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Module 2- Macromolecules of the cell

For each of the six biological polymers listed, indicate which of the properties apply. Each polymer has multiple properties, and a given property may be used more than once.

Polymers:

(a) Cellulose
(b) Messenger RNA
(c) Globular protein
(d) Amylopectin
(e) DNA
(f) Fibrous protein

Properties

1. Branched-chain polymer
2. Extracellular location
3. Glycosidic bonds
4. Informational macromolecule
5. Peptide bond
6. beta linkage
7. Phosphodiester bridge
8. Nucleoside triphosphates
9. Helical structure possible
10. Synthesis requires a template.

A: 2-3-6
B: 4-7-9-10
C: 4-5-9-10
D: 1-3-9
E: 4-7-9-10
F: 4-5-9-10

Protein Bonds

Bond	Amino Acids	Levels of Structure
Peptide	All	Primary
Hydrogen	All	Secondary
Disulfide (covalent)	Cysteine	Tertiary
Hydrogen	All	Secondary
Hydrophobic	Leucine	Tertiary, Quaternary
Ionic	Glutamate	Tertiary, Quaternary

Level of Structure	Basis of Structure	Kinds of Bonds and Interactions Involved
Primary	Amino acid sequence	Covalent peptide bonds
Secondary	Folding into α helix, β sheet, or random coil	Hydrogen bonds between NH and CO groups of peptide bonds in the backbone
Tertiary	Three-dimensional folding of a single polypeptide chain	Disulfide bonds, hydrogen bonds, ionic bonds, van der Waals interactions, hydrophobic interactions
Quaternary	Association of multiple polypeptides to form a multimeric protein	Same as for tertiary structure

<u>Protein Structure:</u>

- Carboxyl group (CO2)
- Amino group
- R group
- Alpha carbon
- Hydrogen atom

Features of Nucleic Acids

For each of the following features of nucleic acids, indicate whether it is true of DNA only (D), of RNA only (R), of both DNA and RNA (DR), or of neither (N).

(a) Contains the base uracil. **R**

(b) Contains the nucleotide deoxythymidine monophosphate**. N**

(c) Is usually double-stranded. **D**
(d) Is a polymer. **DR**
(e) Contains a phosphate group. **DR**
(f) Is an inherently directional molecule, with an N-terminus on one end and a C-terminus on the other end. **N**

Like proteins, nucleotides are important informational macromolecules. How are they similar to proteins and how do they differ in terms of monomer types and assembly, polymer structure, and cellular functions?
Like the proteins, nucleic acids DNA and RNA are composed of monomers, nucleotides for the nucleic acids which are linked together by phosphodiester bridges. As in proteins, the order of monomers carries information, which is genetic information.

Wrong Again. For each of the following false statements, change the statement to make it true, and explain why it is false as written:

(a) Nucleic acids are polymers consisting of chemically ~~identical~~ repeating nucleotide monomers.
(b) A protein may have an alpha helical secondary structure. An alpha helix is spiral in shape and stabilized by covalent bonds between the NH group and the CO group in the adjacent polypeptide backbone.
(c) Whereas a protein can be denatured by high-temperature treatment, extremes of pH both of which disrupt ~~generally have no effect on~~ tertiary structure.
(d) Nucleic acids are synthesized from monomers that contain a high energy phosphodiester bond. They are already activated and do not require carrier molecule.
~~are activated by linking them to a carrier molecule in an energy-requiring reaction.~~
(e) The disaccharide sucrose comprises two monosaccharide ~~glucose~~ monomers covalently linked together.
(f) A beta-pleated sheet is an extended sheet-like conformation with the R groups of successive amino acids jutting out on the alternating ~~same~~ side of the sheet.
(g) It is not easy to predict the final folded structure of a protein from its amino acid sequence using today's powerful supercomputers.

Telling Them Apart. For each of the following pairs of molecules, specify a property that would distinguish between them, and indicate two different tests that could be used to make that distinction:

(a) The protein insulin and the DNA in the gene that encodes insulin
Phosphodiester bonds in DNA but not in protein.
(b) The DNA that encodes insulin and the messenger RNA for insulin
Presence of purine thymine or pentose deoxyribose in DNA but not in RNA.
(c) Starch and cellulose
Starch repeating unit: alpha-D glucose, cellulose repeating unit: beta-D glucose.
Use the enzyme amylase that can digest alpha (1-4) but not beta (1-4).

(d) Amylose and amylopectin
Starch occurs in branched amylose alpha (1-6) glycosidic bonds or unbranched amylopectin alpha(1-4) glycosidic bonds.
(e) The monomeric protein myoglobin and the tetrameric protein hemoglobin
Presence of 4 subunits in hemoglobin but not in myoglobin.
(f) A triacylglycerol and a phospholipid with a very similar fatty acid content
Presence of glycerol but absence of phosphorus in triacylglycerol.
(g) A glycolipid and a sphingolipid
Carbohydrate group (glycolipid) instead of phosphate group (sphingolipid).

Examples of proteins
- *Structural proteins*: collagen, keratin.
- *Motility proteins*: Actin (microfilaments), tubulin (microtubules).
- *Regulatory proteins*: transcription factor bind to DNA sequences to turn genes on.
- *Signaling proteins*: GLUT1. Glucose transporter, found in cells that import glucose, K+ channels.
- *Receptor proteins*: insulin receptor binds to insulin to initiate glucose utilization, found in cell, Ach.
- *Defensive proteins*: antibodies.
- *Storage proteins*: Ferritin stores iron.

Module 3 – Introduction to Cells and Organelles

Describe and similarities and differences between archaea, bacteria and eukaryotes
- They came from the same ancestor cell.
- Eukaryote cell has a plasma membrane, a nucleus, membrane bounded organelles and cytosol supported by the cytoskeleton.
- Main distinction between prokaryote (bacteria and archaea) and eukaryote cell (plant, animal, fungi, algae and protozoa) types is the membrane-bound nucleus of eukaryotic cells.
- **Eukaryotic DNA is organized into linear molecules complexed with large amounts of histones.**
- **Bacterial DNA is present as a circular molecule associated with few proteins.**
- **Archaeal DNA is circular and complexes with proteins similar to eukaryotic histone proteins.**

Table 4-1 A Comparison of Some Properties of Bacterial, Archaeal, and Eukaryotic Cells*

