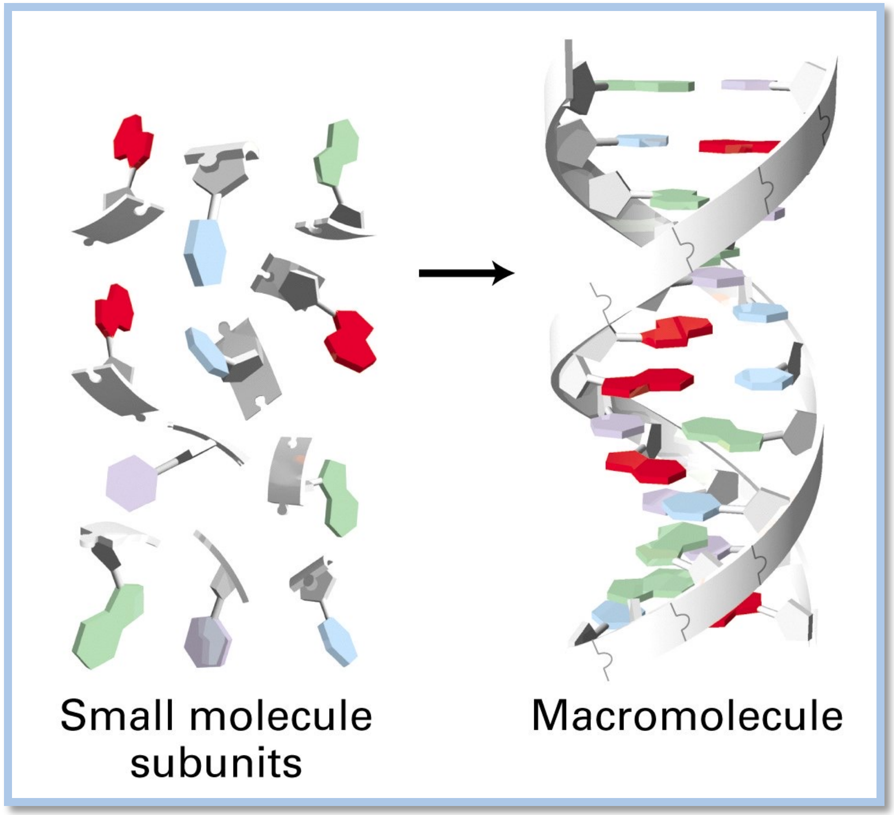
Nucleotides

- Each polynucleotide chain consists of a sequence of nucleotides linked together by phosphodiester bonds, joining adjacent deoxyribose moieties.

The two polynucleotide strands are held together in their helical configuration by hedrogen binding between bases in opposing strands, the resulting base-pairs being stacked between the two chains perpendicular to the axis of molecule like the steps of a spiral staircase.



❖The high degree of stability of DNA double helices results in part from the **large number of hydrogen bonds** between the base-pairs (even though each hydrogen bond by itself is quite weak, much weaker than a covalent bond) and in part from the hydrophobic bonding(or stacking forces) between the stacked base-pairs.



- Stability of DNA double-helix in two ways:

1- hydrogen bonding between purines and pyrimidines of opposite strands.

2- stacking of one base-pair plane over the other.

- Pairing is determined by the molecular shape of the bases and their ability to form hydrogen bonds. Just which pairs come together is referred to as the *base-pair rule* .
- The rule states that adenine (A) pairs with thymine (T) and guanine (G) pairs with cytosine (C).
- Also notice that one strand ends with the number 3′, the three-prime strand,while the other is called the 5′, or five-prime strand.
- This is because the two strands run in opposite directions (i.e., one points in one direction while the other points in the opposite direction).

