

Introduction To Plant Biochemistry

Definition and Role of Biochemistry

- Biochemistry is a branch of life science that deals with the chemical constituents of living cells, the reactions and processes they undergo.

- Biochemistry could be defined as 'the study of life at the molecular level'.

- Can also be defined as The chemistry of life (the chemical basis of life).

- Anything more than a superficial comprehension of life- in all its diverse manifestation - demands a knowledge of biochemistry.

Cont…

- Cells are the fundamental structural and functional unit of living systems.

- They are natural reaction vessels for biochemical reactions.

- Biochemical reactions take place in a very small size of the cell, in mild physiological conditions of temperature, pressure, and at constant pH, in an aqueous medium.

What is Plant Biochemistry ?

- **Plant Biochemistry** is the study of molecular basis of plant life that includes the synthesis and utilization of compounds in the life process of plants (growth & development).

Basic Principle

- Living organisms, whether they are plants, animals or microbes, are made up basically of the same chemical components.
- The formation of compounds (biomolecules) required in the living process of plants, from the chemical components, occurs through biochemical reactions catalyzed in

There are two categories of biochemistry:

- **Descriptive Biochemistry:**
  - Deals with qualitative and quantitative nature of molecules in the living cells.

- **Dynamic Biochemistry:**
  - Deals with reactions and mechanisms of reactions in the living cells.

- To completely understand the molecular level of all the chemical processes associated with living cells.

- To achieve this objective, biochemists have required to:
  - ✓ Isolate the biomolecules found in cells
  - ✓ Determine the structure of biomolecules, and
  - ✓ Analyze how biomolecules function

- Biochemistry describes the molecular logic of life in the entire spectrum of life forms from the simple (viruses and bacteria) to complex human.

Significance

- Biochemistry is essential to all life sciences as a common knowledge:

✓ Genetics; Cell biology; Molecular biology

✓ Physiology and Immunology

✓ Pharmacology and pharmacy & other health sciences

✓ Toxicology; Pathology; Microbiology

✓ Zoology and Botany, chemistry, biology……

The Chemical Elements of Life

- Six nonmetallic elements- carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur account for more than 97% of the weight of most organisms.

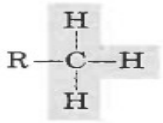
- In addition, there are 23 other elements commonly found in living organisms (3% of the weight of living organisms).

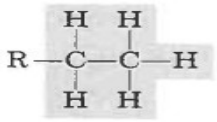
- These include five ions that are essential in all species: calcium, potassium , sodium , magnesium and chloride.

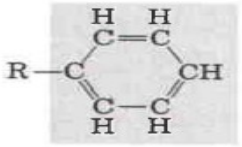
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1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 * La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89** Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (265)	109 Mt (268)	110 (269)	111 (272)	112 (277)	113	114 (285)	115	116 (289)	117	118 (293)

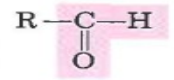
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90** Th 232.0	91 Pa 231	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

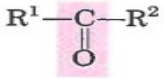
Some common functional groups of biomolecule

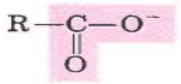
Methyl 

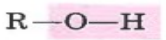
Ethyl 

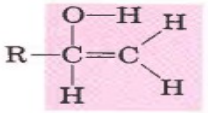
Phenyl 

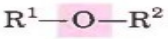
Carbonyl (aldehyde) 

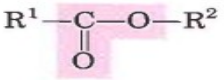
Carbonyl (ketone) 

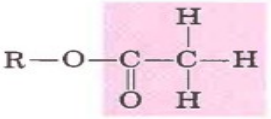
Carboxyl 

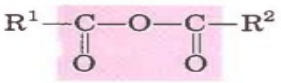
Hydroxyl (alcohol) 

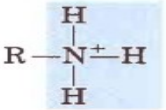
Enol 

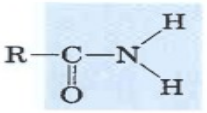
Ether 

Ester 

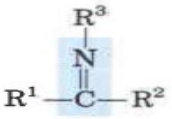
Acetyl 

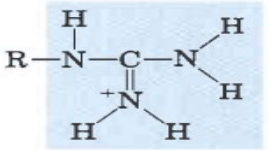
Anhydride (two carboxylic acids) 

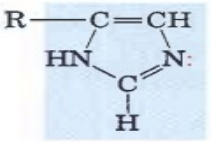
Amino (protonated) 

Amido 

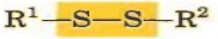
Imine 

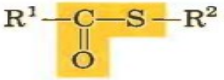
N-Substituted imine (Schiff base) 

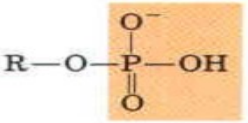
Guanidinium 

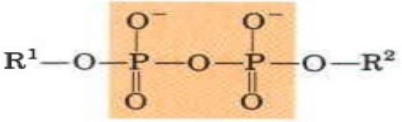
Imidazole 

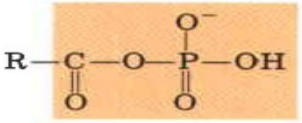
Sulfhydryl 

Disulfide 

Thioester 

Phosphoryl 

Phosphoanhydride 

Mixed anhydride (carboxylic acid and phosphoric acid; also called acyl phosphate) 

Macromolecules

- have properties that are very different from those of their constituent monomers.

- For example, starch is a polymer of glucose but it is not soluble in water and does not taste sweet.

- Observations such as have led to the general principle of the hierarchical organization of life.

- Each new level of organization results in properties that cannot be predicted solely from

Cont…

- The levels of complexity, in increasing order are:
  - Atoms → molecules → macromolecules → organelles → cells → tissues → organs → whole organisms.

- Note: many species lack one or more of these levels of complexity.

- Single-celled organisms, for example, do not have tissues and organs.

