# BO101 LECTURE 4

- **Biomolecules**

# The FOUR Classes of Large Biomolecules

All living things are made up of four classes of large biological molecules:

1. **Lipids**
2. **Protein**
3. **Carbohydrates**
4. Nucleic Acids (DNA & RNA) next class

**Large Biomolecules are called Macromolecules**

Made of are large number of molecules composed of thousands of *covalently* bonded atoms

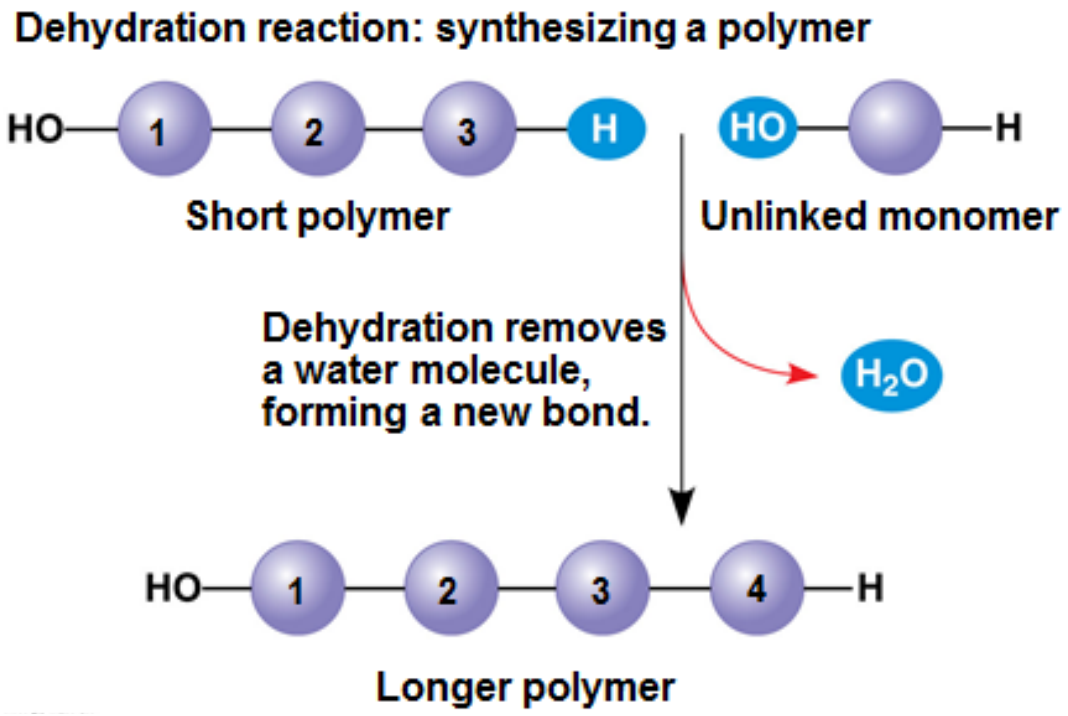
# Biological macromolecules

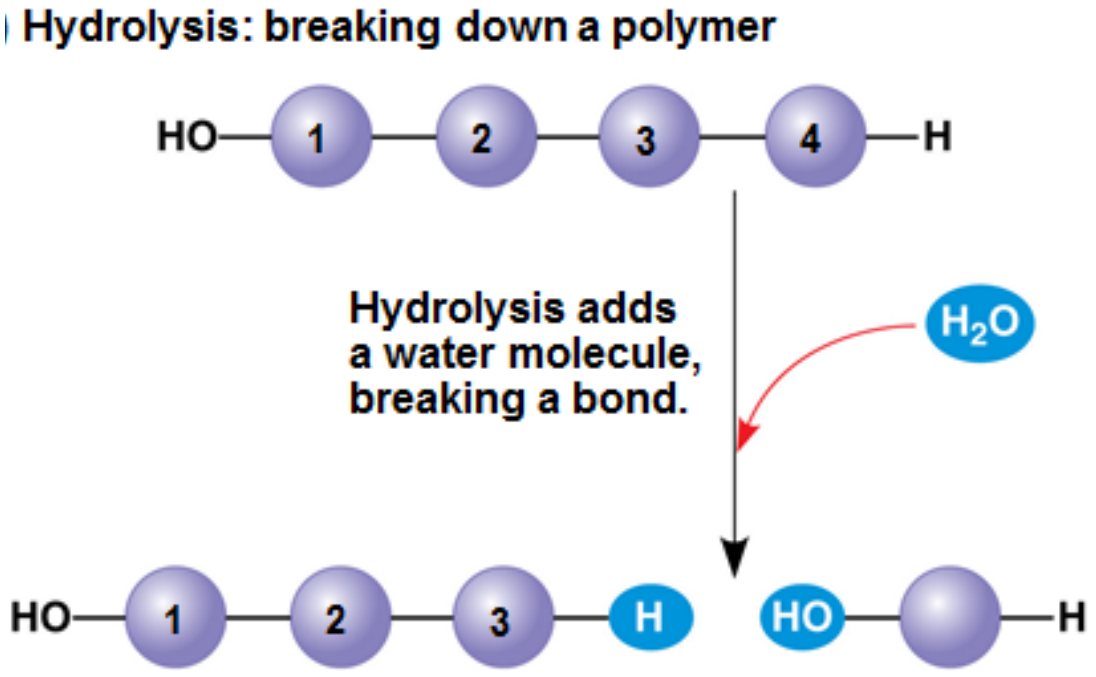
- Biological macromolecules are consisting of many similar building blocks
- Biomolecules that are NOT polymers: lipids
- Biomolecules that are **polymers**
    1. Carbohydrates
    2. Proteins
    3. Nucleic acids

- These small building-block molecules are called **monomers**

# The synthesis and breakdown of polymers

- **Dehydration reaction joins** two monomers together through the loss of a water molecule




- **Hydrolysis reaction** disassembles polymers to monomers by a reaction that is reverse of the dehydration reaction

# Lipids

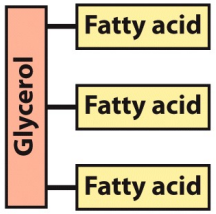
- **Lipids** are the one class of large biological molecules that <u>do not form polymers</u>
- Lipids Are **Hydrophobic** (no affinity for water) because they consist mostly of **hydrocarbons**

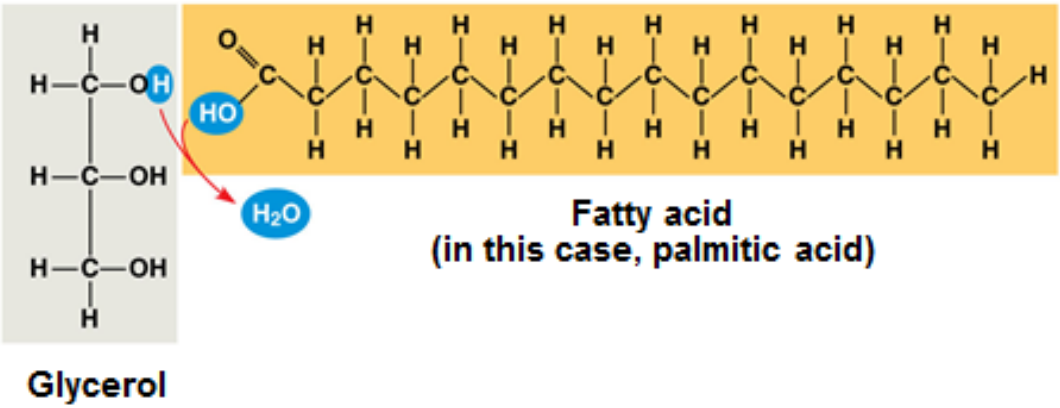
- Biologically important lipids are classified into:

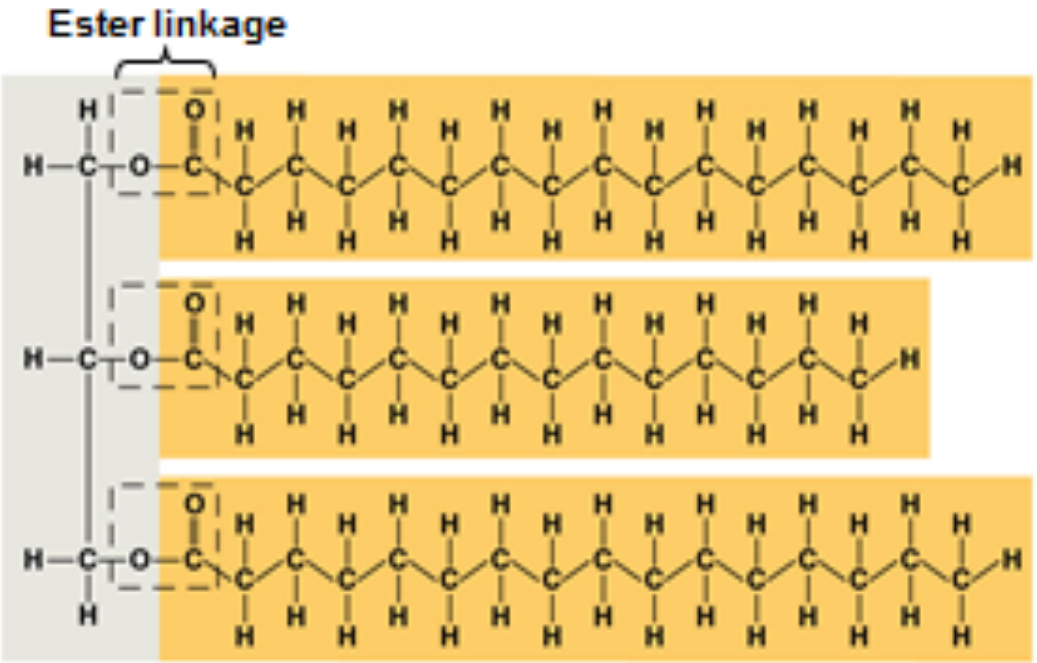
1. storage lipids: fat
2. structural lipids: phospholipid
3. sterols

# Storage lipids

- **Fats** are made from two types of molecules: **glycerol** & **fatty acids**
- Glycerol has 3 hydroxyl groups
- **Fatty acid** consists of a carboxyl group attached to <u>long carbon chain</u>
- **3** fatty acids through a dehydration synthesis reaction joins the hydroxyl group of the glycerol via **ester linkage**
- AKA **triacylglycerol** or **triglyceride**

