Introduction to Molecular Biology

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2018-2019

What is Molecular Biology?

- The attempt to understand biological phenomena in molecular terms.
- The study of gene structure and function at the molecular level.
- As a result, It is the study of molecular basic of the process of replication, transcription and translation of the genetic material.
- Molecular biology mainly concerns itself with Understanding of interactions between the various systems of a cell, including the interactions between DNA, RNA and protein biosynthesis, learning how these interactions are regulated.
- This field overlaps with other areas of biology and chemistry, particularly genetics and biochemistry.
- It is the joining of aspects between genetics and biochemistry

All Life depends on 3 critical molecules

- Since 1859, molecular biologists have started to characterize, isolate, and manipulate the molecular components of cells and organisms, which are:

1. DNA (Discovered in 1869): the storage of genetic information
2. RNA (Discovered in 1961):

- Act to transfer short pieces of information to different parts of cell.
- Provide templates to synthesize into protein.

3- Proteins (Discovered in 1837): : the major structural and enzymatic type of molecule in cells.

Some Terminology

- **Nucleic acid**: Biological molecules (RNA and DNA) that allow organisms to reproduce
- **Gene**: Basic physical and functional units of heredity , located on the chromosomes , consisting of specific sequences of DNA bases
- **Genes encode**: instructions on how to make proteins.
- **Genotype**: The genetic makeup of an organism.
- **Phenotype**: the physical expressed traits of an organism.
- **Genome:** is the entirety of an organism's hereditary information, It is encoded either in DNA or, for many types of virus, in RNA, the genome includes both the genes and the non-coding sequences of the DNA.

Why Genome analysis ?

1- The prediction of genes in uncharacterised genomic sequences.

2- To obtain the complete sequences of as many genomes as possible.

3- For Genetic modification.

4- Genetic modification to develop new varieties at a faster rate.

Note: Human Genome Project (HGP) started in 1990 and finished in 2004 by American geneticists

Sources of DNA

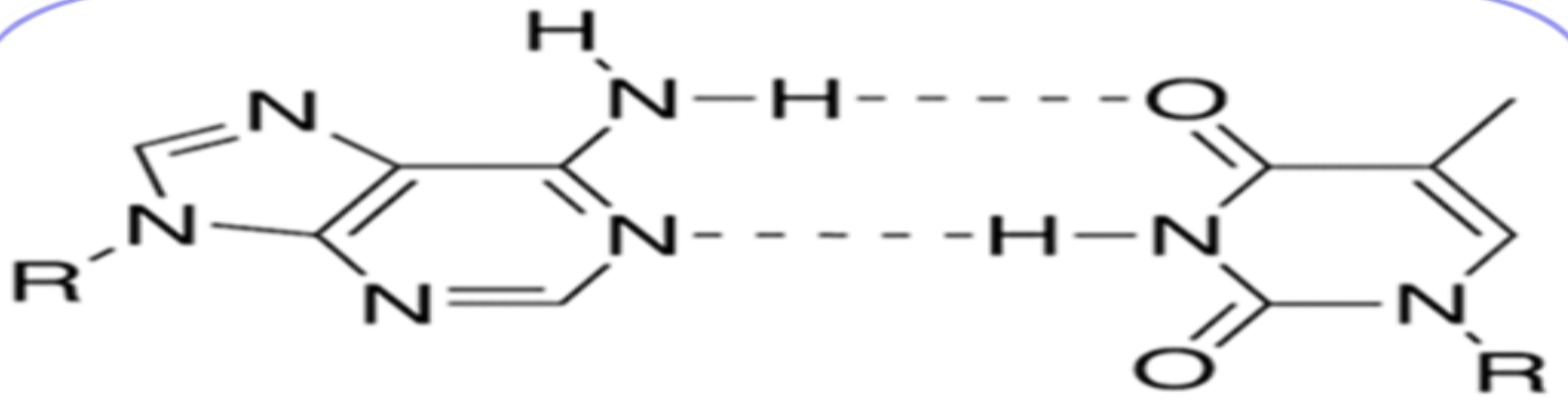
- Blood
- Buccal cells
- Cultured cells (plant and animal)
- Bacteria
- Biopsies
- Forensic samples i.e. body fluids, hair follicles, bone & teeth roots.