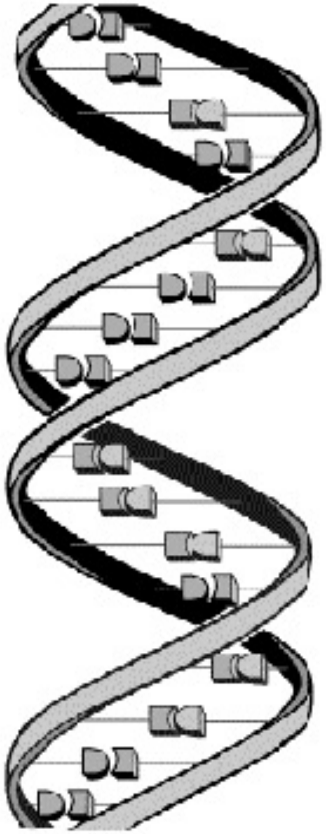
RNA Structure and Function:-

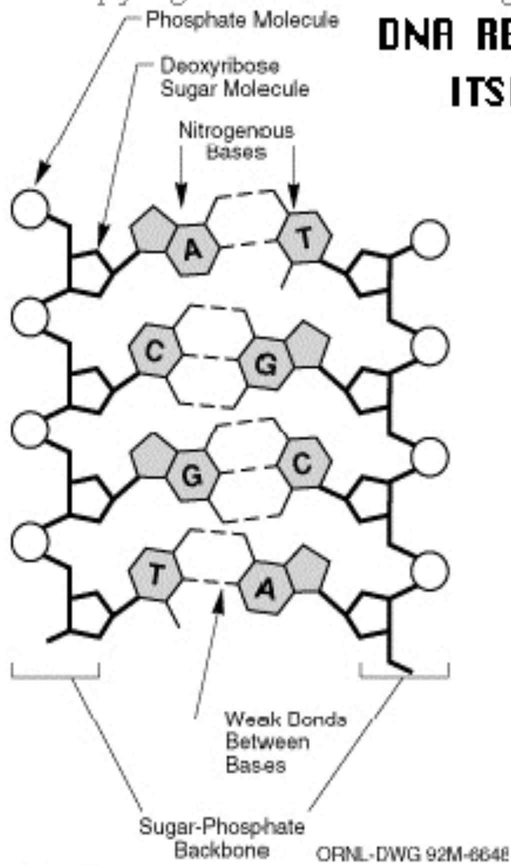
- ribonucleic acid (RNA) is another type of nucleic acid and is important in protein production.
- RNA's nucleotides are different from DNA's nucleotides. RNA's
- nucleotides contain a *ribose* sugar whereas the nucleotides of DNA contain a *deoxyribose* sugar.
- Ribose and deoxyribose sugars differ by one chemical functional group (Ribose has an —OH group and deoxyribose has an —H group on the second carbon.

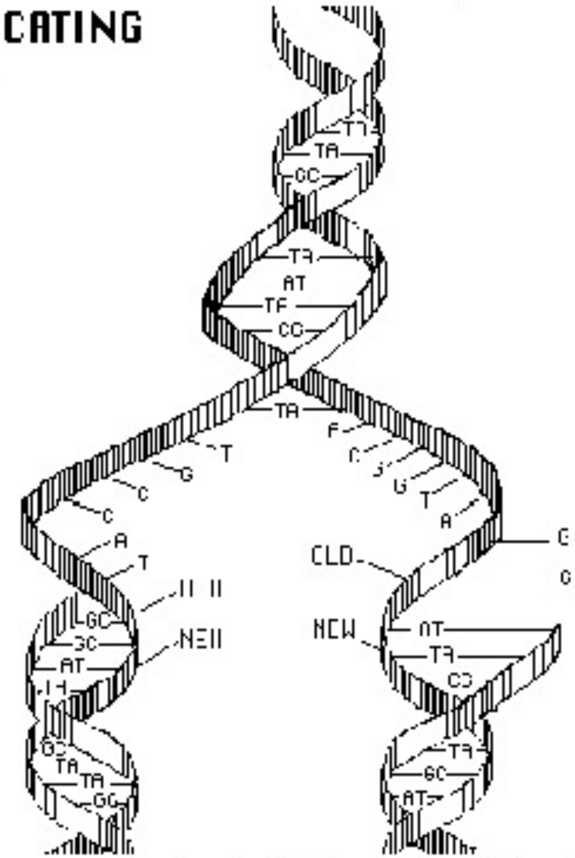
- **RNA differs from DNA in other important ways**. RNA contains the nitrogenous bases **uracil** (U), guanine (G), cytosine (C), and adenine (A). Note that the sets of nitrogenous bases in DNA and RNA are also slightly different. RNA has uracil, whereas DNA has thymine.
- In addition, when **RNA is synthesized from DNA,** it exists only as a single strand. This is different from DNA because DNA is typically double-stranded.
- Cells also use DNA and RNA differently. DNA is found in the cell's nucleus and is the original source for information to make proteins. **RNA is made in the nucleus and then moves into the cytoplasm of the cell where it becomes directly involved in the process of protein assembly.**
- The protein-coding information in RNA comes directly from DNA. RNA is made by enzymes that read the protein coding information in DNA.
- Like DNA replication, RNA synthesis also follows base-pairing rules where the RNA nitrogenous bases pair with the DNA nitrogenous bases: Guanine and cytosine still pair during RNA synthesis but RNA contains uracil, not thymine, so adenine in DNA pairs with uracil in RNA. The thymine in DNA still pairs with adenine in RNA

DNA: the molecule of heredity

- Self-complementarity sets molecular basis of heredity
  - Knowing one strand, creates a template for the other
  - "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material." Watson & Crick, 1953







Types

- **Deoxyribonucleic acid (DNA)**

The DNA segments carrying this genetic information are called genes.

- **Ribonucleic acid (RNA)**

functions in converting genetic information from genes into the amino acid sequences of proteins.

The three universal types of RNA include transfer RNA (tRNA), messenger RNA (mRNA), and ribosomal RNA (rRNA). Messenger RNA acts to carry genetic sequence information between DNA and ribosomes, directing protein synthesis. Ribosomal RNA is a major component of the ribosome, and catalyzes peptide bond formation. Transfer RNA serves as the carrier molecule for amino acids to be used in protein synthesis, and is responsible for decoding the mRNA. In addition, many other classes of RNA are now known.

- **Artificial nucleic acid analogues** have been designed and synthesized by chemists, and include peptide nucleic acid, morpholino- and locked nucleic acid, glycol nucleic acid, and threose nucleic acid. Each of these is distinguished from naturally occurring DNA or RNA by changes to the backbone of the molecules.

▪ Types of RNA

1- rRNA: ribosomal RNA that is required for building ribosomes, which are structures necessary for protein synthesis.

2- tRNA: transfer RNA that serves to transfer individual amino acid molecules from the general cytoplasm to their appropriate location in a growing polypeptide during protein synthesis.

3- mRNA: messenger RNA that carries the specific instructions for building a specific protein.

Note :- Both rRNA and tRNA are generic groups of molecules in that all types of rRNA and all types of tRNA are involved in the synthesis of every type of protein. However, mRNA is specific in that a different type of mRNA is required for every different type of protein.

THANK YOU