Property	Bacteria	Archaea	Eukaryotes	Refer to
Typical size	Small (1–5 μm)	Small (1–5 μm)	Large (10–100 μm)	—
Nucleus and organelles	No	No	Yes	—
Microtubules and microfilaments	Actin-like and tubulin-like proteins	Actin-like and tubulin-like proteins	Actin and tubulin proteins	Chapter 13
Exocytosis and endocytosis	No	No	Yes	Chapter 12
Cell wall	Peptidoglycan	Varies from proteinaceous to peptidoglycan-like	Cellulose and pectin in plants, cellulose or chitin in fungi; none in animals, protozoa	Chapter 15
Mode of cell division	Binary fission	Binary fission	Mitosis or meiosis plus cytokinesis	Chapter 24
Typical form of chromosomal DNA	Usually circular, few associated proteins	Usually circular, associated with histone-like proteins	Linear, associated with histone proteins	Chapter 16
RNA processing	Minimal	Moderate	Extensive	Chapter 18
Transcription initiation	Bacterial type	Eukaryotic type	Eukaryotic type	Chapter 18
RNA polymerase	Bacterial type	Some features of both bacterial, eukaryotic types	Eukaryotic type	Chapter 18
Ribosome size and number of proteins and RNAs	70S with 54 proteins and 3 rRNAs	70S with 65 proteins and 3–4 rRNAs	80S with ~80 proteins and 4 rRNAs	Chapter 19
Translation initiation	Bacterial type	Eukaryotic type	Eukaryotic type	Chapter 19
Membrane phospholipids	Glycerol-3-phosphate + linear fatty acids	Glycerol-1-phosphate + branched polyisoprenoids	Glycerol-3-phosphate + linear fatty acids	Chapter 7

Discuss the 3 main limitations on cell size

1. Need to maintain adequate surface area to volume ratio
   Larger cells have proportionally smaller surface areas. Beyond a certain threshold of this ratio, large cells do not have enough surface area to accommodate the need for nutrients and release of enough wastes. Cells like cells lining the small intestine have characteristics like fingerlike projections that increase the surface area.

2. Rate of diffusion of proteins decreases as the size of molecules increases
   Eukaryotic cells avoid the problem by using carrier proteins or vesicles.

3. Need for adequate local concentrations and essential substances
   To maintain the necessary concentration of a specific molecule, number of molecules must increase with cell volume. An effective solution to the concentration problem is the compartmentalization of activities within organelles.

Discuss the role of plasma membrane

The main role: ensures that cell contents are retained.

- Serves as a permeability barrier between the cell and outside environment.
- Localizes and organizes different functions within the cell.
- Facilitates transport of different molecules within the cell between organelles and also its outside environment: nutrients, ions or water, and wastes.
- Helps the cell to perceive its external environment and respond appropriately thru receptor mediated signal transduction, transmission of signals from outer surface to cell interior.

- Mediate interactions with other cells.

List several eukaryotic organelles and their basic functions

- **Mitochondrion**

Site of aerobic respiration
Provide energy to cell by oxidation of sugars and other fuel molecules.

- **Rough ER**

Has ribosomes either on the side of the membrane facing the cytosol or free in the cytosol which synthesize proteins; some of them to be transported out of the cell.

- **Smooth ER**

Involved in the synthesis of lipids and steroids such as cholesterol and steroid hormones derived from it.

- **Golgi Complex**

The post office: involved in processing and packaging secretory vesicles which are then passed to other components of the cell, and in polysaccharide synthesis. Glycoproteins and membrane lipids from the ER undergo further process: sorted and are packaged for transport (via the trans-Golgi network or TGN).

- **Lysosome**

Storage for hydrolase enzymes capable of digesting any biological molecules.

Cells involved in synthesis of secretory proteins have prominent rough ER networks (fibroblasts in skin secrete collagen). Cell producing steroid hormones have extensive networks of smooth ER (e.g., cells of adrenal gland).

Describe the Endosymbiont Theory

Suggests that mitochondria and chloroplast evolved from the same ancestor bacteria. This is based on similarities in size, membrane lipid composition, rRNA sequences, presence of circular DNA molecules, and bacterial type ribosomes, and ability to reproduce autonomously.

Describe the eukaryotic cytoskeleton and its structural components

- Eukaryotic **cytoskeleton** is an array of fibers giving structure to the cytoplasm giving the cell its shape. In addition, <u>it plays a role in cell movement and cell division</u>.
- A 3-D array of interconnected microfilaments, microtubules, and intermediate filaments.
- A microtubule is a cylinder of protofilaments with a hollow center (lumen). Each protofilament is a linear polymer of tubulin with polarity. Tubulin consists of two proteins: alpha-tubulin and beta-tubulin.
- Microfilaments are polymers of F-actin strands twisted in a helical structure. F-actin polymers are made of G-actin. Microfilaments have a polarity.

Explain key characteristics of prions, viruses, and bacteriophages

- **Viruses** are small and consists of a coat of protein surrounding a core, containing DNA or RNA. They have no cytoplasm, organelles or ribosome and infect cells, using their machinery to produce more viruses. When they infect bacteria, they are called bacteriophages or phages. They are responsible for many diseases, also important tools as research tools.

- **Prions** are infective particles which induce existing, properly folded proteins to convert into disease-associated prion form, and they induce amyloid plaques.
- A **bacteriophage** exists in theory for every type of bacterium, can be highly specific for their hosts.

Wrong Again. For each of the following false statements, change the statement to make it true.

(a) The mitochondria of bacterial cells and human cells are quite identical.

(b) Ribosomes are enclosed by a membrane in bacterial cells.

Ribosomes are not membrane bound.

(c) Instead of a cell wall, ***some*** eukaryotic cells have an extracellular matrix for structural support.

(d) All the ribosomes found in a typical human muscle cell are identical.

Cytoplasmic ribosomes are the eukaryotic types, mitochondrial ribosomes are the prokaryotic type.

(e) DNA is found only in the nucleus of a cell.

DNA is found in the nucleus of a eukaryotic cell but also in the mitochondria and in the chloroplasts.

(f) Because bacterial cells have no organelles, they cannot carry out either ATP synthesis or photosynthesis.

Carry out ATP synthesis using the plasma membrane.

(g) A large amount of the DNA in eukaryotic cells has no function and is called “junk DNA.”

Some of this non-coding DNA is used to produce non-coding RNA: tRNA, regulatory and ribosomal RNA.

Toward an Artificial Cell. Scientists have recently constructed an artificial ribosome in vitro from purified ribosomal proteins and rRNAs. (Some of the following questions may require sleuthing in earlier chapters to answer.)

(a) What types of intermolecular forces do you think are holding the individual proteins and rRNAs together in this macromolecular complex?
Ionic bonds, hydrogen bonds, hydrophobic bonds between nonpolar groups, van der Waals interactions.

(b) Describe how high temperature, high salt, or low pH would disrupt its structure, causing the ribosome to fall apart.

High temperature will break the weak hydrogen bonds, and denature the protein. High salt will interfere with ionic bonding, extremes of pH can change the charge on acidic and basic residues of the proteins, interfering w/ both ionic and hydrogen bonding.

(c) If you were asked to determine which organism the ribosomal components were purified from, how could you do this?

You could sequence the rRNA to determine the source organism. For the ribosomal proteins, you could sequence the proteins themselves or the genes that encode them.

(d) What other molecules would you have to add to the test tube for the ribosomes to make polypeptides?

Need to add amino acids, mRNA to translate tRNAs, aminoacyl-tRNA synthetases, and a source of ATP.

Sentence Completion. Complete each of the following statements about cellular structure in ten words or less.

(a) Unlike animal cells, plant cells have . . . *a rigid cell wall, plastids and large vacuole.*

(b) When placed in a glass of water, a dried date . . .

