BIOCHEMISTRY

study the chemistry of living organisms.

biology + chemistry

INTRODUCTION

welcome back ★

1. Definition

- Science concerned with chemical basis of life
- Science concerned with the chemical constituents of living cells and with the reactions and processes that they undergo

2. The aim of biochemistry

- Describe and explain, in molecular term, all chemical process associated with living cells
- Isolate the numerous molecules found in cells
- Determine their structures
- Analyse how they function

3. Knowledge of biochemistry is essential to all life sciences

- Physiology: overlap with biochemistry
- Immunology: need biochemical techniques Antibodies
- Pharmacology: drug metabolism and interaction
- pathology: inflammation, cell injury and cancer
- Toxicology: poisons
- microbiology: علم الأحياء الدقيقة

متبادل

4. Reciprocal relationship between biochemistry & medicine has stimulated mutual advance

أضاءت

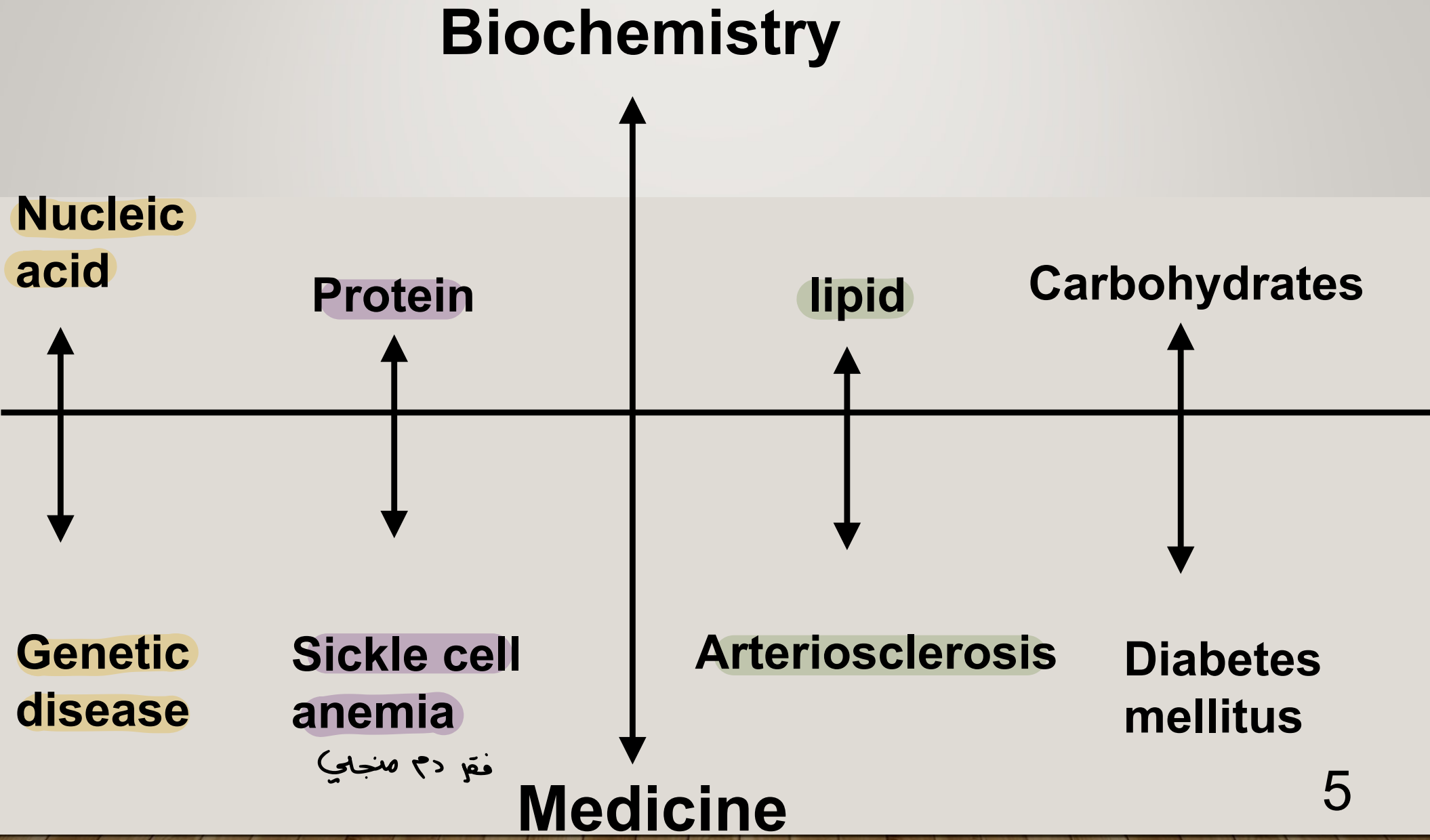
(a) Biochemistry studies have illuminated many aspects of health & disease

(b) The study of various aspects of health & disease has opened up new areas of biochemistry such as 8

1- biotechnology
2- pharmacogenetics
3- nutrition
4- genetics diseases

For example, knowledge of protein structures and function was necessary to elucidate the difference between normal and sickle cell hemoglobin

وضح


Biochemistry
Nucleic acid
Protein
lipid
Carbohydrates
Genetic disease
Sickle cell anemia
فقر دم منجلي
Arteriosclerosis
Diabetes mellitus
Medicine

5. Normal biochemical processes are the basis of health

Definition of health (WHO) world health organization

"Complete physical, mental & social well-being and not merely the absence of disease and infirmity"

عجز

A strictly biochemical viewpoint about health: The situation in which all of the many thousands of intra & extra cellular reactions that occur in the body are proceeding at the rates commensurate (مَتَنا سب) with its maximal survival in the physiological state

6. Biochemical research has impact on (1) nutrition and (2) preventive medicine

7. All diseases have a biochemical basis

(1) Physical agent:

mechanical trauma, extremes of temperature, sudden changes in atmospheric pressure, radiation, electric shock

(2) Chemical agents:

drugs, certain toxic compounds, therapeutic drugs

(3) Biologic agents:

Viruses, Bacteria, Fungi, Higher forms of parasites

(4) Oxygen lack $O_2 \downarrow$ $Co_2 \uparrow$

loss of blood supply, depletion of the oxygen-carrying capacity of the blood, poisoning of the oxidative enzyme

- 5 Genetic disorders:
وراثي Congenital, molecular

(6) Immunology reaction
فرط الحساسية Anaphylaxis, Autoimmune disease
مناعي ذاتي

(7) Nutritional imbalance:
Deficiencies, excesses

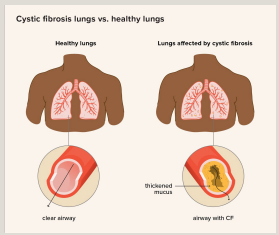
(8) Endocrine imbalances
hormonal deficiencies, excesses

8. Biochemical studies contribute to diagnosis, prognosis & treatment

تشخيص — what is happening right now?