Structure of DNA

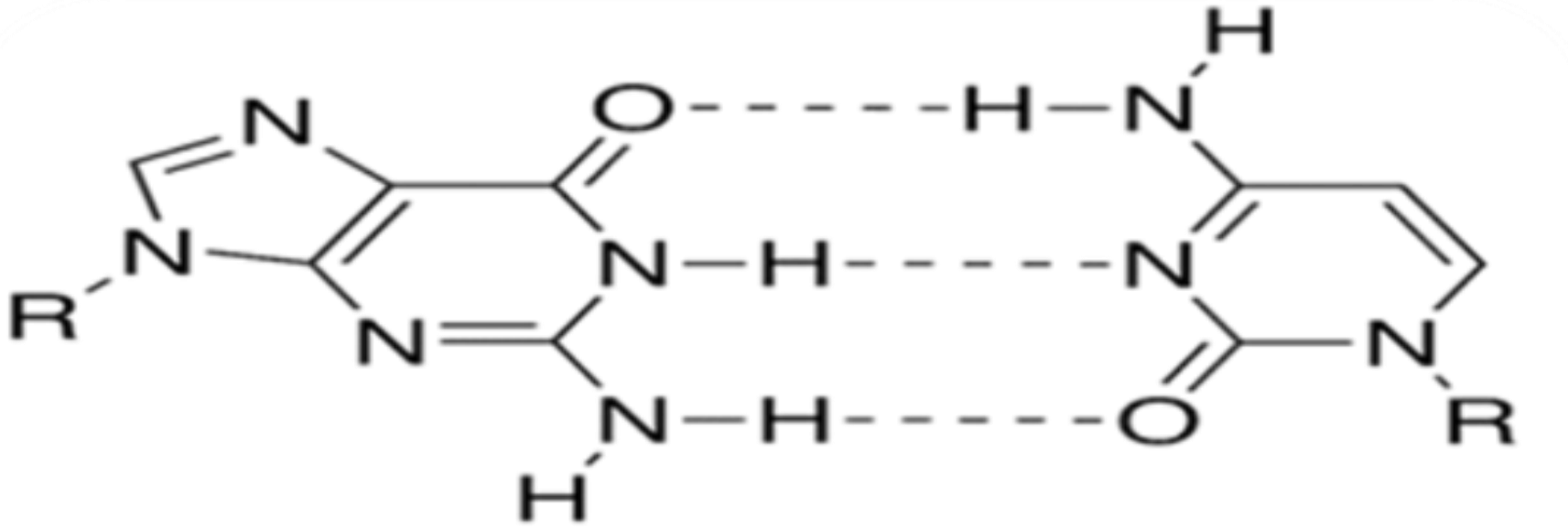
The genetic material of all cellular organisms and most viruses.

(Discovered in 1953)

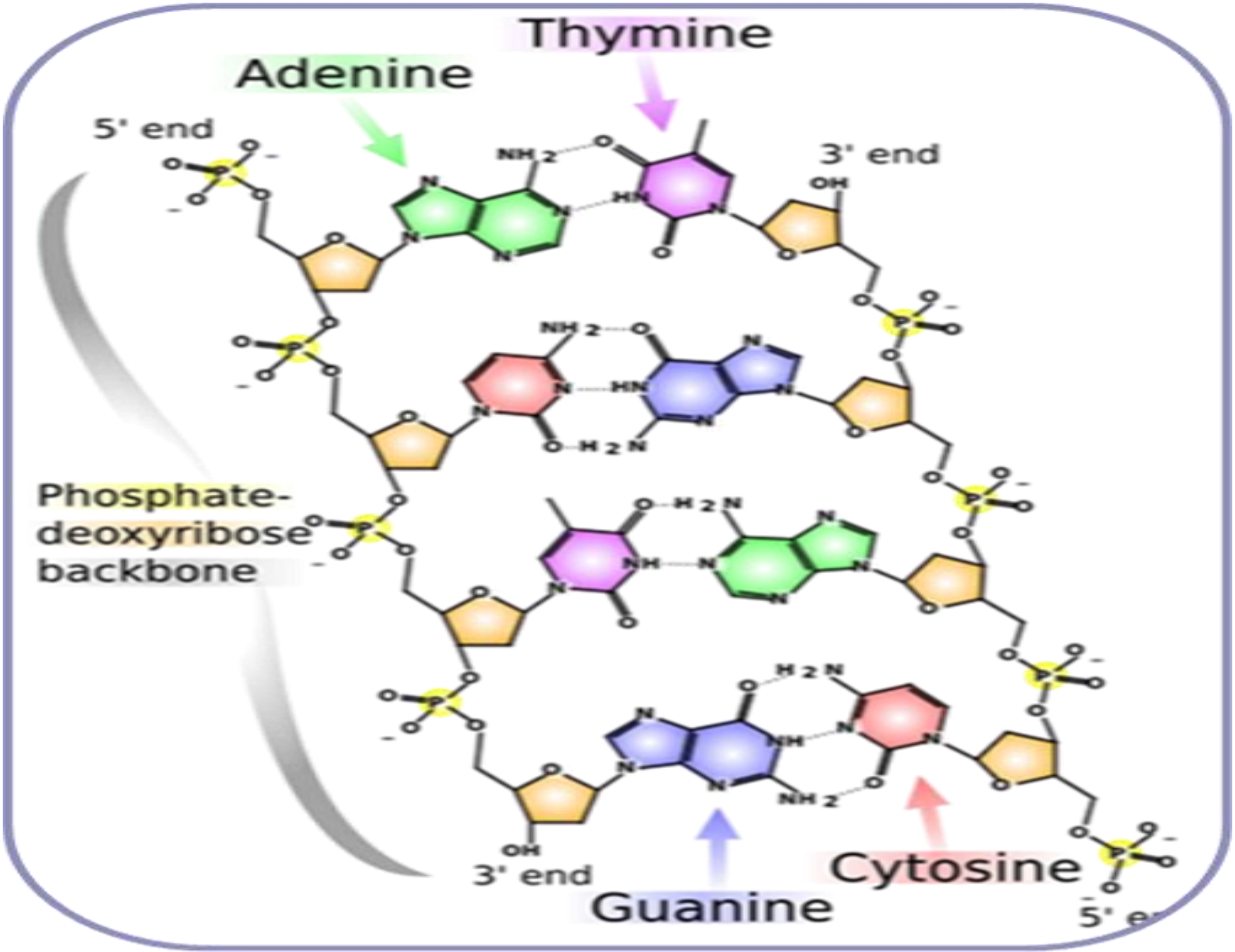
- Made up of 4 different building blocks (so called nucleotide bases), each an almost planar nitrogen organic compound
  - Adenine (A)
  - Thymine (T)
  - Guanine (G)
  - Cytosine (C)
  - Base pairs (A -- T, C -- G)



