Biological Molecules

Learning Outcome B4

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- Analyze the structure and function of biological molecules in living systems

Student Achievement Indicators

- Demonstrate a knowledge of dehydration synthesis and hydrolysis to organic monomers and polymers
- Differentiate among carbohydrates, lipids, proteins and nucleic acid with respect to chemical structure
- Recognize the following molecules in structural diagram:
  - ✓ adenosine triphosphate (ATP)
  - ✓ DNA
  - ✓ disaccharide
  - ✓ glucose
  - ✓ glycerol
  - ✓ hemoglobin
  - ✓ monosaccharide
  - ✓ neutral fat
  - ✓ phospholipid
  - ✓ polysaccharide
  - ✓ ribose
  - ✓ RNA
  - ✓ saturated fat
  - ✓ unsaturated fat
  - ✓ steroids

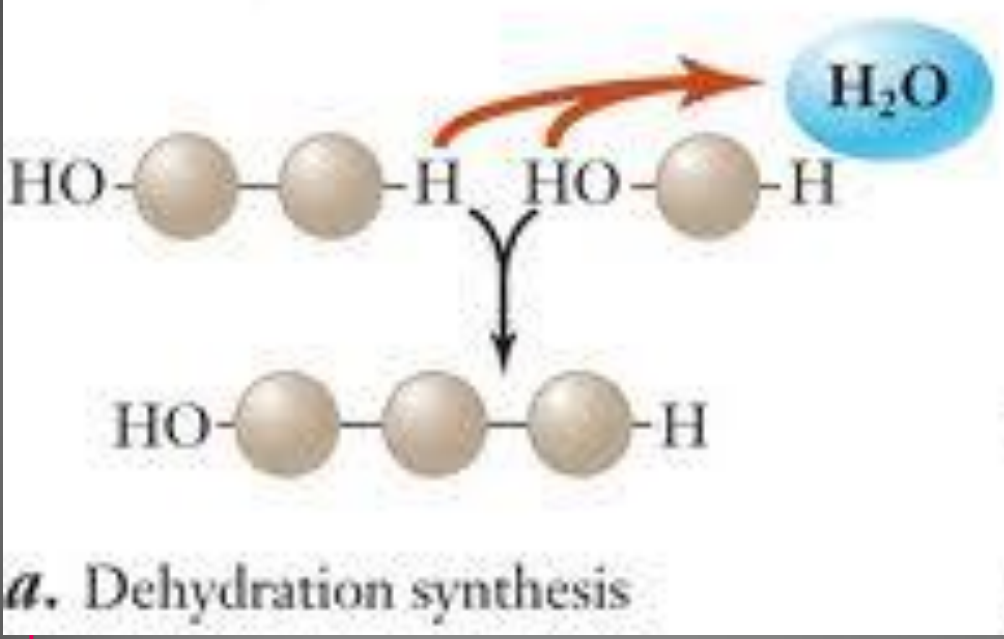
Student Achievement Indicators

- Recognize the empirical formula for a monosaccharide
- List the main functions of carbohydrates
- Differentiate amount monosaccharides, disaccharides and polysaccharides
- Differentiate among starch, cellulose, and glycogen with respect to the following:
  - ✓function
  - ✓type of bonding
  - ✓level of branching

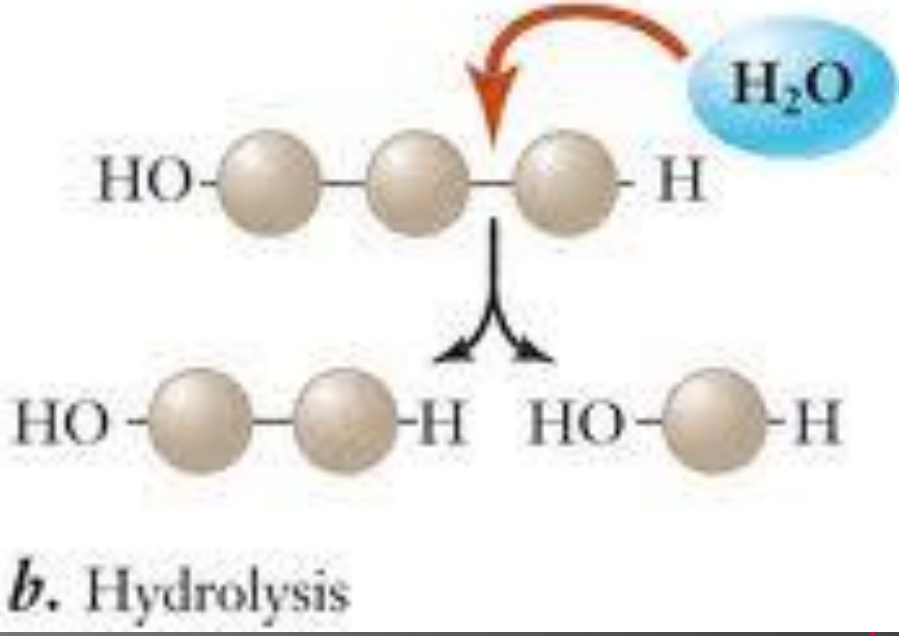
- Describe the location, structure and function of the following in the human body:
  - ✓neutral fats
  - ✓steroids
  - ✓phospholipids

Building & Breakdown Biological Molecules

- Biological molecules are made up of single units (monomers), to make a multi-unit molecule (polymer).
- A polymer is also known as a macromolecule
- When you combine monomers it is known as dehydration synthesis
- When you break down macromolecules it is known a hydrolysis.



a. Dehydration synthesis



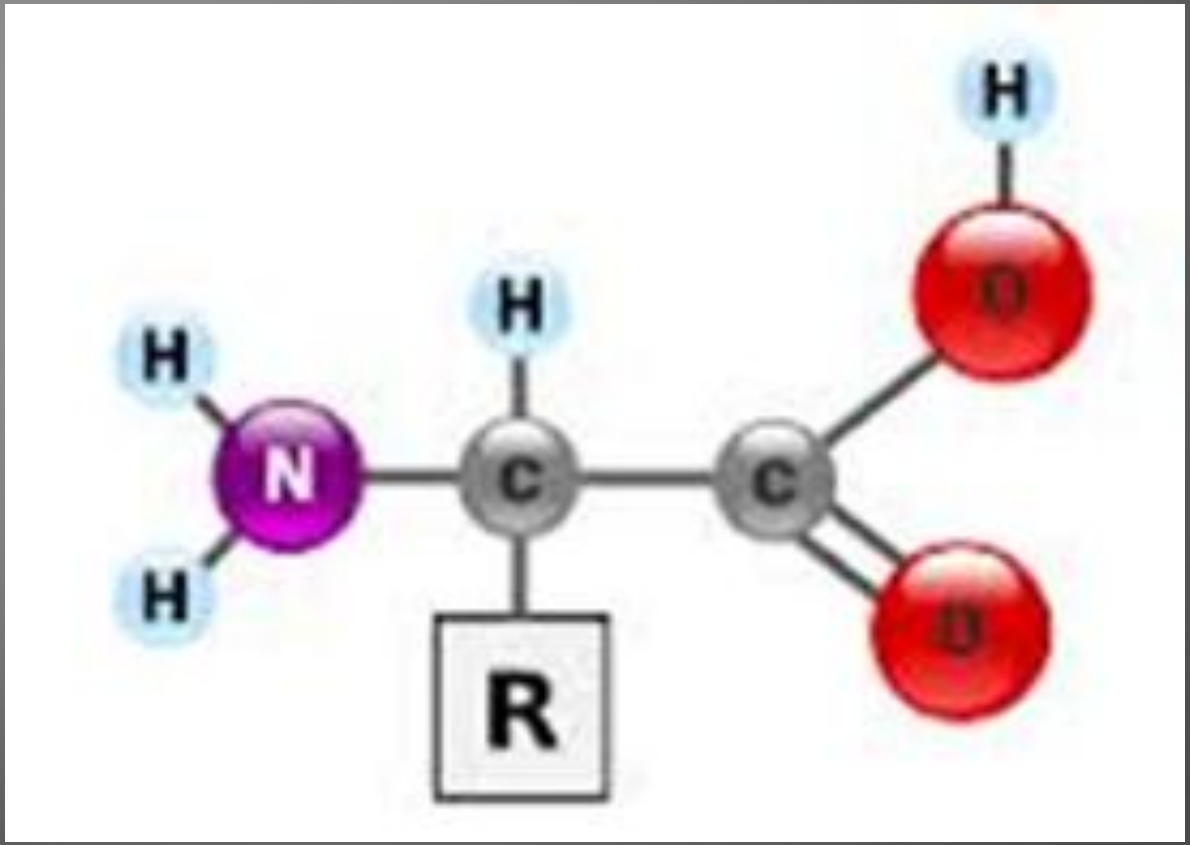
b. Hydrolysis

Proteins

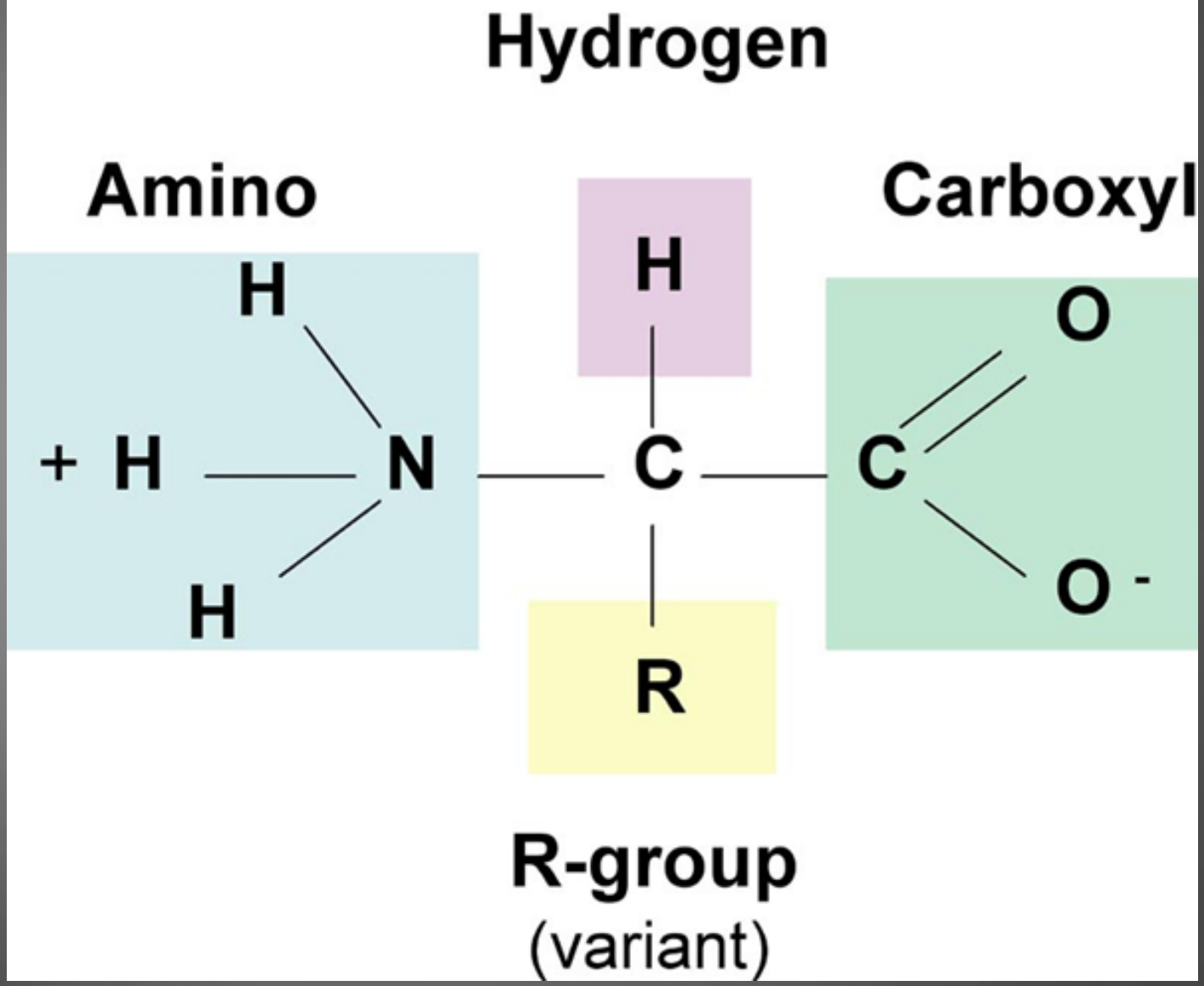
- Structural component of cells
- Predominant part of hair, skin, muscle and nerve
- Also include antibodies and enzymes
- Essential for the building, repair and maintenance of cell structure
- Are polymers or chains of amino acids (building blocks)
- Characterized by the sequence of amino acids it contains.

Amino Acid

- Amino group – NH2
- Acid group – COOH (carboxyl)



Amino Acid Structure

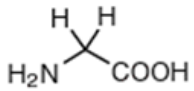


R-group
(variant)

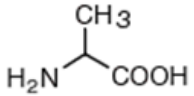
Amino Acid Structure

- R – remainder group
- *Example* – H, CH_3, CH_2CH_3
- All amino acids have an amino group and acid group, but vary in their R group.
- There are 20 amino acids, whose R groups vary from a single hydrogen atom to a ring structure.