توقع — What is likely to happen next?

Disease	causes
Scurvy	Deficiency of vitamin C
Rickets	Deficiency of vitamin D
Arteriosclerosis	Genetic, dietary, environmental factors

Disease	causes
Phenylketonuria	Mainly mutation (طفرة) in the gene coding phenylalanine hydroxylase
Cystic fibrosis تليف كيسي 	Mutation in the gene coding the CFTR protein
Cholera	exotoxin of vibrio cholera
Diabetes type I	(1) genetic and (2) environment factors resulting in deficiency of insulin

Which of the following is an **incorrect match**?

A. Cystic fibrosis — mutation in the CFTR gene
B. Arteriosclerosis — genetic, dietary, and environmental factors
C. Diabetes mellitus type I — excess insulin production
D. Cholera — exotoxin of *Vibrio cholerae*

C

Which of the following is an **incorrect match**?

A. Cystic fibrosis — mutation in the gene coding CFTR protein
B. Arteriosclerosis — genetic, dietary, and environmental factors
C. Diabetes type I — deficiency of insulin
D. Rickets — deficiency of vitamin C

D

9. Many biochemical studies illuminate disease mechanisms & disease inspire biochemical research

Use how biochemistry is used?!	Example
(1) to reveal the fundamental causes &mechanisms of diseases	Demonstration of the genetic defects in CF عرض تشوهات cystic fibrosis
(2) to suggest rational treatment of diseases	use of a diet low in phenylalanine for the treatment of phenylketonuria
(3) to assist in the diagnosis of specific disease	use of the plasma enzyme CK-MB creatine Kinase - myocardial Band in the diagnosis of myocardial infarction جلطة

Use	Example
(4) To act as screening tests for the early diagnosis of certain diseases	use of measurement of blood tyrosine or TSH in the neonatal diagnosis of congenital hypothyroidism thyroid stimulating hormone حديثي الولادة
(5) To assist in monitoring the progress of certain disease	use of the plasma enzyme ALT in monitoring the progress of infectious hepatitis التهاب الكبد الوبائي ALanine aminoTransaminase
(6) To assist in assessing (تقييم) the response of diseases to therapy	use of measurement of blood CEA in certain patients who have been treated for cancer of the colon carcino Embryonic Antigen

A baby is tested for TSH shortly after birth to detect congenital hypothyroidism. This is an example of:

A. Diagnosis

B. Screening

C. Treatment

D. Disease mechanism

B

The measurement of plasma CK-MB in a patient suspected of myocardial infarction is an example of which biochemical application?

A. Revealing disease mechanism

B. Rational treatment

C. Diagnosis

D. Screening test

C

Which of the following is **incorrectly matched**?

A. Genetic defects in CF — revealing disease mechanism

B. Blood tyrosine in neonates — early screening

C. ALT in hepatitis — rational treatment

D. Blood CEA in colon cancer — assessing therapy response

C

THE MOLECULAR COMPOSITION OF CELLS

- Mostly Water: ~80%
- Of remainder weight:
  - Lipids, fats: 10%
  - Carbohydrates: 15%
  - Proteins: 50%
  - Nucleic Acids: 15%

- **Proteins** are key macromolecules (play many structural and functional roles in cells)
- Nucleic Acids (**DNA**, RNA; DNA stores hereditary information in cell)

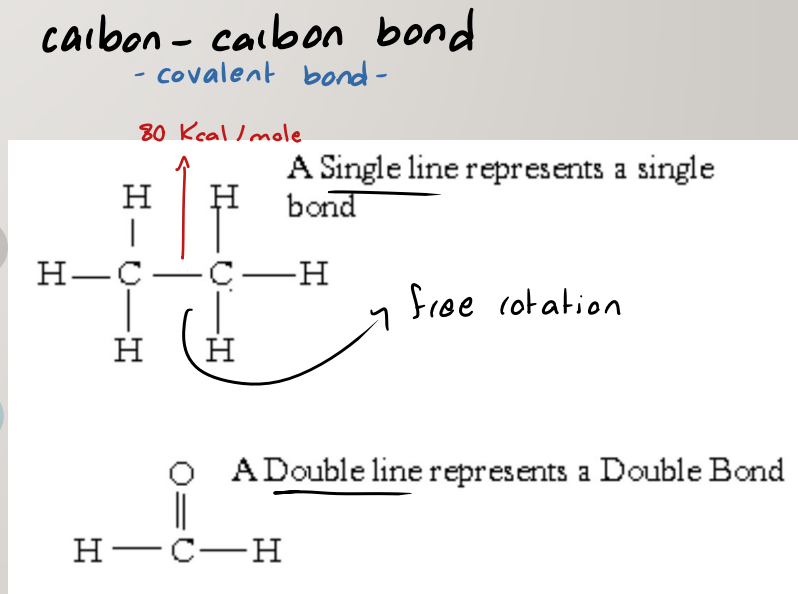
Function وراثية

- At some level, chemical forces determine shape of molecules and shape determines function.

THE FORCES THAT GIVE THESE MOLECULES THEIR PROPERTIES

1. Covalent bond

- most important type of bonds
- strongest type of bond – strength ~ 80 kcal/mol
- **A covalent bond is the sharing of a pair of electrons**
- There is free rotation about a single covalent bond, but not about a double or triple bond.
- Covalent bonds also have a fixed angle.
- Some covalent bonds involve unequal sharing of electrons.