Adenine Thymine



Guanine Cytosine


Thymine
Adenine
5' end
3' end
Phosphate-
deoxyribose
backbone
3' end
Cytosine
Guanine
5' e

Transcription of DNA to RNA

- Why transcription:

  1- (For genome) to direct or effect changes in the cytoplasm of the cell

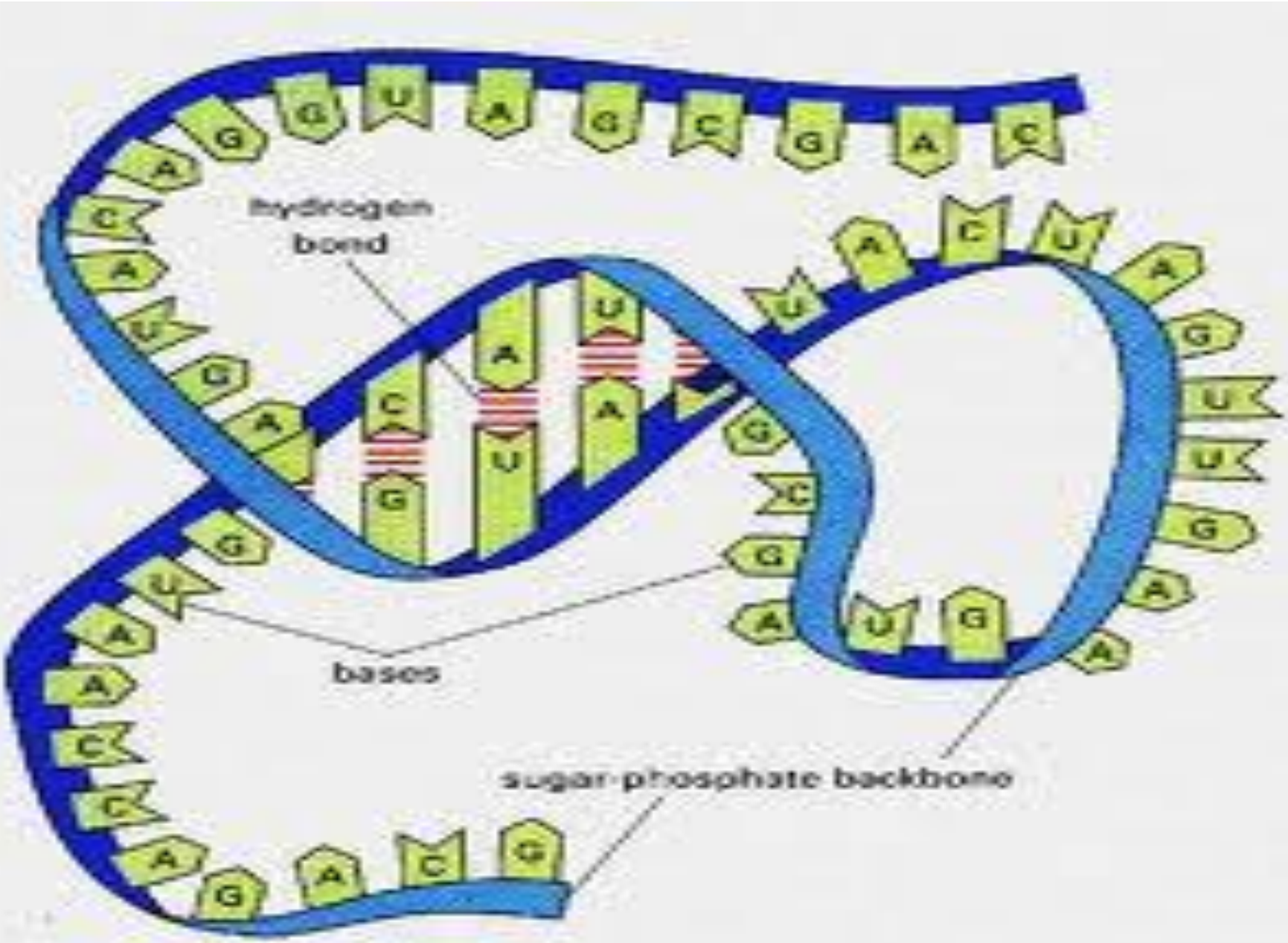
  2- Need to generate new proteins to populate the cytosol (heteregenous intracellular soup of the cytoplasm) .