Small

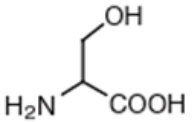


Glycine (Gly, G)
MW: 57.05

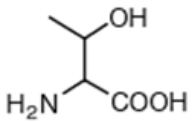


Alanine (Ala, A)
MW: 71.09

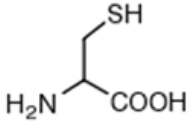
Nucleophilic



Serine (Ser, S)
MW: 87.08, pK_a ~ 16

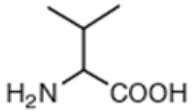


Threonine (Thr, T)
MW: 101.11, pK_a ~ 16

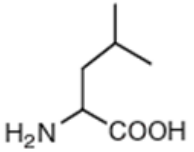


Cysteine (Cys, C)
MW: 103.15, pK_a = 8.35

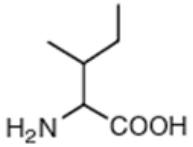
Hydrophobic



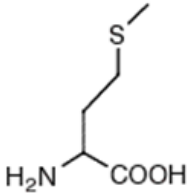
Valine (Val, V)
MW: 99.14



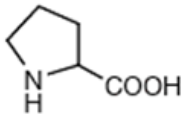
Leucine (Leu, L)
MW: 113.16



Isoleucine (Ile, I)
MW: 113.16

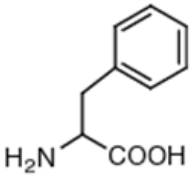


Methionine (Met, M)
MW: 131.19

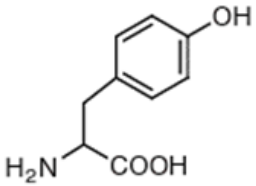


Proline (Pro, P)
MW: 97.12

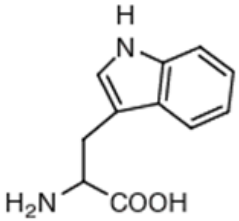
Aromatic



Phenylalanine (Phe, F)
MW: 147.18

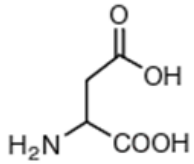


Tyrosine (Tyr, Y)
MW: 163.18

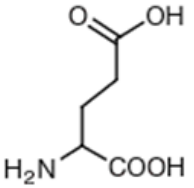


Tryptophan (Trp, W)
MW: 186.21

Acidic

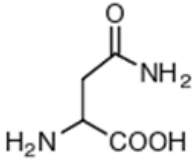


Aspartic Acid (Asp, D)
MW: 115.09, pK_a = 3.9

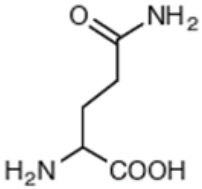


Glutamic Acid (Glu, E)
MW: 129.12, pK_a = 4.07

Amide

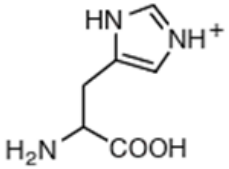


Asparagine (Asn, N)
MW: 114.11

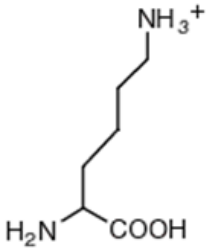


Glutamine (Gln, Q)
MW: 128.14

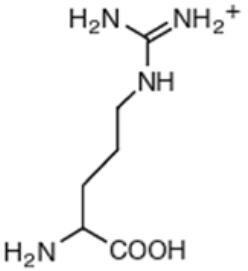
Basic



Histidine (His, H)
MW: 137.14, pK_a = 6.04



Lysine (Lys, K)
MW: 128.17, pK_a = 10.79

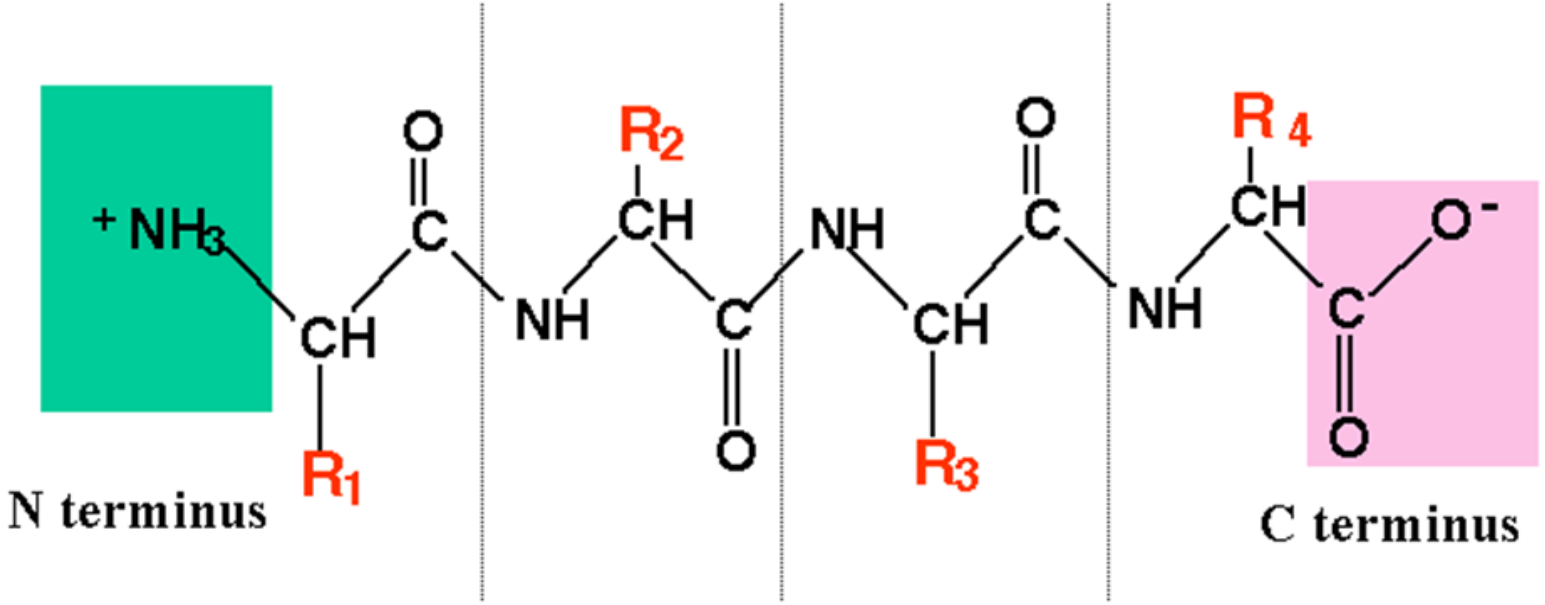


Arginine (Arg, R)
MW: 156.19, pK_a = 12.48

Proteins

- Peptide bond is a bond that holds together two amino acids
- Dipeptide is when two amino acids join together
- Polypeptide is a string of amino acids held together by a peptide bond

Peptide = chain of amino acids



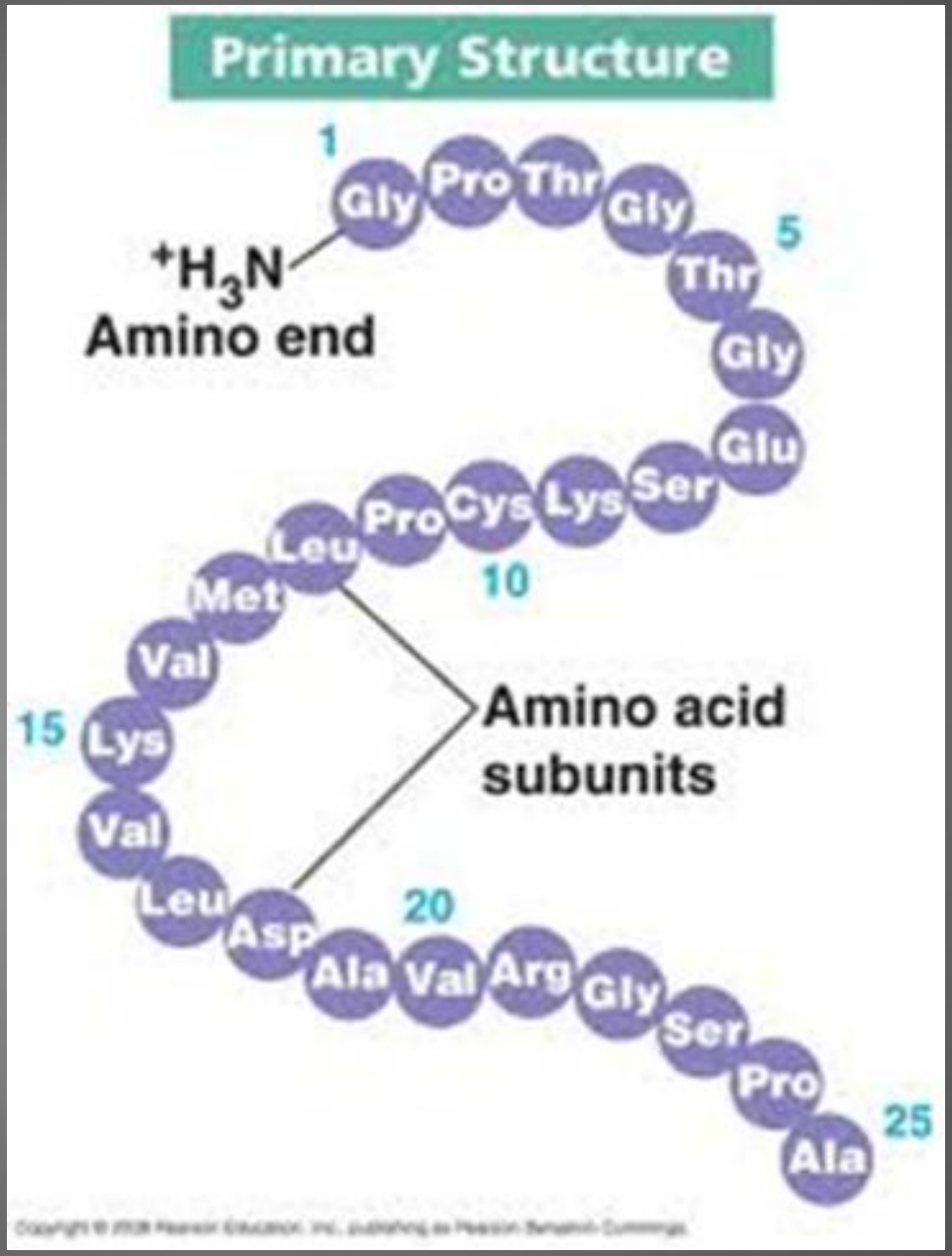
polypeptide chain

Proteins

- Proteins have several levels of organization

Primary Structure

- Amino acids joined by peptide bonds in a linear sequence

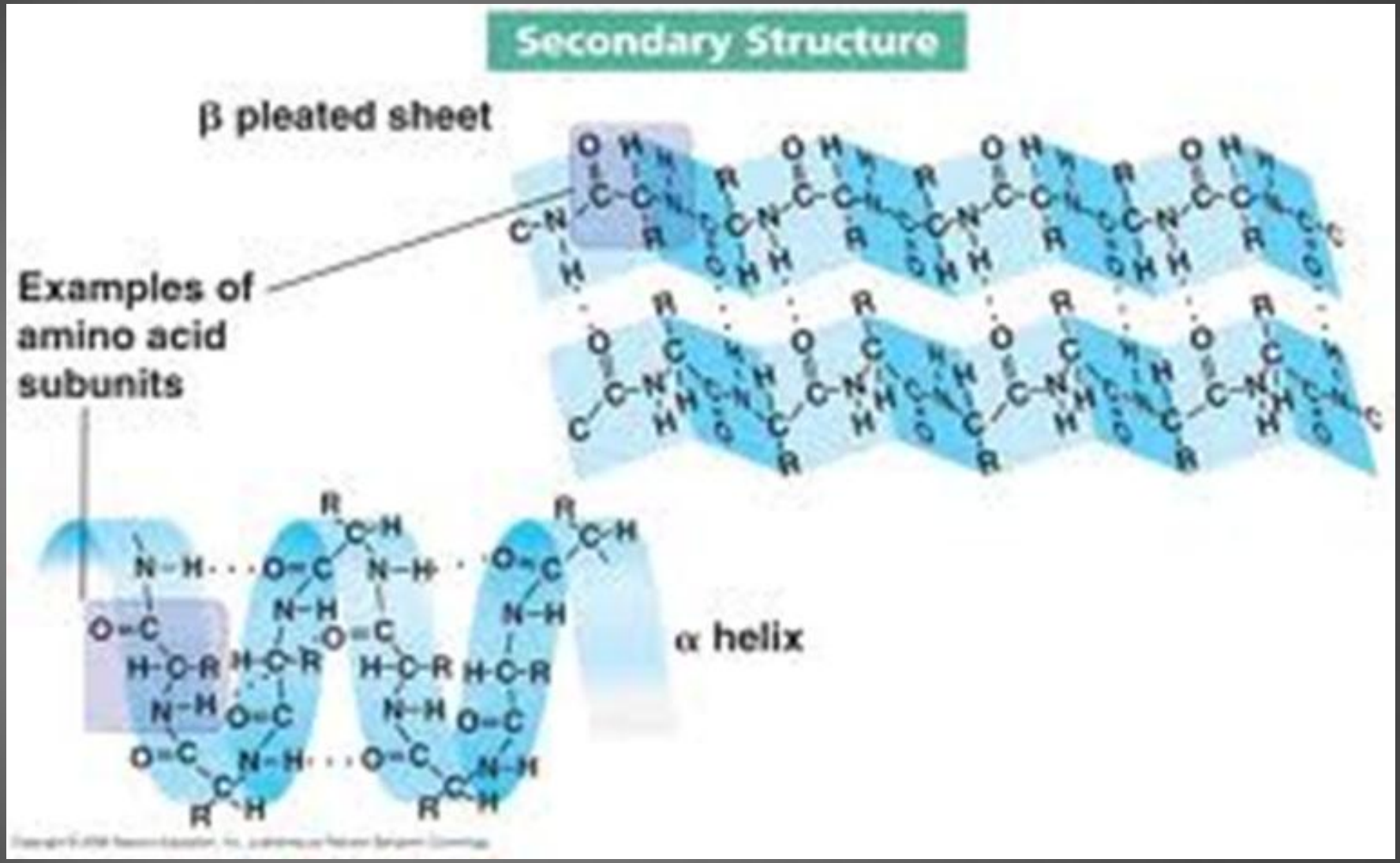

Primary Structure
1
Gly
Pro
Thr
Gly
5
Thr
Gly
Glu
Ser
Lys
Cys
Pro
Leu
10
Met
Val
15
Lys
Val
Leu
Asp
20
Ala
Val
Arg
Gly
Ser
Pro
25
Ala
+H3N
Amino end
Amino acid subunits

Proteins

Secondary Structure

- Proteins arranged in coils
- Hydrogen bonding between amino acids pulls the chain into helical coils or sheet-like chains.

