Plant Molecular Biology
· biological molecules (proteins, nucleic acids)
Plant Biochemistry
· chemical interactions & chemical products
Plant Cytology
· structures, functions, & life processes of a plant cell
Plant Anatomy
· internal features (cells & tissues)
Plant Morphology
· external features (physical form & structures)

Plant Physiology
· functions of plants (photosynthesis)
Plant ecology
· interrelationships - plants, between plants, & environment
Plant Genetics
· Heredity & variation
Plant Paleontology
· biology, evolution, & geologic past (fossils)
Plant Geography
· geographical distribution of plants

Plant Taxonomy - CIDeNDi
· classification, identification, description, nomenclature, diversity
Phycology
· algae
Bryology
· non-vascular plants - mouses, liverworts, hornworts
Mycology
· fungi
Pteridology
· ferns & fern allies

Palynology
· living & fossil spores, pollen grains
Ethnobotany
· traditional knowledge & customs of any people concerning plants
Forestry
· forest conservation & products - lumber, ntfp
Agronomy
· field crops & soils
Horticulture
· growth of fruits, vegtables, flowers, & other ornamental plants

BOTANY - scientific study of plants

What are Plants? PEMCAB CCW NO LOCO EMBRYO

- **Organisms that are**
  - P - Photosynthetic
  - E - Eukaryotic
  - M - Multicellular
  - CAB - Containing chloroplasts with chlorophylls a and b
  - CCW - Having cellulosic cells walls
  - NO LOCO - Lacking the power of locomotion
  - EMBRYO - Producing embryos (embryophytes vs. thallophytes)

Subdisciplines of Botany

- **Plant molecular biology**
  - Structures and functions of important biological molecules (proteins, nucleic acids)
- **Plant biochemistry**
  - Chemical interactions within plants plus the chemicals they produce
- **Plant cell biology (plant cytology)**
  - structures, functions and life processes of plant cells
- **Plant Anatomy**
  - Plant internal features (cells and tissues) as revealed through dissection
- **Plant morphology**
  - Plant external features (physical form and structures)
- **Plant physiology**
  - How plants function (photosynthesis)
- **Plant ecology**
  - Interrelationships among plants, and between plants and their environment
- **Plant genetics**
  - Plant heredity and variation
- **Plant Paleontology (Paleobotany)**
  - Biology and evolution of plants and the geologic past (plant fossils)
- **Plant Geography (Phytogeography, geobotany)**
  - Geographical distribution of plants
- **Plant Taxonomy/Systematics**
  - Plant classification, identification, description, nomenclature, diversity   CIDeNDi
- **Phycology**
  - Algae biology and taxonomy
- **Bryology**
  - Non-vascular plants (mouses, liverworts, hornworts) biology and taxonomy   MLH
- **Mycology**
  - Fungi biology and taxonomy
- **Pteridology**
  - Ferns and fern allies biology and taxonomy
- **Palynology**
  - Scientific study of living and fossils spores and pollen grains
- **Ethnobotany**
  - Scientific study of the traditional knowledge and customs of any people concerning plants and their medical, religious, and other economic uses
- **Forestry**
  - Forest conservation and forest products e.g. lumber, ntfp
- **Agronomy**
  - Field crops and soils
- **Horticulture**
  - The science and art of growing fruits, vegetables, flowers, or ornamental plants
- **Economy Botany**
  - Plants with commercial importance e.g. spices, fibers
- **Pharmacognosy**
  - A branch of pharmacology dealing with medicinal substance of biological origin and especially medicinal substances obtained from plants
- **Plant Pathology (Phytopathology)**
  - Scientific study of plant diseases

Economy Botany
· comercial importance - spices, fibers
Pharmacognosy
· medicinal substances obtained from plants
Plant Pythology
· plant diseases

Characteristics of Living Things

1. **ORGANIZATION**
   - M ○ Molecules
   - O ○ Organelles
   - C ○ Cells
   - T ○ Tissues
   - O Os ○ Organs and organ systems
   - O ○ Organisms
   - P ○ Populations
   - C ○ Communities
   - E ○ Ecosystems
   - T ○ The biosphere

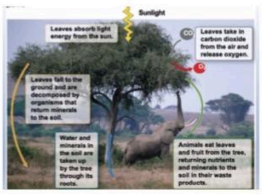
   M O C T O Os O P C E T

   MOLECULES → ORGANELLES → CELLS → TISSUES → ORGANS → ORGAN SYSTEMS → ORGANISMS → POPULATION → COMMUNITIES → ECOSYSTEMS → BIOSPHERE

2. **Exchange of Energy with the environment**
   - Plants and other organisms take in and use energy
     - i. PHOTOSYNTHESIS
       - Biological process that includes captures of light energy and its transformation into chemical energy or organic molecules that are manufactured from carbon dioxide and water

       → converts carbon dioxide (CO_2) & water (H_2O) with the help of light energy into glucose ($C_6H_{12}O_6$) & oxygen (O_2)
       → occurs in the CHLOROPLAST
     - ii. CELLULAR RESPIRATION
       - Cellular process in which energy of organic molecules is released for biological work

       → takes in glucose & oxygen, converts it back into carbon dioxide & water, releasing energy
       → occurs in the MITOCHONDRIA
3. **Interaction with environment**
   - Plants respond to stimuli in their environment
4. **Growth**



   - Plants undergo growth and development

5. **Reproduction**
   - Plants form new individuals by asexual or sexual reproduction
6. **Heredity**
   - DNA molecules transmit genetic information from one generation to the next in plants and other organisms
7. **Evolution**
   - Plants and other organisms evolve
   - Populations change or adapt to survive in changing environment

SCIENTIFIC METHOD

What is it?

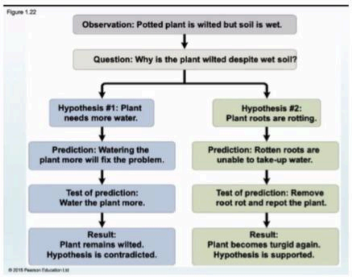
- An objective and logical process by which we ask questions and find answers

Why do we need it?

- To promote open and honest exchange of data with others; to share what we learn

Botany follows the scientific method

1. **Recognize the problem** - or an unanswered question
2. **Develop a hypothesis** - to explain the problem
3. **Design and perform an experiment** - to test hypothesis
4. **Analyze and interpret the data** - to reach a conclusion
5. **Share new knowledge** - with the scientific community; Form theory



Criteria of Science C O N P Tes Ten

- Consistent, observable, natural, predictable, testable, tentative
  - **Consistency**: the results of observations and/or experiments are reasonably the same when performed and repeated
  - **Observability:** the event or evidence of the event, can be observed and explained. The observations are limited to the basic human senses or to extensions of the senses
  - **Natural:** A natural cause (mechanism) must be used to explain why or how the event happens
  - **Predictability:** Specific predictions can be used to foretell an event. Each prediction can be tested to determine if the prediction is true or false.
  - **Testability:** the event must be testable through the processes of science and controlled experimentation
  - **Tentativeness:** scientific theories are subject to revision and correction, even to the point of the theory being proven wrong. Scientific theories have been modified and will continue to be modified

Scientists should be honest!