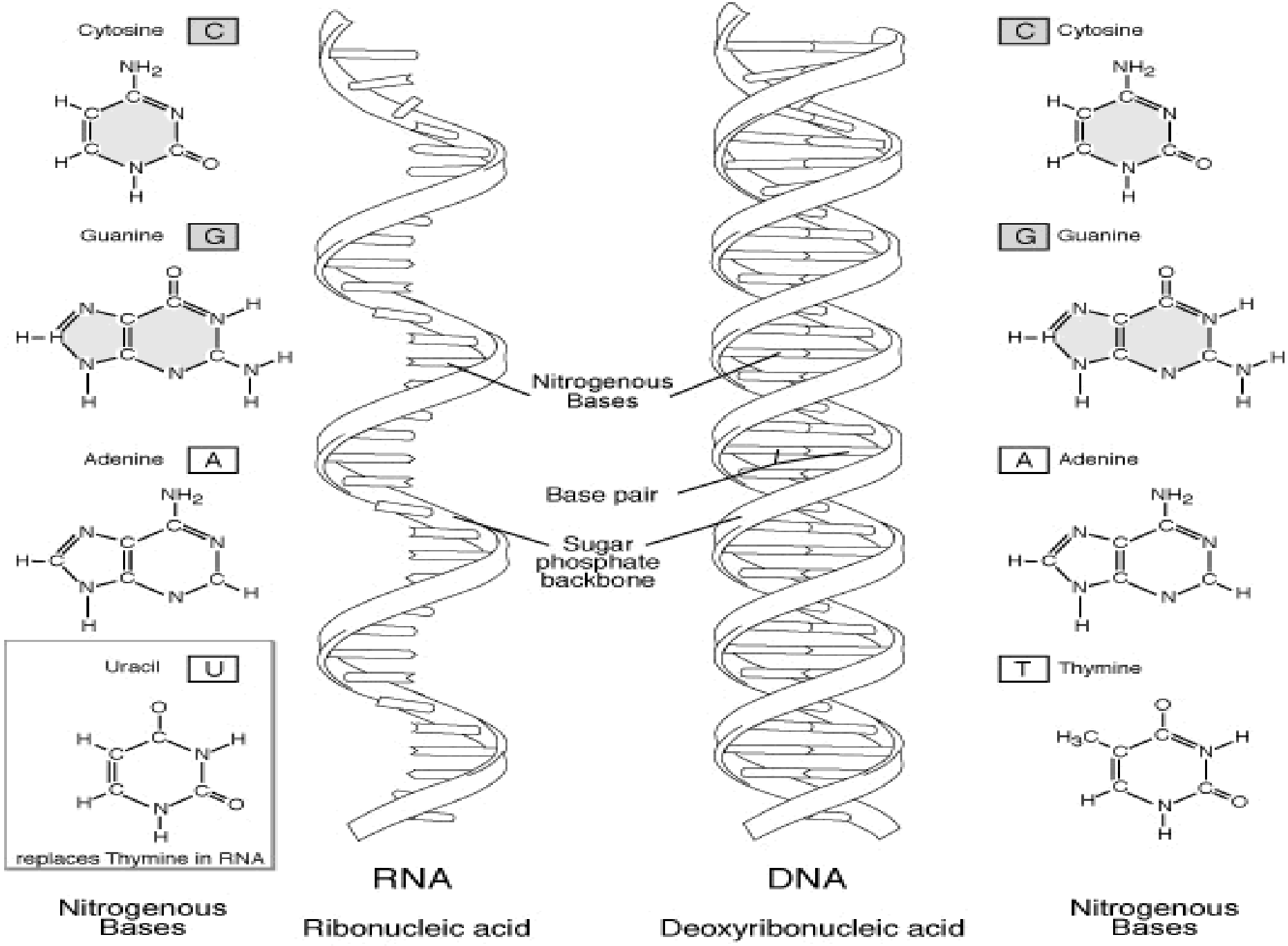
- RNA (Ribonucleic acid)
  - Similar to DNA (except for a chemical modification of the sugar backbone)
  - Instead of T contains U (Uracil) which binds with A.
  - Is not double stranded but single stranded
  - RNA molecules tend to fold back on themselves to make helical twisted and rigid segments.

