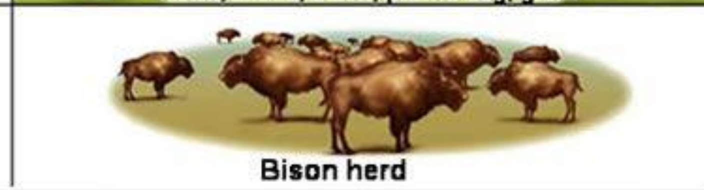
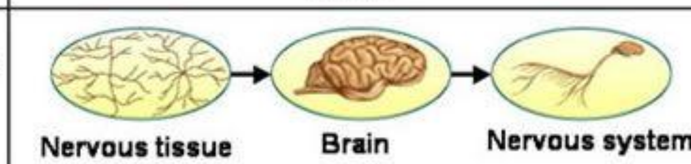
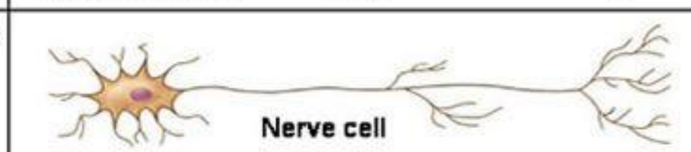
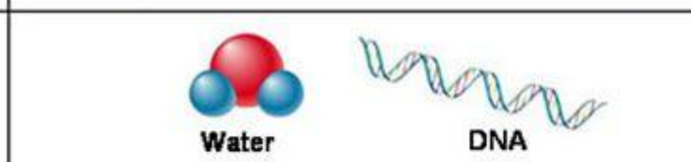
Hierarchy of Biological Organization. Chemical Level

Lecture 1

Levels of Organization

Biosphere	The part of Earth that contains all ecosystems	
Ecosystem	Community and its nonliving surroundings	
Community	Populations that live together in a defined area	
Population	Group of organisms of one type that live in the same area	
Organism	Individual living thing	
Groups of Cells	Tissues, organs, and organ systems	
Cells	Smallest functional unit of life	
Molecules	Groups of atoms; smallest unit of most chemical compounds	

Lower Level of Organisation

Atomic and molecular levels
Molecules are made of atoms of elements like carbon, nitrogen, hydrogen, sulphur. These non-living things combine to form **protoplasm** which is living matter of cell.

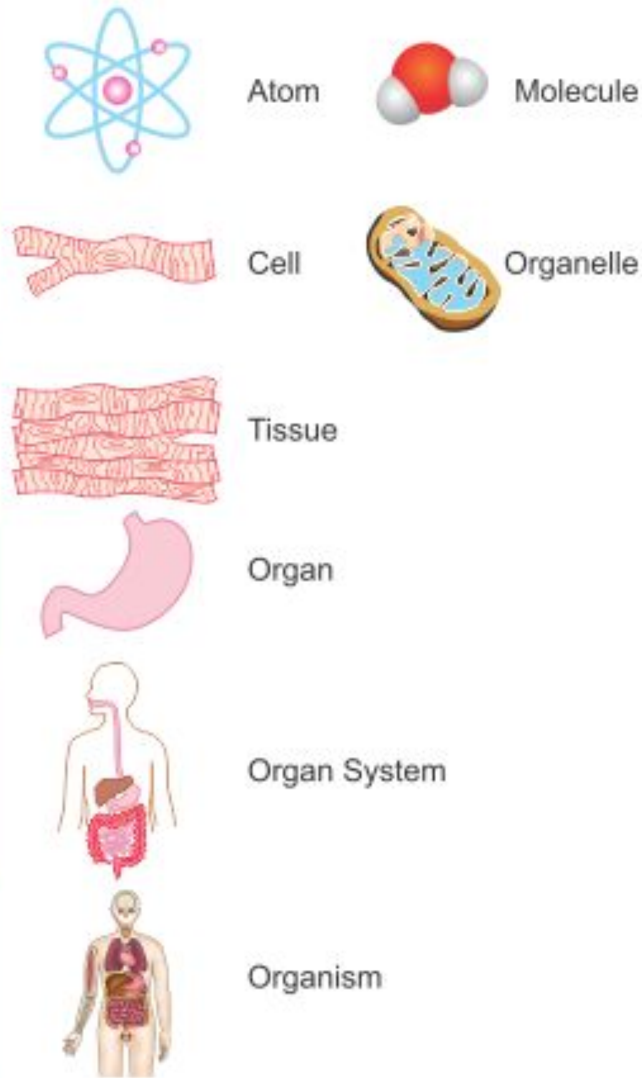
Cellular level
All living things are made up of cells. These are structural and functional unit of life.

Tissue level
The cells organized to form tissue. A tissue is a group of cells which are similar in structure and a specific function.

Organ level
Many tissues combine to form an organ, which performs a particular function.

Organ system level
Group of organs work together to perform life activities. e.g. the organs of digestive system work together to digest food.

Organism level
Several organ systems together to form a multicellular organism. The different organ systems work together to keep the organism alive.



Levels of Organization (Hierarchy)

1.Chemical

a. Basis for life
b. More than 100 different atoms (chemical building blocks of nature)
c. **Atoms → molecules → macromolecules**
d. Cytoplasm – essential material of human life

2.Organelle

a. A structure made of molecules organized so that it can perform a certain function
b. Can not survive outside the cell
c. "tiny organs" that allow each cell to live

3.Cellular

a. Cells – smallest and most numerous structural units that possess and exhibit the basic characteristics of living matter
b. 150 lb adult - 1×10^{14} cells (100 trillion)
c. Membrane, nucleus, cytoplasm, organelles
d. Cells specialize/differentiate to perform unique functions

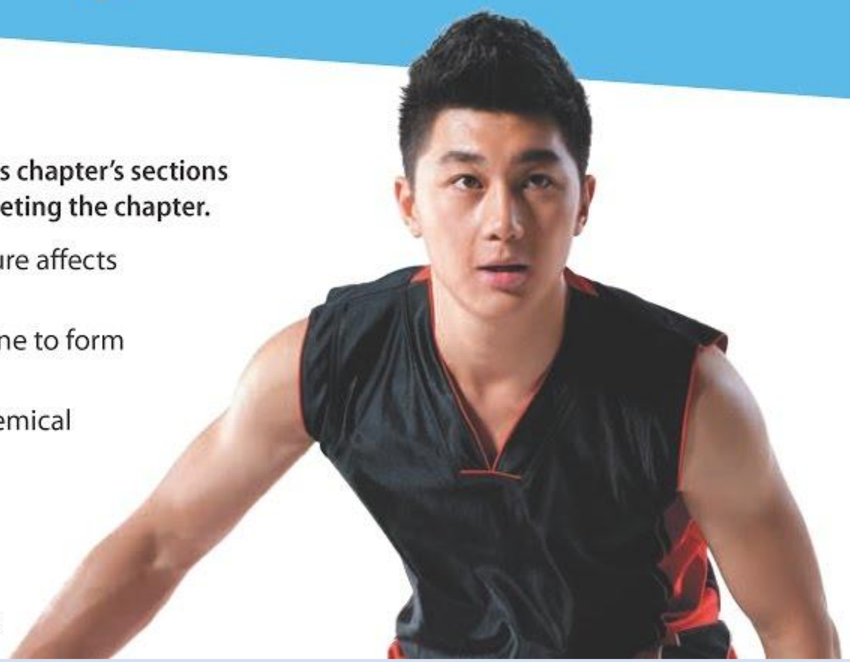
4.Tissue

a. Group of similar cells that develop together from the same part of the embryo
b. Specialized to perform certain functions
c. Surrounded by varying amounts and kinds of nonliving, intercellular substances, or matrix
d. Four major tissues
   1. epithelial
   2. connective
   3. muscle
   4. nervous

Matter:

1. Elements, atom and molecules
2. Chemical bonds
3. Chemical energy.
4. Types of metabolism: catabolism and anabolism
5. Inorganic compounds: water, O_2, nutrients
6. Organic compounds

2 The Chemical Level of Organization



Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

- **2-1** Describe an atom and how atomic structure affects interactions between atoms.
- **2-2** Compare the ways in which atoms combine to form molecules and compounds.
- **2-3** Distinguish among the major types of chemical reactions that are important for studying physiology.
- **2-4** Describe the crucial role of enzymes in metabolism.
- **2-5** Distinguish between organic compounds and inorganic compounds.

Matter:

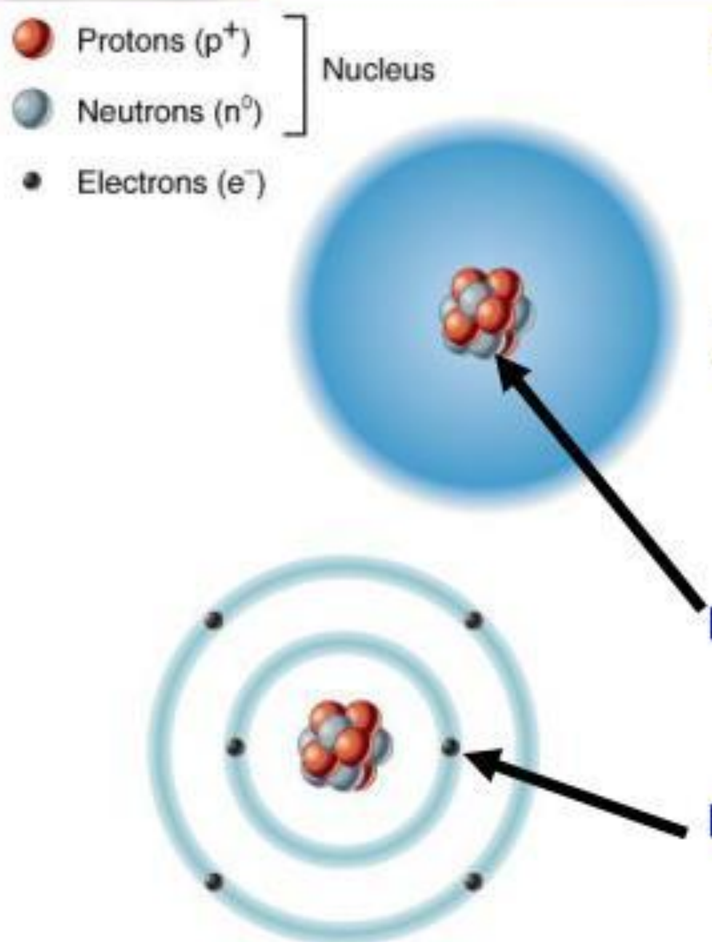
Elements, atom and molecules

Chemical bonds

First Biochemistry Chapter

- Biochemistry – study of substances found in living organisms and their interactions with each other
  - Most important branch of science in medicine
- Substances can be bio-inorganic or bio-organic
  - Bio-inorganic = water, ions, and ionic compounds
  - Bio-organic:
    - Carbohydrates: C, H, O
    - Lipids: C, H, O
    - Proteins: C, H, O, N, S
    - Nucleic Acids: : C, H, O, N, P

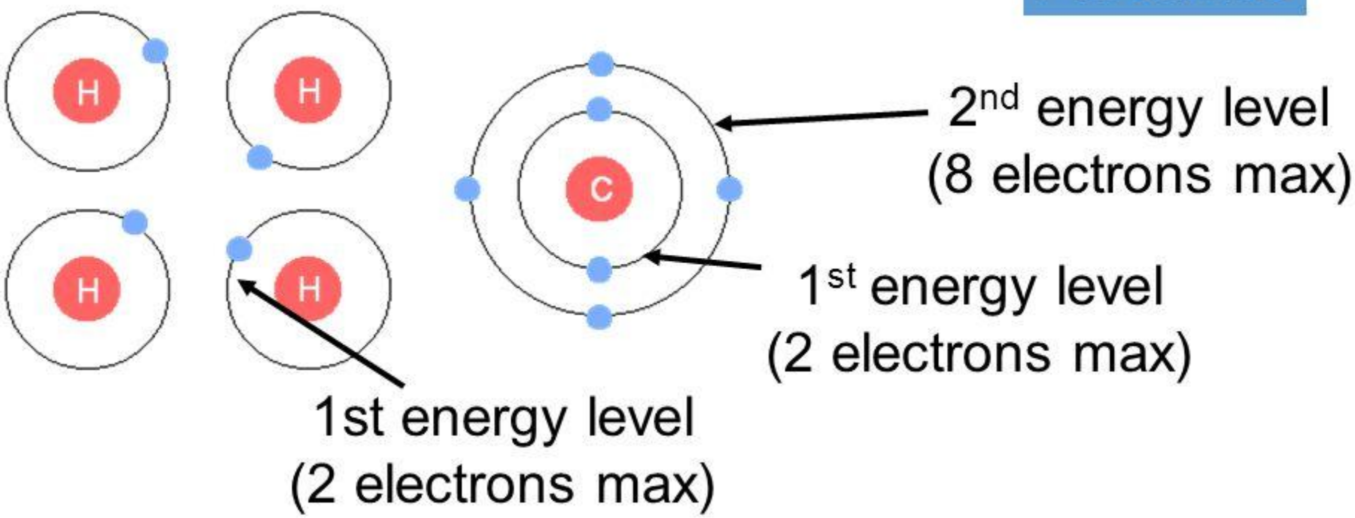
Structure of Atoms



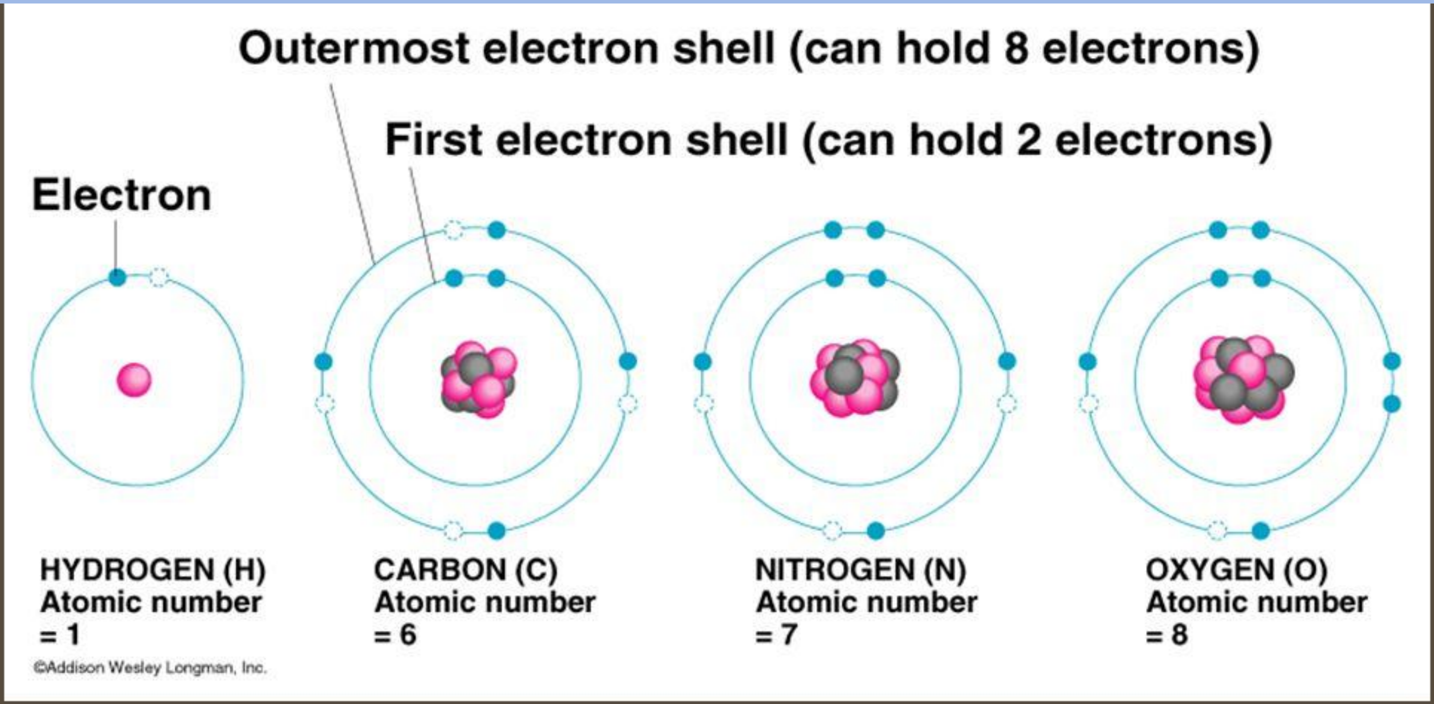
- Atoms are the smallest units of matter that retain the properties of an element
- Atoms consist of 3 types of subatomic particles
  - protons, neutrons and electrons
- Nucleus contains protons (p+) & neutrons (neutral charge)
- Electrons (e-) surround the nucleu as a cloud (electron shells are designated regions of the cloud)

What determines an atom's reactivity?

Electrons



Usually it is the electrons in the highest energy level of an atom that determine how that atom reacts



Octet Rule = atoms tend to gain, lose or share electrons so as to have 8 electrons

- ✓C would like to Gain 4 electrons
- ✓N would like to Gain 3 electrons
- ✓O would like to Gain 2 electrons

Nonpolar covalent bonds

- The atoms have similar electronegativities
  - Share the electron equally

Examples of this are the DIATOMIC molecules

H, O, N, Cl, Br, I, F

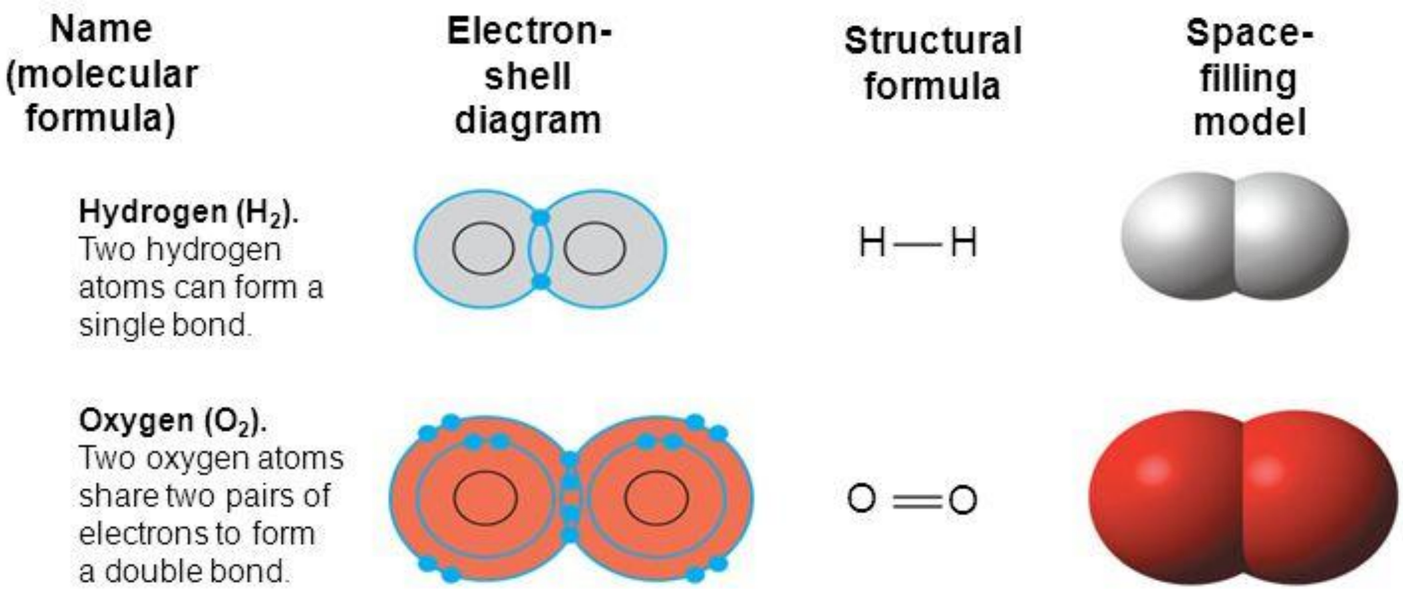
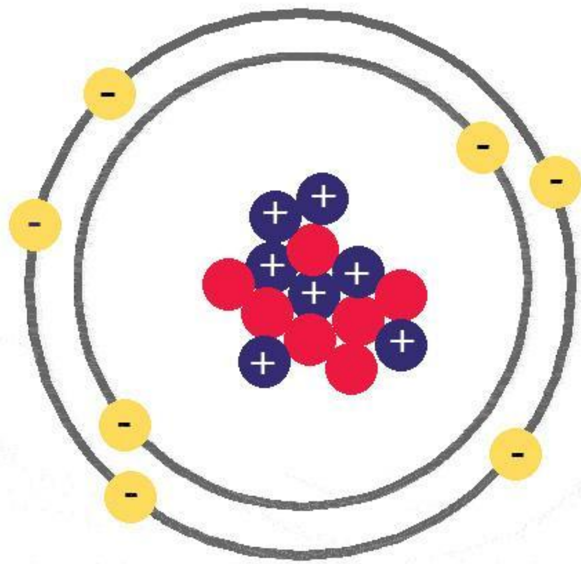


Figure 2.11 A, B

Nitrogen

Nitrogen makes up 78% of air and a vital component of all living things in amino acids and proteins. Nitrogen is also very important as a component of industrially produced chemicals.