1. COVALENT BOND

polar covelant bond O – H

non polar covelant bond C – H

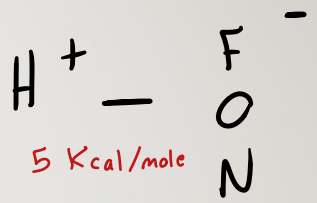
- **Some atoms hold onto electrons more tightly than other atoms. The tendency to attract electrons is a measure of electronegativity of an atom**

اكبر كهرو سلبية O > H

- Oxygen is a more electronegative atom compared to hydrogen, and thus an O-H bond is considered a polar bond.
- **Carbon and hydrogen have similar electronegatvities, therefore, a C-H bond is considered nonpolar.**

C ≈ H كهرو سلبية

2) HYDROGEN BONDS

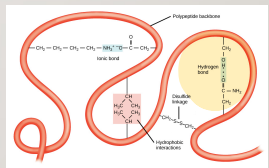


- Attraction between a slight positive charge on a hydrogen atom and a slight negative charge (N, O or F) on a nearby atom
- Strength of bond ~ 5 kcal/mol (relatively weak)
- Strongest when the donor, the hydrogen and the acceptor are about 0.25 nm apart
- Hydrogen bonds give order and structure to molecules
- A single hydrogen bond is weak, however, most molecules are made up of many

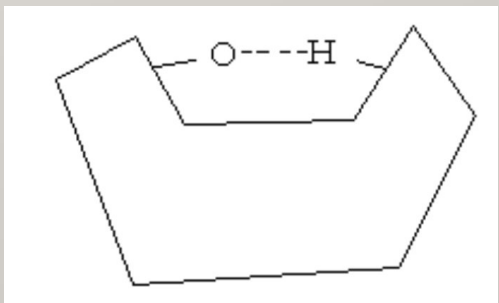
- **Hydrogen bonds; leads to overall strength of molecule**

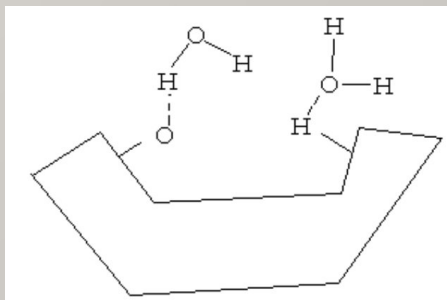
2) HYDROGEN BONDS

- Properties of water are determined by hydrogen bonding interactions.
  - Water is highly structured even when liquid. Formation of ice is due to the lattice array of hydrogen bonds.



- Hydrogen bonds form between different regions of a protein
  - In an aqueous environment, these regions will from hydrogen bonds with water molecules. These molecules adopt a more favorable conformation when they interact with water.





Which of the following statements about hydrogen bonding is correct?

- ○ Hydrogen bonding involves the sharing of electrons between atoms.
- ○ Hydrogen bonding occurs between a hydrogen atom and a highly electronegative atom. ✓
- ○ Hydrogen bonding is stronger than covalent bonding.
- ○ Hydrogen bonding is not affected by the polarity of molecules.

3) IONIC BONDS

$Na^+ - Cl^-$

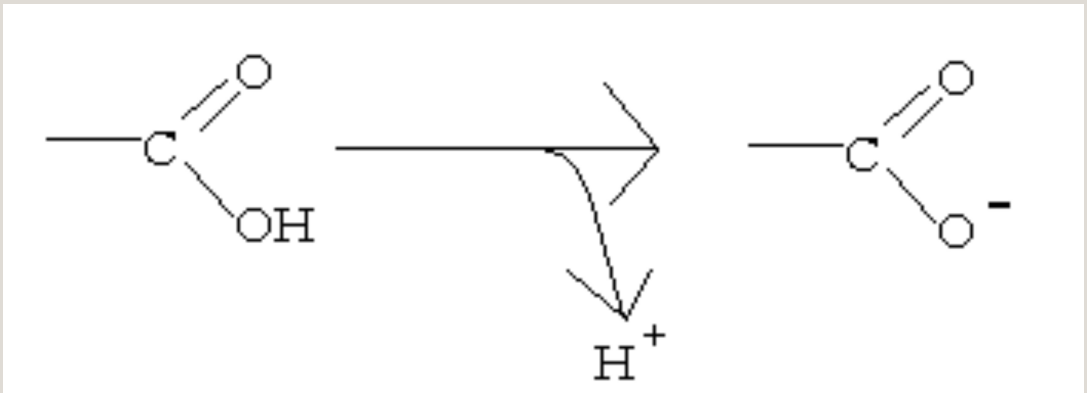
NaCl

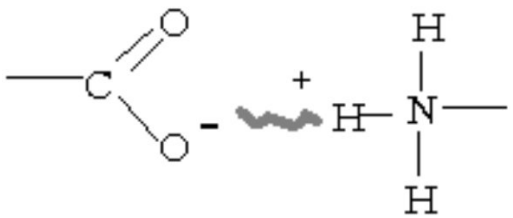
3-7 Kcal/mol

- electrostatic interaction between two oppositely charged groups in a molecule
- Limiting cause of unequal sharing of electrons; one atom keeps the electron

$$NaCl \rightleftharpoons Na^+ + Cl^-$$

- unequal sharing of electrons, Cl^- keeps both electrons.
- **Strength of ionic bond is about 3-7 kcal/mol; strongest when the two atoms are about 0.28 nm apart**
- **In solution this group becomes ionized, loses a proton and becomes negatively charged**





ionic bond

Charged atoms are held by a force called Coulomb/s law:
F = q1q2/ (R)(R)

Force of attraction is proportional to the charges (q) of the two groups and the distance (R) between them

4) VAN DER WAAL INTERACTION

- Nonspecific attractive force that occurs when any two atoms come in close range
- Most favorable when atoms are 0.2-0.3 nm apart

عابرة

- Transient polarity induced between atoms a nonpolar bond leads to attraction with nearby atoms