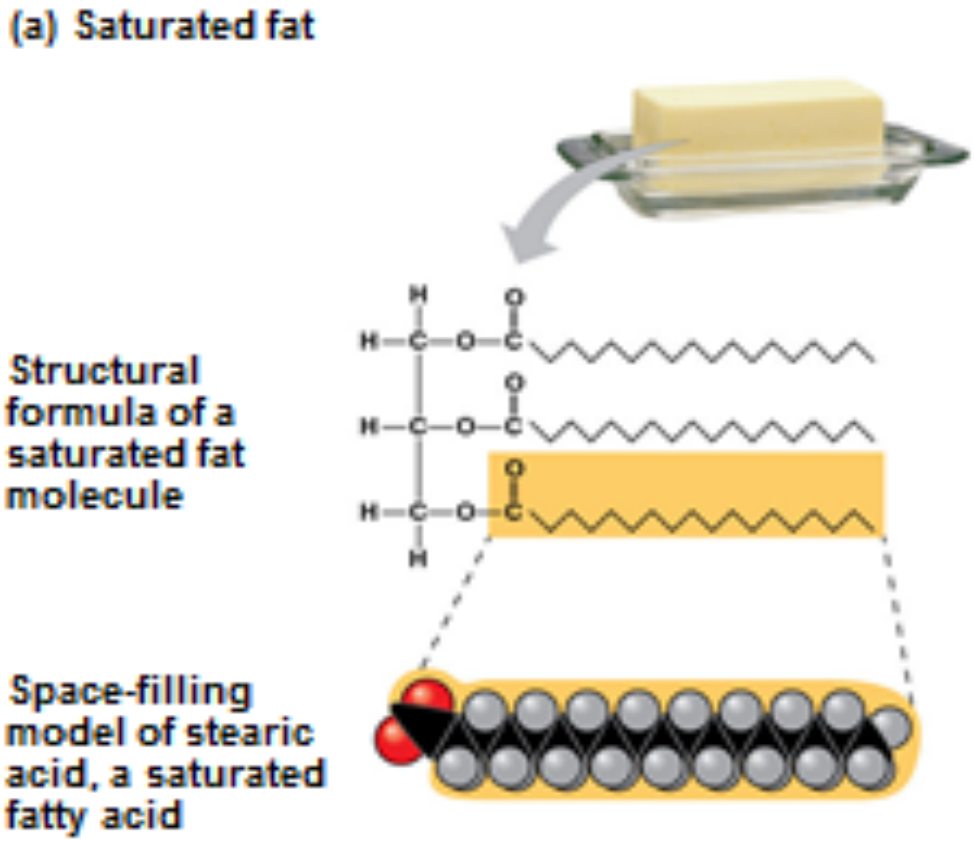


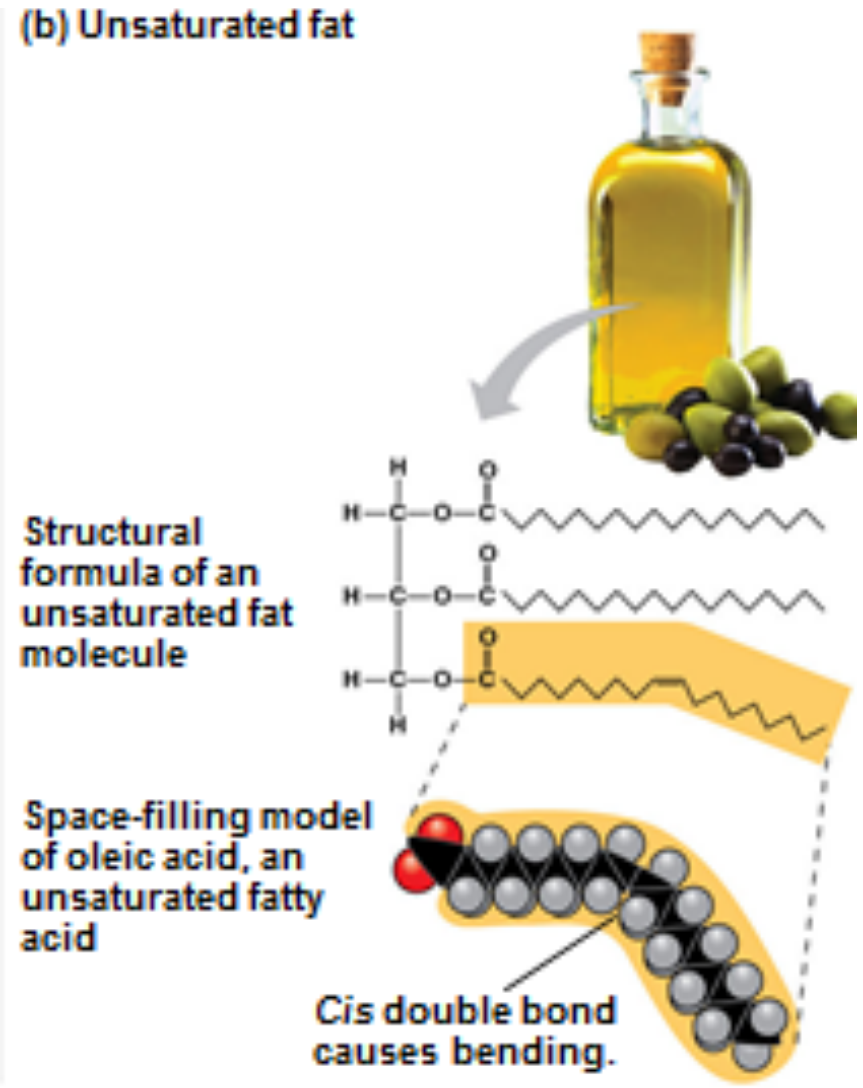
# Storage lipids: Fat

- Most animal fats are saturated (butter)
- **Saturated fatty acids** have the maximum number of hydrogen atoms possible and *no double bonds*
- Fully saturated fatty acids, molecules **can pack together tightly** in arrays, with atoms all along their lengths in **van der Waals contact** with the atoms of neighboring molecules.
- More thermal energy in needed to disorder these arrays of saturated fatty acids, they have higher melting points & solid in room temperature

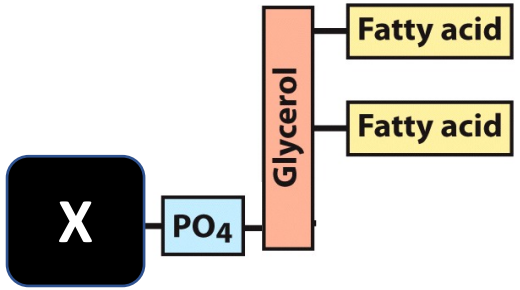


# Storage lipids: oil

- Oils are made from unsaturated fatty acids
- Liquid at room temperature
- Plant fats and fish fats are usually unsaturated
- **Unsaturated fatty acids** have *one or more double bonds*
- Because less thermal energy is needed to disorder these poorly ordered arrays of unsaturated fatty acids, they have lower melting points than saturated fatty acids of the same chain length

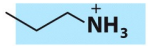
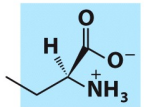
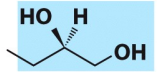
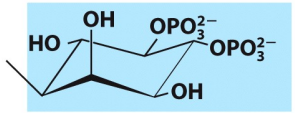
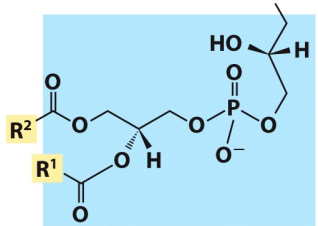


# Structural Lipids

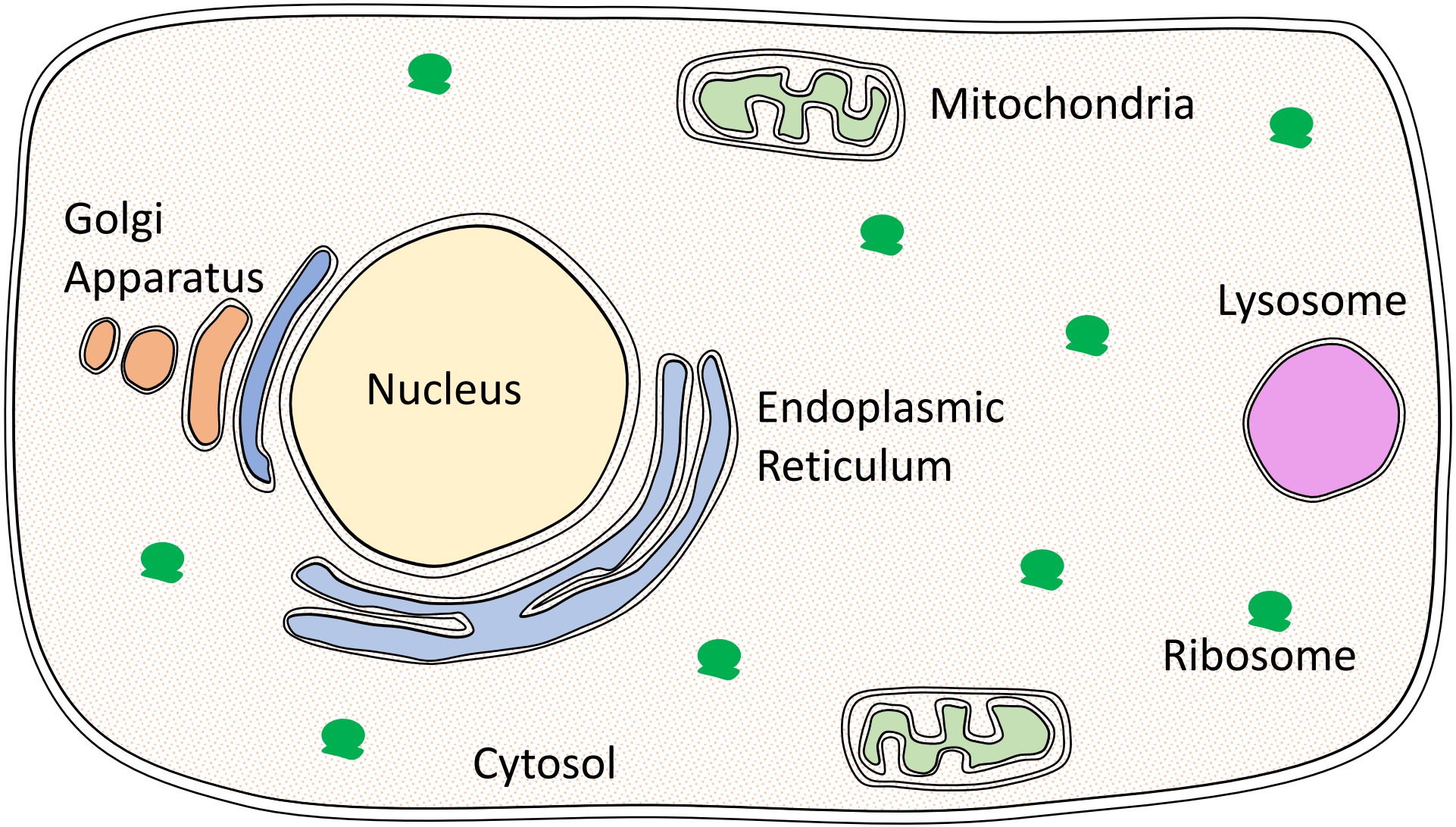



- The central feature of structural lipids are **amphipathic**
- <u>one end of the molecule is **hydrophobic**, the other end is **hydrophilic**</u>

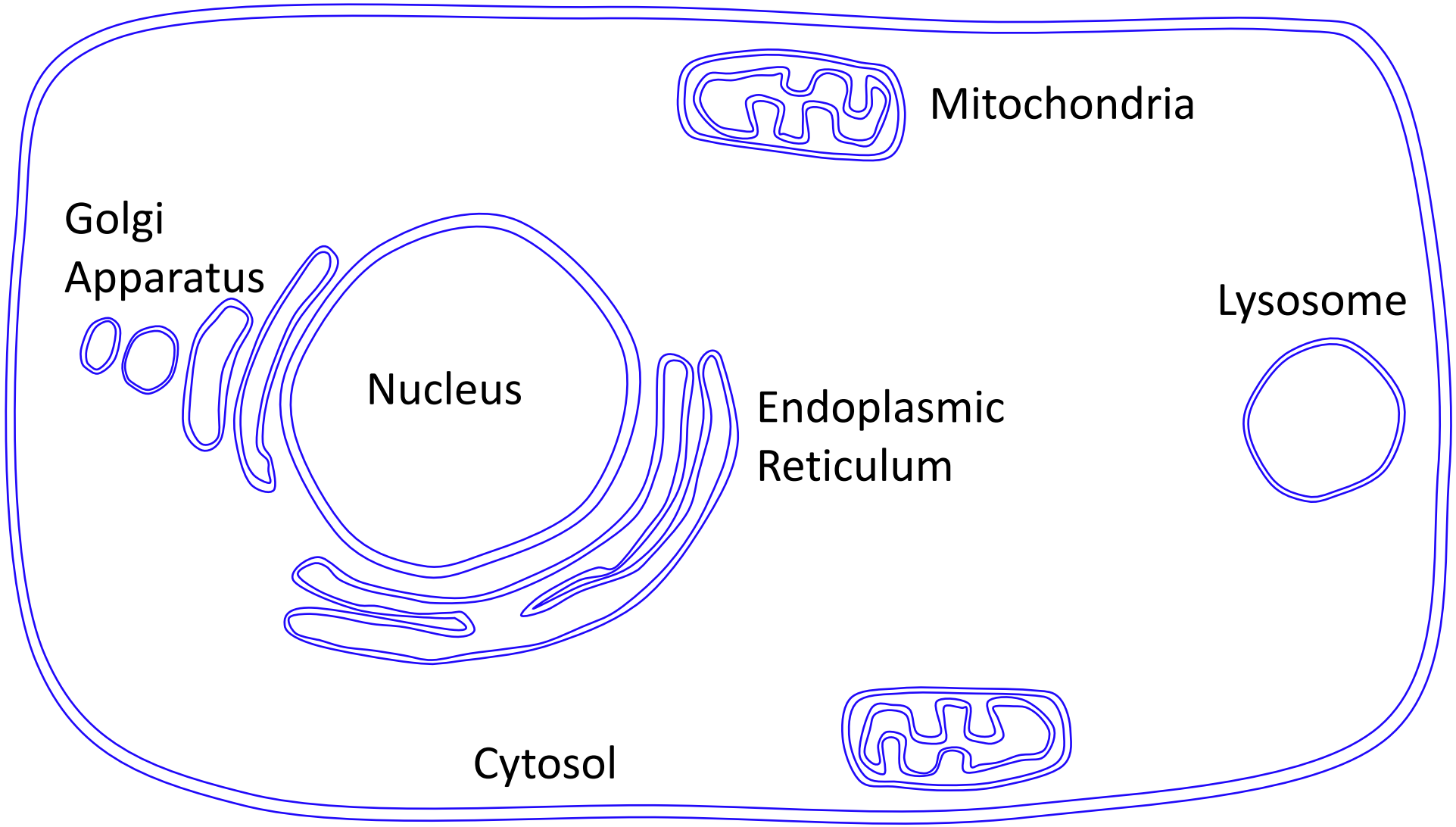
- **Phospholipids** form all biological membranes

| Name of glycerophospholipid | Name of X—O | Formula of X |
|---|---|---|
| Phosphatidic acid | — | —H |
| Phosphatidylethanolamine | Ethanolamine |  |
| Phosphatidylcholine | Choline | |
| Phosphatidylserine | Serine |  |
| Phosphatidylglycerol | Glycerol |  |
| Phosphatidylinositol 4,5-bisphosphate | *myo*-Inositol 4,5-bisphosphate |  |
| Cardiolipin | Phosphatidyl-glycerol |  |