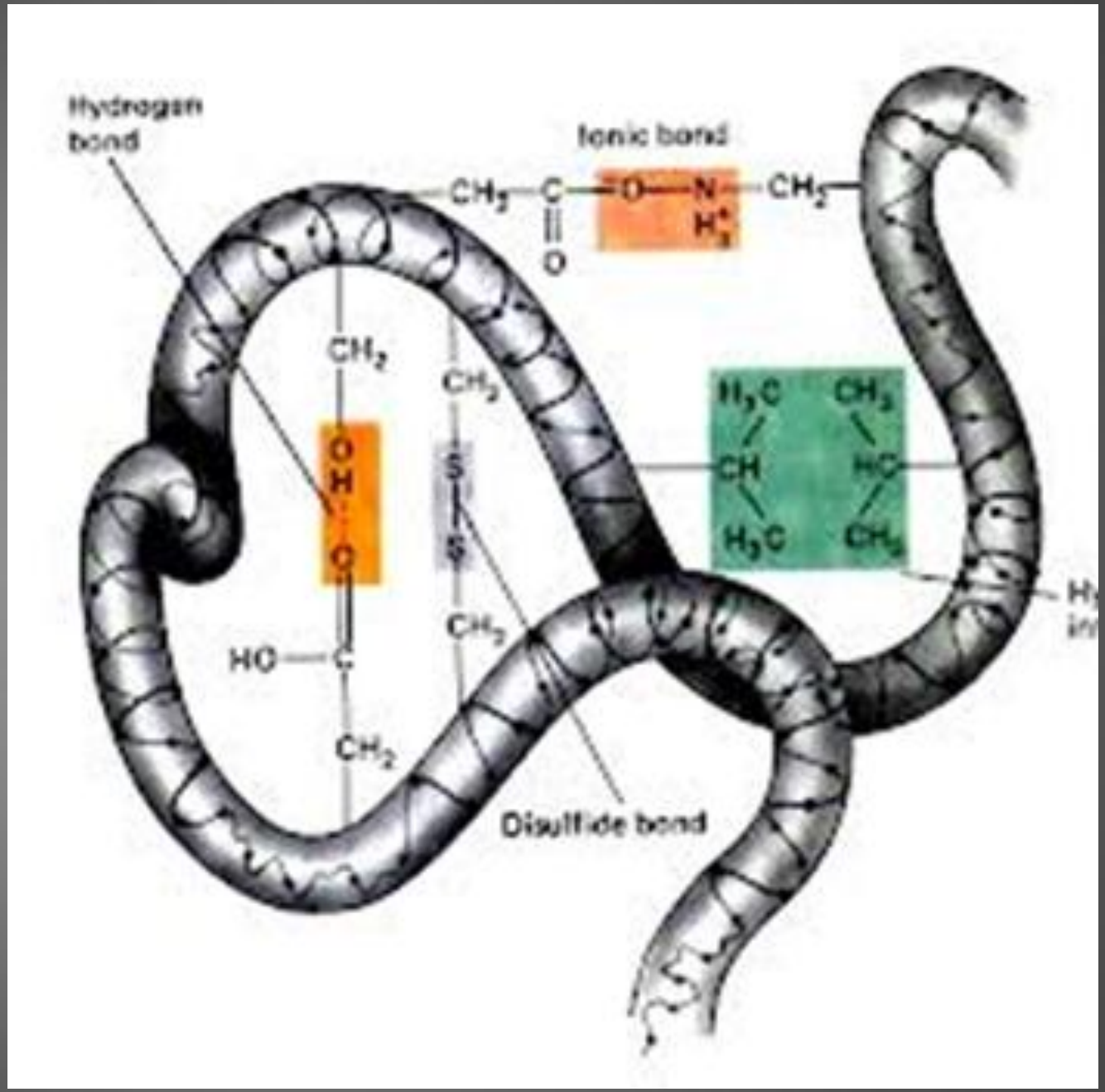
Secondary Structure



Proteins

Tertiary Structure

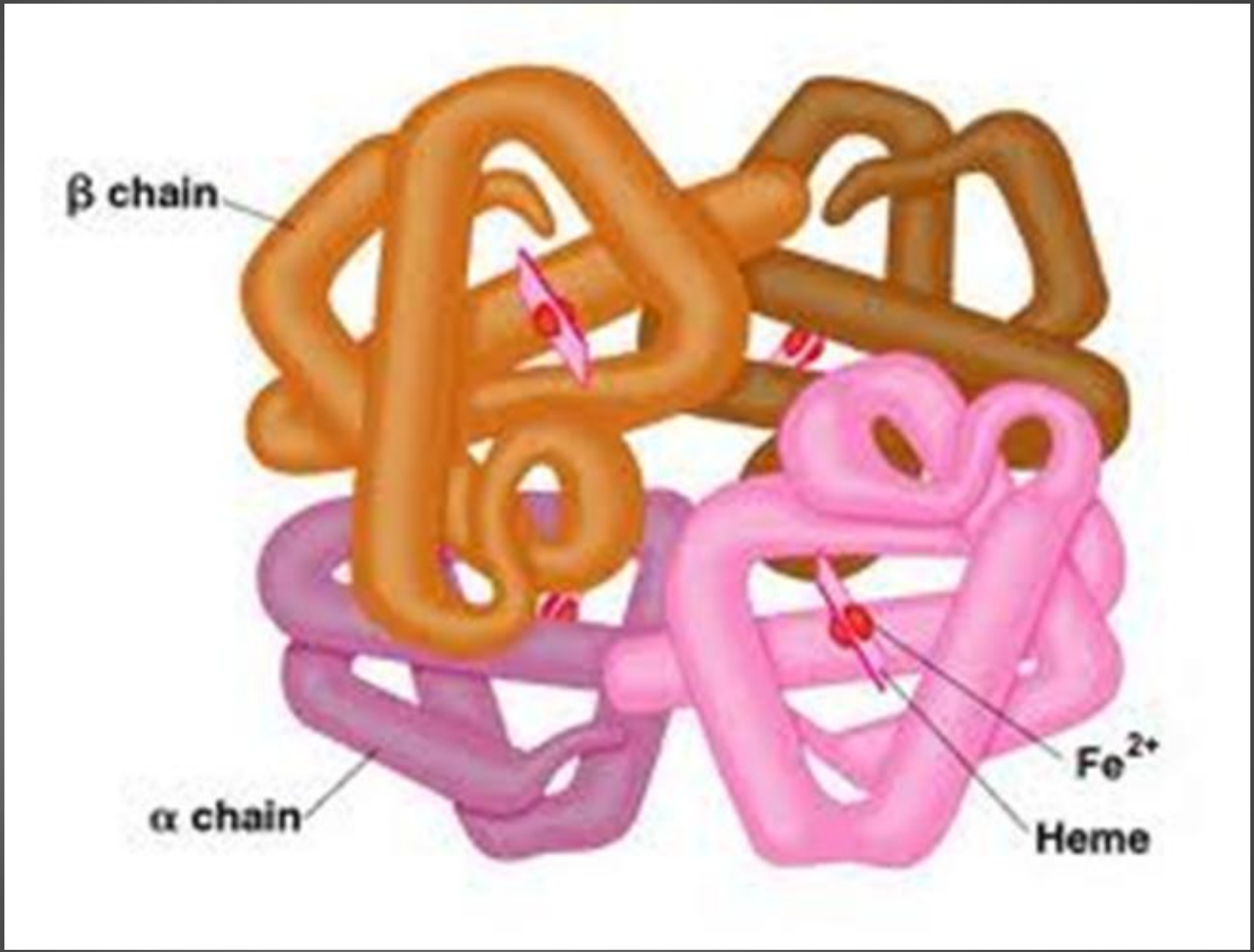
- This protein has a 3-D shape.
- Shape is maintained by various types of bonding between the R-groups (hydrogen, ionic and covalent)

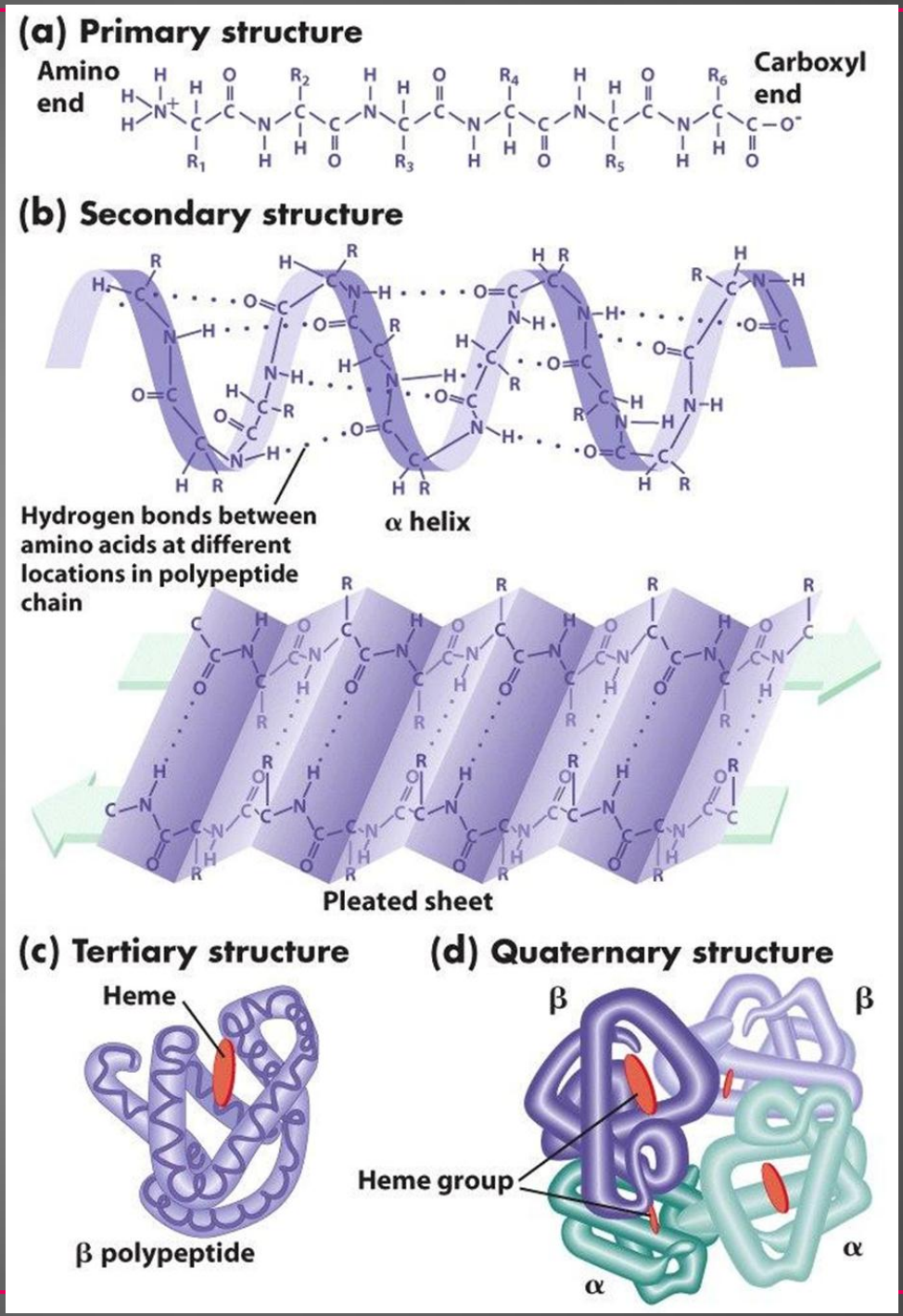

Hydrogen bond
Ionic bond
Disulfide bond

Proteins

Quaternary Structure

- These large globular proteins are formed due to the interactions between two or more different proteins
- The final shape of the protein is very important to function.
- When proteins are exposed to extreme pH or heat they denature.
- When a protein denatures it changes shape and the original shape can not be restored.
- Denaturation occurs when the normal bonding between the R-groups has been denatured.
- When a protein loses its normal shape, it can no longer perform its normal function.