✓ One-sentence explanation

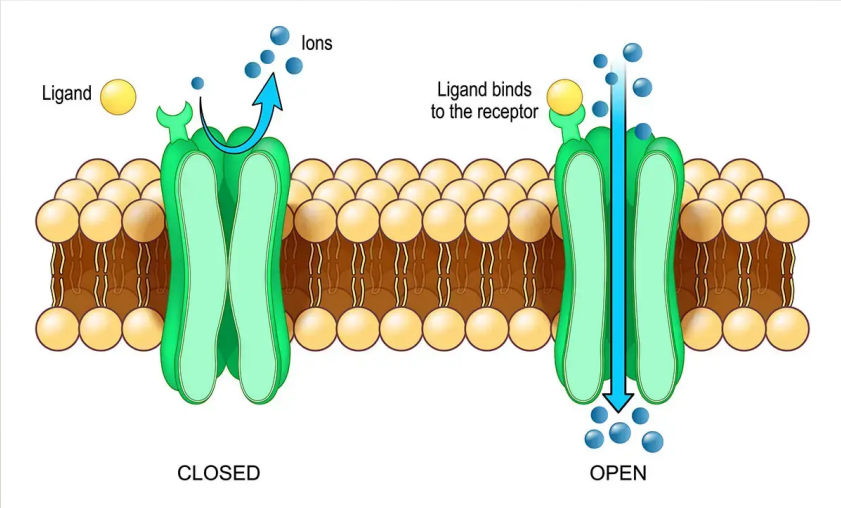
Transient polarity happens when moving electrons temporarily create a dipole in a nonpolar atom, which induces polarity in nearby atoms and causes weak attraction between them.

- Very weak interaction
  - strength is ~1 kcal/mol. However the sum of many Van Der Waal interactions leads to increased strength and stability

4) VAN DER WAAL INTERACTION

- Example: A ligand interacting with its receptor is accomplished by many noncovalent interactions such as Van Der Waal interactions → weak reversible interactions

- A **ligand** binds to its **receptor** mainly through **weak, non-covalent interactions**, not covalent bonds.
- These interactions allow the binding to be **reversible** so the ligand can attach, cause an effect, and then detach.



5) HYDROPHOBIC INTERACTIONS/ ENTROPY

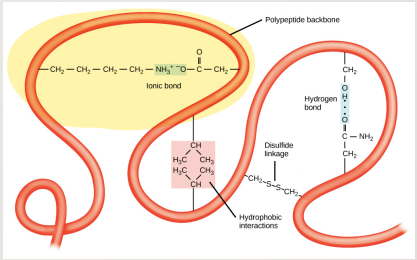
عشوائية
فوضى

- Overall, a molecule is held together by many interactions. A molecule forms a particular shape because it likes to adopt the lowest energy state (minimize entropy)
- In adopting this shape, the alternative conformations are selected, and the groups that cannot form hydrogen bonds with water (the hydrophobic ones) tend to cluster on the inside of the molecule (away from water).
  - **Hydrophobic:** ("water hating") uncharged, nonpolar molecules, don't interact with water
  - **Hydrophilic: ("water loving"): charged or polar molecules; from hydrogen bonds with water**

OTHER INTERACTIONS

- Ionic-dipole — Ammino acids

ion – polar molecule

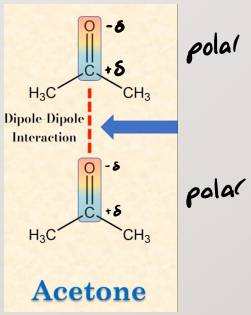


- Dipole-dipole — Acetone

polar molecule – polar molecule

(volatile liquid)

↳ evaporates quickly



polar

polar

- The shape that biological macromolecules adopt is dependent on a large number of molecular interactions.

MACROMOLECULES

- Most biologically important macromolecules are polymers, called biopolymers.

- Biopolymers fall into three classes:
  - proteins,
  - polysaccharides (carbohydrates), and
  - nucleic acids.

Page: 11 Difficulty: 2 Ans: A

The three-dimensional structure of macromolecules is formed and maintained primarily through noncovalent interactions. Which one of the following is *not* considered a noncovalent interaction?

A) carbon-carbon bonds
B) hydrogen bonds
C) hydrophobic interactions
D) ionic interactions
E) van der Waals interactions

SUGARS, CARBOHYDRATES

كيف تتذكرها ؟
بسبب السليلوز إلي في الشجر

- The most abundant biological compounds
- Structurally related but have a different chemical properties
- Involved in the storage and transport of energy (Starch, Glycogen)

  Animals

  plants
- As structural component (Cellulose in plants and Chitin in animals)

أحادي

ثنائي

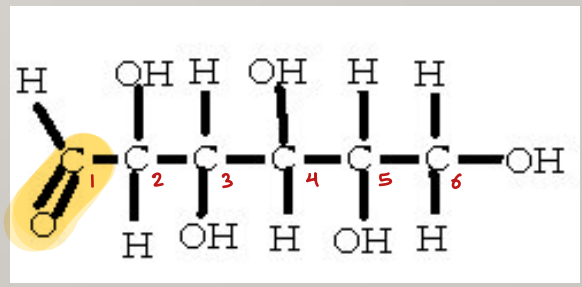
- Divided into: Monosaccharides , disaccharides and Polysaccharides

Most abundant biological compound

carbohydrate الجواب

1) GENERAL FORMULA FOR A SUGAR

- (CH2O)n e.g. Glucose C6H12O6
- In all sugars, n-1 of the carbons has a hydroxyl (OH) group and the C-1 carbon has a carbonyl (C=O) group. The location of the carbonyl group and the orientation of the hydroxyl groups determine the type of sugar. (isomers)
- If the carbonyl group (C=O) is at the end (an aldehyde group) then it is an aldose (e.g. glucose)
- If the carbonyl (C=O) is in the middle (a ketone group) then it is a ketose (e.g. fructose)
- Six carbon sugars are called hexoses (e.g. glucose)
- Five carbon sugars are called pentoses (e.g. ribose)
- Three carbon sugars are called trioses (e.g. glyceraldehyde)

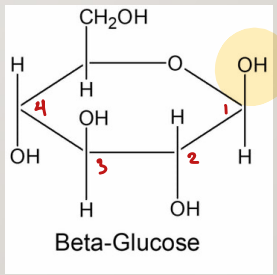


2)CONFORMATION OF SUGARS

a)Monosaccharides

- Glucose is more often found in a ring form in solution:
- The Orientation of the OH group on the C-1 carbon can be either in the alpha (below the plane of the ring) or beta (above the plane of the ring) position

