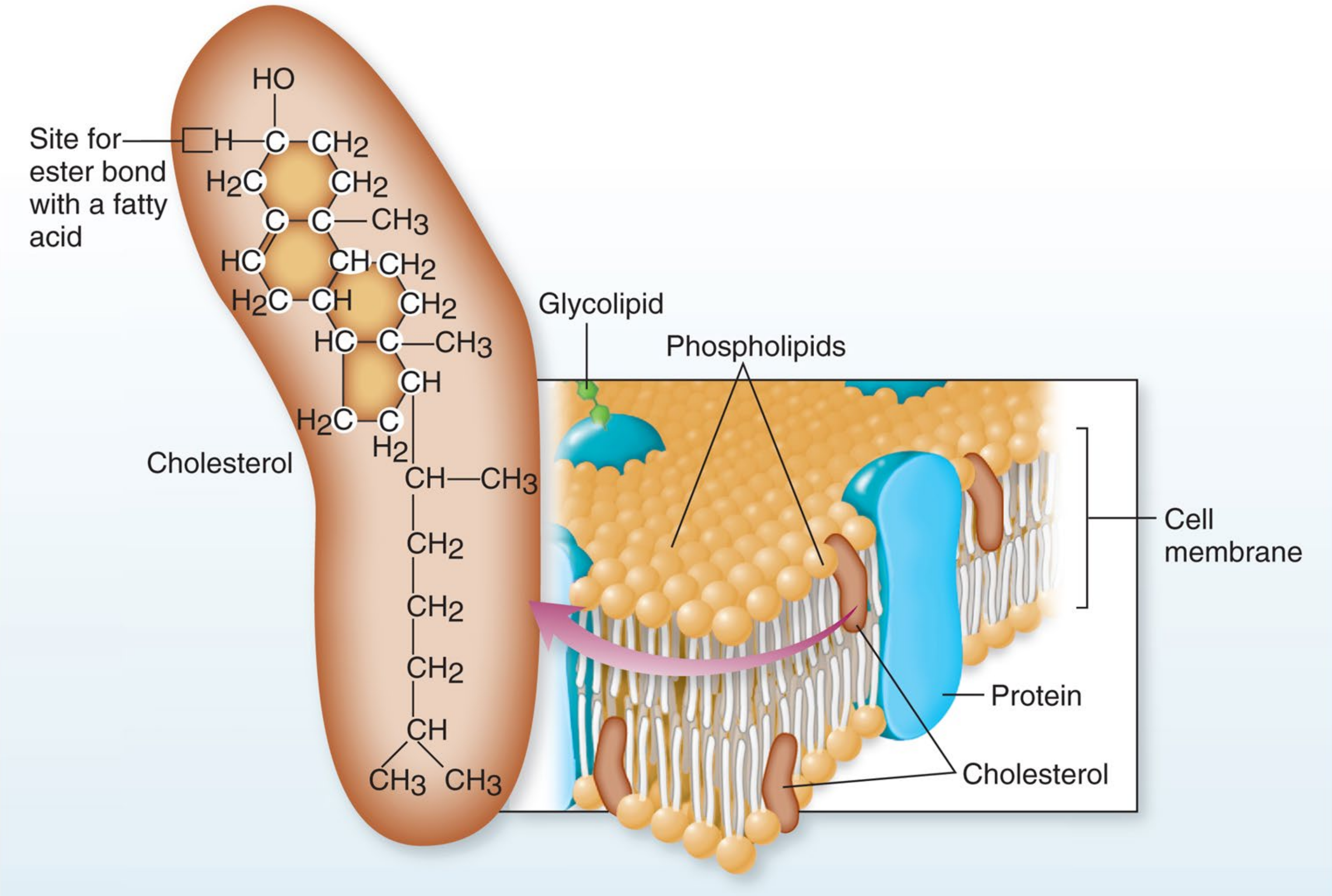
Chapter 2

Organic Chemistry



Organic Chemistry

Study of compounds containing carbon and hydrogen

Four categories of organic compounds

- carbohydrates
- lipids
- proteins
- nucleic acids

Is CO2 (carbon dioxide) an organic molecule?

See Web Site PowerPoint = “Know Your Molecules”

Monomers VS Polymers

Monomers – a small identical molecules (similar subunits) - e.g
amino acid or glucose molecule

Polymers – molecules made of a repetitive series of identical subunits // e.g. polypeptide

An amino acid is a monomer that forms the protein polymer

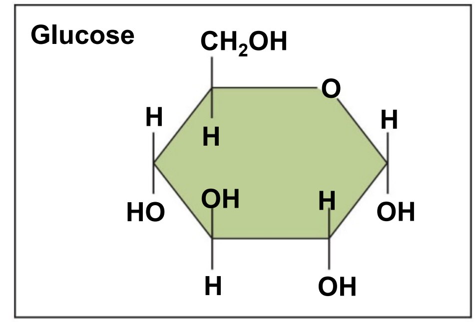
Glucose is a monomer that forms the glycogen polymer.

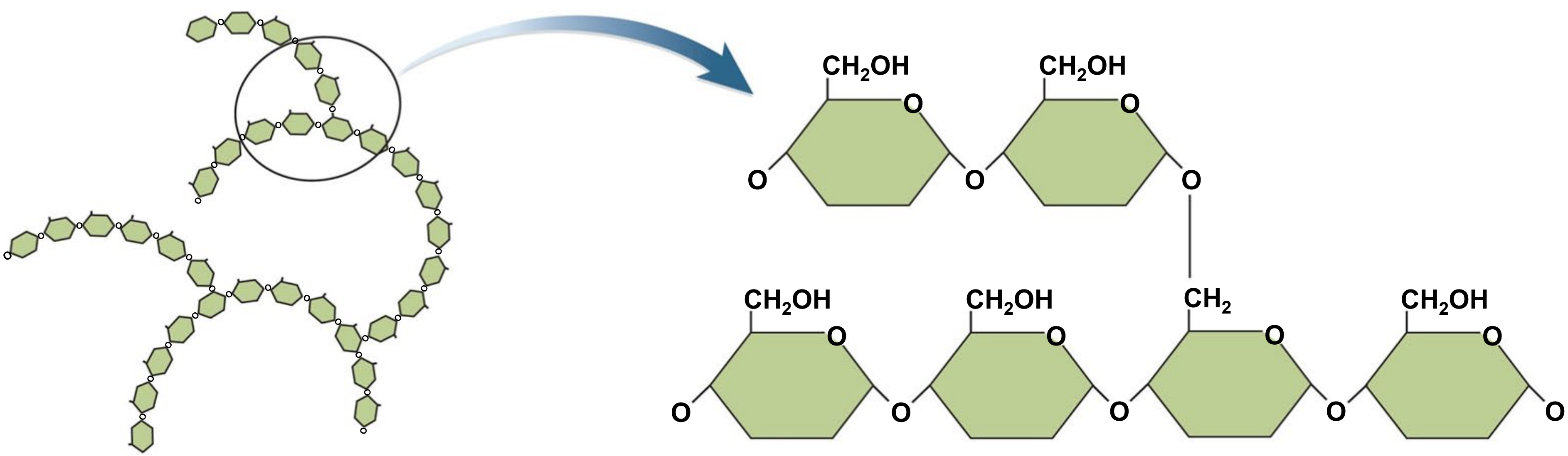
Macromolecules – polymers which continue to "enlarge" to forr
very large organic molecules // high molecular weights /// e.g.
protein

Monomers and Polymers

Glucose is a monomer

Glycogen is a polymer of glucose





What is the carbon cycle?

Carbon to Carbon Molecules

Organic = molecules with carbon and hydrogen

Carbon has 4 valence electrons // may bind with four other atoms to share electrons and complete octet rule. (locate carbon on periodic table)

Other atoms share electrons to provide carbon with four more electrons to fill its valence shell // making carbon's valence orbit "stable"

Forms covalent bonds with hydrogen, oxygen, nitrogen, sulfur, and other elements

Carbon atoms also bind (share electrons) readily with each other // forms branches and ring structures /// forms a carbon chain or carbon backbones

Able to form 3D matrix (e.g. pencils & diamonds)

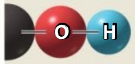
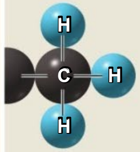
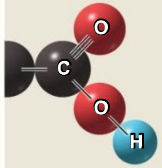
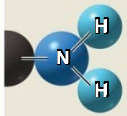
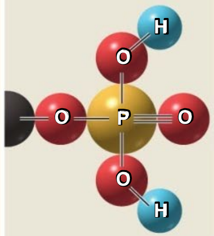
Carbon is the backbone that carries a variety of functional groups

Functional Groups

Small clusters of atoms attached to carbon backbone

Determines many of the properties of organic molecules

E.g. = hydroxyl, methyl, carboxyl, amino, phosphate

Name and Symbol	Structure	Occurs in
Hydroxyl (—OH)		Sugars, alcohols
Methyl (—CH_3)		Fats, oils, steroids, amino acids
Carboxyl (—COOH)		Amino acids, sugars, proteins
Amino (—NH_2)		Amino acids, proteins
Phosphate (—H_2PO_4)		Nucleic acids, ATP

Dehydration Synthesis VS Hydrolysis

Dehydration synthesis (condensation) is how living cells form polymers

– a link between two atoms is created using oxygen
– a hydroxyl (-OH) group is removed from one monomer
– a hydrogen (H+) from another monomer
– producing water as a by-product

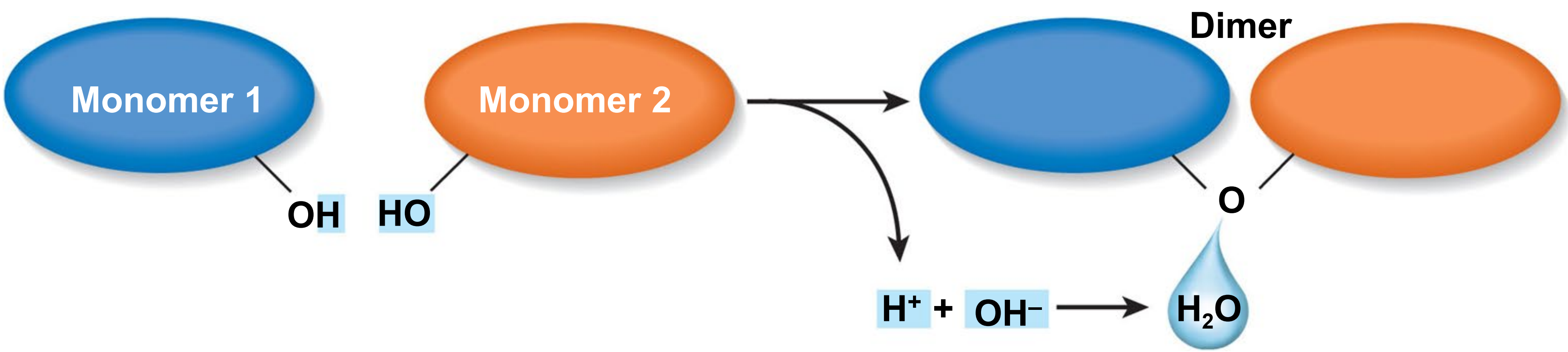
Hydrolysis – opposite of dehydration synthesis

– a water molecule ionizes into –OH and H+
– the covalent bond linking one monomer to the other is broken
– the –OH is added to one monomer
– the H+ is added to the other

Dehydration Synthesis

Monomers covalently bond together to form a polymer with the removal of a water molecule

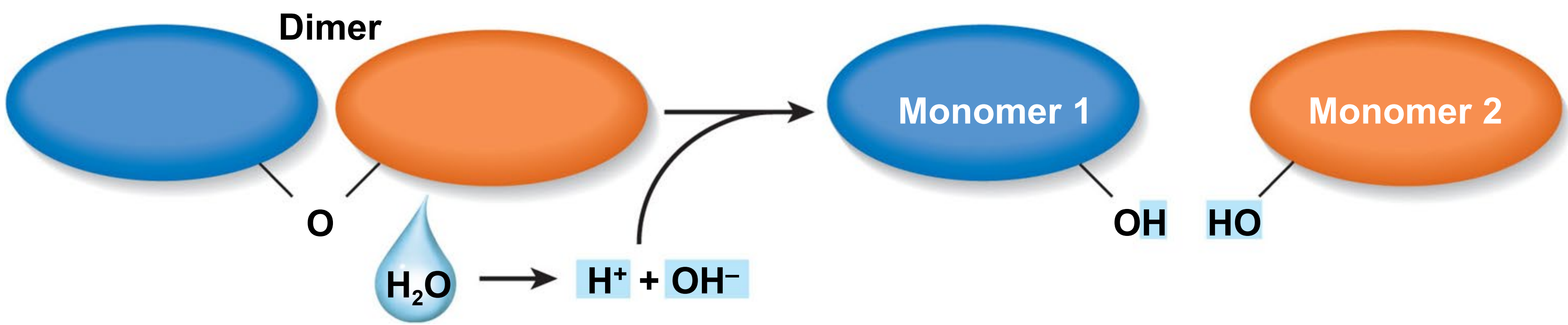
A hydroxyl group is removed from the blue monomer and a hydrogen is removed from the orange monomer to form water



Hydrolysis

Splitting a polymer (lysis) **by the addition of a water molecule** (hydro) // a covalent bond is broken

All digestion reactions consists of hydrolysis reactions



Organic Molecules: Carbohydrates

A hydrophilic organic molecule (soluble in water!)

General formula // note: 2:1 ratio for hydrogen to oxygen

–**$(CH_2O)_n$** **//** n = number of carbon atoms
–for glucose, n = 6, so formula is $C_6H_{12}O_6$

Names of carbohydrates often built from:

–word root '***sacchar-'***
–the suffix '-***ose'***
–both mean '*sugar*' or '*sweet*' // monosaccharide or glucose

Monosaccharides

Simple carbohydrates = simple sugars

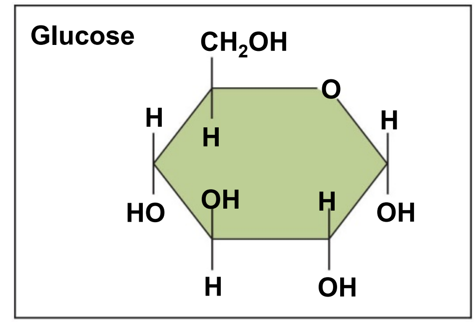
Three important monosaccharides /// glucose, galactose and fructose

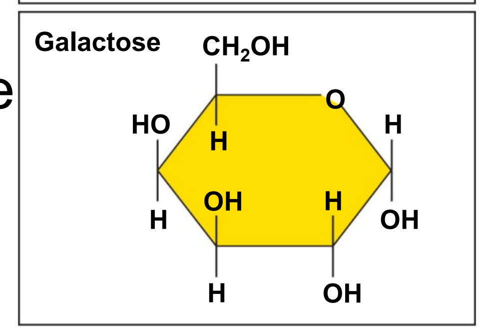
All have same molecular formula - $C_6H_{12}O_6$

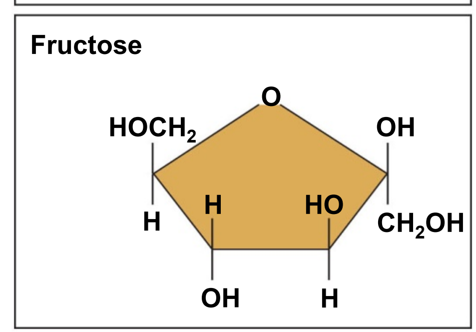
They have same number of atoms, but atoms are arranged differently = isomers

Produced by digestion of complex carbohydrates (e.g. starch, glycogen)

