INTRODUCTION TO BIOLOGY

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Department of Biotechnology
Bennett University

SYLLABUS- EBTY106L

Module 1 (18 hours)

Biochemistry of Life

Simple and Complex Molecules, Bonding, Thermodynamics, Origin and evolution of cells, Diversity of life, Prokaryotic and eukaryotic cells, Functions of different organelles in the cells, Biosynthetic pathways of primary and selected secondary metabolites, Cell Communication, Microbiology, Immunology

Module 2 (18 hours)

Introduction to Genetics & Molecular Biology

Concept of gene, genome, chromosomes and chromatin, Cell cycle and Cell division, Central dogma of molecular Biology: Replication, Transcription and Translation. Epigenetics, Mutation and Genetic Disorders: Progeria, etc. Genetic Engineering, Stem Cells and Tissue Engineering, human disease- an overview

Module 3 (6 hours)

Concepts of Genomics & Bioinformatics

Genomics & personalized medicine, Introduction to Bioinformatics, DNA sequence as data, Sequence alignment using comparative tools, homology, phylogeny, Mining for data in relevant databases

REFERENCE BOOKS:

1. David L. Nelson and Michael M. Cox, *Lehninger Principles of Biochemistry* (7th ed.), W H Freeman & Co, 2017. ISBN 9781464126116.

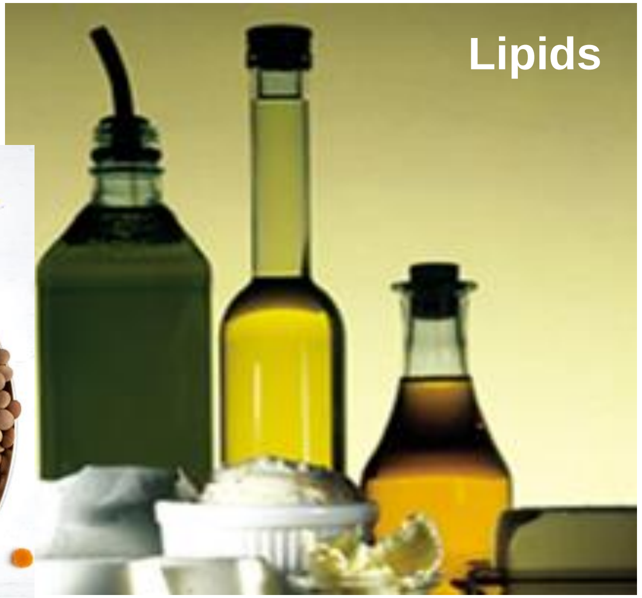
2. Gerald Karp, *Cell and Molecular Biology: Concepts and Experiments* (8th ed.), John Wiley & Sons Inc, 2015. ISBN 9781118886144, ISBN 1118886143.

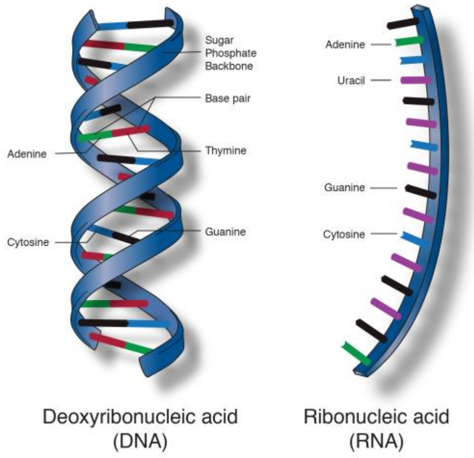
3. *T. K. Attwood, Introduction to Bioinformatics (1st ed.), Pearson Education, 2010*. ISBN 9780582327887, ISBN 0582327881.

4. Harvey Lodish, Arnold Berk, Lawrence Zipursky, Paul Matsudaira, David Baltimore and James Darnell, *Molecular Cell Biology* (8th ed.), W. H. Freeman, 2016. ISBN 9781319067748, ISBN 1319067743.

Evaluation Components:
Quiz 1: 20
Quiz 2: 20
Mid Term Exam: 25
End Term Exam: 35

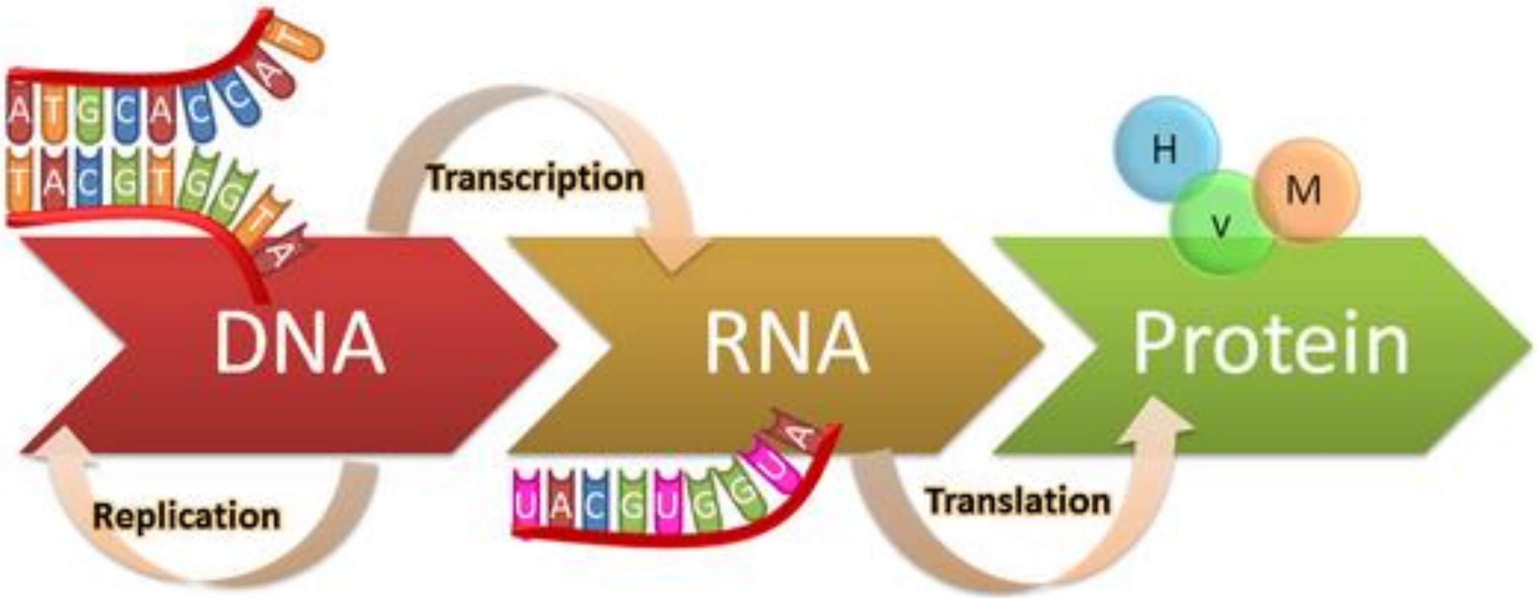
BIOMOLECULES





Nucleic acids

CENTRAL DOGMA OF LIFE



WATER

- Polar biomolecules → dissolve easily in water → Hydrophilic.
- Nonpolar biomolecules → do not dissolve appreciably in water → Hydrophobic
- Amphipathic biomolecules have significant amounts of both hydrophilic & hydrophobic structure.

TABLE 2–2 Some Examples of Polar, Nonpolar, and Amphipathic Biomolecules (Shown as Ionic Forms at pH 7)

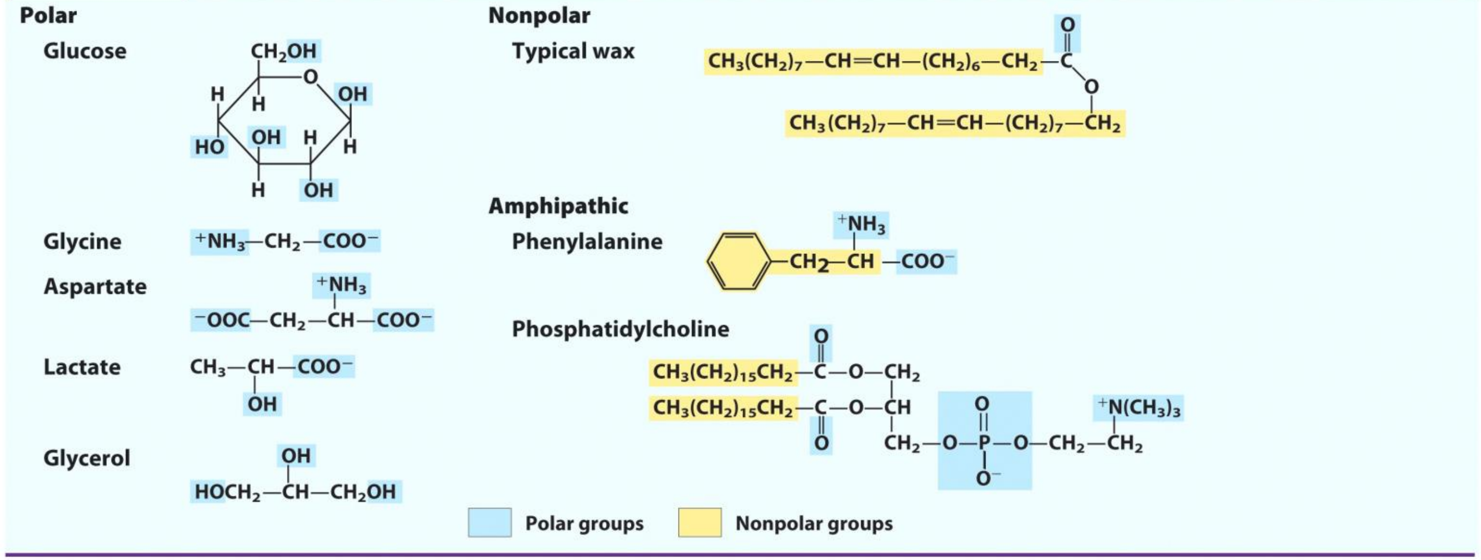


Figure 2-2: Structure of a typical amphipathic (both water-loving and water-hating) molecule.

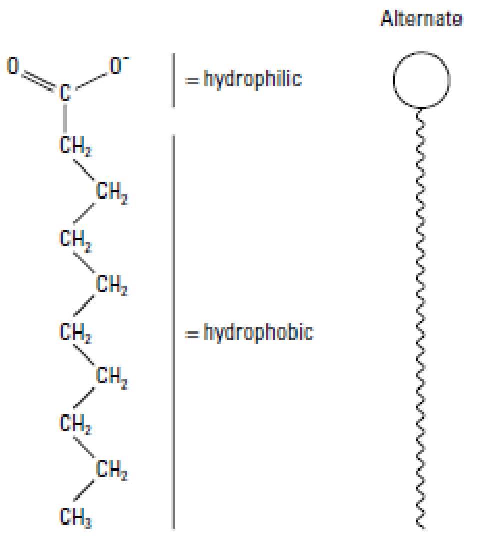
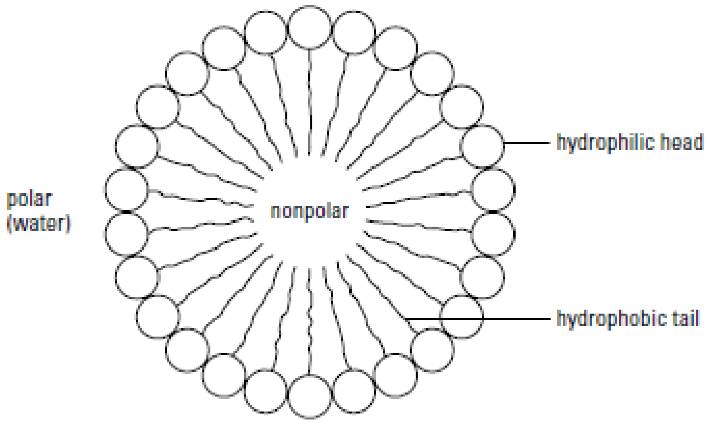


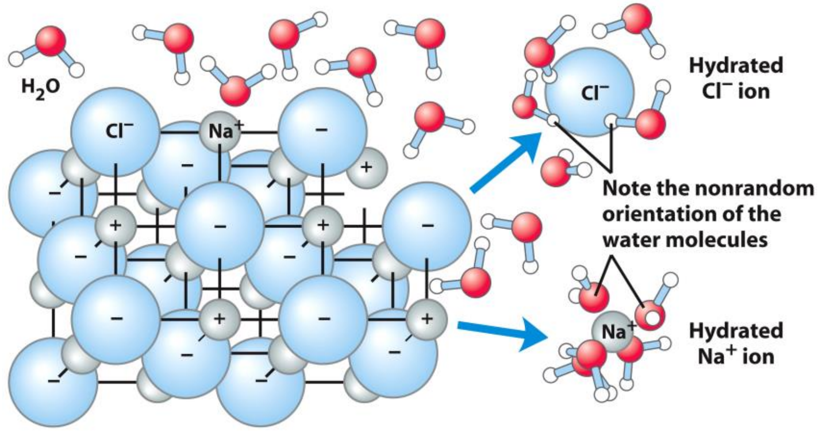
Figure 2-3: Structure of a micelle, composed of amphipathic molecules, with their hydrophilic "heads" pointing "out."