β chain
α chain
Fe^{2+}
Heme


(a) Primary structure
Amino end
Carboxyl end
(b) Secondary structure
Hydrogen bonds between amino acids at different locations in polypeptide chain
α helix
Pleated sheet
(c) Tertiary structure
Heme
β polypeptide
(d) Quaternary structure
β
β
Heme group
α
α

Carbohydrates

- Always have the atomic group CH_2
- Ratio of hydrogen atoms to oxygen atoms is about 2:1
- If the number of carbon atoms in a molecule is low (3-7), the carbohydrate is a monosaccharide, or a simple sugar.
- Larger carbohydrates are formed when monosaccharides are joined into a synthesis reaction.
- Carbohydrates are source of fast, short term energy
- However they combine with other molecules to serve a structure purpose in the body as well.

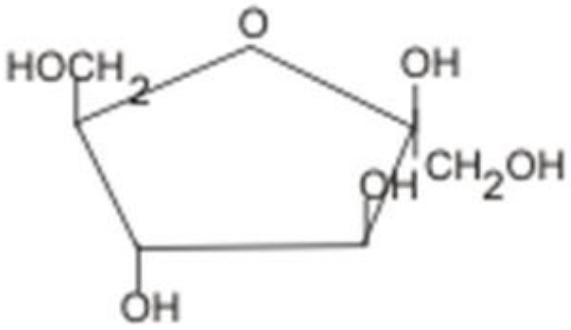
Carbohydrates

Monosaccharide

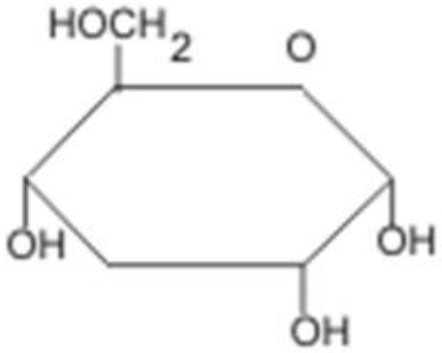
- Means "one sugar"
- Known as simple sugars
- Their name can tell us the number of carbon atoms they contain
- *Example* – pentose sugars such as ribose are named because they contain 5 carbon atoms.
- Hexose sugars, such as glucose contain 6 carbon atoms.
- Glucose is the primary energy source for the body

Carbohydrates

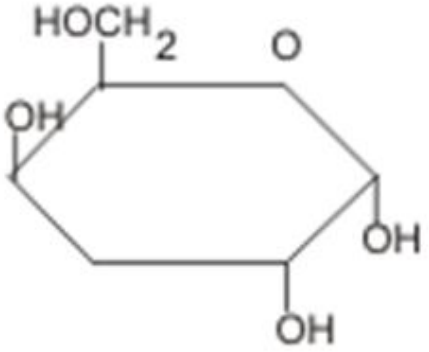
- Most carbohydrate polymers can be broken down into monosaccharaides that are or can be converted into glucose.
- Common monosaccharides are fructose (fruit) and galactose(milk)
- Monosaccharides all have a ring structure $C_6H_{12}O_6$, but the shape of the ring and/or the arrangement of the hydrogen and hydroxyl (OH) groups attached to the rings are different



Fructose



Glucose



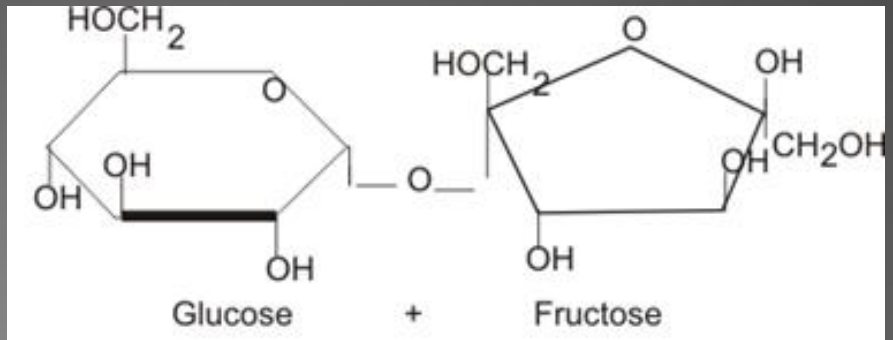
Galactose

Monaosaccharides

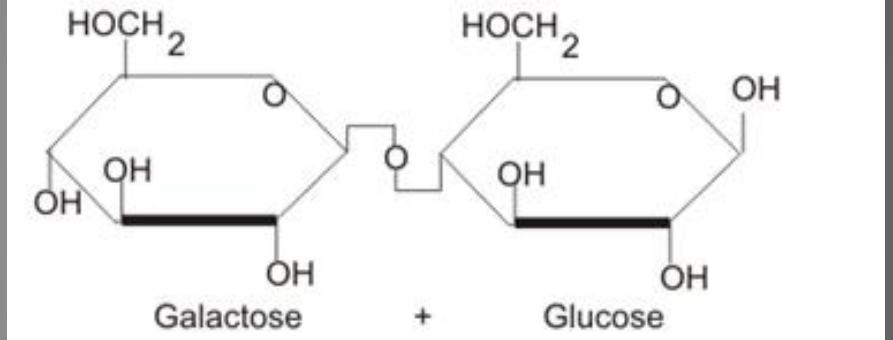
Carbohydrate

Dissacharides

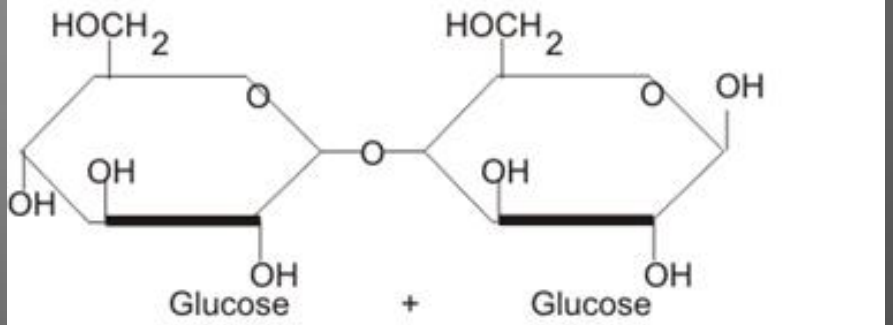
- Contain two monosaccharides
- 2 glucose join → maltose
- Glucose + fructose → sucrose



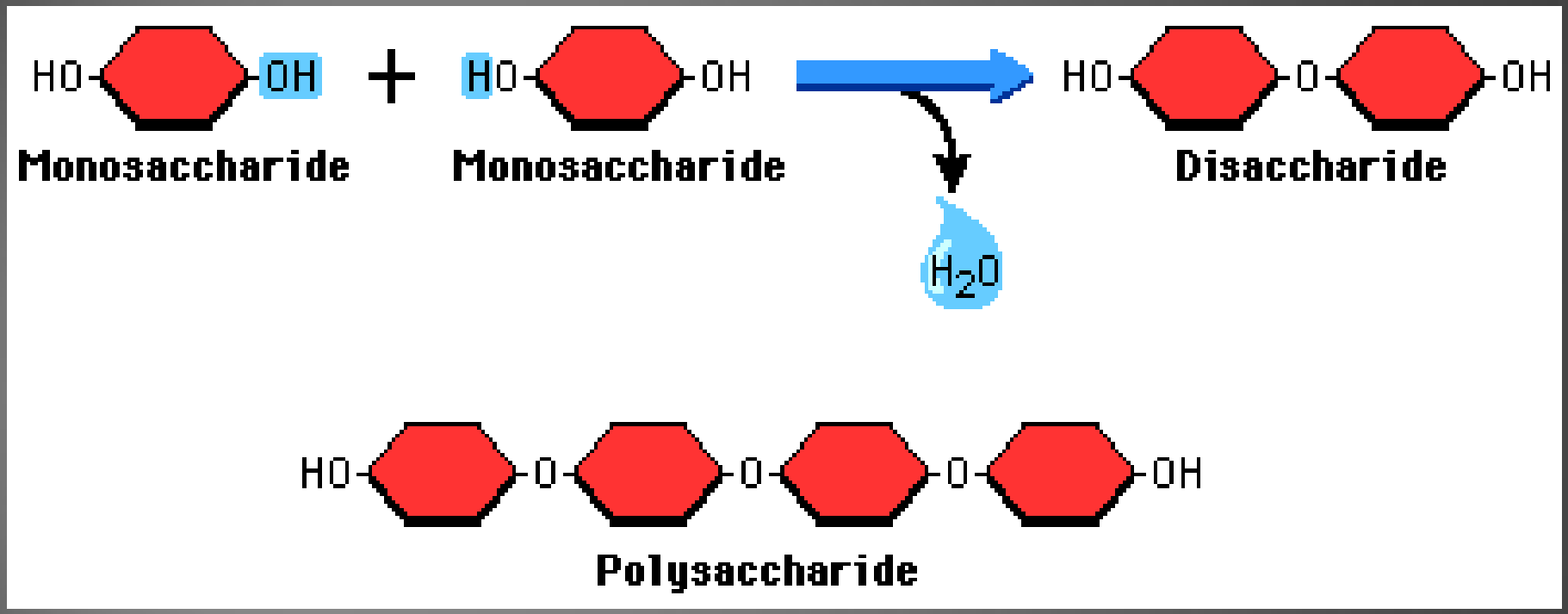
Sucrose



Lactose



Maltose

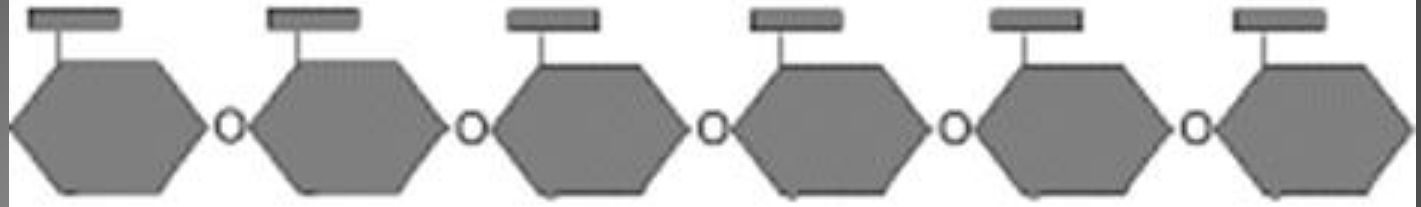

HO
OH
Monosaccharide
HO
OH
Monosaccharide
H_2O
HO
O
OH
Disaccharide
HO
O
O
O
OH
Polysaccharide

Carbohydrates

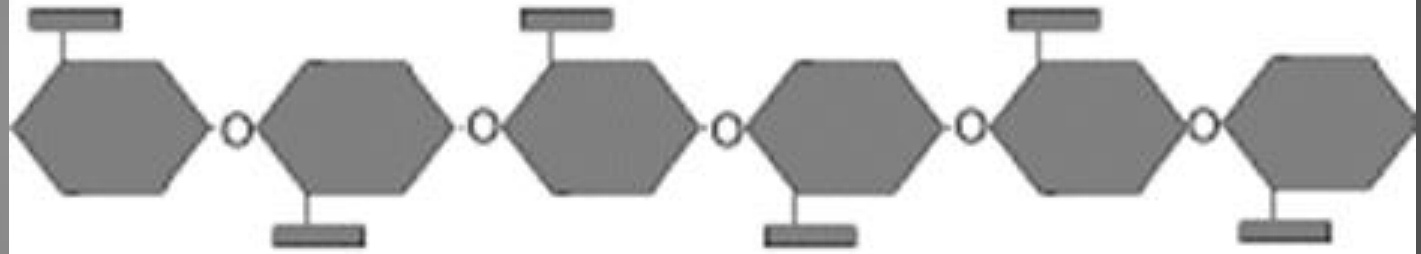
Polysaccharide

- Polymers of monosaccharidese
- 3 polysaccharides are common in organisms
  - starch
  - glycogen
  - cellulose
- They are all chains of glucose but in different forms.