Nitrogen atom

Nucleus:

Protons: 7

Neutrons: 7

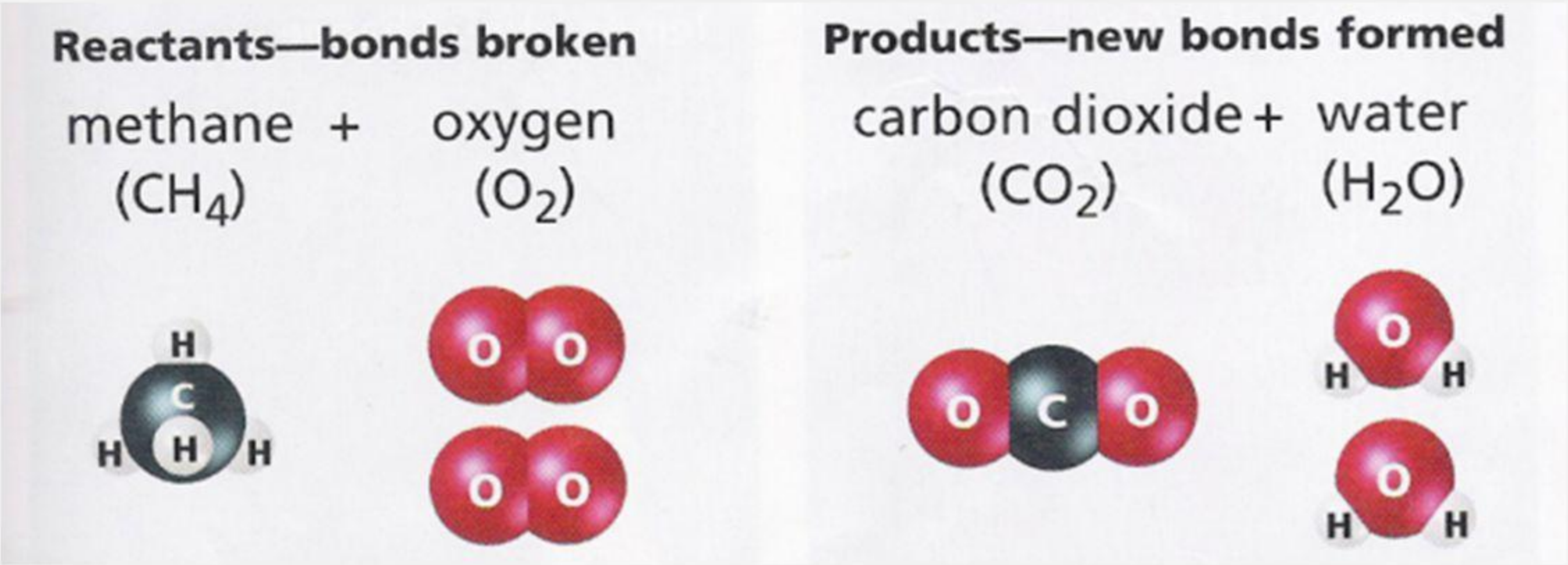
Electrons: 7

$\mathbf{N}^{7}_{14}$

What is a Covalent Bond?

- Atoms in non-ionic compounds share electrons.
- The chemical bond that results from sharing electrons is a **covalent bond**.
- A **molecule** is formed when two or more atoms bond covalently.
- The majority of covalent bonds form between atoms of nonmetallic elements which are near each other on the periodic table.

Chemical reactions involve changes in the chemical bonds that join atoms in compounds.



Metabolic Reactions

- Can form bonds between molecules
  - dehydration synthesis
  - synthesis
  - anabolic reactions
  - ENDERGONIC

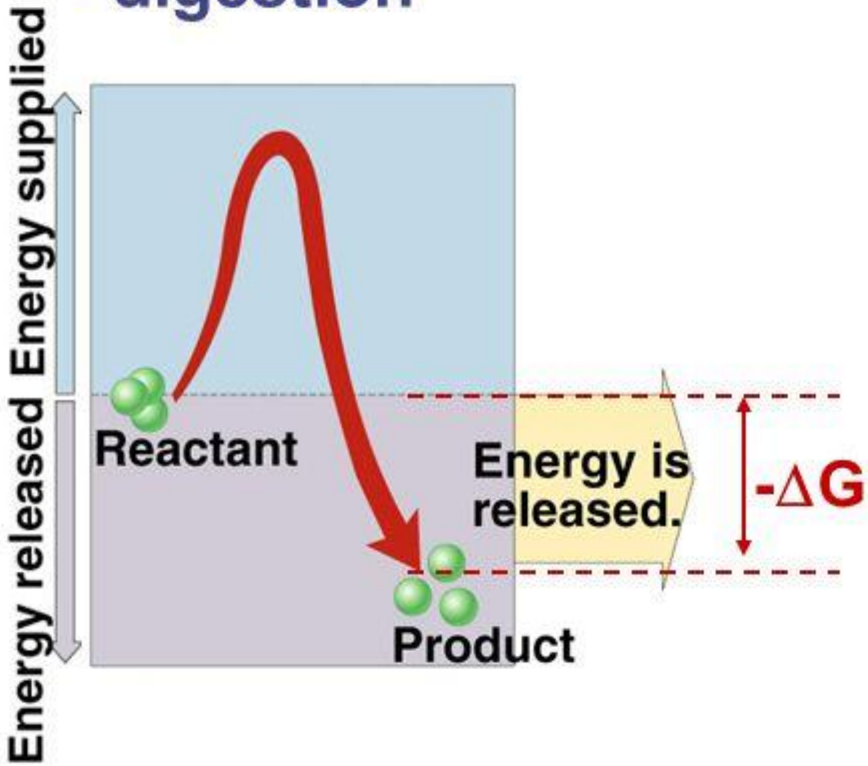
building molecules=
more organization=
higher energy state

- Can break bonds between molecules
  - hydrolysis
  - digestion
  - catabolic reactions
  - EXERGONIC

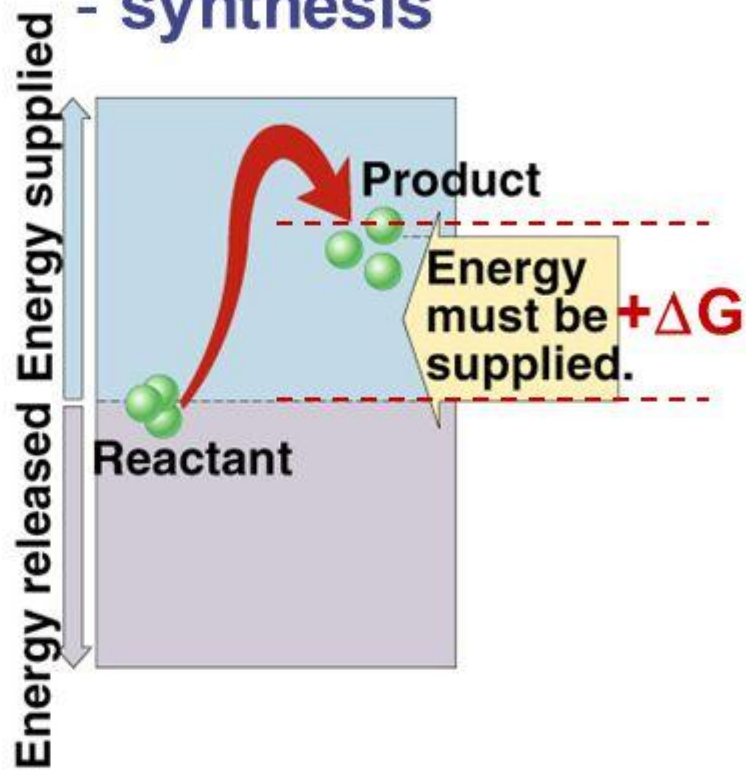
breaking down molecules=
less organization=
lower energy state

Endergonic vs. exergonic reactions

exergonic
- energy released
- digestion



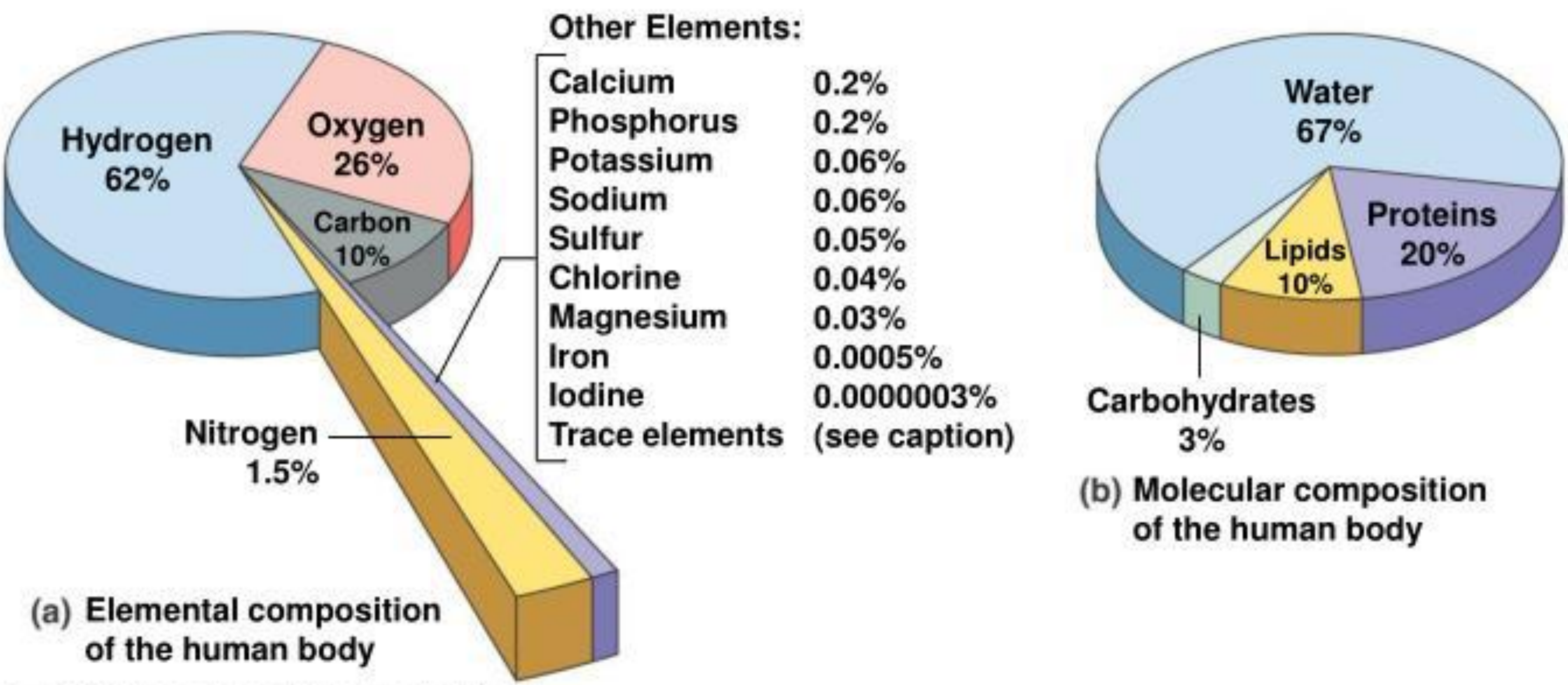
endergonic
- energy invested
- synthesis



ΔG = change in free energy = ability to do work

Matter: Inorganic compounds: water, O_2, nutrients

Chemical Level - Composition of the Body

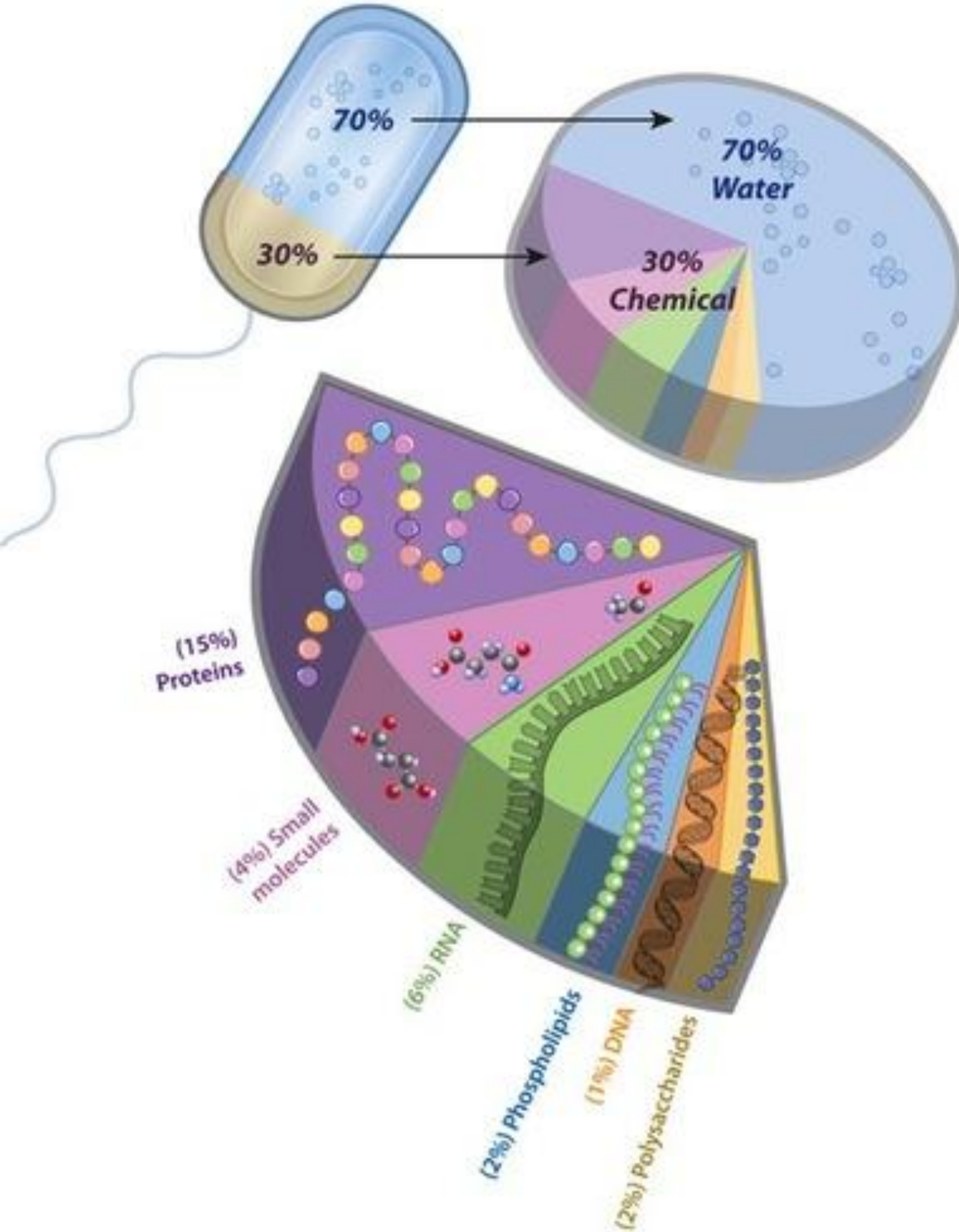


(a) Elemental composition of the human body

(b) Molecular composition of the human body

LE 1-3

Matter:
Organic compounds

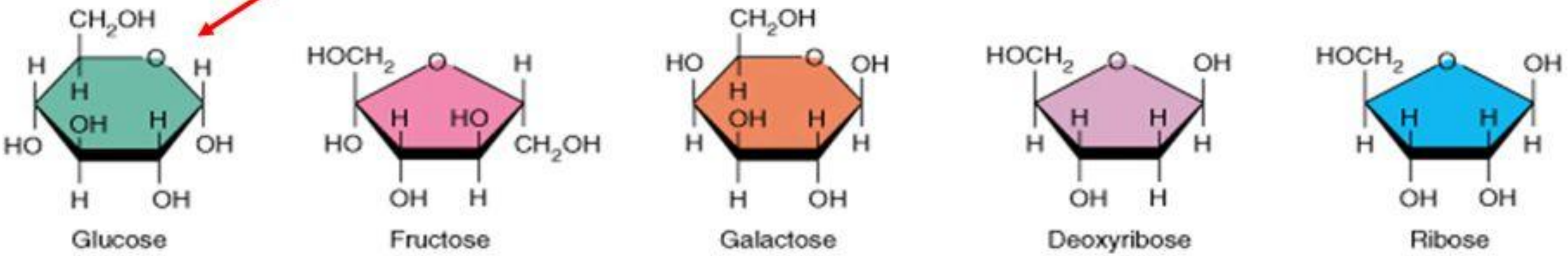


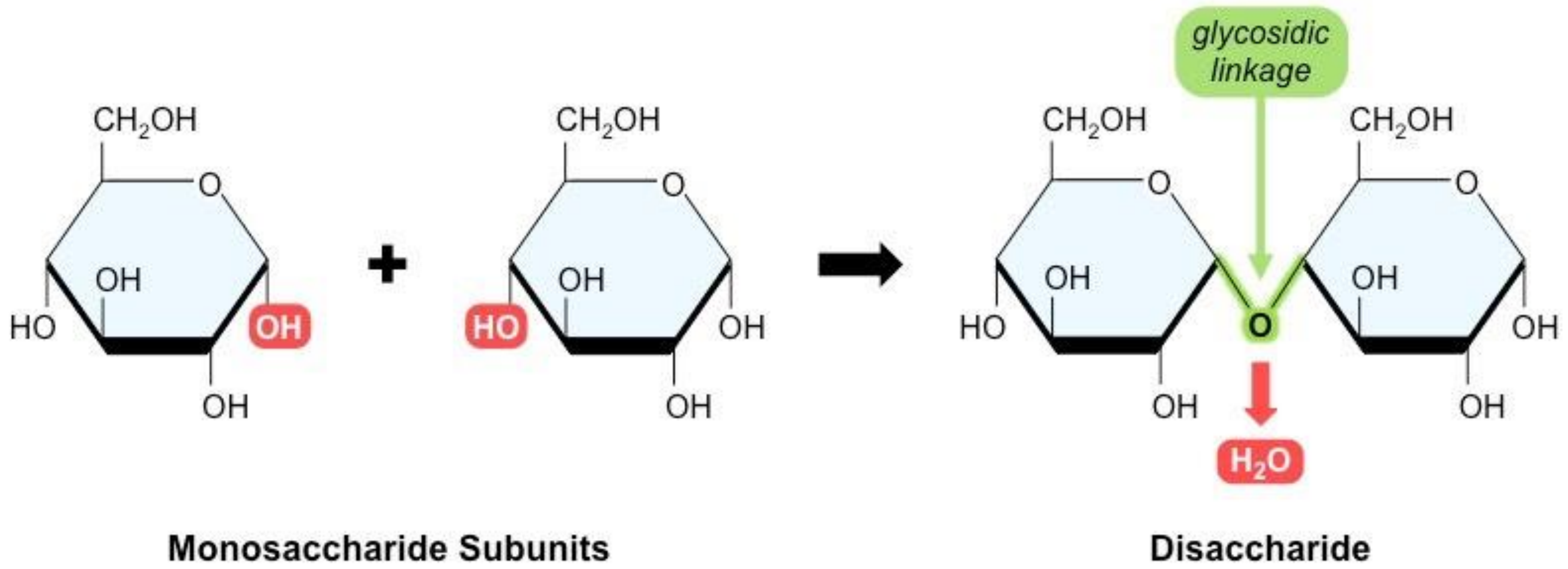
70%
30%
70%
Water
30%
Chemical
(15%) Proteins
(4%) Small molecules
(6%) RNA
(2%) Phospholipids
(1%) DNA
(2%) Polysaccharides