- Commitment to truthfulness of research findings/reports
- Decision on potential benefits of research to mankind and environment vs. ethical issues
  - Cloning
  - Stem cell
  - Human and animal experimentation

***CHEMISTRY** is an integral aspect of **BIOLOGY**.*

- Organisms are composed of matter
- Matter consists of chemical elements in pure form and in combinations called compounds
- An element is a substance that can be broken down to other substances by chemical reactions
- A compound is a substance consisting of two or more different elements combined in a fixed ratio

ELEMENTS of Life

- About 25 of the 92 natural elements are essential to life (about 16 for plants)
- Just 4 of these make up 96-99.5% of living matter
  - Oxygen
  - Hydrogen
  - Carbon
  - Nitrogen

O - H - C - N

Essential Elements of Life

Naturally Occurring Elements in the Living System			
Symbol	Element	% of Human Body Weight	% of [Most] Plant DRY Weight
O	Oxygen	65.0	45
C	Carbon	18.5	45
H	Hydrogen	9.5	6
N	Nitrogen	3.3	1.5
Ca	Calcium	1.5	0.5
P	Phosphorus	1.0	0.2
K	Potassium	0.4	1.0
S	Sulfur	0.3	0.1
Na & Cl	Sodium & Chlorine	0.2 / 0.2	---/0.002
Mg	Magnesium	0.1	0.06

Trace elements of life

Trace Elements of Life
(<0.01% of % Body Weight)

Animals (Human Body)
- Boron (B)
- Chromium (Cr)
- Cobalt (Co)
- Copper (Cu)
- Fluorine (F)
- Iodine (I)
- Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Selenium (Se)
- Silicon (Si)
- Tin (Sn)
- Vanadium (V)
- Zinc (Zn)

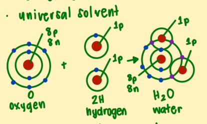
Most Plants
- Boron (B)
- Iron (Fe)
- Manganese (Mn)
- Zinc (Zn)
- Copper (Cu)
- Molybdenum (Mo)

Organisms
· matter
Matter
· chemical elements in the form of compounds
Element
· broken down by chem reactions
Compound
· elements in a fixed ration

TRACE ELEMENTS OF LIFE (PLANTS)
· Boron (B)
· Iron (Fe)
· Manganese (Mn)
· Zinc (Zn)
· Copper (Cu)
· Molybdenum (Mo)
B I M Zi Co M

WATER - H_2O

- most abundant molecule in living organisms
- has special traits that make it important to life
- polar molecule; O = −, H = +
- "solvent of life"
- universal solvent



- since oxygen atoms are large & hydrogen atoms are large, water is a polar molecule

water dissociates and releases hydrogen ions (H^+) and hydroxide ions (OH^-)

$$\underset{\text{water}}{H\text{-}O\text{-}H} \rightleftharpoons \underset{\text{hydrogen ion}}{H^+} + \underset{\text{hydroxide ion}}{OH^-}$$

What are the characteristics of water?

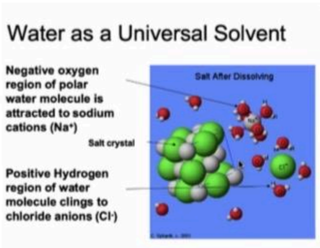
1. liquid at room temperature
2. boils at 100°c
3. freezes at 0°c
4. universal solvent for polar mol.
5. water molecules are cohesive
6. temperature of water changes slowly
7. high heat of vaporization
8. frozen water is less dense, thus ice floats

HOW DO HYDROGEN BONDS FORM?

- Hydrogen bonds form when covalently-bonded H+ is attatched to a negatively-charged atom in a neighboring molecule
- due to its polarity and hydrogen bonding, water has unique characteristics that benefit living things

COMPOUNDS OF LIFE

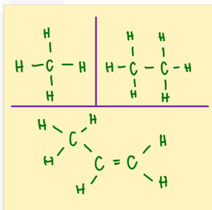
- The cell contains both inorganic [water, inorganic salts and ions] and organic molecules
  - **Water (H_2O)**
    - Biological medium that supports all life
    - The only and most abundant substance in the natural environment that exists in all physical states of matter : solid, liquid and gas
    - A polar molecule
      - O region has partial negative charge
      - H region has a partial positive charge
      - This polarity makes water the "solvent of life."
    - Water as a universal solvent



Organic compounds/ molecules

- All organic molecules contain carbon
- Naturally occurring organic compounds are found in all living organisms and fossil fuels
- All of these rely on the fixing of CO_2 by chlorophyll-containing organisms
- Synthetic organic compounds are derived from fossil fuels or plant materials, e/g herbicides, pesticides

- ***Not all compounds with C are organic..***
  - Oxides of carbon (CO_2, CO)
  - Carbonates (CO_3), bicarbonates (HCO_3)
  - Cyanides ($NaCN$)
  - Compounds with One C [and usu. no H]
- ***Why is carbon so important to life?***
  - All living organisms are made up of organic molecules and use organic molecules to function
  - ***Carbon can form a great variety of organic compounds!***
    - Carbon can form chemical bonds with four other atoms including other carbon atoms
- **Carbon's Bonding Pattern**
  - Carbon has 4 electrons in its outer shell. This means that each carbon atom forms 4 bonds
  - The 4 bonds are in the form of a tetrahedron or a triangular pyramid
  - Carbon can form long chains and rings, especially with hydrogens attached



carbon + hydrogen = HYDROCARBONS

- Compounds with just carbon and hydrogen are "hydrocarbons" : non-polar compounds like oils and waxes

SOME IMPORTANT FUNCTIONAL GROUPS OF ORGANIC COMPOUNDS

Some Important Functional Groups of Organic Compounds

Functional Group	Structure	Name of Compounds	Example
Hydroxyl	–OH	alcohols	ethanol
Carbonyl	>CO	Ketones; aldehydes	Acetone, glucose
Carboxyl	–COOH	Organic acids	Acetic acid
Amino	$-NH_2$	Amines	Amino acids
Phosphate	$-PO_4$	Organic phosphates	Glycerol phosphate

-

Four Basic Types of Organic Molecules

Four Basic Types of Organic Molecules

Organic Molecules	Elements	Building Blocks
Carbohydrates	**C, H, O (1:2:1)**	**mono-saccharides**
Lipids	C, H, O (more C than O)	**[Glycerol and Fatty Acids]**
Proteins	C, H, O, **N,**	**Amino Acids**
Nucleic Acids (DNA and RNA)	C, H, O, N, P	**Nucleotides**

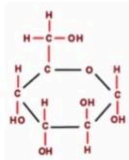
-

CARBOHYDRATES

- Sugars and starches "saccharides"
- The name "carbohydrate" comes from the approximate composition: a ration of 1 carbon to 2 hydrogens to 1 oxygen (CH_2O). ZFor instance the sugar glucose is $C_6H_{12}O_6$

C : H : O
↓
1 : 2 : 1

- Carbohydrates are composed of rings of 5 or 6 carbons =, with alcohol (-OH) groups attached. This makes most carbohydrates water-soluble.