Coding and non-coding RNA

- Not all RNA code for proteins
  - 4% of total RNA is made of coding RNA
  - Of the non-coding RNA
    - Ribosonal RNA (rRNA) and transfer RNA(tRNA) are used in the various protein translational apparatus
    - Small nuclear RNA (snRNA) – found in eucaryotes, is part of the splicing apparatus
    - Small nucleolar RNA (snoRNA) involved in methylation of rRNA
    - Small cytoplasmic RNA (scRNA) plays a role in the expression of specific genes

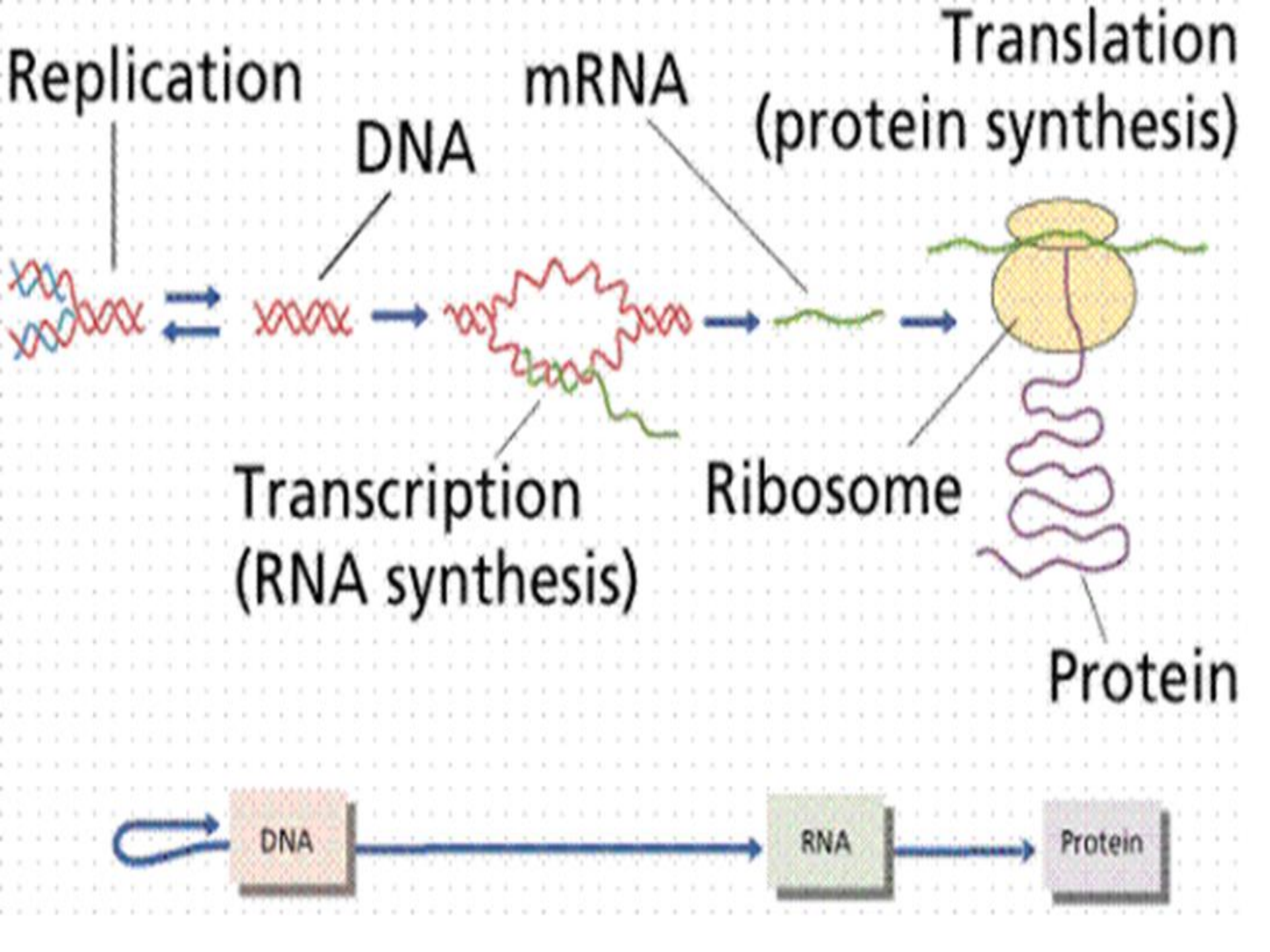
Structure of RNA

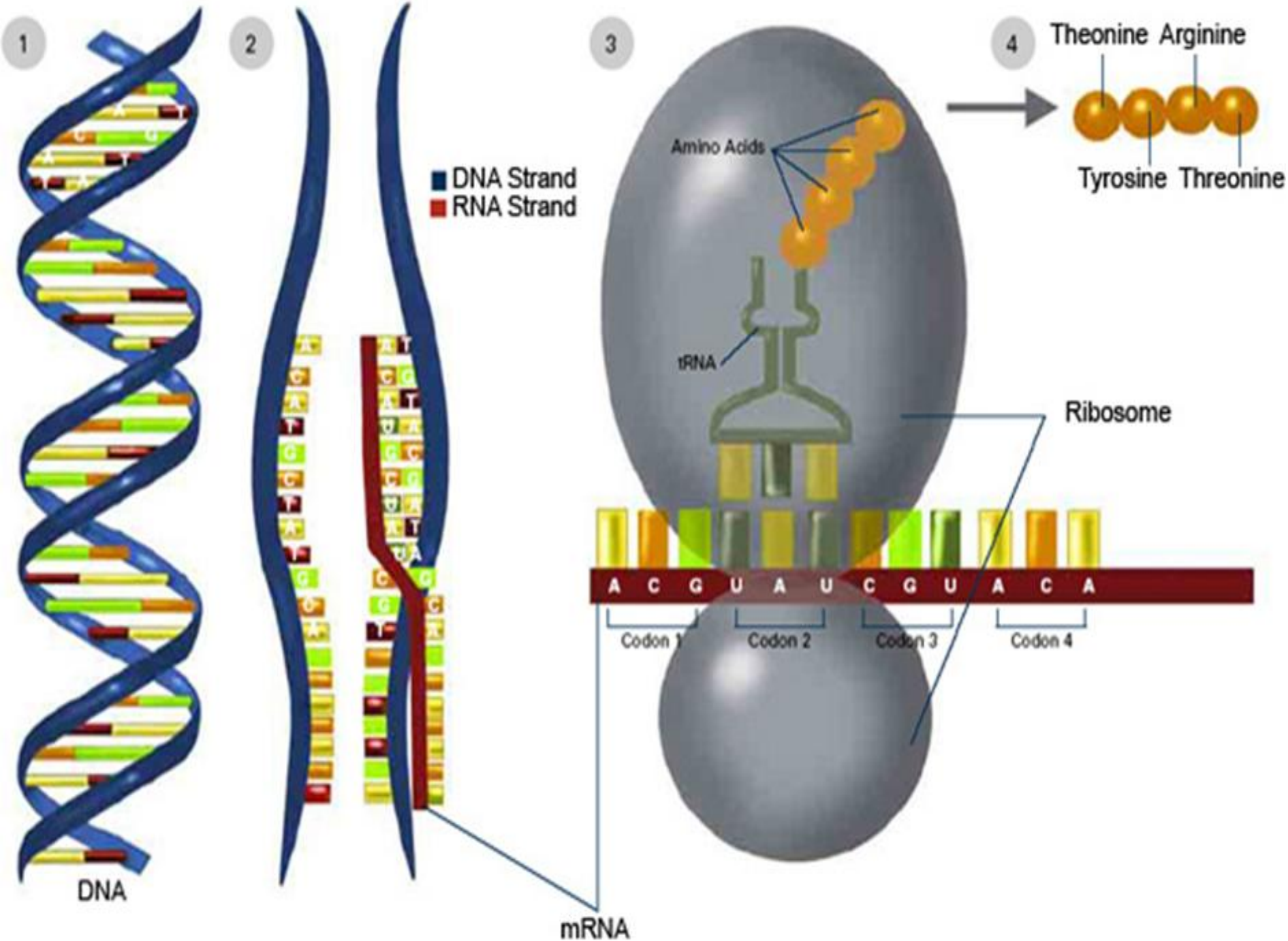



Cytosine
C
Guanine
G
Adenine
A
Uracil
U
replaces Thymine in RNA
Nitrogenous Bases
Nitrogenous Bases
Base pair
Sugar phosphate backbone
RNA
Ribonucleic acid
DNA
Deoxyribonucleic acid
C
Cytosine
G
Guanine
A
Adenine
T
Thymine
Nitrogenous Bases

Translation

- It's a process of generating a protein or polypeptide from an mRNA molecule is known as translation.
- Protein: a polymer or chain of amino acids, whose sequence is determined by the mRNA template
  - 3 nulceotides code for 20 naturally occurring amino acids
  - $4^3 = 64$; thus several trinucleotide sequences (codons) correspond to a single amino acid.
  - There is no nucleotide between codons, and a few codons represent start and stop.
  - Notable exceptions: code of naturally occurring selenocysteine is identical to that for a stop codon, except for a particular nucleotide sequence further downstream.