(c) A cellular structure that is visible with an electron microscope but not with a light microscope is . . . *a ribosome, virus, microtubule, microfilaments etc.…*

(d) Several environments in which you are more likely to find archaea than bacteria are … *salt water, hot spring, acidic environments and sulfur-containing environments.*

One reason that it might be difficult to separate lysosomes from peroxisomes by centrifugation techniques is that . . . *they are very similar in size.*

(f) The nucleic acid of a virus is composed of… *DNA or RNA but not both.*

Telling Them Apart. Suggest a way to distinguish between the two elements in each of the following pairs.

(a) Plant peroxisomes; thylakoids

(b) Rough ER; smooth ER ribosome on cytoplasmic side of the cell.

(c) Animal peroxisomes; leaf peroxisomes

(d) Smooth ER; mitochondria

(e) Vacuole; nucleus

(f) Polio virus; herpes simplex virus

(g) Eukaryotic ribosomes; bacterial ribosomes

Protein Synthesis and Secretion. Order events 1–7 so that they represent the correct sequence corresponding to steps a–g, tracing a typical secretory protein from the initial transcription (readout) of the relevant genetic information in the nucleus to the eventual secretion of the protein from the cell by exocytosis.

Transcription > (a) > (b) > (c) > (d) > (e) > (f) > (g) > Secretion

1. The RNA transcript is transported from the nucleus to the cytoplasm.
2. The RNA message associates with a ribosome and begins synthesis of the desired protein on the surface of the rough ER.
3. As the protein is synthesized, it passes across the ER membrane into the lumen of the rough ER, and from there via a vesicle to the Golgi apparatus.
4. The protein is partially glycosylated within the lumen of the rough ER.
5. Final sugar groups are added to the protein in the Golgi apparatus.
6. The protein is packaged into a secretory vesicle and released from the Golgi apparatus.
7. The secretory vesicle arrives at and fuses with the plasma membrane.

Are They Alive? Biologists sometimes debate whether viruses should be considered alive. Let's join in the debate.

(a) What are some ways in which viruses resemble cells?

They contain nucleic acid (DNA or RNA) and proteins; they are composed primarily of carbon, hydrogen, and oxygen; they are too small … they sometimes have a membrane covering;

(b) What are some ways in which viruses differ from cells?

They are much smaller than most cells; they have DNA or RNA but not both; they cannot replicate on their own; they do not make their own membrane; they have, at most a few enzymes; they do not have cytoplasm or nucleus.

(c) Choose either of the two following positions and defend it: (1) Viruses are alive. (2) Viruses are not alive.

Do not satisfy: metabolism, irritability and ability to reproduce.

(d) Why do you suppose that viral illnesses are more difficult to treat than bacterial illnesses?

(e) Design a strategy to cure a viral disease without harming the patient.

Module 4 – Enzymes

Describe the basic properties of the enzymes

https://infinitabiotech.com/blog/properties-of-enzymes/

- Act as biological catalyst by increasing the rate of reactions without increasing the temperature.
- Are globular proteins.
- A complex 3-D structure.
- They are not depleted and remain unchanged at the end of a reaction.
- Specificity.

Explain why enzymes are good biological catalysts

- They increase the rate of a reaction by lowering the activation energy requirements, without increasing the temperature.
- They change the rate at which equilibrium is achieved without changing its position.
- Most of the enzyme catalyzed reactions are reversibility.

Explain why enzymes only work on a single substrate

Because of the precise chemical fit between the active site of the enzyme and its reactants, enzymes are very specific.

Two models to explain this specificity: *lock-and-key* and *induce-fit* (conformational change of the enzyme).

Explain that enzymes function by lowering the activation energy for biochemical reactions

Before a chemical reaction happens, there is an activation energy, which is the minimal amount of energy the reactants must contain before collisions between them, will be successful in giving rise to products. Enzymes by lowering the activation energy, ensure that a higher proportion of molecules, possess enough energy to undergo reaction without increasing the temperature.

The Need for Enzymes. You should now be in a position to appreciate the difference between the thermodynamic feasibility of a reaction and the likelihood that it will actually proceed.

(a) Define the terms activation energy and transition state.

Activation energy: *minimum amount of energy*, reactants must contain before a chemical reaction happens.

Transition state: *chemical state* which separates the state in which molecules exist as reactants and the state in which they exist as product.

(b) Describe the effect of heat on enzyme activity and explain why using heat to alter enzyme activity is problematic in cells.

Reaction rate is the highest at the optimal temperature (37^0c for human enzymes). Above this optimal temperature, enzyme activity decreases sharply until the enzyme is denatured (inactive).

(c) An alternative solution is to lower the activation energy barrier. What does it mean in molecular terms to say that a catalyst lowers the activation energy barrier of a reaction?

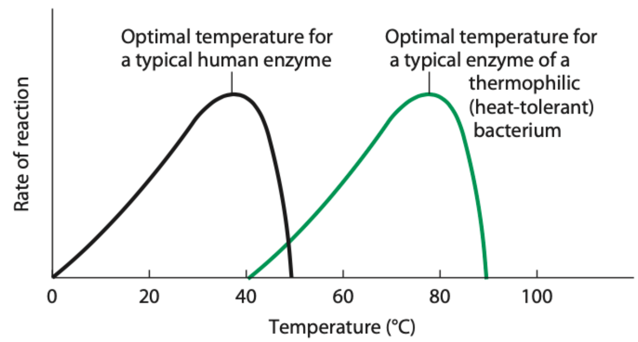
A catalyst by lowering the activation energy requirements, allows a higher proportion of the molecules to possess sufficient energy to undergo reaction without elevation of temperature.

(d) Organic chemists often use inorganic catalysts such as nickel, platinum, or cations in their reactions, whereas cells use proteins called enzymes. What advantages can you see to the use of enzymes? Can you think of any disadvantages?

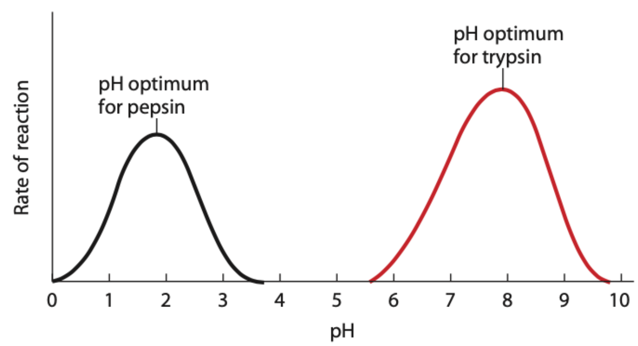
Advantages: specificity and more exact control.

Disadvantages: more susceptible to inactivation by heat, pH, substrate concentration and; also, more energy needed to be expanded to synthesize the enzyme molecules.

Temperature and pH Effects. Figure 6-4 illustrates enzyme activities as functions of temperature and pH. In general, the activity of a specific enzyme is highest at the temperature and pH that are characteristic of the environment in which the enzyme normally functions.