- Carbohydrates are used for energy production and storage, and for structure

- energy production
- storage
- structure

- Can be classified based on:
  - Number of sugar molecules
    - Monosaccharide, disaccharide, polysaccharide
  - Location of carbonyl group
    - Aldose (terminal) [ribose, glucose, galactose]
    - Ketose (inner) [ribulose, fructose]
  - Size or carbon skeleton
    - Ranges from three to seven carbon long
      - 3 Tri • Triose (Glyceraldehyde,C3H6O3)
      - 4 Tet • Tetrose
      - 5 Pen • Pentose
      - 6 Hex • Hexise
      - 7 Hep • Heptose

Monosaccharides

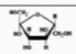
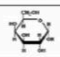
- Also called simple sugars

About some common monosaccharides:

  - Glucose is the main food molecule used by most living things; other molecules are converted to glucose before being used to generate energy. Glucose can also be assembled into starch and cellulose
  - Fructose, or fruit sugar is used to sweeten many food products
  - Ribose and deoxyribose are part of RNA and DNA; they are 5 carbon sugars

Vitamin C is derived from a simple sugar

- **Isomeric Monosaccharides**

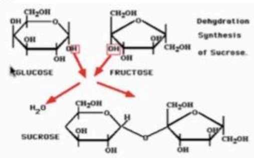
Simple Sugar	Molecular Formula	Structural Formula
Glucose	$C_6H_{12}O_6$	
Fructose	$C_6H_{12}O_6$	
Galactose	$C_6H_{12}O_6$	

- **Common Disaccharides**

Monosaccharides	Disaccharides	Common Name
Glucose + Glucose	Maltose ($C_{12}H_{22}O_{11}$)	Malt sugar
Glucose + Fructose	Sucrose ($C_{12}H_{22}O_{11}$)	Common table sugar
Glucose + Galactose	Lactose ($C_{12}H_{22}O_{11}$)	Milk sugar

Disaccharides

- **Synthesis**



HYDROLYSIS
· breaking apart a bond by adding water
· reverses synthesis of dissacharides

- This reaction can also be reversed by adding water to the bond. This is called hydrolysis breaking apart a bond by adding water.

Polysaccharides

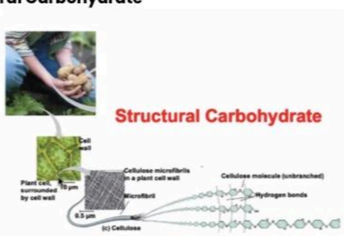
- Many sugars linked together by covalent bonds in the process called polymerization
- Can be classified into:
  a. Structural polysaccharides
  b. Storage polysaccharides

Structural Polysaccharides — cellulose, chitin

Storage Polysaccharides — Starch, Inulin

- **Structural Polysaccharides**
  1. **Cellulose** - Fiber
     a. Most abundant organic compound on earth
        i. Plants produce almost 100 billion tons of cellulose per year!
     b. Toughest organic compound to digest
     c. Major component of the cell wall of plants and protists
     d. Composed of a long straight chain of glucose molecules

Structural Carbohydrate



  2. **Chitin**
     a. The polysaccharide used by certain animals (insects, spiders, crustaceans) to build their exoskeletons
     b. Pure chitin is leathery but becomes hardened when encrusted with calcium carbonate
     c. Found in the cell wall of fungi
     d. Composed of a polymer of glucose with a nitrogen-containing appendage

Pure Chitin = leathery
Pure Chitin + Calcium Carbonate = hard

Storage Polysaccharides

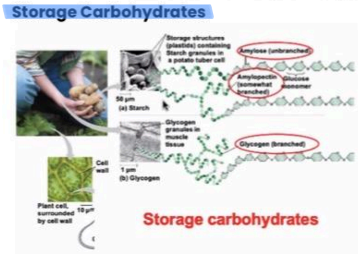
1. **Starch**
   a. A polymer of glucose molecules like cellulose but differ in the configuration of their glucose rings (α configuration for starch; β configuration for cellulose)
   b. May be simple (unbranched), e.g. amylose or very complex (branched), e.g. amylopectin
   c. Plants store starch in their plastids.
   d. Animals store this polysaccharide as glycogen in their liver and muscle cells

α = starch
β = cellulose
both polymers of glucose

Starch → plastids

2. **Inulin**
   a. A polymer of fructose molecules most commonly found in fruits but may also be stored in other plant organs

- **Storage Carbohydrates**



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made of fatty acid monomers

LIPIDS

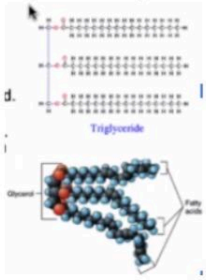
- Lipids are the main non-polar components of cells
- They are macromolecules that do not consist of monomers
- They are mostly hydrocarbons– carbon and hydrogen
- They share one common trait: they have little or no affinity for water
- They are used primarily for energy storage and as major component of cell membranes
- 4 main types: fats/oils (energy storage), phospholipids (cell membranes), waxes (waterproofing), and steroids (hormones).
- FATS
  - Fats are also known as Triglycerides — hydrophobic
  - A triglyceride is composed of 3 fatty acids attached to a molecule of glycerol
    - Fatty acids are long hydrocarbon chains with an acid group at one end
    - Glycerol is a 3-carbon carbohydrate. It has 3 alcohol (-OH) groups, which link up with the acid groups in the fatty acids

TERMS

hydrophobic
- does not mix with water

hydrophillic
- dissolves in water

  - Fats store about twice as much energy per weight as carbohydrates like starch. — x2 energy

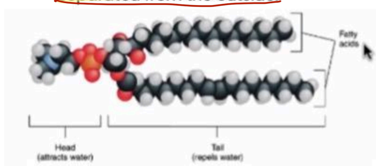


SATURATED vs. UNSATURATED FATTY ACIDS

- Hydrocarbon chains with all single bonds (solid fats) are called saturated fats with double bonds (liquid oils) are called unsaturated
- Most animal fats are saturated. Lard is purified animal fat, and is used for deep frying. However, saturated fat increases blood cholesterol levels and leads to clogged arteries and heart disease
- Several years ago, most companies replaced lard with partially hydrogenated vegetable oil, which was thought to be much healthier than lard.
- Unfortunately, partial hydrogenation leads to trans-fatty acids instead of the cis-fatty acids that occur naturally. And trans fatty acids proved to be even worse for your health than lard.
- **Unsaturated Fatty Acids**
  - Can be obtained from plants and fishes
  - Referred to as oils e.g. olive oil, cod liver oil
  - Seeds are richest in plant oils,
  - Common plants oils
    - Olive oils
    - Sunflower oil
    - Corn oil
    - Coconut oil (VCO!)
    - Peanut oil
    - Sesame oil
    - rice bran oil
    - palm oil
    - Canola oil (from rape seeds [Brassica spp.])

- **Phospholipids**
  - Phospholipids are the main component of cell membranes.
  - Phospholipids are very similar to triglycerides: they have a glycerol with 2 fatty acids attached, plus a phosphate-containing "head" group instead of a third fatty acid
  - The head group is hydrophilic, while the fatty acids are hydrophobic. Cell membranes are 2 layers, with the head groups facing out and the fatty acids forming the interior of the membrane
  - Phospholipids membranes allow only a few molecules to pass through them: water, some gases. They are what keeps the inside of cells separated from the outside.

glycerol (2 fatty acids) (hydrophobic) + phosphate-containg head (hydrophillic) = Phospholipids



- **Steroids and Waxes**
  - Steroids are hydrocarbons with the carbon atoms arranged in a set of 4 linked rings
  - Cholesterol, a common steroid, is an essential component of animal cell membranes (along with the phospholipids). However, too much of it in the blood can cause "plaques" to form in the blood vessels, leading to atherosclerosis (hardening of the arteries in the heart)
  - Waxes: waterproof coating on plants and animals. Composed of fatty acids attached to long chain alcohols
  - **Plant Waxes**
    - Main function: retard water loss from plants
    - Common plant waxes
      - Carnauba wax (from *Copernicia prunifera*)
        - Automobile wax, shoe polish, dental floss, sweets