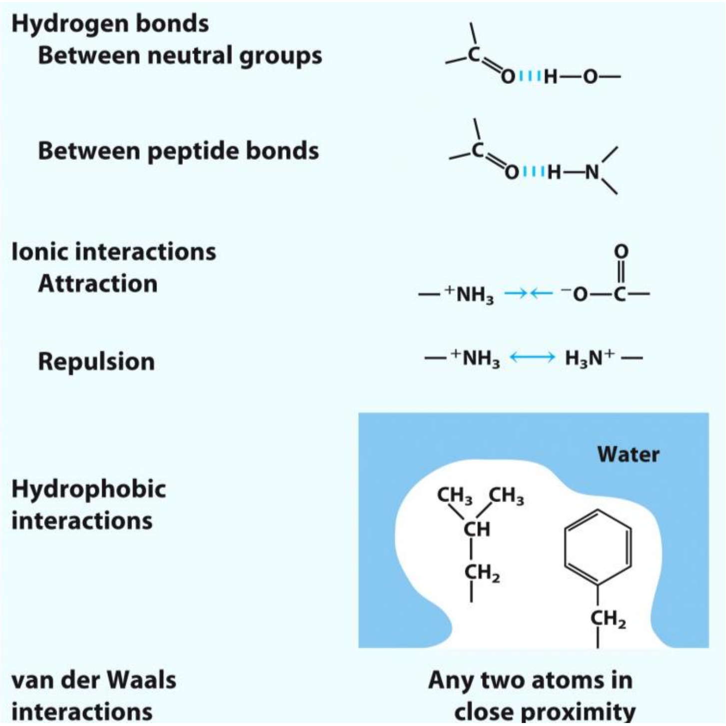
Universal solvent- ionic/ sugar/ alcohol

BONDS

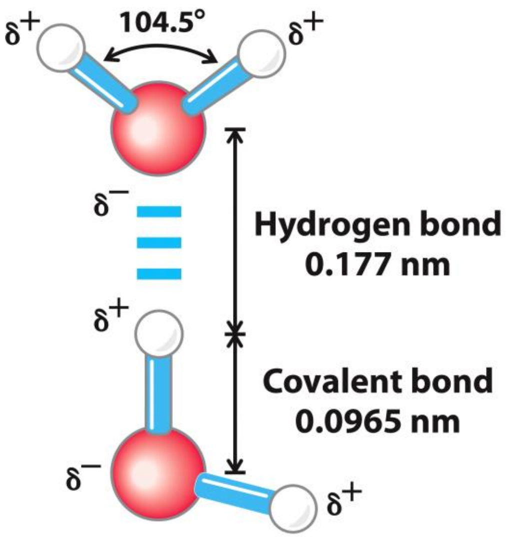
Ionic interactions → between cations and anions.



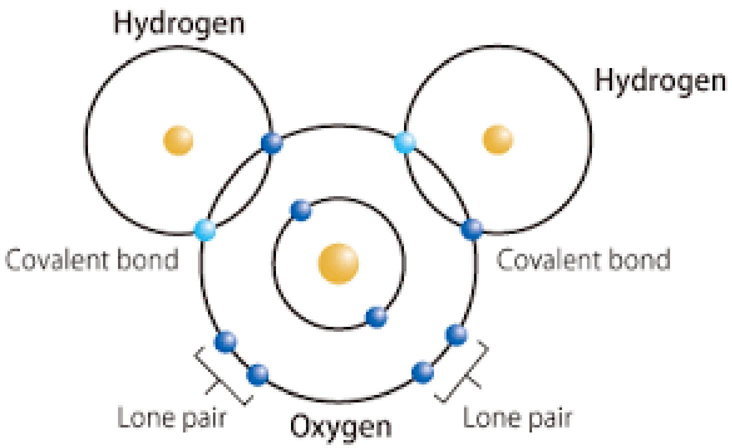
Non-covalent Bonds



Non-covalent interactions are weak electrical bonds (1-5 kcal/mol) & typically ~100-fold weaker than covalent bonds.

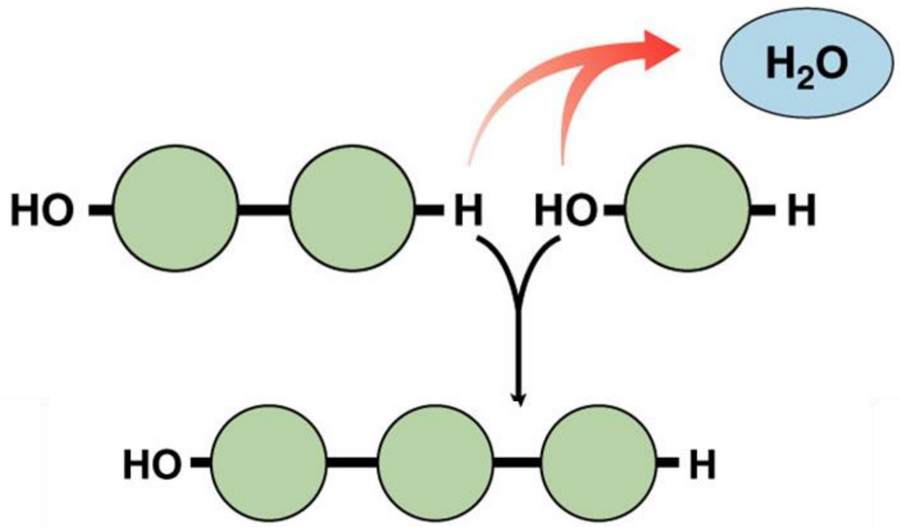


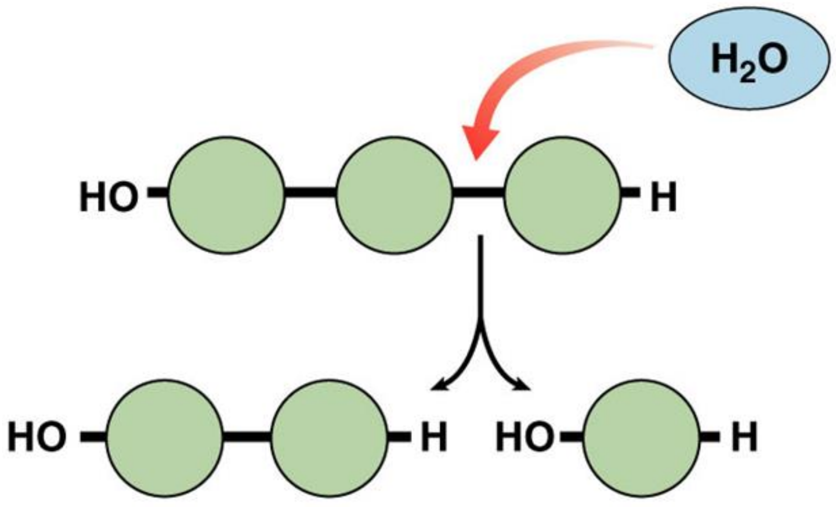
Covalent Bonds



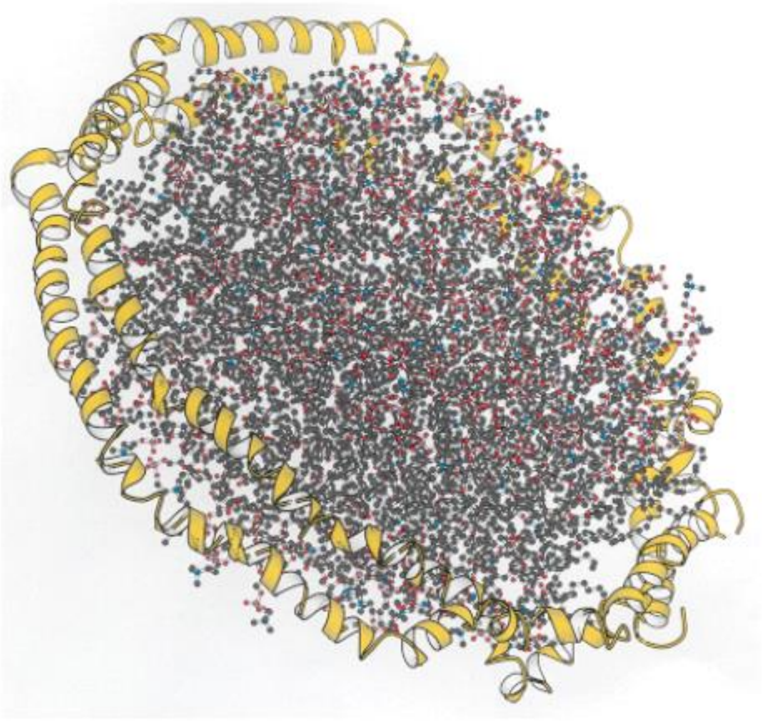
POLYMERS

- Long molecules built by linking together small, similar subunits (monomers)
- Formed by condensation polymerization (dehydration synthesis) → removal of water molecule
- Energy in the form of ATP is required
- Hydrolysis of polymers to monomers → Breaks covalent bond by adding -H/-OH



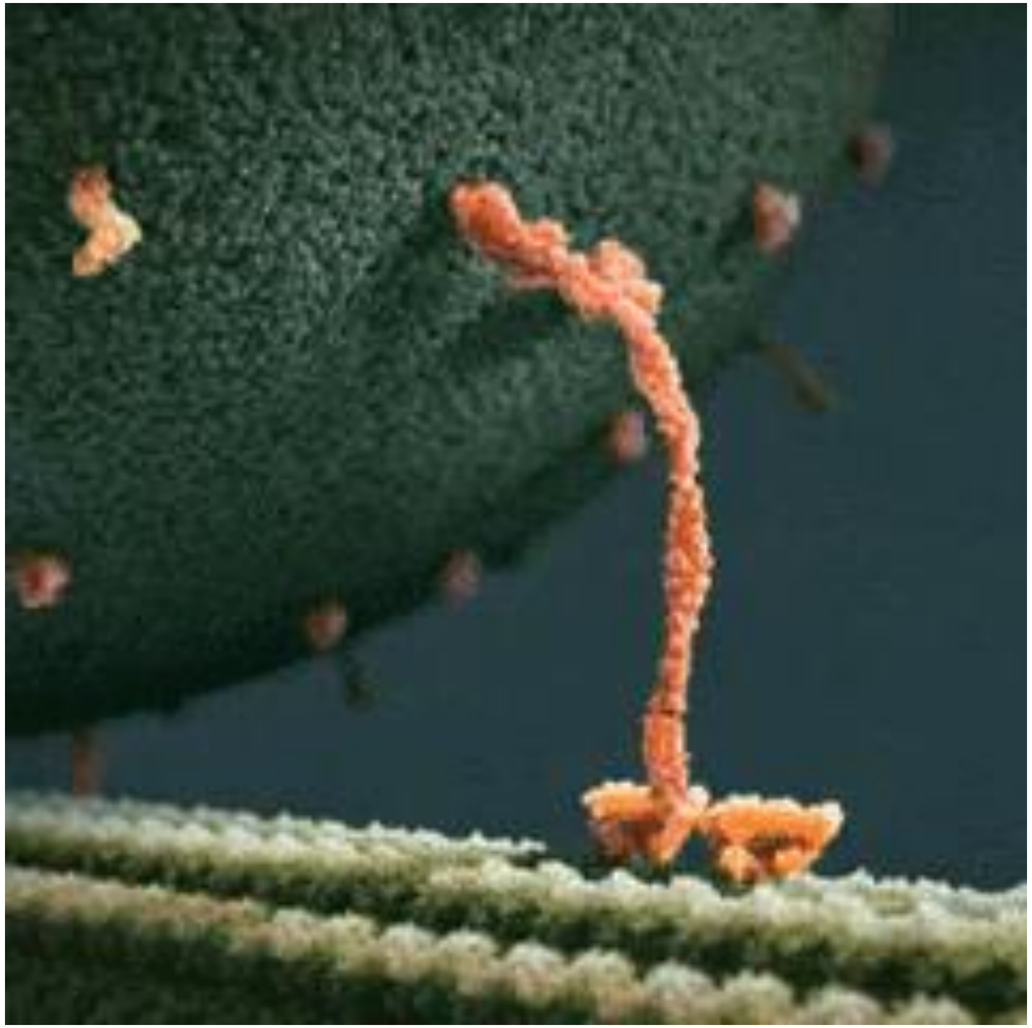


PROTEINS



Part of a lipoprotein particle. A model of the structure of apolipoprotein A-I (yellow), shown surrounding sheets of lipids. The apolipoprotein is the major protein component of high-density lipoprotein particles in the blood. These particles are effective lipid transporters because the protein component provides an interface between the hydrophobic lipid chains and the aqueous environment of the bloodstream. [Based on coordinates provided by Stephen Harvey.]

PROTEINS

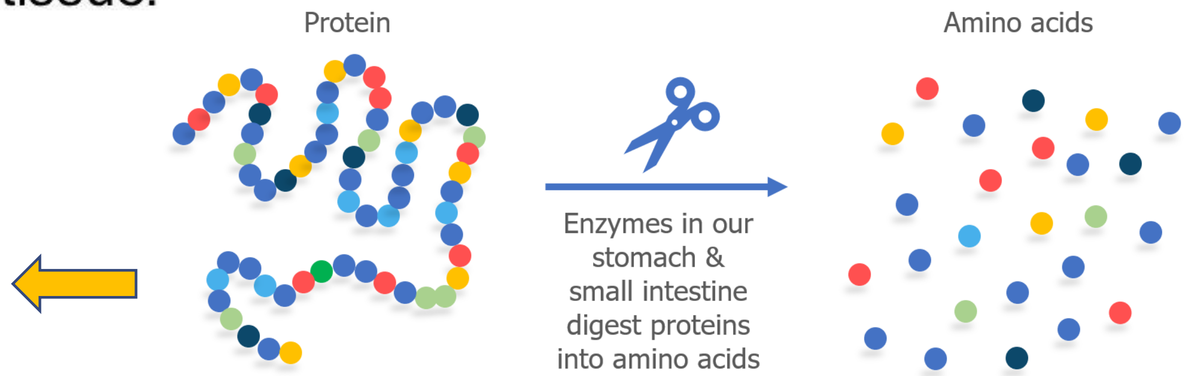


What are Proteins?

Proteins: large complex molecules composed of amino acids.