Structural hierarchy in the molecular organization of cells

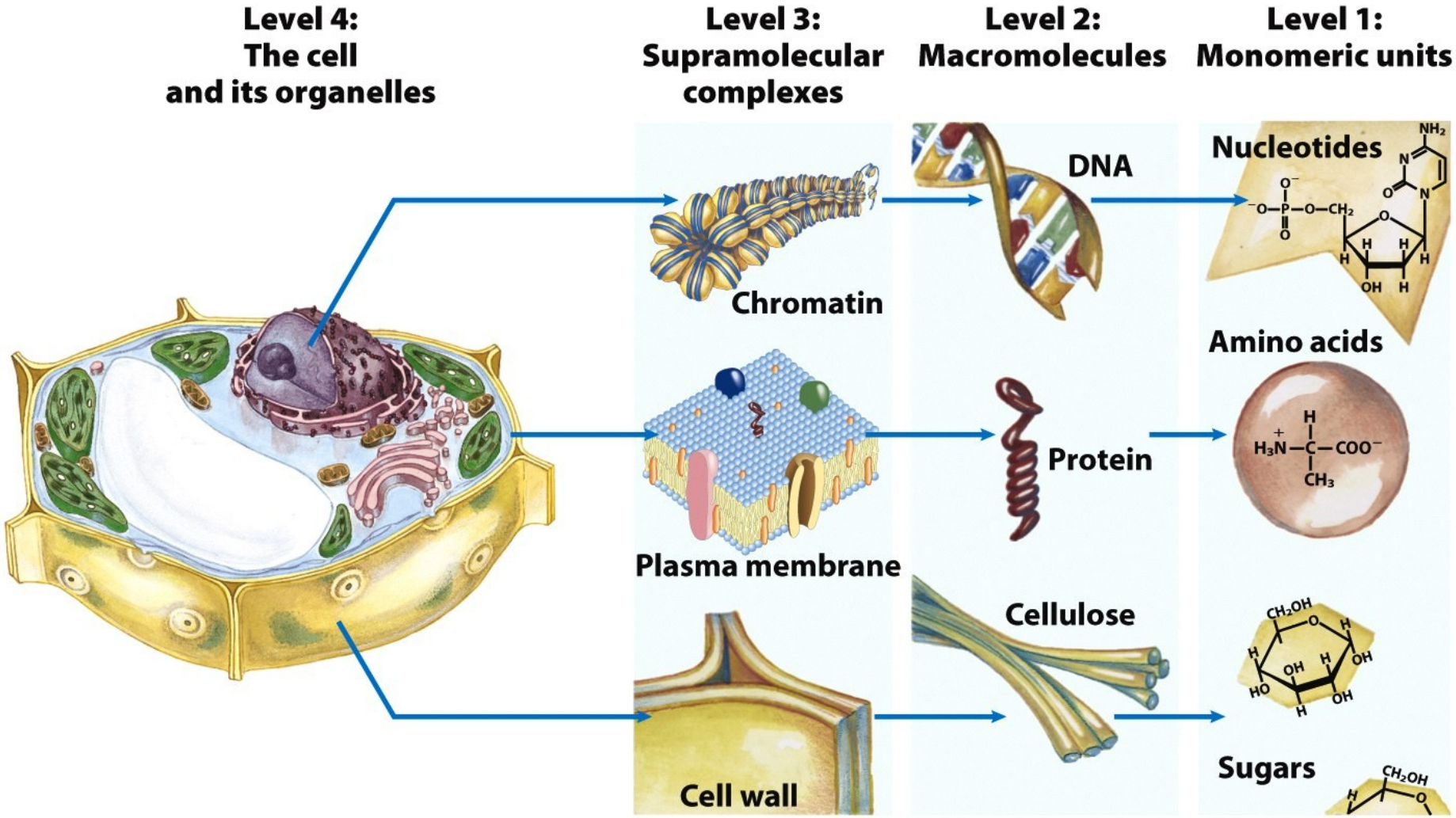
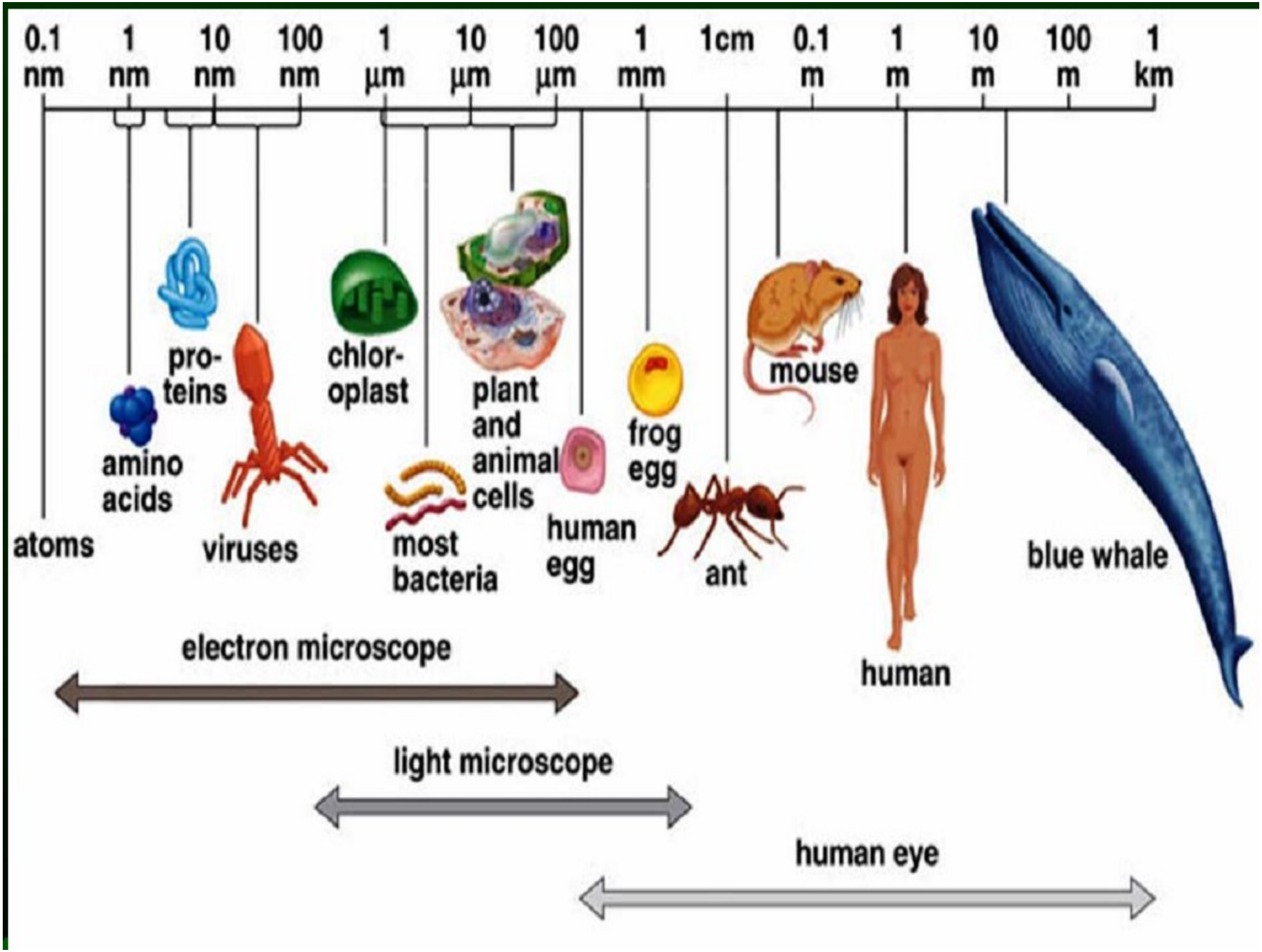


Figure 1-11
Lehninger Principles of Biochemistry, Fifth Edition
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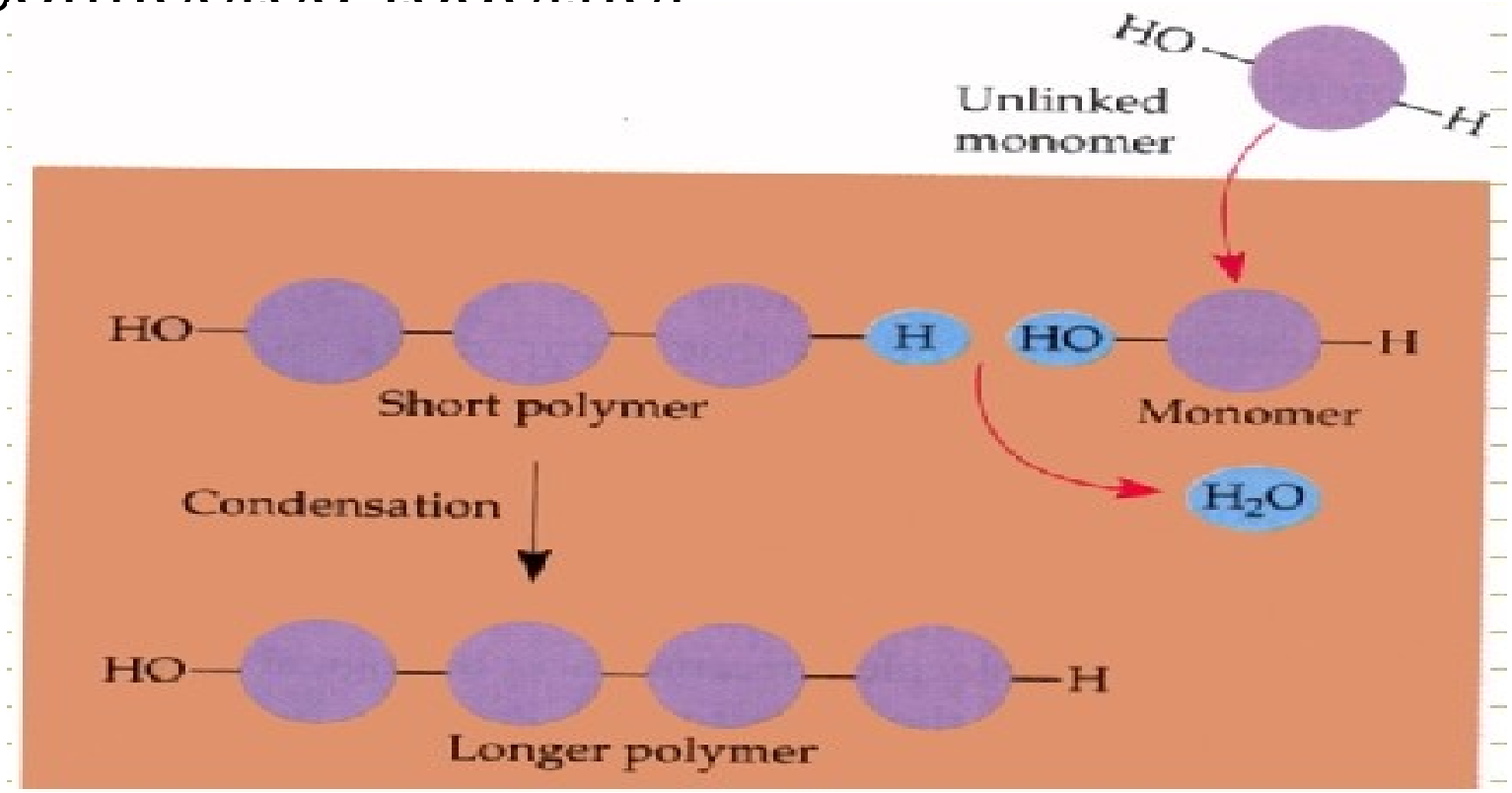

0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1cm
0.1 m
1 m
10 m
100 m
1 km
atoms
amino acids
pro-teins
viruses
chlor-oplast
most bacteria
plant and animal cells
human egg
frog egg
ant
mouse
human
blue whale
electron microscope
light microscope
human eye

Cont..

Macromolecule	Monomer
Carbohydrates	Monosaccharide
Lipids	Glycerol, free fatty acids
Proteins	Amino acids
Nucleic acids	Nucleotides

How do monomers form polymers?