Carbohydrates

Monosaccharides

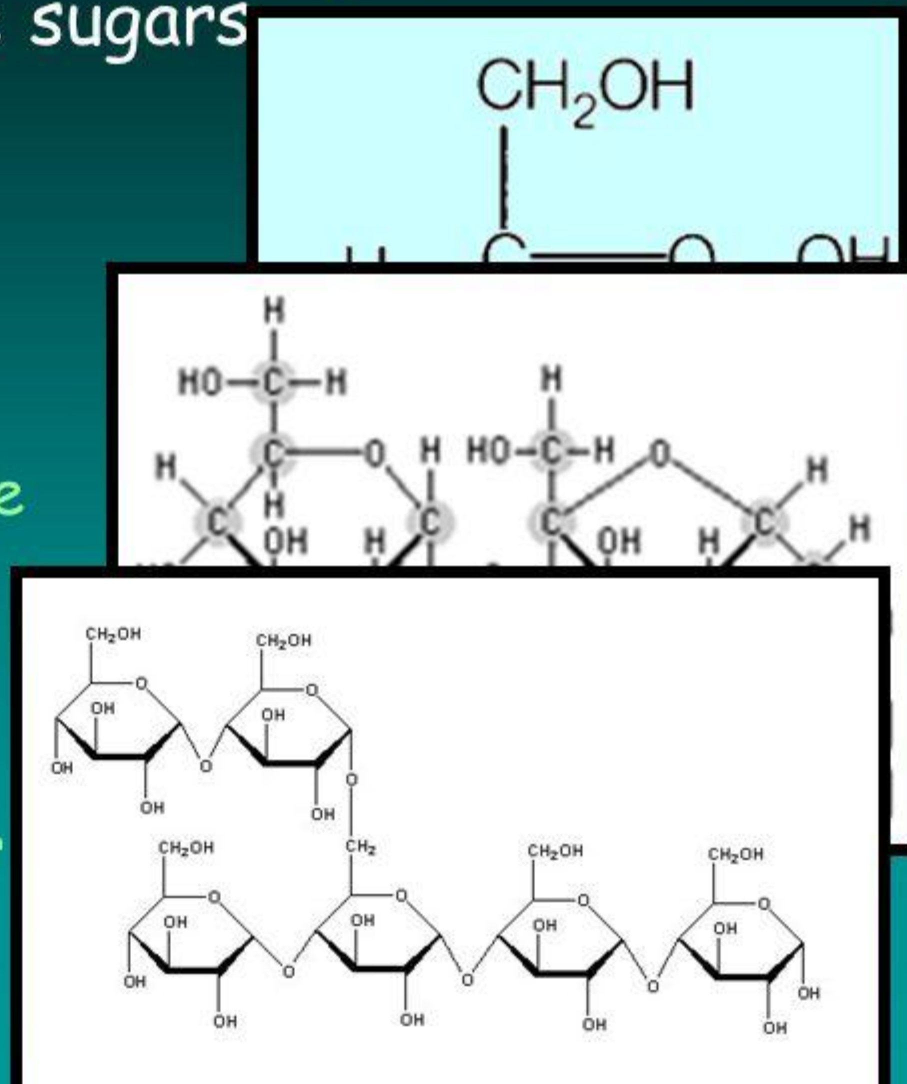
- Monomers = simple sugars = monosaccharides
- Single chain or ring structures
  - glucose – the preferred source of energy in the body
  - fructose
  - galactose
  - deoxyribose
  - ribose




CH2OH
O
OH
HO
OH
OH
+
CH2OH
O
OH
HO
OH
OH
glycosidic
linkage
CH2OH
O
OH
HO
OH
O
CH2OH
O
OH
OH
OH
H2O
Monosaccharide Subunits
Disaccharide

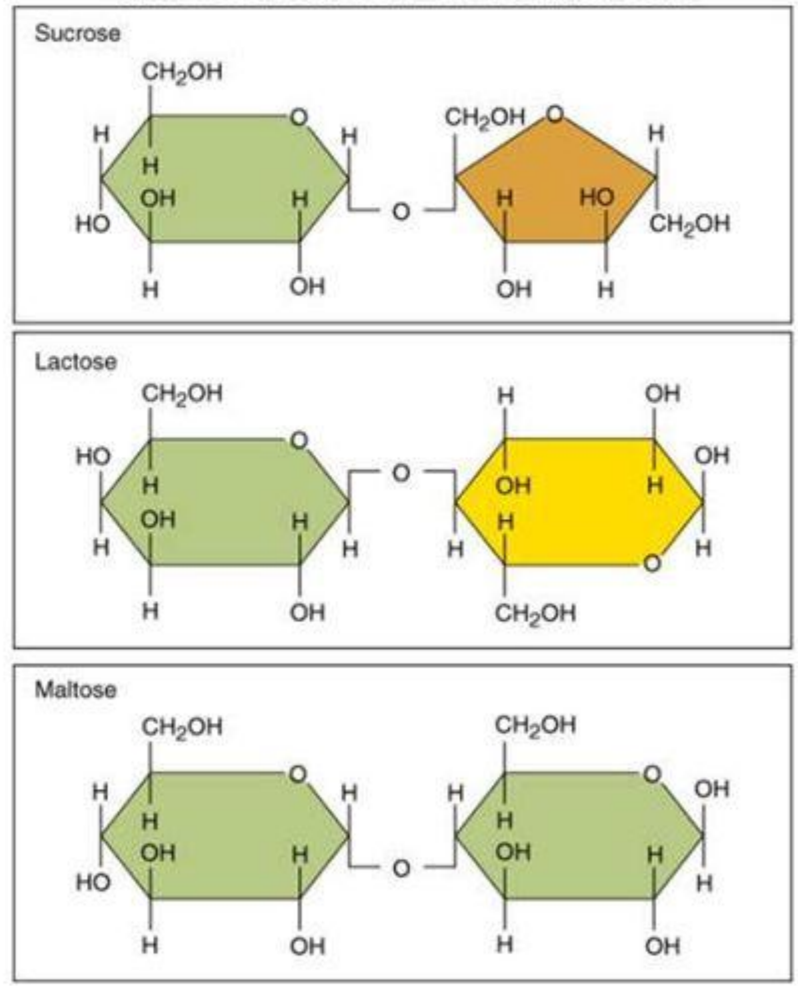
Complex Structures and Functions of Carbohydrates

- Monosaccharides- single sugars
  - Glucose $C_6H_{12}O_6$
  - Fructose
- Disaccharides- double sugars
  - –Sucrose (table sugar)
- Polysaccharides- three or more monosaccharides
  - –Macromolecule
  - –Starch
  - –Glycogen
  - –Cellulose- provides structure for plants (humans cannot digest)



Disaccharides

- **Sugar molecule composed of 2 monosaccharides**
- **Major disaccharides**
  - **sucrose = table sugar**
    - glucose + fructose
  - **Lactose = sugar in milk**
    - glucose + galactose
  - **Maltose = grain products**
    - glucose + glucose



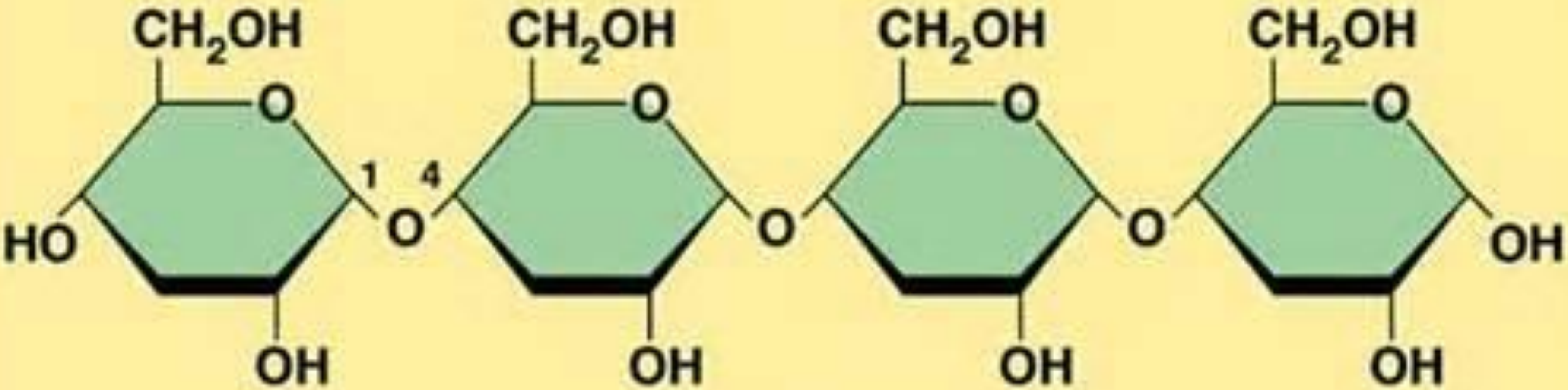
Examples of Polysaccharides

- **starch** – storage molecule made up of glucose monomers (found in plants)
- **glycogen** – storage molecule made up of glucose monomers (found in animals – liver & muscle tissue)
- **cellulose** – structural compound found in the cell walls of plant cells

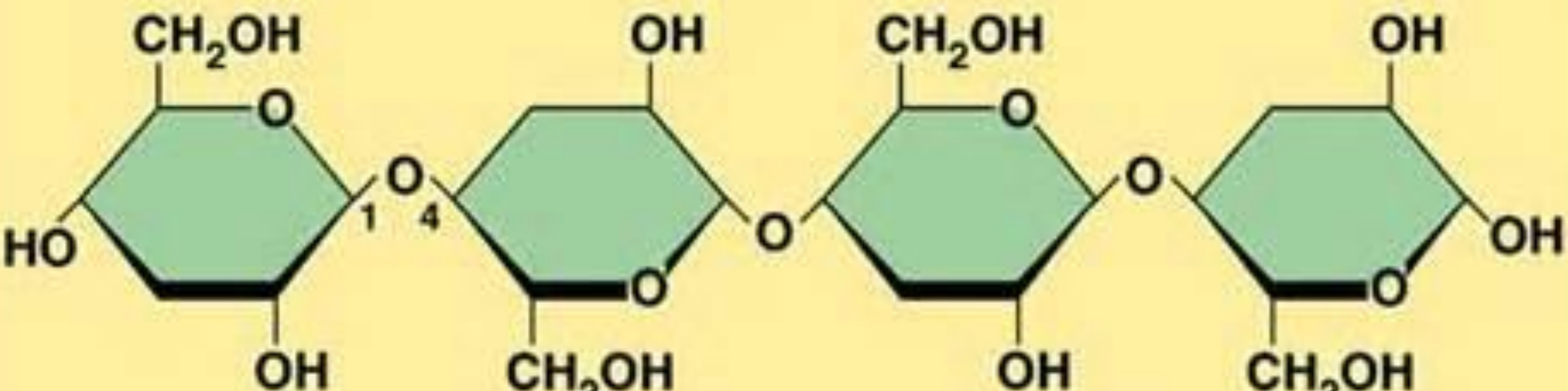
Polysaccharides

- These are formed when three or more monosaccharides join together with a loss of a water molecule each time.
- They may be straight or branched
- Examples: Starch, pectin, cellulose, gums & glycogen
- Pectin, cellulose & gums are also known as **Non-Starch Polysaccharides**
- Starch is made up of glucose units arranged as follows:

1. ***Straight chains are known as amylose or***
2. ***Branched chains are known as amylopectin***



(b) Starch: 1–4 linkage of α glucose monomers



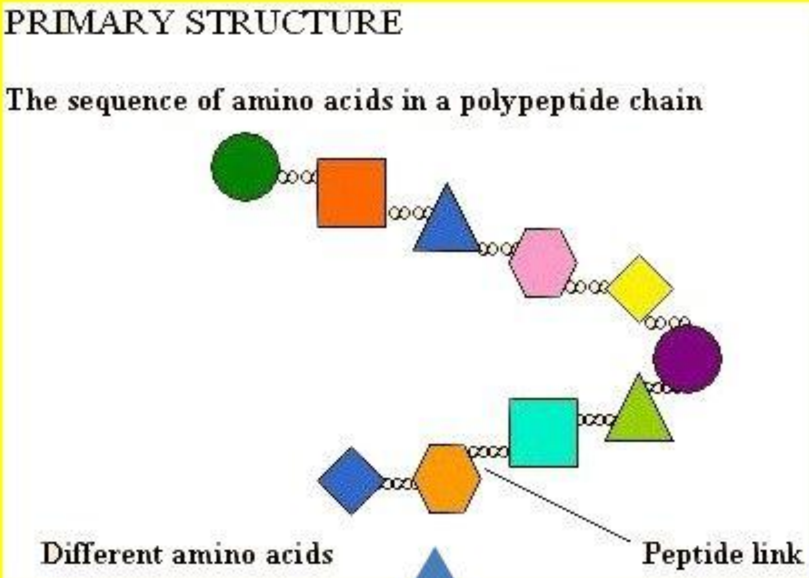
(c) Cellulose: 1–4 linkage of β glucose monomers

Protein and Amino Acid

PRIMARY STRUCTURE

- The primary structure of protein refers to the sequence of amino acids present in the polypeptide chain.
- Amino acids are covalently linked by peptide bonds.
- Each component amino acid in a polypeptide is called a "residue" or "moiety"
- By convention, the 1^0 structure of a protein starts from the amino-terminal (N) end and ends in the carboxyl-terminal (C) end.

Protein Shape

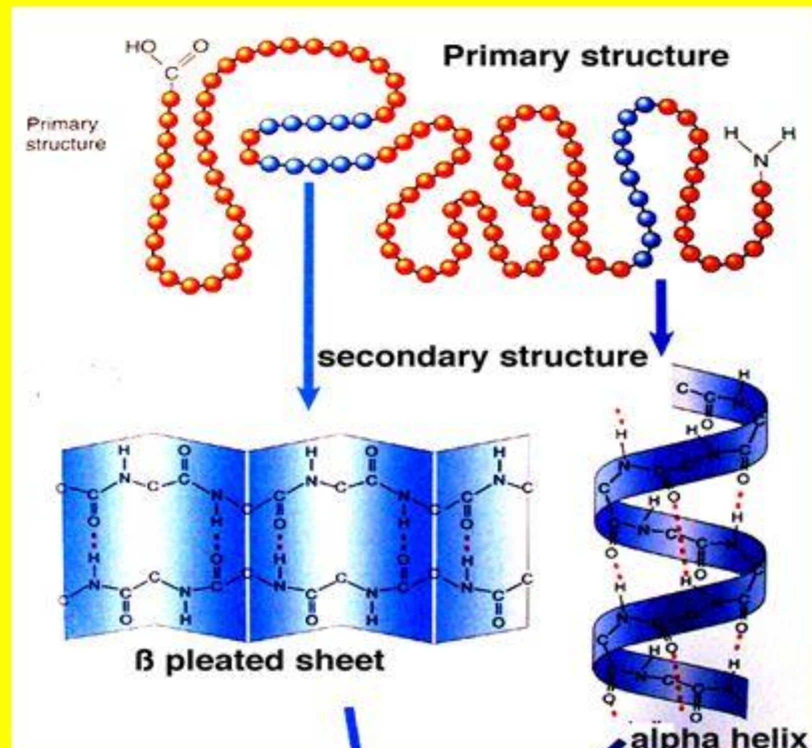


Primary Protein Structure

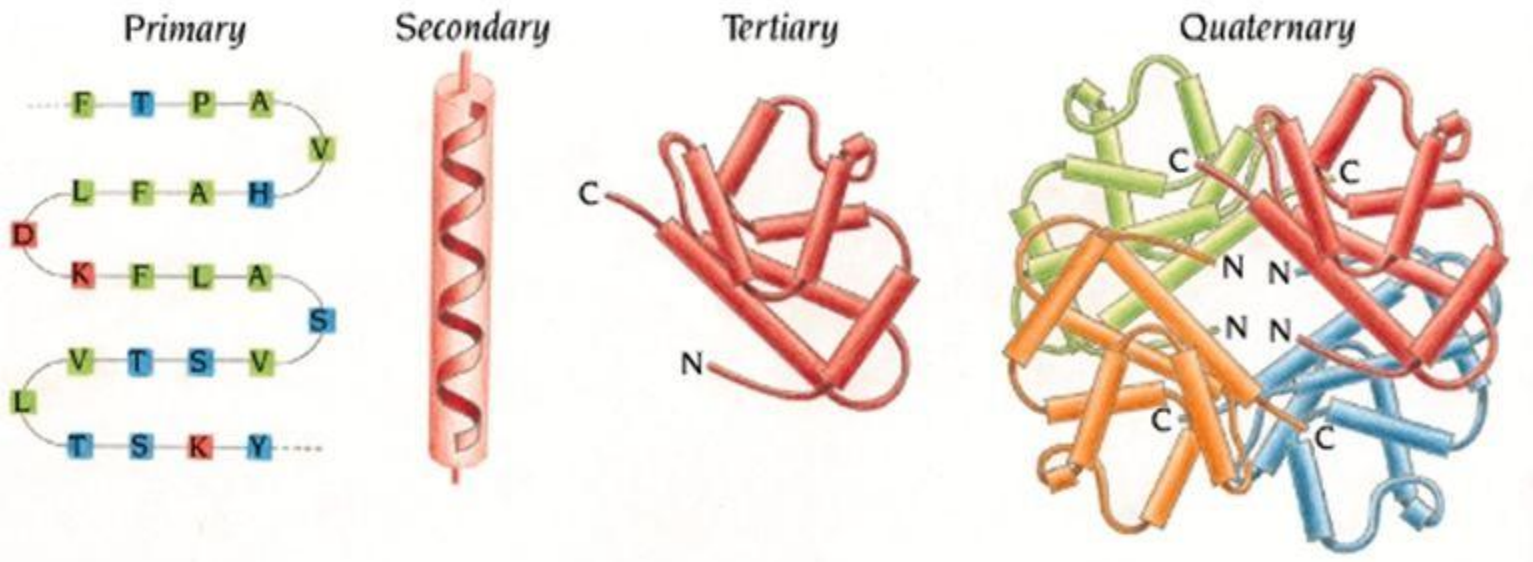
Secondary Protein Structure

<u>Shape</u>

- shape of a protein depends on its **function** & its order of **amino acids**



Levels of Protein Structure



- The AA sequence of a protein's polypeptide chain is called its primary structure.
- Different regions of sequence form local regular secondary structures, (α-helices or β-strands).
- Tertiary structure is formed by packing structural elements into one or several compact globular units called domains.
- The final protein may contain several polypeptide chains arranged in a quaternary structure. By formation of structures, amino acids far apart in the sequence can be brought closer together to form a functional region, called an active site.