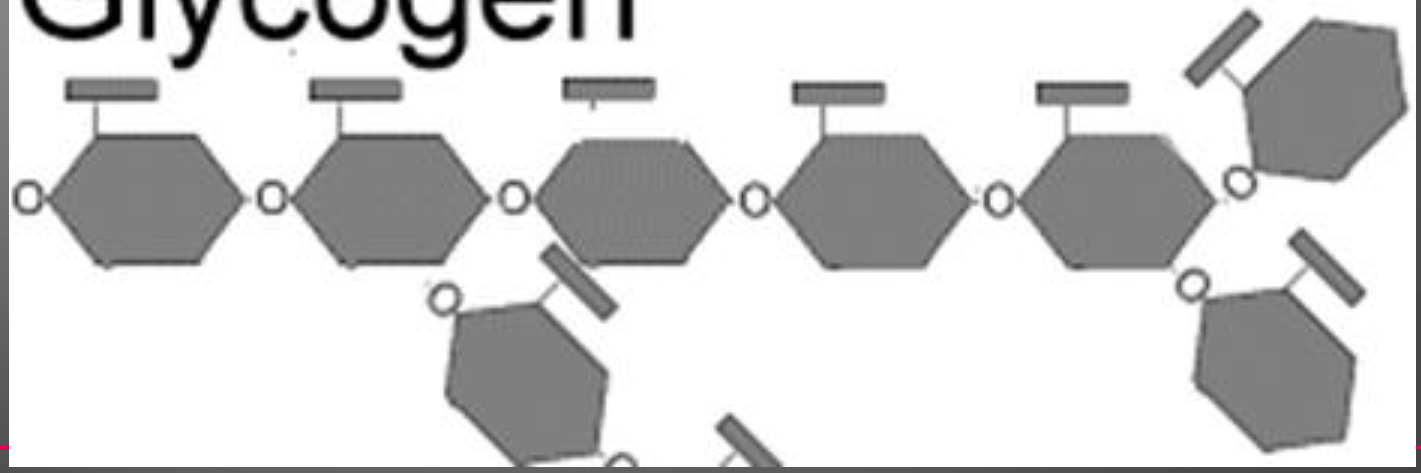
Starch



Cellulose



Glycogen



Carbohydrates

Starch

- Has a few chains of glucose that branch of the main chains
- Storage chain of glucose in plants

- Glycogen
- Has many side chains of glucose
- Storage form of glucose in animals
- Liver stores glucose as glycogen, between eating, the liver releases glucose so that the sugar level in blood is always approximately 0.1%

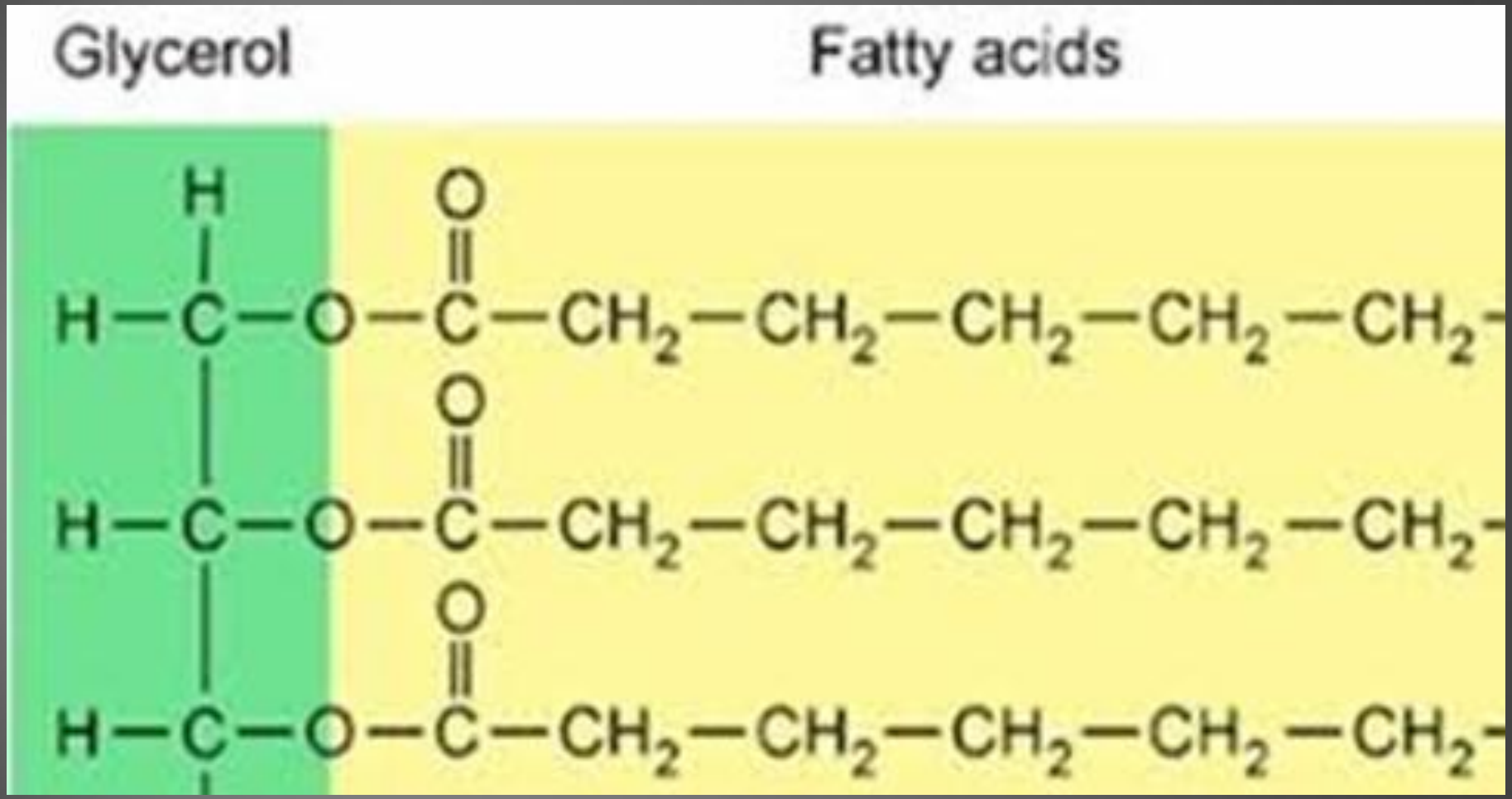
Carbohydrates

Cellulose

- Found in plant cell walls, provides strength to the cell walls
- Cellulose are linked by different linkage that is not starch or glycogen
- Reason humans can not digest cellulose
- Humans are unable to digest food with the type of linkage

Lipids

- Made up of 3 fatty acids and a glycerol
- Water soluble
- At room temperature: fats are solid, oils are liquid
- Fat is used for long term energy storage, cushion for organs and insulation from heat loss


Glycerol
Fatty acids

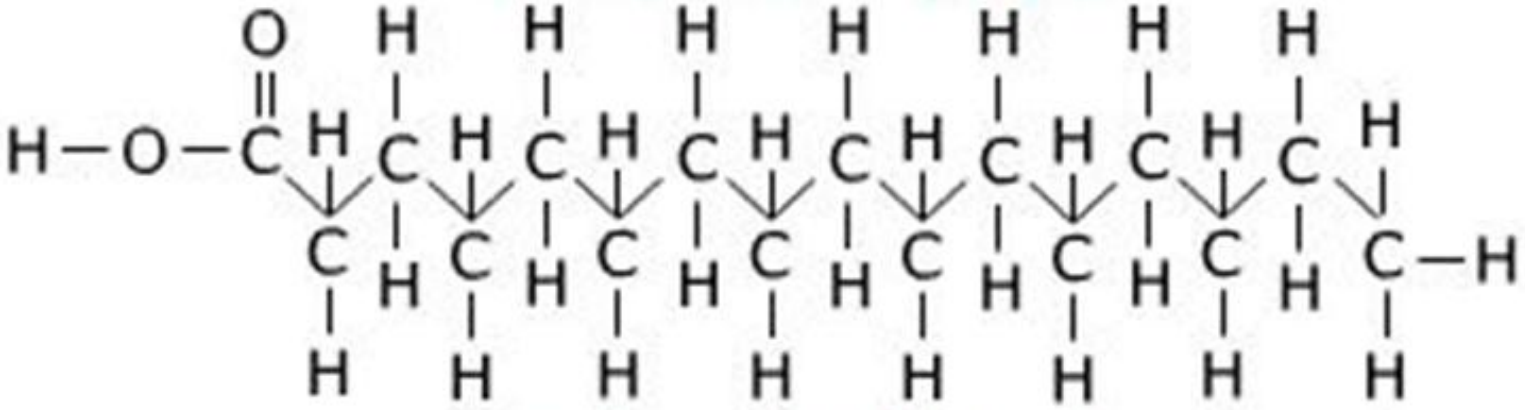
Lipids

Fatty Acids

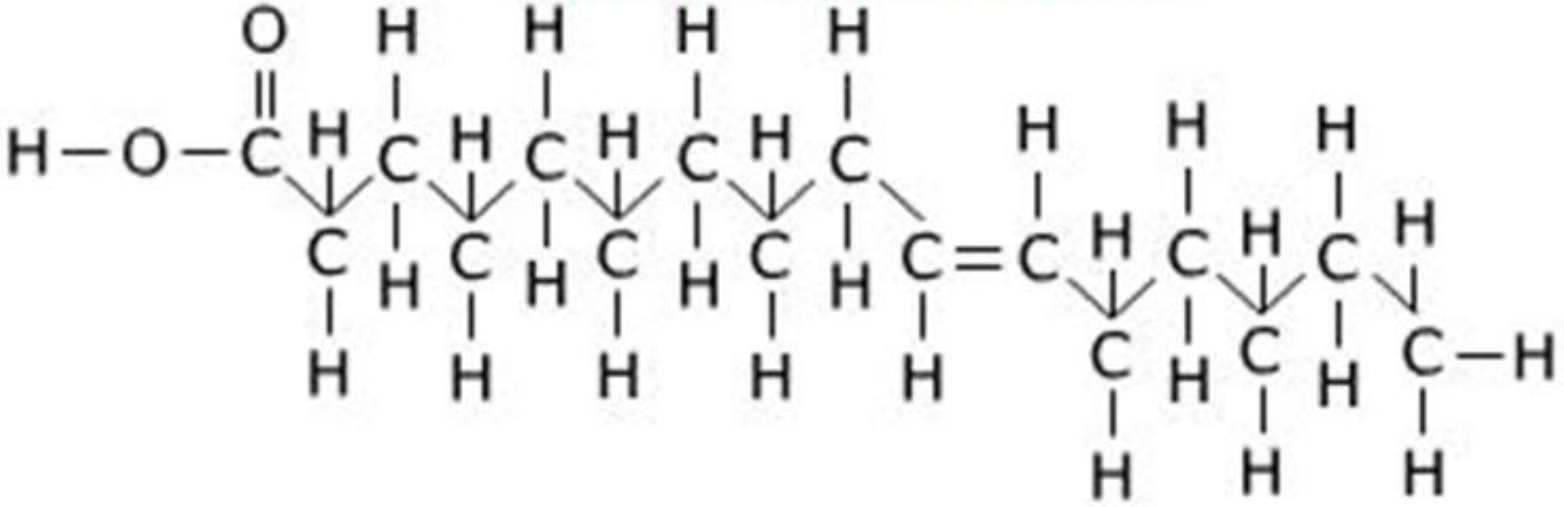
- A hydrocarbon chain with a carboxyl (acid) end group
- Usually contains between 16-18 carbon atoms
- Can be saturated - no bonds between carbon atoms
- Can be unsaturated - have bonds between carbons wherever the number of hydrogen atoms is less than two per carbon atom

Fatty Acids

Saturated Fatty Acids



Unsaturated Fatty Acids



Lipids

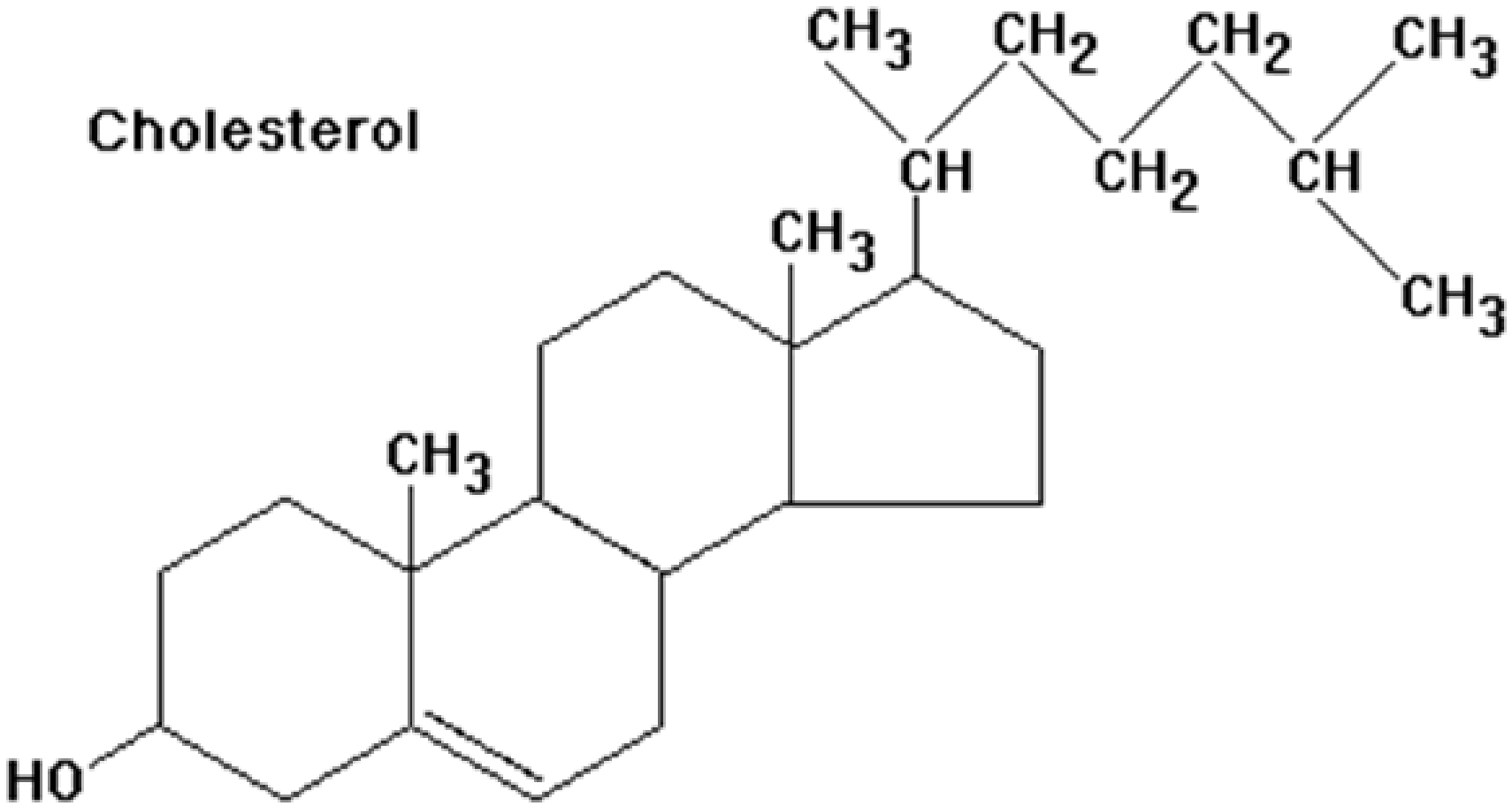
Phospholipids

- Contain a phosphate group
- Phosphate groups forms "head" of molecules which is polar, rest of molecule makes up non-polar "tails"