- In condensation reactions (also called dehydration synthesis), a molecule of water is removed from two monomers as they are connected together



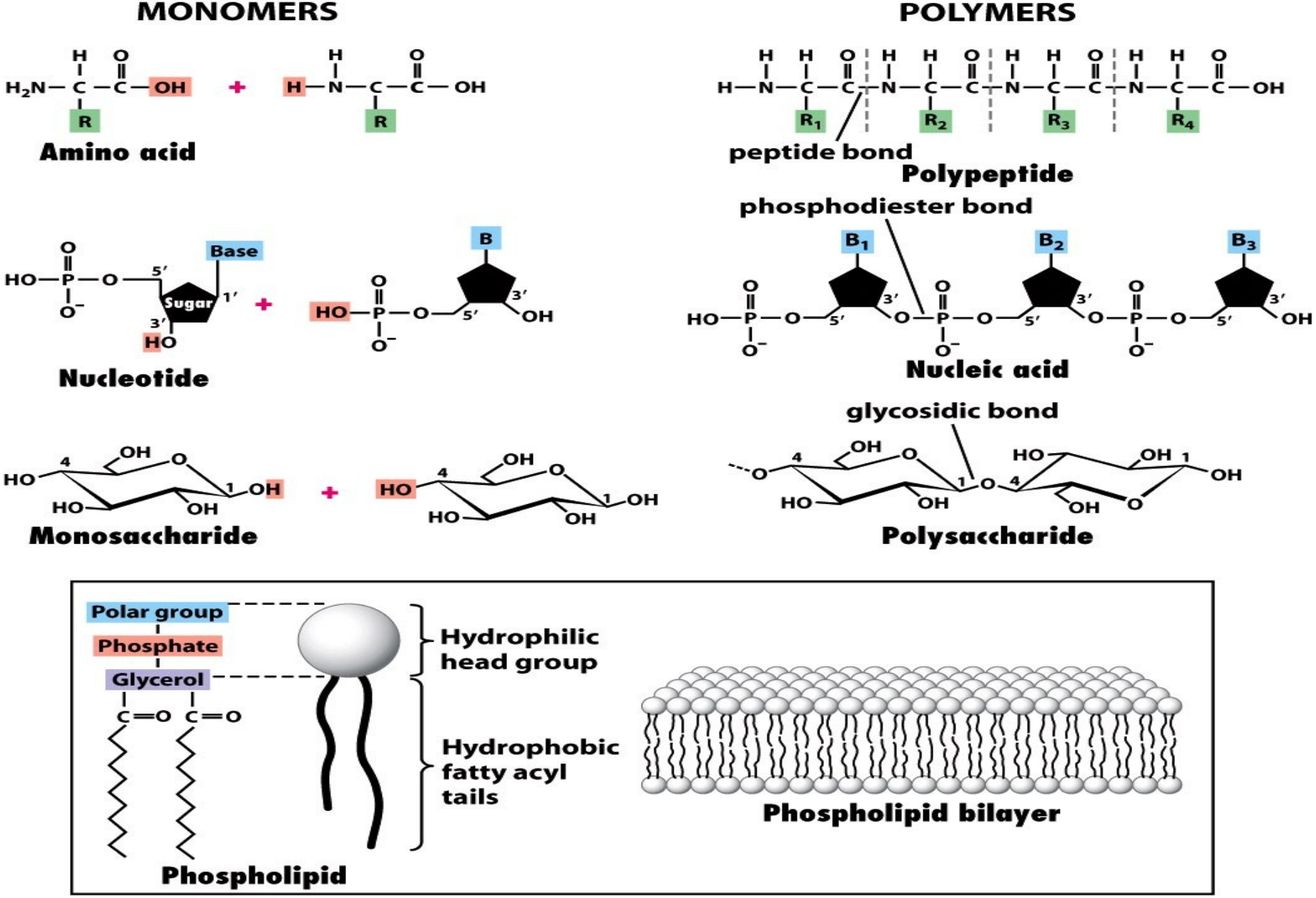
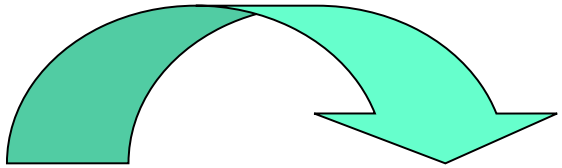


Figure 2-13
Molecular Cell Biology, Sixth Edition
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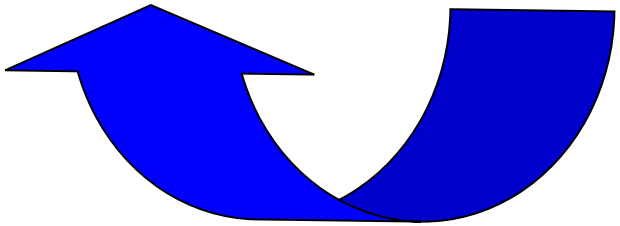
Cont…



Anabolic

- Building block
  - Simple sugar
  - Amino acid
  - Nucleotide
  - Fatty acid
- Macromolecule
  - Polysaccharide
  - Protein (peptide)
  - RNA or DNA
  - Lipid

Catabolic



Proteins

- 20 amino acids are incorporated into proteins in all cells.

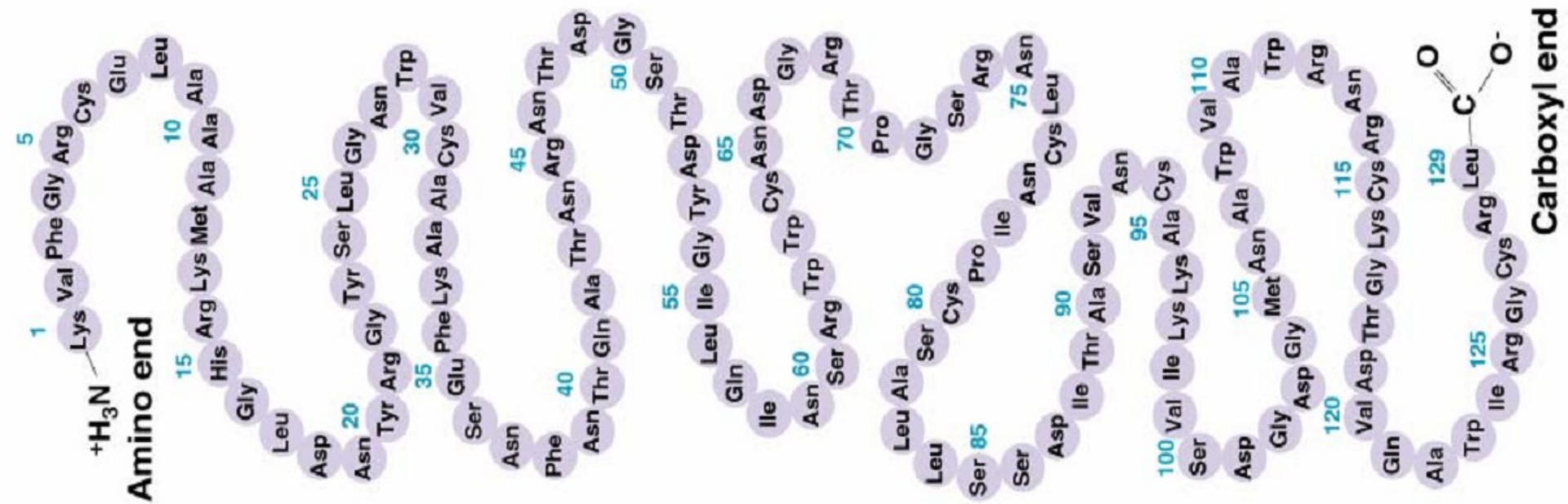
- Each amino acid contains an amino group and a carboxylate group, as well as a side chain (R group) that is unique to each amino acid.

- The amino group of one amino acid and the carboxylate group of another are condensed during protein synthesis to form an amide linkage.