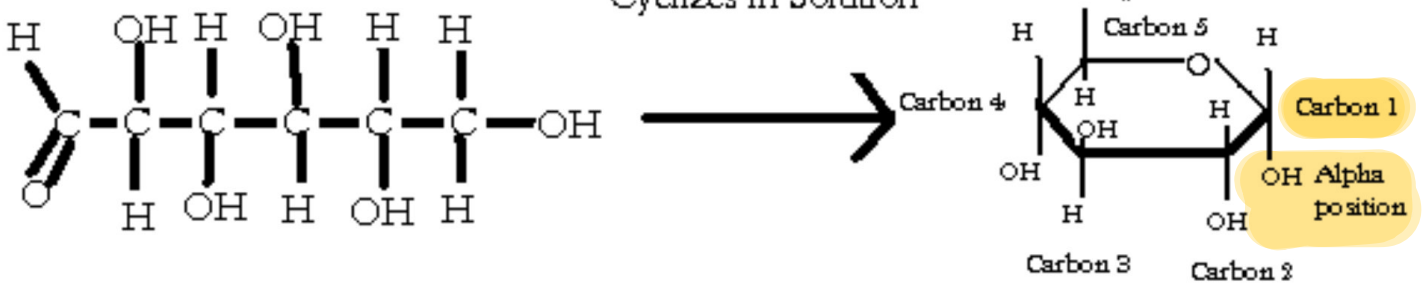
changes suger properties



Beta-Glucose

beta position

α suger



Alpha-D-Glucose

7. Glucose, the primary source of energy for a cell, is a type of

- ○ Polypeptide
- ○ Polysaccharide
- ○ Disaccharide
- ○ Monosaccharide ✓

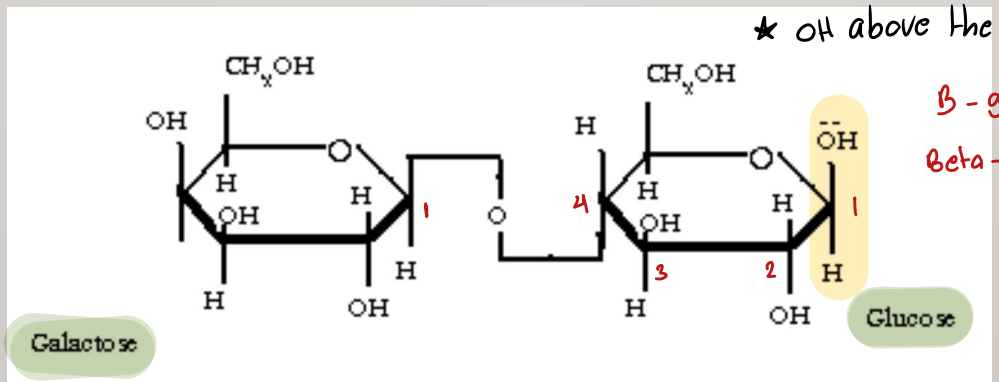
SUGARS, CARBOHYDRATES

b)Disaccharides

- Disaccharides consist of two Monosaccharides linked by a covalent bond:
- **Lactose (form)**
- (Galactose (1-> 4) Glucose)
- The enzyme lactase breaks down lactose to glucose and galactose. Many adult individuals stop synthesizing lactase enzyme. As a result a large percent of certain populations becomes lactose-intolerant.

lactose = glucose + galactose

↳ unable to fully digest lactose in dairy products.



Lactose (galactose (1-> 4) glucose

SUGARS, CARBOHYDRATES

c) Polysaccharides

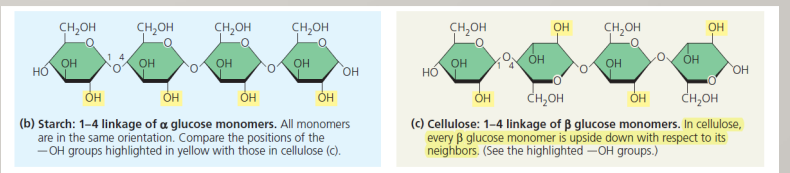
starch
glycogen
cellulose

- Polysaccharides consist of many monosaccharide units (usually glucose monomers) linked together to form long chains.
- e.g. starch, glycogen, cellulose (Alpha)
- Polysaccharides are used as a form of storage of energy (1) and also for structural roles (2).
- Starch is an unranked polymer of Glucose (1-> 4) linkage (Alpha)
- Cellulose – plays an important structural role in plants; one of the most abundant molecules on earth. it is an unbranched polymer of glucose in (1->4) linkage. (beta)

- Starch is made from **α-glucose**.
- Cellulose is made from **β-glucose**.

Because of this difference:

- Humans can digest **starch**.
- Humans **cannot digest cellulose**.



(b) Starch: 1–4 linkage of α glucose monomers. All monomers are in the same orientation. Compare the positions of the —OH groups highlighted in yellow with those in cellulose (c).

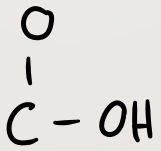
(c) Cellulose: 1–4 linkage of β glucose monomers. In cellulose, every β glucose monomer is upside down with respect to its neighbors. (See the highlighted —OH groups.)