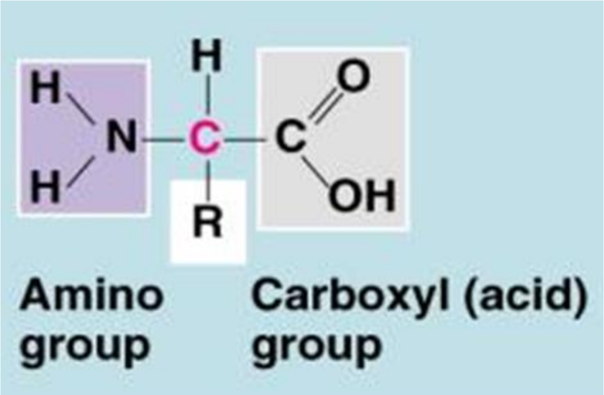
- Contain carbon, hydrogen, oxygen, nitrogen
- Primary source of nitrogen in our diets
- 20 different amino acids are used to make proteins
- Essential component of the body cells, tissues and fluids.
- Building blocks of muscle, bone, skin, hair, and virtually every other body part or tissue.

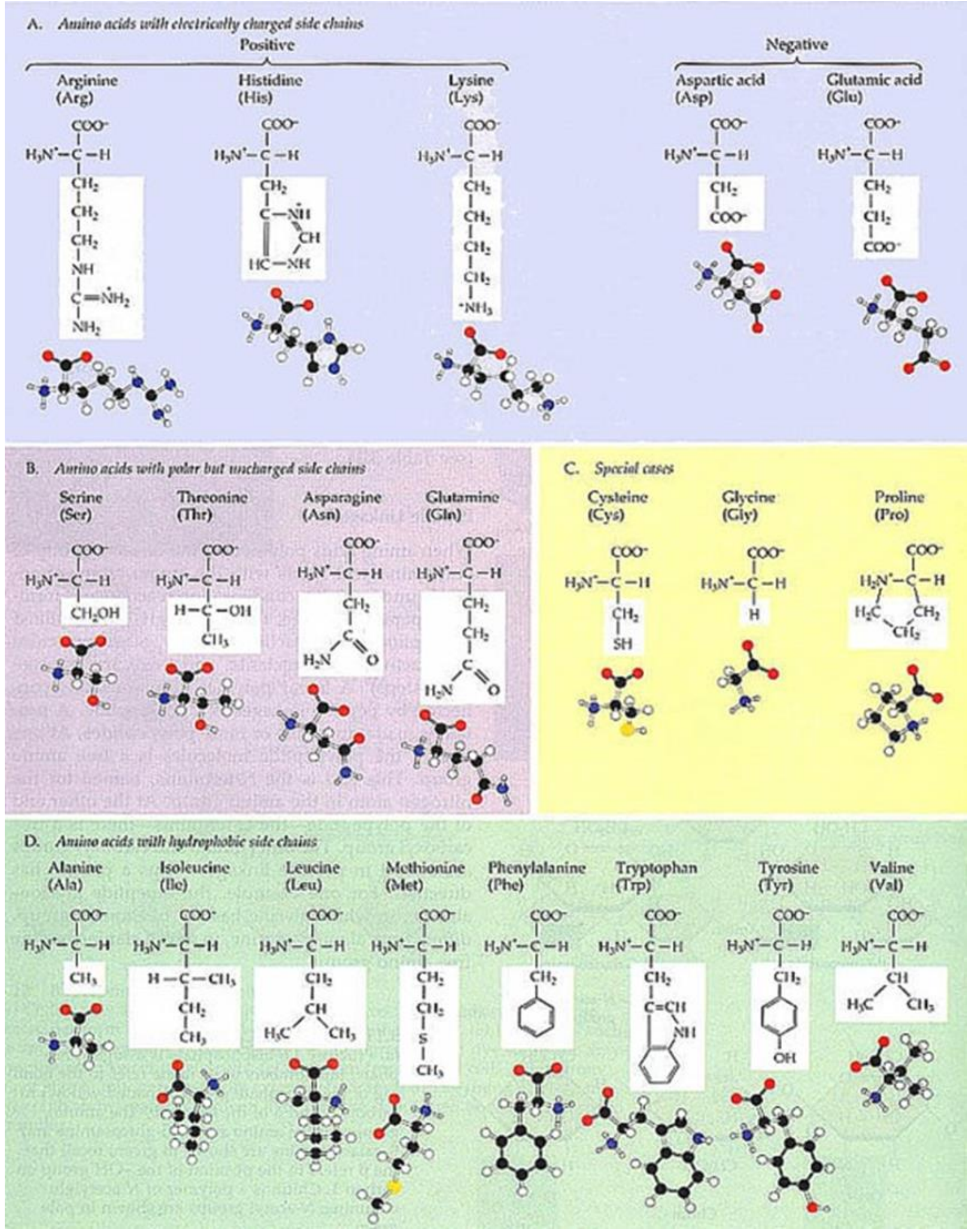
- Proteins are macromolecules composed of amino acids linked together through peptide bonds.



AMINO ACIDS

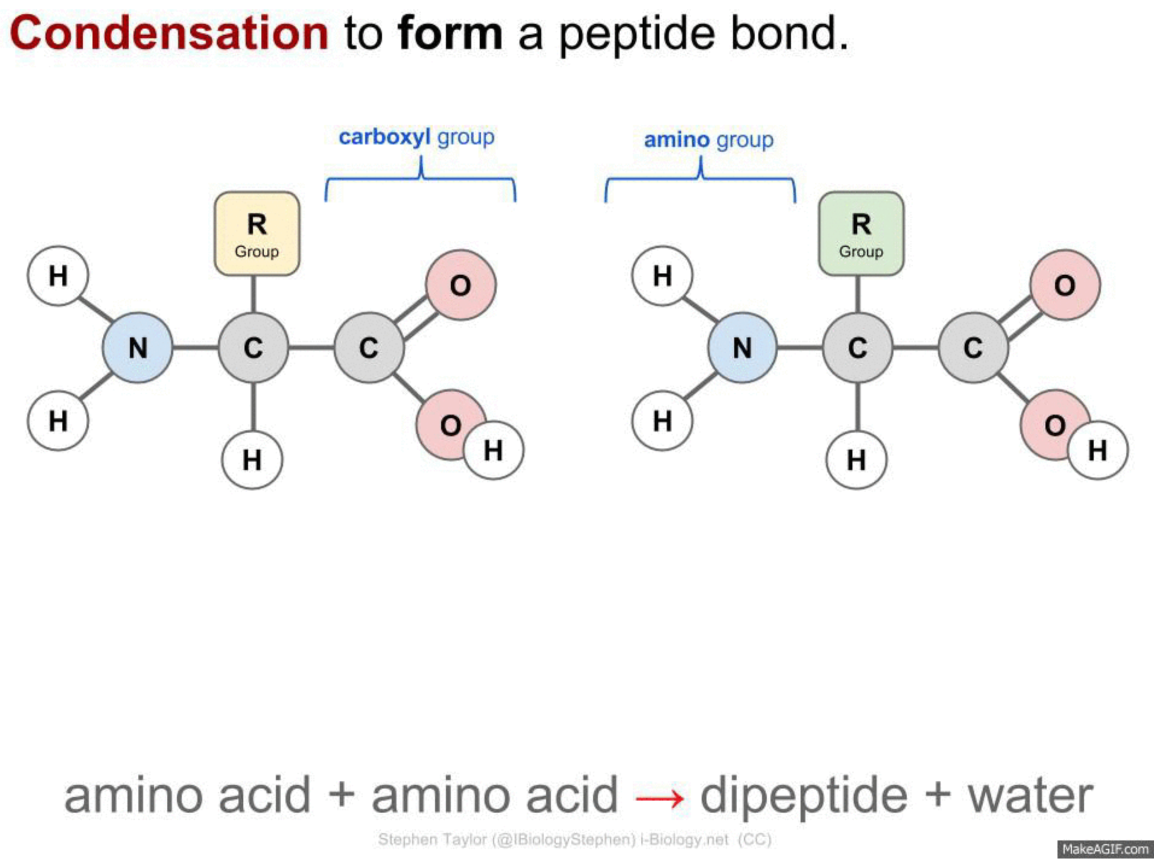
- Macromolecules formed from amino acids
- 20 naturally occurring AA's
- R= side group → determines the chemical properties





PEPTIDE BONDS

- Peptide Bond is formed by condensation of two AA's to form a peptide bond



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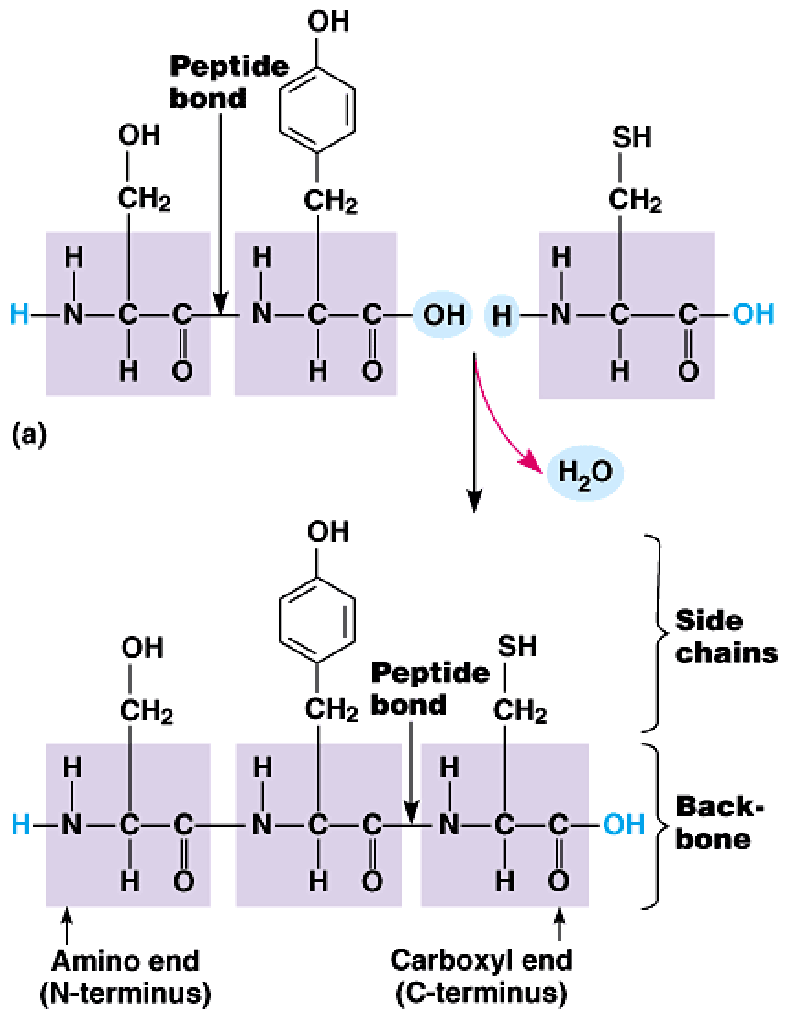
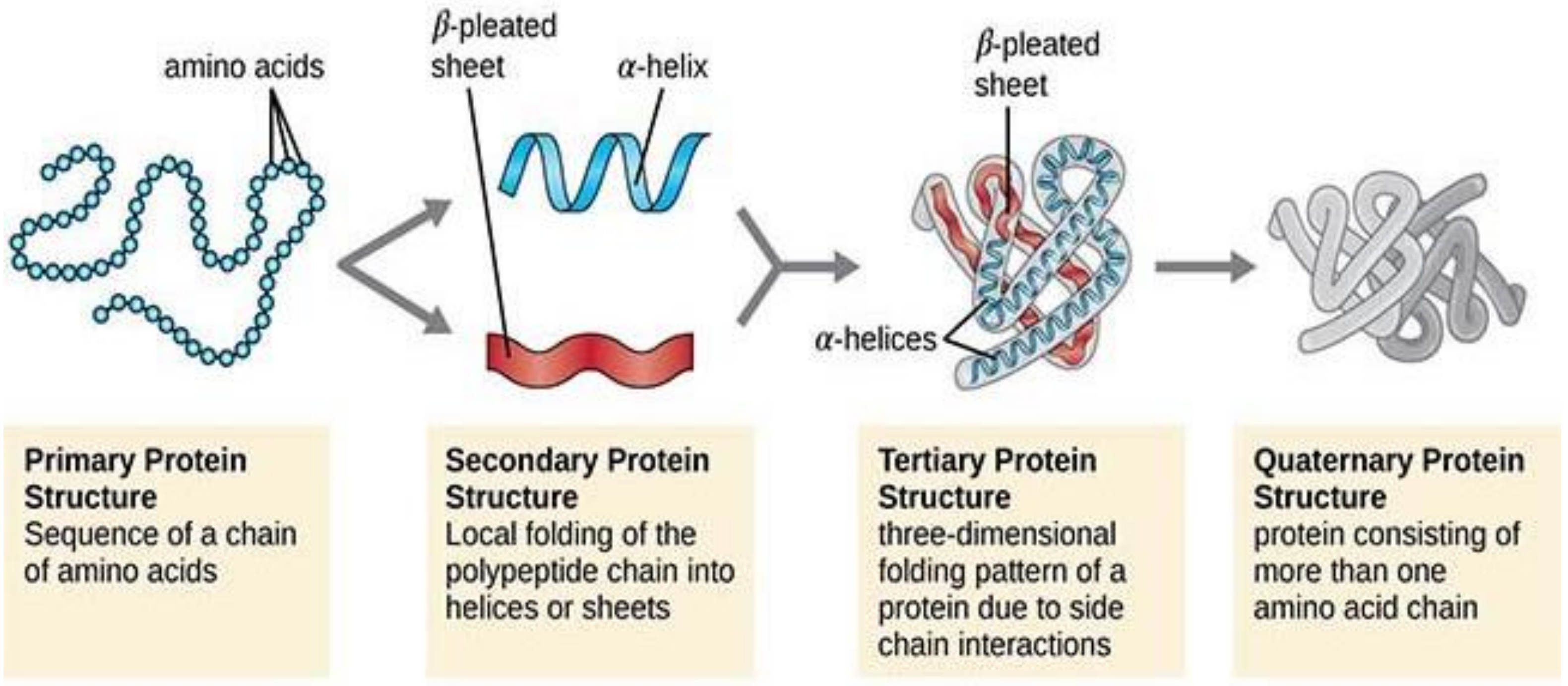
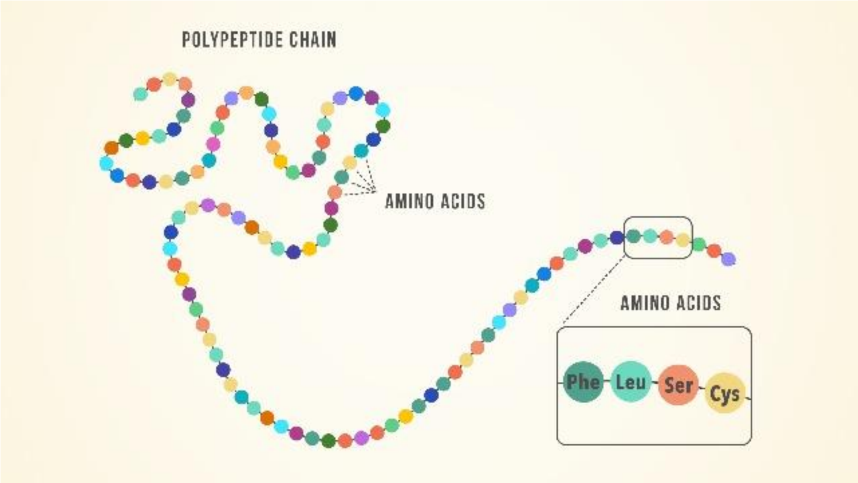