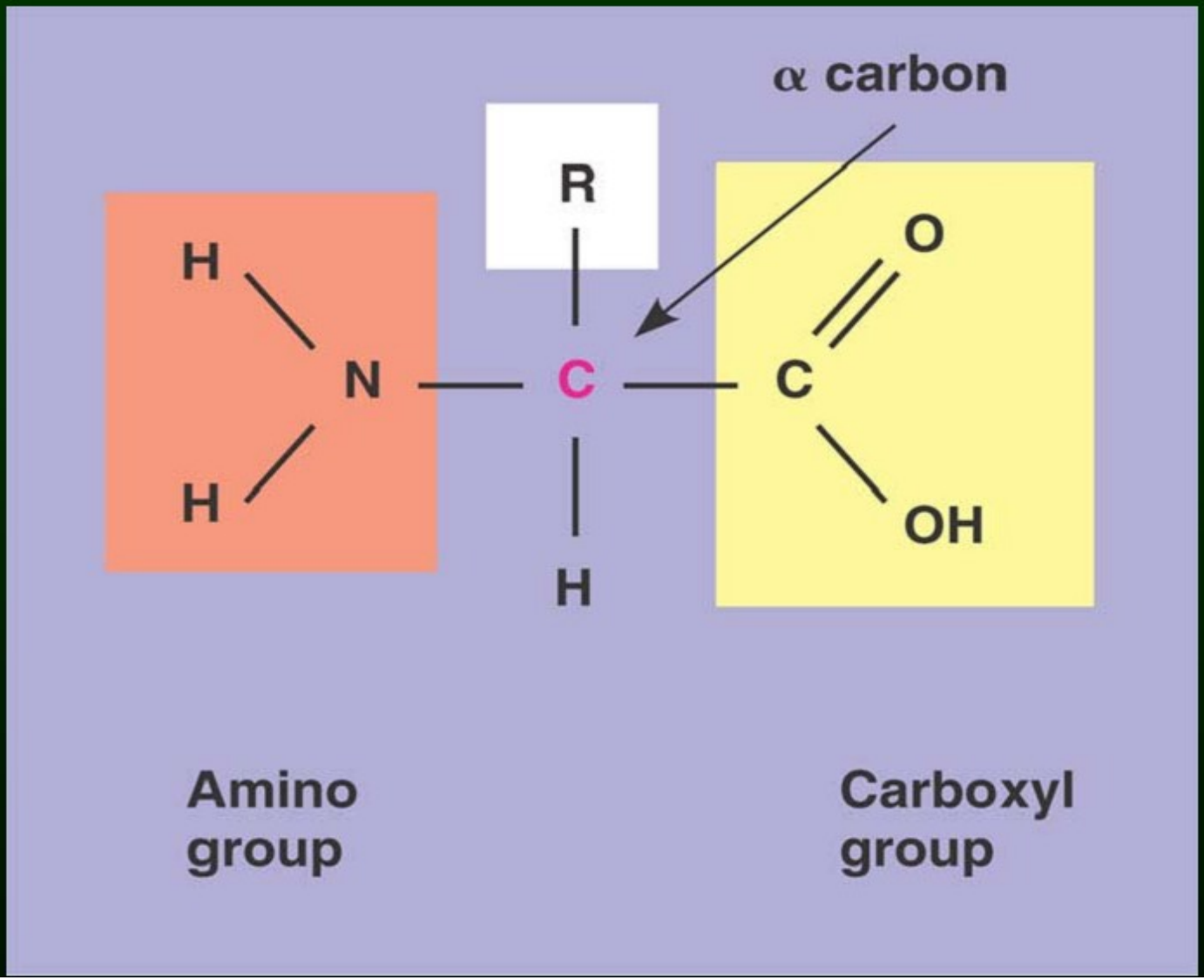
- The bond between the carbon atom of one amino acid residue and the nitrogen atom of

- The end-to-end joining of many amino acids forms a linear polypeptide that may contain hundreds of amino acid residues.

- A functional protein can be a single polypeptide or it can consist of several distinct polypeptide chains that are tightly bound to form a more



Amino Acid Structure



Polysaccharides

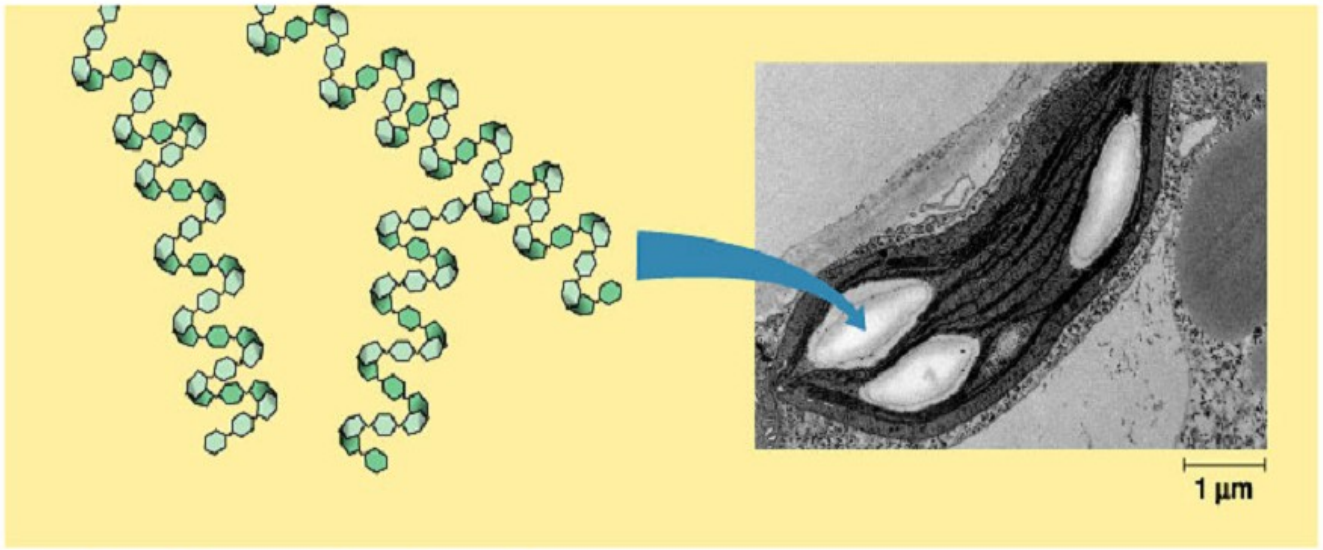
- Carbohydrates, or saccharides, are composed primarily of carbon, oxygen, and hydrogen.

- This group of compounds includes simple sugars (monosaccharides) as well as their polymers polysaccharides.

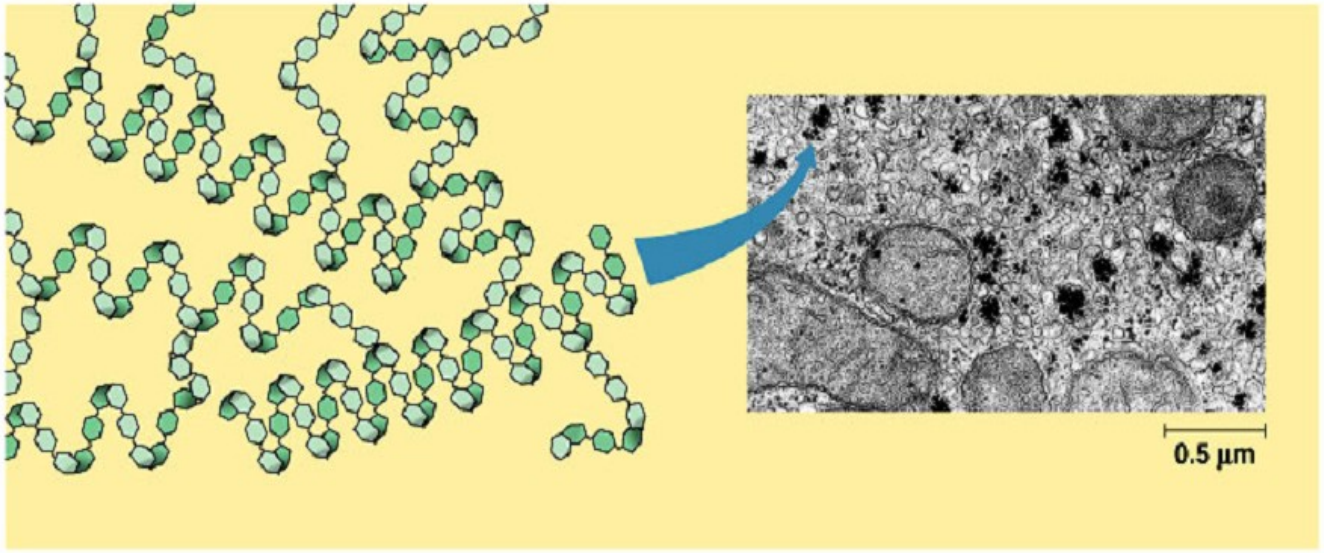
- All monosaccharides contain several hydroxyl groups and are therefore polyalcohols.

- The most common monosaccharides contain either five or six carbon atoms.