جابت سؤال بأي نوع alpha linkage موجودة من di-polysaccharide

-starch
-lactose
-glycogen
-cellulose
-two choices

مثال ع polysaccharide كأنه وهاد موجود
بالانترو

LIPIDS

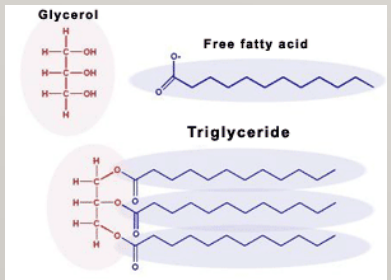


- fatty acid by adding a carboxyl group (COOH) group to a hydrocarbon

مزدوجة المطبية

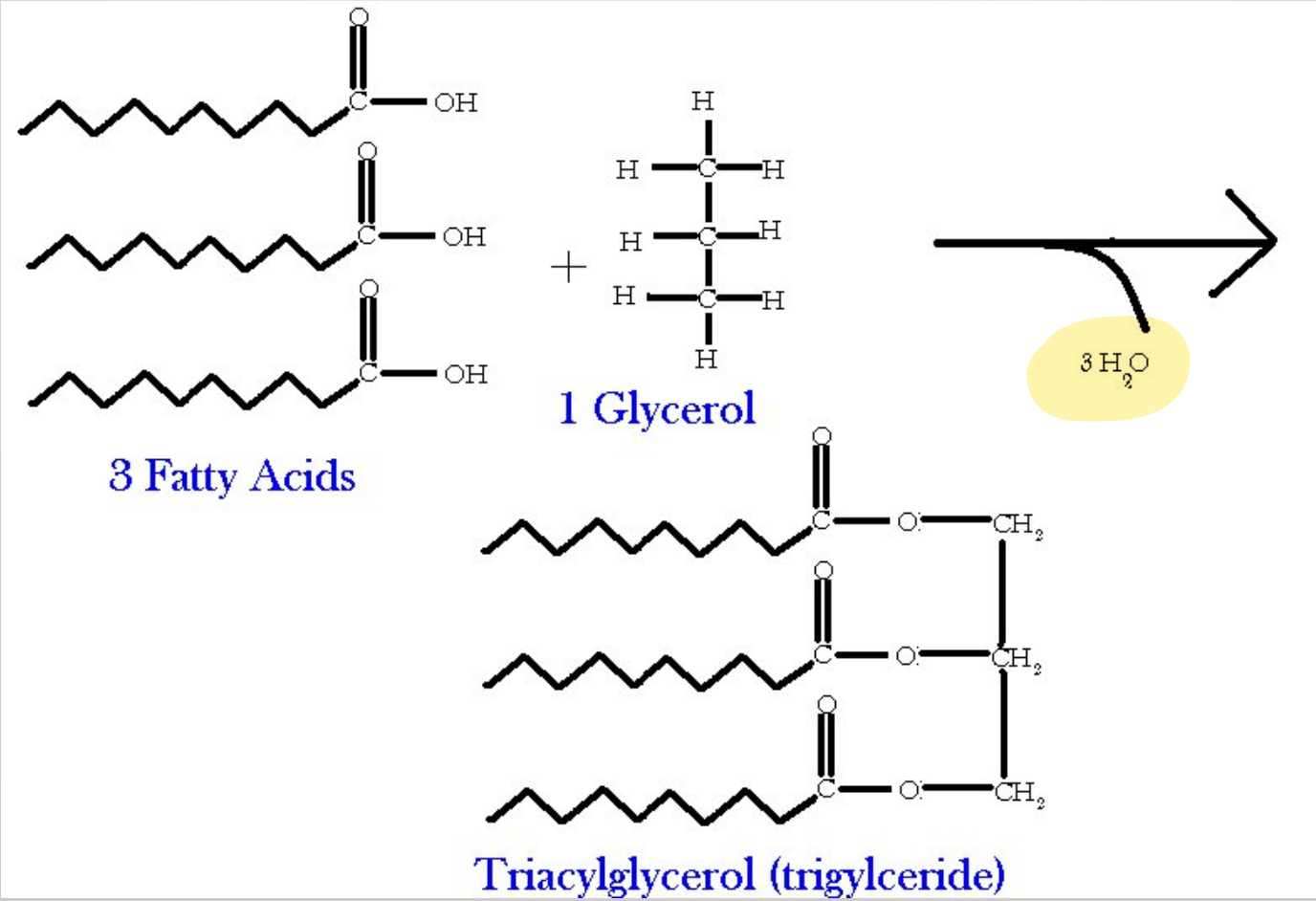
- A fatty acid is an amphipathic molecule: contains both hydrophobic and hydrophilic portions

- Three fatty acids and one glycerol molecule can be combined in a dehydration synthesis to from a lipid (a triglyceride).



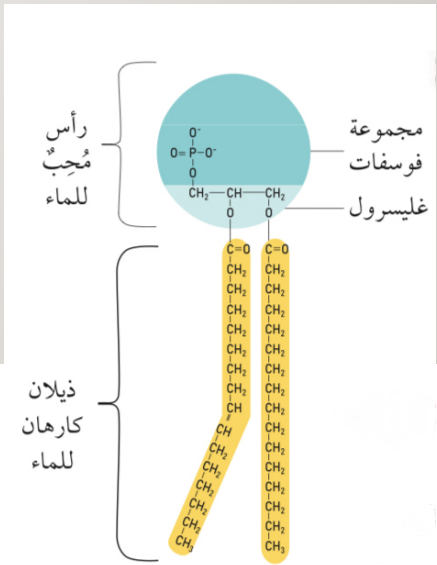
- Triglycerides are major storage forms of fatty acids inside cells