(a) Temperature dependence. The reaction rate for both a typical human enzyme (black) and a typical enzyme from a thermophilic bacterium (green) varies with temperature. It is highest at the optimal temperature, which is about 37°C (body temperature) for the human enzyme and about 75°C (the temperature of a typical hot spring) for the bacterial enzyme. Above the optimal temperature, the enzyme is rapidly inactivated by denaturation.



(b) pH dependence. The reaction rate of an enzyme is highest at its optimal pH, which is about 2.0 for pepsin (stomach pH) and near 8.0 for trypsin (intestinal pH). At the pH optimum for an enzyme, ionizable groups on both the enzyme and the substrate molecules are in the most favorable form for reactivity.

Figure 6-4 The Effect of Temperature and pH on the Reaction Rate of Enzyme-Catalyzed Reactions. Every enzyme has an optimun temperature and pH that usually reflect the environment where that enzyme is found in nature.

(a) Explain the shapes of the curves in Figure 6-4 in terms of the major chemical or physical factors that affect enzyme activity.

Figure 6-4a: The velocity of the reaction increases as the temperature is increased consistent with the effect of temperature in general on chemical reaction, which usually double in reaction velocity for every 10^0C increase. As the T is raised above the optimum, sharp decline in activity as the enzyme undergoes denaturation.

Figure 6-4b: pH optimum corresponds to the ionizable groups on both the enzyme and the substrate molecules, are in the most favorable form for chemical reactivity. pH away from optimum, results in loss of enzyme activity due to *titration* of the ionizable groups on the enzyme or substrate.

(b) For each enzyme in Figure 6-4, suggest the adaptive advantage of having the enzyme activity profile shown in the figure.

Figure 6-4a shows that both enzymes are maximally active at or near the temperature of the milieu in which they are found.

Figure 6-4b shows the differences in pH optima for the two enzymes reflects the different environments in which the two enzymes are active.

(c)- Some enzymes have a very flat pH profile—that is, they have essentially the same activity over a broad pH range. How might you explain this observation?

They have no amino acids at its active site that undergo ionization or protonation, and probably catalyzes a reaction in which neither substrates nor the products can be ionized or protonated.

Module 5 – Membrane and the Endomembrane systems

Describe 5 important function of membranes and give examples

1. Boundary and permeability barrier

The plasma membrane surrounds the cell and regulates passage of molecules both into and out of the cells. Also, intracellular membranes compartmentalize functions in eukaryotic cells.

2. Organization and localization of function

Mitochondrial membranes are critical for respiration.

3. Cell-to-cell interactions

Cadherin is a membrane protein which has extracellular sequences of amino acids that binds Ca^{2+}, and promote adhesion between similar types of cells in tissue.

4. Signal transduction

Chemical signal molecules bind to membrane protein receptors, on the outer surface of plasma membrane; which are transmitted to the interior of the cell: e.g., muscle and liver cell membrane contain insulin receptors and can respond to this hormone, which helps cells take in glucose.

5. Transport processes

Membranes are sites of specific proteins which carry out and regulate the transport of substances across the membrane: e.g., **aquaporin** which is an integral membrane protein that transports water.

Differential centrifugation: used to separate organelles by size and density differences.

Immunostaining: technique in which antibodies are labeled with a fluorescent dye to enable them to be identified and localized microscopically based on their fluorescence.

Explain the Fluid Mosaic

- The fluid part is that the plasma membrane is as lipid bilayer – main classes of lipids: phospholipids, glycolipids and sterols.
- The mosaic part includes proteins attached or embedded in the bilayer membrane, and lipid rafts and other lipid domains.

Describe the 3 classes of membrane proteins

- **Integral**: has one or more hydrophobic amino acid segments that anchor the protein to the membrane.
- **Peripheral**: hydrophilic and remain on the membrane surface. Typically attached to the polar head groups of phospholipids by ionic and hydrogen bonding.
- **Lipid-anchored**: hydrophilic proteins attached to the bilayer by covalent attachments to lipid molecules embedded in the lipid bilayer.

Explain what is meant by membrane asymmetry

Refers to the difference in both the kinds of lipids present and the degree of unsaturation of the fatty acids in the phospholipid molecule; e.g., most of the glycolipids present in plasma membrane are restricted to the outer monolayer (carbohydrate groups protrude from outer membrane surface). Once established, asymmetry mostly maintained because movement of lipids from one monolayer to the other requires the passage of hydrophilic head groups through the hydrophobic interior of the membrane**., flip-flop** or **transverse diffusion**.

Explain laboratory techniques that can be used to study membranes and membrane-associated molecules

Thin-Layer Chromatography: useful to separate membrane lipids according to their degree of polarity. The sample is spotted on a glass TLC plate. Components of the sample are carried upward by the solvent on the plate.

FRAP (Fluorescent recovery after photobleaching): molecules in a living cell are tagged with a fluorescent protein (e.g., GFP). A high-density laser beam is used to bleach the dye in a tiny spot on the cell surface, and is seen with a fluorescence microscope ass a dark spot. Eventually fluorescent proteins diffuse in and the pot is indistinguishable from the rest of the cell surface.

Differential scanning calorimetry: the membrane is placed in a sealed chamber, the calorimeter, and its uptake of heat is measured as the temperature is slowly increased.

Freeze-fracturing: A lipid bilayer or a membrane is frozen and then hit sharply with a diamond knife. The resulting fracture often follows the plane between the two layers of membrane lipid: split between its inner and outer monolayers, revealing the inner surface of each.

Electrophoresis: several techniques which use electric field to separate molecules according to size.

X-ray crystallography – determine 3-D structure of proteins.

DNA sequencing - Amino acid and nucleotide sequences can be deduced from DNA thus it reveals functionally important amino acids, families of homologous proteins, structure and orientation of proteins in membrane and functional relationships between proteins. Also, it, allows specific mutation in the protein sequence to allow determination effects on function.

Describe glycosylation

Initial steps of N-glycosylation (addition of short-chain of carbohydrates to oligosaccharides) starts on cytosolic surface of the ER membrane; later steps take place in the lumen of the rough ER. The process is usually completed within the Golgi complex. It consists in adding carbohydrate chains to specific amino acid residues of proteins to form **glycoproteins**. Enzymes catalyzes this reaction.

N-linked glycosylation (or N-glycosylation): involves the addition of a specific oligo-saccharide unit to the *nitrogen atom on the terminal amino group of certain asparagine residues*.
O-linked glycosylation: involves addition of an oligosaccharide to the oxygen atom on the hydroxyl group of certain serine or threonine residues. Each step of glycosylation is strictly dependent on preceding modifications.

Describe the theory of lipid rafts and give examples of where they have important functions
Lipid rafts or lipid microdomains are involved *in cell signaling*. In the outer membrane layer of animal cells, they are characterized by elevated concentrations of cholesterol and glycosphingolipids. Moreover, the glycosphingolipids in lipid rafts, are more unsaturated, and the rigidity and hydrophobic nature of the cholesterol, and the hydrocarbon tails of the glycosphingolipids and the phospholipids, allow tight packing, making lipid rafts thicker and less fluid than the rest of the membrane.
Lipid rafts have roles in:

- Detection and response to extracellular signals.