Protein Synthesis

- Human life is impossible without proteins. Why?

Proteins are of two Kinds

1. Structural

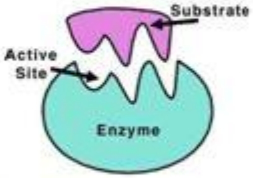
✓**Actin & Myosin: muscle proteins**

✓**Keratin: nails, hair, horns, feathers**

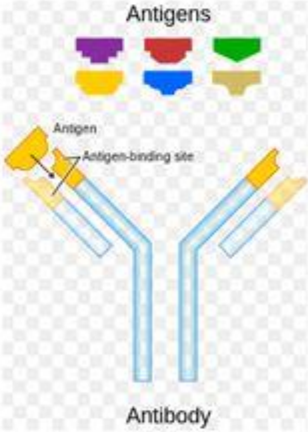
✓**Collagen: bones, teeth, cartilage, tendons, ligament, blood vessels, skin matrix**

2. Functional

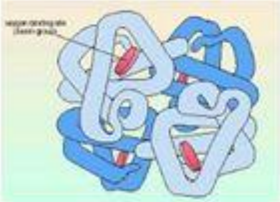
✓**Enzymes**



✓**Antibodies**



✓**Haemoglobin**



Hemoglobin (Hb)

Hb is found in RBCs its main function is to transport O2 to tissues.

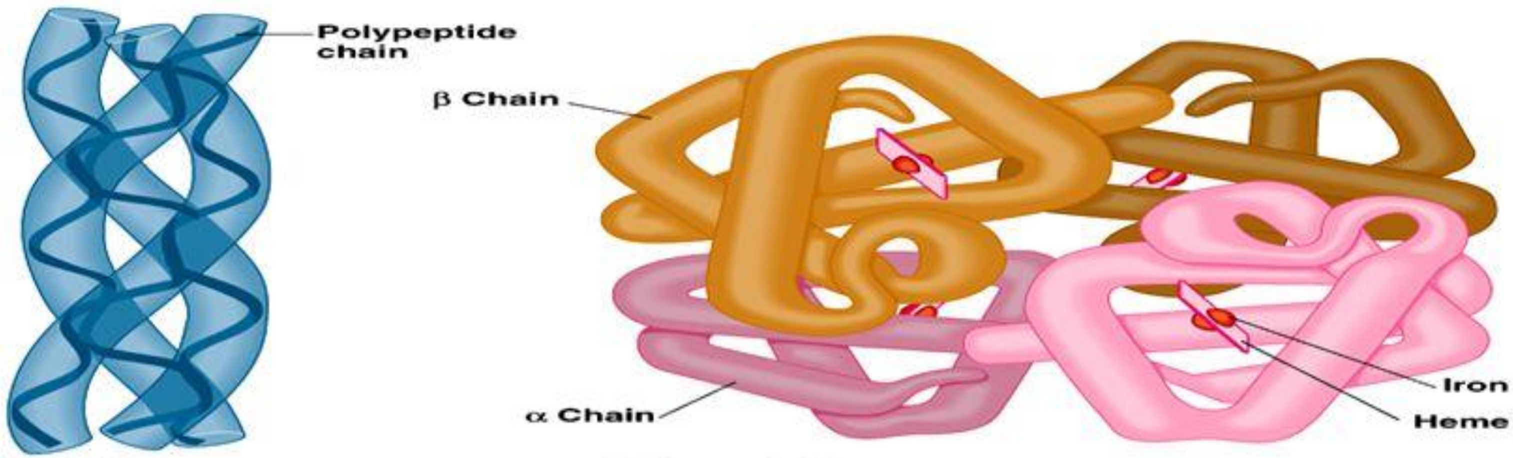
Structure: 2 parts : heme + globin

Globin: four chains.

Heme: porphyrin ring with central iron. Iron is the site of attachment with O2.

There are 4 heme groups each attached to on globin chain. So one Hb molecule can carry up to 4 O2 molecules.

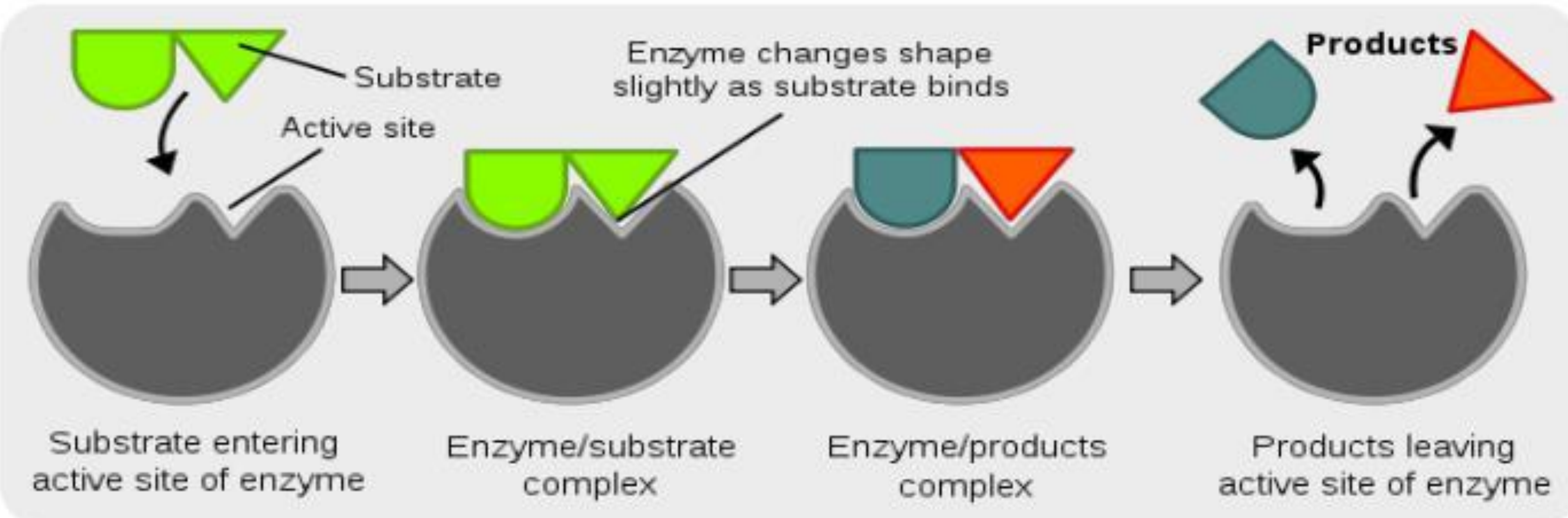
According to sequence of amino acids in the primary structure of each chain, there are four types of chains; α, β, γ and δ.



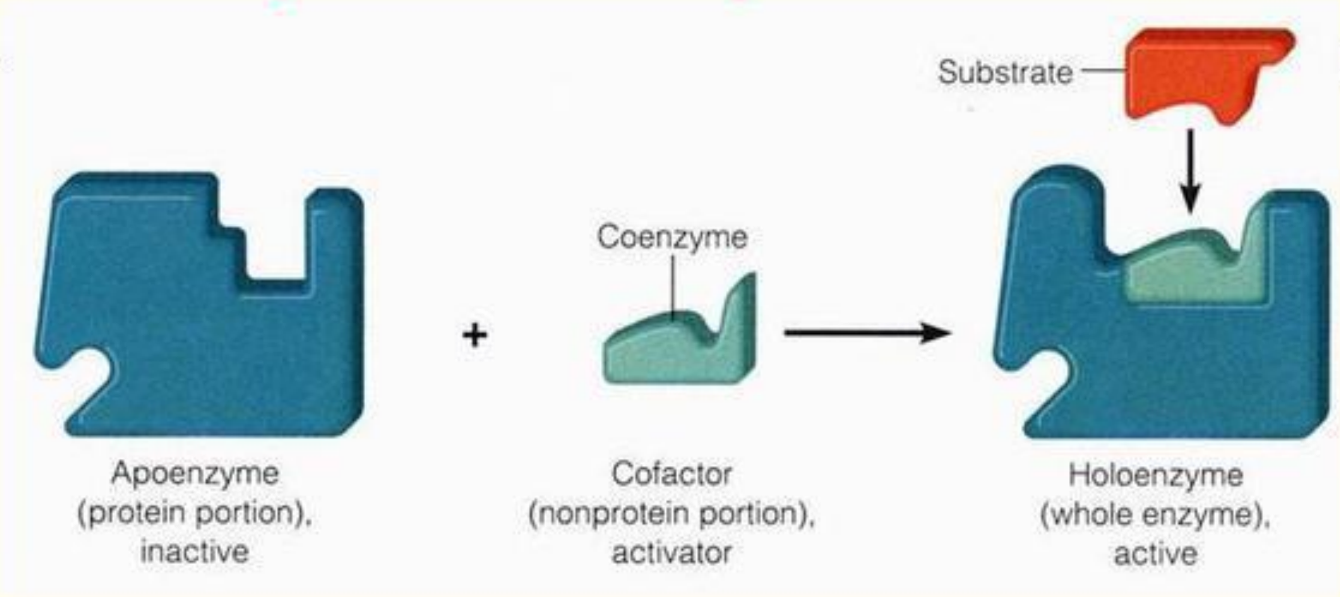
(a) Collagen (b) Hemoglobin

Structure & Function of Enzymes

- Enzymes are made of proteins
- It catalyzes reaction by speeding them up and lowering the energy it take to have a reaction proceed = lowers Energy of Activation
- Enzymes can help build up molecules (condensation synthesis reactions) OR help breakdown molecules (hydrolysis/digestion)
- Substrates are the reactants and enter the enzymes active site.
- The enzyme-substrate complex (ES complex) allows a reaction to occur and produce the product(s)



Enzyme components

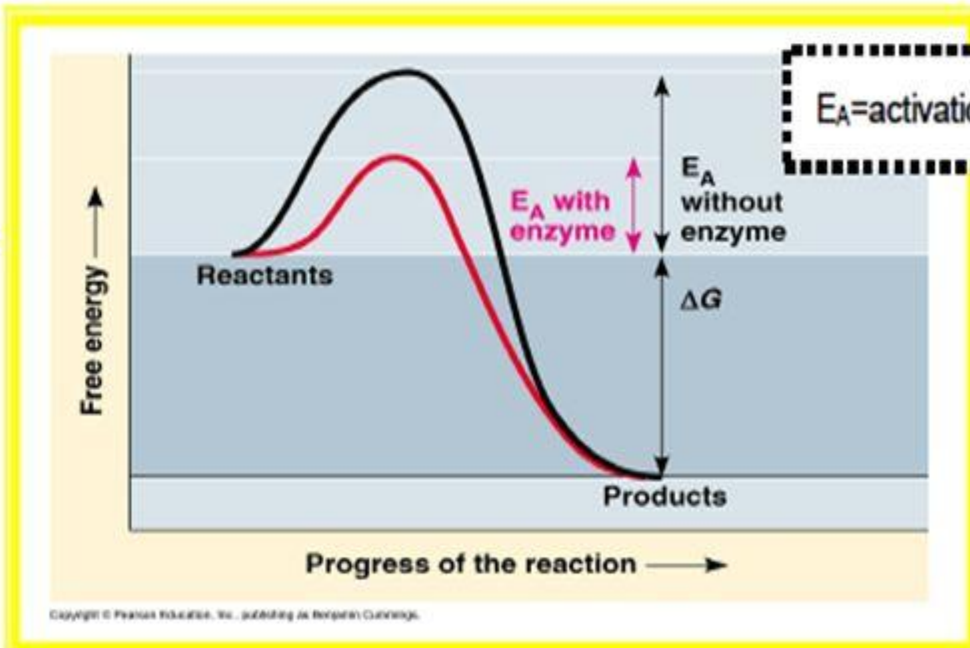


- Cofactors may be metal ions
- Cofactors may accept or donate atoms removed from the substrate or donated to the substrate
- Cofactors may act as electron carriers
- Often derived from vitamins
- e.g. NAD and NADP - electron carries derived from nicotinic acid

HOW do enzymes CATALYZE chemical reactions??

- Enzymes **speed up** the rate of chemical reactions by **lowering the required activation energy** (the amount of energy needed to start the reaction).

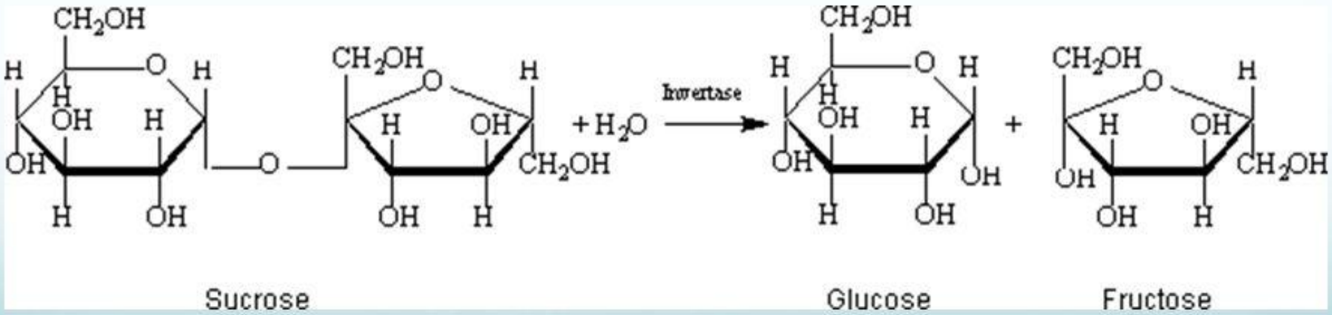
Increase rate
Decrease energy



E_A=activation energy

Enzymes

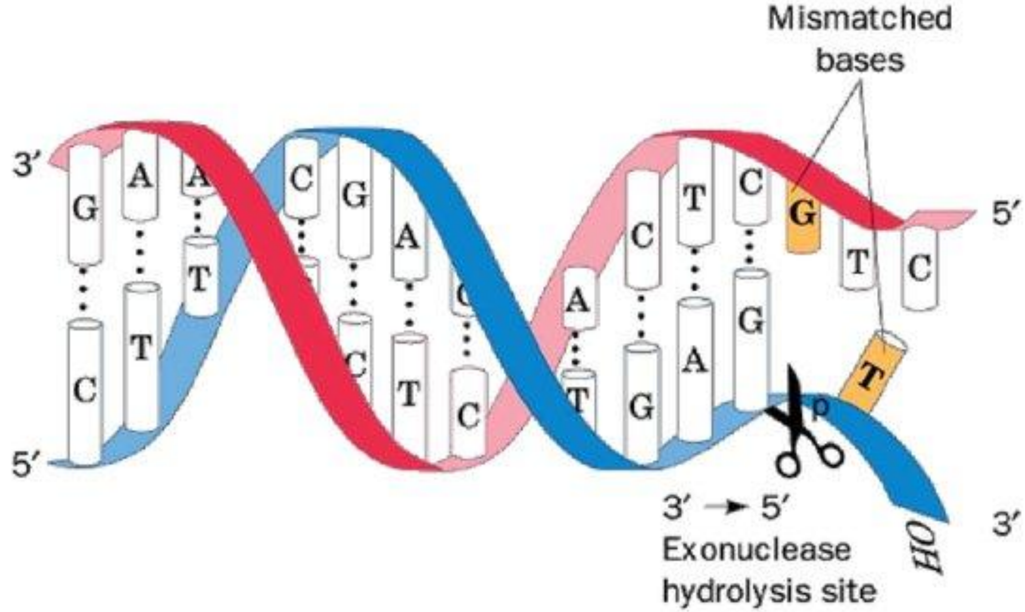
- A classic example of an enzymatic reaction is the hydrolysis of sucrose into glucose and fructose.



Enzymes in DNA replication

- ***Exonucleases***

Group of enzymes that remove nucleotide bases from the end of a DNA chain.