–Note: glucose is blood sugar





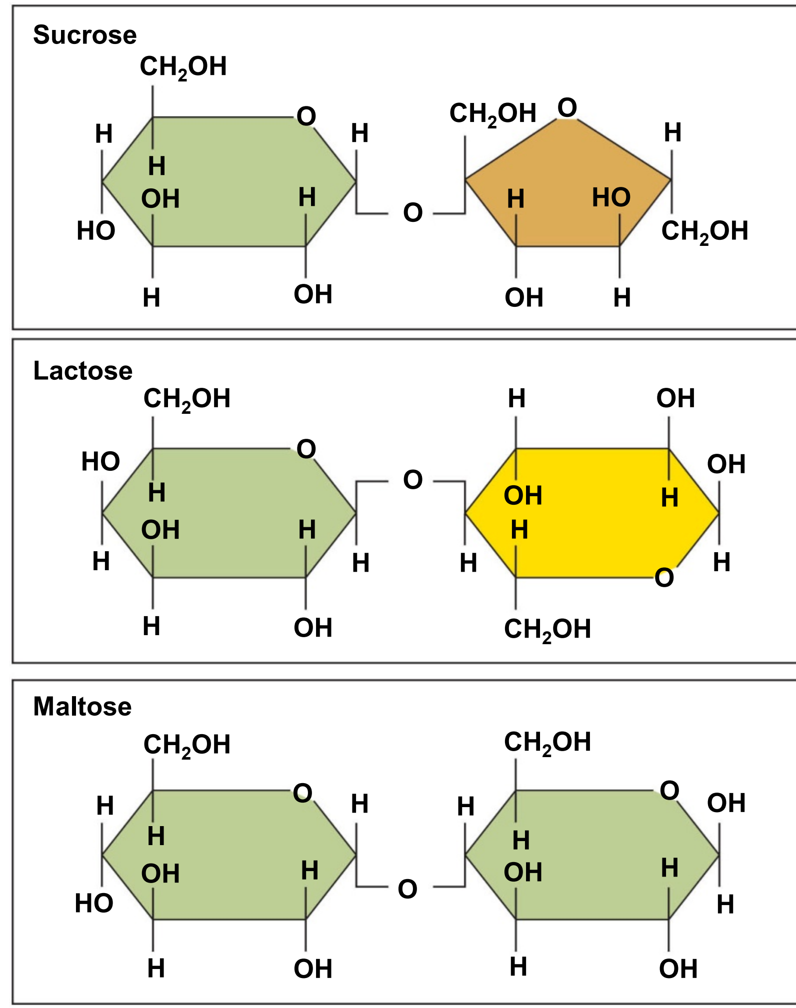


Disaccharides

Sugar molecule composed of 2 monosaccharides

Three important disaccharides

- –sucrose - table sugar // glucose + fructose
- –lactose - sugar in milk // glucose + galactose
- –maltose - grain products // glucose + glucose



Polysaccharides

Long covalent bonded chains of glucose molecules

Three important polysaccharides (glycogen – starch - cellulose)

Glycogen: energy storage polysacharide in animals

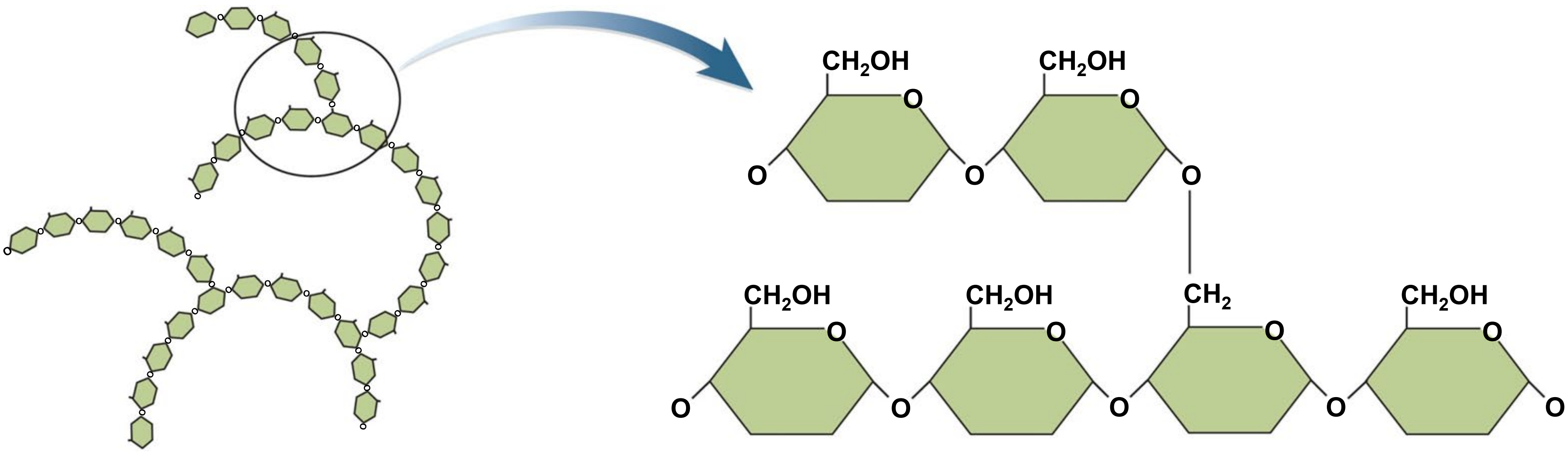
- made by cells of liver, muscles, brain, uterus, and vagina
- liver produces glycogen after a meal when glucose level is high, then breaks it down between meals to maintain blood glucose levels
- muscles store glycogen for own energy needs
- uterus “sweats” glycogen to nourish embryo

Polysaccharides

Starch: energy storage polysaccharide in plants /// only significant digestible polysaccharide in the human diet

Cellulose: structural molecule of plant cell walls /// this is the “fiber” in our diet, but our digestive system lack enzymes to breakdown this polymer, so cellulose passes out of our digestive system as food residue

Glycogen



(a) (b)

Carbohydrate Functions

Source of energy // all digested carbohydrates converted to glucose // oxidized to make ATP

Also, a structural molecule when conjugated with lipids or proteins

Glycolipids // e.g. component of cell membrane with lipid inserted into membrane and sugar projecting from surface of membrane

Glycoproteins // e.g. component of cell membrane with protein inserted into membrane and surgar projecting from surface of membrane

Carbohydrate Functions

Proteoglycans (mucopolysaccharides) // forms gel between cells – its the “glue that binds cells and tissues together

Forms gelatinous filler in umbilical cord and eye

Joint lubrication

Seen as the tough, rubbery texture of cartilage

TABLE 2.6	Carbohydrate Functions
Type	**Function**
Monosaccharides	
Glucose	Blood sugar—energy source for most cells
Galactose	Converted to glucose and metabolized
Fructose	Fruit sugar—converted to glucose and metabolized
Disaccharides	
Sucrose	Cane sugar—digested to glucose and fructose
Lactose	Milk sugar—digested to glucose and galactose; important in infant nutrition
Maltose	Malt sugar—product of starch digestion, further digested to glucose
Polysaccharides	
Cellulose	Structural polysaccharide of plants; dietary fiber
Starch	Energy storage in plant cells
Glycogen	Energy storage in animal cells (liver, muscle, brain, uterus, vagina)
Conjugated Carbohydrates	
Glycoprotein	Component of the cell surface coat and mucus, among other roles
Glycolipid	Component of the cell surface coat
Proteoglycan	Cell adhesion; lubrication; supportive filler of some tissues and organs

Lipids

Hydrophobic organic molecule (not soluble in water)

Composed of carbon, hydrogen and oxygen // with high ratio of hydrogen to oxygen

Less oxidized than carbohydrates, and therefore has more calories/gram

Five primary human lipids

–**fatty acids**
–**triglycerides**
–**phospholipids**
–**eicosanoids**
–**steroids**

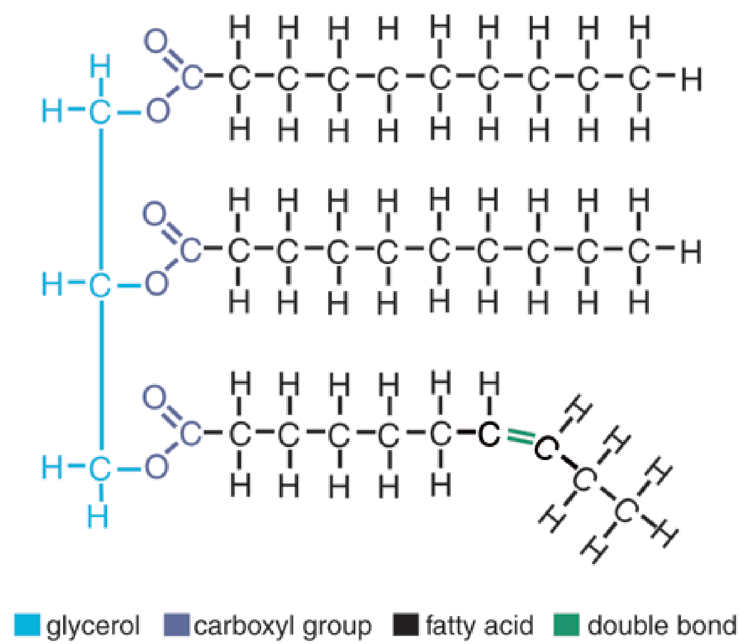


TABLE 2.7 Lipid Functions

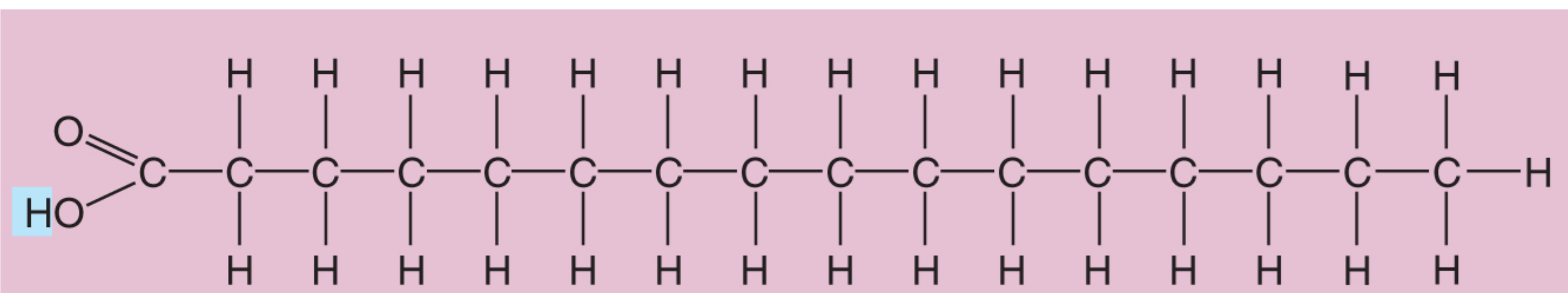
Type	Function
Bile acids	Steroids that aid in fat digestion and nutrient absorption
Cholesterol	Component of cell membranes; precursor of other steroids
Eicosanoids	Chemical messengers between cells
Fat-soluble vitamins	Involved in a variety of functions including blood clotting, wound healing, vision, and calcium absorption
Fatty acids	Precursor of triglycerides; source of energy
Phospholipids	Major component of cell members; aid in fat digestion
Steroid hormones	Chemical messengers between cells
Triglycerides	Energy storage: thermal insulation; filling space; binding organs together; cushioning organs

Fatty Acids

Chains of 4 to 24 carbon atoms // carboxyl (acid) group on one end, methyl group on the other and hydrogen bonded along the sides

Classified as:

– saturated – all carbon atoms saturated with hydrogen
– unsaturated - contains C=C bonds without hydrogen
– polyunsaturated – contains many C=C bonds
– essential fatty acids – obtained from diet, body can not synthesize



Palmitic acid (saturated)
$CH_3(CH_2)_{14}COOH$

Triglycerides (Neutral Fats)

Three fatty acids covalently bonded to a three-carbon alcohol (a glycerol molecule)

– each bond formed by dehydration synthesis

– once joined to glycerol /// fatty acids can no longer donate protons – it is a neutral fats

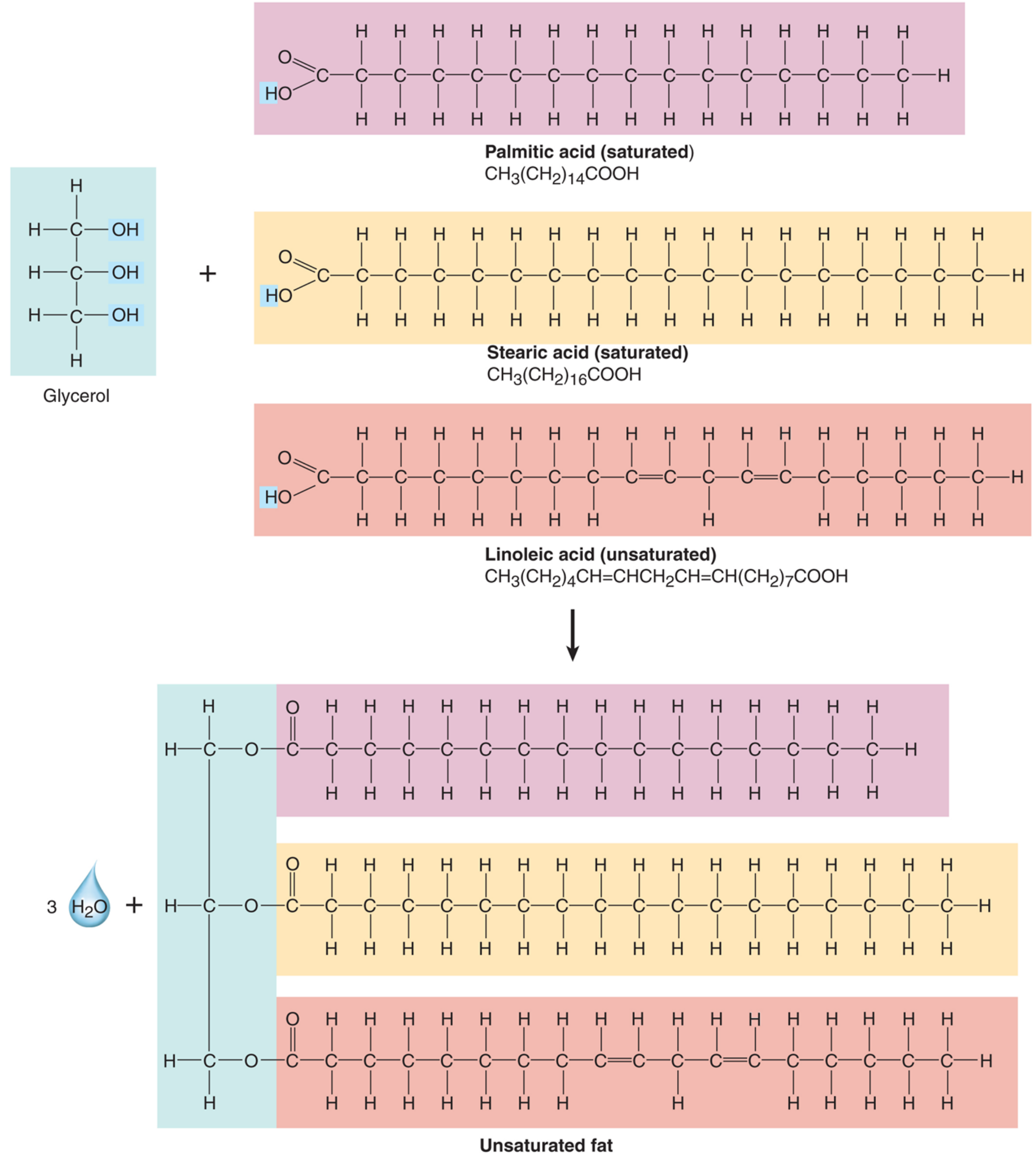
– maybe broken down by hydrolysis

Triglycerides when at room temperature

– If liquid its called an oils // often polyunsaturated fats from plants

– If solid its called a fat // saturated fats from animals

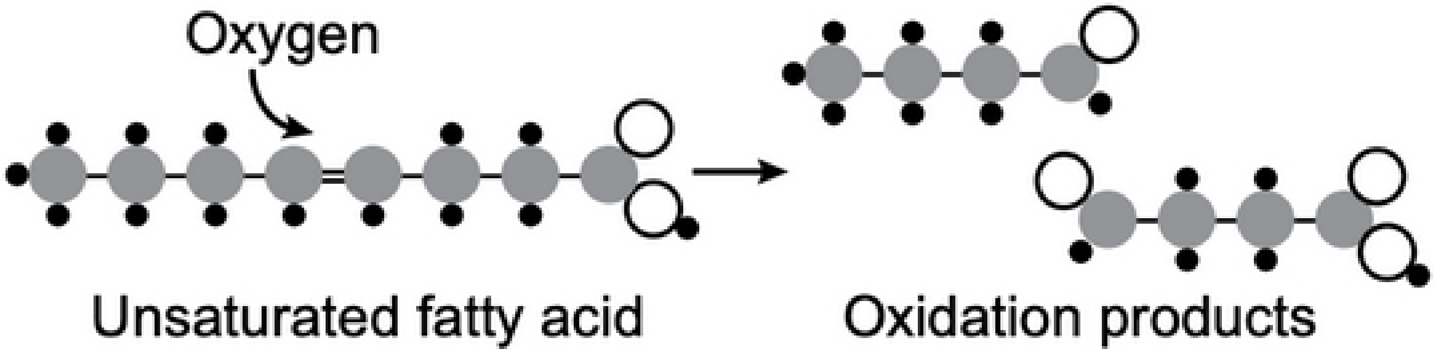
Primary Functions - energy storage, but also used for insulation and shock absorption (called adipose tissue)



Glycerol plus three fatty acids make a triglyceride molecule. This is how we store fat.