Storage polysaccharides



starch

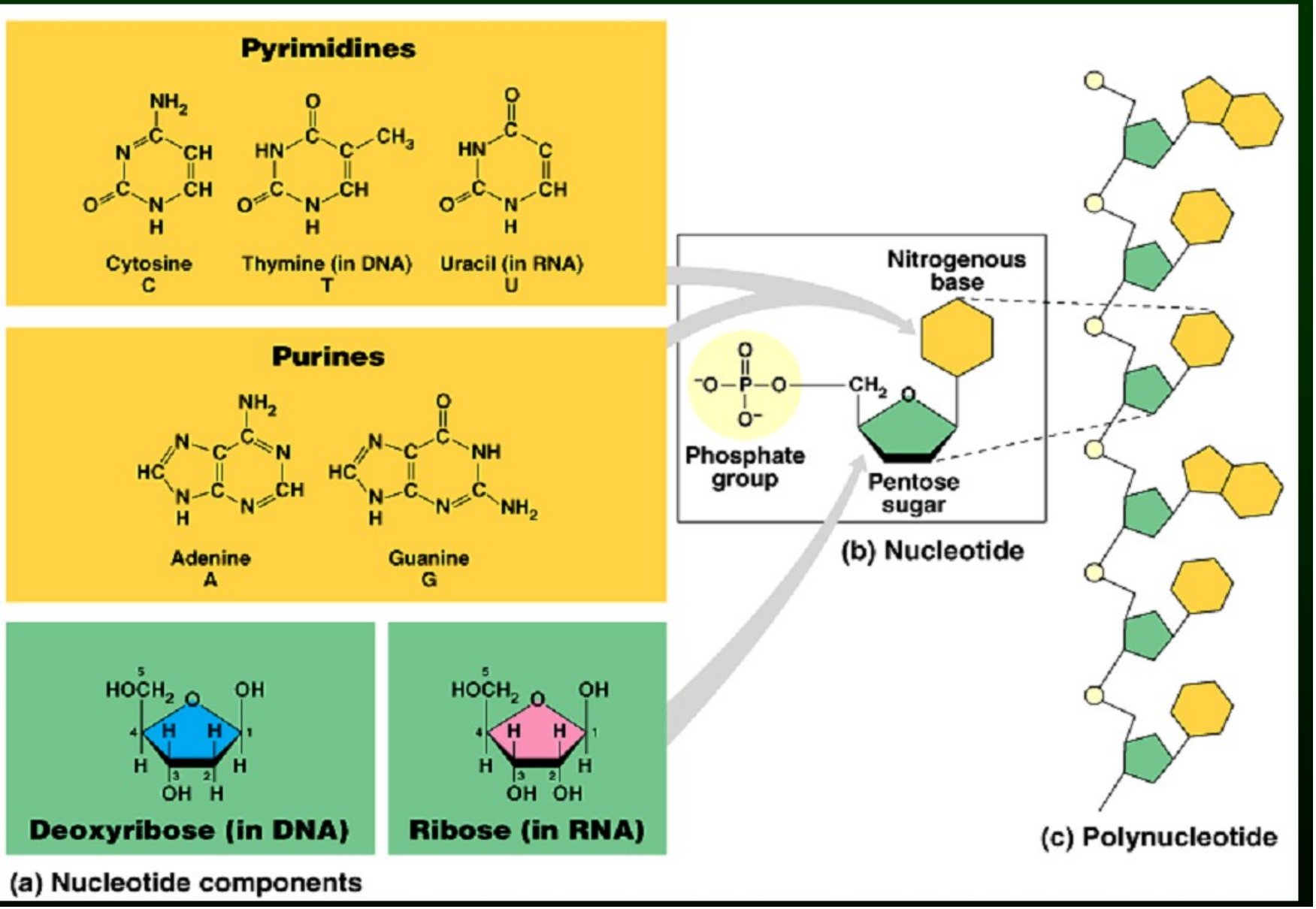


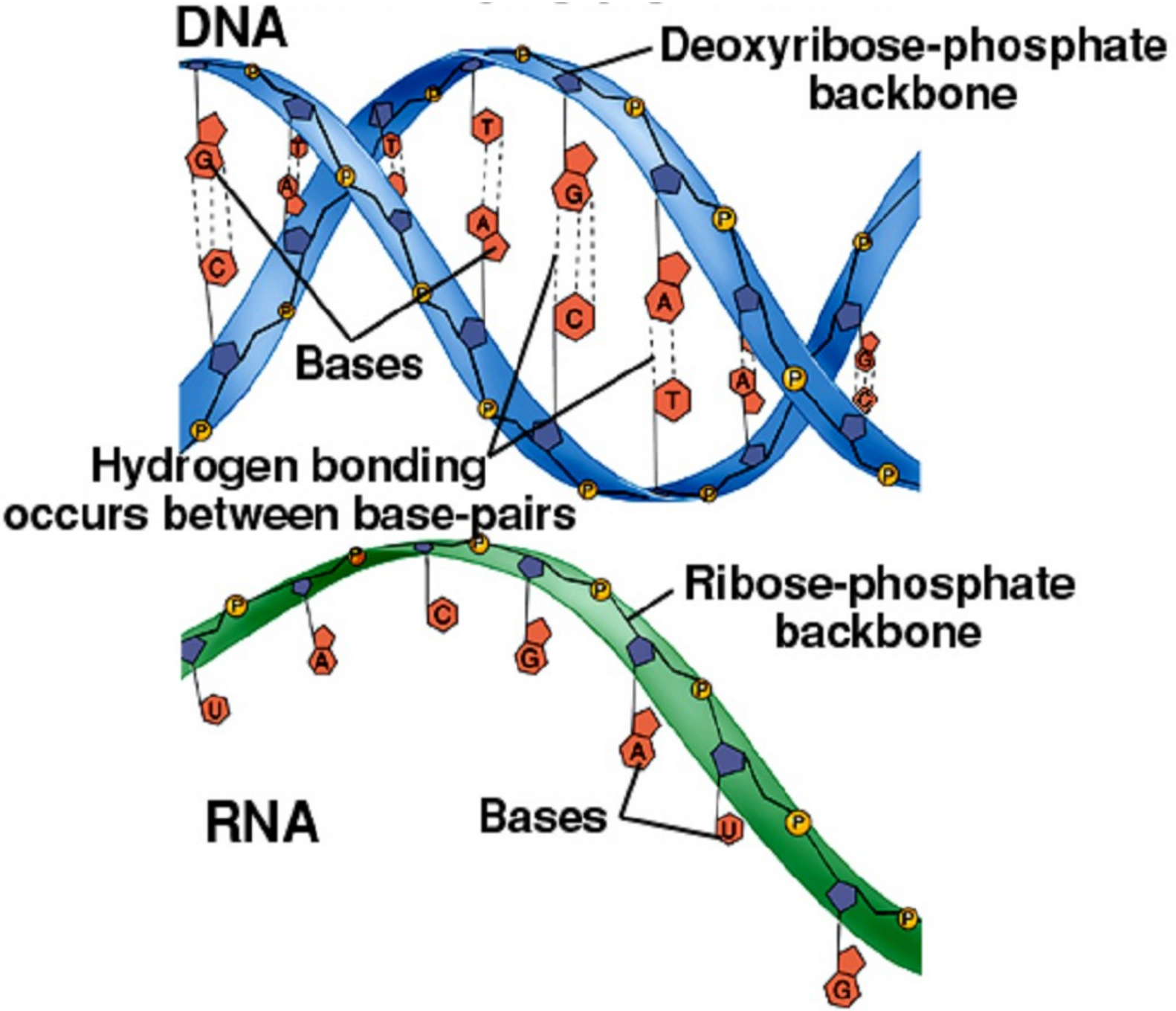
glycogen

Nucleic Acids

- Nucleic acids are large macromolecules composed of monomers called nucleotides.
- The term polynucleotide is a more accurate description of a single molecule of nucleic acid.
- Nucleotides consist of a five-carbon sugar, nitrogenous base, and at least one phosphate group.
- In ribonucleotides, the sugar is ribose; in deoxyribonucleotides, the sugar is deoxyribose.
- The nitrogenous bases of nucleotides belong to two families known as purines and pyrimidines

Nucleic Acids are Polymers




DNA
Deoxyribose-phosphate backbone
Bases
Hydrogen bonding occurs between base-pairs
Ribose-phosphate backbone
RNA
Bases

RNA

- RNA contains ribose rather than deoxyribose and it is usually a single-stranded polynucleotide.

- There are four different kinds of RNA molecules.
- Messenger RNA (mRNA) is involved directly in the transfer of information from DNA to protein.

- Transfer RNA (tRNA) is a smaller molecule required for protein synthesis.

- Ribosomal RNA (rRNA) is the major component of ribosomes.

Lipids and Membranes

- The term “lipid” refers to a diverse class of molecules that are rich in carbon and hydrogen but contain relatively few oxygen atoms.

- Most lipids are not soluble in water but they can dissolve in some organic solvents.

- Lipids often have a polar, hydrophilic (water loving) head and a nonpolar, hydrophobic (water-fearing) tail.

- In an aqueous environment, the hydrophobic tails of such lipids associate while the hydrophilic heads are exposed to water, producing a sheet called a lipid bilayer.