OVERVIEW- AMINO ACID TO PROTEIN



POLYPEPTIDE- PRIMARY STRUCTURE



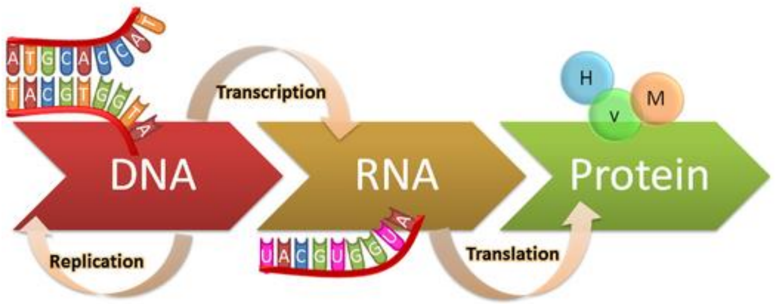
Primary Structure- Polypeptide

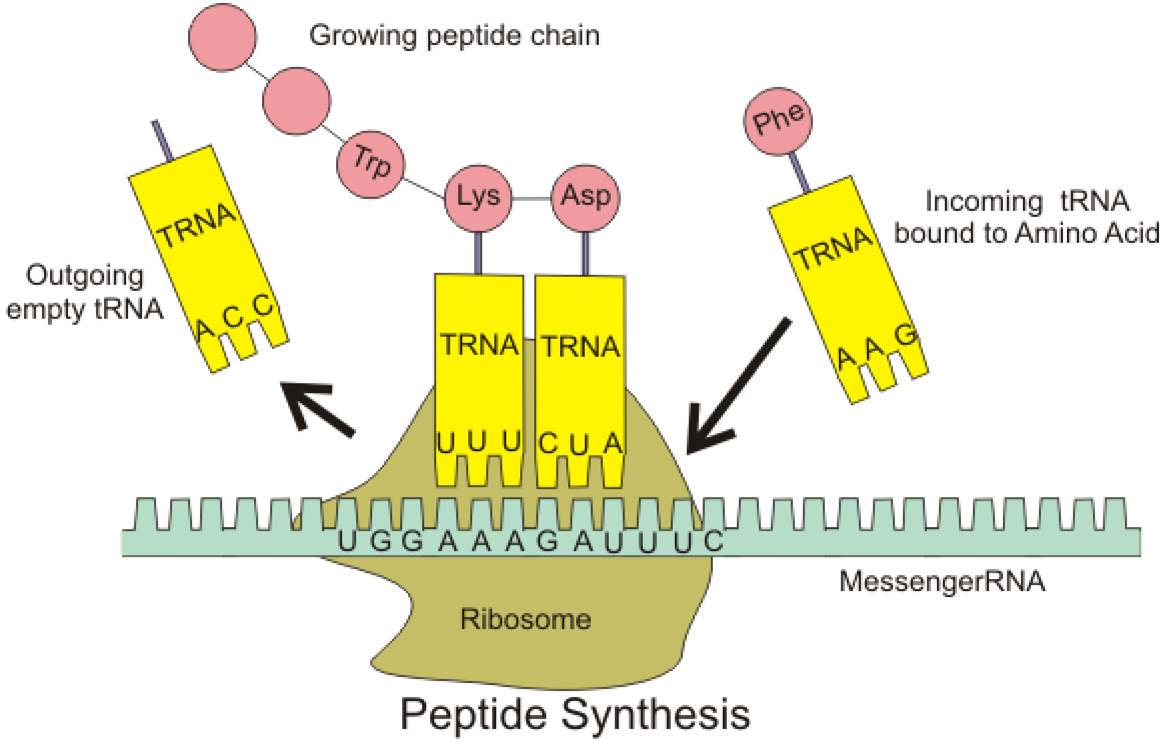
- The first AA – N-terminal
- Last AA- C-terminal
- N→C (Start → End)
- Usually ~50 AA → Polypeptide

- Average Molecular Weight (MW) of 1AA = 128 Dalton (Da)
- Peptide bond formation eliminates H20 (MW= 18Da)
- <u>So each AA addition</u> = 128-18 → 110 Da

What will be the MW of a protein formed of 50 amino acids?

POLYPEPTIDE



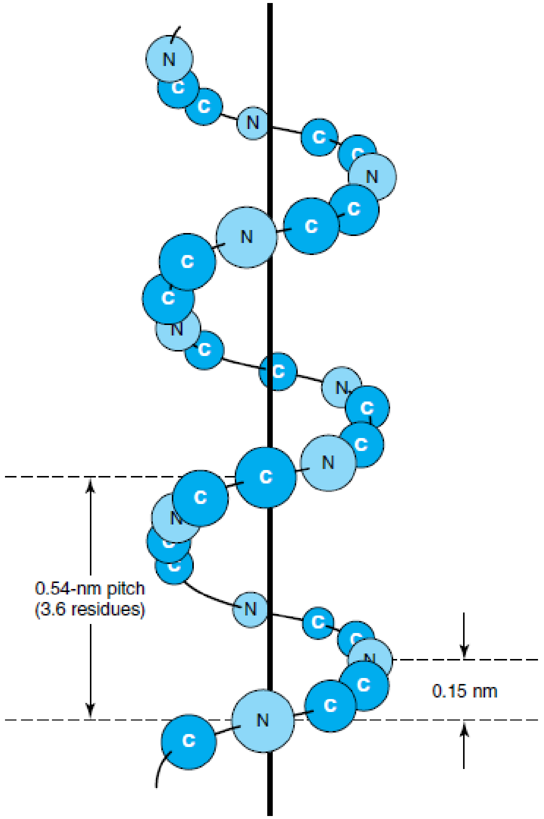


- AA sequence dictated by DNA
- Who makes polypeptides in cells?

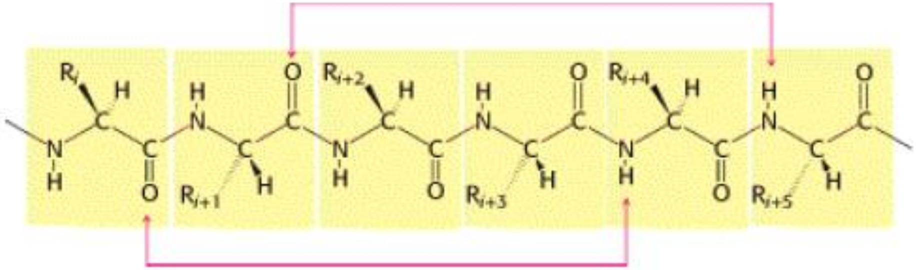
- Ribosome, a cell organelle

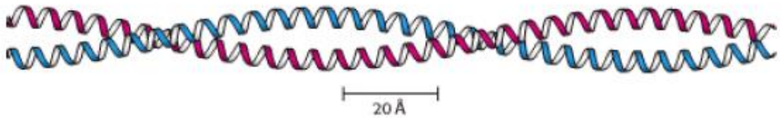
POLYPEPTIDE- SECONDARY STRUCTURE

α-Helix



n+4





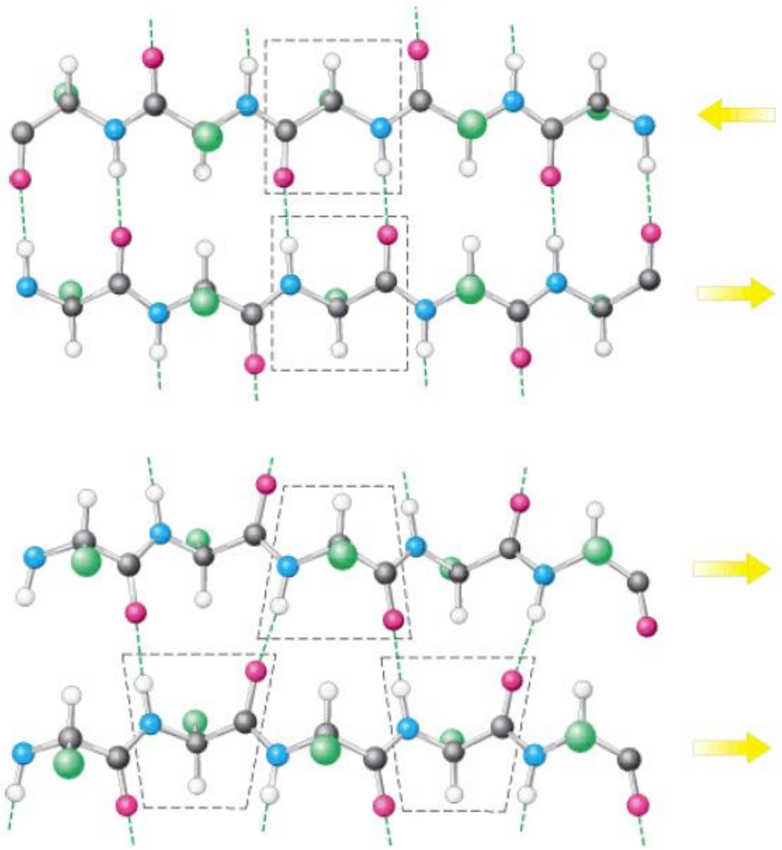
Keratin (hair/ claws)

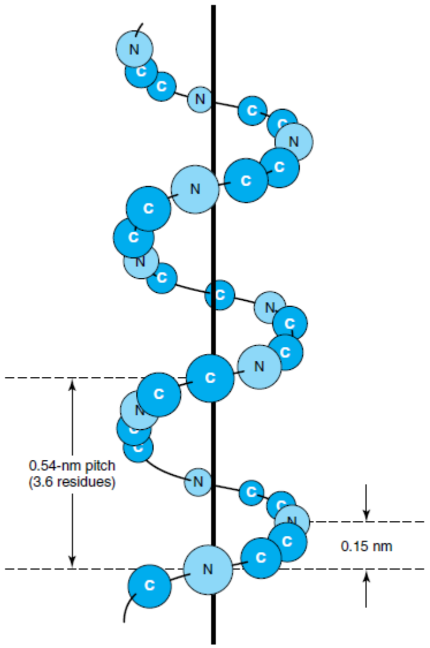
POLYPEPTIDE- SECONDARY STRUCTURE

β-sheet

Anti-Parallel

Parallel





Length/ AA-
α-helix: 0.15nm
β-sheet: 0.35nm

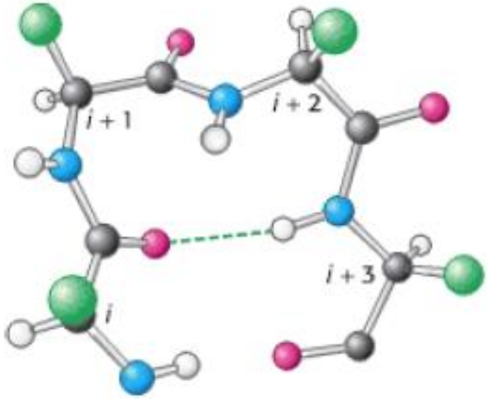
What would be the lengths of α-helix and linear secondary structures formed by a 10AA chain?

