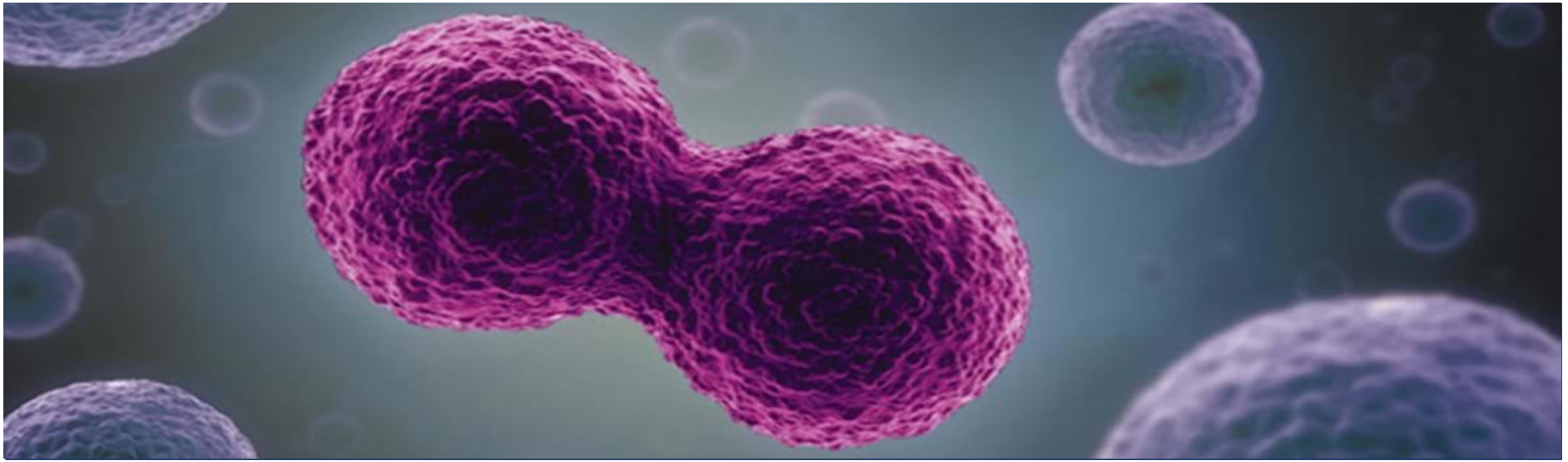
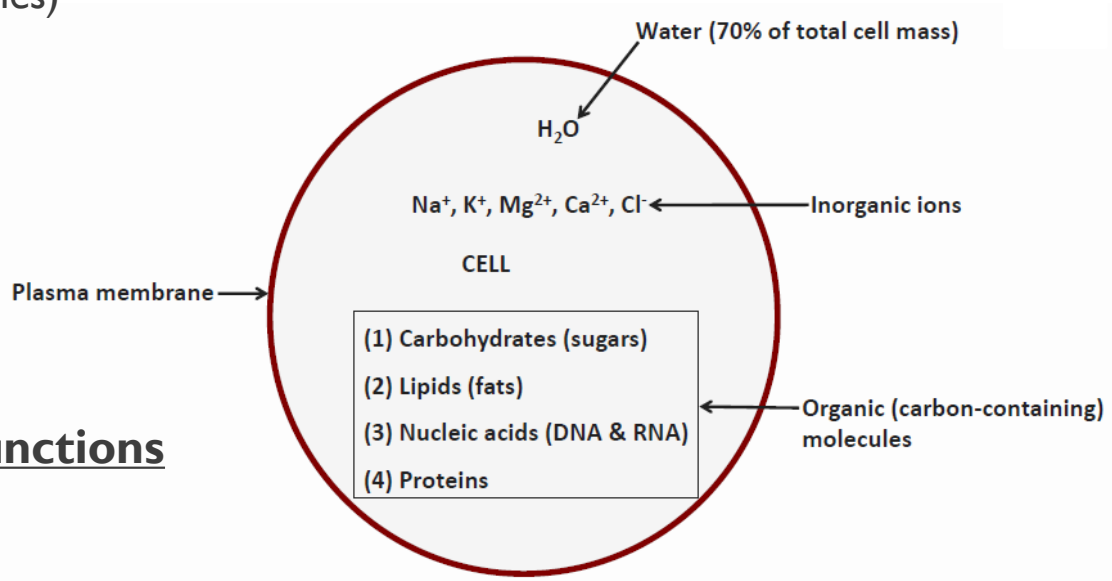
BIOL 266 – FINAL REVIEW

EMMANUEL ORFANOS



PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

- Cells are the **smallest** units exhibiting characteristics of life:
  - They can self-reproduce (unlike viruses & specific cell organelles)
  - They **ALL** contain the same sets of molecules
    - 70% of H_2O
    - Inorganic ions (sodium, potassium, magnesium,…)
    - Organic molecules (Carbs, Fats, Nucleic Acids & Proteins)