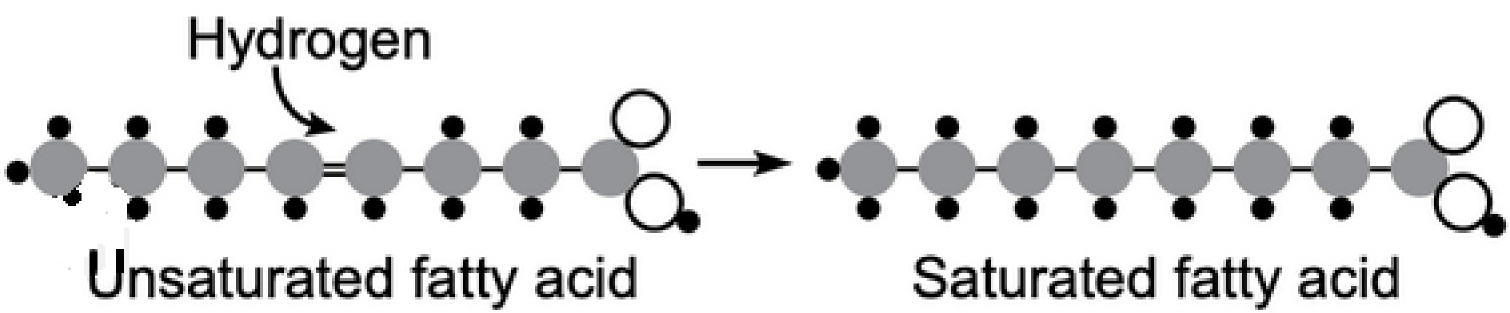
Oxidation:

Oxygen splits an unsaturated fatty acid at a double bond.



Hydrogenation:

Adding hydrogen across the double bond of an unsaturated fatty acid produces a saturated fatty acid.



Hydrolytic vs. oxidative rancidity

Oxidative rancidity

Oxidation of the fatty acid chain, mainly *C=C* double bonds in unsaturated fatty acids

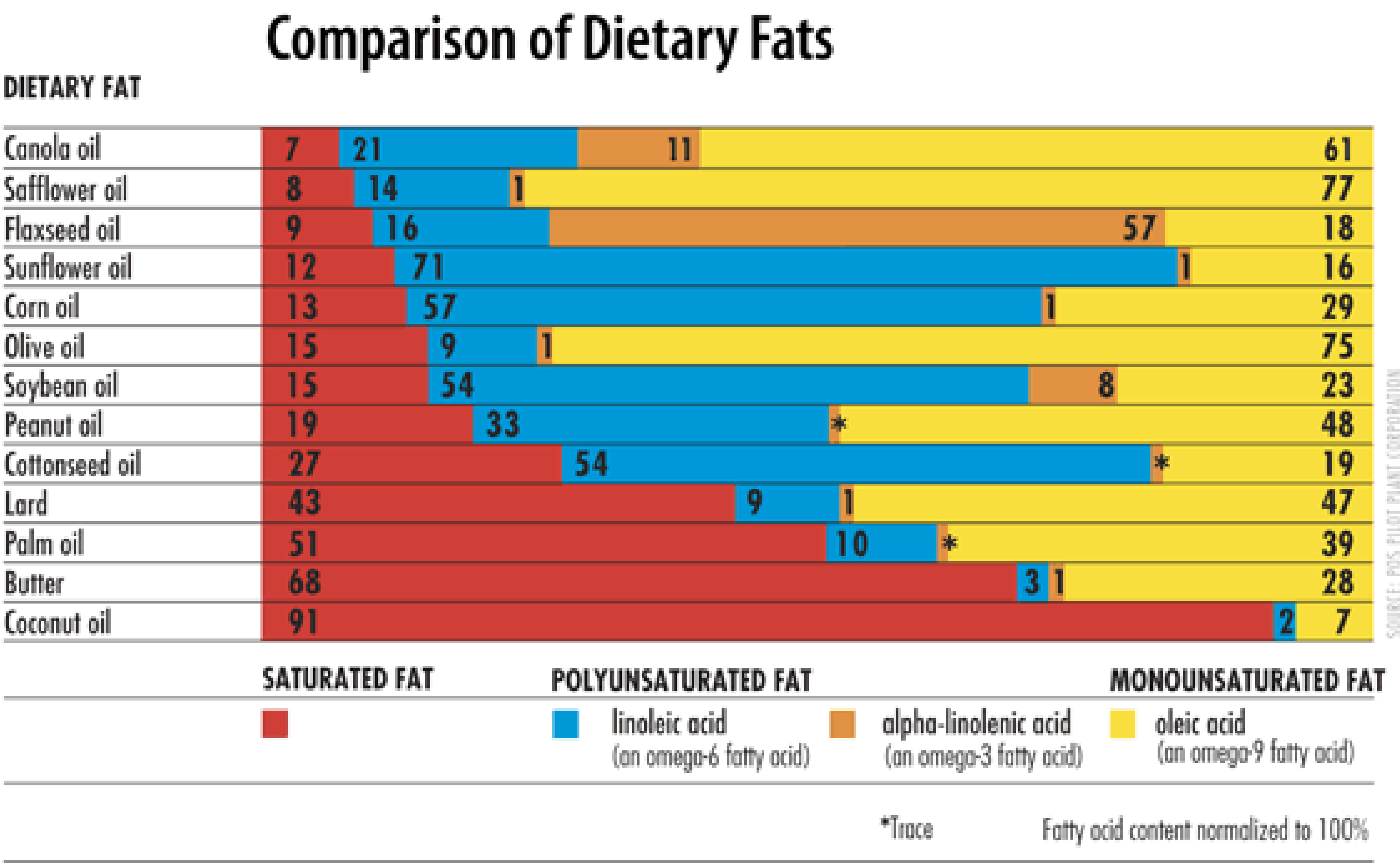
Catalysed by: light, heat, enzymes, trace metals and free radicals

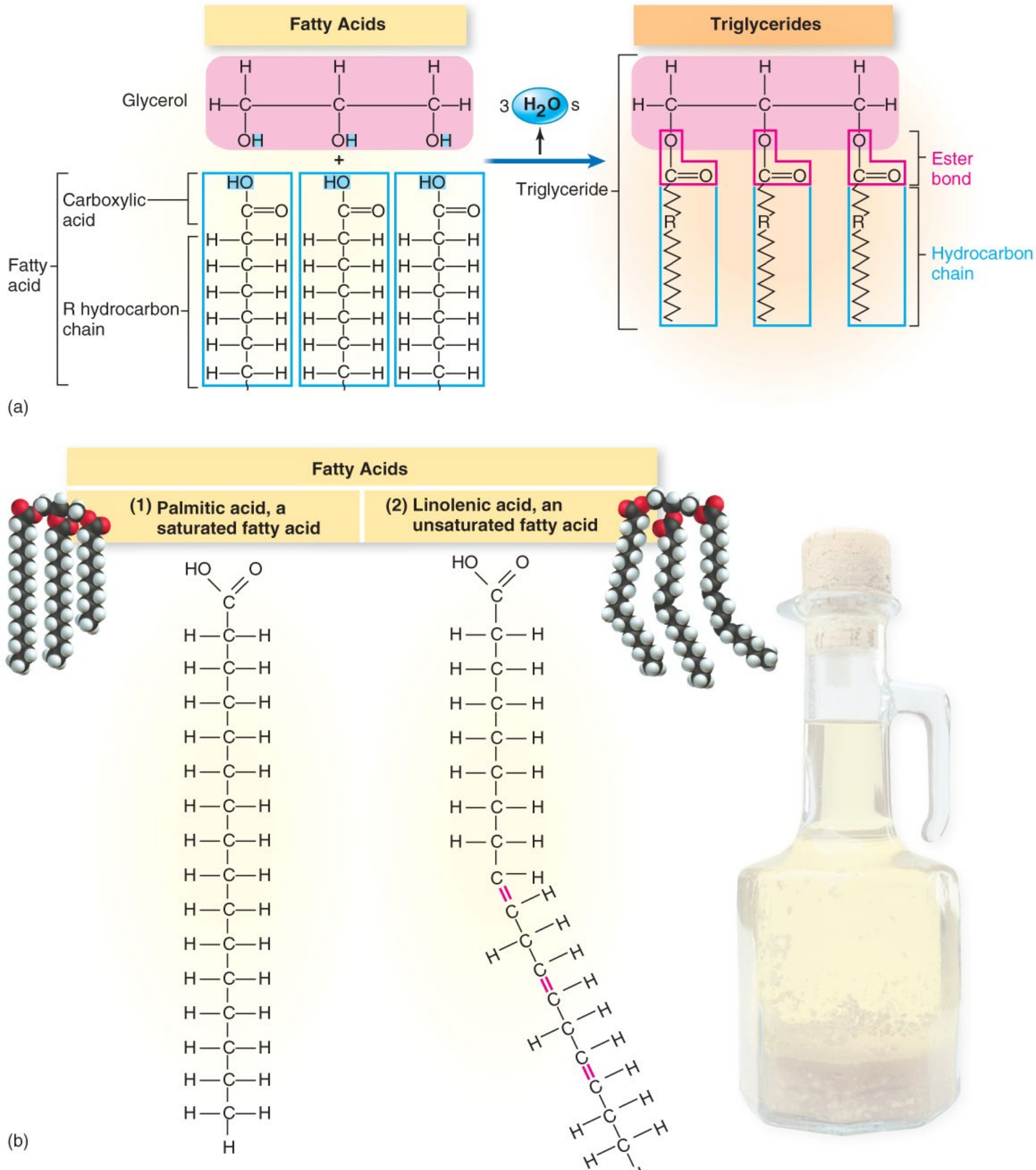
End products have an unpleasant smell

Hydrolitic rancidity

Breaking the triglyceride into fatty acids and glycerol

Catalysed by heat, enzymes and moisture


Comparison of Dietary Fats
DIETARY FAT
Canola oil 7 21 11 61
Safflower oil 8 14 1 77
Flaxseed oil 9 16 57 18
Sunflower oil 12 71 1 16
Corn oil 13 57 1 29
Olive oil 15 9 1 75
Soybean oil 15 54 8 23
Peanut oil 19 33 * 48
Cottonseed oil 27 54 * 19
Lard 43 9 1 47
Palm oil 51 10 * 39
Butter 68 3 1 28
Coconut oil 91 2 7
SATURATED FAT
POLYUNSATURATED FAT
MONOUNSATURATED FAT
linoleic acid (an omega-6 fatty acid)
alpha-linolenic acid (an omega-3 fatty acid)
oleic acid (an omega-9 fatty acid)
*Trace
Fatty acid content normalized to 100%
SOURCE: POS PILOT PLANT CORPORATION


Fatty Acids
Triglycerides
Glycerol
Carboxylic acid
Fatty acid
R hydrocarbon chain
3 H_2O s
Triglyceride
Ester bond
Hydrocarbon chain
(a)
Fatty Acids
(1) Palmitic acid, a saturated fatty acid
(2) Linolenic acid, an unsaturated fatty acid
(b)

Phospholipids

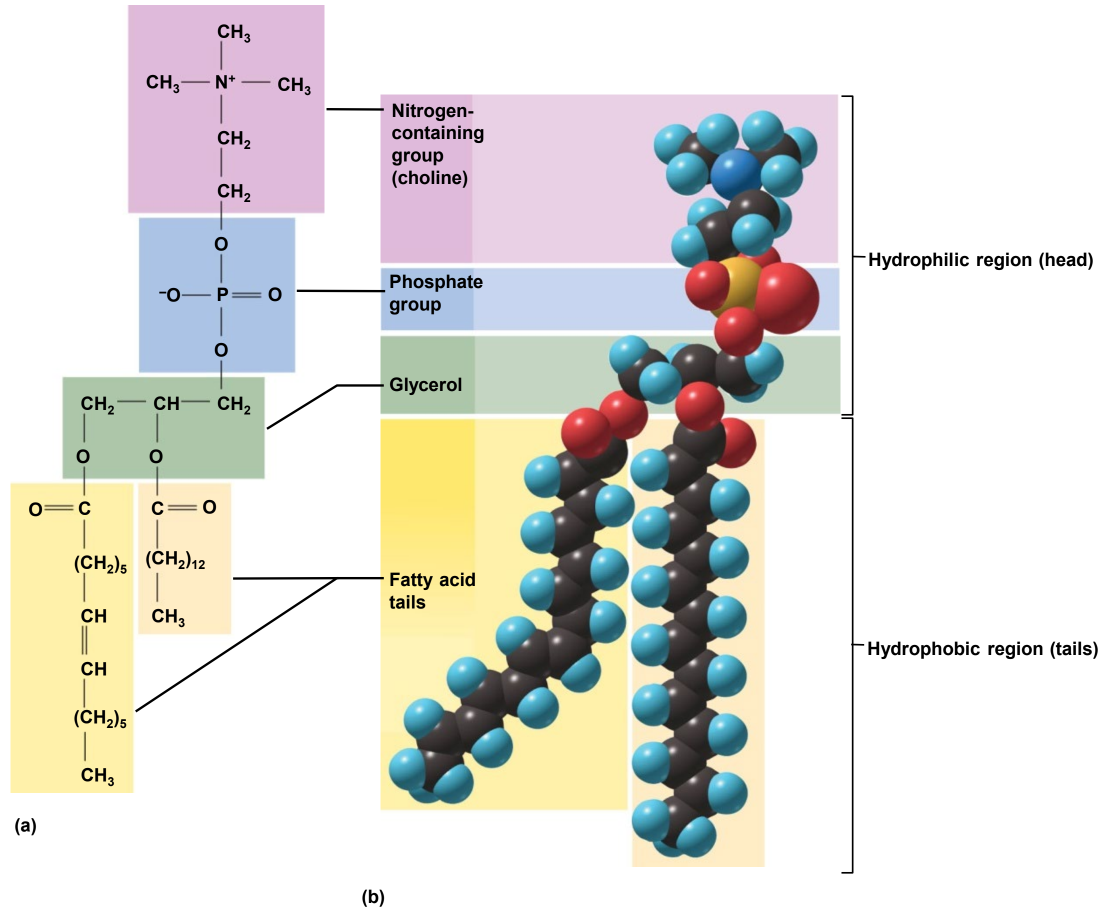
Structure like triglyceride by one fatty acid is replaced by a phosphate group