Lipid rafts containing receptors are coupled to lipid rafts on the inner mono layer. Receptor-mediate endocytosis (or cathrin-dependent cytosis) starts when a specific molecule (ligands) binds to their receptor molecules on the outer surface of the plasma. Receptor-ligand complexes accumulate in coated pits where invagination is facilitated by adaptor proteins: clathrin and dynamin. The coated vesicle that loses its clathrin, now fuses with an early endosome. Coat proteins and dynamin are recycled to the plasma membrane. It can also, move into lipid rafts located in the outer monolayer. Some lipid rafts contain **kinases**, enzymes that generate second messengers in a cell phosphorylation (addition of a phosphate group) of target molecules.

- Transport of nutrients and ions across membranes.
- Binding of activated immune system cells to microbial target.
- Transport of cholera toxin into intestinal cells.

Explain how DNA sequencing is used to study membrane proteins
DNA sequencing - Amino acid and nucleotide sequences can be deduced from DNA sequencing; thus, it reveals functionally important amino acids, families of homologous proteins, structure and orientation of proteins in membrane and functional relationships between proteins.
Also, it, allows specific mutation in the protein sequence to allow determination effects on function.

List the organelles that make up the endomembrane system and describe how molecules are trafficked through this system

- ER (rough and smooth)
- Golgi complex
- Vacuoles
- Lysosome

Proteins synthesized in the rough ER must be directed to various destinations within the cell and outside. Sorting of proteins begins in the ER and early compartments of the Golgi (vesicular transport model and cisternae maturation model). The final sorting that will leave the Golgi complex occurs in the TGN. Once a protein reached its destination, it must be prevented from leaving. Each protein contains *a tag targeting to a transport vesicle* that will take it to the correct destination. Some tags can also be used to exclude materials from certain vesicles. Tags may be an amino acid sequence, a hydrophobic domain, oligosaccharide side chain, membrane lipids, or lipid phosphate groups.

Describe endocytosis, exocytosis and phagocytosis
Endocytosis: taking in of matter by a cell by invagination of its membrane to form a vacuole. A small segment of the plasma membrane folds inward. Then it pinches off to form an endocytic vesicle containing ingesting substances or particles.
Phagocytosis: a specific form of endocytosis, is the ingestion of large particle up to and including whole cell or microorganisms. For complex organisms, it is usually restricted to specialized cells called phagocytes (neutrophils, macrophages, and dendritic cells).
Exocytosis: process by which the content of a cell vacuole is released to the outside of the cell through fusion of the vacuole with cell membrane.

Functions of Membranes. For each of the following statements, specify which one of the five general membrane functions (permeability barrier, localization of function, regulation of transport, detection of signals, or intercellular communication) the statement illustrates.
(a) Intracellular organelles that are engaged in degradative chemical reactions are limited by membranes. *Localization of function.*
(b) On their outer surface, cells of multicellular organisms carry specific glycoproteins that are responsible for cell-cell adhesion. *Intercellular communication*
(c) The interior of a membrane consists primarily of the hydrophobic portions of phospholipids and amphipathic proteins *Regulation of transport*
(d) Cellular membranes have a two-layered structure with hydrophobic tails facing each other. *Localization of function.*
(e) All of the acid phosphatase in a mammalian cell is found within the lysosomes. *Localization of function.*
(f) The membrane of a plant root cell has an ion pump that exchanges phosphate inward for bicarbonate outward. *Regulation of transport.*
(g) Ions and large polar molecules cannot cross the membrane without the aid of a transport protein. *Permeability barrier.*
(h) Insulin does not enter a target cell but instead binds to a specific membrane receptor on the external surface of the membrane, thereby activating the enzyme adenylyl cyclase on the inner membrane surface. *Detection of signals.*
(i) Adjacent plant cells frequently exchange cytoplasmic components through membrane-lined channels called *plasmodesmata*. *Intercellular communication*

Wrong Again. For each of the following false statements, change the statement to make it true and explain your reasoning.

(a) Because membranes have a hydrophobic interior, polar and charged molecules cannot pass through membranes. *Can pass through the membrane only with the help of a transport protein embedded in the membrane.*

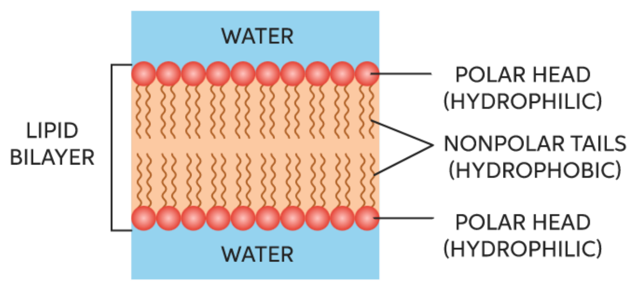
(b) Different cellular organelles have membranes with an identical chemical composition.

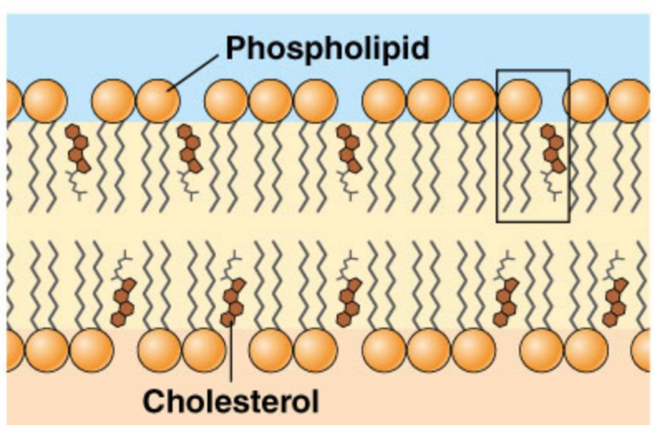
(c) Glycoproteins are proteins containing oligosaccharide chains which protrude from the ~~inner~~ outer membrane.

(d) Membrane fluidity is affected by temperature. When temperature decreases, membrane fluidity ~~increases~~ decreases, and the temperature at which this occurs is known as the transition temperature (Tm).

(e) You would expect membrane lipids from tropical plants such as palm and coconut to have ~~short-chain~~ long-chain fatty acids ~~with~~ without multiple C=C double bonds (saturated).

Imagine that a new type of cell was discovered on Mars in an organism growing in benzene, a nonpolar liquid. The cell has a lipid bilayer made of phospholipids, but its structure is very different from that of our cell membranes.





(a) Draw what might be a possible structure for this new type of membrane. What might be characteristic features of the phospholipid head groups?

Membrane will be likely reverse than ours: Two nonpolar groups will be facing the nonpolar solvent and it would have a hydrophilic interior.

(b) What properties would you expect to find in membrane proteins embedded in this membrane?

Proteins embedded in the membrane, would likely have hydrophilic regions spanning the membrane with hydrophobic groups protruding from both sides.

(c) How might you isolate and visualize these unusual membranes?

Temperature and Membrane Composition. Which of the following responses are likely to be seen when a bacterial culture growing at 37°C is transferred to a culture room maintained at 20°C? Explain your reasoning.