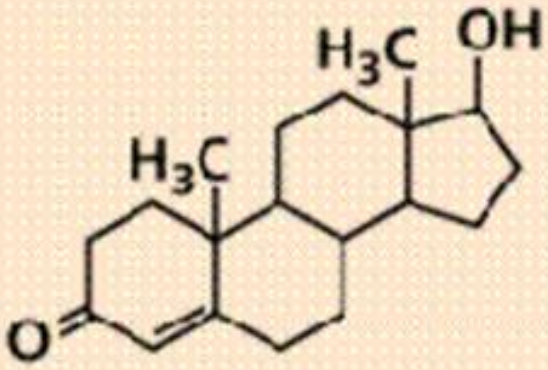
Steroids

- Lipids with a structure that varies greatly from that of fats
- Have a backbone of 4 fuses carbon rings, each one differing primarily by the arrangement of atoms in the rings and the type of functional groups attached to them
- Cholesterol is a precursor of several other steroids

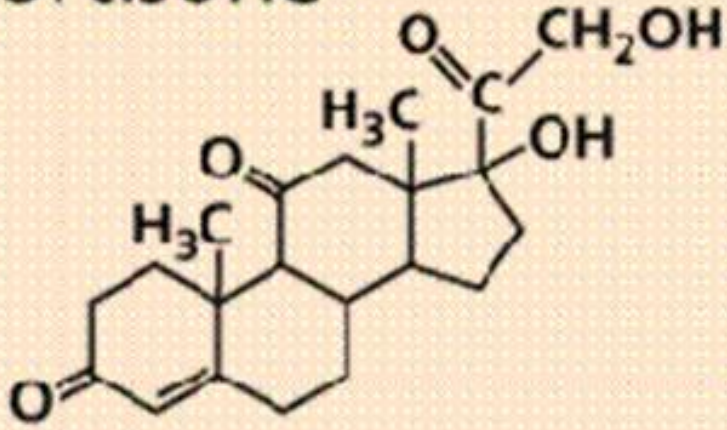
Cholesterol



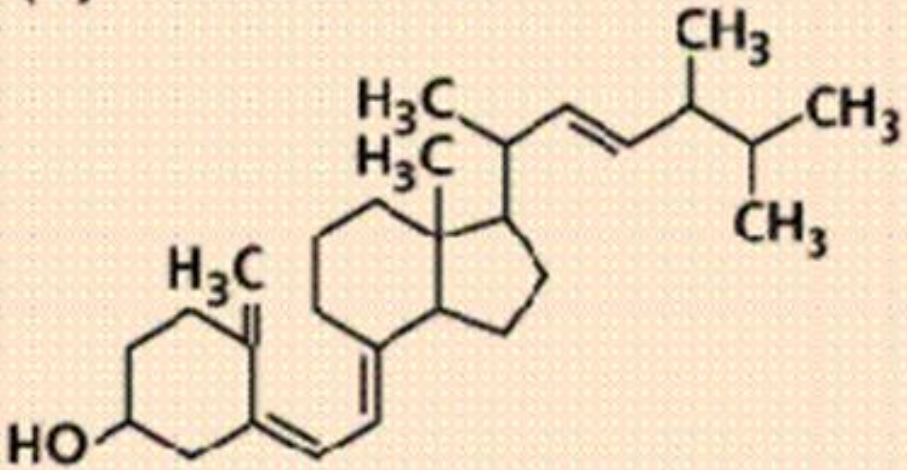
(a)Testosterone



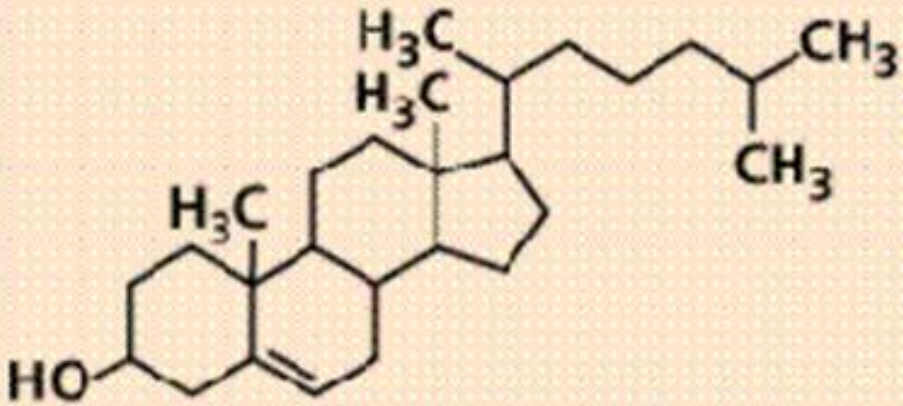
(b)Cortisone



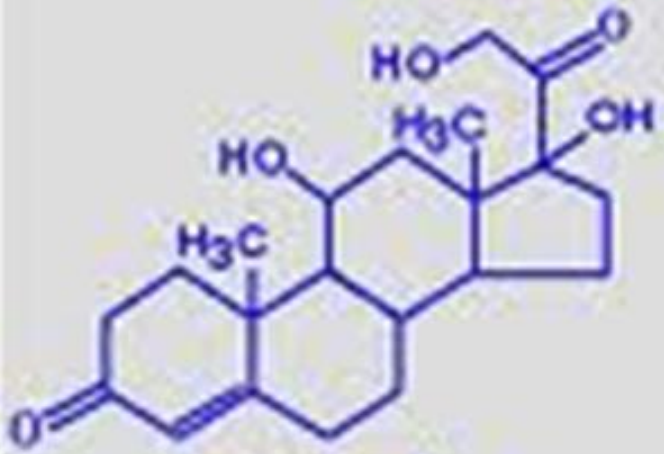
(c)Vitamin D



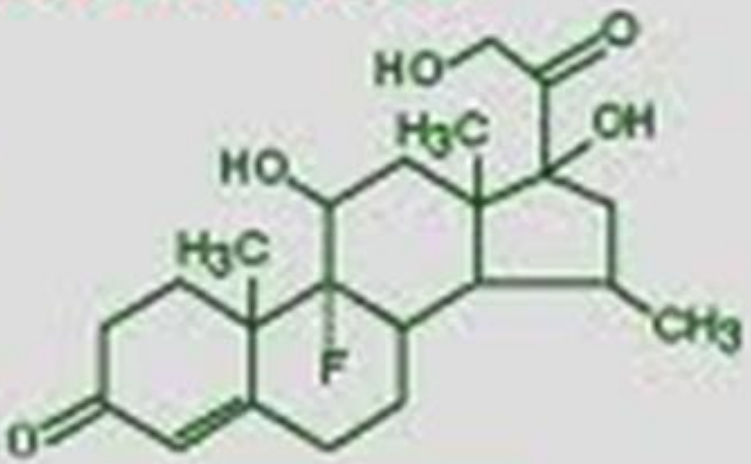
(d)Cholesterol



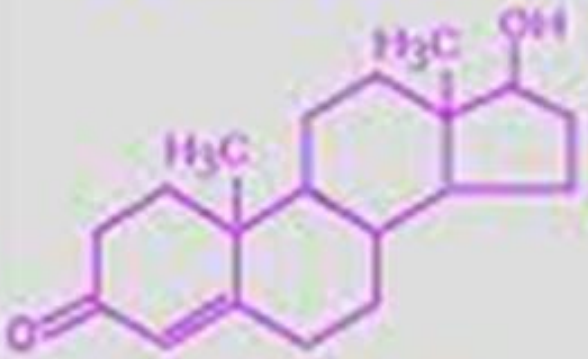
Some Steroid Hormones



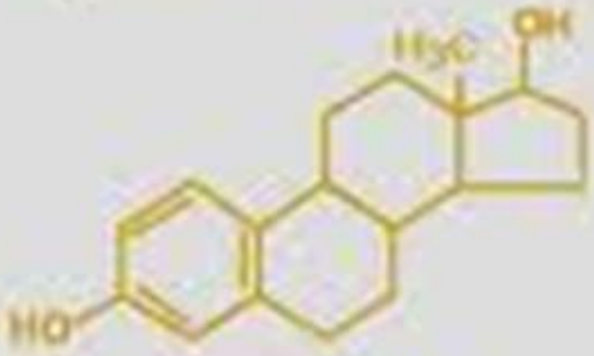
cortisol
(a glucocorticoid)



dexamethasone
(a cortisone analogue)



testosterone
(an androgen)



estradiol
(an estrogen)

Lipids

Soap

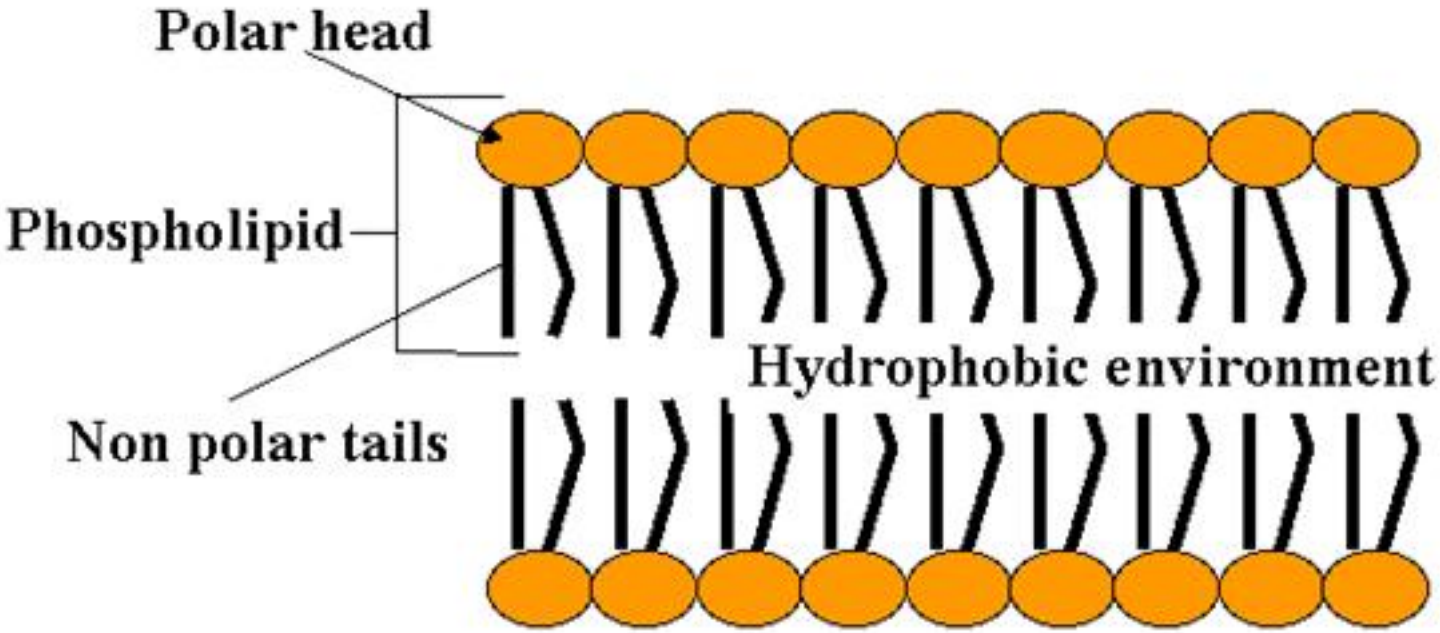
- Is made up of a fatty acid and an inorganic base
- Soap has a non-polar end and a polar end (charged end)
- The non-polar end is a hydrocarbon chain represented in diagram by R
- The polarity of soap allows soap to mix with water
- Since fats are non-polar they do not mix with water
- If soap is added to an oil/water mixture, the oil will not miss with the water
- This is called emulsification
- This occurs when the non- polar ends of the emulsifier (soap) are attracted to the no- polar fat and the polar ends are attracted to the water.