Replication
DNA
mRNA
Translation
(protein synthesis)
Transcription
(RNA synthesis)
Ribosome
Protein
DNA
RNA
Protein


1
2
3
4
DNA Strand
RNA Strand
Amino Acids
tRNA
Ribosome
Theonine
Arginine
Tyrosine
Threonine
A C G U A U C G U A C A
Codon 1
Codon 2
Codon 3
Codon 4
DNA
mRNA

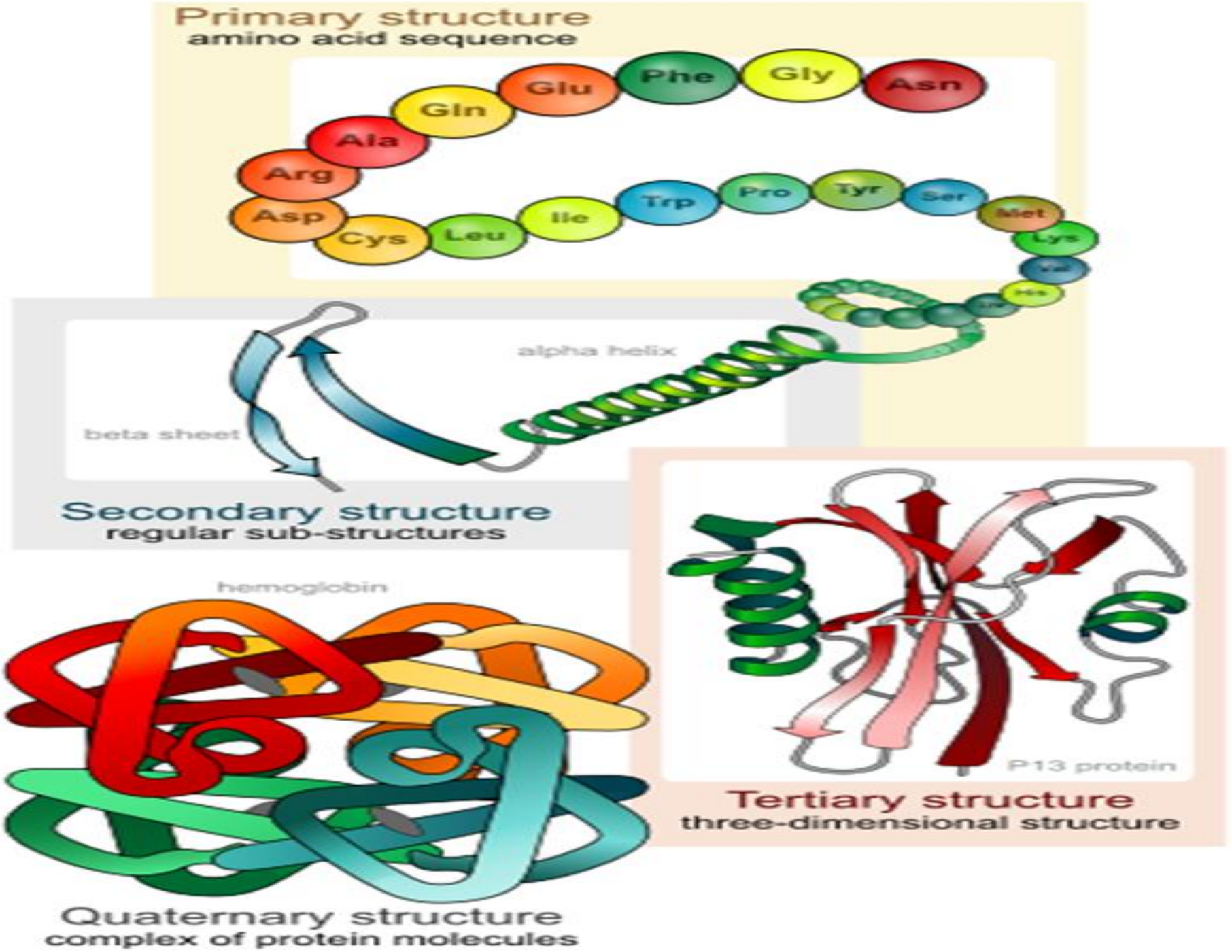
Structure of Protein

- **Primary protein structure:** Sequence of a chain of amino acid.

- **Secondary protein structure:** A chain of amino acids linked by hydrogen bonds.

- **Tertiary protein structure:** It occurs when certain attraction occurs between alpha helices and pleated sheets.

- **Quaternary protein structure:** Protein containing more than one amino acid chains.