(a) No change in membrane fluidity
(b) A gradual increase in the proportion of saturated fatty acids in membrane lipids
(c) Increased mobility of membrane proteins
(d) Increase in the activity of the desaturase enzyme
(e) Increase in the synthesis of saturated fatty acids

a: unlikely because membrane fluidity is temperature dependent.
b: unlikely long-chain and saturated fatty acids increase fluidity.
c and d: are likely, short-chain and unsaturated fatty acids will increase membrane mobility.
e: unlikely because bacteria do not contain cholesterol.

Membrane Fluidity and Temperature. The effects of temperature and lipid composition on membrane fluidity are often studied by using artificial membranes containing only one or a few kinds of lipids and no proteins. Assume that you and your lab partner have made the following artificial membranes:

Membrane 1: Made entirely from phosphatidylcholine with saturated 16-carbon fatty acids.
Membrane 2: Same as membrane 1, except that each of the 16-carbon fatty acids has a single cis double bond.
Membrane 3: Same as membrane 1, except that each of the saturated fatty acids has only 14 carbon atoms.

After determining the transition temperatures of samples representing each of the membranes, you discover that your lab partner failed to record which membranes the samples correspond to. The three values you determined are –36°C, 23°C, and 41°C. Assign each of these transition temperatures to the correct artificial membrane, and explain your reasoning.

Membrane 1: saturated, 16C
Membrane2: less saturated, 16C
Membrane 3: saturated, 14C
$T2 < T3 < T1$
Double bonds are very disruptive of phospholipid packing in the membrane, so M2 has the lowest Tm.

The Little Bacterium That Can't. ***Acholeplasma laidlawii*** **is a small bacterium that cannot synthesize its own fatty acids and must therefore construct its plasma membrane from**

whatever fatty acids are available in the environment. As a result, the *Acholeplasma* membrane takes on the physical characteristics of the fatty acids available at the time.

(a) If you give *Acholeplasma* cells access to a mixture of saturated and unsaturated fatty acids, they will thrive at room temperature. Can you explain why?

Under these conditions, Acholeplasma cells can incorporate an appropriate combination of saturated and unsaturated fatty acids into their membrane to obtain optimum level of membrane fluidity.

(b) If you transfer the bacteria of part (a) to a medium containing only saturated fatty acids but make no other changes in culture conditions, they will stop growing shortly after the change in medium. Explain why.

Saturated fatty acids make a membrane less fluid. If only saturated acids are available, the Tm increases until the Tm = ambient temperature and the membrane will gel.

(c) What is one way you could get the bacteria of part (b) growing again without changing the medium? Explain your reasoning.
Temperature could be raised to preserve membrane fluidity.

(d) If you were to maintain the *Acholeplasma* culture of part (b) under the conditions described there for an extended period of time, what do you predict will happen to the bacterial cells? Explain your reasoning.
When a membrane gels, all cell functions that depends on the mobility of membrane proteins or lipids, will be impaired or disrupted. Without the ability of transport solutes, detection and transmission of signals, and to carry out other membrane dependent processes, the cell will die.

(e) What result would you predict if you were to transfer the bacteria of part (a) to a medium containing only unsaturated fatty acids without making any other changes in the culture conditions? Explain your reasoning.
Unsaturated fatty acids increase membrane fluidity, thus increasing the permeability of the membrane to ions and other solutes, and making it impossible to maintain critical concentration gradients.

How do differences in the structure and arrangement of rough versus smooth ER reflect their different functions?

Both types of ER make phospholipids, but membrane and secretory proteins are all produced by the ribosomes on the rough ER. Other than the lipid synthesis, smooth ERs are involved in the metabolism of carbohydrates and steroids.

https://pediaa.com/difference-between-smooth-and-rough-er/

Why is it necessary for material flowing through the Golgi to move in both the anterograde and the retrograde directions?

Every time a secretory vesicle fuses with the plasma membrane by exocytosis, a bit of membrane that originated in the ER becomes part of the plasma membrane. To balance the flow of lipids towards the plasma membrane, and to ensure a supply of components for forming new vesicles, the vesicles from the Golgi cisternae are sent back towards the ER.

What features of membrane lipids and proteins contribute to their proper trafficking and targeting in cells?
Each protein contains a specific tag targeting a protein to a vesicle to reach its destination. Membrane lipid could be also tagged to help vesicles to reach them.

What problems would a cell have if it could not produce lysosomes?
The accumulation of specific substances within the cell due to the absence of lysosomes, severely impairs the cell or destroy it.

Why is it important for the biochemical reactions occurring in peroxisomes to be isolated from the cytoplasm in a separate organelle?
The generation and degradation of hydrogen peroxide (H_2O_2) occurs within the peroxisome protecting other parts of the cell from exposure to this harmful compound.

Endoplasmic Reticulum. For each of the following statements, indicate if the statement is true of the rough ER only (R), of the smooth ER only (S), or of both rough and smooth ER (RS).

(*a) Contains less cholesterol than does the plasma membrane RS*
(b) Does not contain free ribosomes R
(c) Is involved in steroid biosynthesis S
(d) Is involved in the breakdown of polycyclic aryl hydrocarbons S
(e) Is the site for biosynthesis of secretory proteins R
(f) Is the site for the folding of membrane-bound proteins R
(g) Tends to form tubular structures S
(h) Usually consists of flattened sacs R
(i) Visible only by electron microscopy RS

Biosynthesis of Integral Membrane Proteins. In addition to their role in cellular secretion, the rough ER and the Golgi apparatus are also responsible for the biosynthesis of integral membrane proteins. More specifically, these organelles are the source of glycoproteins commonly found in the outer phospholipid monolayer of the plasma membrane.
(a) In a series of diagrams, depict the synthesis and glycosylation of glycoproteins of the plasma membrane.
Starts in the cytosol side of the ER and ends in the ER lumen: addition of carbohydrate to integral protein.
(b) Explain why the carbohydrate groups of membrane glycoproteins are always found on the outer surface of the plasma membrane.
Outer monolayer originally faced the rough ER and Golgi, where the enzymes involved in glycosylation are located.
(c) What assumptions did you make about biological membranes in order to draw the diagrams in part a and answer the question in part b?