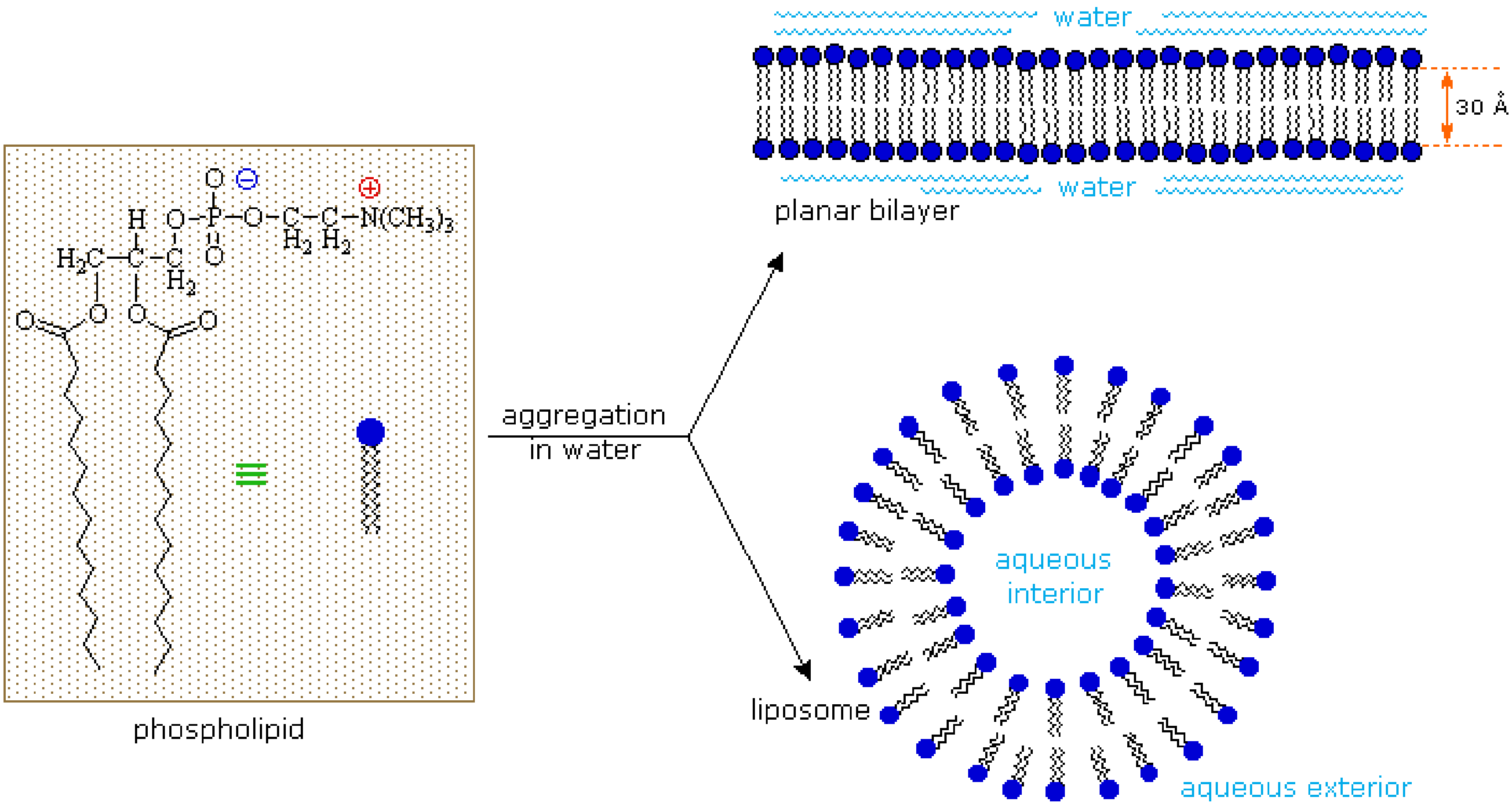
Structural foundation of cell membrane

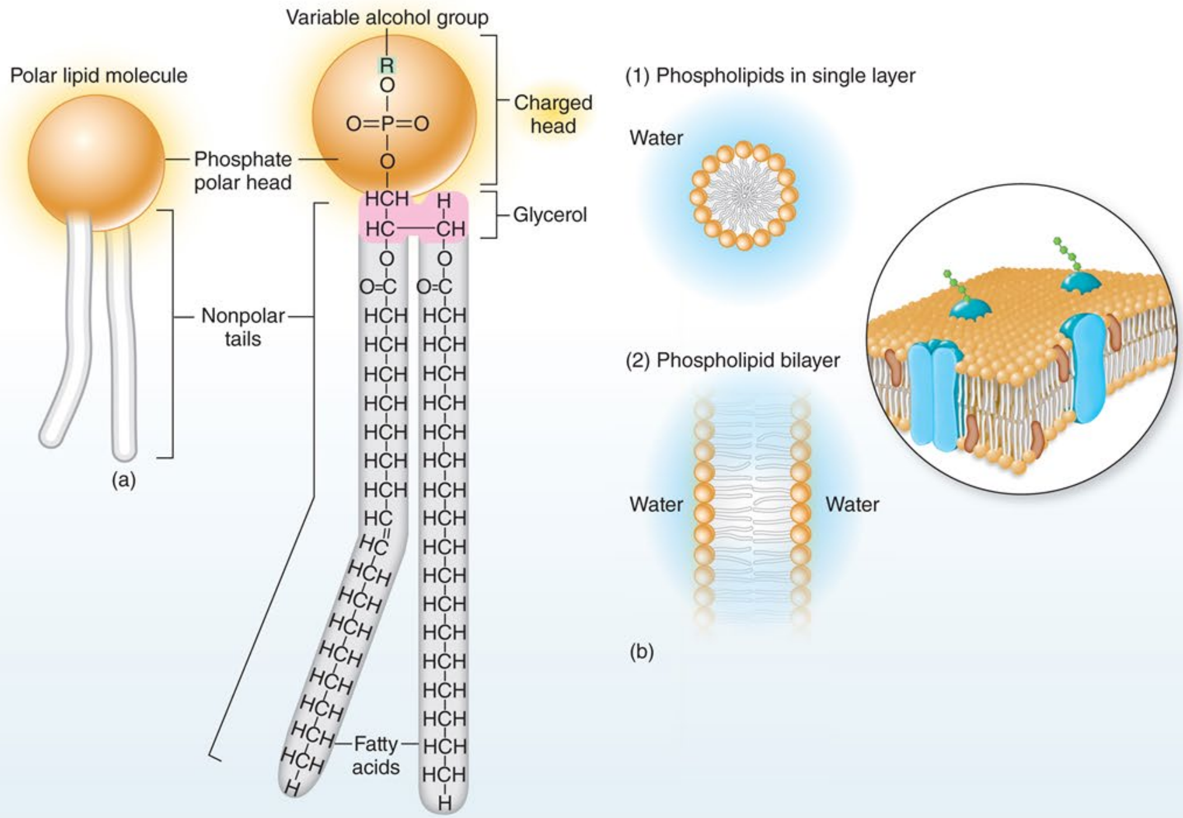
Amphiphilic // single molecule containing both a neutral and charged region

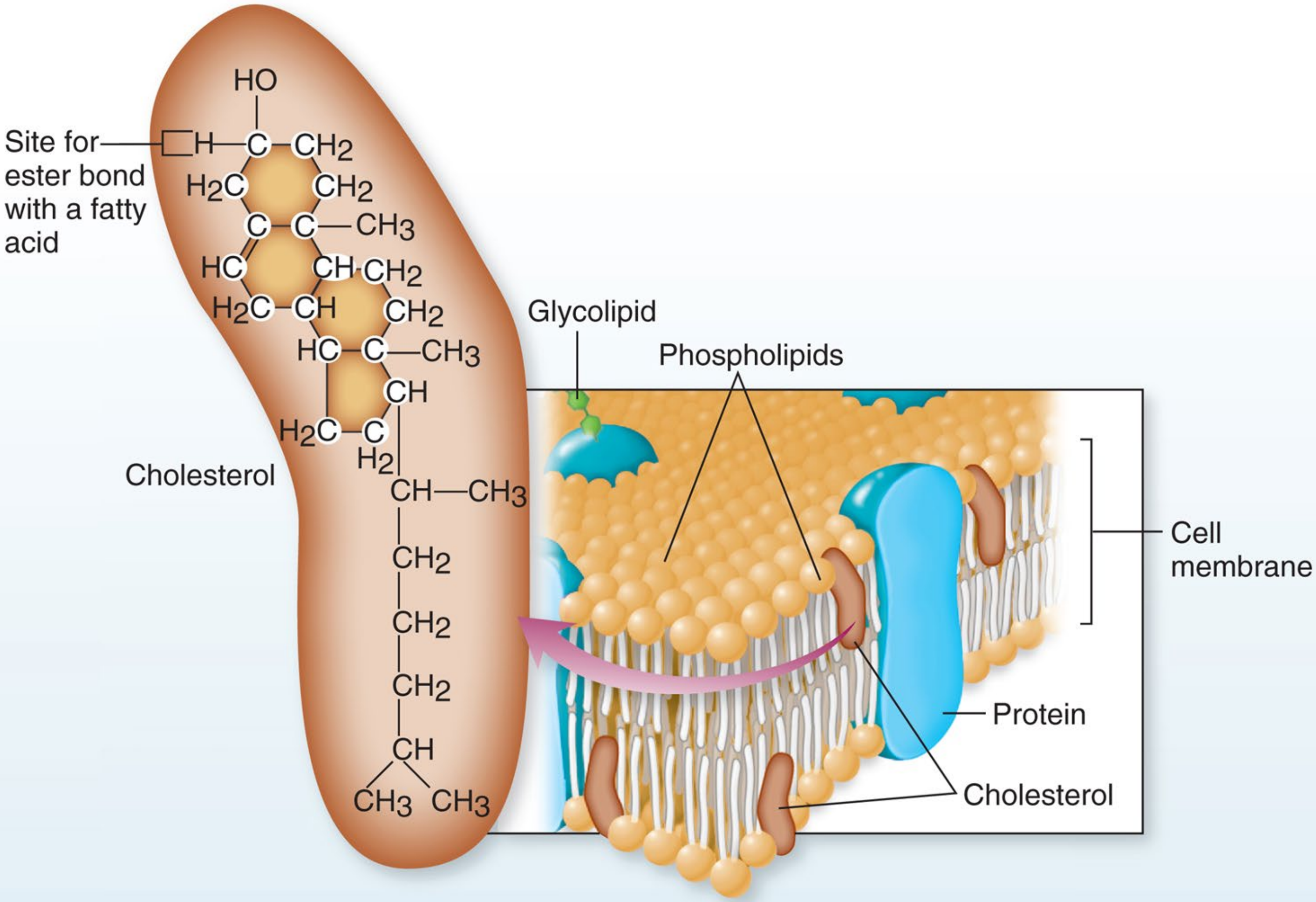
Fatty acid “tails” are hydrophobic // water fear

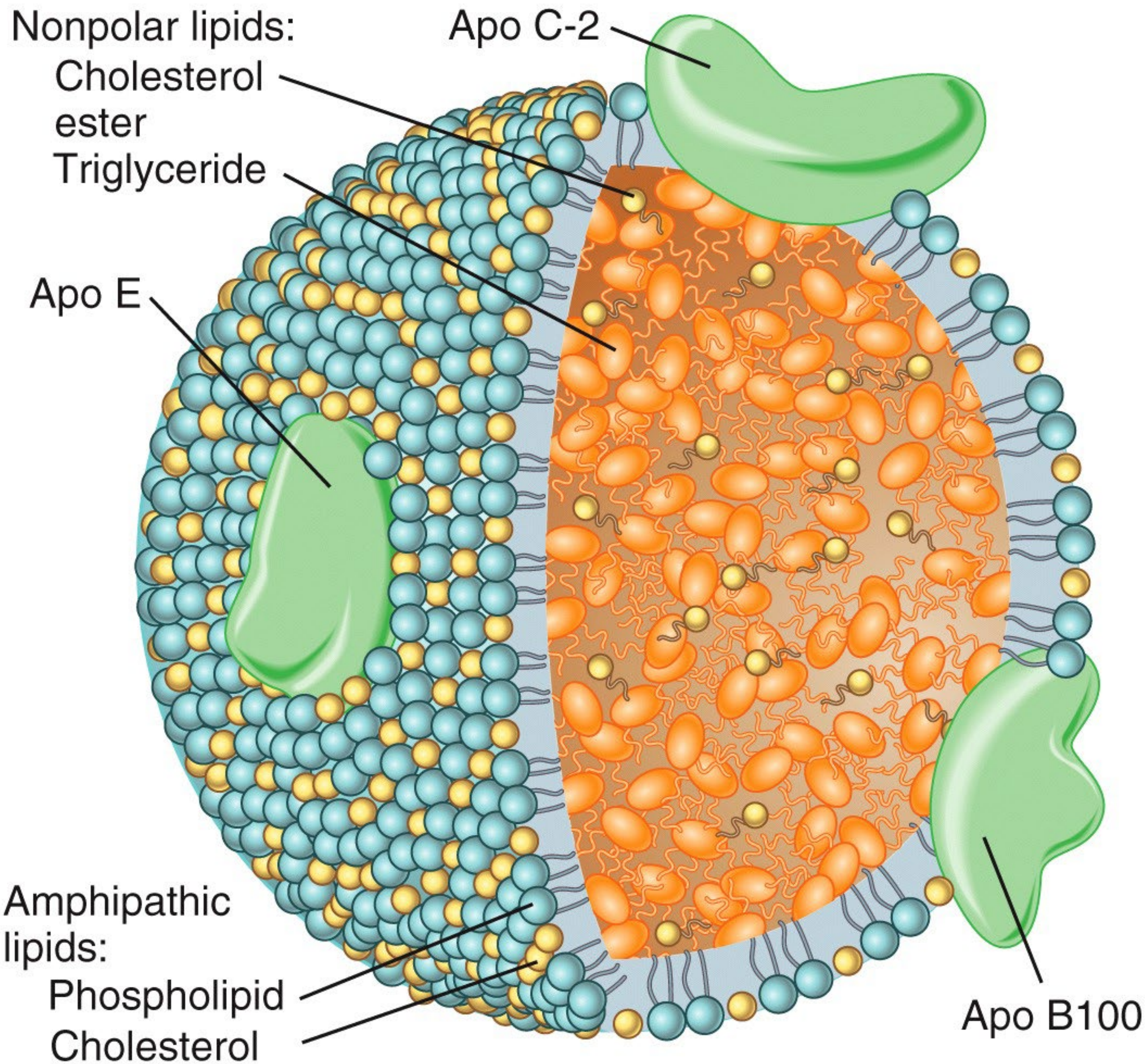
Phosphate “head” is hydrophilic // water seeking

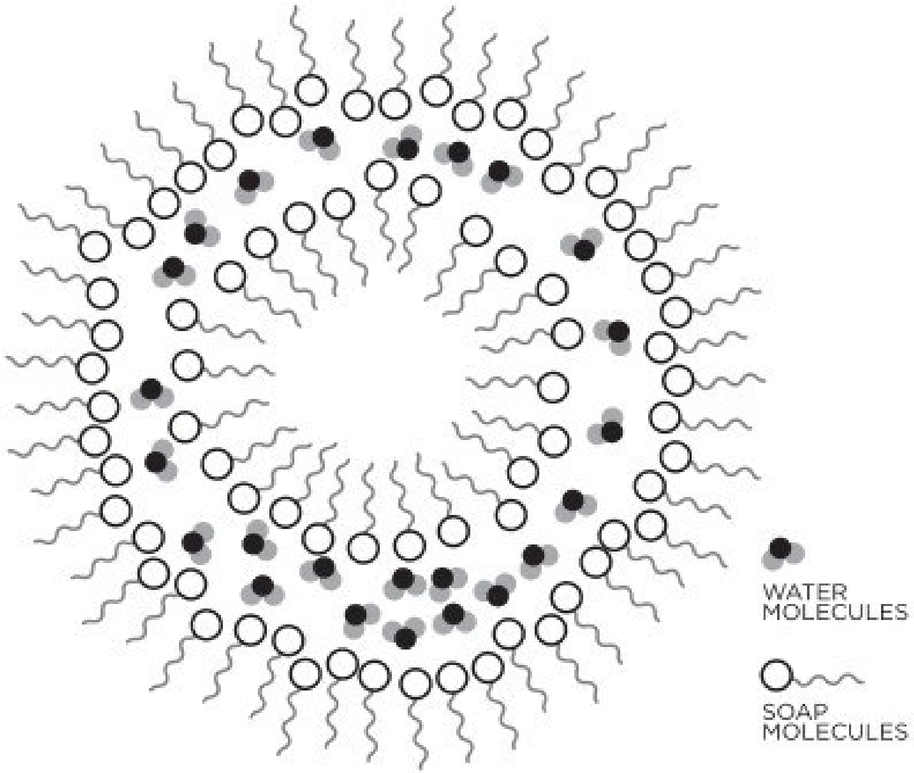



phospholipid
aggregation
in water
water
water
planar bilayer
30 Å
liposome
aqueous
interior
aqueous exterior


Polar lipid molecule
Phosphate polar head
Nonpolar tails
(a)
Variable alcohol group
Charged head
Glycerol
Fatty acids
(1) Phospholipids in single layer
Water
(2) Phospholipid bilayer
Water
Water
(b)