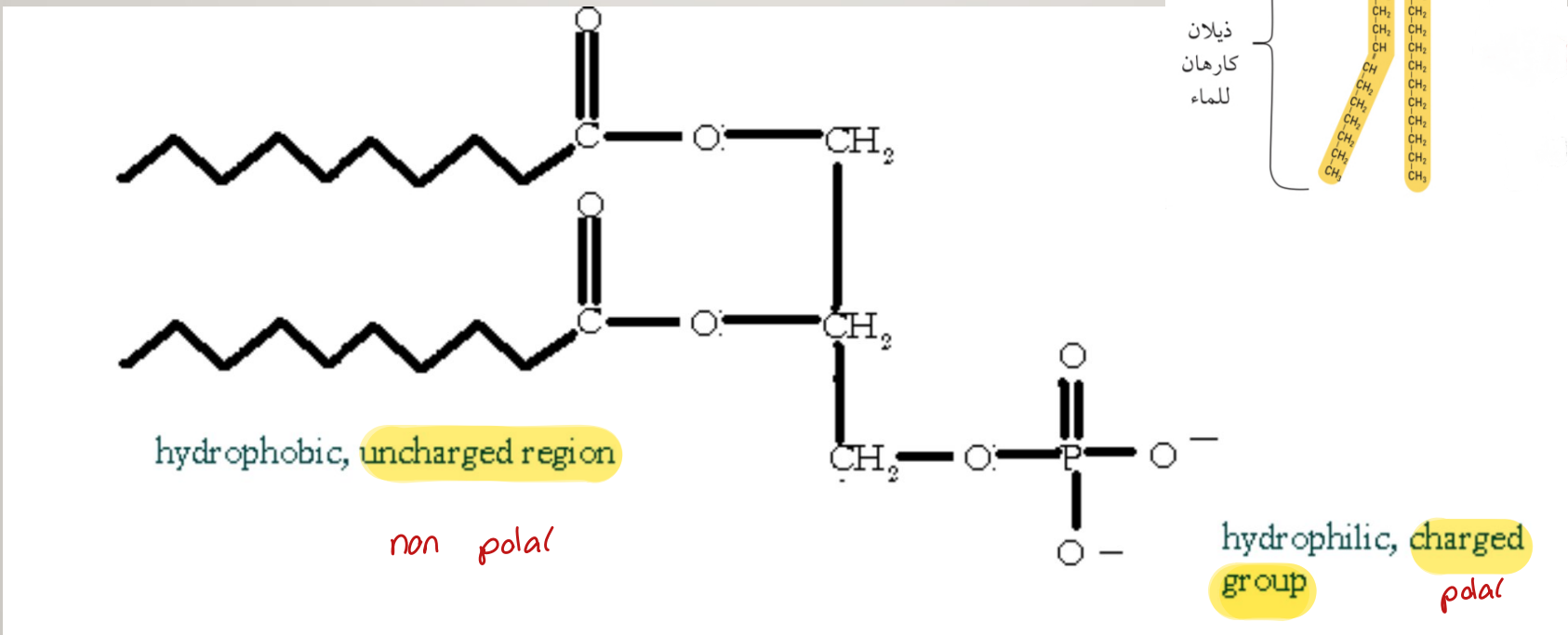
Lipids



PHOSPHOLIPIDS

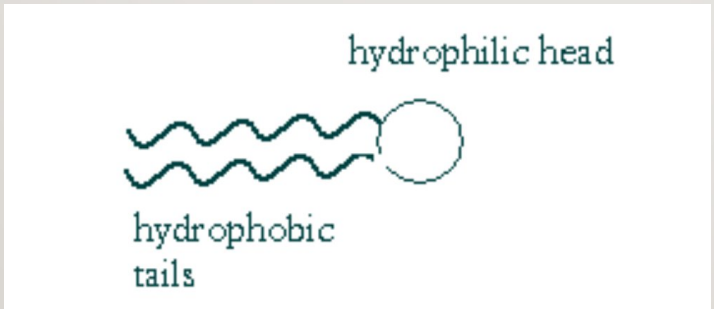
- A subgroup of lipids that play a key role in cell structure. Phospholipids are formed by combining two fatty acids and a phosphate group



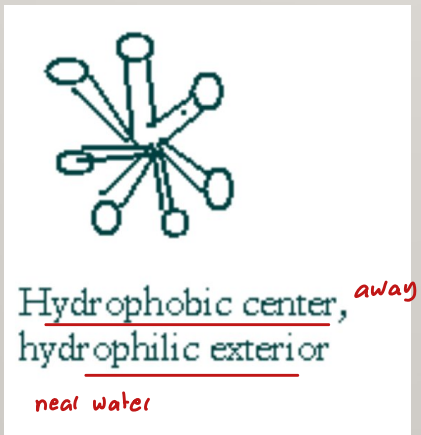


PHOSPHOLIPIDS

- The phospholipid can also be represented as:



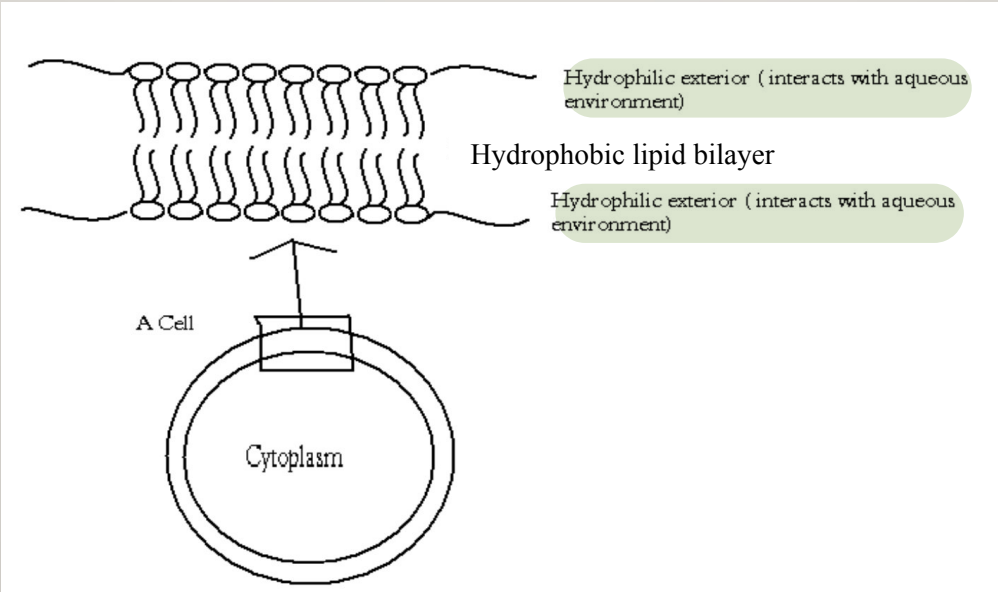
- In solution, phospholipids will assemble to form micelles.