Cellular Digestion. For each of the following statements, indicate the specific digestion process or processes for which the statement is true: phagocytosis (P), receptor-mediated

endocytosis (R), autophagy (A), or extracellular digestion (E). Each statement is true of one or more of these processes.
(a) Can involve endocytosis only *P,R,A,E*
(b) Can direct contents of newly formed vesicles to lysosomes *A*
(c) Highly efficient uptake of extracellular nutrients *P,R,E*
(d) Digested material is sourced from another species *A*
(e) Involved in the progression of rheumatoid arthritis
(f) Important for certain developmental processes *P,A,E*
(g) Involves acid hydrolases *P,R,A,E*
(h) Involves fusion of endocytic vesicles with an early endosome *P,R*
(i) Involves fusion of lysosomes with the plasma membrane *E*
(j) Occurs within lysosomes *P, R, A*
(k) Serves as a source of nutrients within the cell *P,R,A*

Lysosomal Storage Diseases. Despite a bewildering variety of symptoms, lysosomal storage diseases have several properties in common. For each of the following statements, indicate whether you would expect the property to be common to most lysosomal storage diseases (M), to be true of a specific lysosomal storage disease (S), or not to be true of any lysosomal storage diseases (N).
(a) Impaired metabolism of glycolipids that causes mental deterioration
(b) Leads to accumulation of degradation products in the lysosome
(c) Leads to accumulation of excessive amounts of glycogen Sin the lysosome
(d) Results from an inability to regulate the synthesis of glycosaminoglycans
(e) Results from an absence of functional acid hydrolases
(f) Results in accumulation of lysosomes in the cell
(g) Symptoms include Muscle weakness and mental retardation.
(h) Triggers proliferation of organelles containing catalase

Module 6 – Membrane Transport

Hydrophobic <=> non-polar
Polar <=> hydrophilic with exceptions (sugar)

Explain how hydrophobic molecules cross cell membranes
Small hydrophobic molecules, including, uncharged and no polar molecules (oils, steroids), can cross the bilayer membrane by simple diffusion using the concentration gradient existing between the inside of the cell and its outside. They pass though the gaps in the membrane which are due to a mixture of unsaturated or saturated fatty acids tails in both of the monolayers of the bilayer. Large non polar molecules need to use facilitated diffusion to cross the lipid bilayer.
https://www.quora.com/How-do-hydrophobic-non-polar-molecules-cross-the-plasma-membrane-when-they-have-to-pass-through-the-polar-phosphate-group-first
https://www-ncbi-nlm-nih-gov.proxy1.library.jhu.edu/books/NBK9847/

Distinguish between channel proteins and carrier proteins

Channel and carrier proteins facilitate the transport of polar molecules cross the bilayer membrane down their concentration gradient in a process called **facilitated diffusion**.

- **Channel proteins** form hydrophilic channels through the membrane that allow passage of solutes without major change in the conformation of the molecule, this process is thus quicker compared to carrier protein transport. Most of the channel proteins are small and very specific, and are referred **to ion channels**. Some of these channels, such as the **pores** found in the outer membrane of bacteria, mitochondria and chloroplasts, are relatively large and nonspecific. These pores are formed by transmembrane proteins called **porins**, and allow selected hydrophilic solutes with MW up to about 600 Da to diffuse across the membrane.
- **Carrier proteins** (also called *transporters or permeases*) bind one or more solute molecule on one side of the membrane and then undergo a conformational change that transfers the solute to the other side of the membrane, shielding the polar or charged groups of the solute from the nonpolar interior of the membrane. The carrier proteins are analogous to enzymes in their specificity and kinetics. They can specific to one compound, or a small group of closely related compounds or even to a specific stereoisomer (GLUT1 recognizes only glucose and few closely related monosaccharides, such as galactose, and it accepts the D- but not L-isomer of these sugars. Like enzymes, carrier-facilitated proteins exhibit saturation kinetics (upper limit velocity Vm, and constant Km corresp. to the concentration of solute needed to achieve ½ of Vm).

Define diffusion. Explain why diffusion is a passive and spontaneous process

Diffusion is the result of second law of thermodynamic which states that "chemical reactions and physical processes proceed in the direction of decreasing free energy", for the cell, the free energy is minimized as molecules flow down their concentration gradient (meaning from higher to lower concentration regions) and as ions flow down their electrochemical gradient. As a result, whenever there exists a difference of concentration of a specific substance, a concentration gradient, diffusion happens, the substance is transported to regions of lower concentration and this process does not require any metabolic energy (exergonic).

Explain why a concentration gradient of a substance across a membrane represents a potential energy

A concentration gradient of a substance across membrane corresponds to an energy which is proportional to the energy released by moving the substance down its concentration gradient which is used, in indirect active transport, to move a transported solute against its concentration or electrochemical potential.

Explain how transport protein facilitate diffusion

In facilitated diffusion, integral membrane proteins move large polar or charged molecules across the hydrophobic regions of the membrane by forming a hydrophilic passage through the lipid bilayer membrane through which polar or charged solutes can pass.

A <u>transport protein</u> is a specialized transmembrane protein that serves either as a hydrophilic channel through an otherwise hydrophobic membrane or as a carrier that binds a specific solute on one side of the membrane and then undergoes a conformational change to move the solute across the membrane.

Distinguish between osmosis, facilitated diffusion, and active transport

- **Osmosis** is the diffusion of water across a selectively permeable membrane. Because most solutes cannot cross cell membranes by diffusion, water will diffuse from the side of the membrane with the lower solute concentration (more water) to the side with higher solute concentration (less water). At equilibrium, the overall solute concentration is the same.
- **Facilitated diffusion** allows large nonpolar or polar and charged solutes cross the membrane using transport proteins, it is a passive transport as the solute diffuses down the concentration or electrochemical gradient, and does not require metabolic energy (exergonic process): ex.., movement of glucose across the plasma membrane of erythrocyte or any cell. Passive transport is nondirectional.
- **Active transport** moves a solute up its concentration or electrochemical gradient, away from its thermodynamic equilibrium therefore requires energy (endergonic). It is unidirectional. It occurs only when coupled to an exergonic chemical reaction (**direct**) or exergonic inward movement of ions-protons (**indirect**).

https://physics.stackexchange.com/questions/271228/does-there-exist-a-membrane-that-has-unbalanced-concentration-as-equilibrium

Describe the two forces that combine to produce an electrochemical gradient

The movement of an ion is determined by its electrochemical gradient which is the sum of its concentration gradient of that ion and the net difference in charge for that ion across the membrane.

Describe the process of co-transport

Carrier proteins transport one solute (uniporter, e.g., glucose) or two solutes. When two solutes are transported and their transport is coupled such that transport of either stops if the other is absent is called **co-transport** (*coupled transport*). If the two solutes are moved in same direction: the co-transport is **symport** otherwise it is **antiport**.

Explain how large molecules can be transported across cell membranes

Large non polar molecules are transported by facilitated diffusion, large polar molecules are transported by facilitated diffusion or active transport.

Define facilitated diffusion and why it is important in membrane transport

Lipid bilayers are readily permeable to small molecules, and relatively permeable to nonpolar molecules and less permeable to polar molecules. Lipid bilayers are very impermeable to ions. Polar, large polar/non polar molecules and ions need proteins or pumps to be able to cross the lipid bilayer. Facilitated diffusion allows to move a solute down its concentration gradient or electrochemical gradient without requiring an input of metabolic energy, it also speeds up the movement of substances which could cross the plasma membrane but to a slower rate.

Discuss in details how carrier proteins assist in moving substances up a concentration gradient

Cells also require transport/carrier proteins that actively pump certain solutes across the membrane against their concentration or electrochemical gradients. This process is known as active transport. The pumping activity is directional because it is tightly coupled to a source of metabolic energy, such as ATP hydrolysis or an ion gradient.