The 3′ →5′ exonuclease function of DNA polymerase I and DNA polymerase III

EXPRESSION OF ANTIOXIDANT AND PROOXIDANT ENZYMES CHANGES IN CANCER

- Manganese Superoxide Dismutase
  - ↓ in most cancers
  - Candidate Tumor Suppressor Gene
- Cu/Zn Superoxide Dismutase ↓
- Catalase ↓
- Glutathione Peroxidase-1 ↓
- Cyclooxygenase-2 ↑
- Nitric Oxide Synthase-2 ↑

} **Antioxidant** (Manganese Superoxide Dismutase through Cyclooxygenase-2)

} **Prooxidant** (Nitric Oxide Synthase-2)

→ **A prooxidant state is common in human cancer**

→ Most cancers poorly metabolize hydrogen peroxide

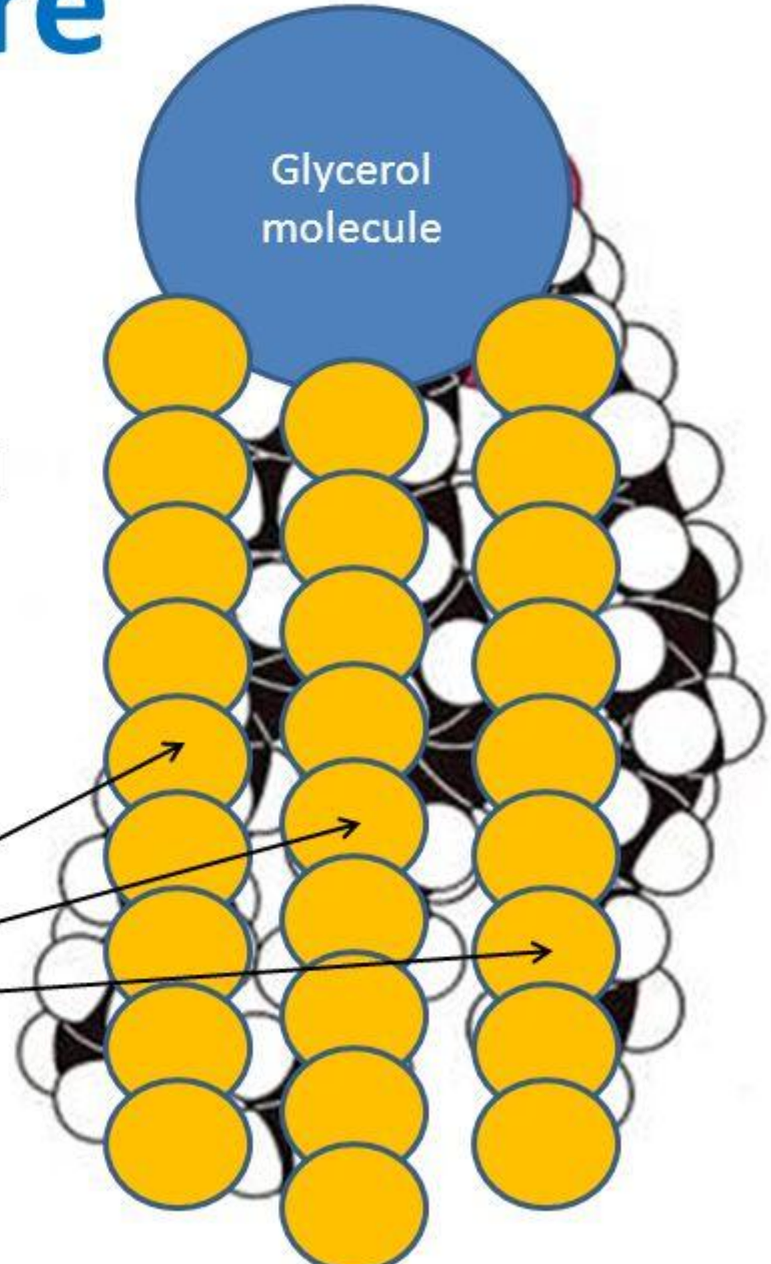
H_2O_2 concentration is commonly increased in human tumor cells

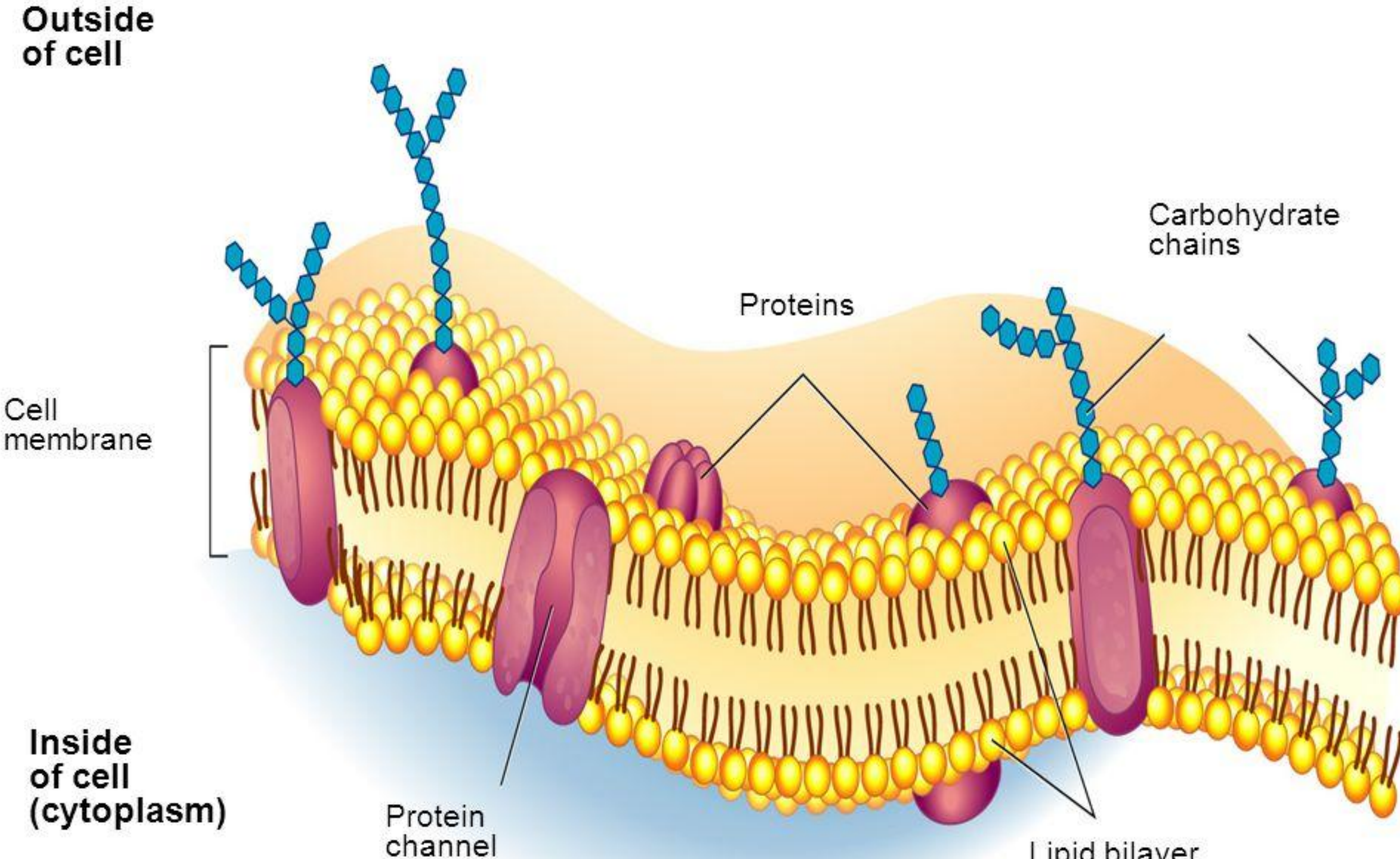
Oberley & Oberley, Histol Histopathol 1997; Szatrowski and Nathan, Cancer Res 1991

Lipids (Fats) and Fatty Acids

Lipid Structure

- Fats, Oils, Waxes
- Provide energy for cells, cell structure, insulation
  - Lipids & Proteins compose the cell membrane
  - Cholesterol: gives cell membrane flexibility
- Structure (2 parts):
  - "Head" = glycerol
  - "Tails" = fatty acids
- Monomer: Fatty Acid
- Polymer: Lipid

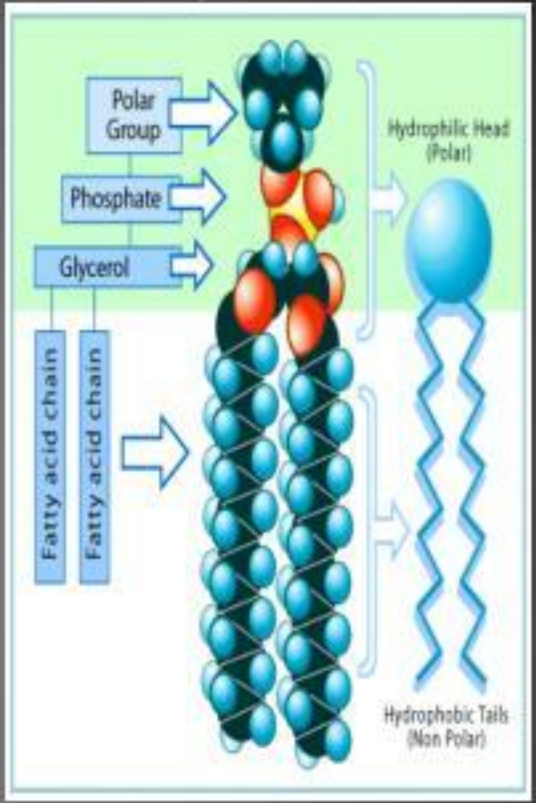


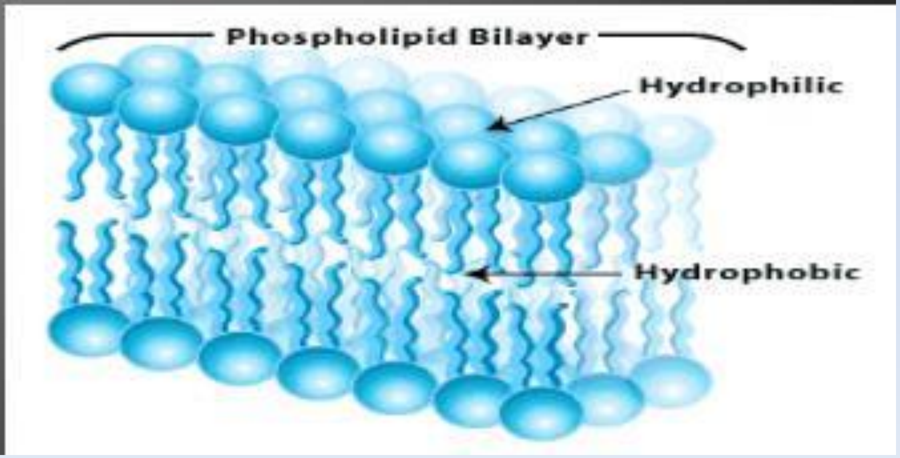


Cell Membrane Structure

More on the Phospholipids…

- The "heads" are **hydrophilic (polar)** and are attracted to the water inside and outside of the cell.
- The "tails" are **hydrophobic (non polar)** and do NOT like the water. The tails point to the middle of the plasma membrane.

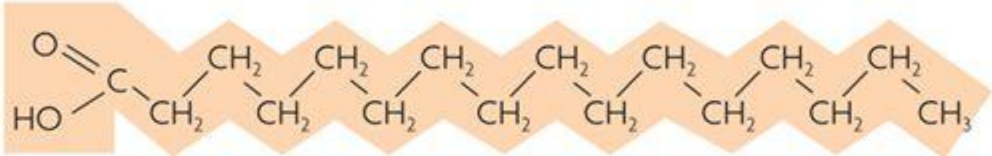




Saturated vs. Unsaturated

- A lipid's **function** can be affected by the **saturation** of the fatty acids
  - <u>Saturated</u>: it is "saturated" with hydrogen atoms (maximum number of hydrogen, every spot filled).

Saturated fatty acid



Saturated fats contain fatty acids in which all carbon–carbon bonds are single bonds.

  - <u>Unsaturated</u>: at least one double bond between carbon atoms thus the chain has fewer hydrogen.

Unsaturated fatty acid

Unsaturated fats have fatty acids with at least one carbon–carbon double bond.

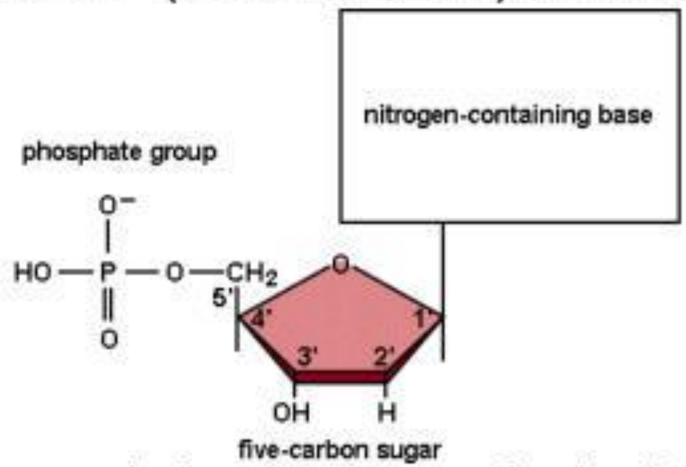
Biological Importance of Lipids:

1. They are more palatable and storable to unlimited amount compared to carbohydrates.
2. They have a high-energy value (25% of body needs) and they provide more energy per gram than carbohydrates and proteins but carbohydrates are the preferable source of energy.
3. Supply the essential fatty acids that cannot be synthesized by the body.
4. Supply the body with fat-soluble vitamins (A, D, E and K).
5. They are important constituents of the nervous system.
6. Tissue fat is an essential constituent of cell membrane and nervous system. It is mainly phospholipids in nature that are not affected by starvation.

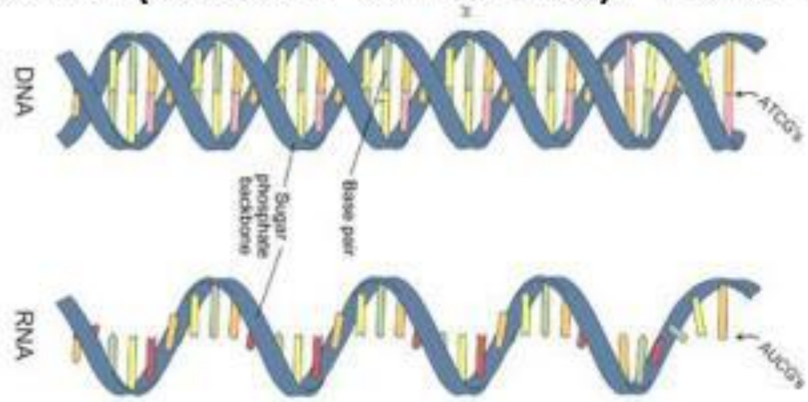
Nucleic acids: DNA, RNA and ATP

Nucleic Acids: Structure

- Nucleic Acids are made up of…
  - Monomers (basic unit): **nucleotides**



  - Polymers (chain of units): **DNA or RNA**



What is DNA?

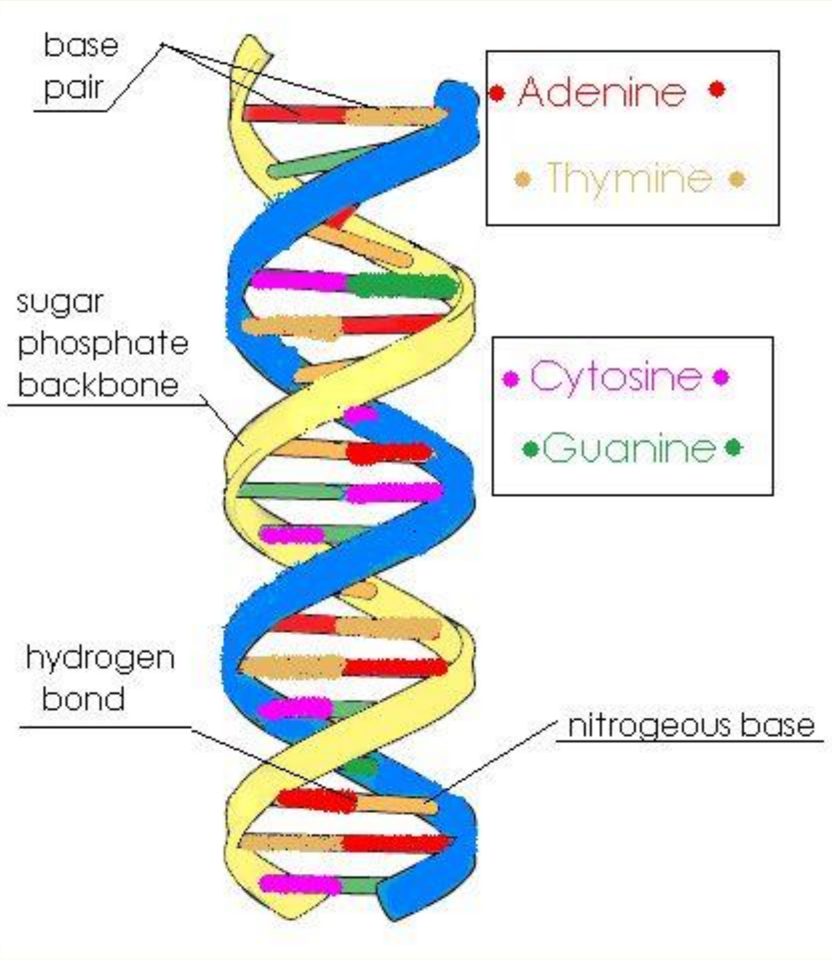
DNA= Deoxyribu-Nucelic Acid

- ***DNA is a very large molecule, made up of smaller units called nucleotides***

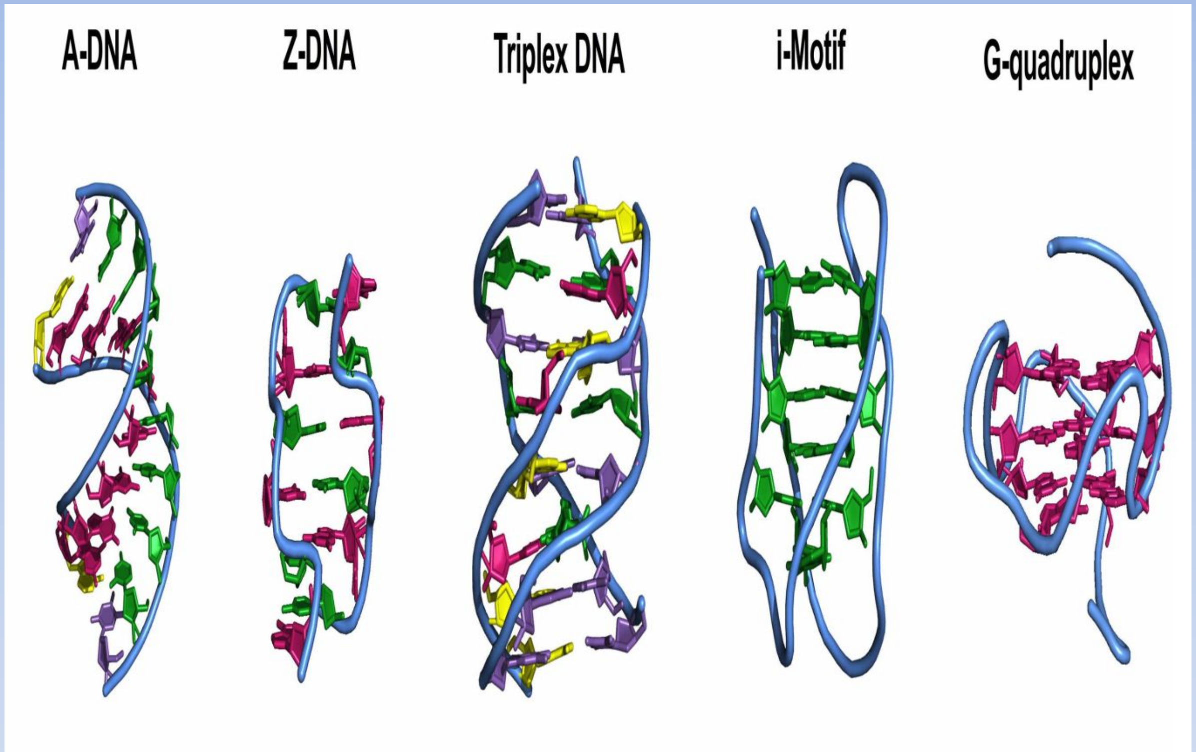
- ***Each nucleotide has three parts: a sugar (ribose), a phosphate molecule, and a nitrogenous base.***

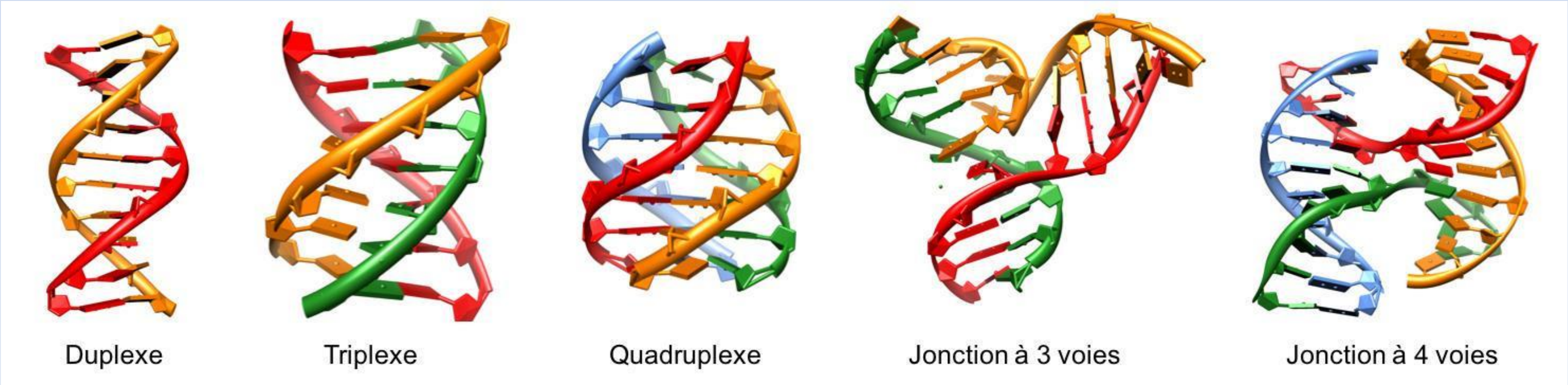
- ***The nitrogenous base is the part of the nucleotide that carries genetic information***

- ***The bases found in DNA are four: adenine, cytosine, guanine, and thymine (ATP, CTP, GTP, and TTP)***



DNA structure





C1 Nucleic Acid Structure : RNA structure

1. **Single stranded nucleic acid**
2. **Secondary structure are formed some time**
3. **Globular tertiary structure are important for many functional RNAs, such as tRNA, rRNA and ribozyme RNA**

Forces for secondary and tertiary structure: **intramolecular** hydrogen bonding and base stacking.