POLYPEPTIDE- SECONDARY STRUCTURES

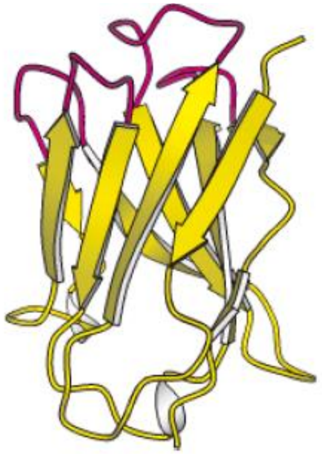
Alpha helix

Beta strand (sheet)

Anything else –
turn/loop

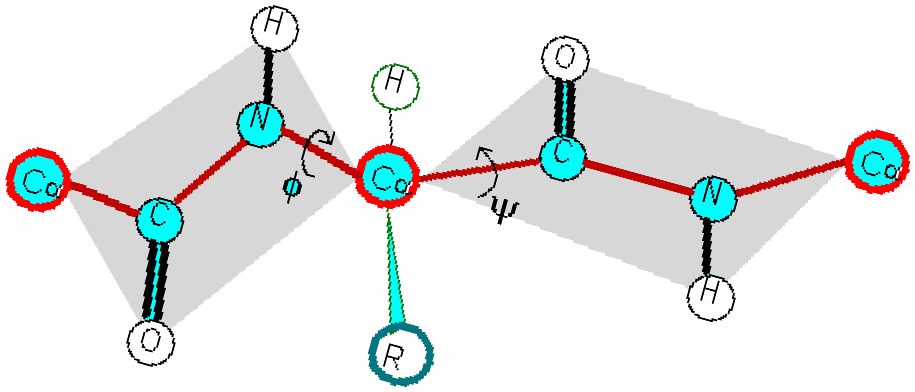


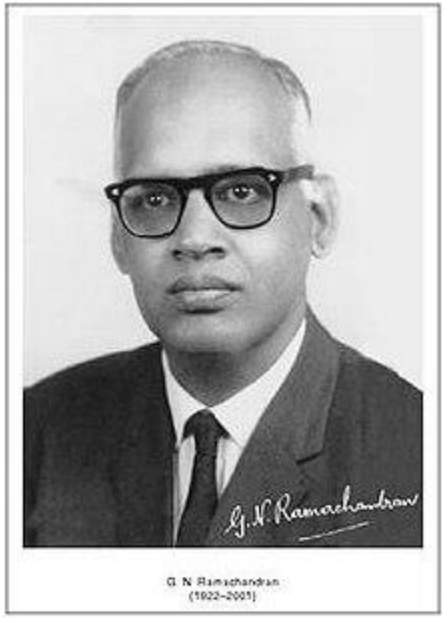
Turn

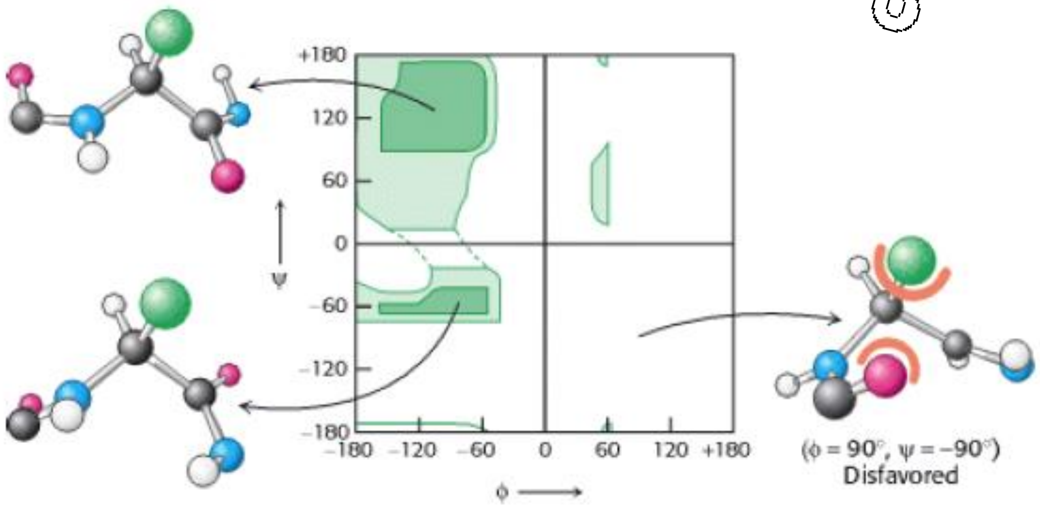


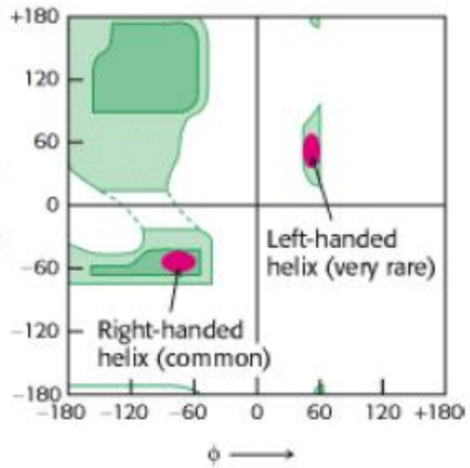
Loop

RAMACHANDRAN PLOT

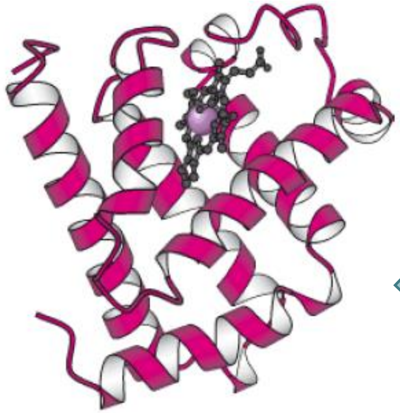






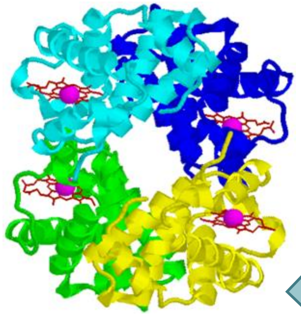


STRUCTURE LEVELS

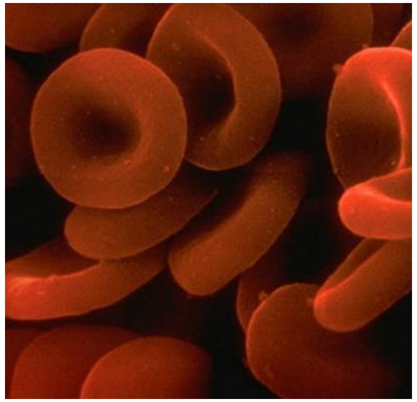


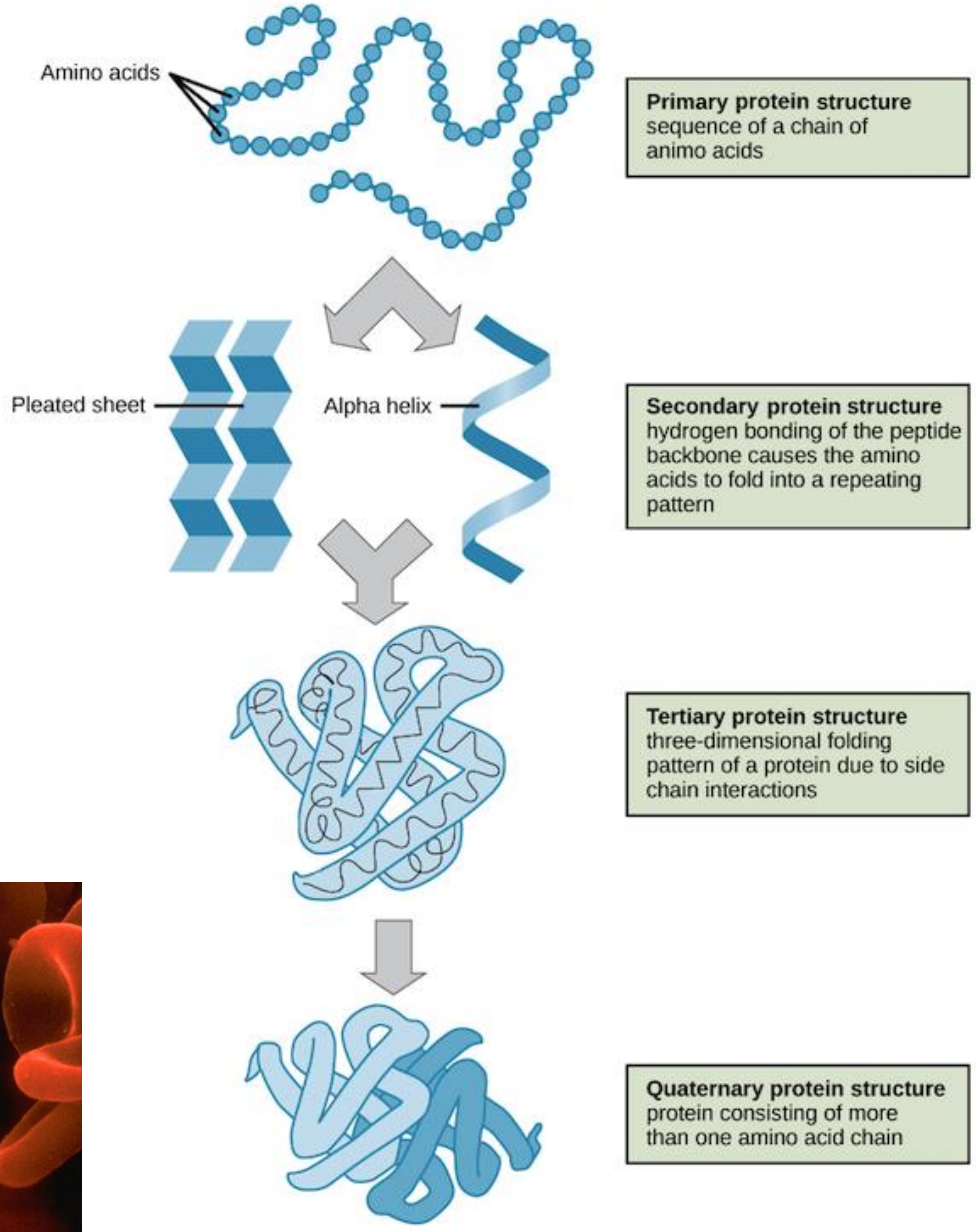
Tertiary Structure

Black- Heme
Purple- Iron

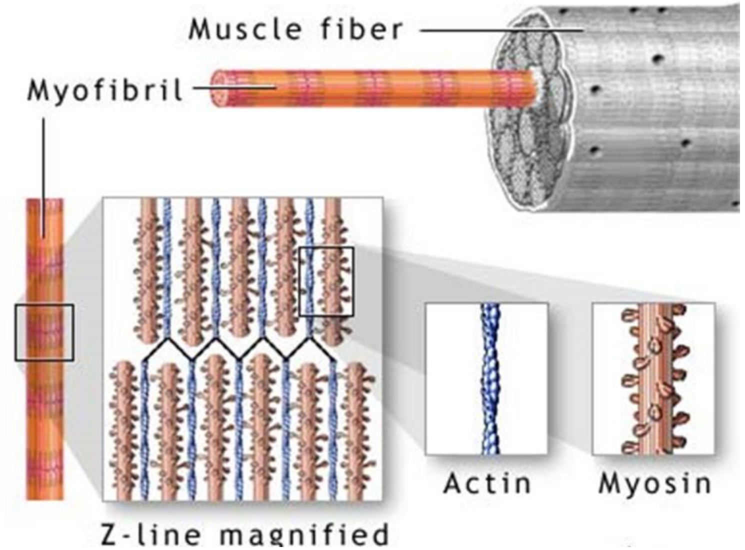


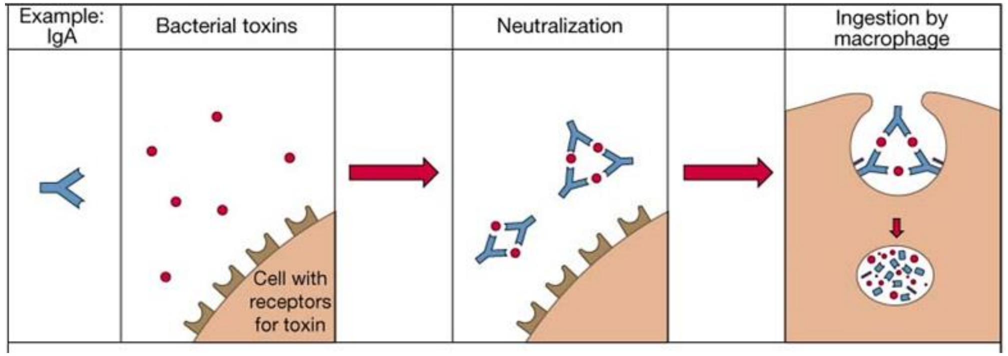
Quaternary Structure

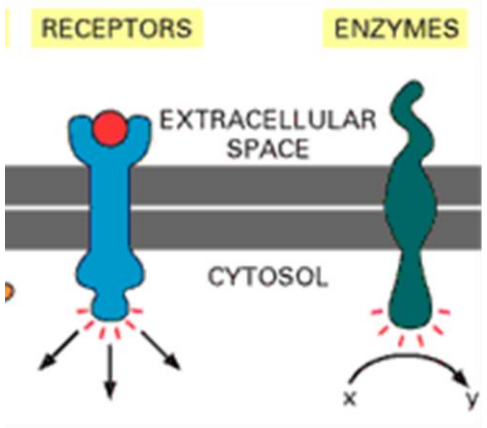




REAL LIFE

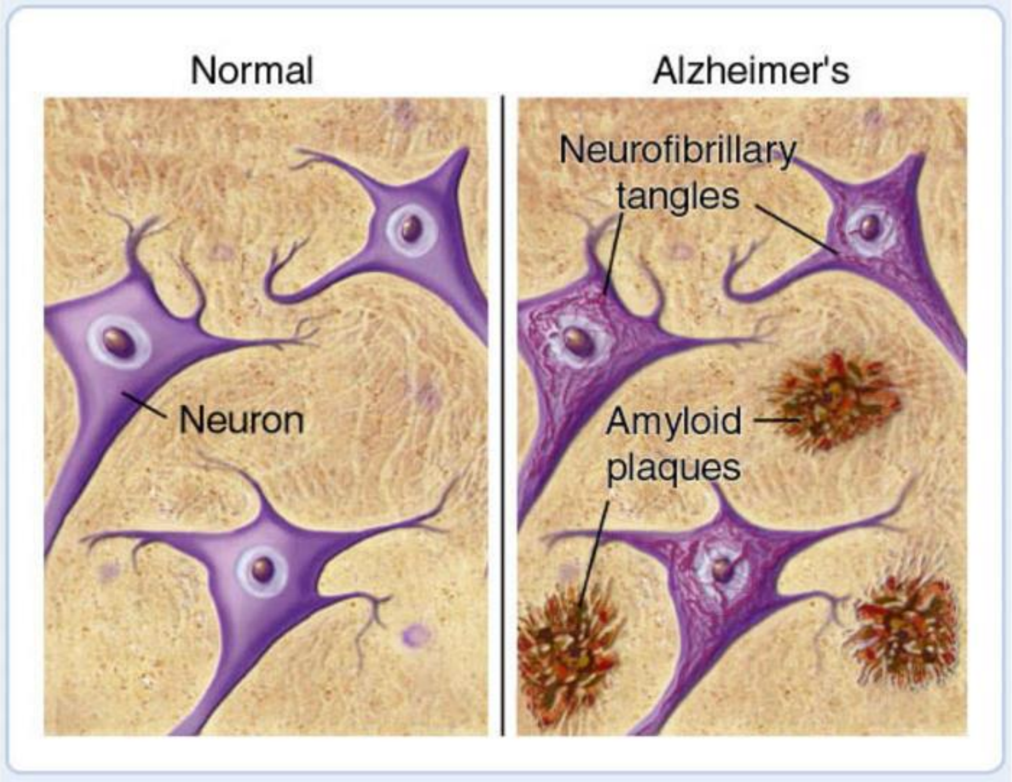

Muscle fiber
Myofibril
Actin
Myosin
Z-line magnified


Example: IgA
Bacterial toxins
Neutralization
Ingestion by macrophage
Cell with receptors for toxin