# Eukaryotic Cell

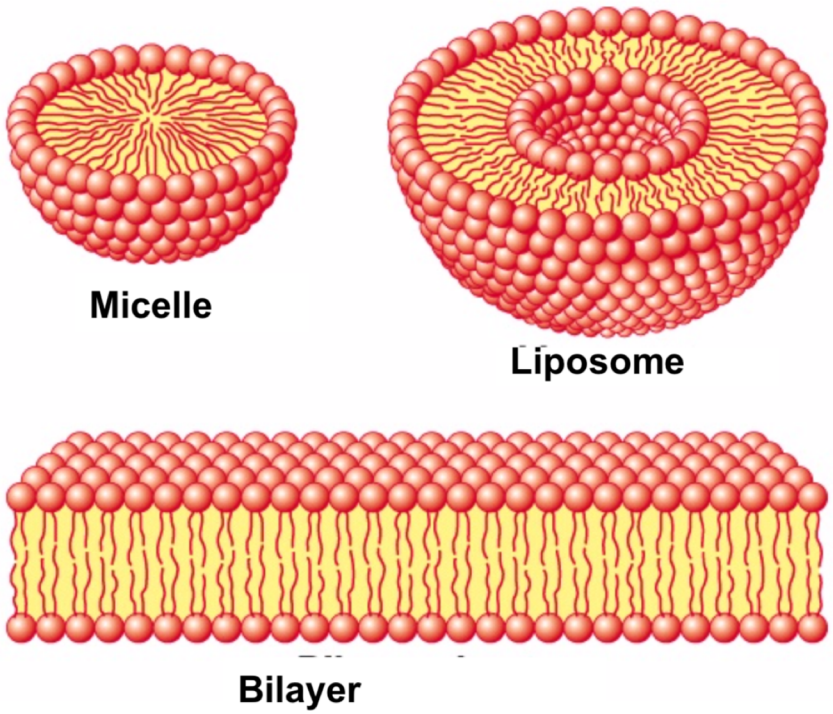


# Eukaryotic Cell: membrane

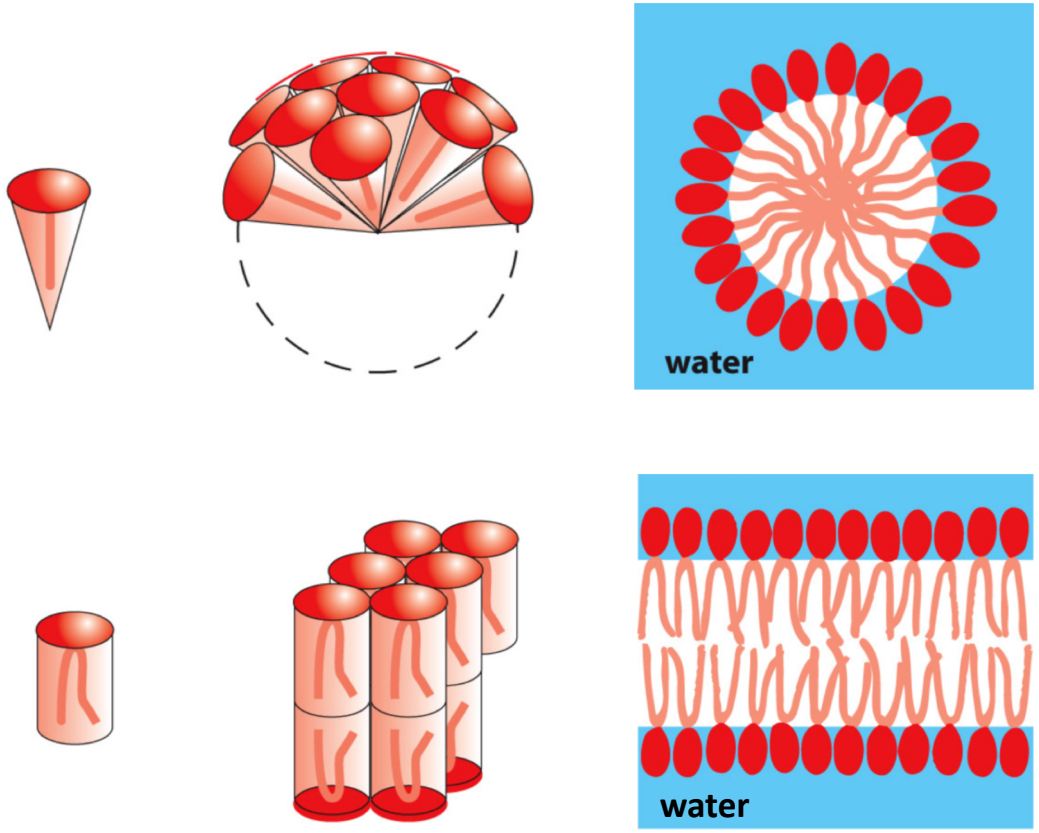


# Structural Lipids

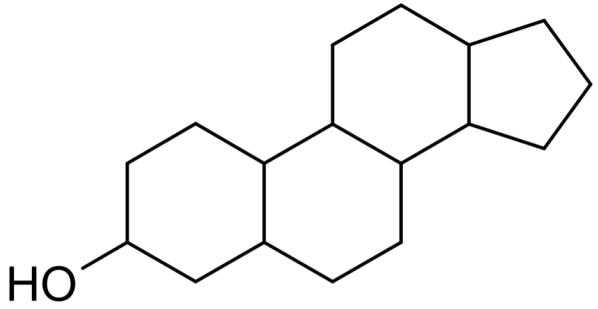
- Phospholipids spontaneously form 3 types of structures in water




- Shape of the Phospholipid molecules determine their packing and structure



# Sterols




- **Sterols** are lipids characterized by a carbon skeleton consisting of four fused rings
- **Cholesterol**, an important sterol, is a component in animal cell membranes
- The overall length of the molecule is similar to a 16-carbon fatty acid chain.
- In addition to their roles as membrane constituents, sterols serve as precursors for a variety of biologically important molecules.
- Example: **Steroid hormones, Vitamin D, Bile acids** etc.

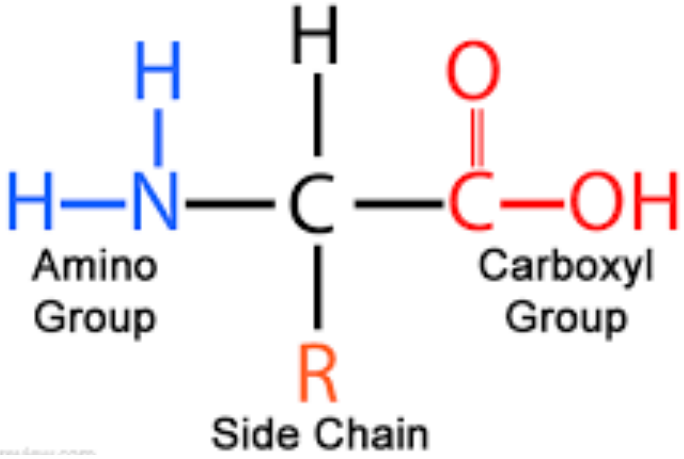
# Proteins: variety of function

Proteins are structural and functional biological macromolecule

- Examples:

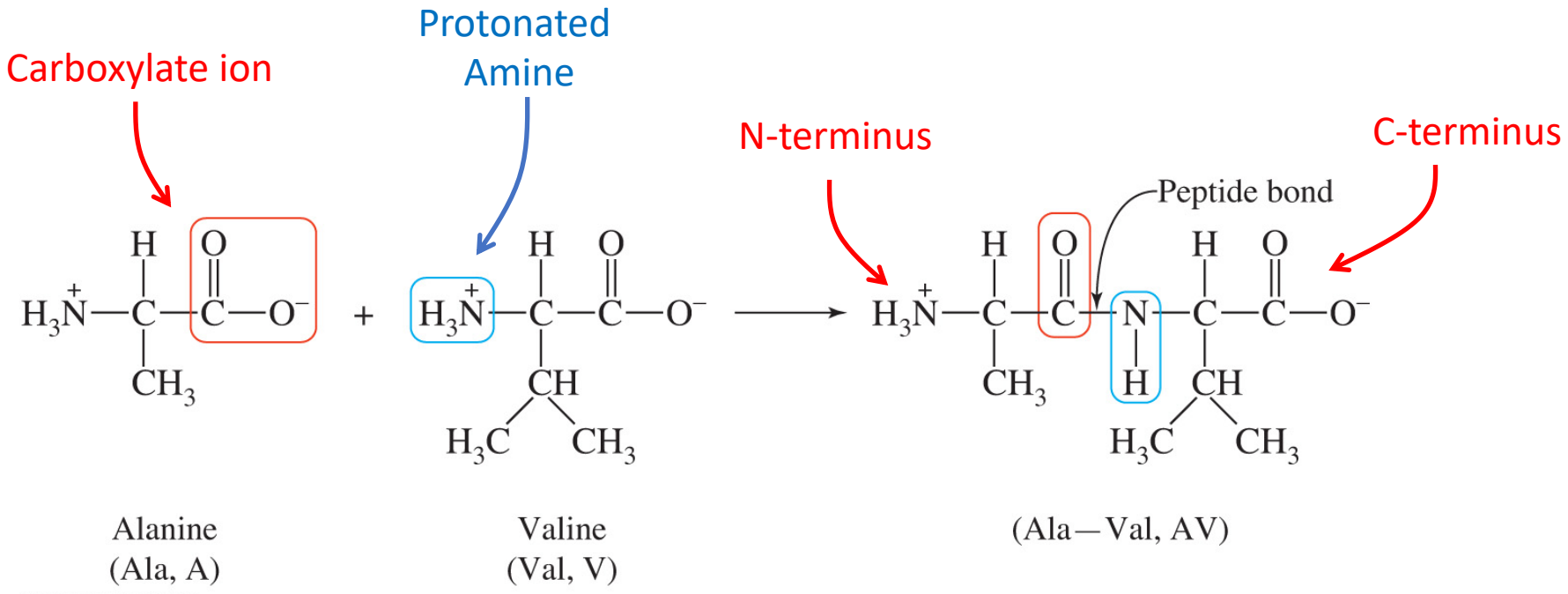
1. **Enzymes:** Proteins form enzymes speed chemical reactions
2. Actin and myosin found in muscles; Collagen is found in tendons, cartilage and bone.
3. Protein forms **antibodies** that help prevent infection, illness and disease.
4. **Keratin** is found as a horny impermeable protein in skin, hair, nails
5. **Hemoglobin** is a protein that transports oxygen throughout the body.
6. **Albumin** & **Globulin** protein in the blood maintains fluid balance
7. Regulate body functions including metabolic rate (thyroid hormone) and blood glucose (**insulin** and **glucagon**)

# Amino Acids: The building blocks of proteins



# Amino Acids: The building blocks of proteins

- Proteins are polymers of amino acids
- Two amino acids are joined by ***peptide bond***