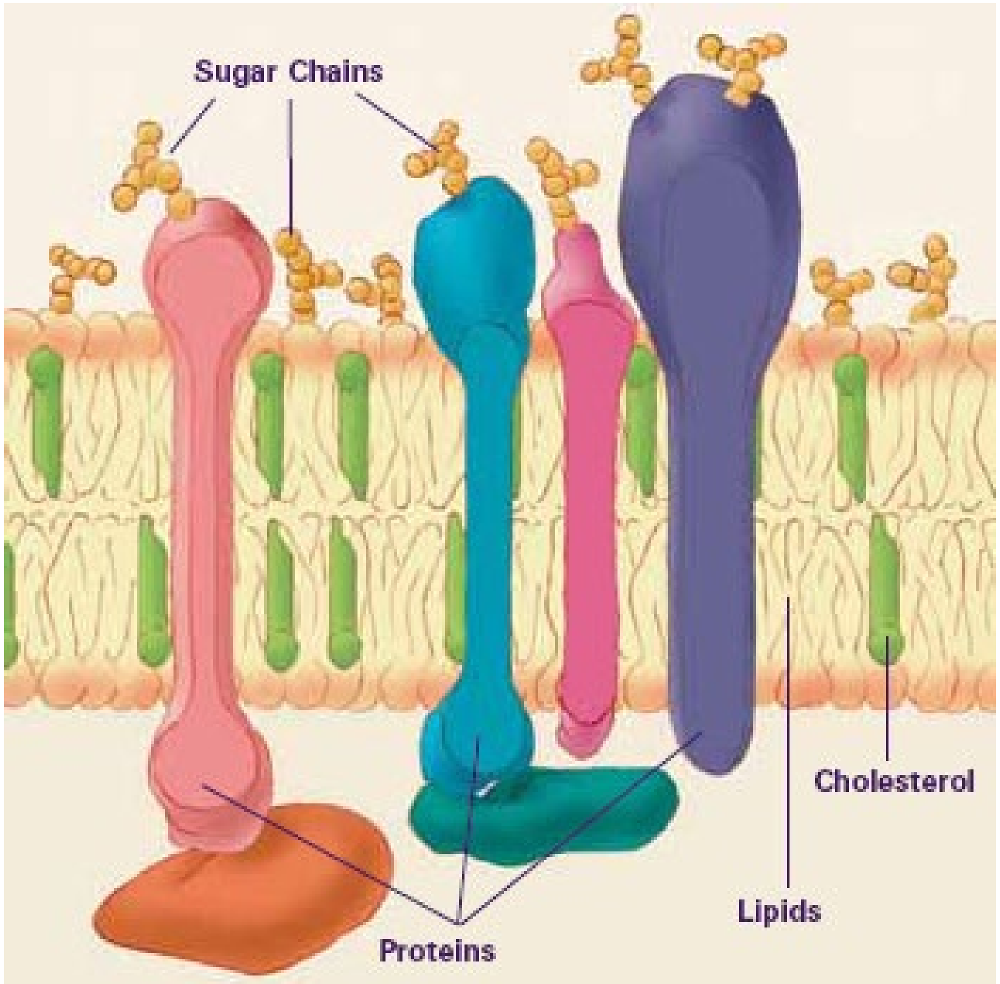

Site for ester bond with a fatty acid
HO
H
C
CH2
H2C
CH2
C
C
CH3
HC
CH
CH2
H2C
CH
CH2
HC
C
CH3
CH
H2C
C
H2
CH
CH3
CH2
CH2
CH2
CH
CH3
CH3
Cholesterol
Glycolipid
Phospholipids
Cell membrane
Protein
Cholesterol


Nonpolar lipids:
Cholesterol ester
Triglyceride
Apo C-2
Apo E
Amphipathic lipids:
Phospholipid
Cholesterol
Apo B100



What is the structure of a soap bubble?

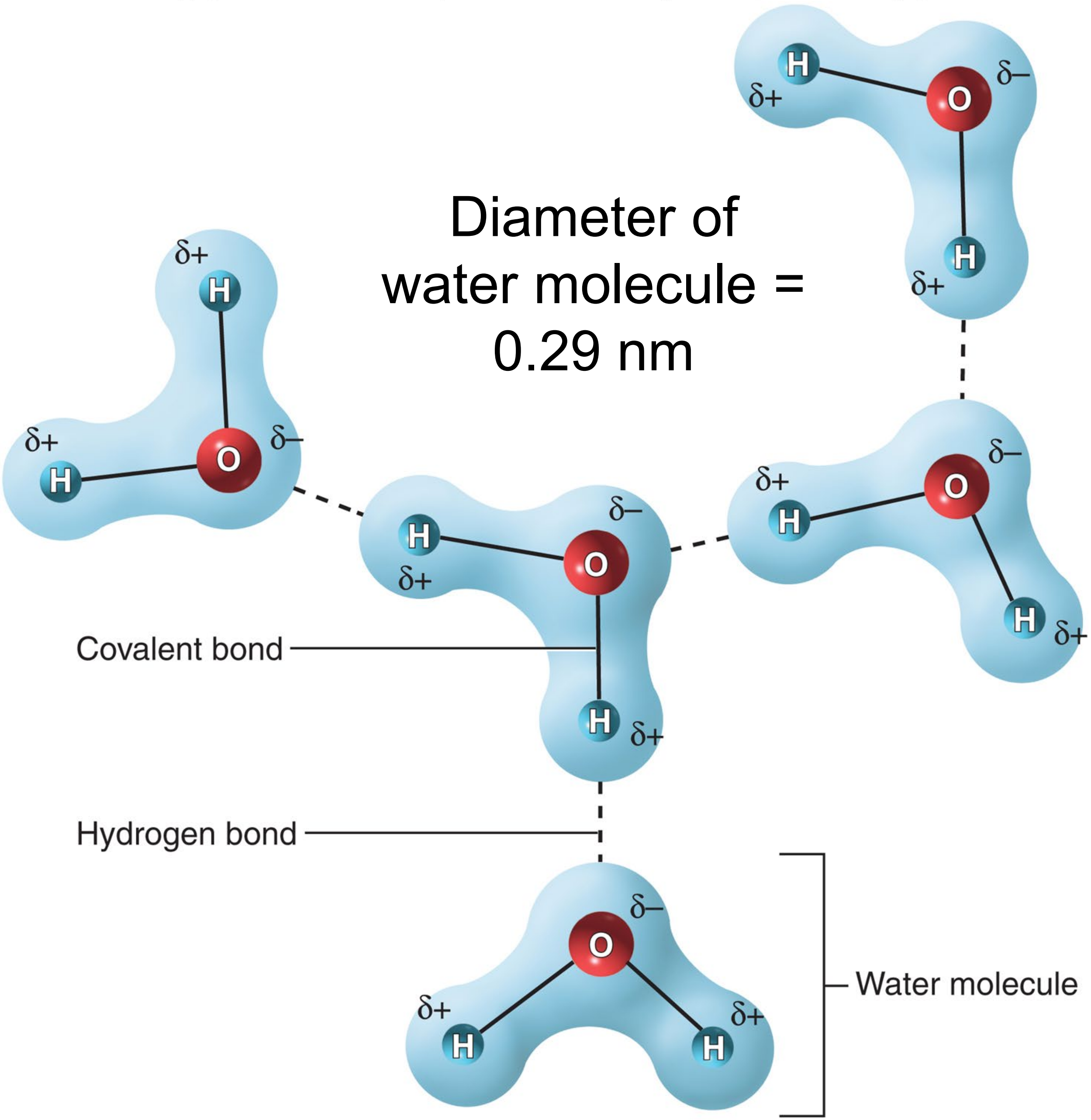
Width of a Plasma Membrane



Approximately 25 water molecules are needed to span the width of a plasma membrane!

5.5 to 7.5 nm Thick

Diameter of water molecule = 0.29 nm



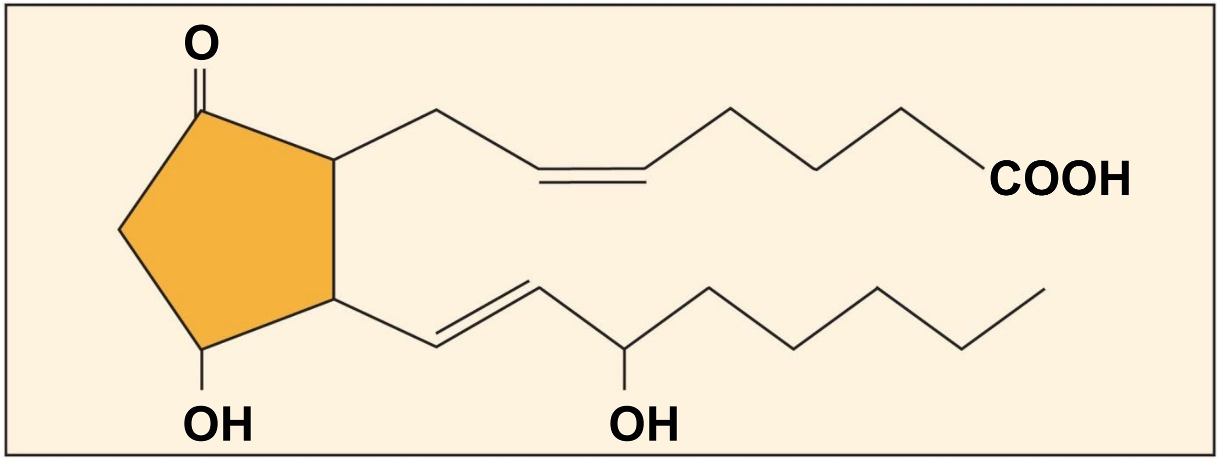
Eicosanoids

20 carbon compounds derived from a fatty acid called arachidonic acid

Hormone-like chemical signals between cells

Includes prostaglandins – produced in all tissues

Role in inflammation, blood clotting, hormone action, labor contractions, blood vessel diameter



Steroids and Cholesterol

Steroid – a lipid with 17 of its carbon atoms in four rings

Cholesterol - the precursor lipid from which the other steroidal hormones are synthesized

E.g. cortisol, progesterone, estrogens, testosterone, bile acids

Cholesterol

– synthesized only by animals // especially liver cells

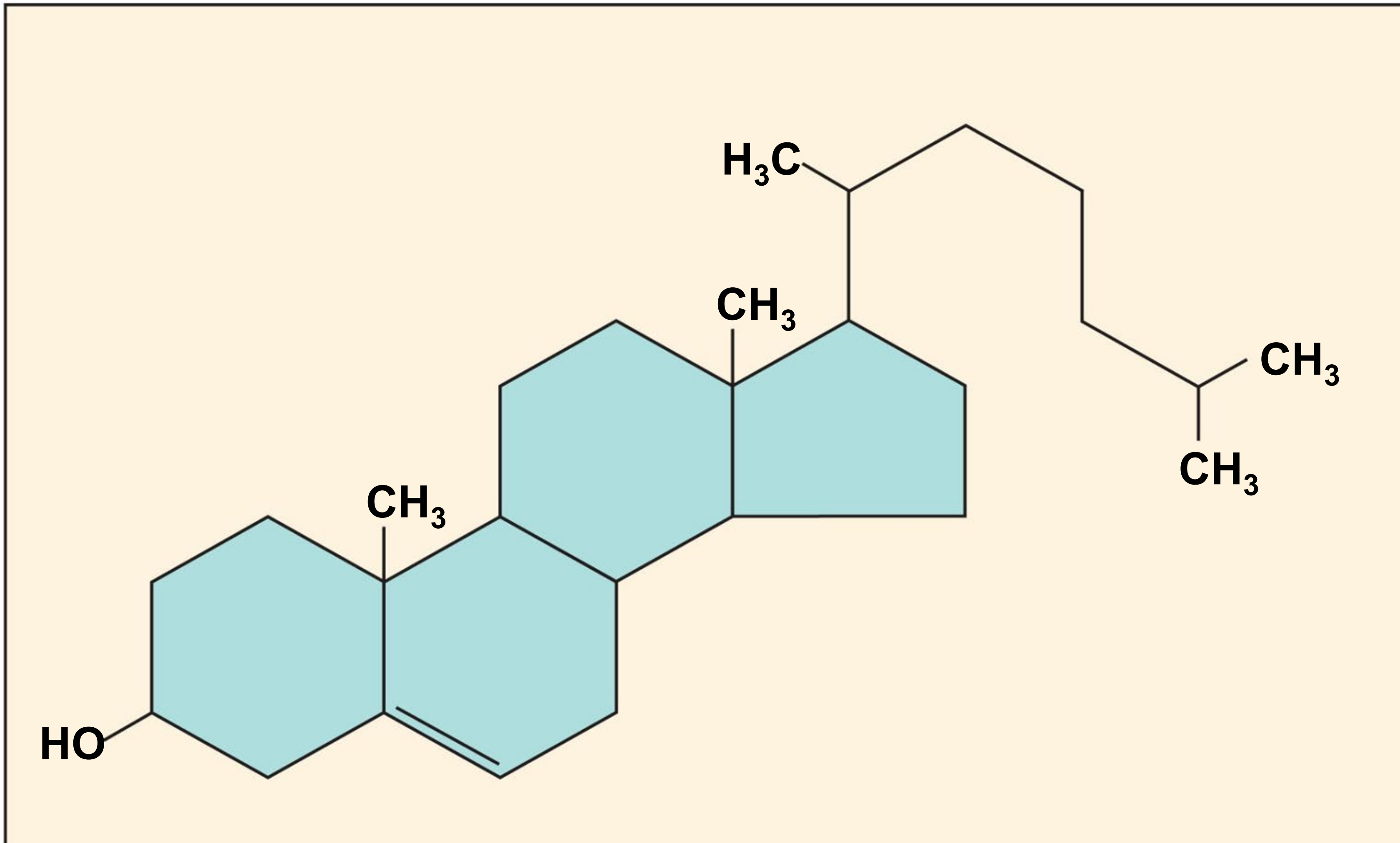
– 15% from diet, 85% internally synthesized

– important component of cell membranes

– required for proper nervous system function

– never metabolized for energy!

Cholesterol



“Good” and “Bad” Cholesterol

Good and bad is in reference to the phospholipid “transporters”

Transport structures (i.e. shells) are constructed of phospholipids and proteins

Transporters move triglycerides, fatty acids, fat soluble vitamins, and cholesterol in the blood. Another type of phospholipid transporter moves fat across digestive system's basal absorptive cell surface and into lacteals.

Good’ and ‘bad’ cholesterol refers to two different transporter “types” associated with the blood

“Good” and “Bad” Cholesterol

The actual transporters are complexes of cholesterol, fat, phospholipids, and protein

The transporters form a “hollow” shell

HDL – high-density lipoprotein – “good” cholesterol”

– lower ratio of lipid to protein in its shell

– may help to prevent cardiovascular disease

– picks up free blood cholesterol and returns it to liver

LDL – low-density lipoprotein – “bad” cholesterol”

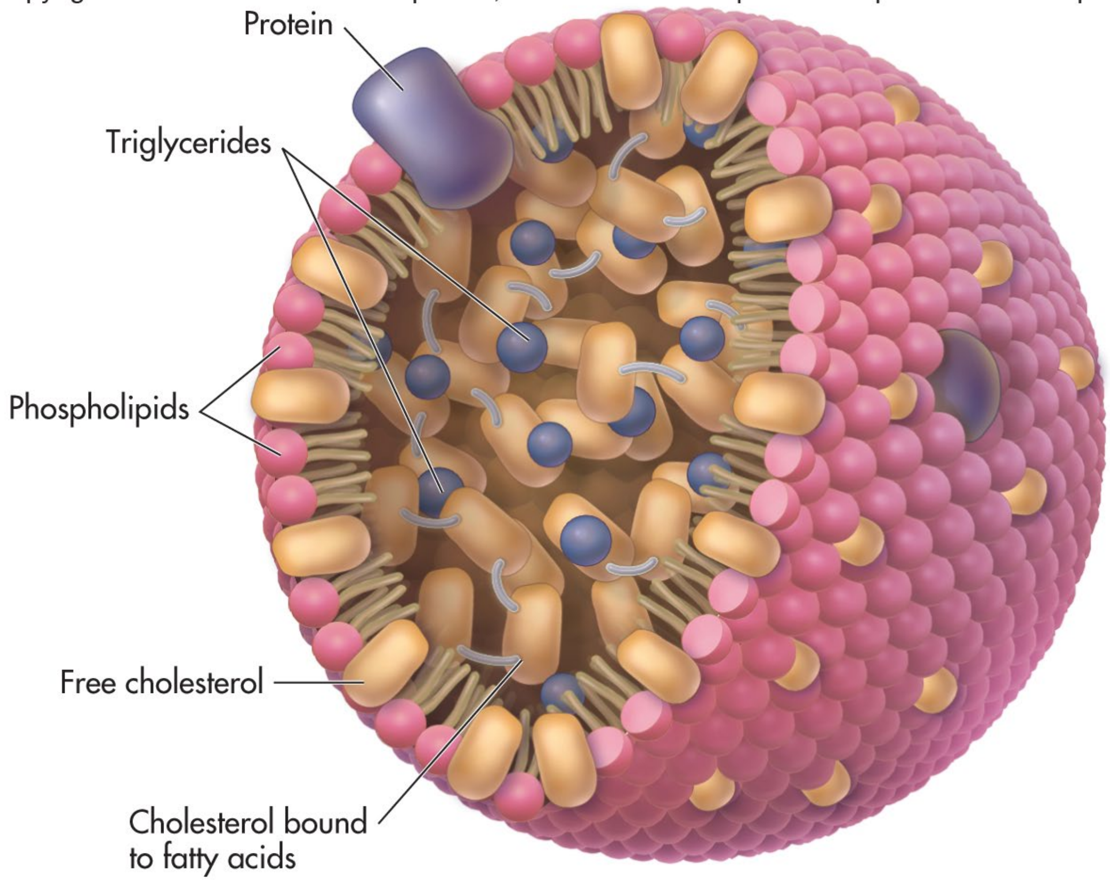
– high ratio of lipid to protein in its shell

– contributes to cardiovascular disease

– may accumulate under endothelial cells

– initiate cardiovascular disease.