4 linked rings of hydrocarbons = STEROIDS

fatty acids + long chains of alcohols = WAXES

Carnauba Wax – Copernica prunifera

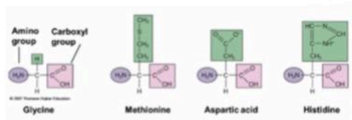
- Candellila wax (from *Euphorbia cerifera, E. antisyphill*)
  - Lip balms, binder for chewing gums, varnish
- Bayberry wax (from *Myrica faya*)
  - Candles
- Jojoba oil (from *Simmondsia chinensis*)
  - Cosmetics, fungicide, fuel (jojoba biodiesel)
- Cuticular wax
- Suberin

polypeptide bonds
+
amino acids
=
PROTEINS

PROTEINS

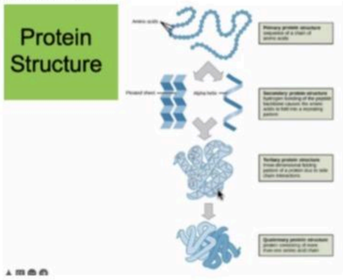
- Protein molecules are constructed from building blocks called amino acids. Amino acids are joined to each other with special covalent peptide bonds
- Each amino acid contains an amino group (which is basic), a carboxyl group (which is acidic) and an R group
  - There are 20 different kinds of amino acids in proteins. Each one has a functional group (the "R group") attached to it.

amino group
(basic)
+
carboxyl group
(acidic)
+
r group
(Functiona group)
= AMINO ACID



- Different R groups give the 20 amino acids different properties, such as charged (+ or -), polar, hydrophobic, etc.
- The different properties of a protein come from the arrangement of the amino acids

PROTEIN STRUCTURE



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Functions of Proteins

Functions of Proteins

Type of Protein	Function	Examples
Enzymatic	catalyst	Digestive enzymes
Structural	support	Collagen, keratin, membrane proteins
Storage	storage	Casein, proteins in seeds
Transport	transport	Hemoglobin, carrier proteins
Hormonal	coordination	Insulin, auxin, gibberellin
Receptor	response	Receptors in nerve cells
Contractile and motor proteins	movement	Actin, myosin
Defensive	Protection against diseases	antibodies

-

Plant Storage Proteins

- Found in seeds
- Common plant storage proteins
- Zein (corn)
- Gliadin (wheat)
- Glutenin (wheat, rice)
- Ricin D (castor bean, *Ricinus communis*)
- Abrin (rosary bean, *Abrus precatorious*)
-

The Deadliest Plants in the World!

- Extremely poisonous proteins: ricin D from the seeds of castor bean (*Ricinus communis*) and abrin from the seeds of rosary bean (*Abrus precatorious*).
- It has been estimated that gram from gram, ricin is 6,000 times more poisonous than cyanide and 12,000 times more poisonous than rattlesnake venom
- The seeds of the rosary bean (Abrus precatorious) are often made into bracelets and earrings.

NUCLEIC ACIDS

- Nucleic acids store genetic information in the cell
- Two types: RNA (ribonucleic acid) and DNA (deoxyribonucleic acid)
- Nucleic acids are made up of nucleotides. Each nucleotide has 3 parts: a sugar, a phosphate and nitrogenous base
- The sugar ribose is replaced by a -H in DNA
- DNA is a stable molecule which can survive thousands of years under proper conditions

sugar + phosphate + nitrogenous base
= NUCLEOTIDES
↓
NUCLEIC ACIDS

Structure of DNA

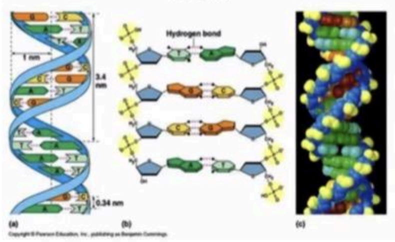
- Four kinds of nitrogen bases in DNA: adenine, gunaine, cytosine and thymine
- The nucleotides containing these bases are put together to form a structure called a double helix
- A double helix has the shape of a ladder that has been twisted lengthwise so that the sides of the ladder coil around each other
- The sides of the ladder are formed by sugar and phosphate groups
- The rugs of the ladder consist of nitrogen bases

DNA
- Adenine
- Guanine
- cytosine
- thymine

double helix
=
sugar +
phosphate
groups

DNA	RNA
· adenine	· adenine
· guanine	· guanine
· cytosine	· cytosine
· thymine	· uracil

DNA



RNA

- RNA consists of a single chain that also uses 4 bases; however, the thymine in DNA is replaced by uracil in RNA. RNA is much less stable than DNA, but it can act as an enzyme to promote chemical reactions in some situations

SECONDARY METABOLITES

- **Products of cells' metabolic activities**
  - Functions:
    - Responsible for the bright colors of flower to attract pollinators
    - Responsible for the bitter taste in certain plant parts that help protect the plant from predators
  - Plant secondary metabolites have been a fertile area of chemical investigation for many years, driving the development of both analytical chemistry and of new synthetic reactions and methodologies. **The subject is multi-disciplinary with chemists, biochemists and plant scientists** all contributing to our current understanding. In recent years there has been an upsurge in interest from other disciplines, related to the realization that **secondary metabolites are dietary components that may have a considerable impact on human health**, and to the development of gene technology that permits modulations of the contents of desirable and undesirable components

bright colors
↳ attract pollinators
bitter taste
↳ protect against predators

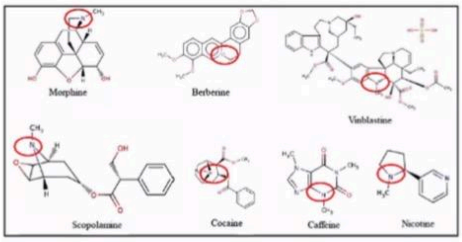
- **Main groups of secondary metabolites**
  A. Terpenoids - dimers and polymers of 5-C precursors called isoprene units
     - 50,000 identified terpenes
     [monoterpenes polyterpenes]

Compound	Source	Action/Comment
methanol	Mints and eucalyptus tree	Strong aroma; used in cough medicines
lycopene	tomatoes	red/orange pigments
rubber	Rubber tree	Component of rubber tires
taxol	Pacific yew	Anti-ovarian cancer
gibberellins	Many plants	Stem elongation
beta-carotene	carrot	orange/red pigment

B. **Phenolic compounds**
- Formed by a benzene ring, a carboxyl group and one or more hydroxyl groups in their molecules, giving them antioxidant properties, being indicated for treatment and prevention of a number of diseases, among them cancer

Compound	Source	Action/Comment
Coumarins	Leaves of cherry blossoms (Prunus spp.)	Regulate cellular routes that can be exploited for cancer prevention
Phenolic Acids e.g. Salicylic Acid	Willow tree	Precursor of aspirin; provides plant resistance vs pathogens
Tannins	Rangeland plants	Major plant defense vs herbivory
Lignins	Woody plants	Provide greater rigidity to the cell wall
Flavonoids, e.g. anthocyanins	Fruits/vege. leaves/flowers	Provide color important in the plant-pollinator-dispersers interaction; antioxidant

C. Alkaloids - include alkaline substances with N



· morphine
· berbenne
· vanbastine
· scopolamine
· cocaine
· caffiene
· nacotane

Examples of well-known alkaloids

Compounds	Source	Action/comment
coniine	Poison hemlock	Nerve toxin; killed Socrates
Strychnine	Strychnine tree	Nerve stimulant
tomatine	Tomato leaves	Tomato and potato pest control
morphine	Opium poppy	Pain killer
quinine	Quinine tree	Anti-malaria, butter flavor of tonic drinks
tubocurarine	Curare tree	Component for arrow poisons; muscle relaxant during surgery
vincristine	periwinkle	anti-leukemia

MINOR SECONDARY METABOLITES

- Mustard oil glycosides : N-S compounds in cabbage, broccoli, horseradish, mustard
- Polyacetylenes: ins sunflower and magnolia family
- Cyanogenic glycosides: in pea and rose family; fatal in large amounts

Read this review article:

Plant secondary metabolites and its dynamical systems of induction in response to environmental factors: A review

Robert Hooke
- discovered the "cell"
- improved the microscope

Antonie Van Leeuwenhoek
- invented the simple microscope
- "father of Microbiology/Microscopy"

Hans & Zacharias Janssen
- invented the first compound microscope (2 lenses)

Matthias Schleiden
- plants are composed of cells

Theodore Schwann
- animals are composed of cells

Rudolf Virchow
- cells come only from pre-exist cells

PROKARYOTES
- Bacteria
- Archaea

Bac Arc

EUKARYOTIC CELLS
- Protists
- Fungi
- Plants
- Animals

Pro Fu Pl Ani

PROKARYOTES - BacArc (1-2)
EUKARYOTIC CELLS - ProFu Pl Ani (3-6)

THE DISCOVERY OF THE CELL

The discovery of the cell came about through the works of 17th century scientists who had invented fairly primitive microscopes.