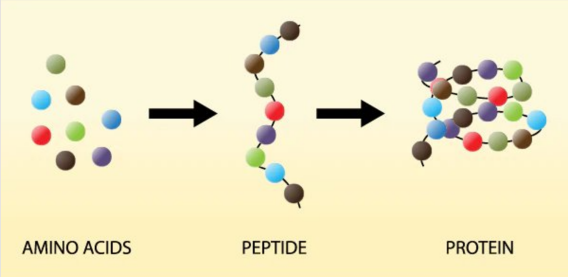
PHOSPHOLIPIDS

- Phospholipids form a lipid bilayer in an aqueous solution. A typical cell is enclosed by a plasma membrane, which is made up of a phospholipid bilayer
- The hydrophobic interior of the plasma membrane is impermeable to charged or polar molecule

غير منفذ



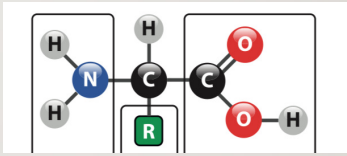
PROTEINS



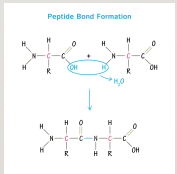
- have many functions in the cell
- structural and functional roles
- 105 different kinds of proteins made in eukaryotic cells
- Proteins are polymers of building blocks known as amino acids
- 20 different amino acids and so can make 20n combinations of proteins length n

AMINO ACIDS & PEPTIDE BONDS

- R group (side chain) varies among the 20 different amino acids. 20 different amino acids make up all proteins

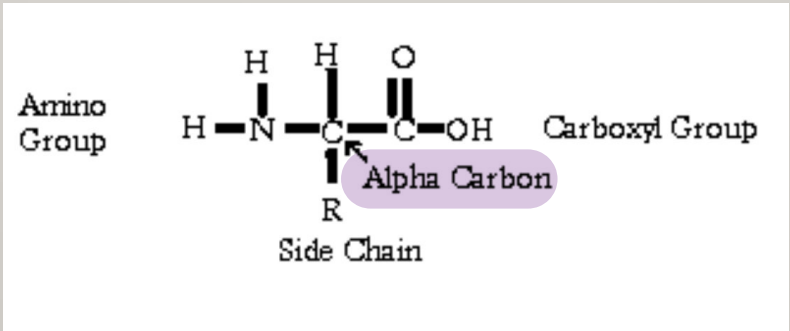


- Peptides are oligomers of amino acids formed: via a dehydration reaction when the carboxyl group of one peptide is linked to the amino group of a second amino acid



- A long polypeptide made up of many amino acids is called a protein. Each protein has a specific order of amino acids and adopts a particular shape – which is determined by the sequence of amino acids

تسلسل



Page: 30 Difficulty: 2 Ans: E

The three-dimensional structure of a protein is determined primarily by:

A) electrostatic guidance from nucleic acid structure.
B) how many amino acids are in the protein.
C) hydrophobic interaction with lipids that provide a folding framework.
D) modification during interactions with ribosomes.
E) the sequence of amino acids in the protein.

LEVELS OF PROTEIN STRUCTURE

(1) Primary Structure

The linear sequence of amino acids (e.g. NH3+..met-cys-leu-lys-glu…COO-))

(2) Secondary Structure

The local arrangement of amino acids that are close together in the linear chain to form structures that include -helices, -pleated sheets and random coils and loops.

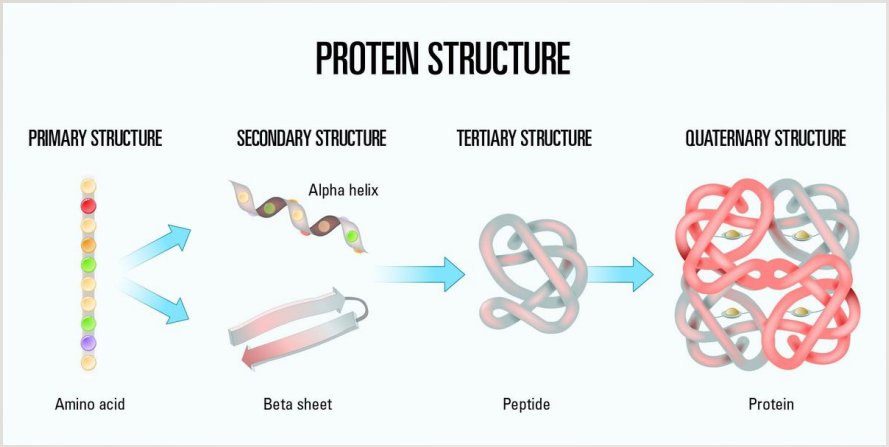
(3) Tertiary Structure

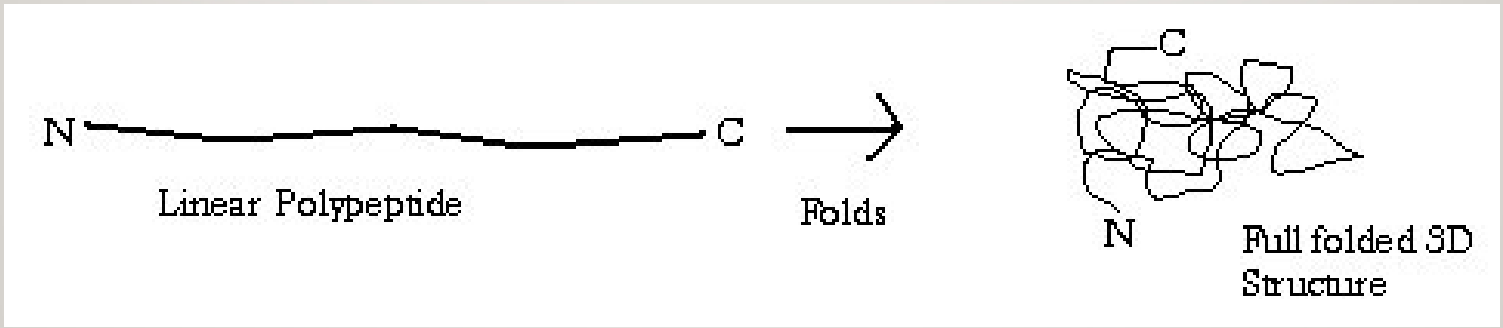
Spatial arrangement of amino acids that are far apart in the linear polypeptide chain to form the full 3-dimensional (folded) structure of the protein. Also includes disulfide bonds

↳ covelant bond

(4) Quaternary structure

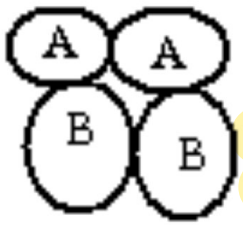
Interaction of more than one polypeptide chain; association between different proteins to form complexes such as dimers, trimers, tetramers





e.g.
Hemoglobin
(oligomeric protein)

made of more than one polypeptide chain



Consits of 4 polyp[eptide chains:
2 A chains — alpha
2 B chains — beta

Good luck ★