Structure of Lipoprotein Transporter



Note: fat soluble products are transported inside the shell // pink hydrophillic phosphate heads of the phospholipid make shell water soluble

Proteins

Greek word meaning “of first importance” // most versatile molecules in the body /// organic molecule / hydrophilic

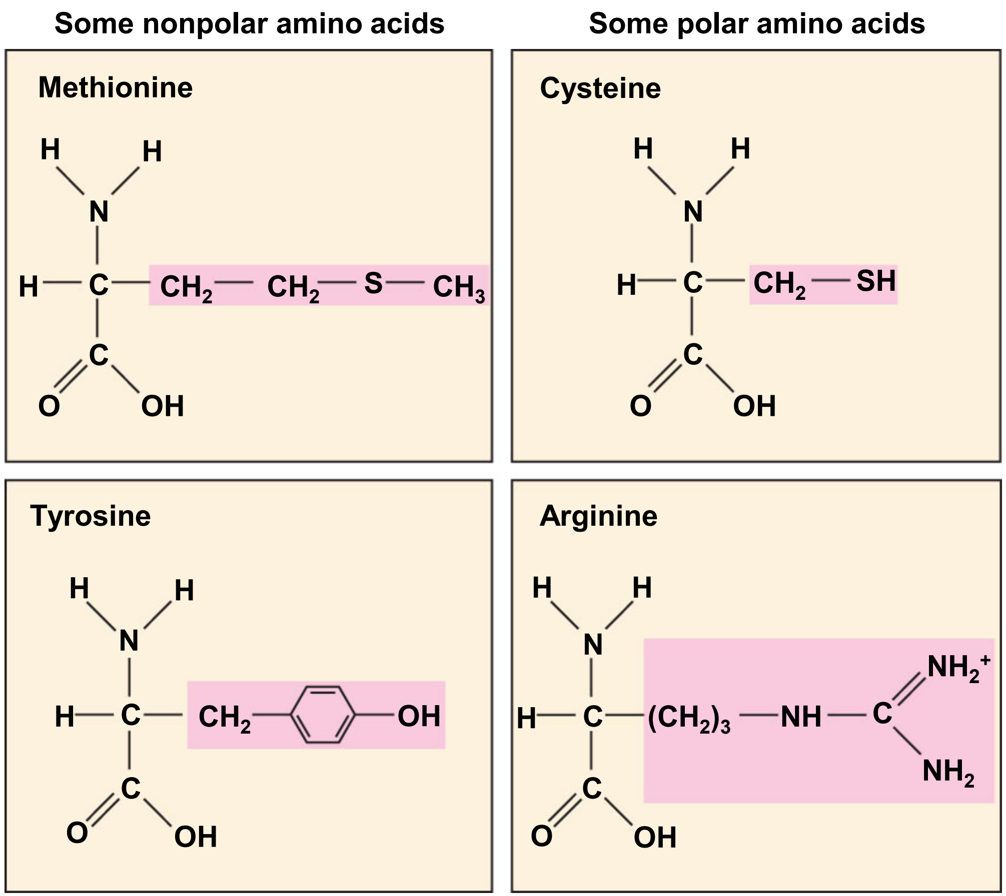
Protein - a polymer of amino acids

Amino acid – central carbon with 3 attachments // amino group ($NH2$), carboxyl group ($COOH$) and radical group (R group)

20 amino acids used similar “backbone” to make the proteins but unique radical (R) group

- –properties of amino acid determined by -R group
- –amino acids are defined as either essential or non-essential

Representative Amino Acids



20 different amino acids in humans // they differ only in the R group

Naming Peptides

Peptide – any molecule composed of two or more amino acids joined by peptide bonds

Peptide bond – joins the amino group of one amino acid to the carboxyl group of the next

–formed by dehydration synthesis

Peptides named for the number of amino acids

– **dipeptides** have 2

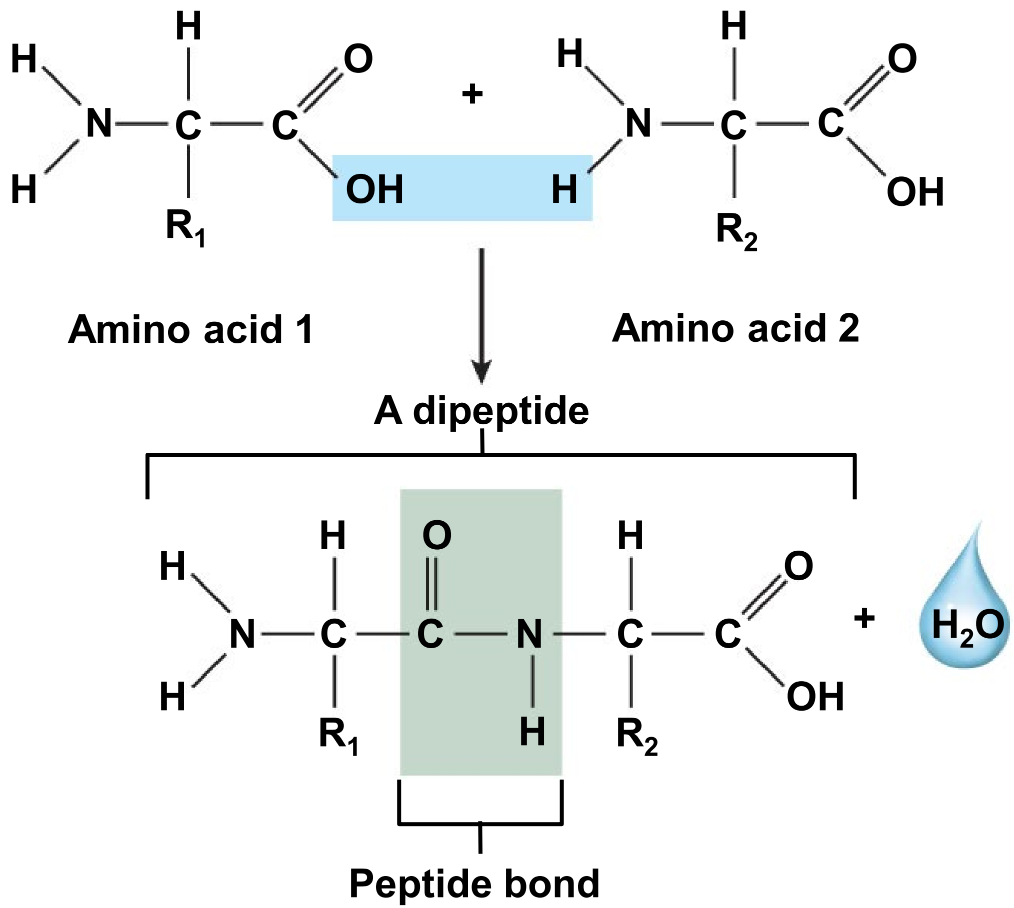
– **tripeptides** have 3

– **oligopeptides** have fewer than 10 to 15

– **polypeptides** have more than 15

– **proteins** have more than 50

Dipeptide Synthesis



Dehydration synthesis (but oxygen is not the link) creates a peptide bond that joins amino acids // covalent bond between carbon and nitrogen = peptide bond

Protein Structure and Shape

Primary structure

Protein's sequence amino acid which is encoded in the genes

Secondary structure

– coiled or folded shape held together by hydrogen bonds

– hydrogen bonds
  – between slightly negative C=O
  – and slightly positive N-H groups

–most common secondary structure are:
  • alpha helix – springlike shape
  • beta helix – pleated, ribbonlike shape

Protein Structure and Shape

Tertiary structure // further bending and folding of proteins into globular and fibrous shapes

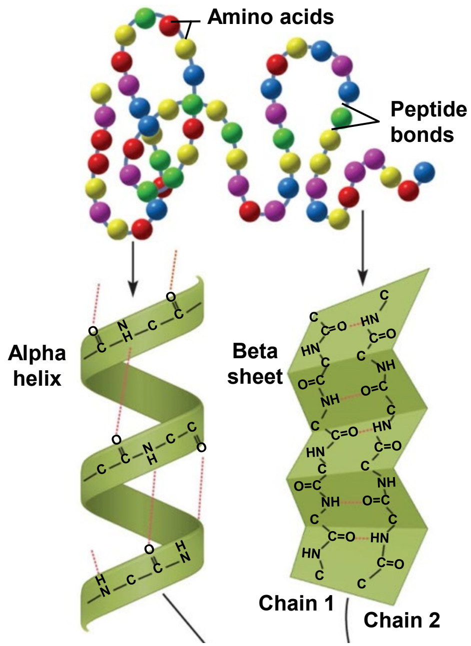
Globular proteins –compact tertiary structure well suited for proteins embedded in cell membrane and proteins that must move about freely in body fluid

Fibrous proteins – slender filaments better suited for roles as in muscle contraction and strengthening the skin

Quaternary structure

- –associations of two or more separate polypeptide chains
- –functional conformation – three dimensional shape

Structure of Proteins

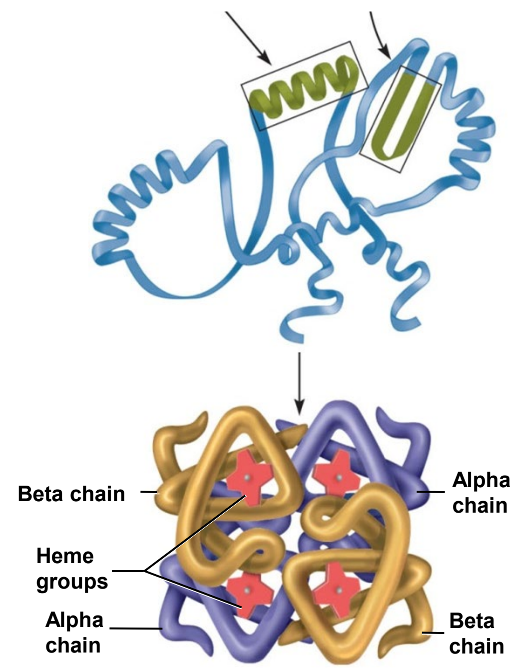


Primary structure

Sequence of amino acids joined by peptide bonds

Secondary structure

Alpha helix or beta sheet formed by hydrogen bonding



Tertiary structure

Folding and coiling due to interactions among R groups and between R groups and surrounding water

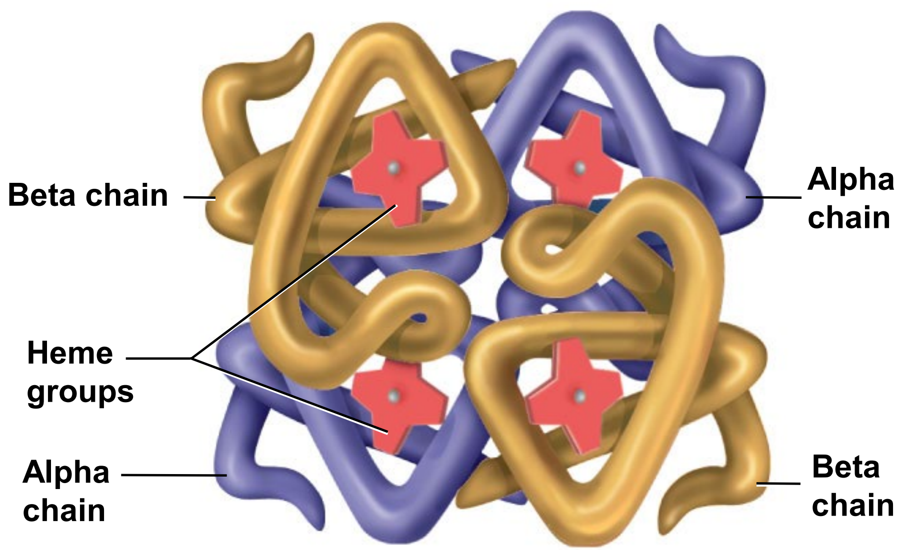
Quaternary structure

Association of two or more polypeptide chains with each other

Conjugated Proteins

Proteins that contain a non-amino acid moiety are called a **prosthetic group**

Hemoglobin contains four complex iron containing rings called a ***heme* moieties**



Quaternary structure

Association of two or more polypeptide chains with each other

Protein Conformation and Denaturation

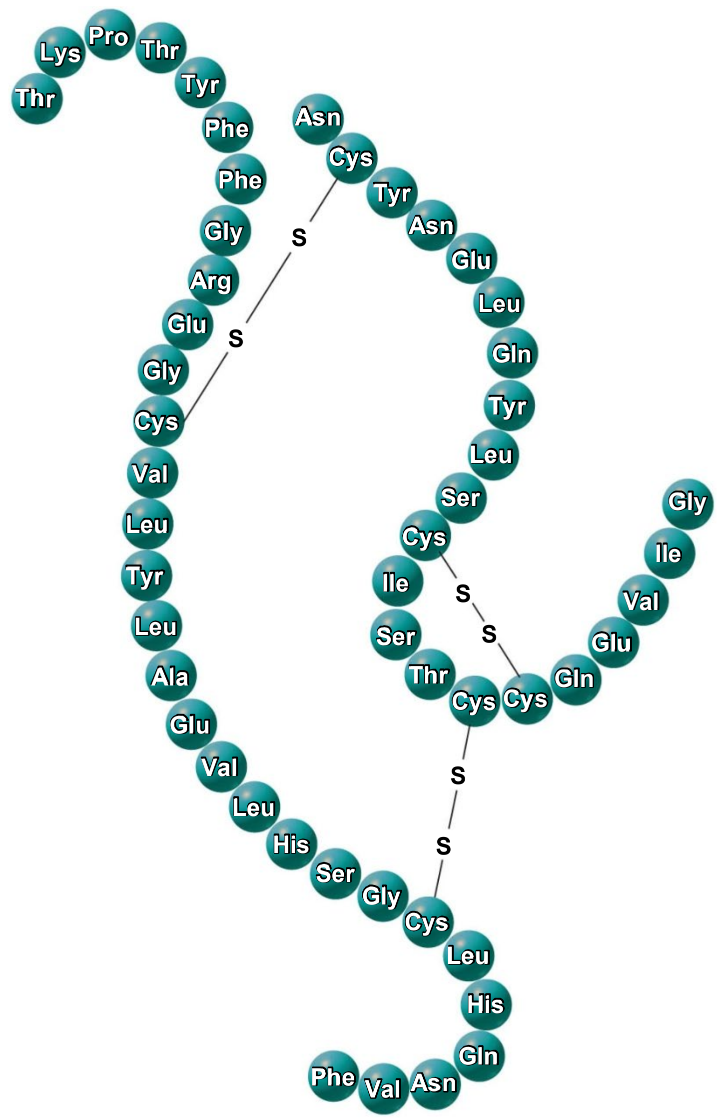
Conformation – unique three-dimensional shape of protein crucial to function

Some proteins have ability to reversibly change their conformation – important in.....