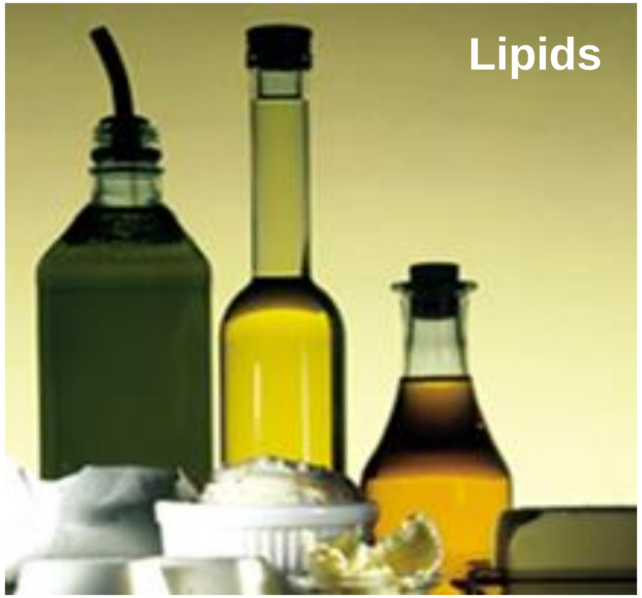

RECEPTORS
ENZYMES
EXTRACELLULAR SPACE
CYTOSOL
x
y

REAL LIFE

In Alzheimer's disease patients, levels of β-amyloid become elevated, and this protein undergoes a conformational transformation from a soluble α-helix–rich state to a state rich in β–sheet and prone to self-aggregation.

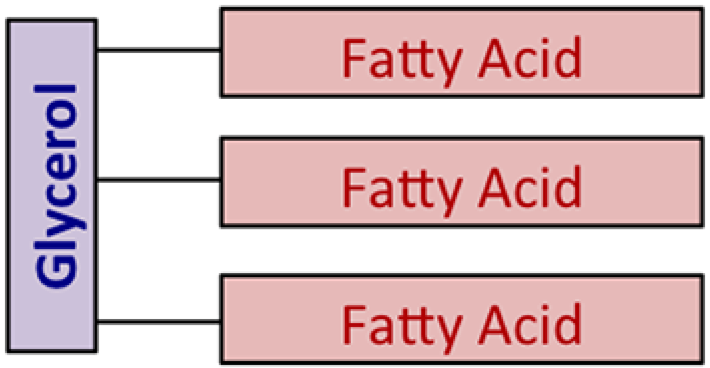


LIPIDS

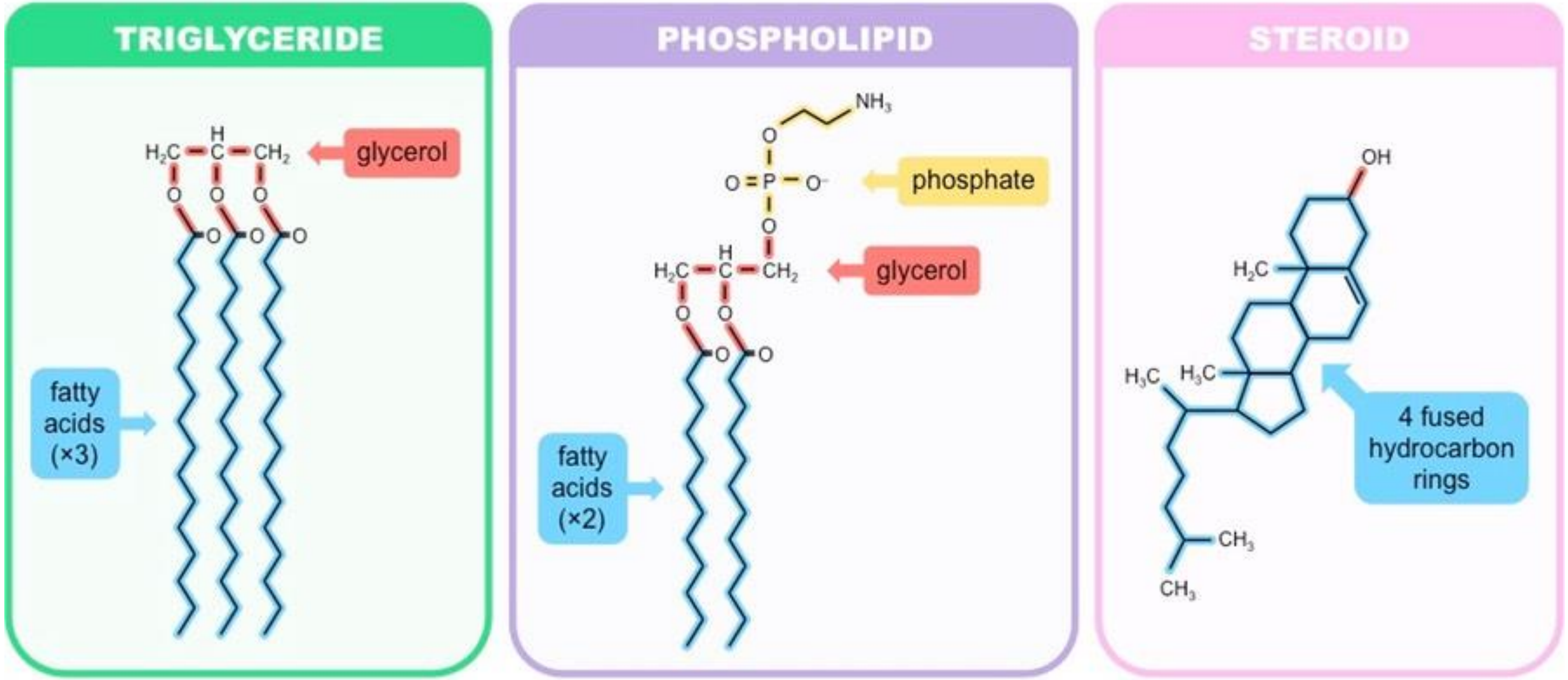


- Metabolic fuel- storage & transport
- Structural components of membranes
- Outer coating in animals
- Pigments – carotene (carrots)
- Cofactors- Vitamin K
- Hormones- Vitamin D derivatives
- Thromboxanes- blood clotting
- Prostaglandins- short range messengers

LIPIDS



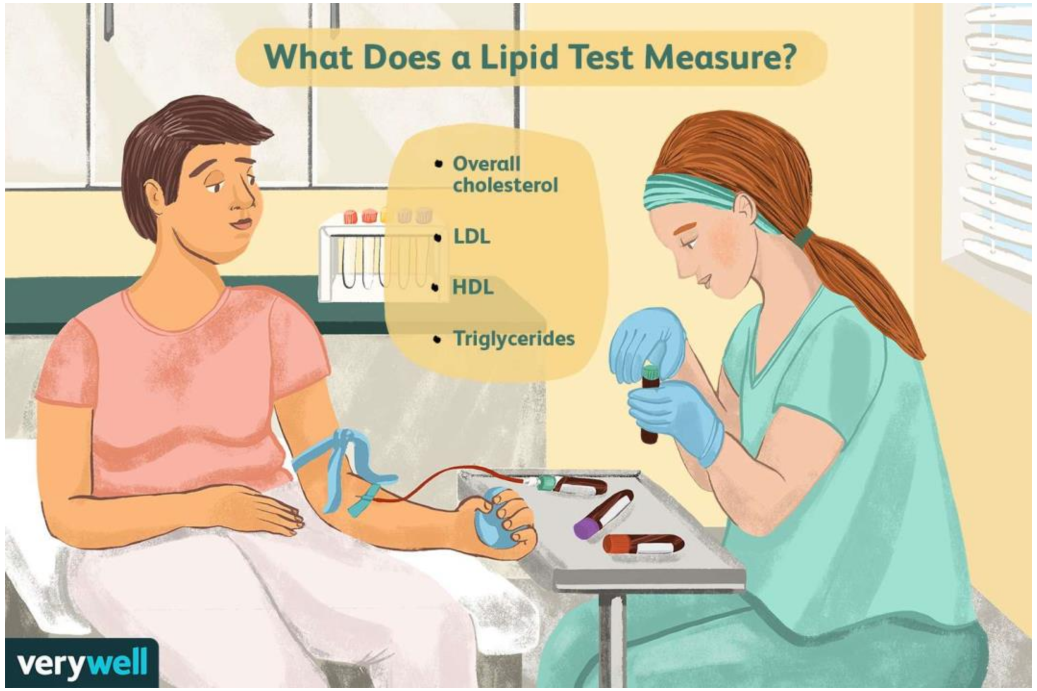
Glycerol
Fatty Acid
Fatty Acid
Fatty Acid



TRIGLYCERIDE
glycerol
fatty acids (×3)
PHOSPHOLIPID
phosphate
glycerol
fatty acids (×2)
STEROID
4 fused hydrocarbon rings

LIPIDS

- The lipids are a heterogeneous group of compounds, including fats, oils, steroids, waxes, and related compounds, that are related more by their physical than by their chemical properties.
- They have the common property of being
- (1) relatively **insoluble in water** and
- (2) **soluble in nonpolar solvents** such as ether and chloroform.

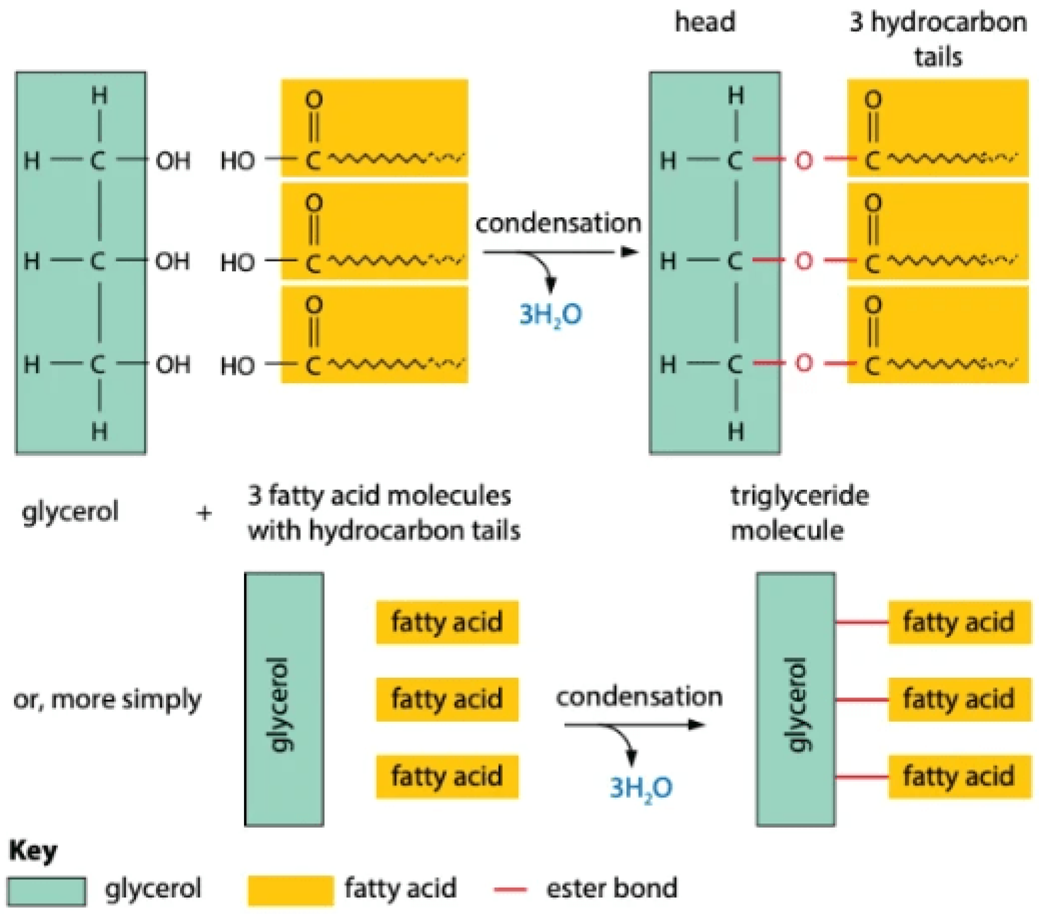


- Have elements C, H and O, but O is very less as compared to Carbohydrates

LIPID CLASSIFICATION

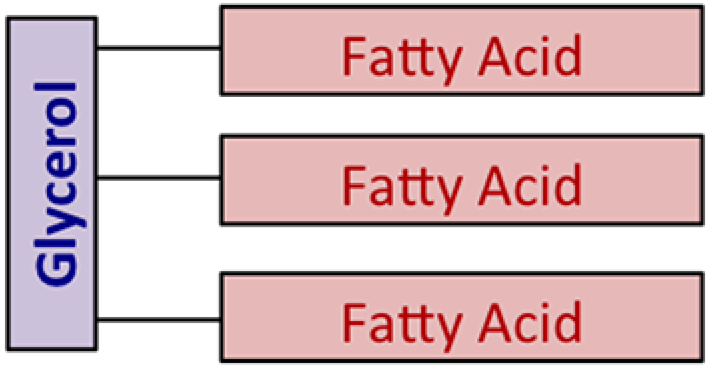
- Saponifiable lipids contain an ester that can undergo basic hydrolysis.
  - **Triglycerides**, **waxes**, **phospholipids**, and **sphingolipids**
    - **Simple lipids** contain a fatty acid and alcohol.
      - **Triglycerides** and **waxes**
    - **Complex lipids** contain a fatty acid, alcohol, and other components.
      - **Phospholipids** and **sphingolipids**
- Nonsponifiable lipids do not contain an ester and cannot be hydrolyzed.
  - **Steroids** and **prostaglandins**