1665: English **Robert Hooke** was the first to use the term "cell"; is observations under the microscope are included in his illustrated book *Micrographia*

Robert Hooke (1635-1703)

1668: Dutch microscopist **Antonie van Leeuwenhoek** made his own microscopes (ca. 500) and observed various types of microscopic organisms; he is known as the **FATHER OF MICROSCOPY.**

Antonie van Leeuwenhoek (1632 -1723)

1838: German botanist **Matthias Scheliden** found that plants were composed of cells

1839: German physician **Theodore Schwann** found that animals were composed of cells

1855: German physician **Rudolf Virchow** concluded that cells can only come from preexisting cells.

The cell theory states:

1. All organism are composed of one or more cells
2. Cells are the basic unit of structure and function in organisms
3. All cells come only from other cells

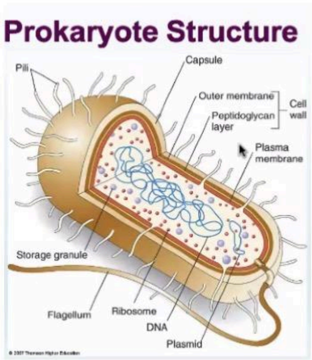
GENERAL CELL TYPES

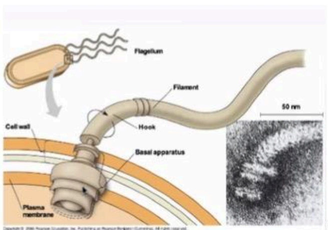
a. **Prokaryotes:** Bacteria and Archaea
b. **Eukaryotic cells** : Protists, Fungi, Plants, Animals

Cell structure is diverse but all cells share common characteristics

1. Genetic material in a nucleoid or nucleus
2. Cytoplasm: a semifluid matrix
3. Plasma Membrane: a phospholipid bilayer
4. Ribosome for protein synthesis

Prokaryote structure

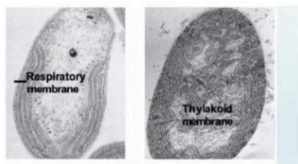




P

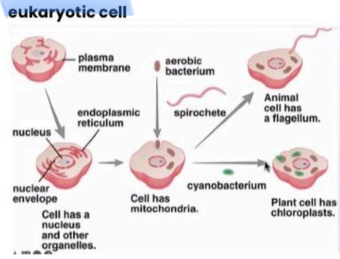
Prokaryotic cells usually lack complex compartmentalization

Some prokaryotes do have specialized membranes that perform metabolic functions



(a) Aerobic prokaryote (b) Photosynthetic prokaryote

Evolution of the eukaryotic cell



- Eukaryotes arose from a symbiotic relationship between various prokaryotes
  - Endosymbiotic hypothesis
    - Heterotrophic bacteria became mitochondria
    - Cyanobacteria became chloroplasts
    - Host cell was a large prokaryotic cell
  - Evidences for the endosymbiotic hypothesis
    - Mitochondria and chloroplasts

Heterotrophic bacteria
↓
mitochondria

cyanobacteria
↓
chloroplast

outer membrane
↳ engulfing vesicle
inner membrane
↳ prokaryote

- Similar to bacteria in both size and structure
- Bounded by a double membrane- the outer membrane may represent the engulfing vesicle, and the inner membrane from the prokaryote
- Each contain circular DNA ad divide by splitting
- Have their own ribosomes and so produce some proteins like the prokaryotes
- Have RNA base sequence suggesting a prokaryotic origin

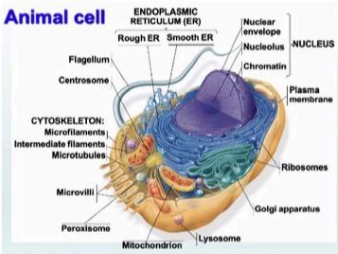
◦ **EUKARYOTIC CELLS**
  - With a membrane-bound nucleus
  - With membrane-bound organelles
  - Cellular functions compartmentalized within organelles and the endomembrane system
  - Possess a cytoskeleton for support and to maintain cellular structure

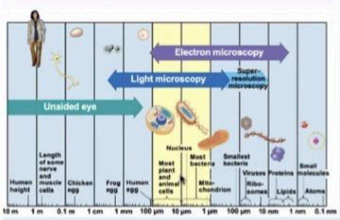
A comparison of prokaryotic, animal and plant cells

TABLE 4.3 A Comparison of Prokaryotic, Animal, and Plant Cells

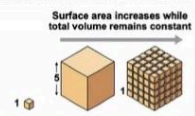
	Prokaryote	Animal	Plant
EXTERIOR STRUCTURES			
Cell wall	Present (protein-polysaccharide)	Absent	Present (cellulose)
Cell membrane	Present	Present	Present
Flagella/cilia	Flagella may be present	May be present (9 + 2 structure)	Absent except in sperm of a few species (9 + 2 structure)
INTERIOR STRUCTURES			
ER	Absent	Usually present	Usually present
Ribosomes	Present	Present	Present
Microtubules	Absent	Present	Present
Centrioles	Absent	Present	Absent
Golgi apparatus	Absent	Present	Present
Nucleus	Absent	Present	Present
Mitochondria	Absent	Present	Present
Chloroplasts	Absent	Absent	Present
Chromosomes	A single circle of DNA	Multiple; DNA-protein complex	Multiple; DNA-protein complex
Lysosomes	Absent	Usually present	Present
Vacuoles	Absent	Absent or small	Usually a large single vacuole

ANIMAL CELL





- Metabolic requirements set upper limits on the size of cells
- The surface area to volume ratio of a cell is critical
- As a cell increases in size, its volume grows proportionately more than its surface area



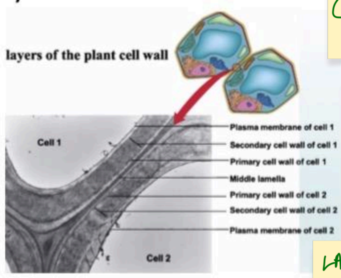
Total surface area [sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

PLANT CELLS

Three structures define a plant cell:

a. Cellulosic Cell Wall
b. Plastids
c. Large Central Vacuole

Layers of the Plant Cell Wall:



Primary Wall
- First wall laid down
- Surrounds
  - Growing cells
  - Meristematic cells
  - Cells in succulent tissues
- Composed of
  - Cellulose
  - Hemicellulose
  - Pectin
  - Glycoprotein
- With plasmodesmata for exchange of substances

Secondary Wall
- Inner wall
- Surrounds cells of secondary tissues
  - wood, cork

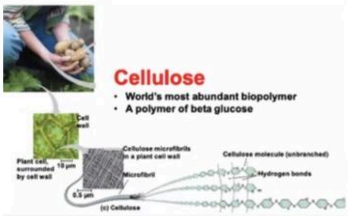
PLANT CELL STRUCTURE
① Cellulosic Cell Wall
② Plastids
③ Large Central Vacuole

LAYERS OF THE PLANT CELL WALL
· Plasma membrane of cell 1
· Secondary cell wall of cell 1
· Primary cell wall of cell 1
· Middle lamella
· Primary cell wall of cell 2
· Secondary cell wall of cell 2
· Plasma membrane of cell 2

- Composed of
  - Cellulose
  - Hemicellulose
  - Pectin
  - lignin/suberin

CELLULOSE

- World's most abundant biopolymer
- A polymer or beta glucose

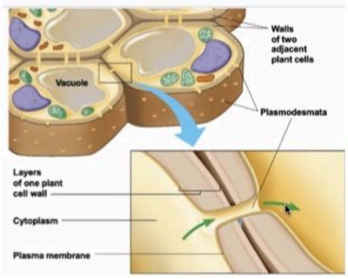


Several organisms in addition to plants synthesize cellulose.