- enzyme function
- muscle contraction
- opening and closing of cell membrane pores

Denaturation ***//*** extreme conformational change that destroys function and protein can not revert to its original shape // caused by extreme heat, pH or agitation

Primary Structure of Insulin



Proteins Have Many Functions

Structure

– keratin – tough structural protein // strength to hair, nails, and skin

– collagen – durable protein in deeper layers of skin, bones, cartilage, and teeth

Communication

– some hormones and other cell-to-cell signals

– receptors to which signal molecules bind

– ligand – any hormone or molecule that reversibly binds to a protein

Membrane Transport

– channels in cell membranes that governs what passes through

– carrier proteins – transports solute particles to other side of membrane

– turn nerve and muscle activity on and off

Proteins Have Many Functions

Catalysis are enzymes

Recognition and Protection

– immune recognition

– antibodies

– clotting proteins

Movement

– **motor proteins** - molecules with the ability to change shape repeatedly

Cell adhesion

– proteins bind cells together

– immune cells to bind to cancer cells

– keeps tissues from falling apart

Proteins may be structural or functional // the recipe for making proteins are encoded in DNA as "genes"

Enzymes

Enzymes - proteins that function as biological catalysts

Permit reactions to occur rapidly at normal body temperature

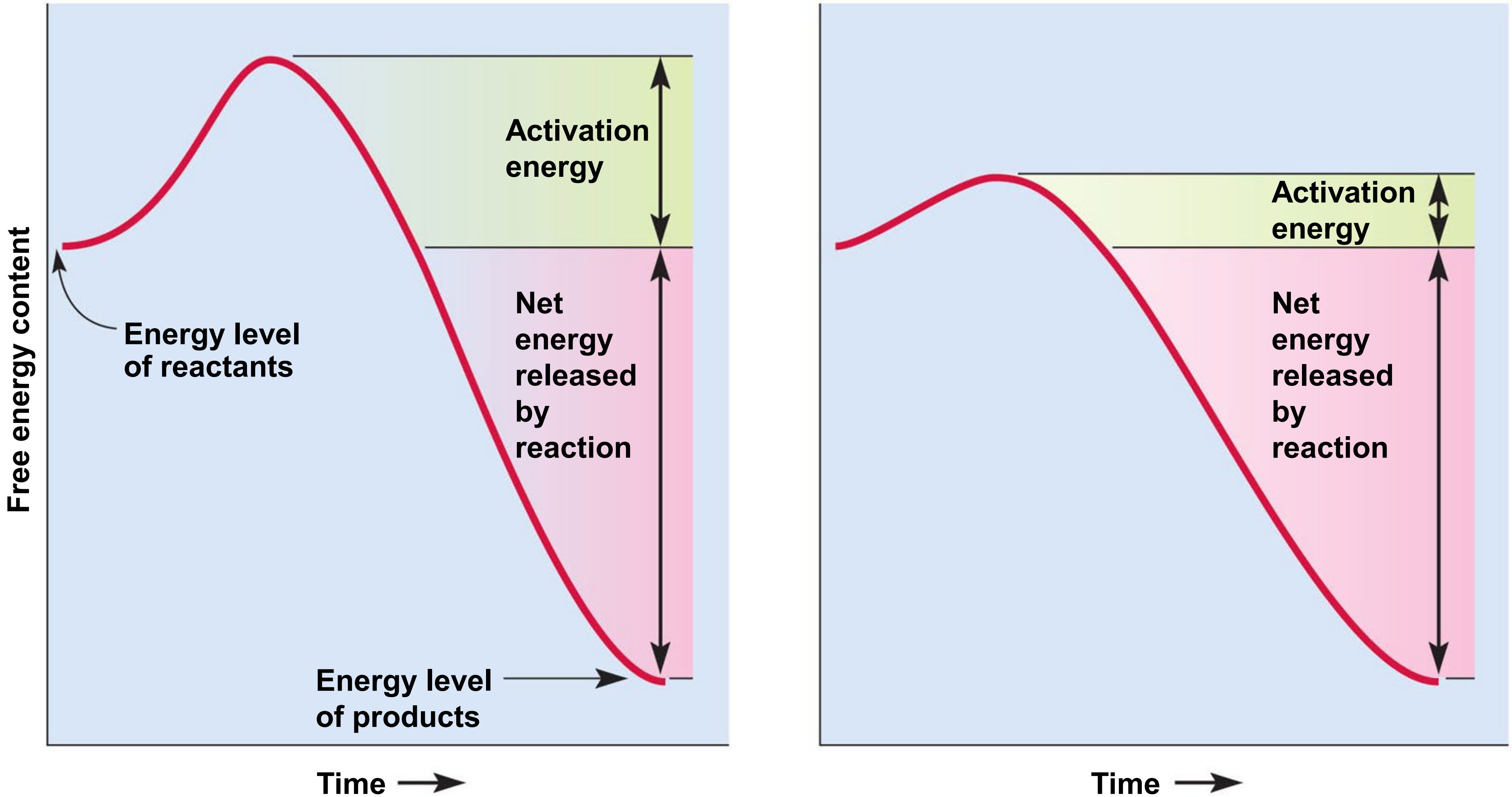
Substrate - substance that the enzyme acts upon

Naming Conventions

named for substrate with -"ase" as the suffix (e.g. amylase = enzyme that digests starch (note difference for amylose /// "ose" indicates sacharide – amylose polymer of glucose)

Enzymes lowers **activation energy** - energy needed to get reaction started /// enzymes facilitate molecular interaction

Enzymes and Activation Energy



(a) Reaction occurring without a catalyst

(b) Reaction occurring with a catalyst

Enzyme Structure and Action

Substrate approaches active site on enzyme molecule

Substrate binds to active site forming enzyme-substrate complex

- – highly specific fit – like a ’lock and key’
- – enzyme-substrate specificity

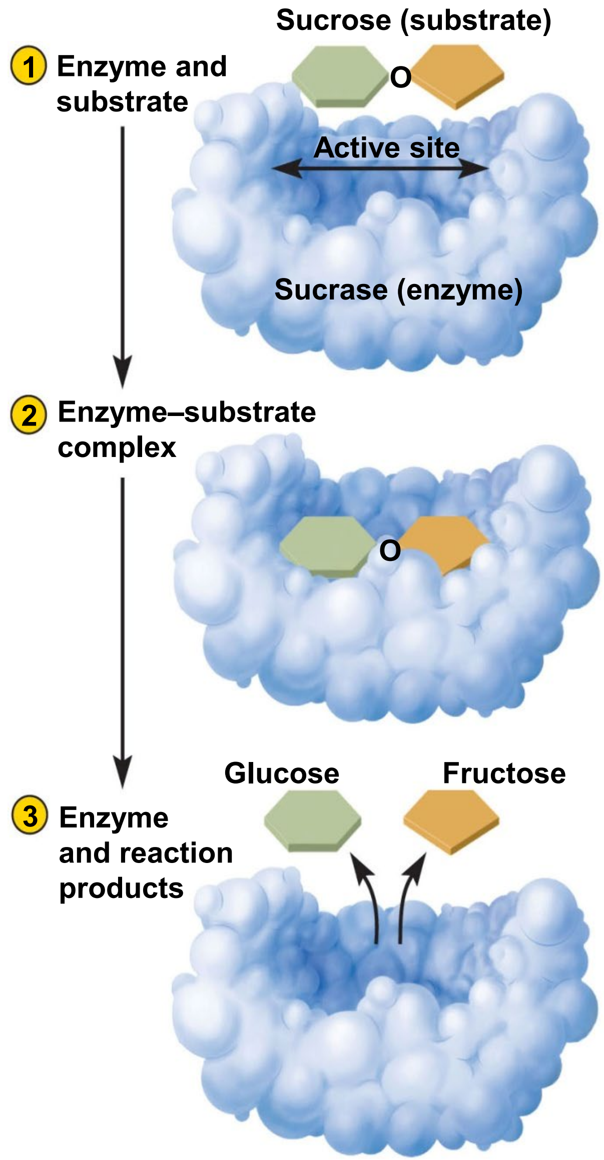
Enzyme breaks covalent bonds between monomers in substrate

• adding H+ and OH- from water – Hydrolysis

• reaction products released – glucose and fructose

• enzyme remains unchanged and is ready to repeat the process

Enzymatic Reaction Steps



Catabolic reaction

About Enzymatic Action

Enzymes are reusable /// enzymes are not consumed by the reactions

Astonishing speed /// one enzyme molecule may consume millions of substrate molecules per minute

Factors that change enzyme shape // pH, temperature, agitation

Denature changes shape and alters or destroys the ability of the enzyme to bind to substrate

Enzymes action have optimum pH /// salivary amylase works best at pH 7.0 /// pepsin works best at pH 2.0

Temperature optimum for human enzymes – body temperature (37 degrees C)

Enzymes Control Metabolic Pathways

Chain of reactions // each step catalyzed by a different enzyme

$$A \xrightarrow{\alpha} B \xrightarrow{\beta} C \xrightarrow{\gamma} D$$

A is initial reactant, B+C are intermediates and D is the end product

Regulation of metabolic pathways // involves the activation or deactivation of the enzymes

Cells can regulate pathways /// turn on when end products are needed or turn off when the end products are not needed

Metabolic pathways are regulated in many ways // EG. enzyme “a” maybe inhibited by end product “D”

Nucleotides

Organic Molecules

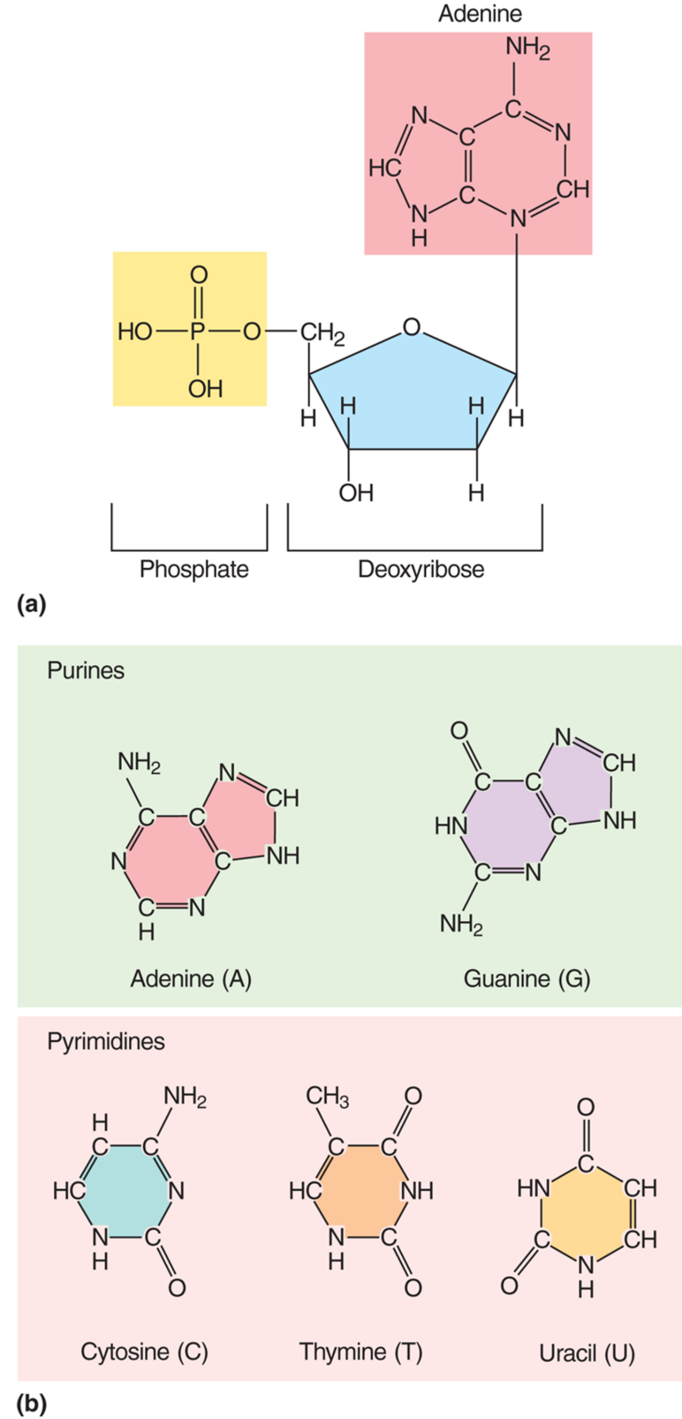
Three components of a nucleotide

- nitrogenous base (single or double carbon-nitrogen ring)
- sugar (monosaccharide)
- one or more phosphate groups

DNA = Double stranded macromolecule of nucleic acid = A, T, G, C

RNA = Single stranded macromolecule of nucleic acids = A, U, G, C

ATP – best know nucleotide /// adenine (nitrogenous base) + ribose (sugar) + Three phosphate groups



DNA Nucleotides

DNA (deoxyribonucleic acid)

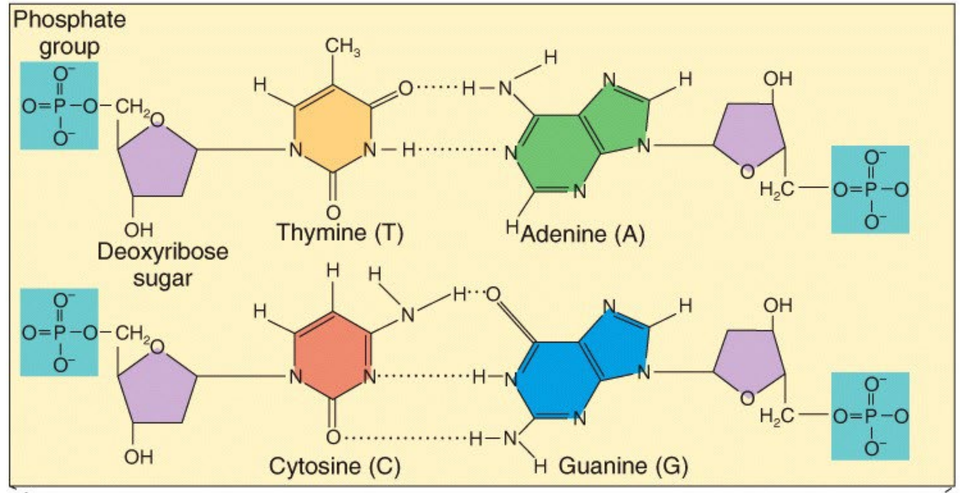
100 million to 1 billion nucleotides long (G, C, A, T)

Our genes are constructed from DNA

instructions for synthesizing all proteins // functional or structural proteins

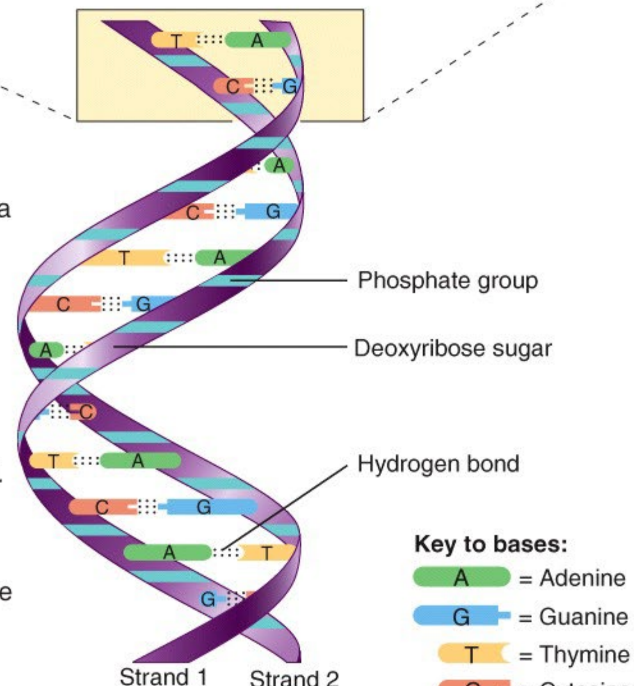
transfers hereditary information from cell to cell and generation to generation

DNA codes for protein // either a structural molecule or a functional protein (*enzyme – the enzymes can make other organic molecules*)



(a) Components of nucleotides

- DNA is made of two strands twisted in a spiral staircase-like structure called a double helix.
- Each strand consists of nucleotides bound together.
- Each nucleotide consists of a deoxyribose sugar bound to a phosphate group and one of 4 nitrogenous bases [adenine (A), thymine (T), guanine (G), cytosine (C)].
- The nitrogenous bases pair together through hydrogen bonding to form the "steps" of the double helix.
- Adenine pairs with thymine and guanine pairs with cytosine.