TRIGLYCERIDE FORMATION

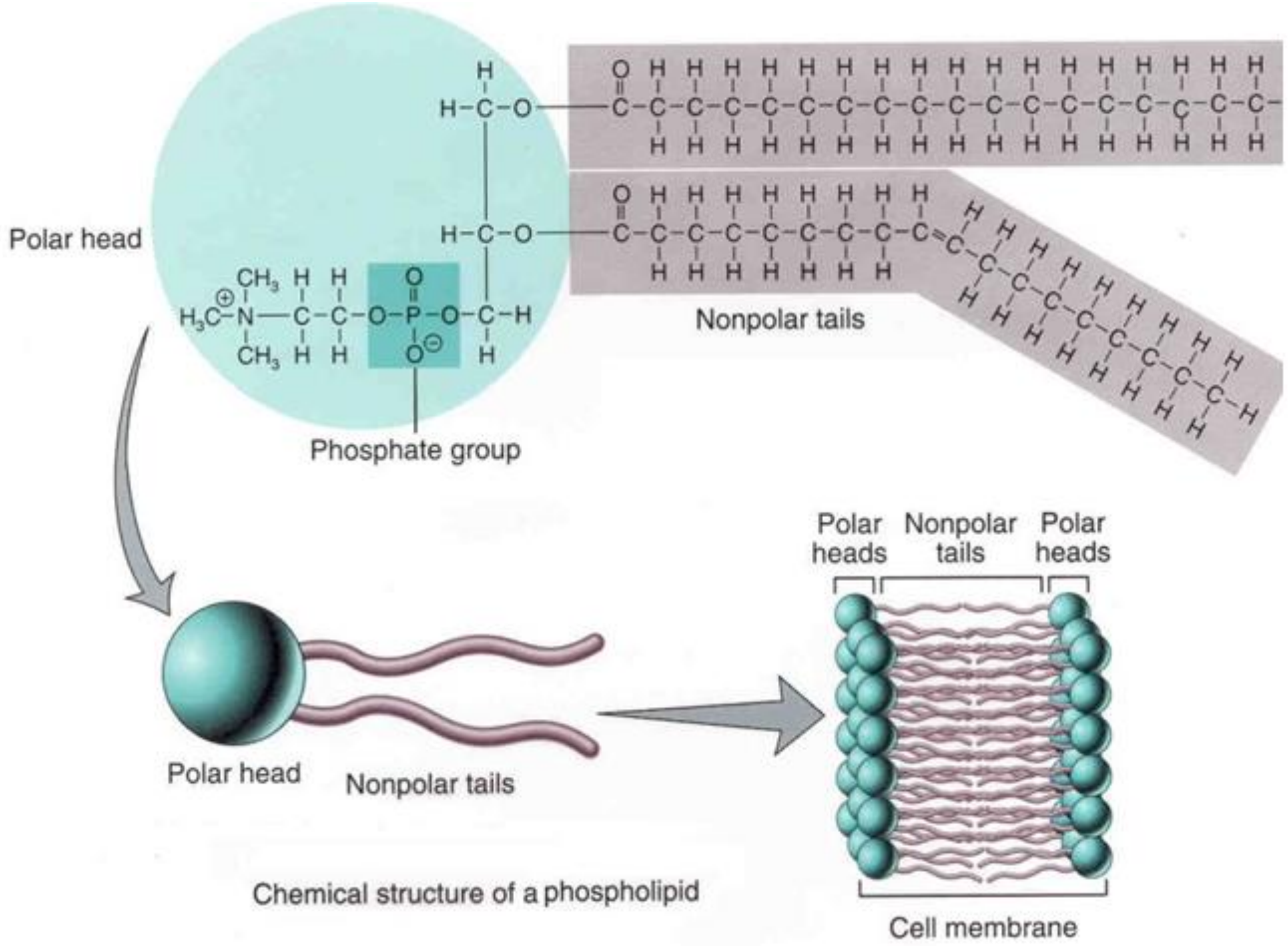


1 Glycerol and 3 fatty acid molecules react to form a Triglyceride

LIPIDS



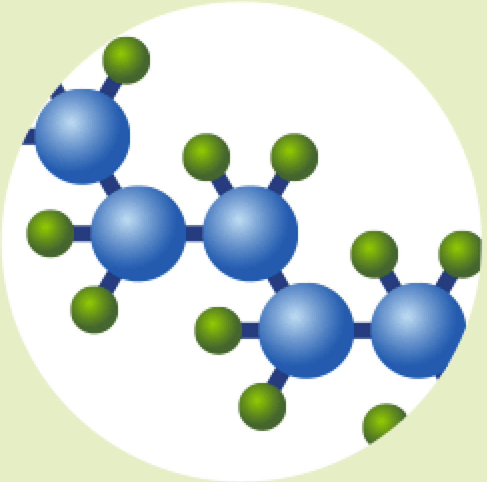
Glycerol
Fatty Acid
Fatty Acid
Fatty Acid



Polar head
Nonpolar tails
Phosphate group
Polar head
Nonpolar tails
Polar heads
Nonpolar tails
Polar heads
Chemical structure of a phospholipid
Cell membrane

LIPIDS

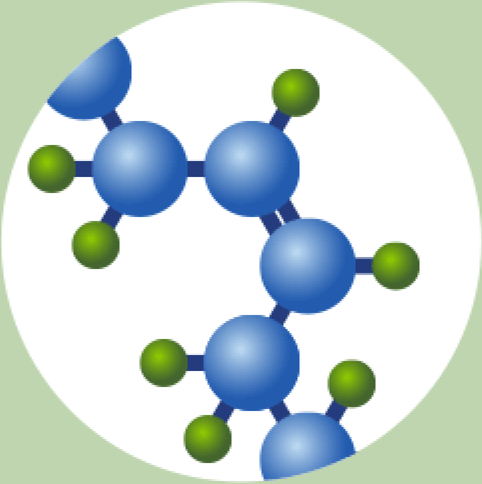
SATURATED FATS



SINGLE BONDS BETWEEN CARBONS

MAINLY SOLID AT ROOM TEMPERATURE

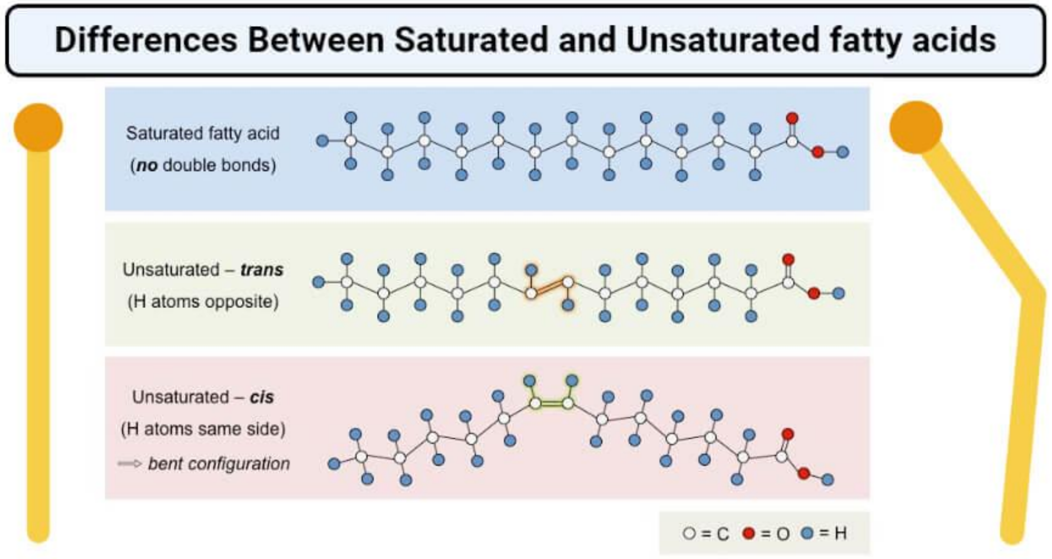
UNSATURATED FATS



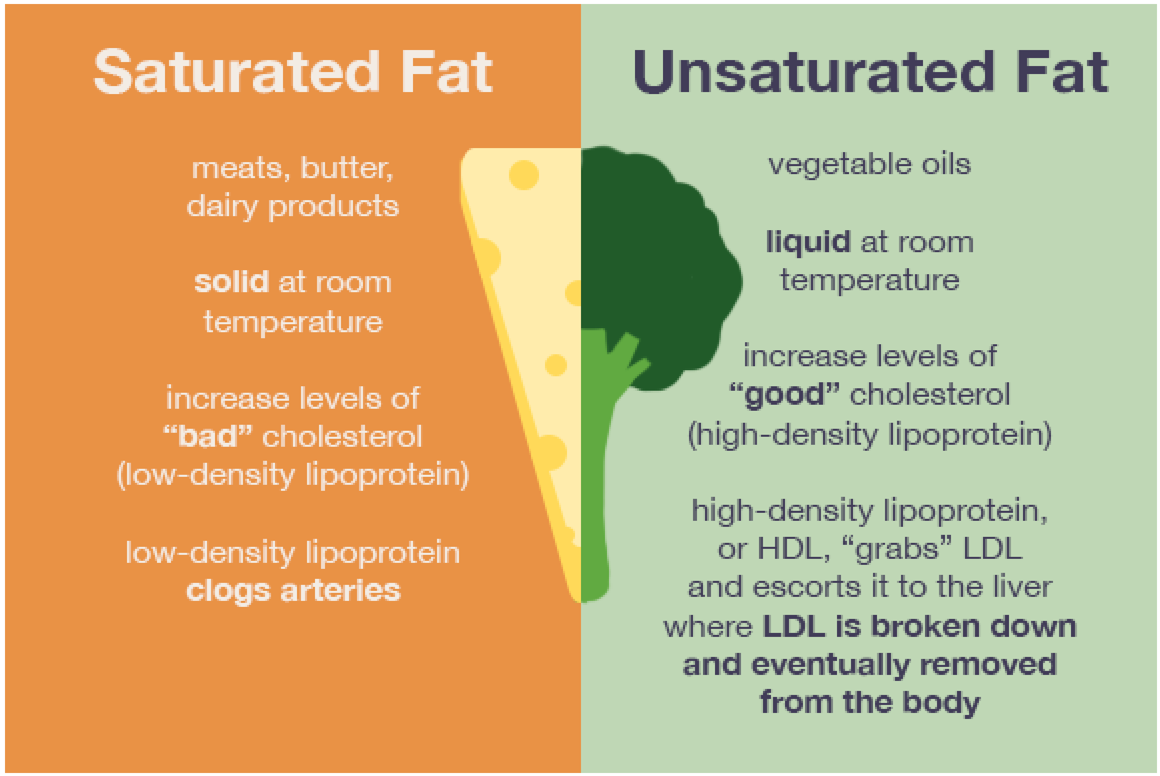
ONE OR MORE DOUBLE BONDS BETWEEN CARBONS