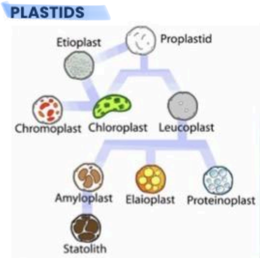
1. Bacteria, e.g. *Acetobacter zylinum* and *Agrobacterium tumefaciens*
2. Slime molds e.g. *Dictyostelium discoideum*
3. Water molds, e.g. *Saprolegnia spp.*

Plant cell walls provide our dietary fiber..

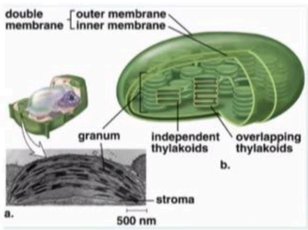
Soluble fiber **Insoluble Fiber**

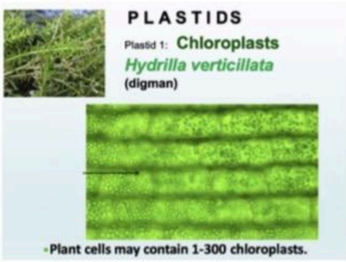


PLASTIDS



CHLOROPLASTS





CHLOROPLASTS
- where photosynthesis occurs
- DNA, RNA, proteins, ATP
- 1-300 in plants cell

- Plant cells may contain 1-300 chloroplasts
- Chloroplasts are typically 5-10 microns in diameter
- Have their own DNA, RNA, proteins, ATP
- They normally occur around the perimeter of photosynthetic cells and adjacent to the intercellular air spaces to maximize CO_2 uptake
- Pigments present include chlorophylls and carotenoids

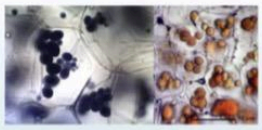
CHROMOPLASTS

CHROMOPLASTS
- flowers & fruits
- carotenoid pigments (yellow, orange, red)
- serve as attractants to signal fruit is ripe

- Commonly found in flowers and fruits
- Contain a diversity of carotenoid pigments [yellow, orange, red]
- Responsible for flower, fruit and even root coloration in many species, e.g. carrots and sweet potato tuber
- Functions:
  - Serve as attractants for fruit dispersal signaling that fruit is ripe
  - High nutritional value to animals; may birds eat chromoplast-rich fruits to supply their feathers with color.

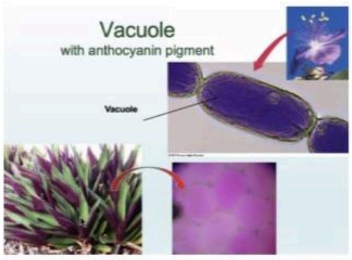
LEUCOPLASTS

- Non-pigmented plastids
- Found in organisms that are associated with long term storage such as roots and seeds
- Types
  1. Amyloplasts- for synthesis and storage of starch
     a. May be present in osteocytes/statolith in the root and be involved in gravity detection
     b. Capable of re-differentiating into other plastic types, e.g. in the re-greening of potato tubers where cell layers deep within the tuber undergo chloroplast formation
  2. Proteinoplasts- protein synthesis and storage
  3. Elaioplasts- lipid synthesis and storage


(Left) Amyloplasts (Starch Grains)
(Right) Elaioplast

VACUOLE

- largest fluid-filled organelle with single-membrane [tonoplast]
- Meristematic cells contain numerous small pro vacuoles which eventually fuse forming a large acidic central vacuole



- Functions:
  - Participate in growth through regulation of turgor
    - Turgid vacuole make up 50-90% of cell volume
  - Maintain homeostasis
  - Function as storage organelle (of proteins in seeds, malic acid in CAM pathway, anthocyanin pigment)
  - Sequester toxic materials (secondary metabolites , crystals)
  - Contain both anti-fungal enzymes and anti-herbivory compounds
  - Degrade old organelles (autophagy)
  - Participate in programmed cell death via autolysis

NUCLEUS

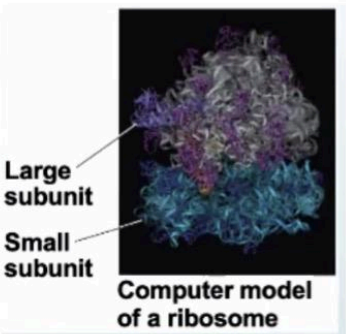
- A double membraned organelles containing nuclear genes aligned on chromosomes
- Acts as an organizer of cytoplasmic and nuclear activities during the cell cycle
- Helps in shutting of regulatory factors and gene products via nuclear pores
- Aids production of mRNAs and ribosomes
- Organizes the uncoiling of DNA to replicate key genes
- It thus coordinates innumerable metabolic pathways to achieve growth, division and differentiation of the cells. And stores the genetic material of the cell in the form of multiple, linear chromosomes

NUCLEOLUS

- The descent region of chromatin within the nucleus
- Responsible for the synthesis of ribosomes
- The nucleus may contain multiple nucleoli, but within each species the number of nucleoli appears to be fixed

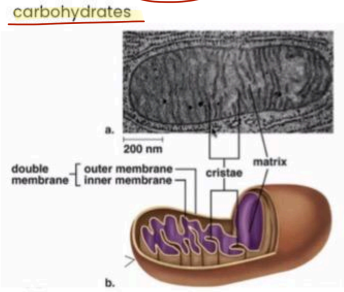
RIBOSOMES

- The site of protein synthesis in the cell
- Composed of ribosomal RNA and proteins
- Found within the cytosol of the cytoplasm of attached to the endoplasmic reticulum



MITOCHONDRIA

- Found in all eukaryotic cells
- Founded by a double membrane surrounding fluid-filled matrix
- Inner membranes (cristae) house protein complexes that produce ATP
- Matrix contains enzymes that break down carbohydrates