Primary structure
amino acid sequence
Glu
Phe
Gly
Asn
Gln
Ala
Arg
Asp
Cys
Leu
Ile
Trp
Pro
Tyr
Ser
Met
Lys
alpha helix
beta sheet
Secondary structure
regular sub-structures
P13 protein
Tertiary structure
three-dimensional structure
hemoglobin
Quaternary structure
complex of protein molecules

Biological function of proteins

1- Enzyme catalysis: DNA polymerases, lactate dehydrogenase, trypsin

2- Transport: hemoglobin, membrane transporters, serum albumin

3- Storage: ovalbumin, egg-white protein, ferritin

4- Motion: myosin, actin, tubulin, flagellar proteins

5- Structural and mechanical support: collagen, elastin, keratin, viral coat proteins

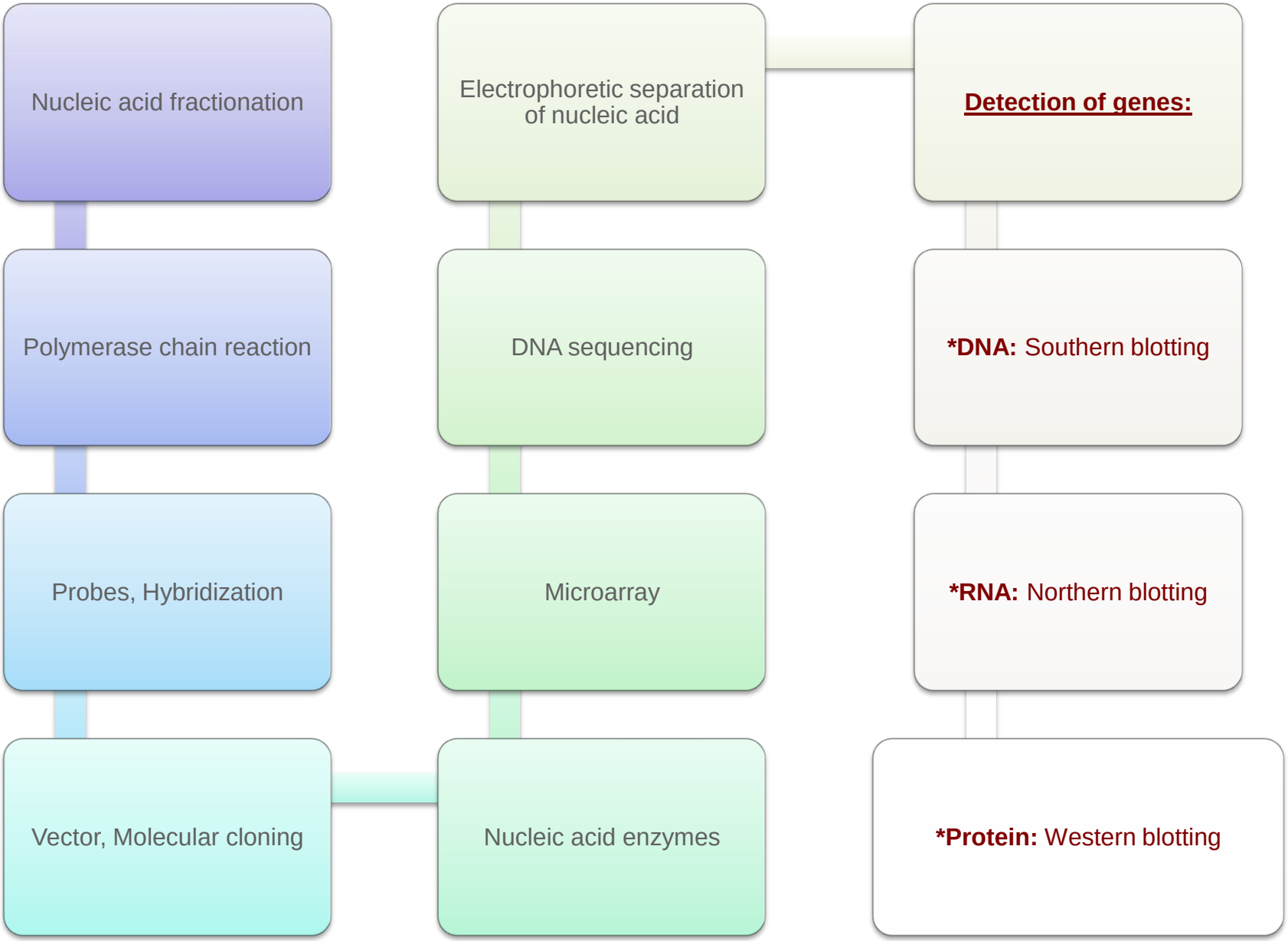
6- Defense: antibodies, complement factors, blood clotting factors, protease inhibitors

7- Signal transduction: receptors, ion channels, rhodopsin, G proteins, signalling cascade proteins

8- Control of growth, differentiation and metabolism: repressor proteins, growth factors, cytokines, bone morphogenic proteins, peptide hormones, cell adhesion proteins

9- Toxins: snake venoms, cholera toxin

Common Tools of Molecular Biology



Application of Molecular Biology

1- Research

2- Diagnosis

3- Transplantation

4- Paternity

5- Forensic analysis

6- Gene therapy

7- Drug Design