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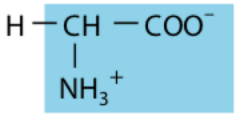
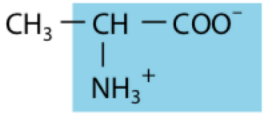
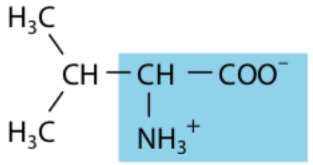
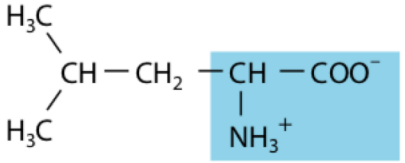
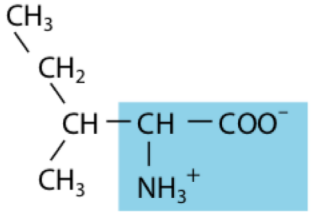
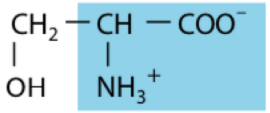
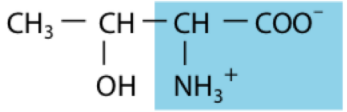
# Twenty amino acids

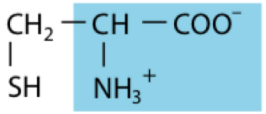
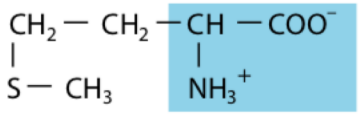
## With Aliphatic Side Chains

| | | |
|---|---|---|
| Glycine | Gly [G] |  |
| Alanine | Ala [A] |  |
| Valine | Val [V] |  |
| Leucine | Leu [L] |  |
| Isoleucine | Ile [I] |  |

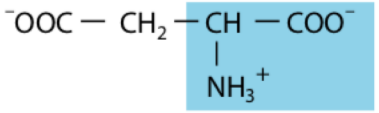
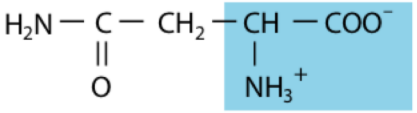
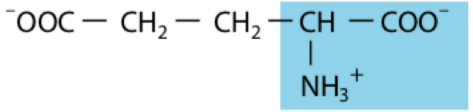
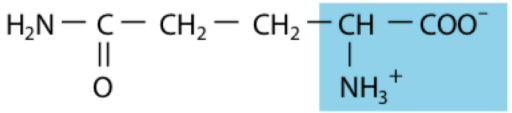
## With Side Chains Containing Hydroxylic (OH) Groups

| | | |
|---|---|---|
| Serine | Ser [S] |  |
| Threonine | Thr [T] |  |
| Tyrosine | Tyr [Y] | See below. |

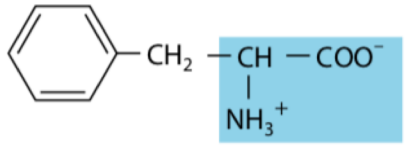
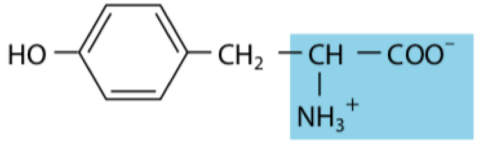
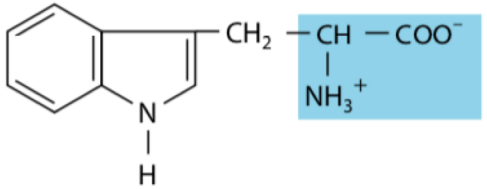
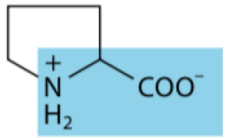
## With Side Chains Containing Sulfur Atoms

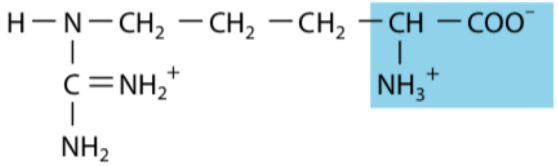
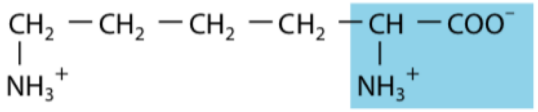
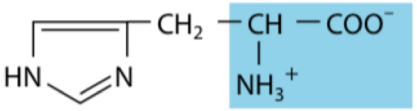
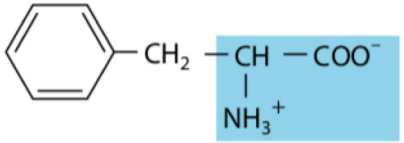
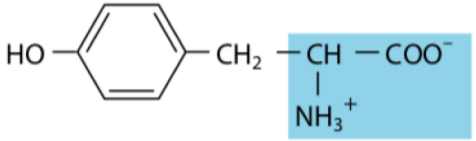
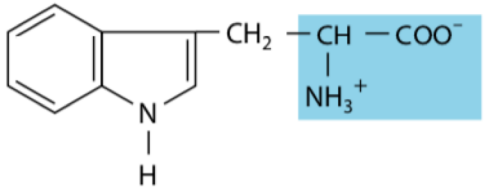
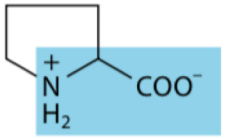
| | | |
|---|---|---|
| Cysteine | Cys [C] |  |
| Methionine | Met [M] |  |

## With Side Chains Containing Acidic Groups or Their Amides

| | | |
|---|---|---|
| Aspartic acid | Asp [D] |  |
| Asparagine | Asn [N] |  |
| Glutamic acid | Glu [E] |  |
| Glutamine | Gln [Q] |  |

# Twenty amino acids

| | | |
|---|---|---|
| **Containing Aromatic Rings** | | |
| Histidine | His [H] | See above. |
| Phenylalanine | Phe [F] |  |
| Tyrosine | Tyr [Y] |  |
| Tryptophan | Trp [W] |  |
| **Imino Acid** | | |
| Proline | Pro [P] |  |

| | | |
|---|---|---|
| **With Side Chains Containing Basic Groups** | | |
| Arginine | Arg [R] |  |
| Lysine | Lys [K] |  |
| Histidine | His [H] |  |
| **Containing Aromatic Rings** | | |
| Histidine | His [H] | See above. |
| Phenylalanine | Phe [F] |  |
| Tyrosine | Tyr [Y] |  |
| Tryptophan | Trp [W] |  |
| **Imino Acid** | | |
| Proline | Pro [P] |  |

# Abbreviations of twenty amino acids

| AMINO ACID | | | AMINO ACID | | |
|---|---|---|---|---|---|
| Aspartic acid | Asp | D | Alanine | Ala | A |
| Glutamic acid | Glu | E | Glycine | Gly | G |
| Arginine | Arg | R | Valine | Val | V |
| Lysine | Lys | K | Leucine | Leu | L |
| Histidine | His | H | Isoleucine | Ile | I |
| Asparagine | Asn | N | Proline | Pro | P |
| Glutamine | Gln | Q | Phenylalanine | Phe | F |
| Serine | Ser | S | Methionine | Met | M |
| Threonine | Thr | T | Tryptophan | Trp | W |
| Tyrosine | Tyr | Y | Cysteine | Cys | C |

Need to memorize

# Linear orders of amino acids can make a huge number of proteins

Consider a peptide with two amino acids

AA1 – AA2

20 x 20 = 400 different molecules

AA1 – AA2 – AA3

20 x 20 x 20 = 8000 different molecules

For 100 amino acid protein the # of possibilities are: $20^{100} = 1.27x10^{130}$

The total number of atoms in the <u>universe</u> is estimated at $9x10^{78}$

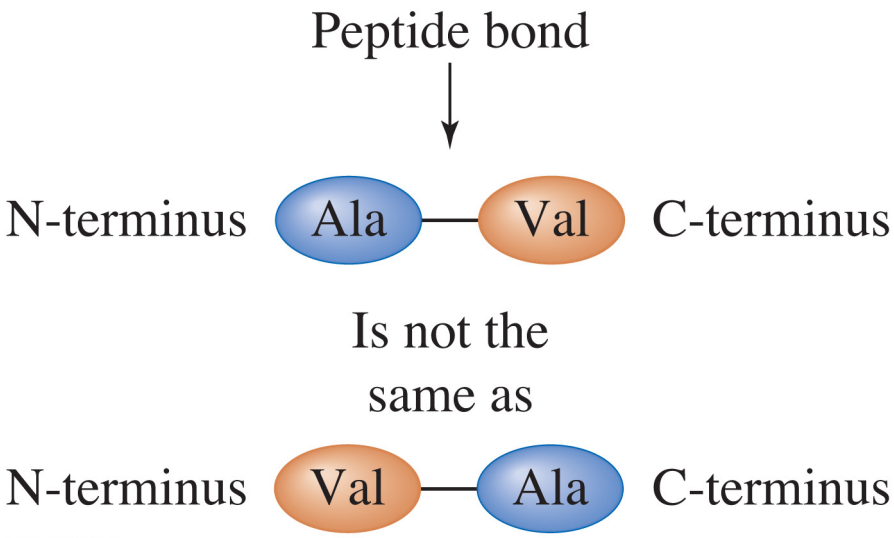
# Primary structure of proteins

- The order or sequence of amino acids in a protein chain are important in determining its **structure and function**.
- Arranging amino acids in a different order creates different protein
- For example, *angiotensin II* (blood pressure regulating protein) sequence:

Asp—Arg—Val—Tyr—Ile—His—Pro—Phe

- Any other order of amino acids in this peptide would result in a peptide that would not function as angiotensin II.

**edit ≠ diet ≠ tide ≠ tied**

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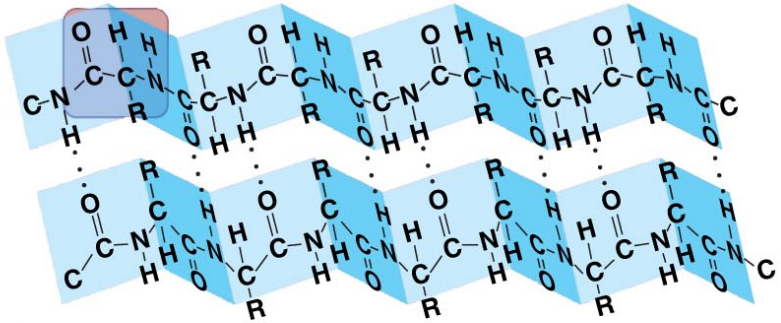
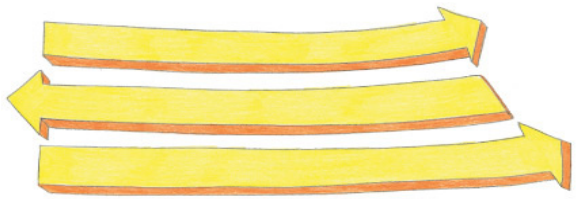
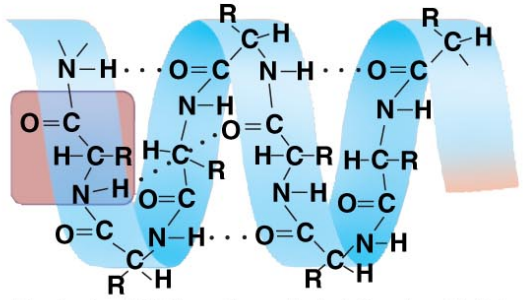
# Secondary structure of proteins

- α helix, β sheet or random coil
- **Based on the sequence of amino acids (primary structure) protein might fold like a  helix or sheet**
- **Stabilized by** Hydrogen bond between the N-H of a peptide bond to the C=O of another peptide bond (R groups are not involved)





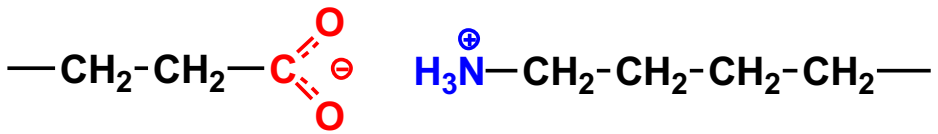
**β sheet**



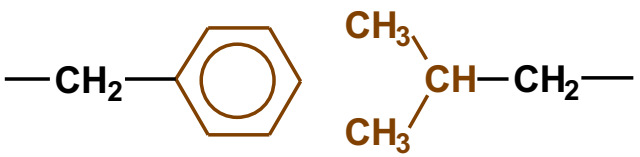
**α helix**

# Tertiary structure of proteins:

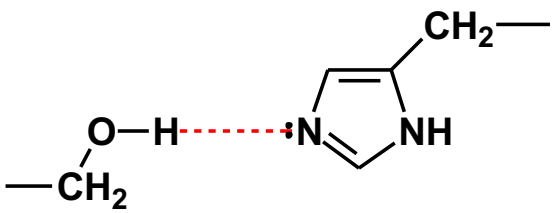
Non-covalent bonds between side-chains guide the overall conformation