FUNCTIONS OF SMOOTH ER

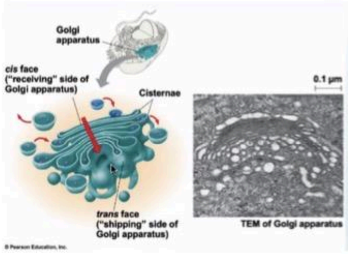
a) The smooth ER

a) Synthesizes lipids

b) Metabolizes carbohydrates

c) Detoxifies drugs and poisons

d) Stores calcium ions



Microbodies - single-membrane vesicles containing enzymes

A. Peroxisomes

oxidase → H_2O_2

catalase X H_2O_2

a. Contain oxidase that catalyzes h2o2 production

b. Produce catalase that breaks down h2o2

c. Found in leaves

B. Glyoxysomes

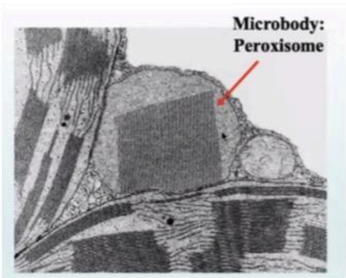
glyoxysomes

fats → carbs

a. With enzymes for converting fats to carbohydrates

b. Found in germinating oil-bearing seeds and seedlings

c. Rarely found in animals cells



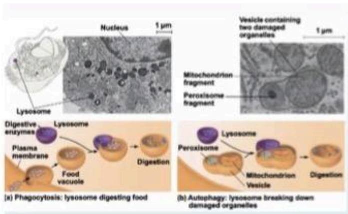
LYSOSOMES: Digestive Compartments

a) A lysosome is a membranous sac of hydrolytic enzymes that can digest macromolecules

b) Lysosomal enzymes work best in the acidic environment inside the lysosome

c) Hydrolytic enzymes and lysosomal membranes are made by rough endoplasmic reticulum and then transferred to the Golgi apparatus for further processing

- Some types of cell can engulf another cell by phagocytosis; this forms a food vacuole
- A lysosome fuses with the food vacuole and digests the molecules
- Lysosomes also use enzymes to recycle the cell's own organelles and macromolecules, a process called autophagy — recycle



CYTOSKELETON

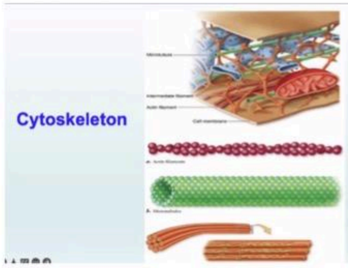


Table 6.1 The Structure and Function of the Cytoskeleton

Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Hollow tubes	Two intertwined strands of actin	Fibrous proteins coiled into cables
25 nm with 15-nm lumen	7 nm	8–12 nm
Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins (such as keratins)
Maintenance of cell shape (compression-resisting "girders"); cell motility (as in cilia or flagella); chromosome movements in cell division; organelle movements	Maintenance of cell shape (tension-bearing elements); changes in cell shape; muscle contraction; cytoplasmic streaming in plant cells; cell motility (as in amoeboid movement); division of animal cells	Maintenance of cell shape (tension-bearing elements); anchorage of nucleus and certain other organelles; formation of nuclear lamina

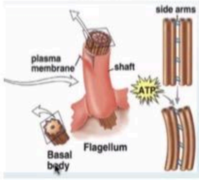
Cyclosis (circular streaming movement of organelles and other particles around central vacuole) is guided by actin filaments and microtubules of the cytoskeleton

Cytoskeletons also enhance exchange of materials among organelles, between membranes and organelles and even between cells.

Cytoplasmic/cyclosis Streaming

FLAGELLA

- With a 9+2 pattern of microtubules and are involved in cell movement
- Occur only in the sperm cells of sperm cells of lower vascular and nonvascular plants.



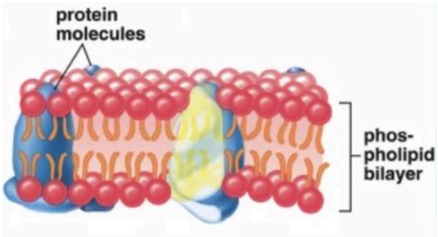
CELL MEMBRANE

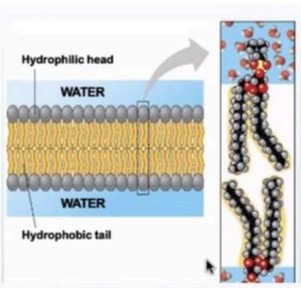
- also known as the plasma membrane

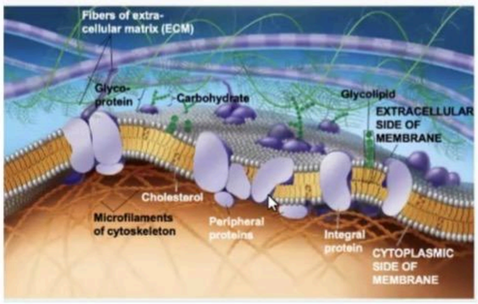
Plasma Membrane

PLASMA MEMBRANE

- The plasma membrane separates the internal environment of the cell from its surroundings
- The plasma membrane is a phospholipid bilayer with embedded proteins





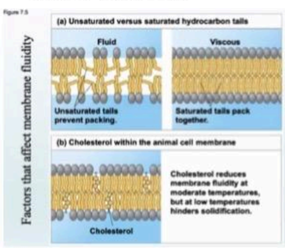


The plasma membrane has a fluid consistency and mosaic pattern of embedded proteins (**Fluid Mosaic Model)**

a) The fluid mosaic model states that a membrane is a fluid structure with a "mosaic" of various proteins embedded in it
b) Proteins are not randomly distributed in the membrane

The Fluidity of Membranes

a) Phospholipids in the plasma membrane can move within the bilayer
b) Most of the lipids, and some proteins, drift literally
c) Rarely, a lipid may flip-flop transversely across the membrane
d) Membranes must be fluid to work properly; they are usually about as fluid as salad oil
e) Membranes rich in unsaturated fatty acids are more fluid than those rich in saturated fatty acids
f) The temperature at which a membrane solidifies depends on the types of lipids
g) As temperatures cool. Membranes switch from a fluid state to a solid state

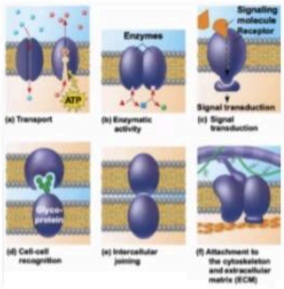


1. Temperature, Length, Degree of saturation, cholesterol content

a) The steroid cholesterol has different effects on membrane fluidity at different temperatures
b) At warm temperatures (such as 37°C), cholesterol restrains movement of phospholipids
c) A t cool temperatures, it maintains fluidity by preventing tight packing

Membrane Proteins and their Functions

a) A membrane is a collage of different proteins, often grouped together, embedded in the fluid matrix of the lipid bilayer
    i) **Peripheral proteins** are bound to the surface of the membrane
    ii) **Integral proteins** penetrate the hydrophobic core
        1) Integral proteins that span the membrane are called transmembrane proteins
b) Proteins determine most of the membrane's specific functions



6 major functions of membrane proteins

a) Transport
b) Enzymatic activity
c) Signal transduction
d) Cell-cell recognition
e) Intercellular joining
f) Attachment to the cytoskeleton and extracellular matrix (ECM)

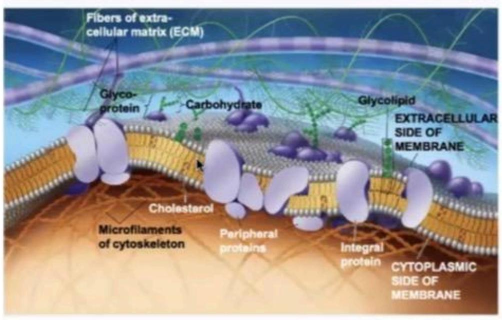
Transport Proteins

- Transport proteins allow passage of hydrophilic substances across the membrane
- Soome transport proteins, called **channel proteins,** have a hydrophilic channel that certain molecules of ions can use as a tunnel
- Channel proteins called **aquaporins** facilitate the passage of water
- Other transport proteins, called **carrier proteins,** bind to molecules and change shape to shuttle them across the membrane
- A transport protein is specific for the substance it moves