RNA

- RNA molecules are classified according to their structure and function

RNA type	Size	Function
Messenger (mRNA)	750 base pairs on average	directs amino acid sequence of proteins
Transfer (tRNA)	from 73 to 93 base pairs	transports amino acids to the site of protein synthesis
Ribosomal (rRNA)	very large; MW up to 10^6	combines with proteins to form ribosomes
Ribozymes (catalytic RNA)	very large	catalyze cleavage of part of their own sequences in mRNA and tRNA

Review ? -
What are the four macromolecules?

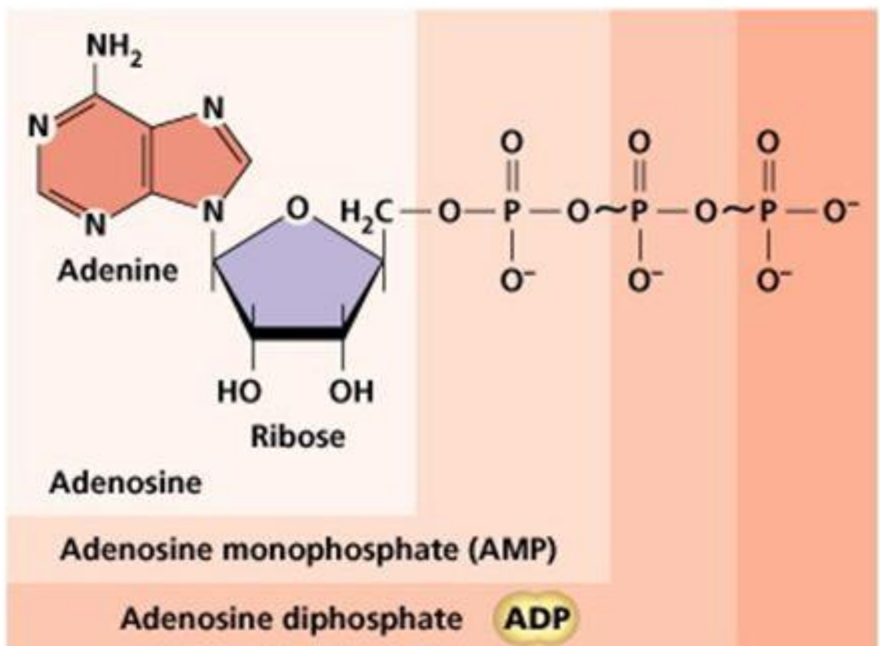
- Lipids
- Carbohydrates
- Protein
- Nucleic Acids

- What is the monomer of nucleic acids and what do nucleic acids make up?

- Nucleotides; DNA and RNA

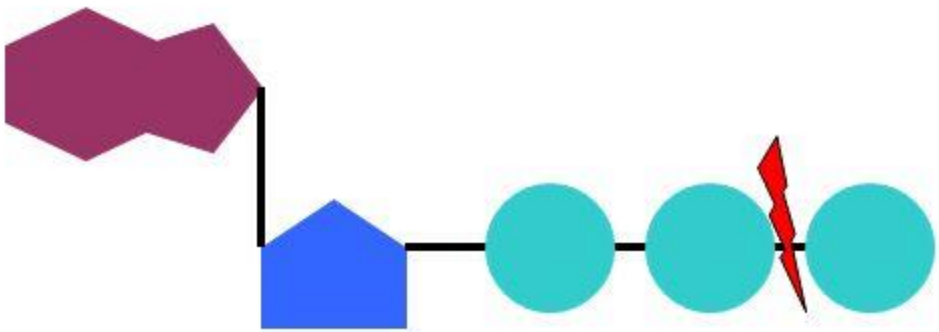
Another molecule of biological importance:ATP

- Adenosine Triphosphate (ATP) – primary energy transferring molecule in the cell
- ATP ↔ ADP + P_i + Energy

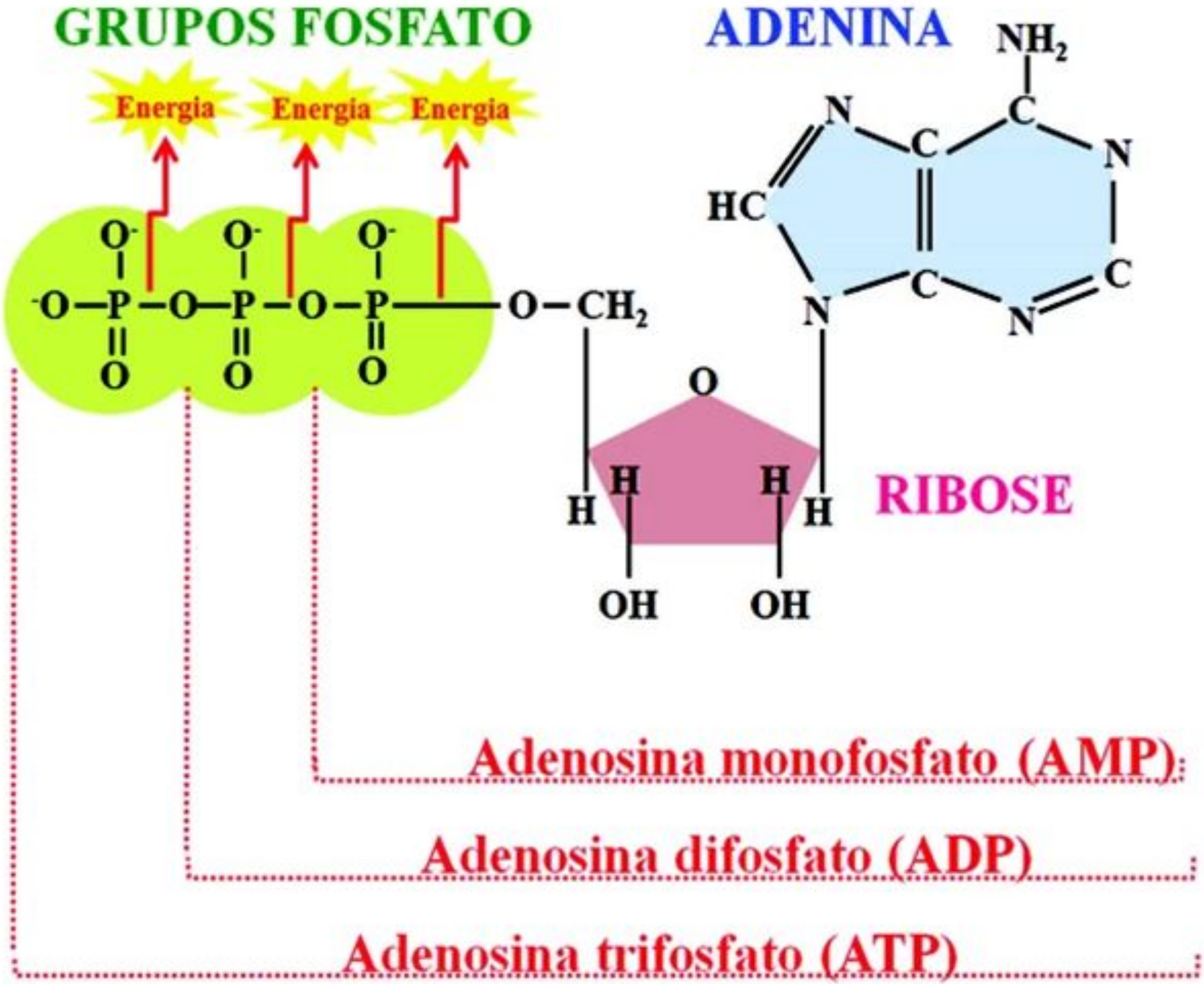


ATP

- Adenosine triphosphate = ATP



The ATP molecules releases energy when a bond holding a phosphate group to the molecule is broken


GRUPOS FOSFATO
ADENINA
Energia
Energia
Energia
RIBOSE
Adenosina monofosfato (AMP)
Adenosina difosfato (ADP)
Adenosina trifosfato (ATP)

Questions for knowledge testing

You need to match the statement and the molecule

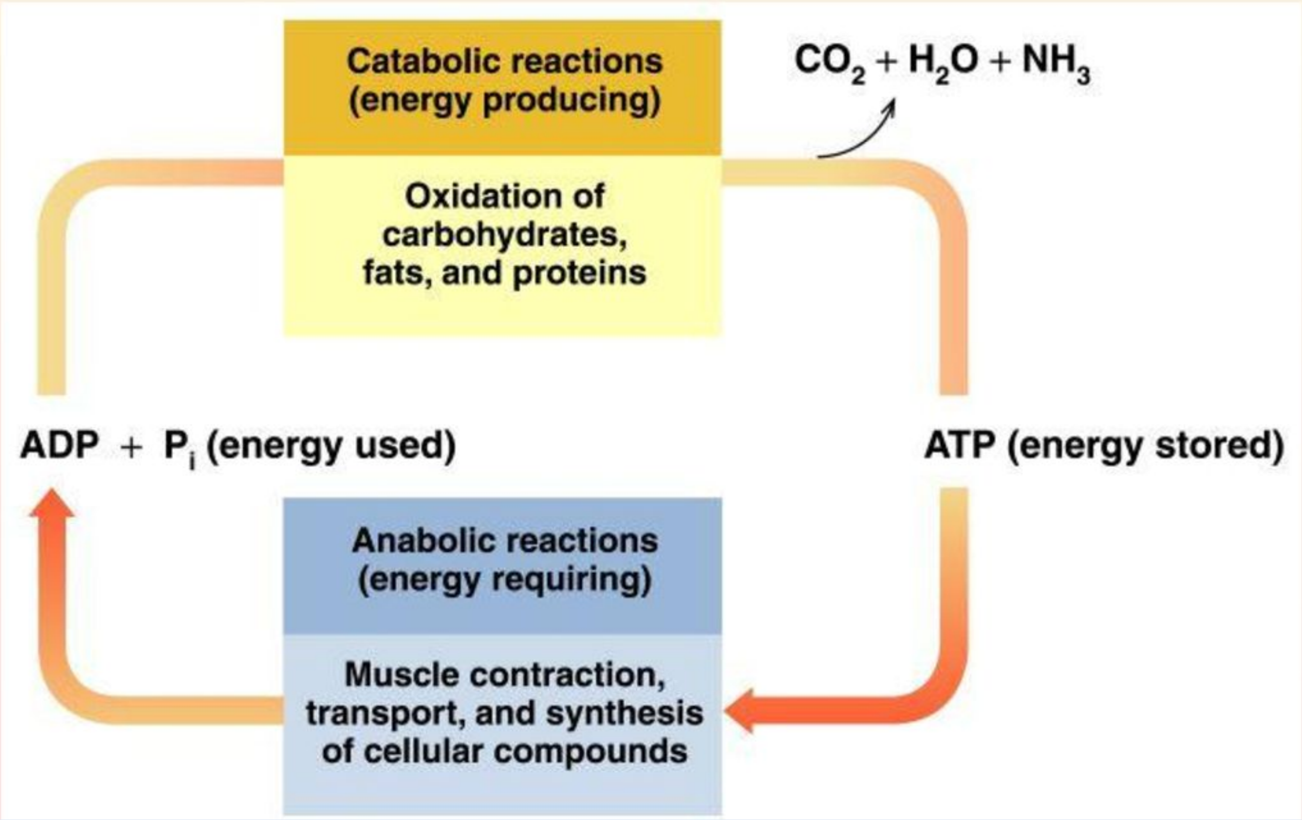
Proteins, Lipids, Carbohydrates or Nucleic Acids?

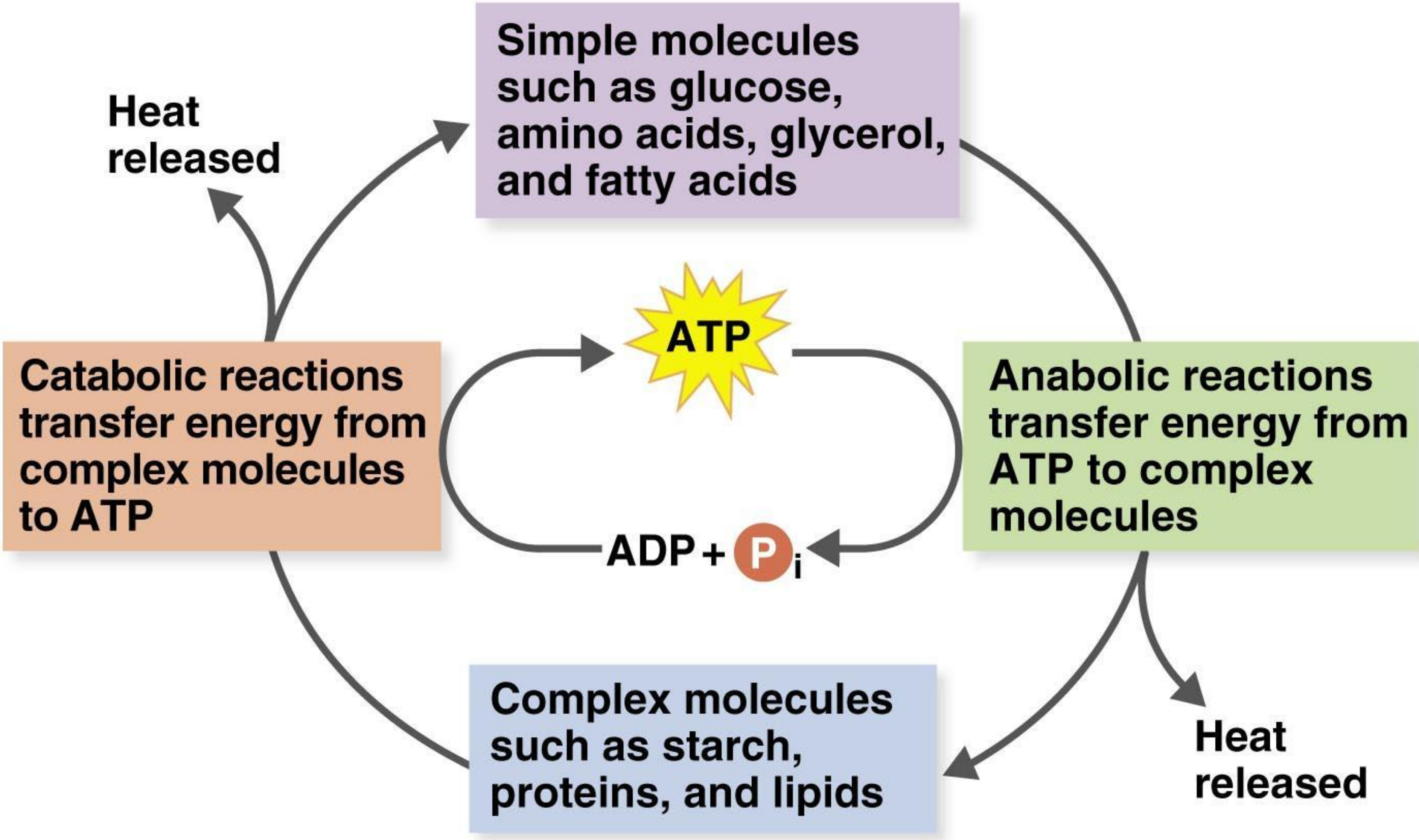
1. The monomer is monosaccharide
2. The function is to carry genetic material
3. Examples include oils, fats, and waxes
4. The monomer is amino acid
5. An example is RNA
6. The source is pasta, bread, fruits
7. The monomer is glycerol and 3 fatty acids
8. The function is to store and used as energy
9. Examples include hemoglobin and antibodies
10. The monomer is nucleotide