**Ionic bonding ("salt bridge")**




**Van der Waals interactions**

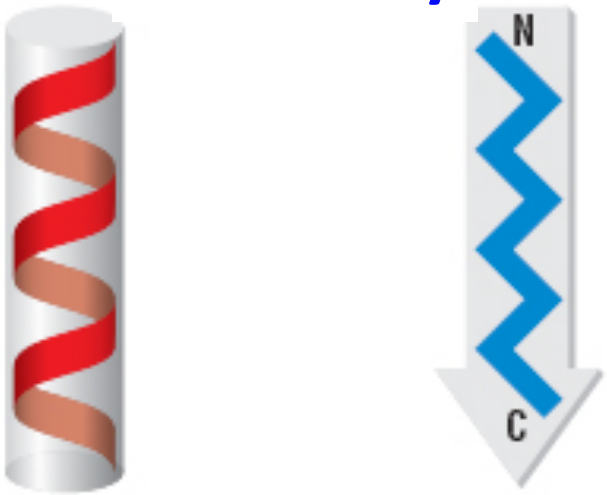



**Hydrogen bonding**

# Three levels of protein structure

**Primary**

**Secondary**




**α helix** **β sheet**

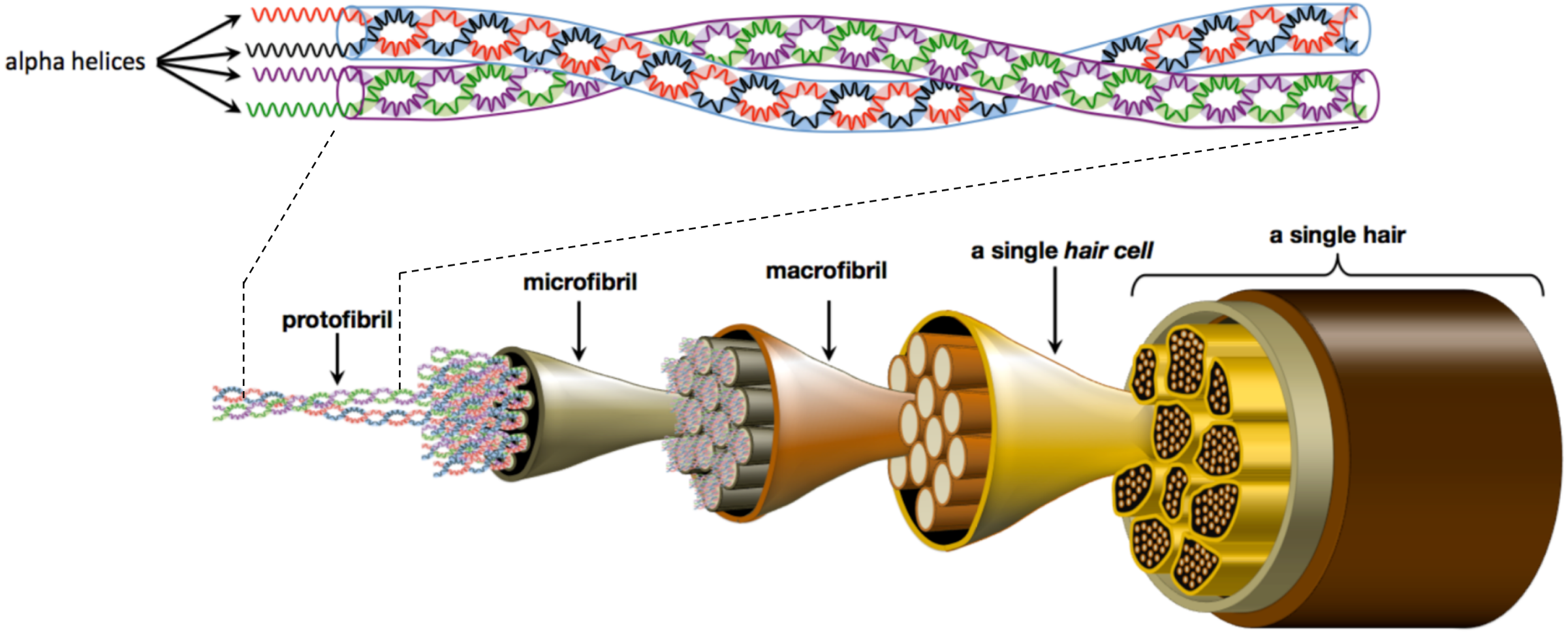
**Tertiary.**

# 3-dimensional structure of proteins

- Proteins are classified into groups based on their three-dimensional shape.
- ***Globular proteins*** are compact, spherical structures that are soluble in an aqueous environment. Example: **Hemoglobin** in blood
- ***Fibrous proteins*** are long, thread-like structures that have high helical content. Keratins, in hair, nails
- ***Membrane proteins*** are part of Biological membrane

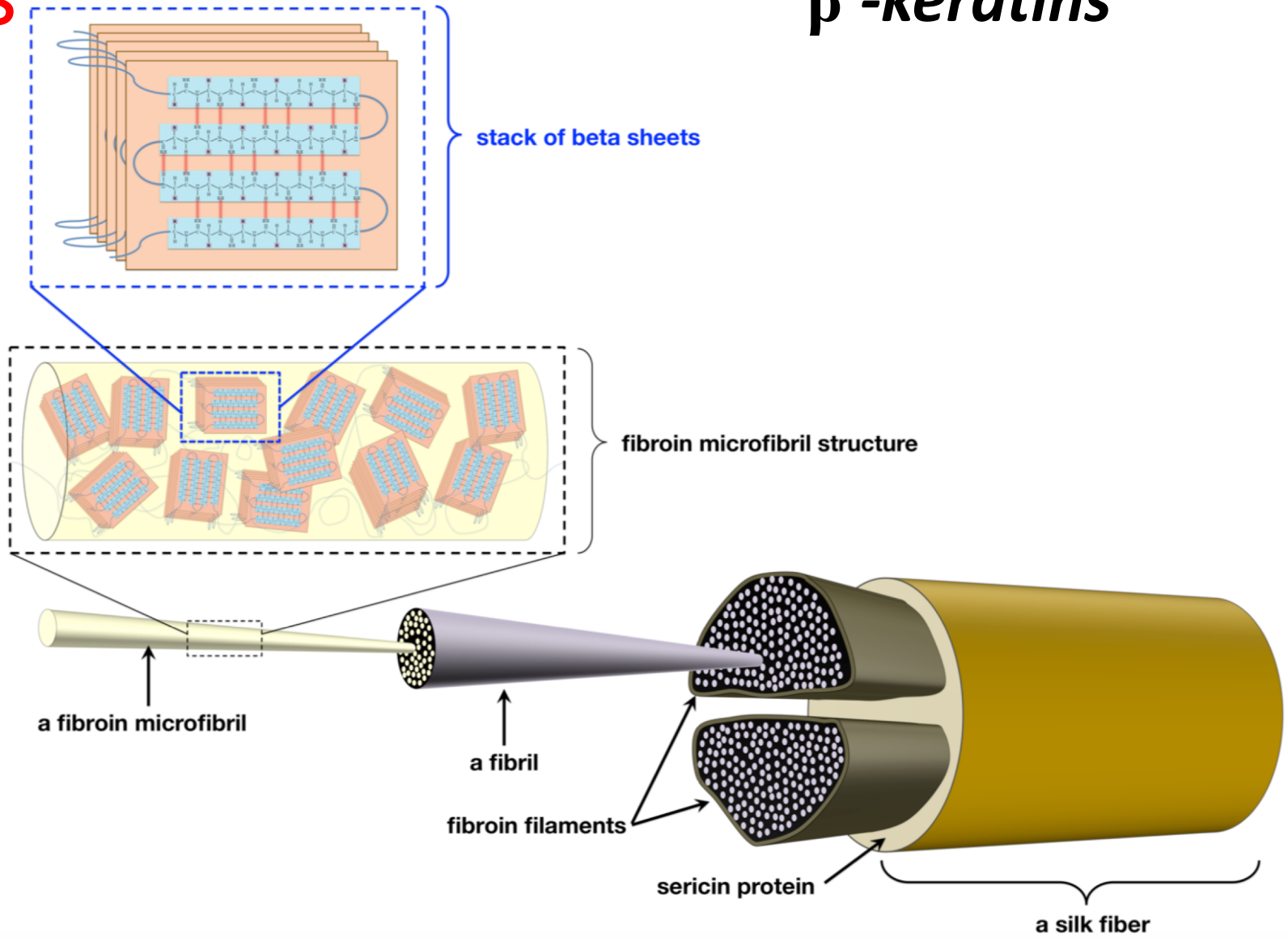
# Fibrous proteins

***α-keratins***

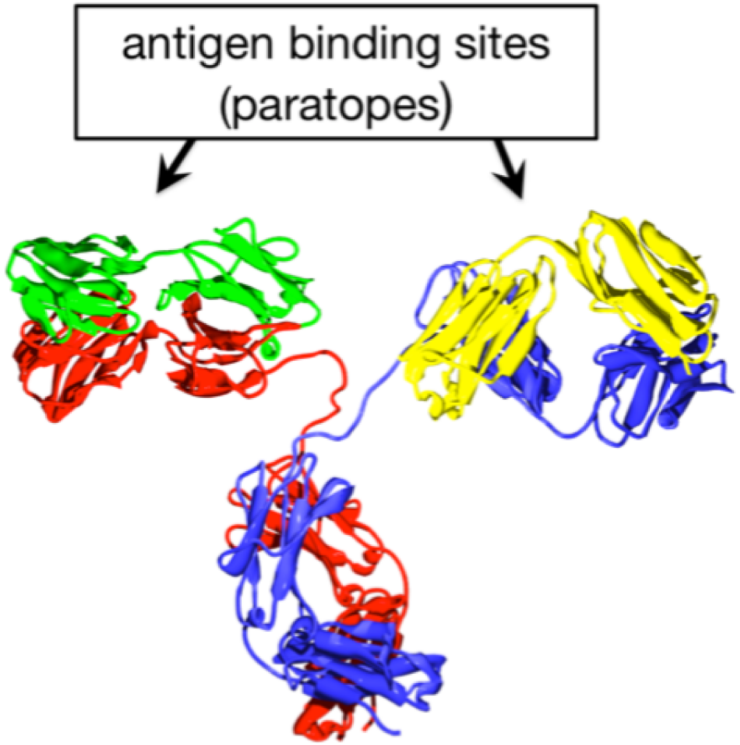


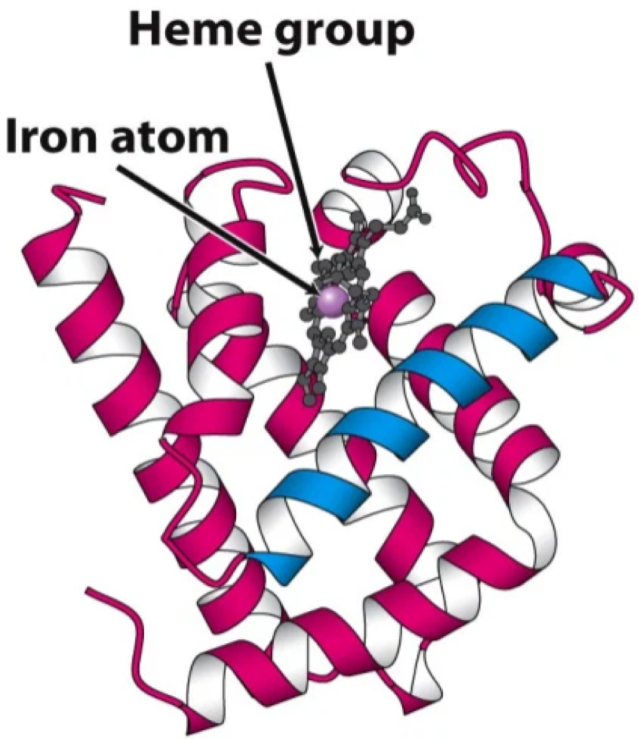
# Fibrous proteins

## β -*keratins*



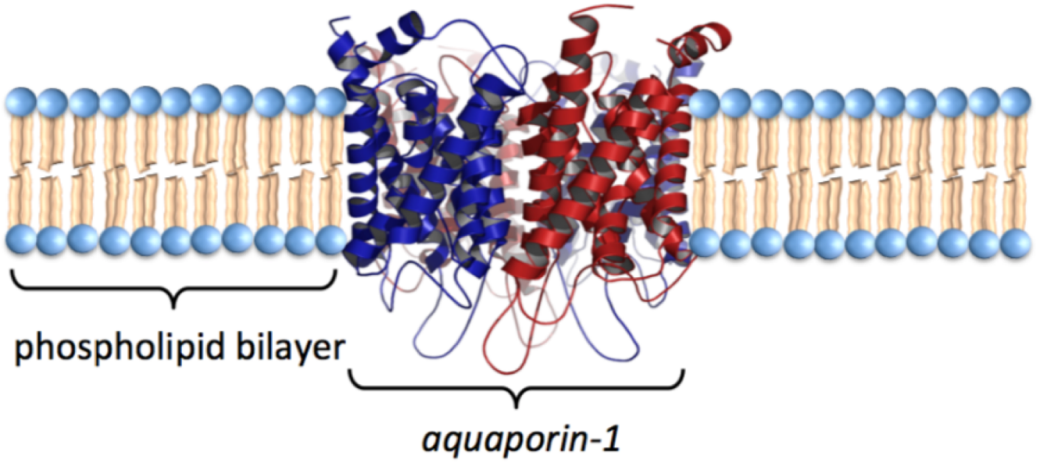
# Globular proteins



# Membrane proteins

- Membrane proteins extend **through the membrane**
- They form membrane **channel** and **pump** across the membrane bilayer
- Example: *aquaporins*