MAINLY LIQUID AT ROOM TEMPERATURE

LIPIDS

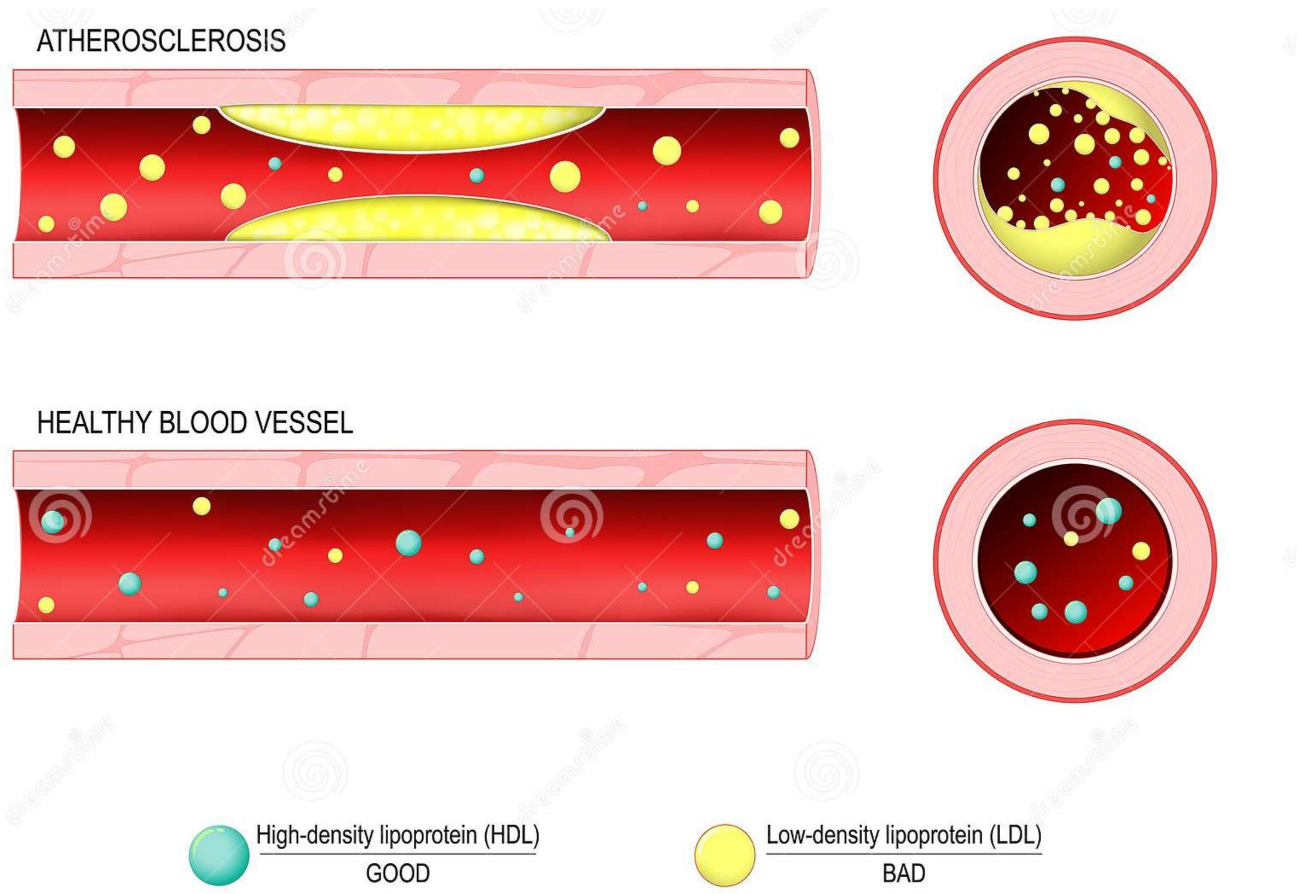


Differences Between Saturated and Unsaturated fatty acids
Saturated fatty acid
(*no* double bonds)
Unsaturated – *trans*
(H atoms opposite)
Unsaturated – *cis*
(H atoms same side)
bent configuration
= C = O = H

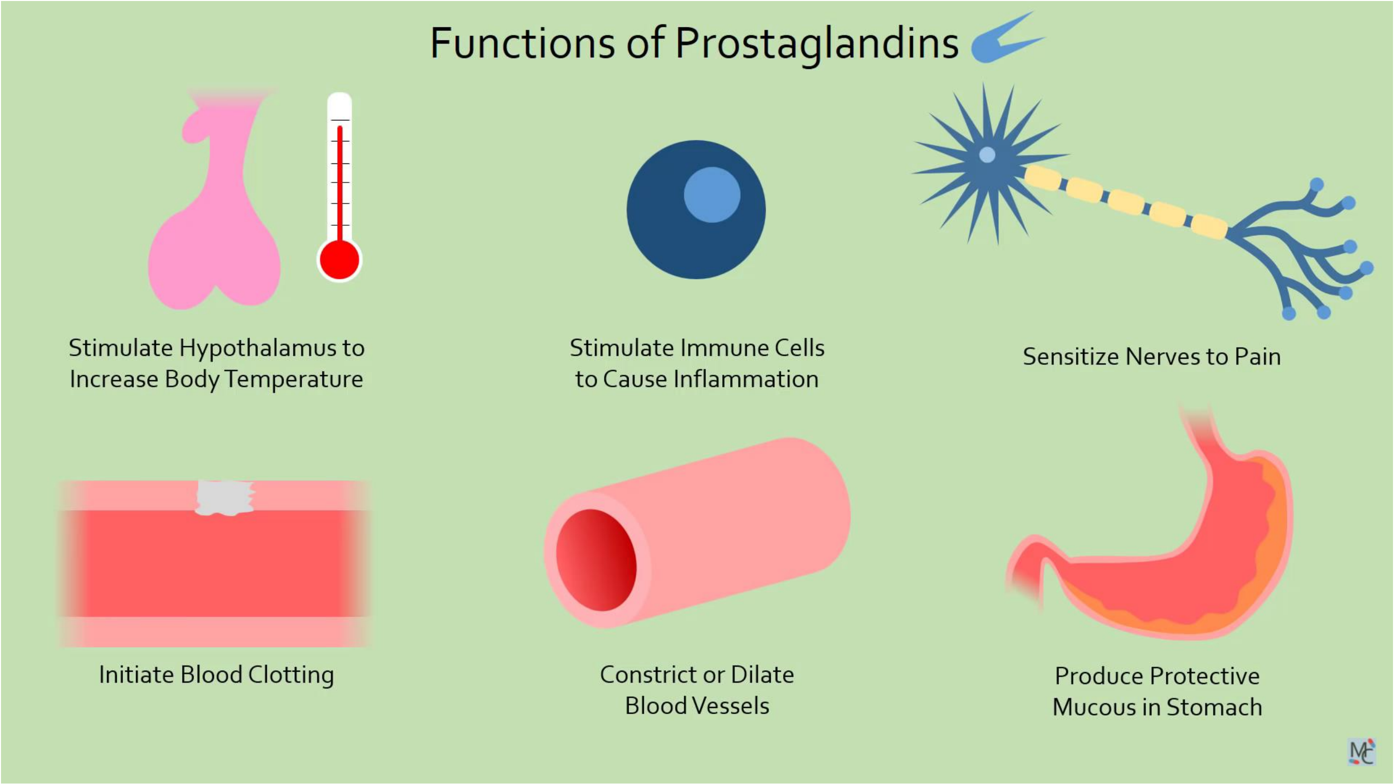


Saturated Fat
meats, butter, dairy products
solid at room temperature
increase levels of **"bad"** cholesterol (low-density lipoprotein)
low-density lipoprotein **clogs arteries**
Unsaturated Fat
vegetable oils
liquid at room temperature
increase levels of **"good"** cholesterol (high-density lipoprotein)
high-density lipoprotein, or HDL, "grabs" LDL and escorts it to the liver where **LDL is broken down and eventually removed from the body**

GOOD VS BAD CHOLESTEROL

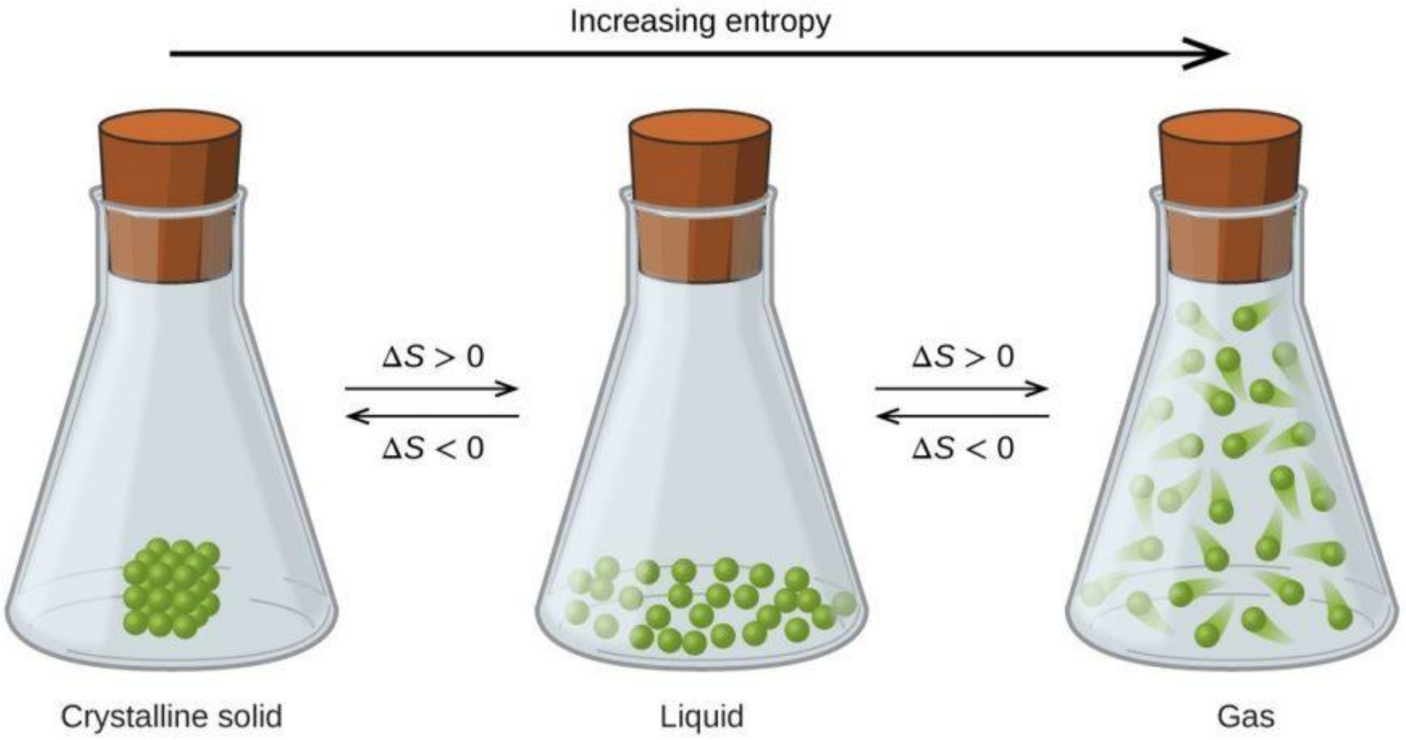


PROSTAGLANDINS



Aspirin → Pain reliever (analgesic)
→ Reduces fever (antipyretic)

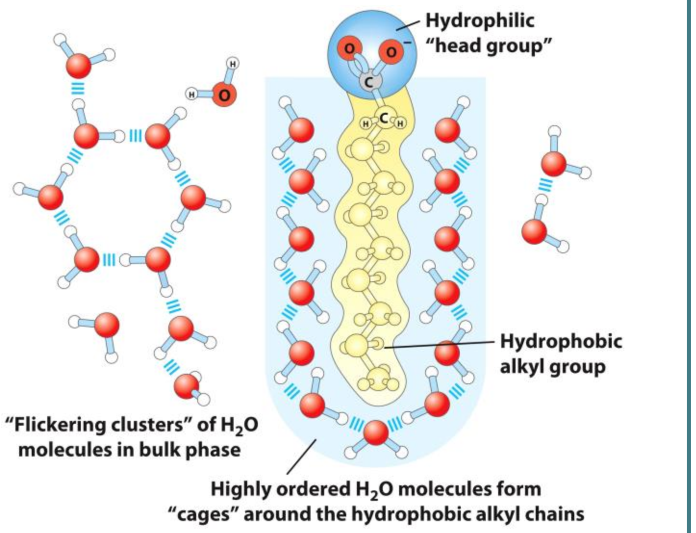
ENTROPY

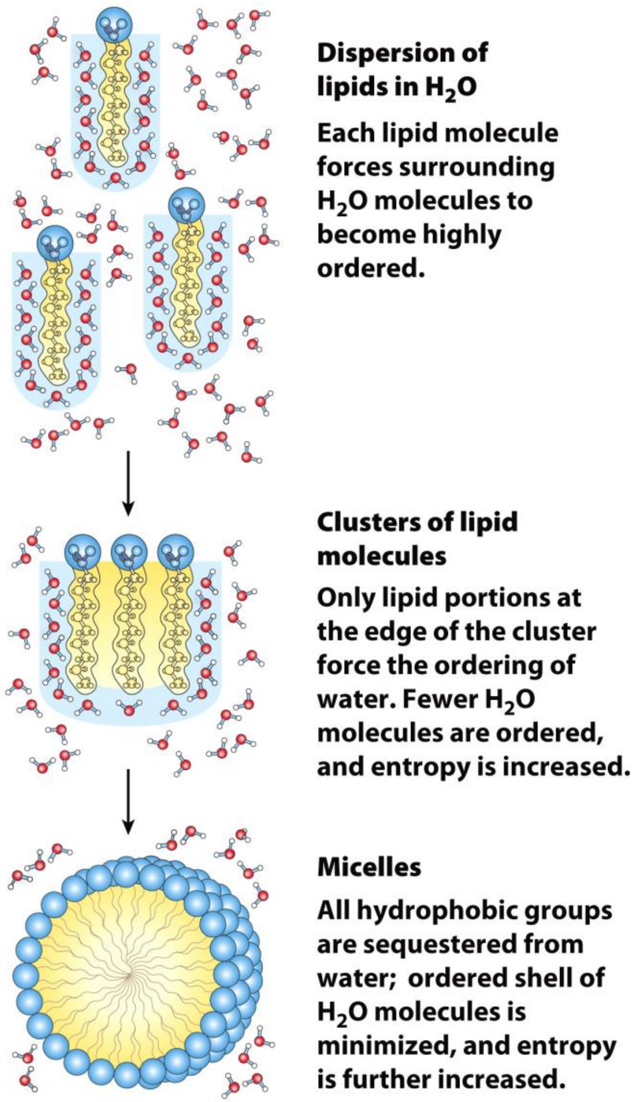


Increasing entropy
ΔS > 0
ΔS < 0
ΔS > 0
ΔS < 0
Crystalline solid
Liquid
Gas

HYDROPHOBIC EFFECT

Suspension of a hydrophobic substance in water is <u>thermodynamically unfavorable</u> due to the decreased entropy of water molecules in the cage-like shell.





- The hydrophobic effect, and the term hydrophobic interactions, refers to the entropy-driven aggregation of nonpolar molecules in aqueous solution that occurs to minimize the ordering of water molecules with which they are in contact. This is not an attractive force, but rather a thermodynamically driven process.
- The hydrophobic effect drives the formation of membranes and contributes to the folding of proteins and the formation of double helical DNA.

Questions?