Types of metabolism: catabolism and anabolism

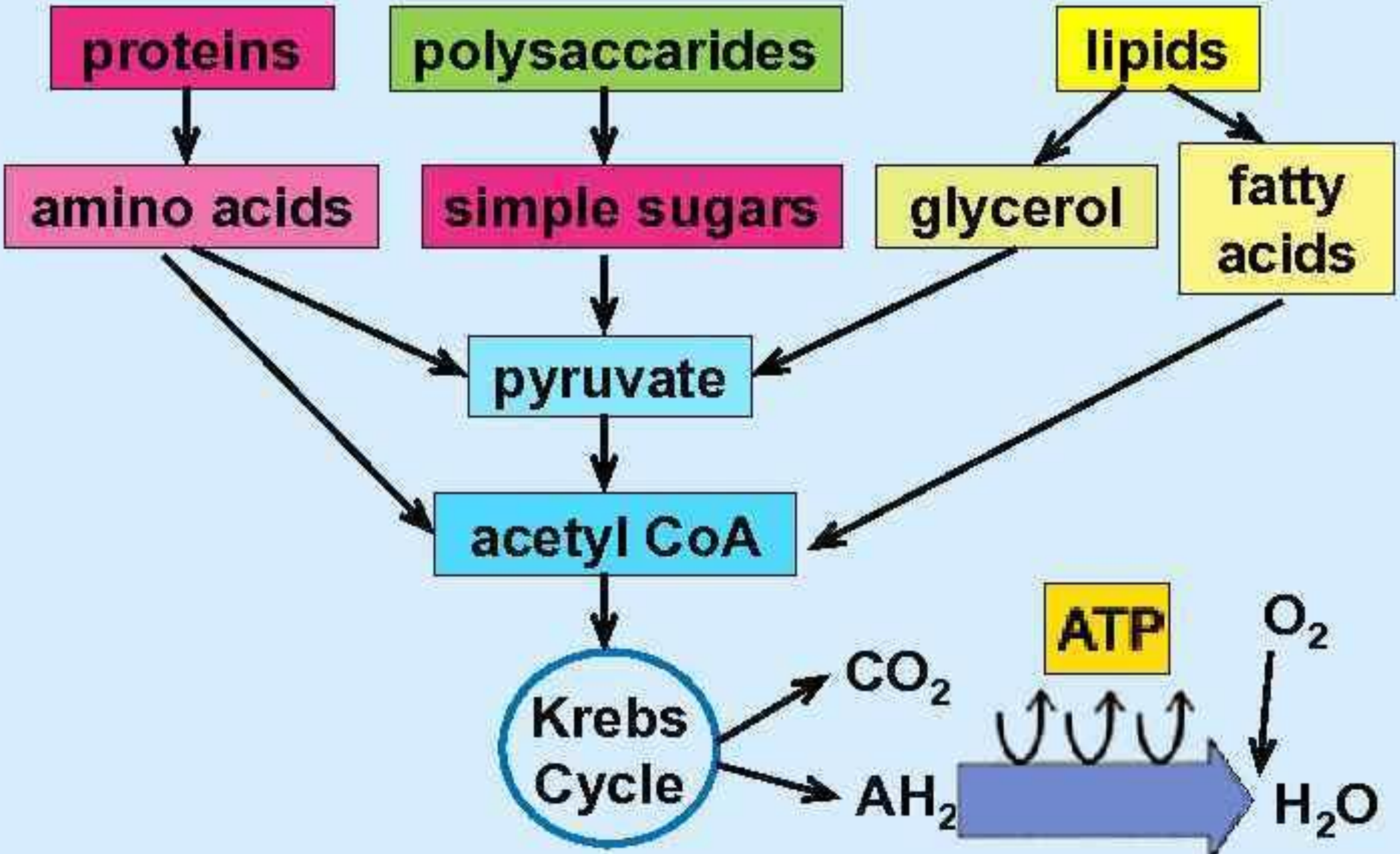
Metabolism

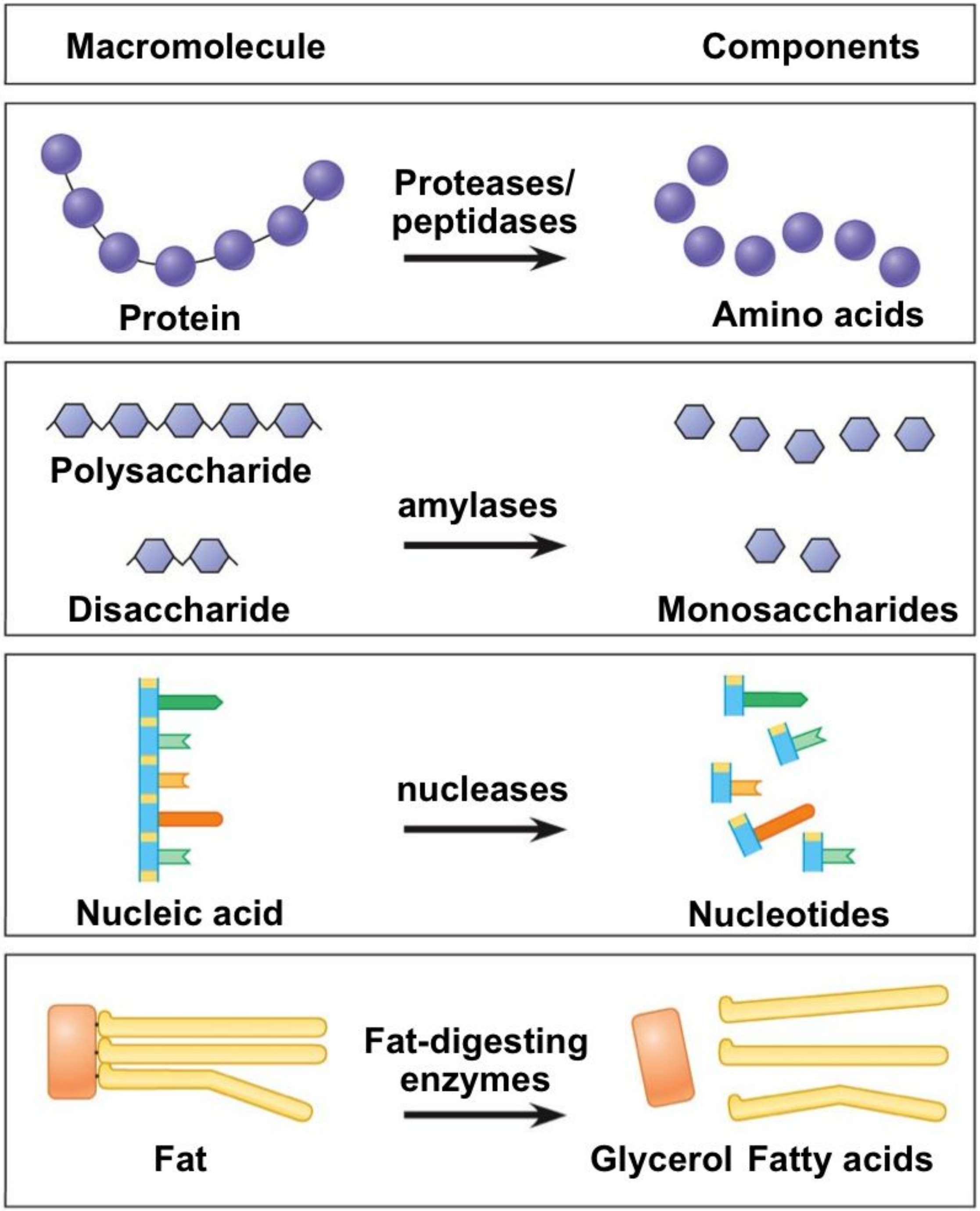
- **Metabolism** involves two main processes, **catabolism** and **anabolism**
- **Catabolic reactions** break down large, complex molecules to provide smaller molecules and energy (ATP)
- **Anabolic reactions** use ATP energy to build larger molecules from smaller building blocks




Simple molecules such as glucose, amino acids, glycerol, and fatty acids
Heat released
ATP
Catabolic reactions transfer energy from complex molecules to ATP
Anabolic reactions transfer energy from ATP to complex molecules
ADP + P i
Complex molecules such as starch, proteins, and lipids
Heat released

Catabolism


proteins
polysaccarides
lipids
amino acids
simple sugars
glycerol
fatty acids
pyruvate
acetyl CoA
Krebs Cycle
CO_2
AH_2
ATP
O_2
H_2O



Macromolecule
Components
Proteases/
peptidases
Protein
Amino acids
Polysaccharide
amylases
Disaccharide
Monosaccharides
nucleases
Nucleic acid
Nucleotides
Fat-digesting
enzymes
Fat
Glycerol
Fatty acids

Anaerobic respiration

A. Without oxygen
B. Pyruvate remains in the cytoplasm (no link reaction, no Krebs cycle)
C. Pyruvate is converted into waste and removed from the cells
D. No ATP is produced (except from glycolysis)
E. In humans the waste=lactate (lactic acid)
F. In yeast the waste=ethanol and CO_2

Cellular Respiration

Written Equation

Glucose + Oxygen → Water + Carbon Dioxide + Energy

Balanced Chemical Equation

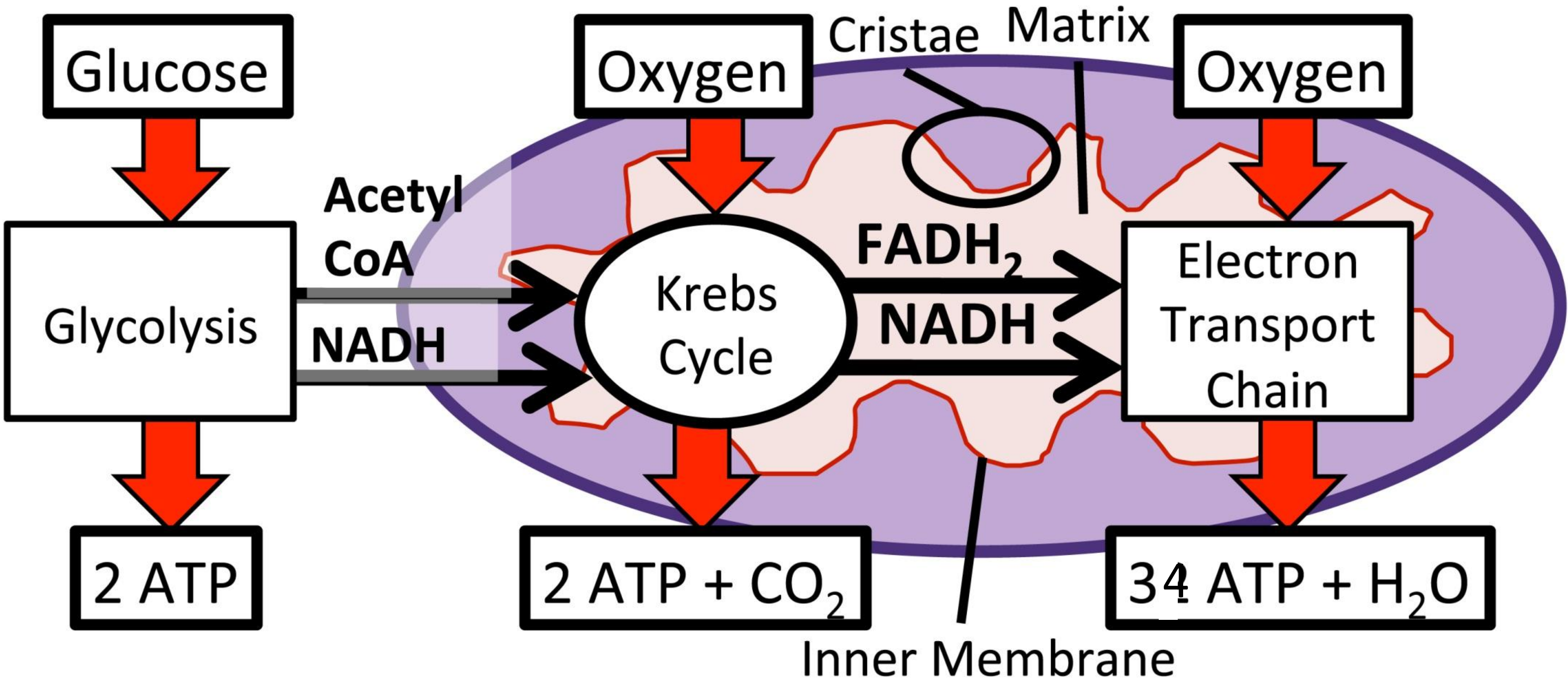
$$\underbrace{C_6H_{12}O_6 + 6O_2}_{\text{Reactants}} \rightarrow \underbrace{6H_2O + 6CO_2 + 36ATP}_{\text{Products}}$$

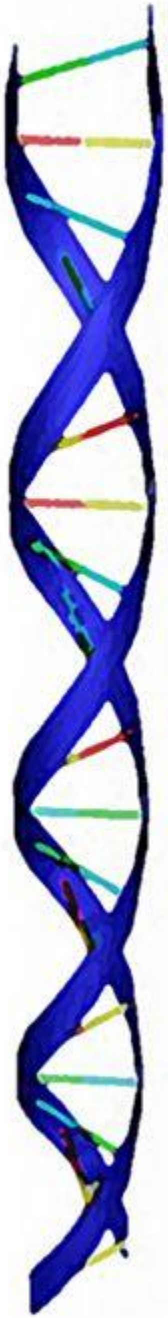
Energy Transformation

- Takes energy of bonds in glucose and puts it into bonds of ATP (Adenosine TRIphosphate)

Cellular Respiration

$$O_2 + C_6H_{12}0_6 \rightarrow CO_2 + H_2O + \text{Energy}$$

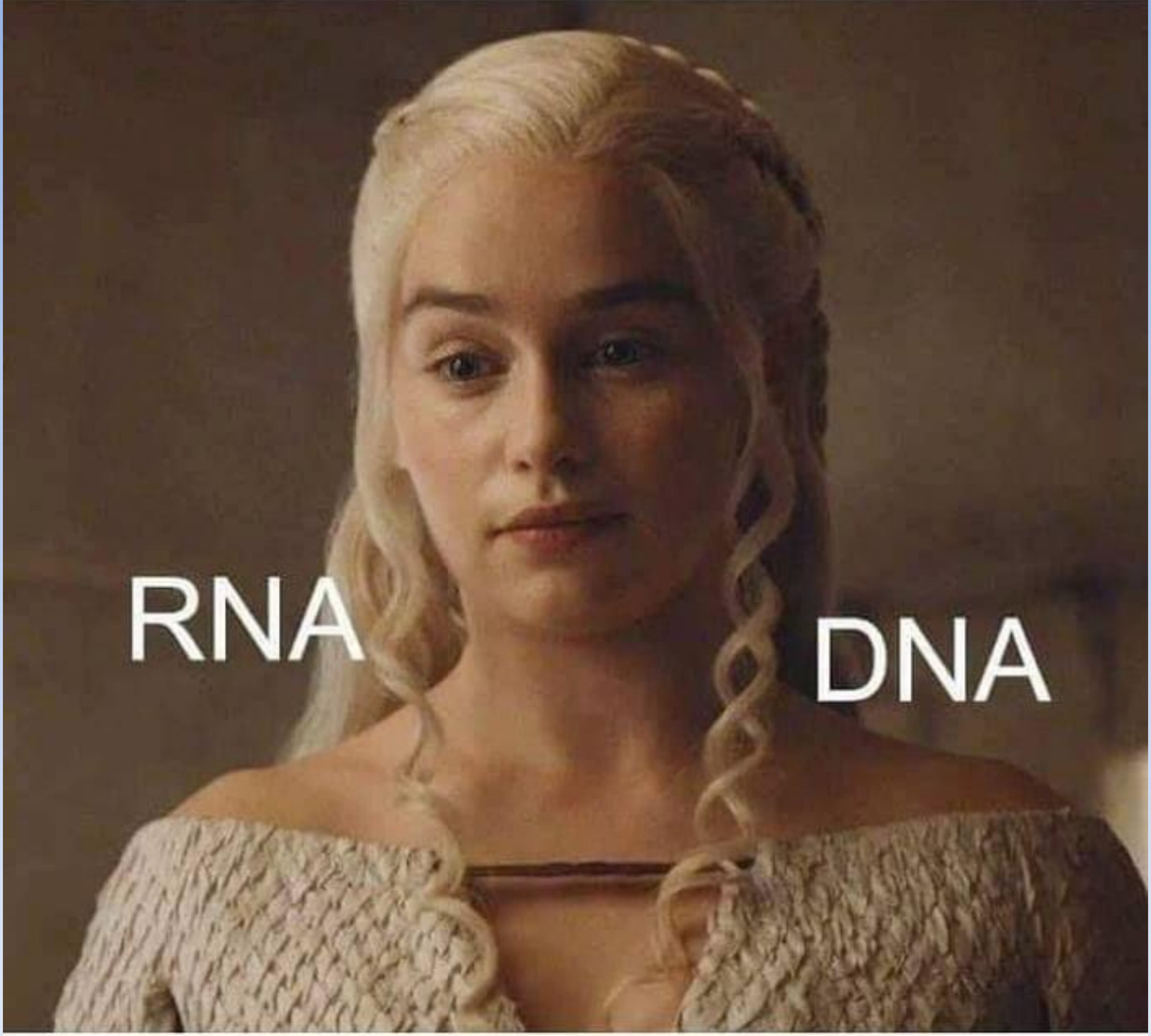




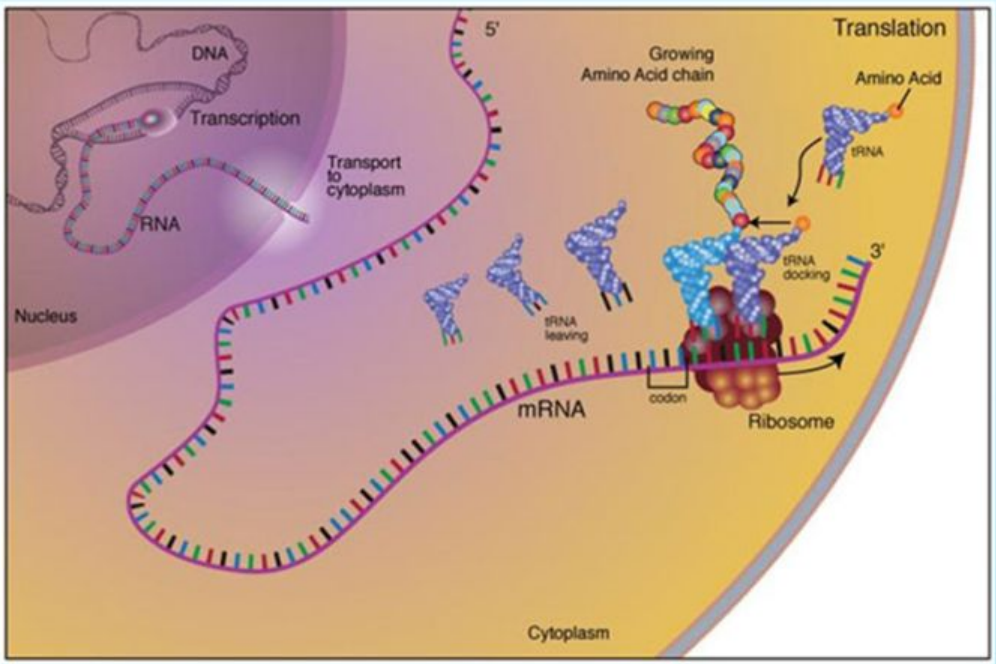
Protein Synthesis

- The *genetic code* – the sequence of nucleotides in DNA – is ultimately translated into the sequence of amino acids in proteins – *gene expression*
- in general, one gene encodes information for one protein (can be structural or enzymatic) – *one-gene, one-protein hypothesis*
- DNA does not directly synthesize proteins
- RNA acts as an intermediary between DNA and protein – polymer of nucleotides but has several important differences:

	RNA	DNA
sugar	ribose	deoxyribose
bases	A,**U**,C,G	A,**T**,C,G
strands	single	double


RNA
DNA

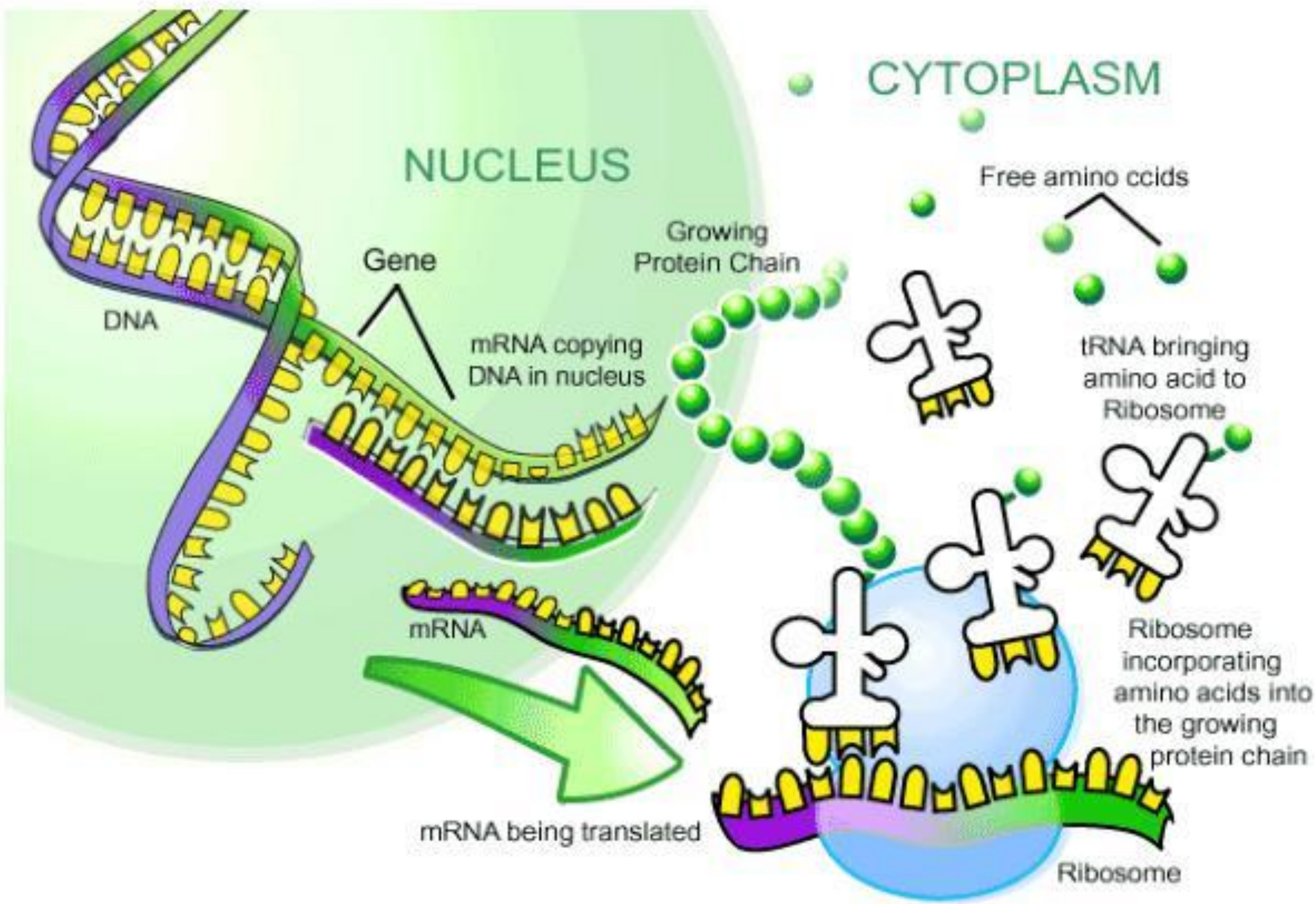
The Process of Protein Synthesis



1. DNA in nucleus as a template.
2. mRNA is processed and released into cytoplasm.
3. mRNA binds to ribosomes.
4. tRNA carries amino acid to mRNA.
5. Anticodon-codon complementary base pairing occurs.
6. Peptide chain is transferred from resident tRNA to incoming tRNA.
7. tRNA departs.
8. Protein modification after translation.