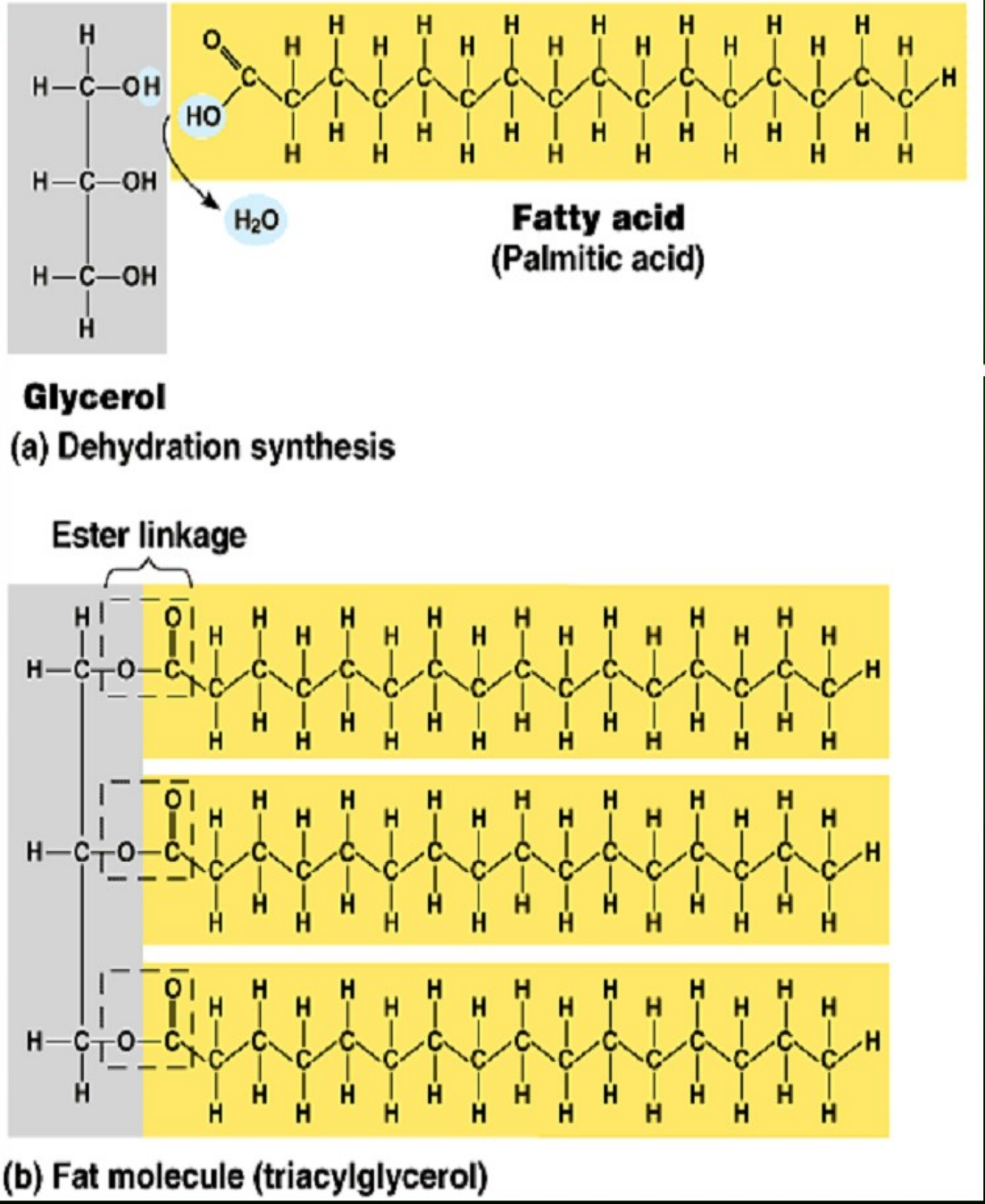
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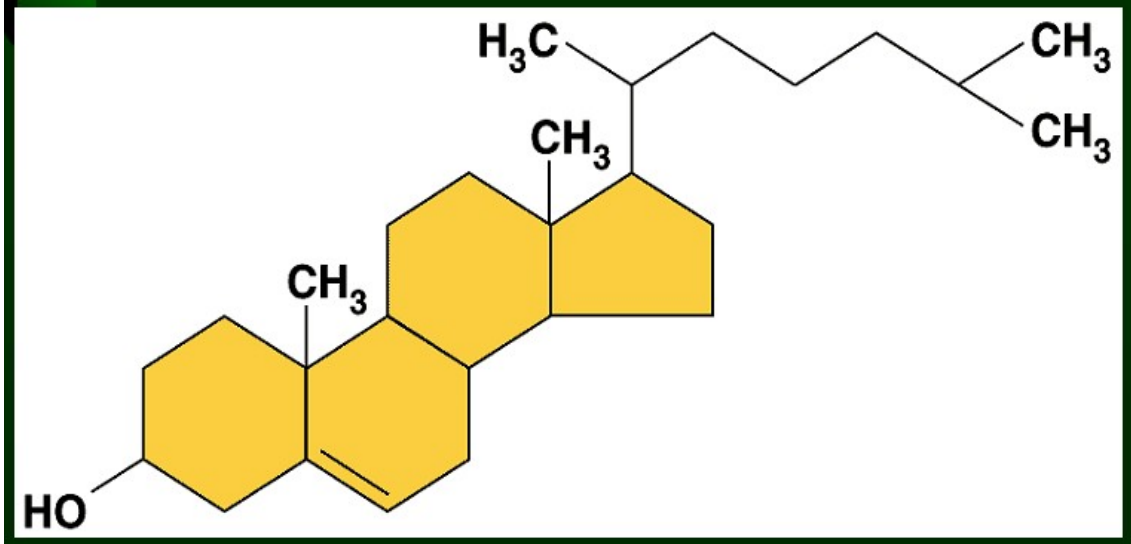
- Lipid bilayers form the structural basis of all biological membranes.

- Membranes separate cells or compartments within cells from their environments by acting as barriers that are impermeable to most water-soluble compounds.

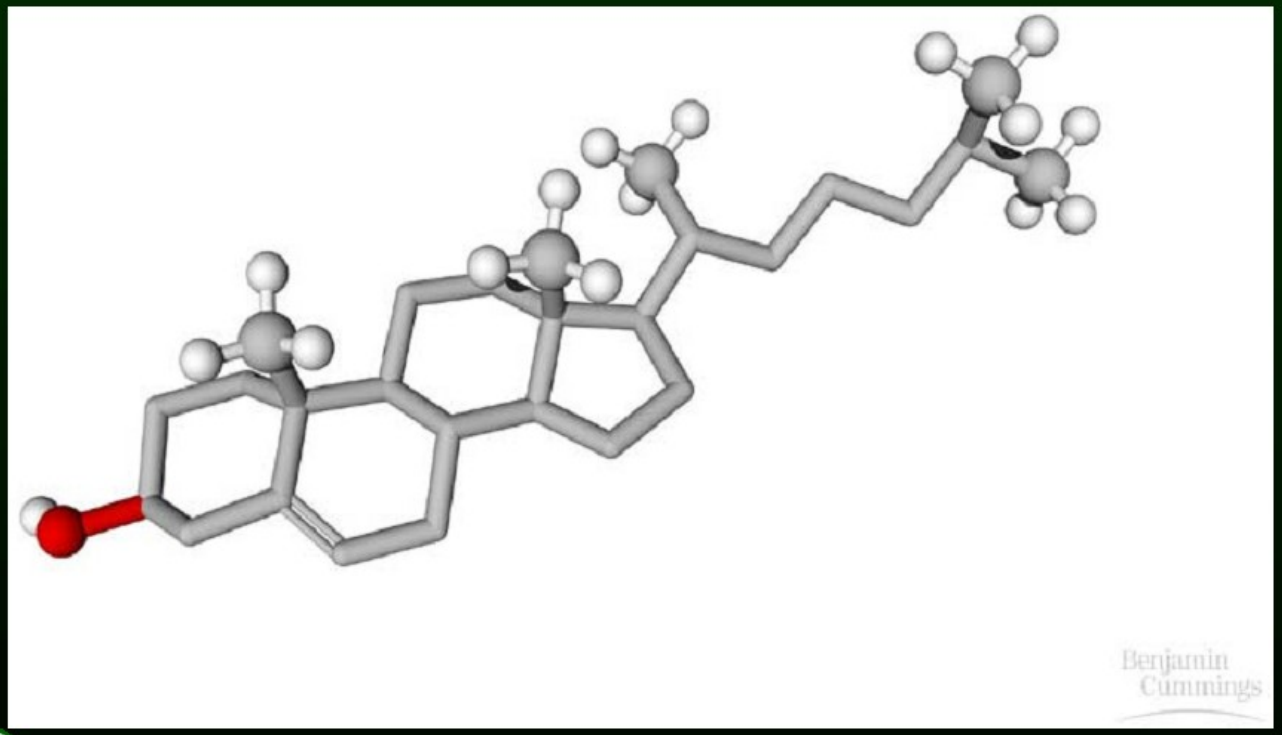
- Membranes are flexible because lipid bilayers are stabilized by noncovalent forces.

Fatty acids & triacylglycerol





Cholesterol: a steroid



The Energetics of Life

- Living organisms are constantly transforming energy into useful work to sustain themselves, to grow, and to reproduce.

- Almost all this energy is ultimately supplied by the sun.