The Role of Membrane Carbohydrates in Cell-cell Recognition

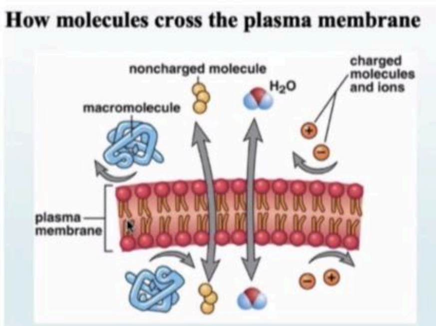
- Cells recognize each other by binding to molecules, often containing carbohydrates, on the extracellular surface of the plasma membrane
- Membrane carbohydrates may be covalently bonded to lipids (forming **glycolipids**) or more commonly to proteins (forming **glycoproteins**)

- Carbohydrates on the external side of the plasma membrane vary among species, individuals, and even cell types in an individual



The Permeability of the Plasma Membrane

- The plasma membrane is differentially permeable
- Macromolecules cannot pass through because of size, and tiny charges molecules do not pass through the nonpolar interior of the membrane
- Small, uncharged molecules pass through the membrane, following their **concentration gradient**



Movement of materials across a membrane may be passive or active

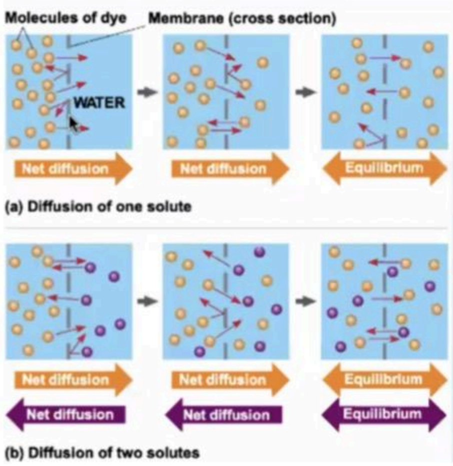
1. **Passive transport** does not use chemical energy; **diffusion** and **facilitated transport** are both passive
2. **Active transport** requires chemical energy and usually a carrier protein

Exocytosis and **endocytosis** transport macromolecules across plasma membranes using vesicle formation, which requires energy

Passive transport is diffusion of a substances across a membrane with no energy investment

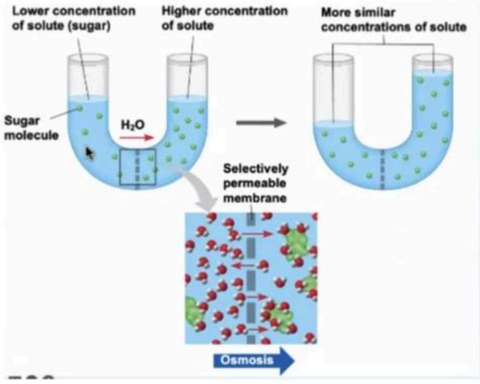
- **Diffusion** is the tendency for molecules to spread out evenly into the available space
- Although each molecule moves randomly, diffusion of a population of molecules may be directional

- At dynamic equilibrium , as many molecules cross the membrane in one direction as in the other



Effects of Osmosis on Water Balance

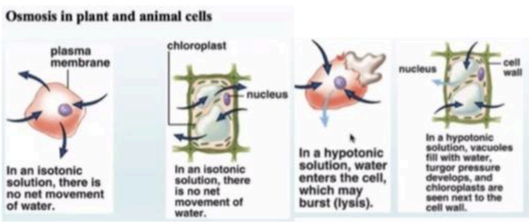
- **Osmosis** is the diffusion of water across a selectively permeable membrane
- Water diffuses across a membrane from the region of lower solute concentration to the region of higher solute concentration until the solute concentration is equal on both sides

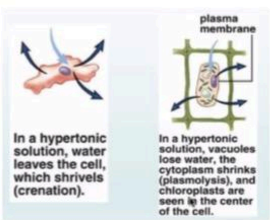


Water Balance of Cells

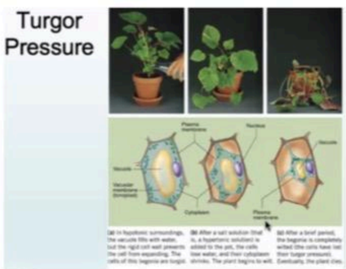
Tonicity Is the ability of a surrounding solution to cause a cell to gain or lose water

a) **Isotonic** solutionL Solute concentration is the same as that inside the cell; no net water movement across the plasma membrane
b) **Hypertonic** solution: Solute concentration is greater than that inside the cell; cell loses water
c) **Hypotonic** solutionL Solute concentration is less than that inside the cell; cell gains water





Plants prefer to be **hypotonic** to remain **turgidity** for its structure



Transport by carrier Proteins

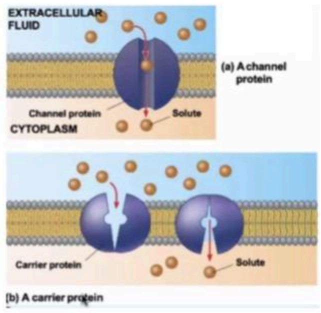
Some biologically useful molecules pass through the plasma membrane because of channel proteins and carrier proteins that span the membrane

Carrier proteins are specific and combine with only a certain types of molecule

Facilitated transport and **active transport** both require carrier proteins.

Facilitated Diffusion: Passive Transport Aided by Proteins

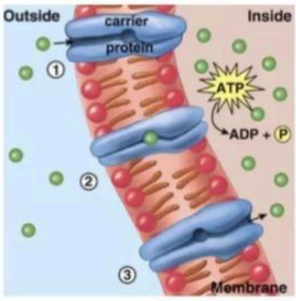
a) In **facilitated diffusion,** transport proteins speed the passive movement of molecules across the plasma membrane
b) Transport proteins include channel proteins and carrier proteins

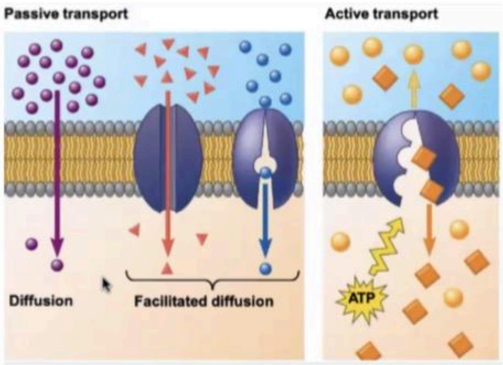


Active Transport

During active transport, ions or molecules are moved across the membrane against the concentration gradient - from an area of lower to higher concentration

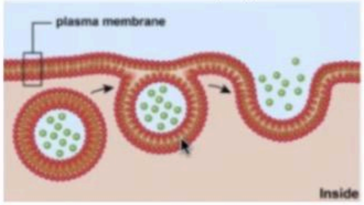
- **Energy** in the form of ATP is required for the carrier protein to combine with the transported molecule





Exocytosis

During exocytosis, vesicles fuse with the plasma membrane for secretion and assembly of proteins in the cell membrane



Cell wall precursors like polysaccharides and pectins are transported into the lumen of exocytotic Golgi vesicles which contain cellulose synthase in their membrane. After the fusion of the vesicles, the cellulose synthase is incorporated into the plasma membrane. After the fusion of the vesicles, the cellulose synthase is incorporated into the plasma membrane and the cell wall matrix precursors are deposited into the existing cell wall.

Endocytosis

During **endocytosis**, cells take in substances by invaginating a portion of the plasma membrane, and forming a vesicle around the substance

Endocytosis occurs as:

1) **Phagocytosis:** large particles
2) **Pinocytosis**: small particles
3) **Receptor** : mediated endocytosis