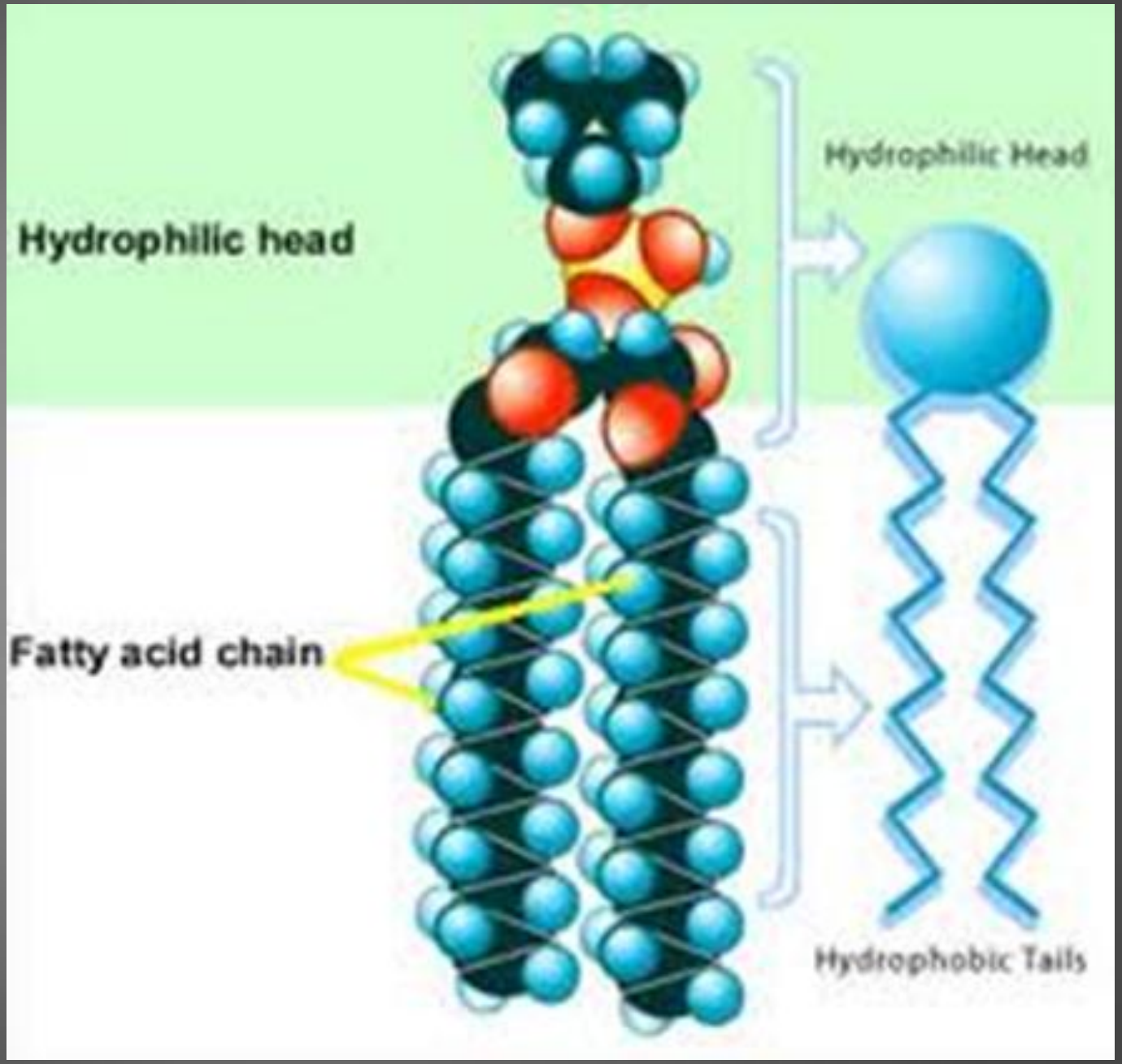
Lipids

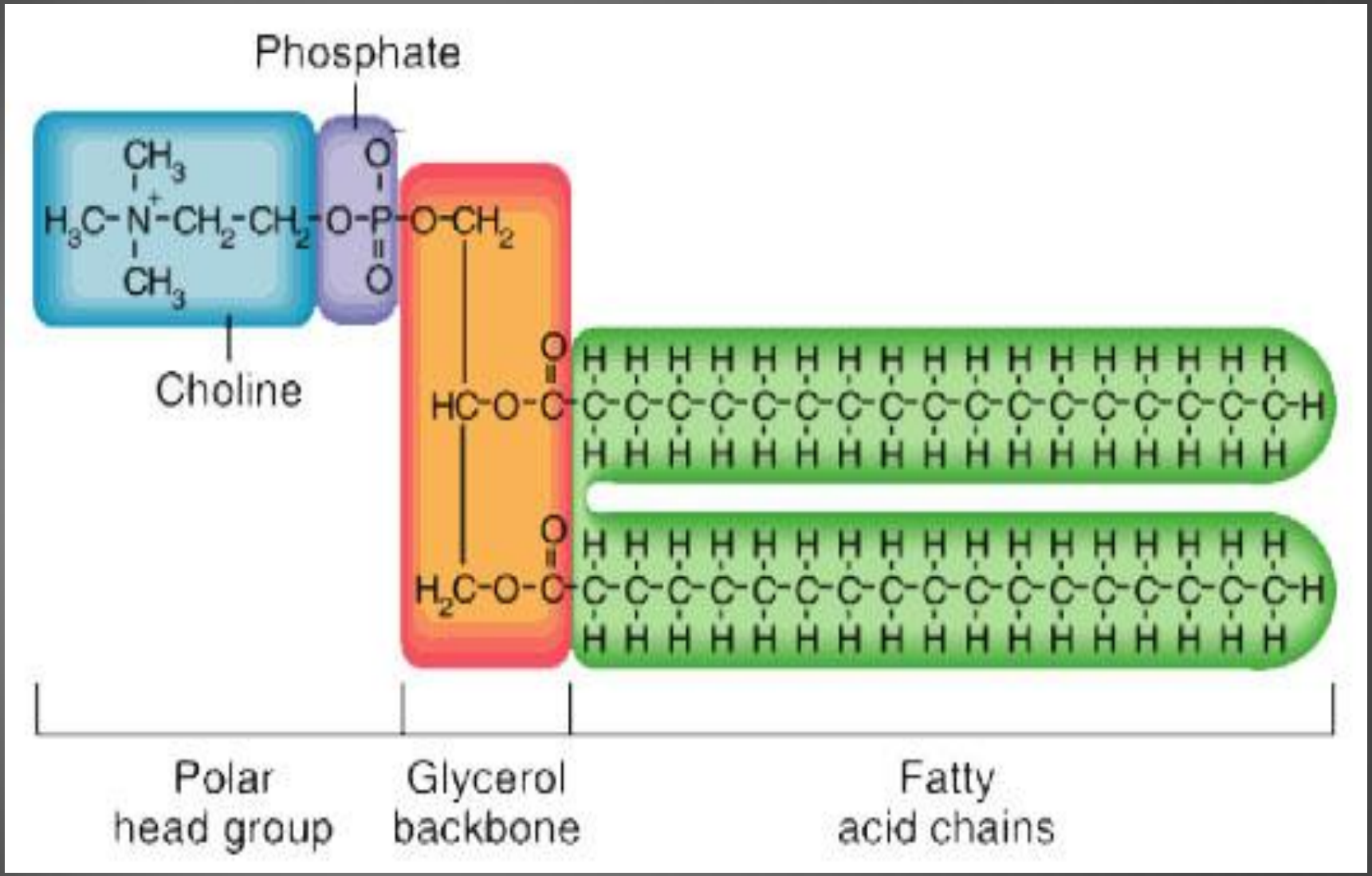
Other Phospholipids

- Contain a phosphate group and a nitrogen group
- Constructed like fats, except the third fatty acid is replaced by a phosphate group.
- Not neutral like other fats because phosphate and nitrogen are ionized.
- Phosphate and nitrogen form hydrophilic head (water-loving) and a hydrophobic tail.
- Makes up cell membrane

Plasma membrane




Hydrophilic head
Fatty acid chain
Hydrophilic Head
Hydrophobic Tails


Phosphate
Choline
Polar
head group
Glycerol
backbone
Fatty
acid chains

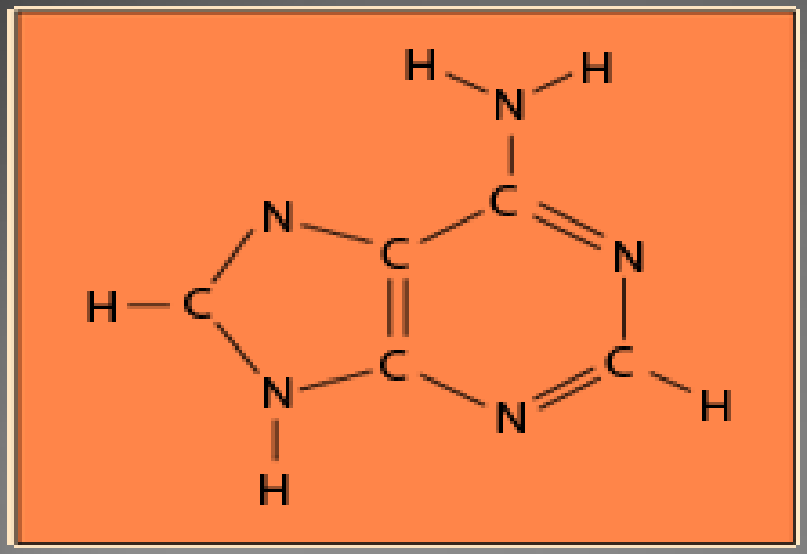
Nucleic Acid

- Important for growth and reproduction of cells and organisms
- Human genes are made up of nucleic acids called DNA
- DNA – deoxyribonucleic acid
- RNA works with DNA to produce proteins
- RNA – ribonucleic acid
- DNA and RNA are made up of nucleotides
- Nucleotides are linked together to form nucleic acids by dehydration synthesis

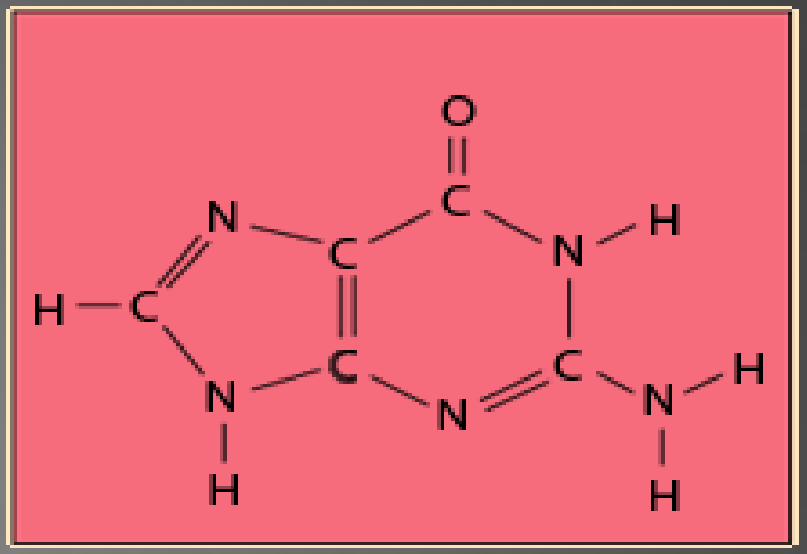
Nucleic Acid

Nucleotides

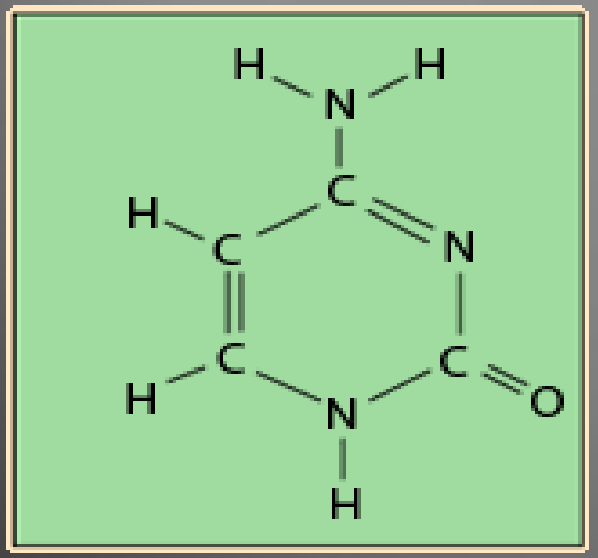
- Contain three types of molecules: a phosphate group, a pentose sugar and a nitrogen-containing organic base
- Adenine – A
- Thymine – T
- Guanine – G
- Cytosine – C
- In DNA the sugar is deoxyribose
- In RNA, the sugar is ribose
- In both DNA and RNA the base can have either single of double rings
- **Remember purines and pyrimidines**