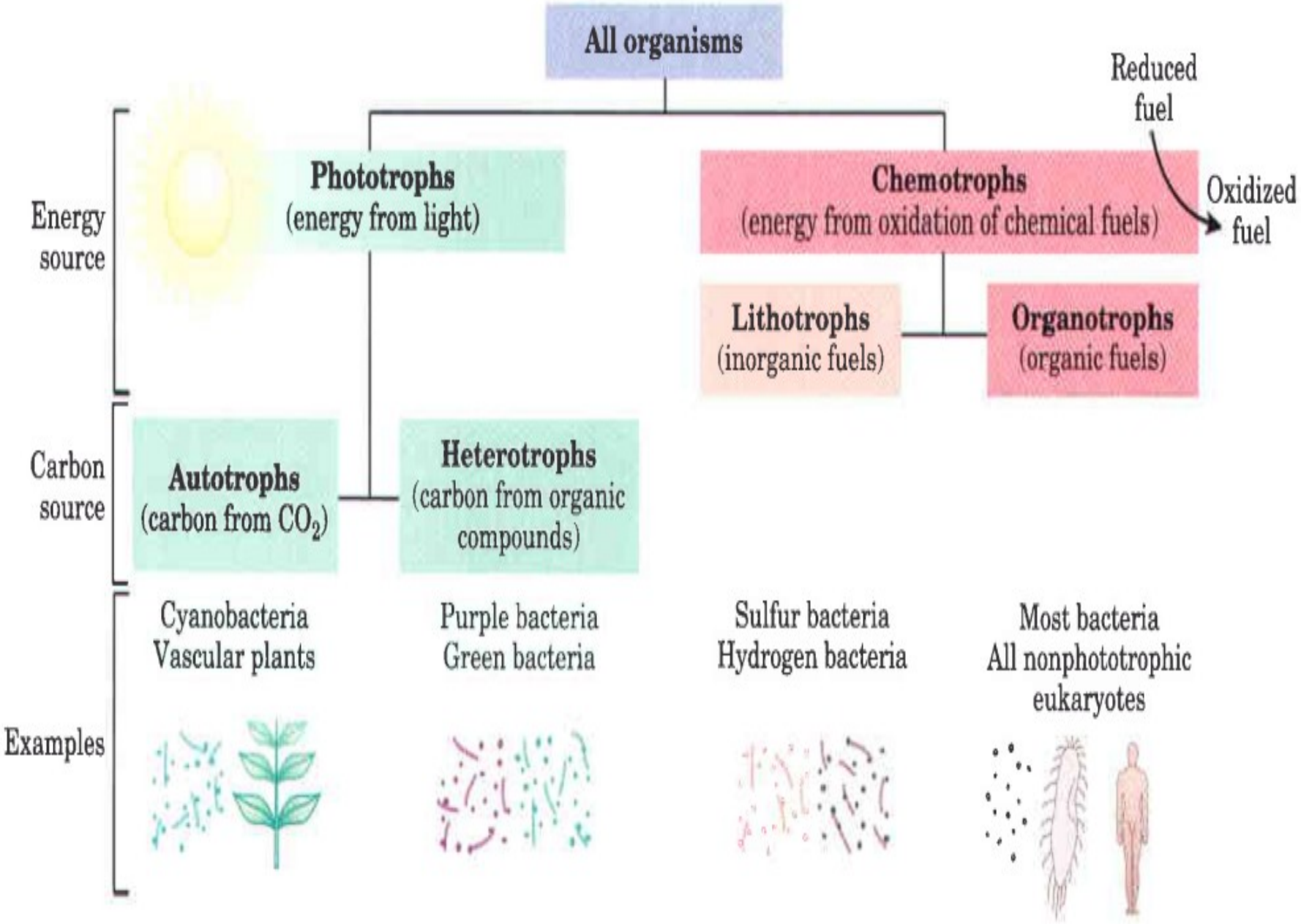
- Sunlight is captured by plants, algae, and photosynthetic bacteria and used for the synthesis of biological compounds.

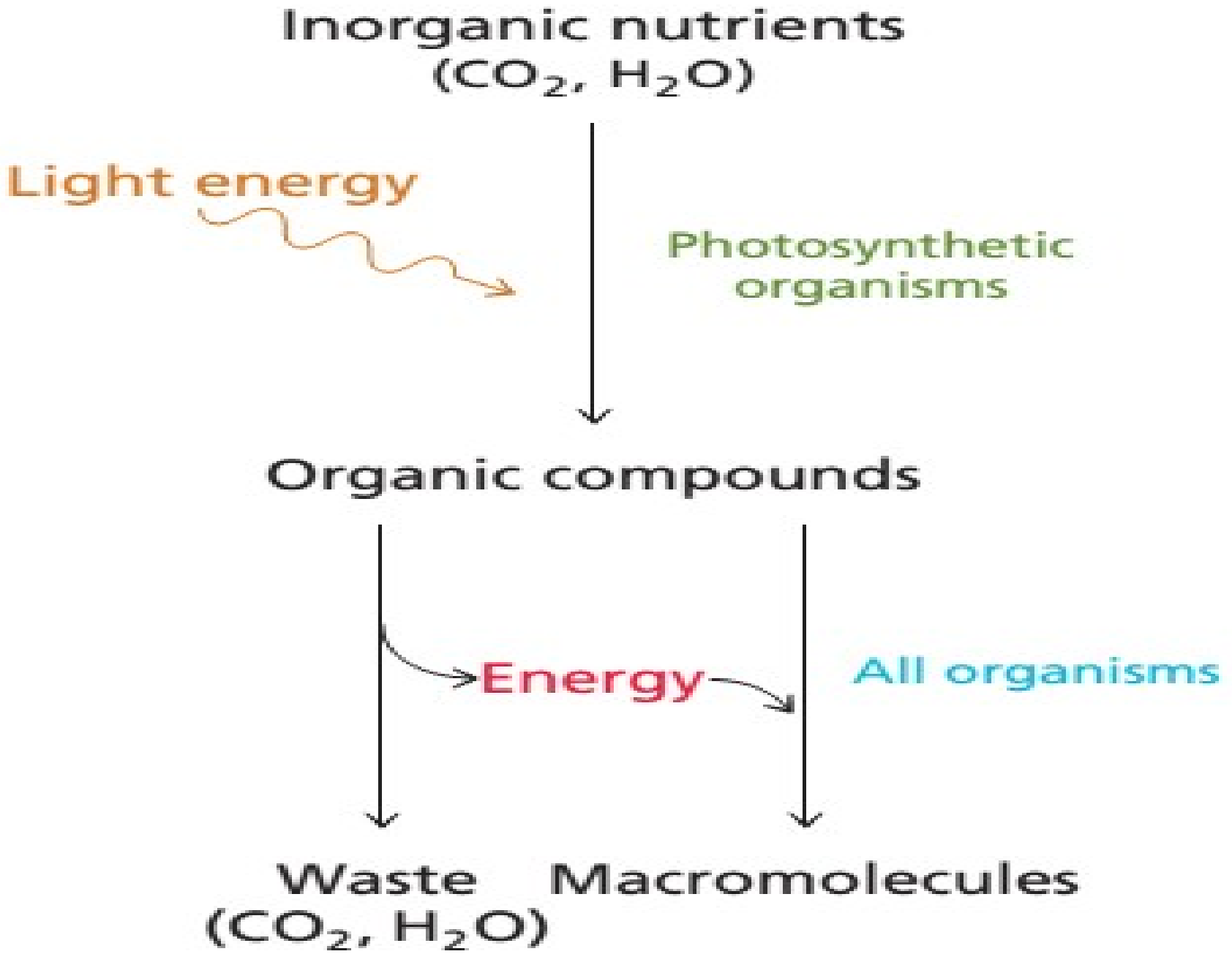
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- Photosynthetic organisms can be ingested as food and their component molecules used by organisms such as protozoa, fungi, non photosynthetic bacteria, and animals.

- These organisms cannot directly convert sunlight into useful biochemical energy.

- The breakdown of organic compounds in both photosynthetic and nonphotosynthetic organisms releases energy that can be used to drive the synthesis of new molecules and macromolecules.


All organisms
Reduced fuel
Oxidized fuel
Energy source
Phototrophs
(energy from light)
Chemotrophs
(energy from oxidation of chemical fuels)
Lithotrophs
(inorganic fuels)
Organotrophs
(organic fuels)
Carbon source
Autotrophs
(carbon from CO_2)
Heterotrophs
(carbon from organic compounds)
Examples
Cyanobacteria
Vascular plants
Purple bacteria
Green bacteria
Sulfur bacteria
Hydrogen bacteria
Most bacteria
All nonphototrophic eukaryotes


Inorganic nutrients
(CO_2, H_2O)
Light energy
Photosynthetic organisms
Organic compounds
Energy
All organisms
Waste
(CO_2, H_2O)
Macromolecules

What is a plant?

- Between 260,000 and 300,000 plant species have been discovered and identified.
- Plants are important food sources to humans and other consumers.
- Without plants, most life on Earth as we know it would not be possible.



Plant Characteristics

- Plants range in size from microscopic water fern to giant sequoia trees that are sometimes more than 100 m in height.