DNA → RNA → Protein

Protein Synthesis-Transcription

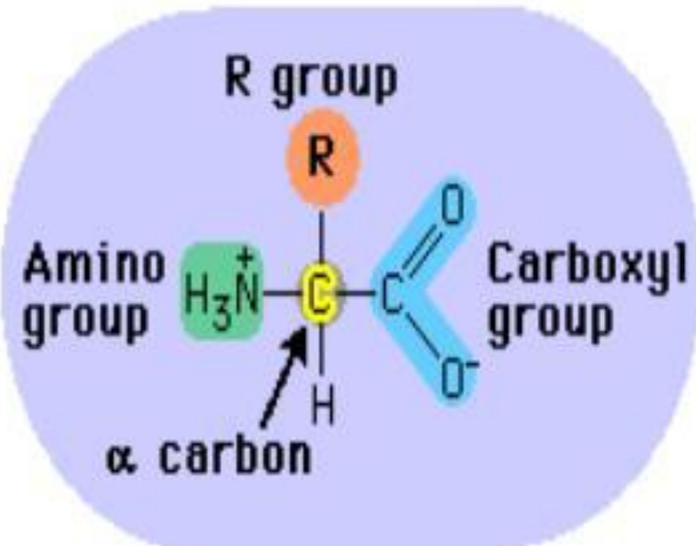


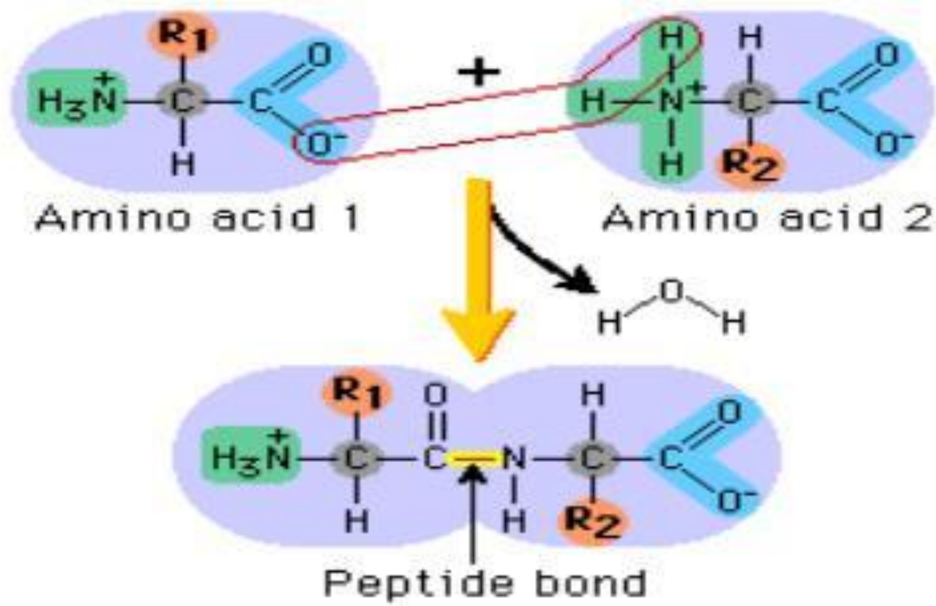
Protein Synthesis: Translation

Amino Acids

There are 20 amino acids, each with a basic structure

Amino acids are held together by <u>peptide bonds</u>





First position (5' end)	U	C	A	G	Third position (3' end)
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC	UCC	UAC	UGC	C
	UUA Leu	UCA	UAA Stop	UGA Stop	A
	UUG	UCG	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC	CCC	CAC	CGC	C
	CUA	CCA	CAA Gln	CGA	A
	CUG	CCG	CAG	CGG	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC	ACC	AAC	AGC	C
	AUA	ACA	AAA Lys	AGA Arg	A
	AUG	ACG	AAG	AGG	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC	GCC	GAC	GGC	C
	GUA	GCA	GAA Glu	GGA	A
	GUG	GCG	GAG	GGG	G

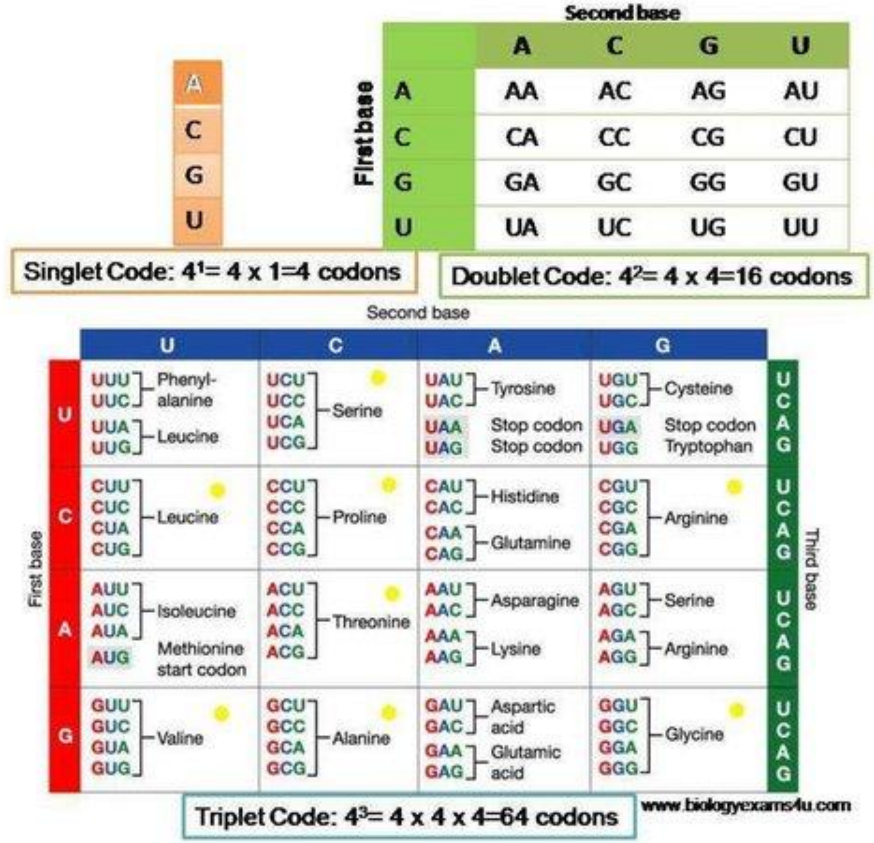
Amino acid names:

Ala = alanine
Arg = arginine
Asn = asparagine
Asp = aspartate
Cys = cysteine
Gln = glutamine
Glu = glutamate
Gly = glycine
His = histidine
Ile = Isolevcine
Leu = leucine
Lys = lysine
Met = methionine
Phe = phenylalanine
Pro = proline
Ser = serine
Thr = threonine
Trp = tryptophan
Tyr = Tyrosine
Val = valine

Properties of Genetic Code

1. Code is a Triplet:

As pointed out earlier, the coding units or **codons for amino acids** comprise **three letter words**, 4 x 4 x 4 or 43 = **64**. 64 codons are quite adequate to specify **20 proteinous amino acids.**



A
C
G
U

Singlet Code: 4^1= 4 x 1=4 codons

Second base

First base	A	C	G	U
A	AA	AC	AG	AU
C	CA	CC	CG	CU
G	GA	GC	GG	GU
U	UA	UC	UG	UU

Doublet Code: 4^2= 4 x 4=16 codons

Second base

First base	U	C	A	G	Third base
U	UUU, UUC – Phenyl-alanine; UUA, UUG – Leucine	UCU, UCC, UCA, UCG – Serine	UAU, UAC – Tyrosine; UAA Stop codon; UAG Stop codon	UGU, UGC – Cysteine; UGA Stop codon; UGG Tryptophan	U C A G
C	CUU, CUC, CUA, CUG – Leucine	CCU, CCC, CCA, CCG – Proline	CAU, CAC – Histidine; CAA, CAG – Glutamine	CGU, CGC, CGA, CGG – Arginine	U C A G
A	AUU, AUC, AUA – Isoleucine; AUG Methionine start codon	ACU, ACC, ACA, ACG – Threonine	AAU, AAC – Asparagine; AAA, AAG – Lysine	AGU, AGC – Serine; AGA, AGG – Arginine	U C A G
G	GUU, GUC, GUA, GUG – Valine	GCU, GCC, GCA, GCG – Alanine	GAU, GAC – Aspartic acid; GAA, GAG – Glutamic acid	GGU, GGC, GGA, GGG – Glycine	U C A G

Triplet Code: 4^3= 4 x 4 x 4=64 codons

www.biologyexams4u.com

Properties of Genetic Code

2. The Code is Degenerate:

The occurrence of more than **one codon** for a **single amino acid** is referred to as degenerate. A review of genetic code dictionary will reveal that most of the amino acids have more than one codon. Out of 61 functional codons, AUG and UGG code to one amino acid each. But remaining 18 amino acids are coded by 59 codons.

- **a given amino acid may be coded for by more than one codon**

64 codons and only 20 amino acids:
so some amino acids are coded for by several codons – exceptions [next slide]:

Valine
GUU
GUC
GUA
GUG

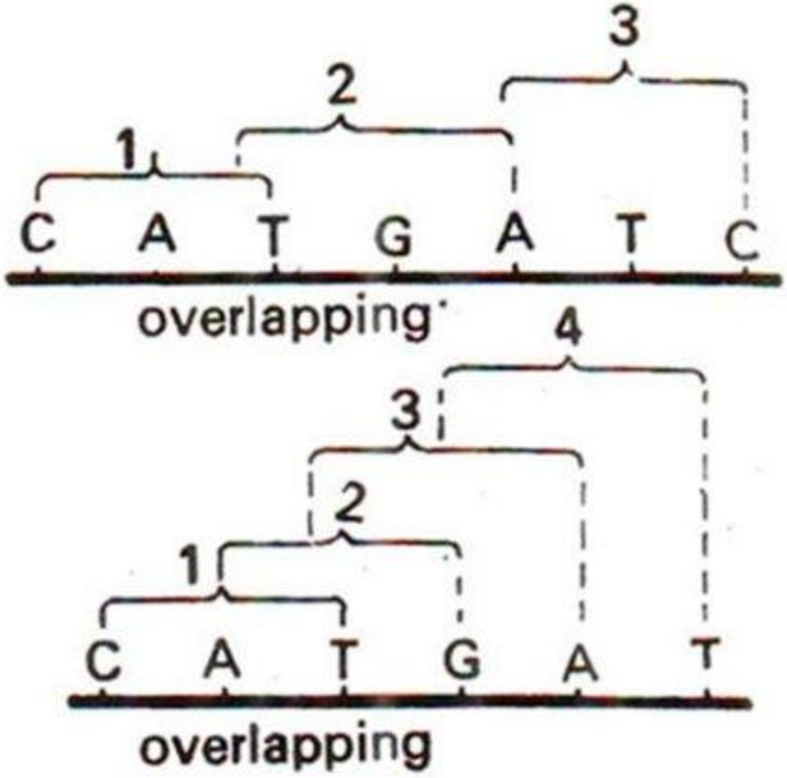
Lysine
AAA
AAG

Tyrosine
UAU
UAC

Properties of Genetic Code

3. The Code is Non-overlapping:

In a non-overlapping code, the same letter (i.e., base) is **not used in the formation of more than one codon**.



Properties of Genetic Code

4. The Code is Comma Less:

A comma less code means that no **nucleotide** or comma (or punctuation) **is present in between two codons**. Therefore, code is continuous and comma less and no letter is wasted between two words or codons.

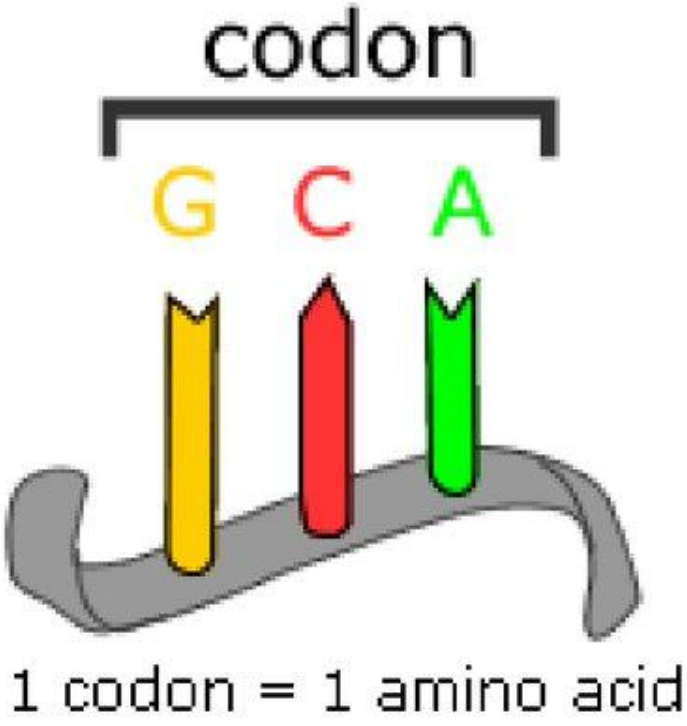
A—U—G, —C—A—G

aa1 aa2

Properties of Genetic Code

5. The Code is Unambiguous:

There is no ambiguity in the genetic code. A given **codon always codes** for a **particular amino acid**, wherever it is present.

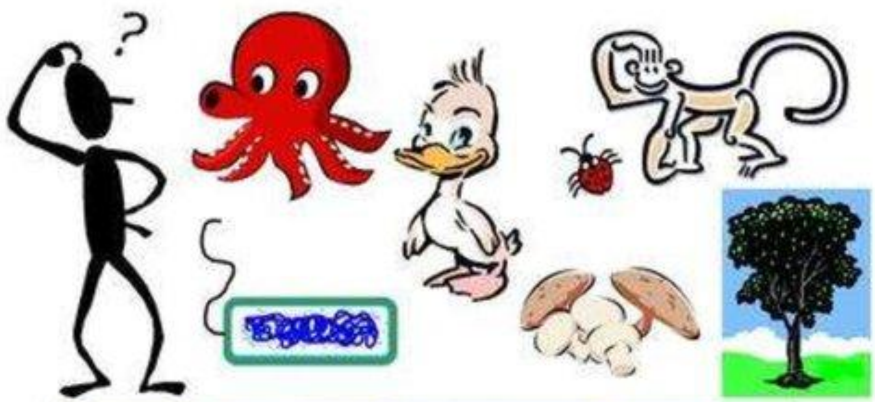


Properties of Genetic Code

6. The Code is Universal:

The genetic code has been found to be **universal** in **all kinds of living organisms** — prokaryotes and eukaryotes.

What does the DNA of all these organisms have in common?



They all share a universal genetic code.

Properties of Genetic Code

7. Co-linearity:

DNA is a linear polynucleotide chain and **a protein is a linear polypeptide chain.** The sequence of amino acids in a polypeptide chain corresponds to the sequence of nucleotide bases in the gene (DNA) that codes for it. Change in **a specific codon in DNA produces** a **change of amino acid in the corresponding position in the polypeptide.** The gene and the polypeptide it codes for are said to be co-linear.

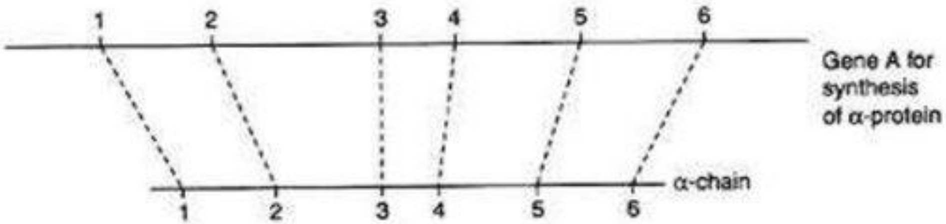
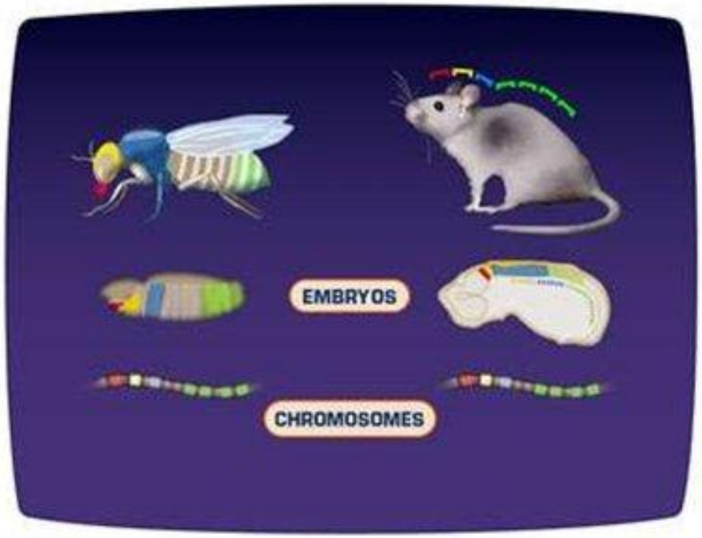


Fig. 15.3 Diagram illustrating colinearity between gene and protein.



YouTube

https://youtu.be/2zAGAmTkZNY