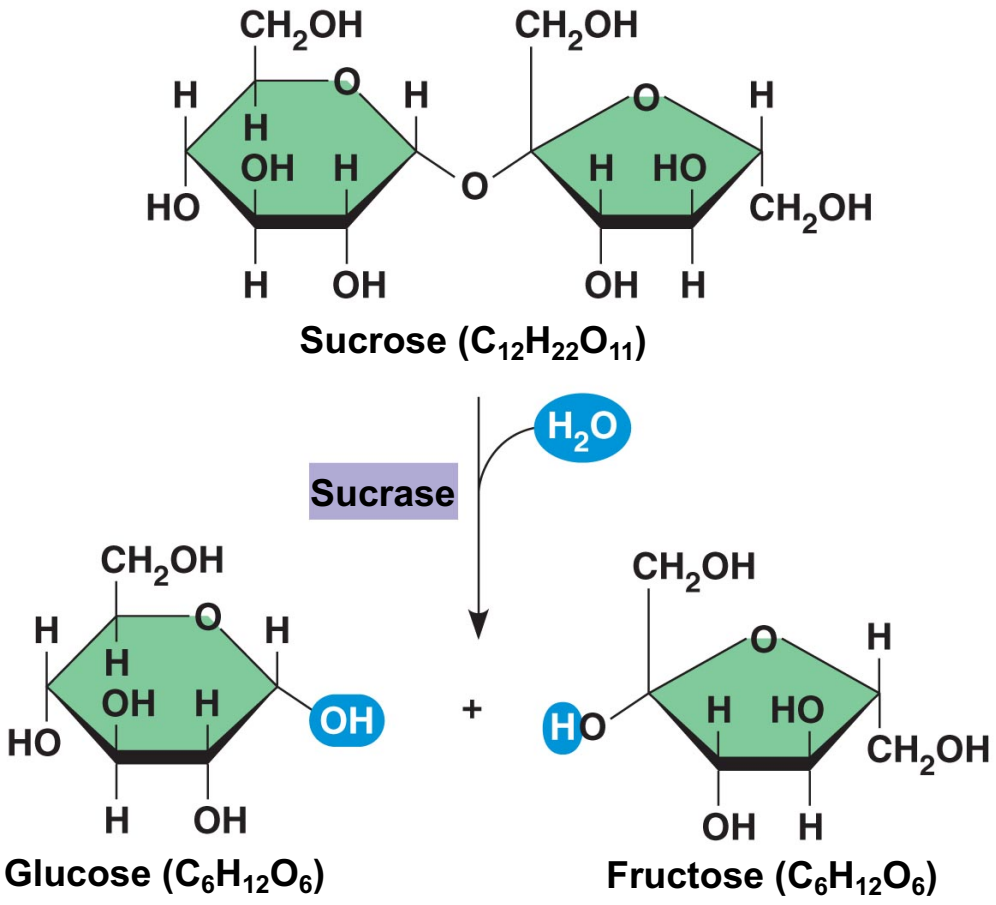



- *Aquaporin* facilitate the transport of water molecules in and out of cells.

# Protein with function: Enzymes
# Enzymes are biological catalysts

- A **catalyst** is a chemical agent that speeds up a reaction without being consumed by the reaction
- An **enzyme** is a **catalytic protein**
- All enzymes are protein in nature, but all proteins are not enzymes
- Chemicals upon which the enzymes act are called **substrates**
- Enzyme converts substrates into product(s)

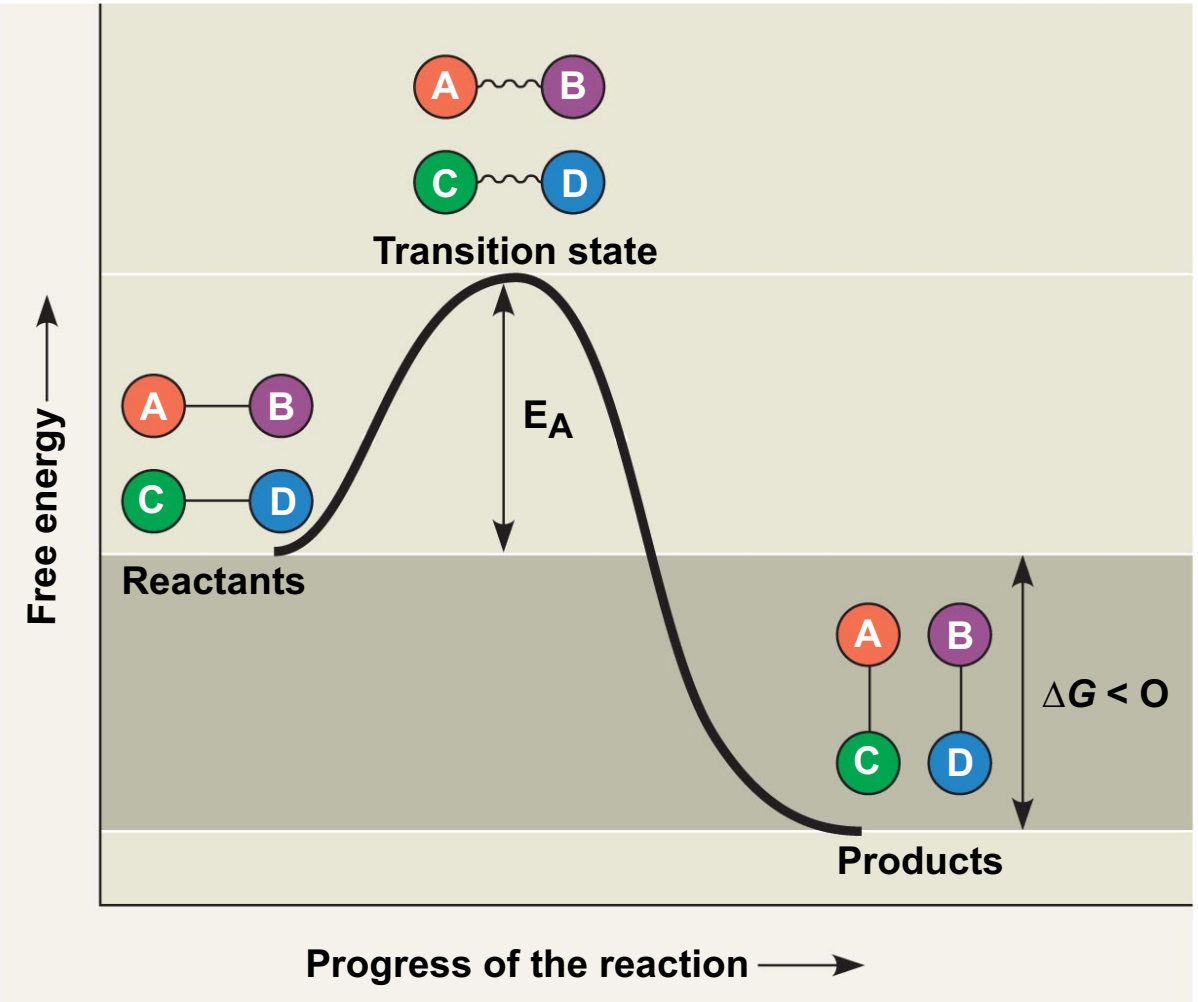
- Example of Enzyme: (suffix: ***ase***)
- Hydrolysis of sucrose by the enzyme **sucr*ase*** is an example of an enzyme-catalyzed reaction



# Activation Energy Barrier

- Every chemical reaction the reactants pass through a **transition state**
- **transition state** has greater free energy than that of the reactants or products alone
- **The initial free energy needed to start a chemical reaction is called the activation energy ($E_A$)**
- Activation energy is often supplied in the form of heat from the surroundings, in biology we have ENZYMES