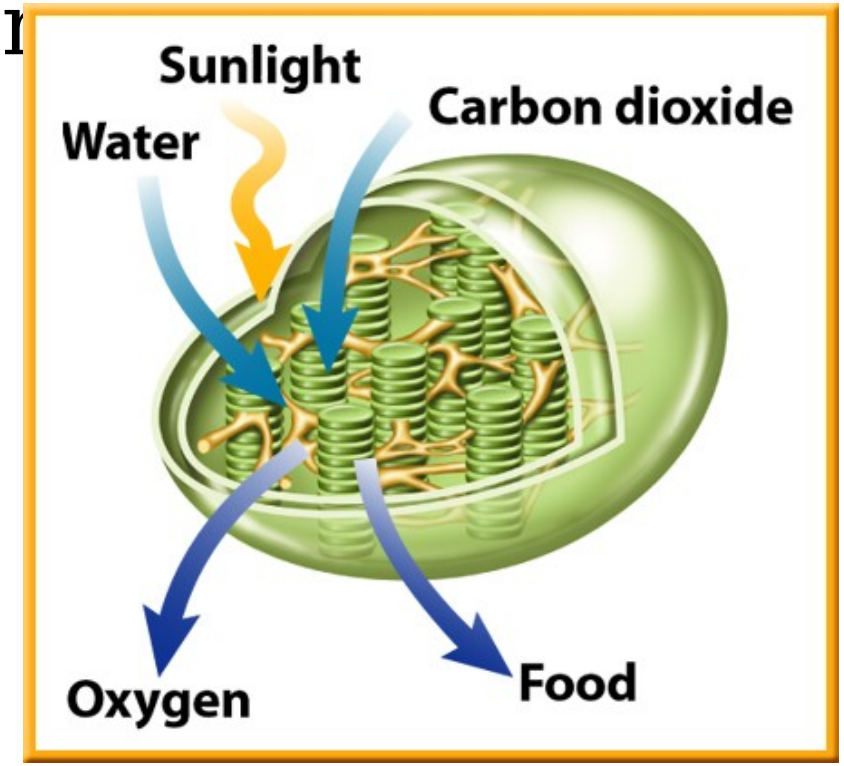
- Most have roots or rootlike structures.
- Plants are adapted to nearly every environment on Earth.
- All plants need water.

Plant Cells

- A plant cell has a cell membrane, a nucleus, and other cellular structures.
- In addition, plant cells have cell walls that provide structure and protection.

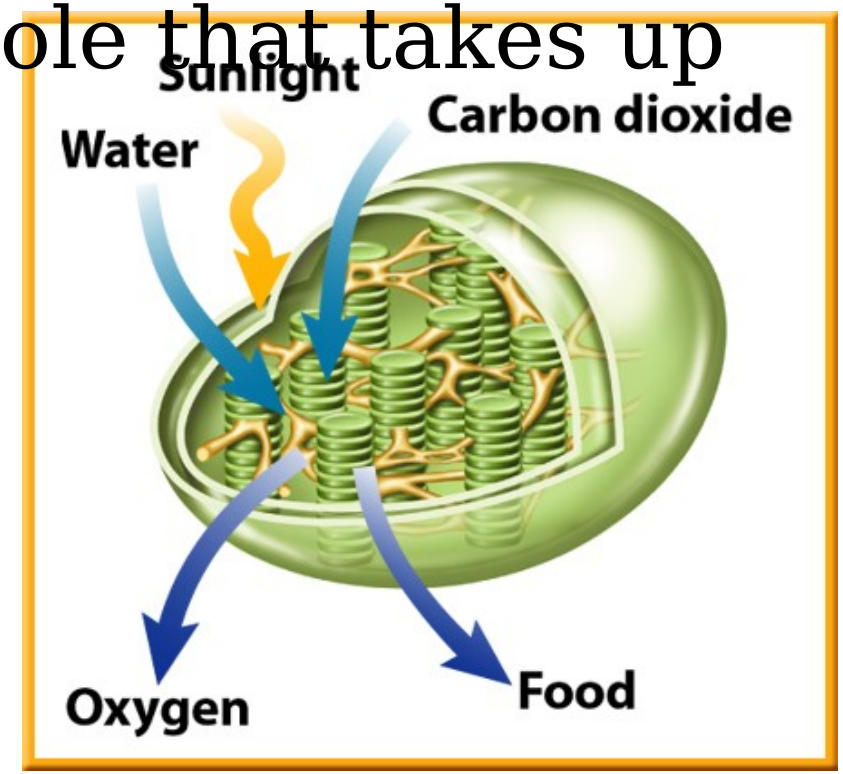
Plant Cells

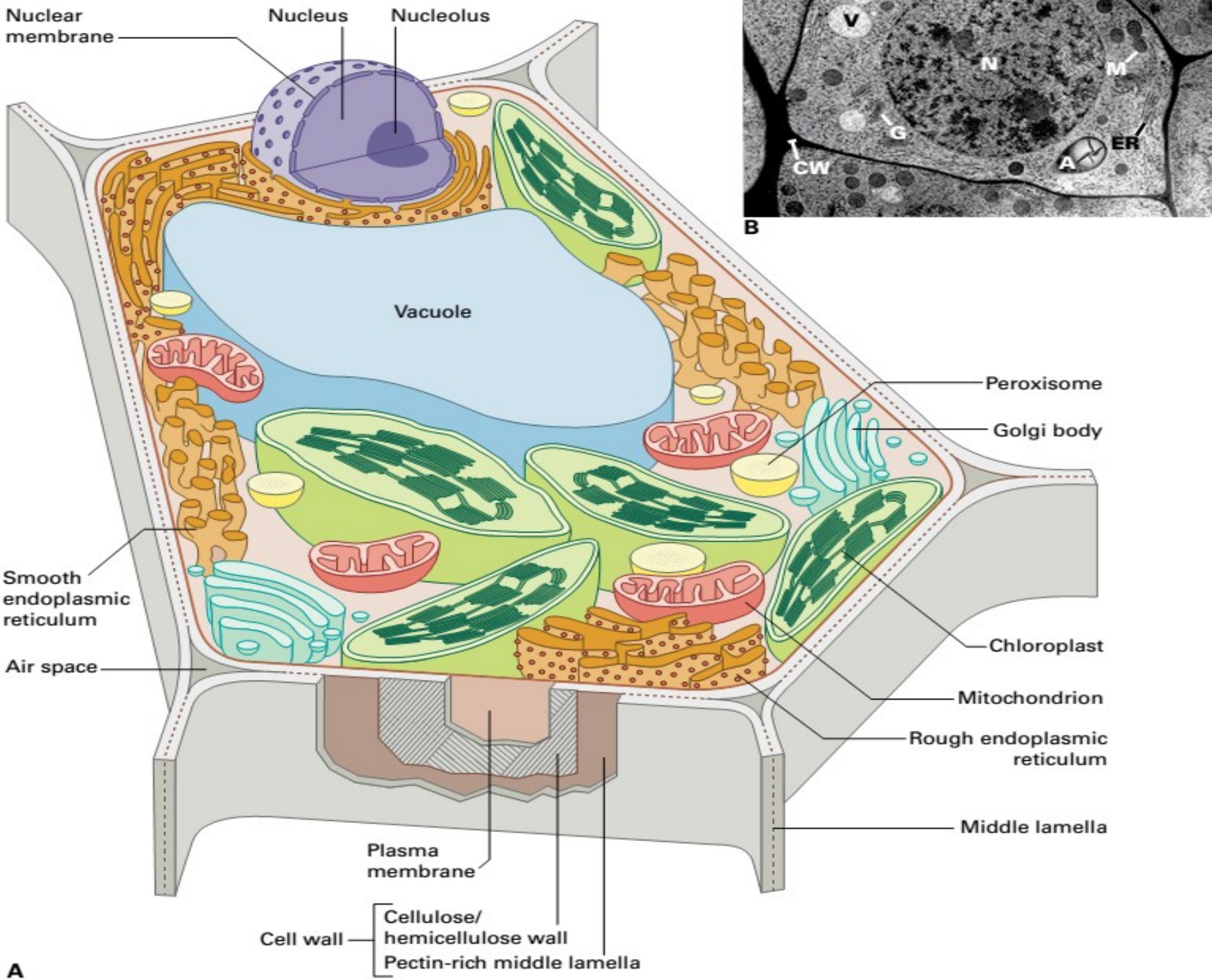
- Many plant cells contain the green pigment chlorophyll (KLOR uh fihl) so most plants ar
- Chlorophyll is found in a cell structure called a chloroplast.



Plant Cells

- Most plant cells have a large, membrane-bound structure called the central vacuole that takes up most of the space inside the cell.
- This structure plays an important role in regulating the water content of the cell.




Nuclear membrane
Nucleus
Nucleolus
Vacuole
Peroxisome
Golgi body
Smooth endoplasmic reticulum
Air space
Chloroplast
Mitochondrion
Rough endoplasmic reticulum
Middle lamella
Plasma membrane
Cell wall
Cellulose/ hemicellulose wall
Pectin-rich middle lamella
A
V
N
M
G
ER
CW
A
B

The fluid-mosaic membrane model