The active transport can be:

- **Direct** as it involves a transport coupled to an exergonic chemical reaction mostly ATP hydrolysis.
- **Indirect** when it is driven by the co-transport of cations-protons; the exergonic inward movements of protons provide the energy to move the transported solute against its concentration gradient or electrochemical potential. Concentration gradient of one molecule provides the energy for the transport of the second molecule against its concentration gradient.

Draw a diagram depicting Na-K pump

1. Initial binding of 3 Na+ to E1 on inner side of the membrane
2. Na+ binding triggers autophosphorylation of the alpha subunit using ATP and ADP is released, causing E1 to E2.
3. A conformational change to E2 expels 3 Na+ to the outside of the cell.
4. 2 K+ from outside the cell bind to E2.
5. K+ binding triggers dephosphorylation causing conformational change back to E1.
6. During this process, 2 K+ expelled to the inside as ATP binds.

For which of the three types of transport mechanisms is the magnitude of the concentration gradient relevant? For which is the electrochemical gradient important?

Magnitude of concentration gradient relevant: simple diffusion

Magnitude electrochemical gradient: indirect active transport.

How is osmosis different from the simple diffusion of molecular oxygen (O2) across a membrane? How are they similar?

Simple diffusion is the movement of solutes across a membrane permeable to the solute from the region of high concentration to low solute concentration; osmosis is the movement of water across a selectively permeable membrane, a membrane not permeable to the dissolved solute from the region where solute concentration is lower to the region with higher solute concentration, or from a more dilute solution to a region of more concentrated solution. At equilibrium the solute concentration is equal on both sides of the membrane.

They are both transport molecules, and do not require any input of metabolic energy to occur, and they both reach equilibrium when solute concentration is same on both sides of the membrane (follow 2nd law of thermodynamic: equilibrium: free energy of system is minimized).

How would you determine whether a specific integral membrane transporter is operating by facilitated diffusion or active transport?

Active transport is unidirectional compared to facilitated diffusion. In facilitated diffusion, the solutes are transported by the membrane transporter down their concentration or *electrochemical gradients. Active transport has a directionality, an active transport system that transports a solute across the membrane in one direction will not transport that solute in the other direction. So, by changing the concentration of the solute across the membrane, a membrane transporter operating by facilitated diffusion will still operate, and if the transporter system stops functioning, the transporter is operating by active transport.*

Both the Na+/glucose symporter and the Na+/K+ pump move sodium ions across a membrane. How is the movement different for the two types of transporters?
Na+/glucose symporter and the Na+/K+ pump uses as ATP as source of energy thus are active transport.

- *Na+/glucose is a symporter uses direct active transport and which transports the glucose and 2 Na+ ions inward the cell, in the same direction. The glucose is transported against its concentration gradient and is driven simultaneously by the inward transport of the sodium ions down their electrochemical gradient maintained by the Na+/K+ pump.*
- *Na+/K+ pump uses direct active transport, it moves 3 Na+ ions out of the cell allowing two K+ ions to move in the cell, in both cases the ions are moved against their electrochemical concentration gradients.*

True or False? Indicate whether each of the following statements about membrane transport is true (T) or false (F). If false, reword the statement to make it true.
(a) Facilitated diffusion of glucose occurs rapidly because the concentration gradient is maintained by ~~packaging intracellular glucose into vesicles~~ transporting glucose across the membrane with the glucose transporter GLUT1.
(b) The exergonic movement of an ion coupled with the movement of a solute ~~down~~ up a concentration gradient is an example of secondary active transport.
(c) The Keq value for the diffusion of polar molecules out of the cell is less than one because membranes are essentially impermeable to such molecules.
(d) Aquaporins facilitate the rapid movement of water molecules into or out of cells. T
(e) Oxygen can move freely across the plasma membrane by simple diffusion. T
(f) In simple diffusion, the net rate of transport for a specific substance is ~~indirectly~~ directly proportional to the concentration difference for that substance across the membrane. T
(g) ABC transporters are of medical interest because they are known to be involved in drug resistance.
(h) Transport channel proteins have a high level of specificity for a solute. T

Telling Them Apart. From the following list of properties, indicate which one(s) can be used to distinguish between each of the following pairs of transport mechanisms.

Transport Mechanisms
(a) Simple diffusion; facilitated diffusion 3,7
(b) Facilitated diffusion; active transport 2,4,6
(c) Simple diffusion; active transport 2,3,4,6,7
(d) Direct active transport; indirect active transport 4,5
(e) Symport; antiport 1

(f) Uniport; coupled transport 5
(g) P-type ATPase; V-type ATPase 8

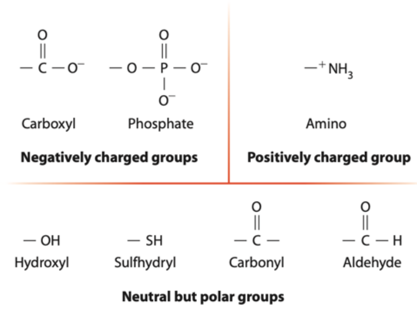
Properties
1. Directions in which two transported solutes move
2. Direction the solute moves relative to its concentration gradient or its electrochemical potential
3. Kinetics of solute transport
4. Requirement for metabolic energy
5. Requirement for simultaneous transport of two solutes
6. Intrinsic directionality
7. Competitive inhibition
8. Sensitivity to the inhibitor vanadate

Mechanisms of Transport. For each of the following statements, answer with a D if the statement is true of simple diffusion, with an F if it is true of facilitated diffusion, and with an A if it is true of active transport. Any, all, or none (N) of the choices may be appropriate for a given statement.
(a) Requires the presence of an integral membrane protein A,F
(b) Solutes move down their free energy gradient in the direction of thermodynamic equilibrium. D
(c) Is not subject to saturation D
(d) Requires the hydrolysis of ATP A
(e) Is a way of establishing a difference in the concentration gradient of solutes across a membrane A
(f) Applies only to small, nonpolar solutes D
(g) Applies only to ions N
(h) Transport can occur in either direction across the membrane, depending on the prevailing concentration gradient D,F
(i) Has a positive Δ*G*
(j) Usually has intrinsic directionality A

Discounting the Transverse Carrier Model. At one time, membrane biologists thought that transport proteins might act by binding a solute molecule or ion on one side of the membrane and then diffusing across the membrane to release the solute molecule on the other side. We now know that this transverse carrier model is almost certainly wrong. Suggest two reasons that argue against such a model. One of your reasons should be based on our current understanding of membrane structure and the other on thermodynamic considerations.

1) *Integral membrane proteins are embedded in the membrane and protrude from one or both sides base on their hydrophobic or hydrophilic regions.*
2) *To traverse the membrane, a protein will have to have its hydrophilic region(s) to move through the hydrophobic interior of the membrane which will require a lot of energy and hence thermodynamically impossible.*

Carboxyl group: CO2
Hydroxyl group: OH
Phosphoryl group: PO3^{-}



Phosphester bond: bond between phosphate group and sugar.
Phosphodiester bond: phosphate group linked to two adjacent nucleotides.
Glycosidic bond: bond between a carboxyl and hydroxyl group.