# Activation Energy Barrier




**In all spontaneous change reactants pass through a transition state**

**The free energy of the system decreases**

Free energy of products - Free energy of the reactant

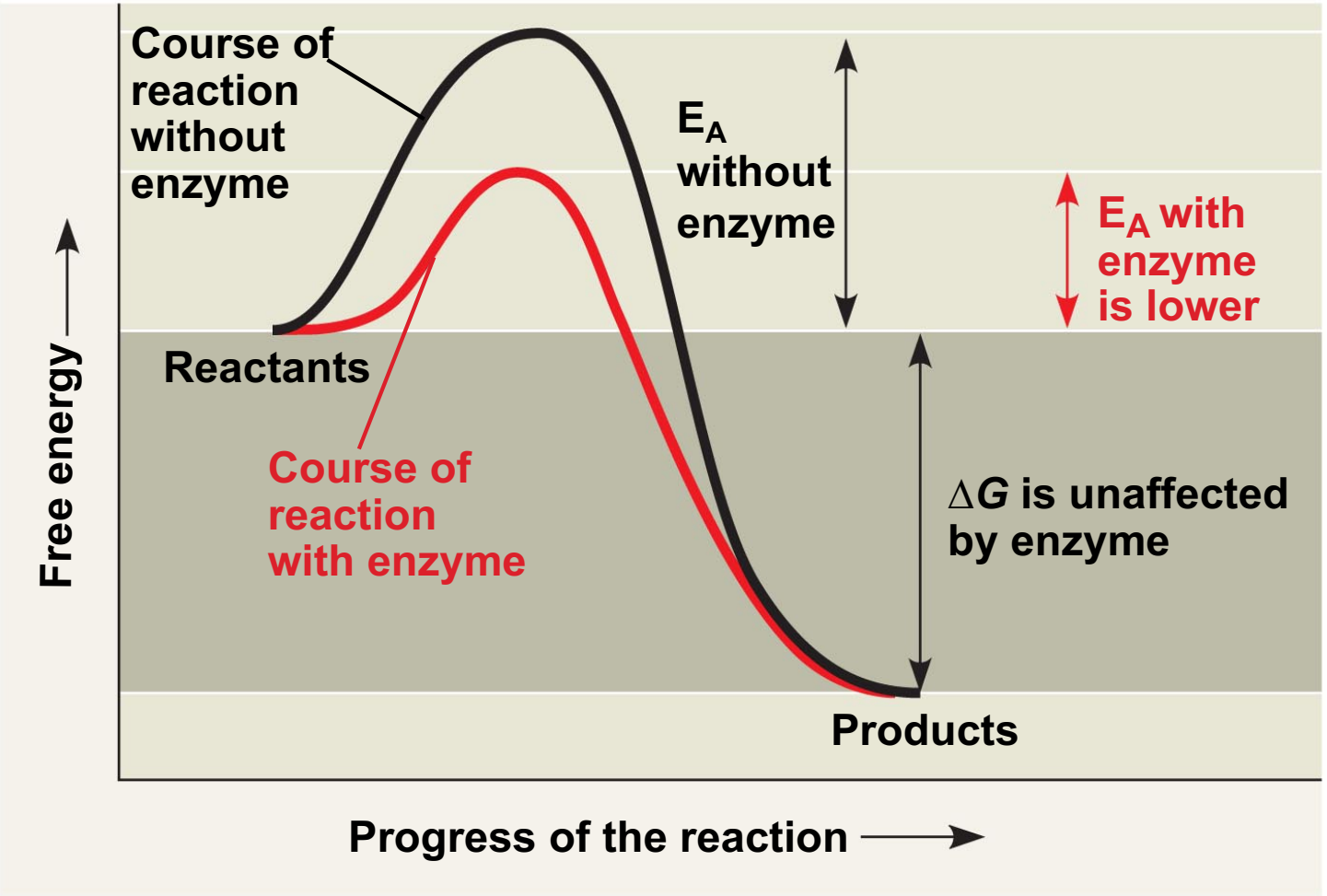
$\Delta G < 0$

**The system becomes more stable**

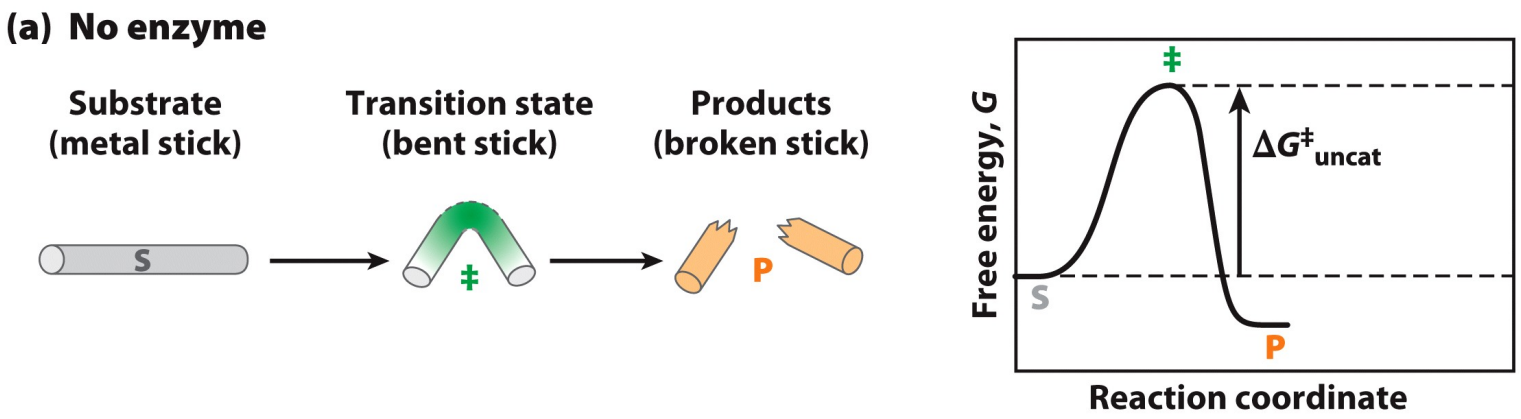
# Enzyme Lowers Activation Energy Barrier

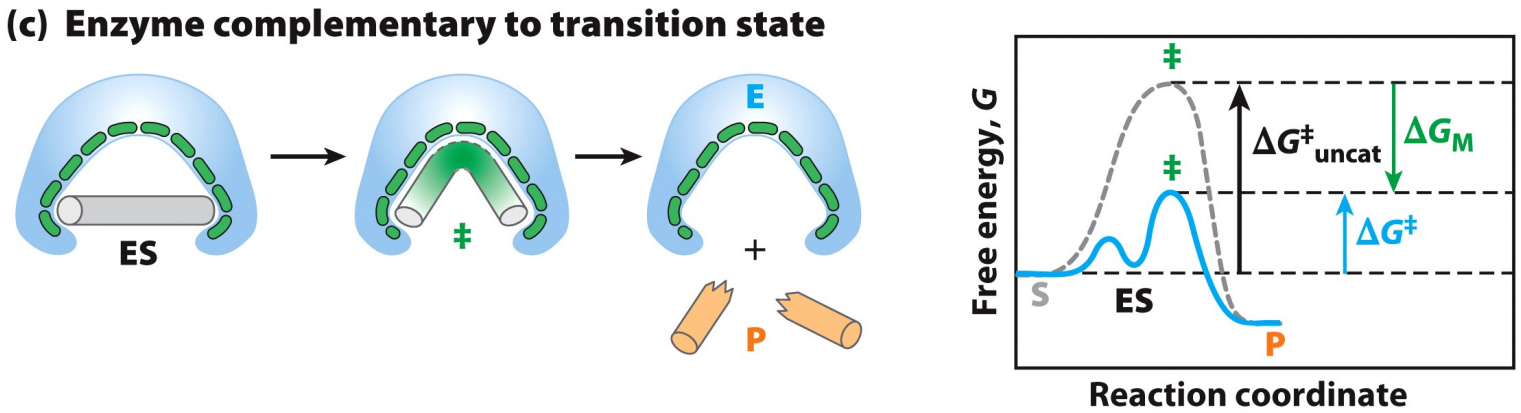
- **Enzymes catalyze reactions by lowering the $E_A$ barrier**

- **Enzymes do not affect the change in free energy ($\Delta G$)**; instead, they speed up reactions that would occur eventually
- Enzyme provides an **alternative transition state of lower energy** called the **"enzyme-substrate complex"**

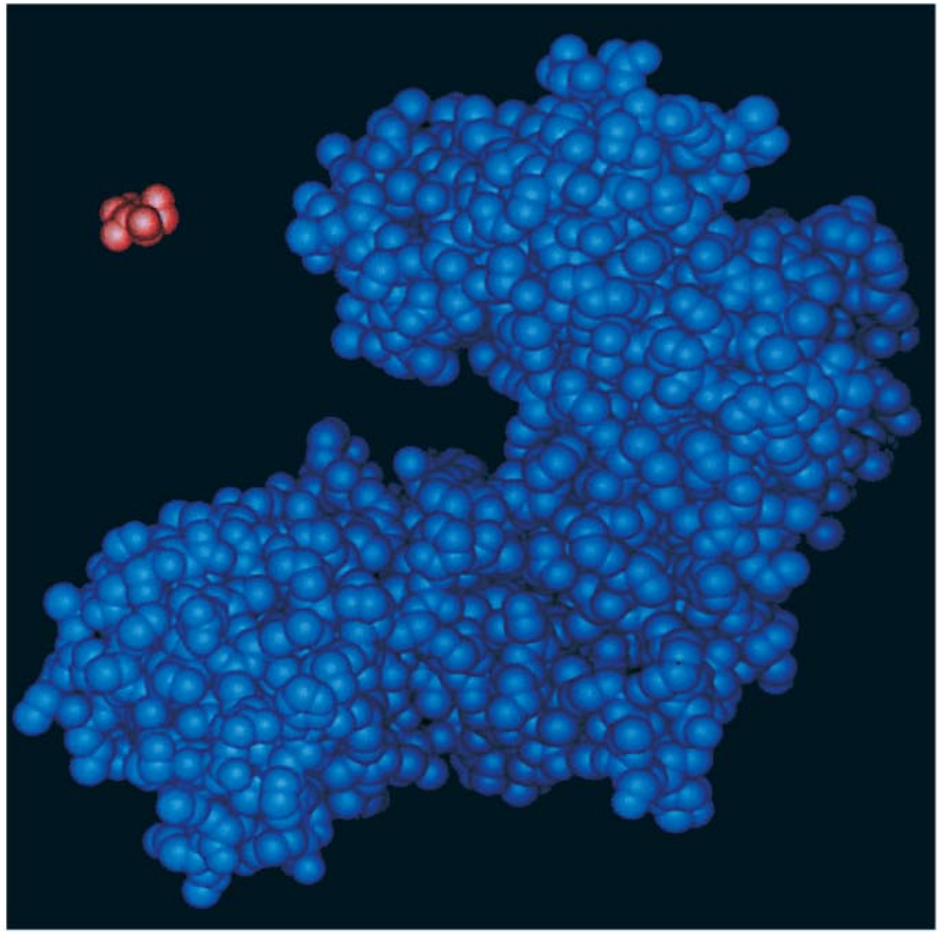


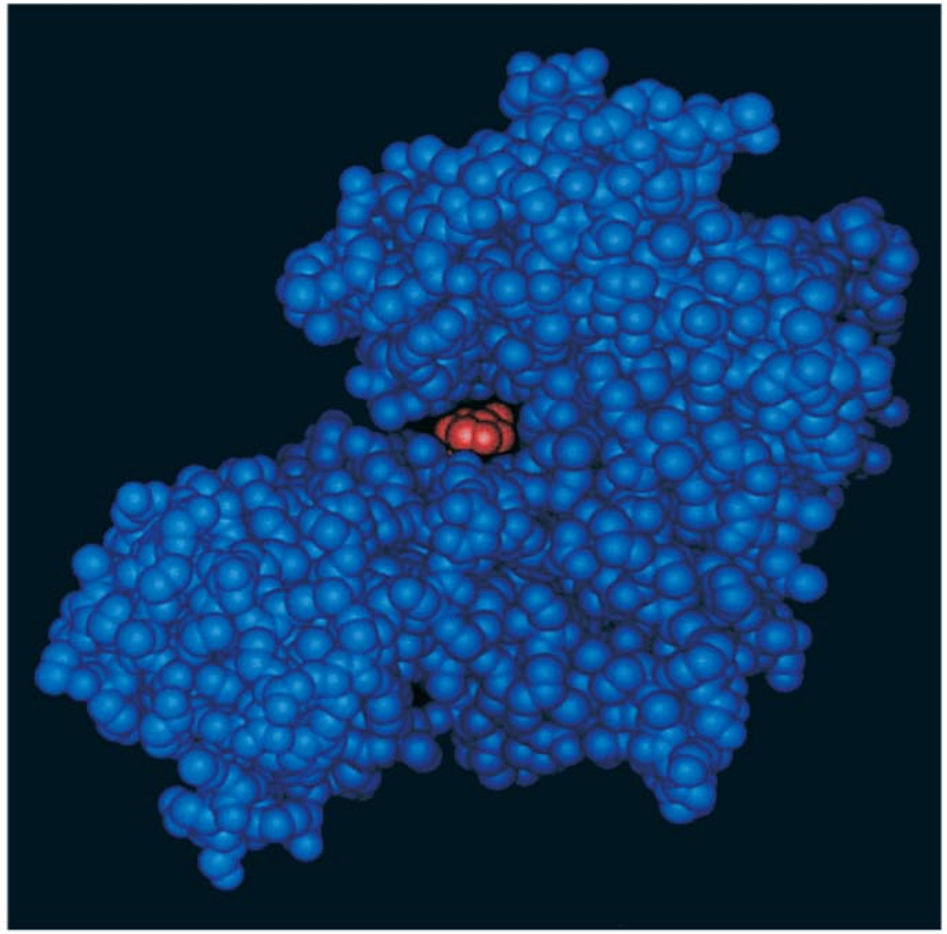
- Enzymes first bind **weakly** to the substrate
- This changes enzyme structure slightly so that then they bind **more tightly** to the transition state of substrate
- The free energy (binding energy) released by the formation of these interactions partially supply part of the energy required to reach the transition state