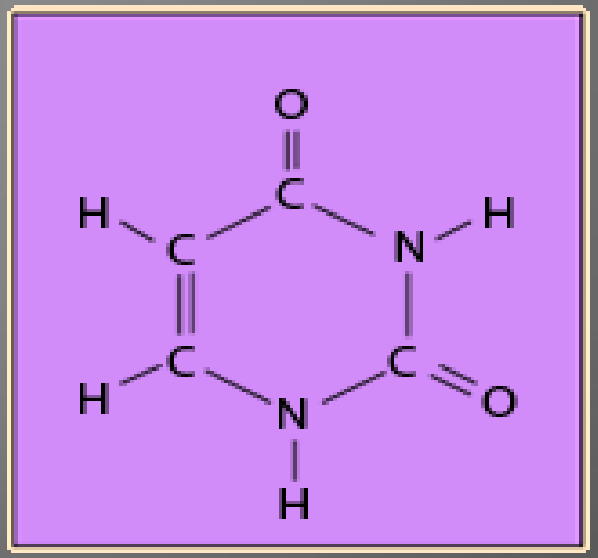
Adenine



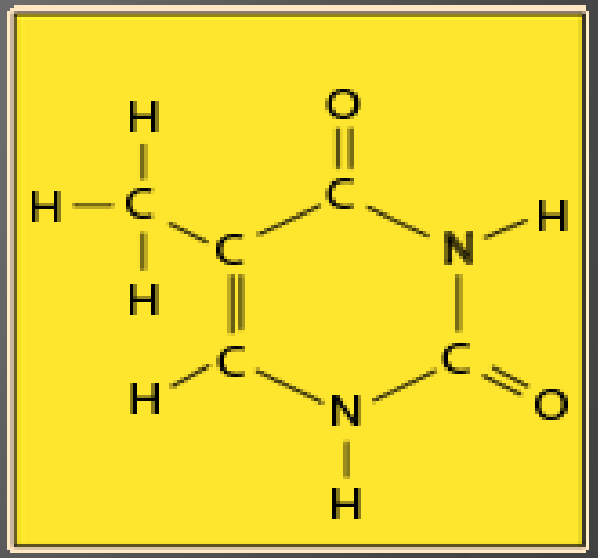
Guanine



Cytosine



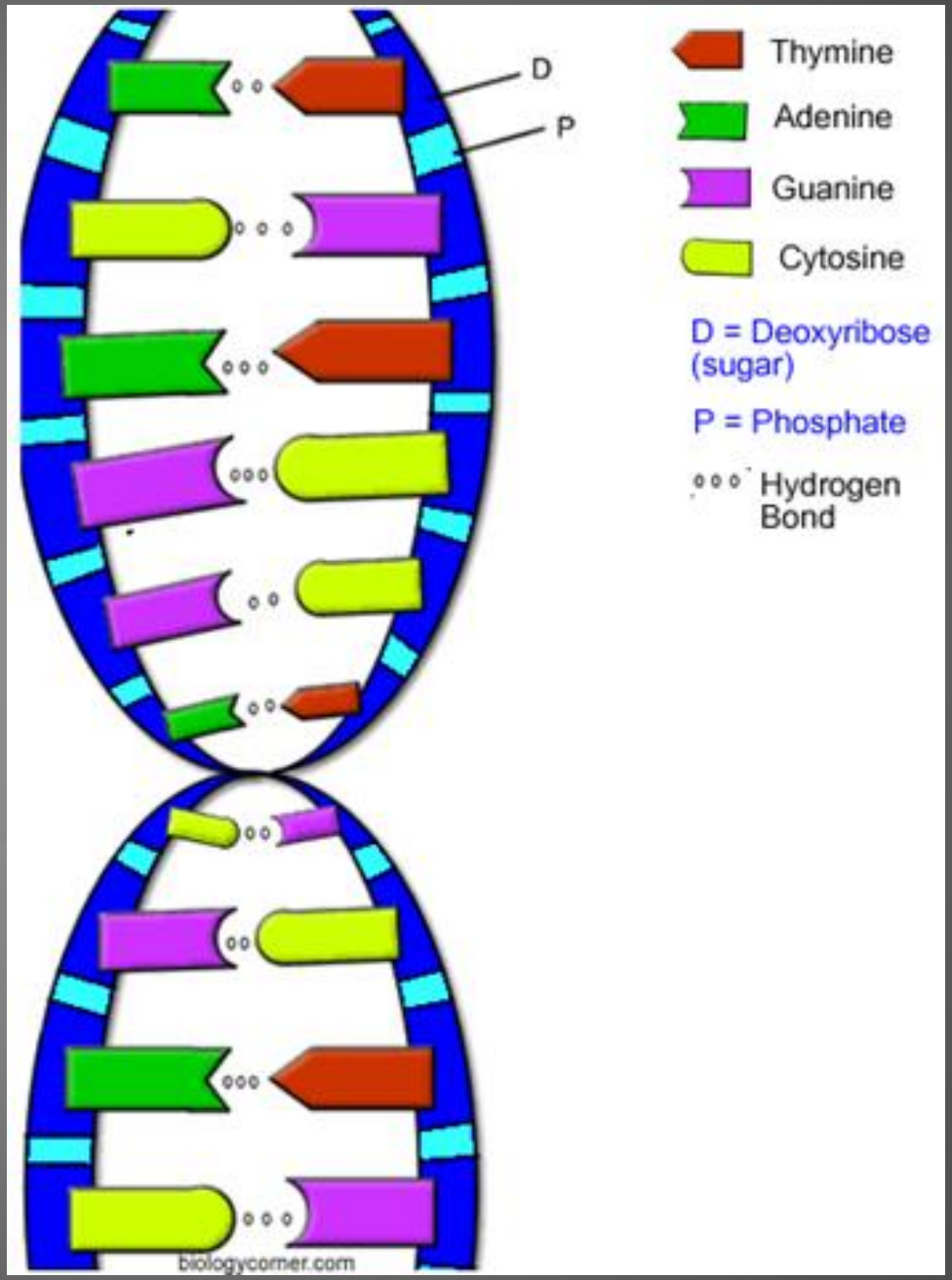
Uracil



Thymine

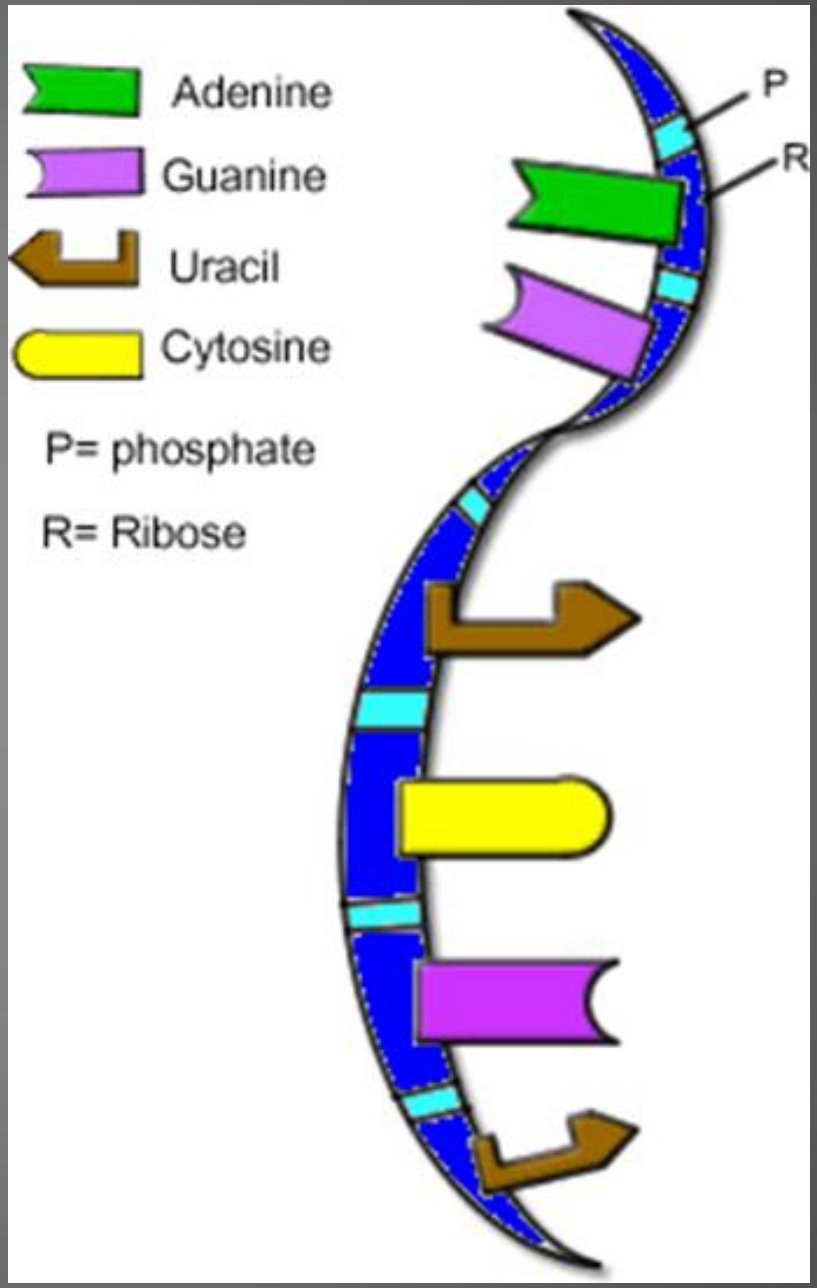
Nucleic Acid

- When nucleotides join, they form a macromolecule called a stand or DNA “backbone”
- This “backbone” is made up of alternating phosphate a sugar
- DNA is double started, the strands are held together by hydrogen bonding between bases.


D
P
Thymine
Adenine
Guanine
Cytosine
D = Deoxyribose (sugar)
P = Phosphate
Hydrogen Bond
biologycorner.com

Nucleic Acid

- RNA is single stranded
- There is also a change in the nitrogen bases, there is no thymine.
- Thymine is replaced with a base called uracil

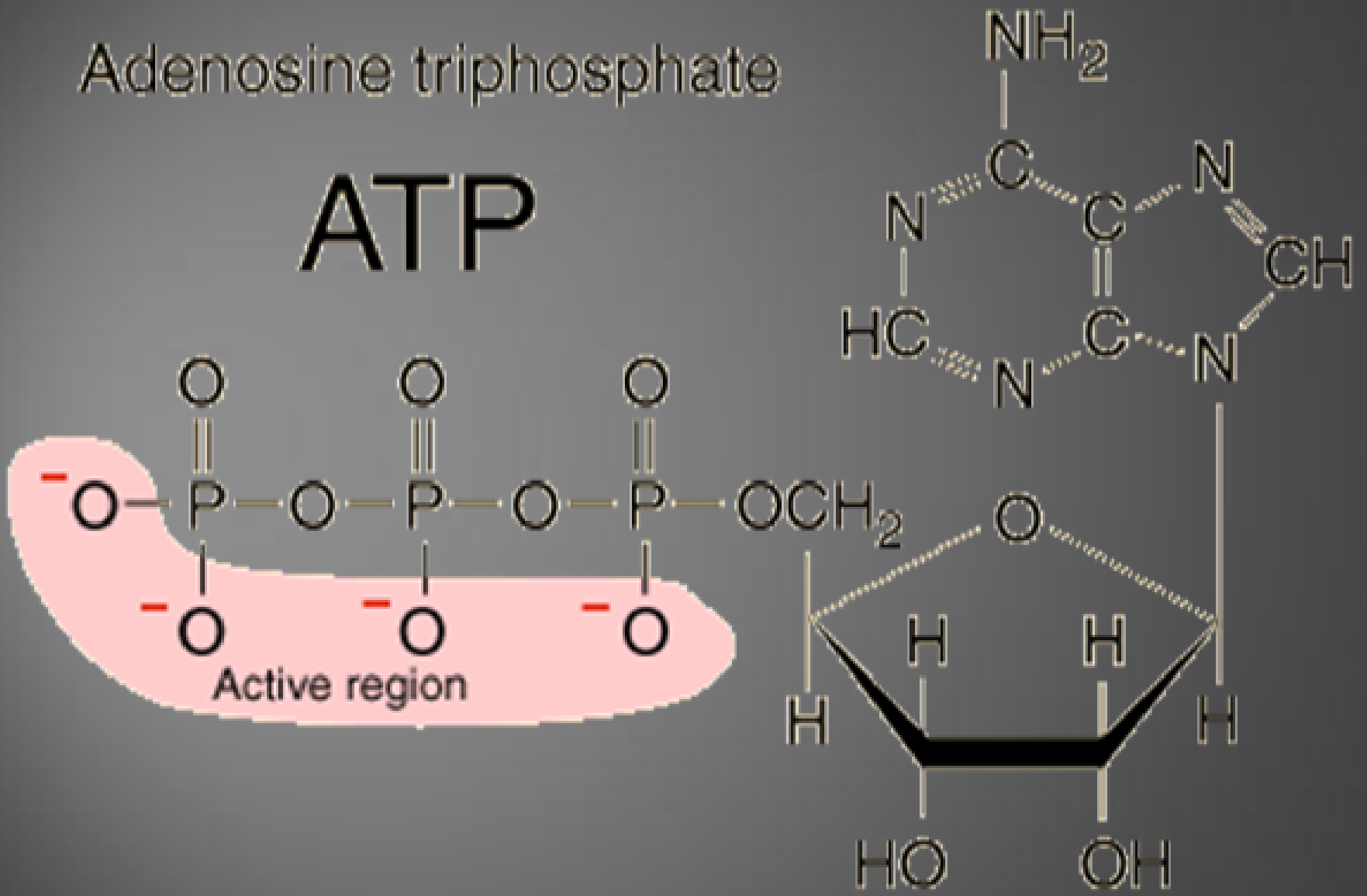

Adenine
Guanine
Uracil
Cytosine
P= phosphate
R= Ribose
P
R

ATP (Adenosine Triphosphate)

- A nucleotide that functions as an energy carrier of cells
- The base adenine is joined to the sugar ribose (together they are known as adenosine)
- Has three phosphate groups
- There are two high-energy bonds between the phosphates and when these bonds break energy is released.

Adenosine triphosphate

ATP



Review

Macromolecules	Monomers (building blocks)
proteins	amino acids
carbohydrates	monosaccharides
lipids	glycerol and fatty acids
nucleic acids	nucleotide