(b) Portion of a DNA molecule

RNA Nucleotides

RNA (ribonucleic acid) – 3 types associated with protein synthesis

Nucleotides = G, C, A, U

messenger RNA, ribosomal RNA, transfer RNA

70 to 10,000 nucleotides long

carries out genetic instruction for synthesizing proteins

assembles amino acids in the right order to produce proteins

single strand // not double stranded like DNA

Micro-RNA // functions as a biocatalyst

Adenosine Triphosphate (ATP)

Body's most important energy-transfer molecule // the molecule which provides energy for all cellular work // "molecular money"

Briefly stores energy gained from exergonic reactions // less than a second

ATP not used to store energy

Holds energy in covalent bonds between phosphates

2nd and 3rd phosphate groups have high energy bonds // denoted by this symbol " ~ "

Most energy transfers to and from ATP involve adding or removing the 3rd phosphate

Adenosine Triphosphate (ATP)

Adenosine triphosphatases (ATPases) hydrolyze the 3^{rd} high energy phosphate bond

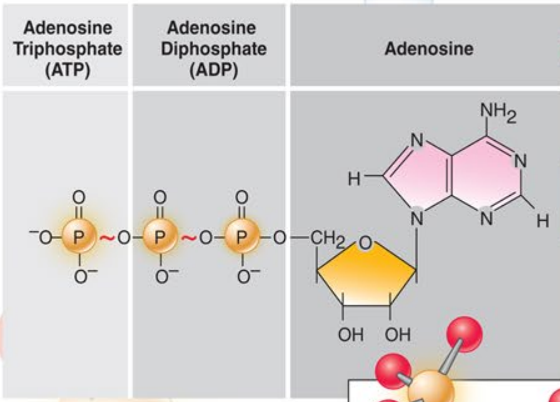
Separates into ADP + P_i + energy

Phosphorylation

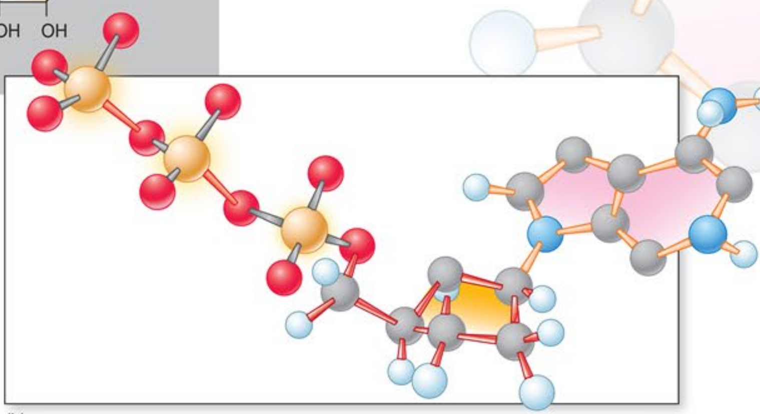
addition of free phosphate group to ADP molecule

carried out by enzymes called **kinases** (phosphokinases)

ATP can be formed by directly phosphorylation of ADP (substrate level phosphorylation) or by a mechanism within mitochondria called oxidation-phosphorylation which requires using an electron chain and ATP-synthetase

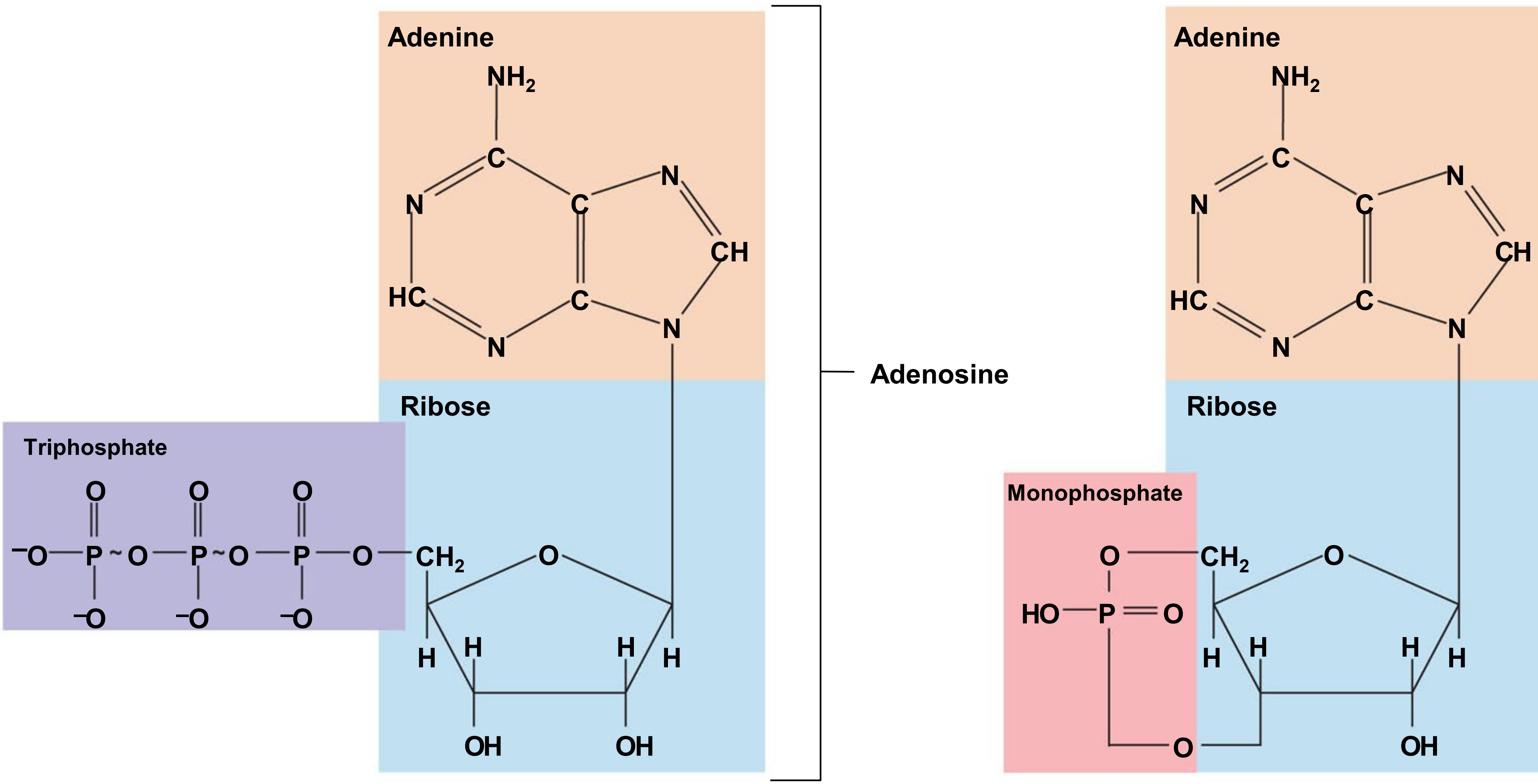

Adenosine Triphosphate (ATP)
Adenosine Diphosphate (ADP)
Adenosine
NH2
N
N
H
N
N
H
O
P
O−
−O
~
O
P
~
O
P
O
CH2
O
OH
OH

(a)



(b)

ATP (Adenosine Triphosphate)

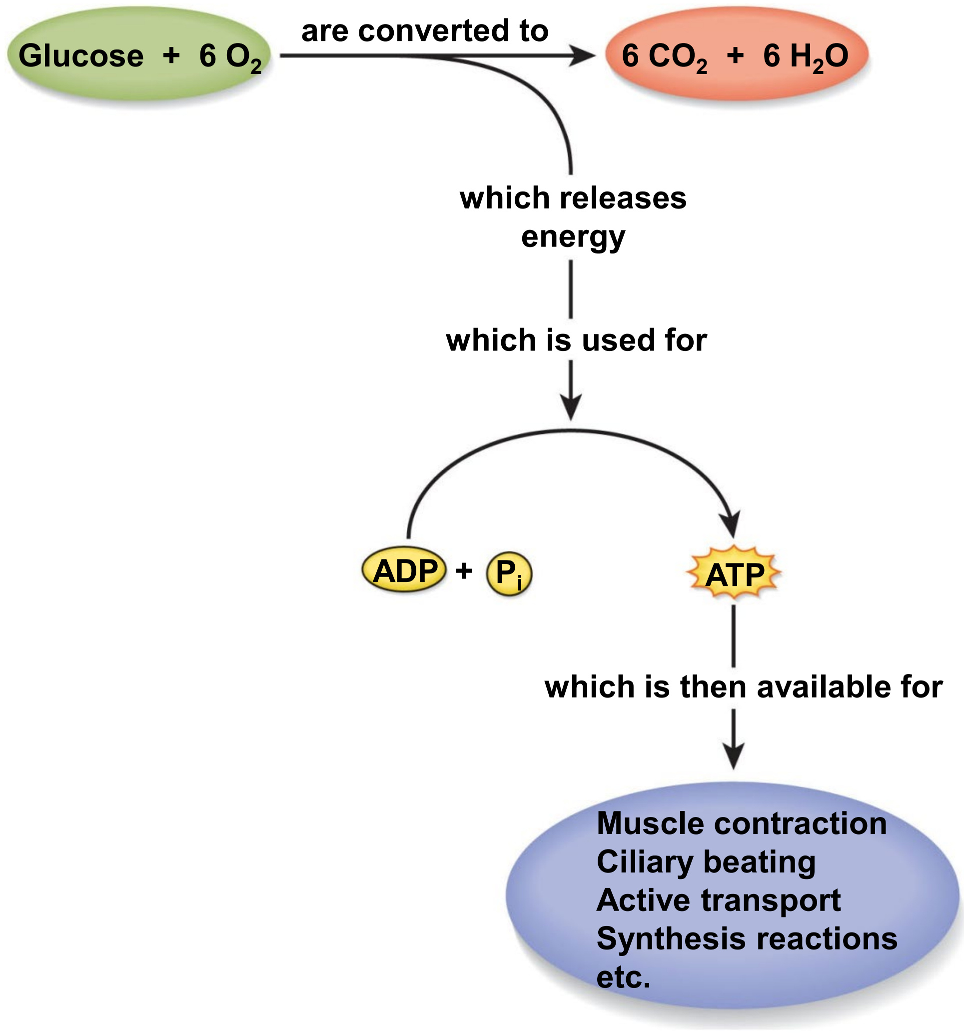


(a) Adenosine triphosphate (ATP)

(b) Cyclic adenosine monophosphate (cAMP)

ATP contains adenine, ribose and 3 phosphate groups

Sources and Uses of ATP

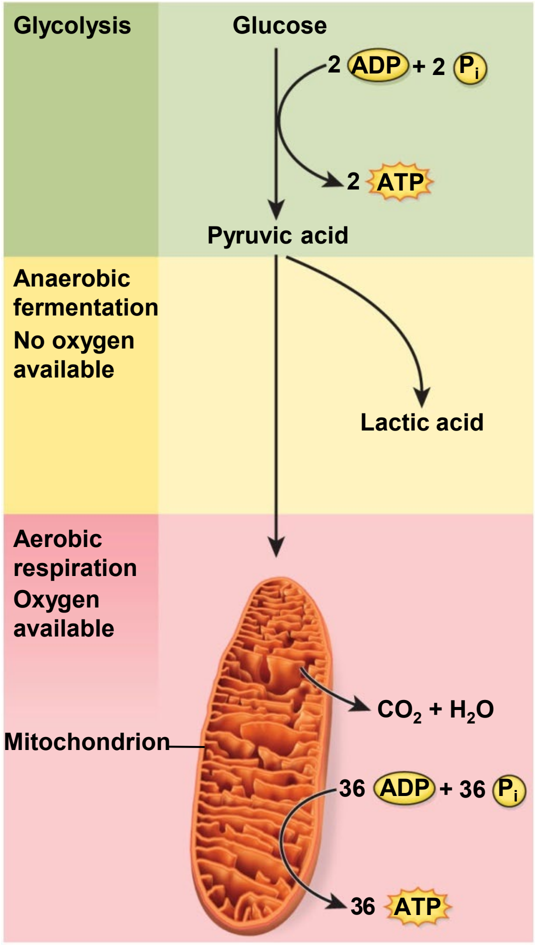


Overview of ATP Production

Occurs in cytoplasm and is anaerobic.

If oxygen is available, then pyruvic converted to acetyl-CoA and moves into mitochondria.

Inside the mitochondria the Krebs Cycle and electron transport chain produces 36 ATP, metabolic water, and carbon dioxide.



Stages of glucose oxidation

- ATP consumed within 5 to 15 seconds after formation
- entire amount of ATP in the body would support life for less than 1 minute if it were not continually replenished
- cyanide halts ATP synthesis // stops electrons from moving down electron transport chain which is inside the mitochondria
- Two test questions here!!!

Other Nucleotides

Guanosine triphosphate (GTP)

–another nucleotide involved in energy transfer

–donates phosphate group to other molecules

Cyclic adenosine monophosphate (cAMP)

–nucleotide formed by removal of both second and third phosphate groups from ATP

–formation triggered by hormone binding to cell surface

–cAMP becomes “second messenger” within cell

–activates metabolic effects inside cell

Cofactors and Coenzymes

Some enzymes require co-factors and coenzymes

Cofactors

about 2/3rds of human enzymes require a non-protein cofactor

inorganic partners (iron, copper, zinc, magnesium and calcium ions)

some bind to enzyme and induces a change in its shape, which activates the active site

essential to function

Coenzymes

Coenzymes = organic cofactors derived from water-soluble vitamins (niacin, riboflavin)

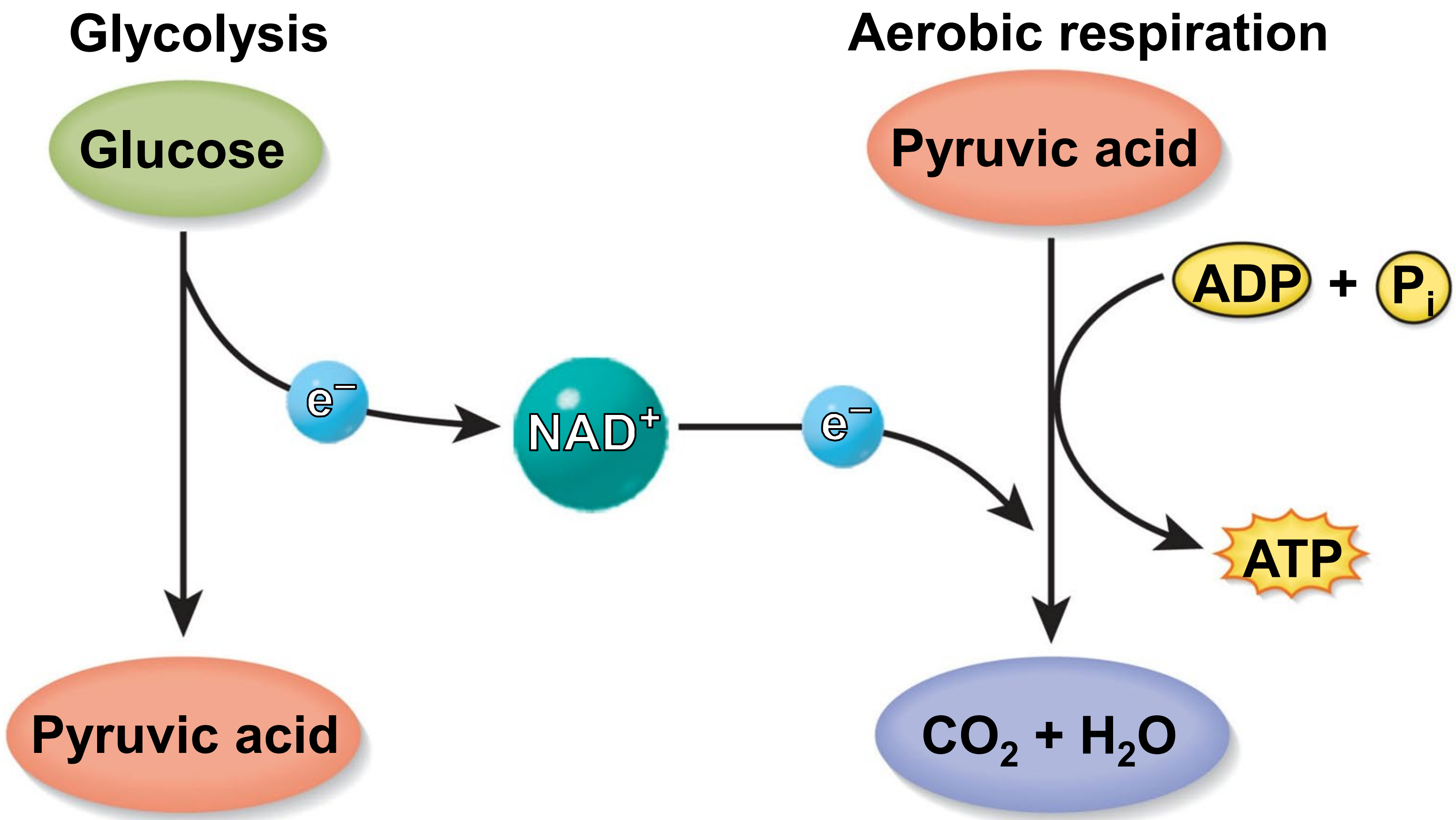
They accept electrons from an enzyme in one metabolic pathway and transfer them to an enzyme in another metabolic pathway /// This is an Oxidation-Reduction Reaction

The molecule losing the electron is “oxidized” and the molecule gaining the electron is “reduced” (i.e. redox reaction)

The electron carrier is reqired by the enzyme to catalyze the reaction reaction (e.g   AB -----> A + B)

NAD to NADH or FAD to FADH are examples of electron carriers

Coenzyme NAD^+



- NAD^+ transports electrons from one metabolic pathway to another