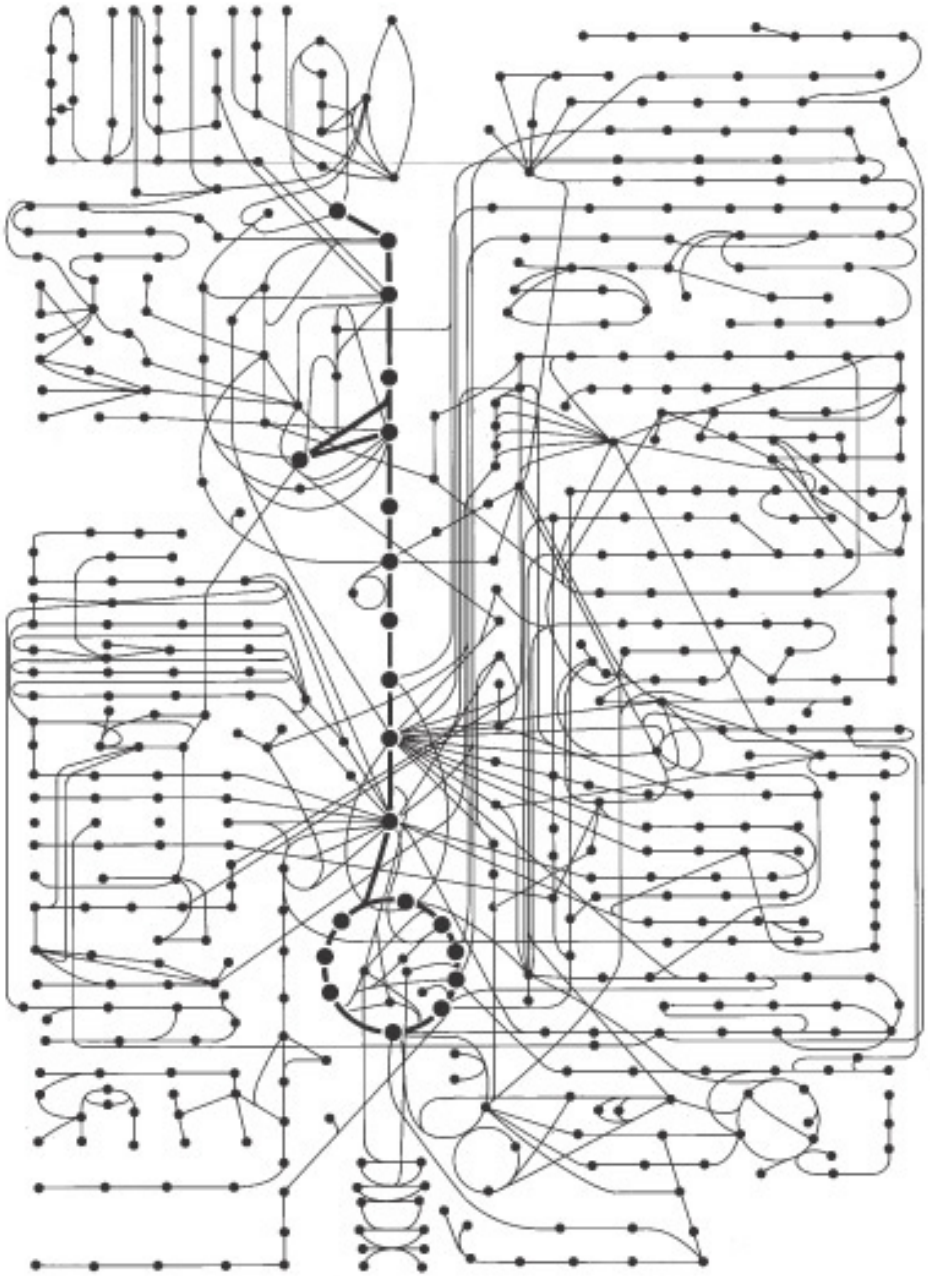
Enzyme must be more complementary to the reaction transition state structure than to the substrate for efficient catalysis to occur





# Each enzyme catalyzes a single reaction

- There are approximately 1300 different **enzymes** found in the **human cell**.
- These **enzymes** can combine with coenzymes to form nearly 100,000 various chemicals
- There is a specific enzyme for a specific reaction



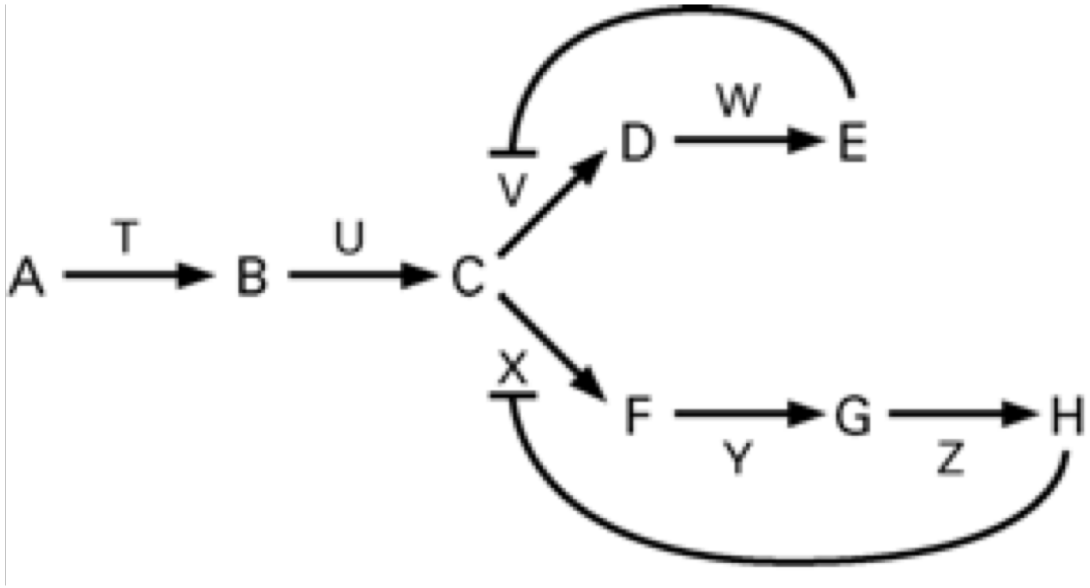
# Some enzymes are NOT active by themselves

- **Cofactors** are nonprotein enzyme helpers
- Cofactors may be inorganic metal ion (Fe, Cu, Zn, Mg etc.)

- An organic cofactor is called a **coenzyme**
- Coenzymes are **vitamins**

# Feedback inhibition provides a way for an enzyme to slow its activity

- Feedback inhibition - product inhibits more product formation
- Chemical chaos would result if a cell's metabolic pathways were not tightly regulated
- Enzyme Activity is modulated to suit the needs of the cell

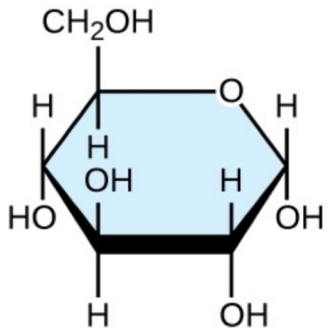


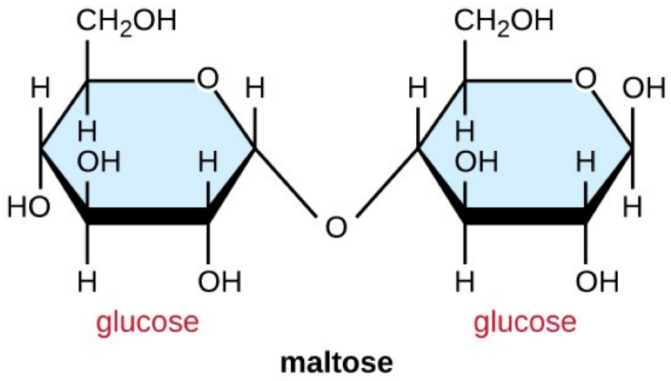
# Carbohydrates

- **Carbohydrates** are the polymers of sugars
- The simplest carbohydrates are *monosaccharides*, or single sugars
- Carbohydrate macromolecules are *polysaccharides*, polymers composed of many sugar building blocks

# Monosaccharides & Disaccharides

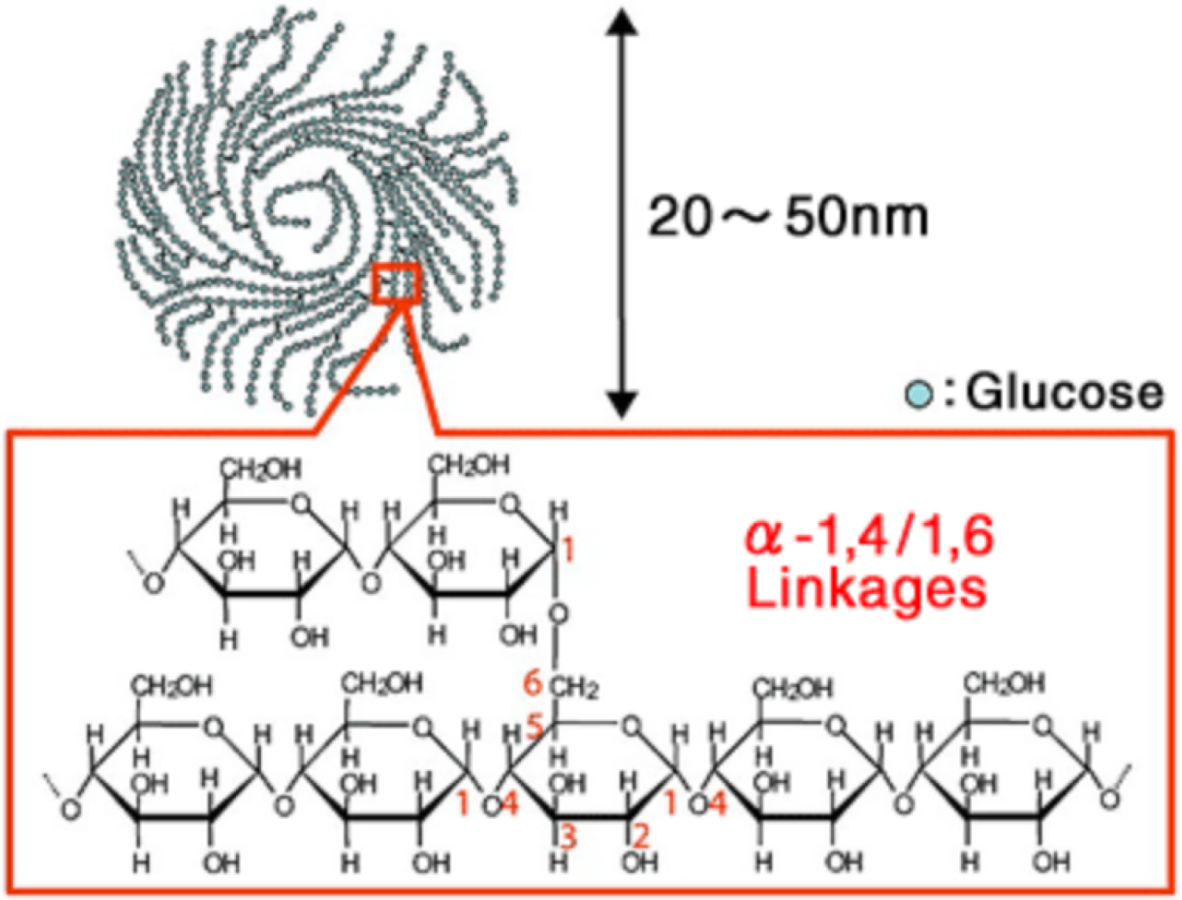
- **Monosaccharides** have molecular formulas that are usually multiples of $CH_2O$
- Glucose ($C_6H_{12}O_6$) is the most common monosaccharide
- A **disaccharide** is formed when a dehydration reaction joins two monosaccharides
- This covalent bond is called a **glycosidic linkage**



# Polysaccharides (glycans)

- **Glycogen** is a storage polysaccharide in animals
- Humans store glycogen in **liver** & **muscle** cells



# In the human diet, carbohydrates constitute approximately half the total caloric intake, yet only 1% of tissue weight is carbohydrate. WHY?

- Most of the carbohydrates in the human diet are **used as fuel** to **supply the energy** requirements of the organism.
- Although some carbohydrate is stored in the form of glycogen, the mass stored is relatively small compared with adipose tissue and muscle mass.
- Thus, carbohydrate contributes relatively little to the weight of the body.

# Glycoproteins

- Glycoproteins are proteins with carbohydrates attached, generally as oligosaccharides.
- Attached sugars can also function as signals for proper folding, or as sites of interaction between cells.
- Example of glycoproteins:
- The A, B, and O blood group antigens are examples of cell-surface Glycoproteins (oligosaccharides).
- Glycated Hemoglobin (HbA1): The level of **glycated hemoglobin** is increased in persons with diabetes

# Questions

1. All proteins contain the

(A) Same 20 amino acids

(B) Different amino acids

(C) 300 Amino acids occurring in nature

(D) Only a few amino acids

2. Which of the following statement(s) are CORRECT about primary structure of proteins?

A. It refers to alpha-helix

B. It refers to amino acid sequence

C. It refers to hydrogen bonding between proteins

# Questions

3. How many tetra-peptides can be made with 20 amino acids?

A. 400

B. 8000

C. $10^9$

D. None of the above

4. Which of the following statements about enzyme kinetics is FALSE?

A. Enzyme lowers free energy ($\Delta G$) of the reaction

B. Most enzymes operating in the human body work best at a temperature of 37°C.

C. Increase in the substrate concentration will result in the increase of product formation

# Questions

- 5.Enzymes increase the rate of a reaction by

A. decreasing the activation energy.

B. increasing the overall free energy of the reaction.

C. both (A) and (B).

D. None of the above

- 6. What is the single letter abbreviation of this tetrapeptide "Aspartic acid-Glutamic acid-Alanine-Aspartic acid"

A. REAR

B. DEAD

C. AGAG

D. none of the above

# Questions

- 7. Which of the following is a fibrous protein

A. Antibody/Immunoglobulin

B. Haemoglobin

C. Keratin

D. T-cell receptor

- 8. Glycoproteins are made of

A. Amino acids and Glycerol

B. Amino acids and carbohydrates

C. Glycerol and fatty acids

D. none of the above