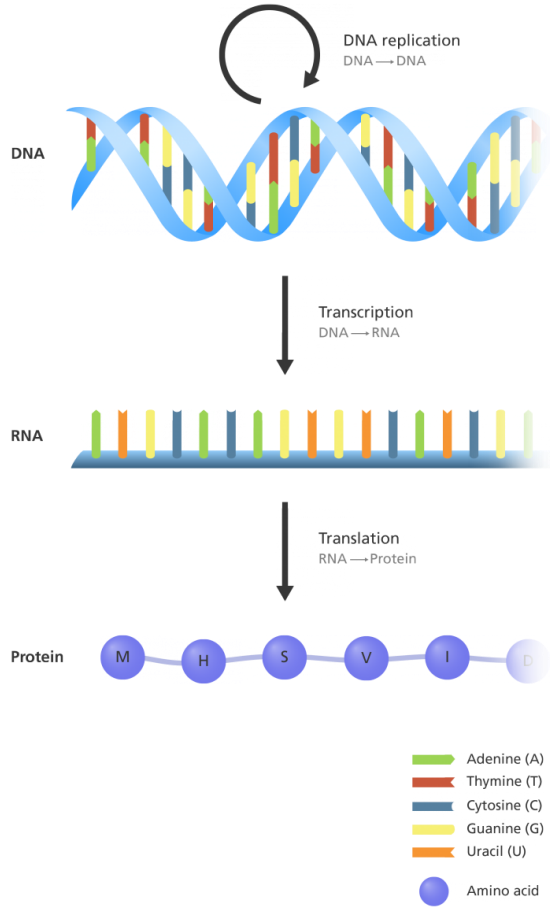
- Cells vary in **shape, size, chemical requirements & functions**
  - Nerve cell > yeast cell (size)
  - Photosynthetic cells require sunlight, whereas animal cells do not.

PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

- The **Central Dogma** is the flow of genetic information
  - DNA becomes RNA through **transcription** (same language – nucleic acids)
  - RNA becomes proteins through **translation** (different language – nucleic acids to amino acids)

- Evolution is the result of mutation & selection for better suited organisms over many generations.
  - Mutations are genetic changes that could be beneficial, detrimental or neutral to the organism

- The genome is the entire sequence of nucleotides in an organism's DNA.
  - The part of the genome that is expressed will determine the size/shape and behavior of a cell.



CELL COMPONENTS QUESTION

Which of the following ORGANIC components are you most likely to find in a cell?

A) DNA & Magnesium

B) RNA & lactose

C) Calcium & DNA polymerase

D) Glucose & H_2O

PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

- The **Cell Theory** states the following:
  - All living organisms contain one or more cells
  - The cell is the smallest basic unit of life (with respect to structure & organization in organisms)
  - Cells arise from pre-existing cells through cell division

- This can be seen through a microscope
  - Unstained, living cells can be seen with **bright-field, phase-contrast & differential interference contrast** optics
  - Stained cells will have increased contrast, but this will kill the cells
  - Fluorescence microscopy using the light absorbed at a specific (excitation) wavelength and emits light at another, longer (emission) wavelength
    - Immunofluorescence microscopy uses antibodies directed a specific protein with a fluorescent protein (ex: GFP)

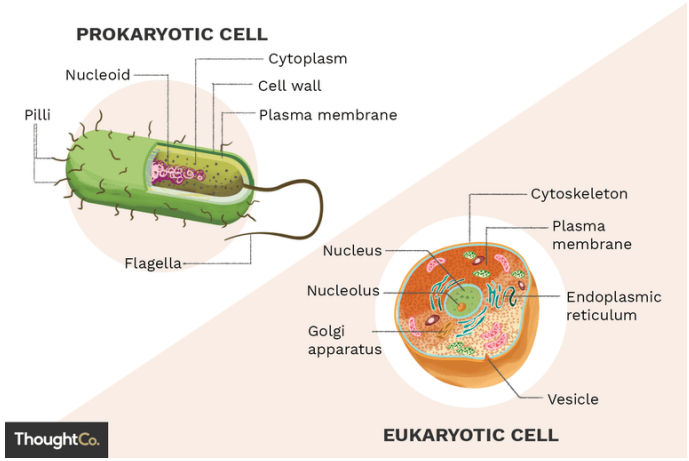
PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

- **Electron microscopy** provides the highest magnification & best resolution
  - **Disadvantage:** cells must be chemically fixed (dead)
  - **Transmission electron microscope** uses beam of electrons (very small λ) to analyze a very thin specimen

- Personally, I would go back to the chapter 1 lectures and memorize resolution & magnification values for each type of microscopy.

PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

Prokaryotes	Eukaryotes
Lack a nucleus	DNA is segregated within a defined nucleus
Lack internal membranes	Organelles are enclosed in internal membranes
Reproduce & evolve quickly	May be uni or multicellular
Can be Bacteria or Archaea	Much bigger than prokaryotes

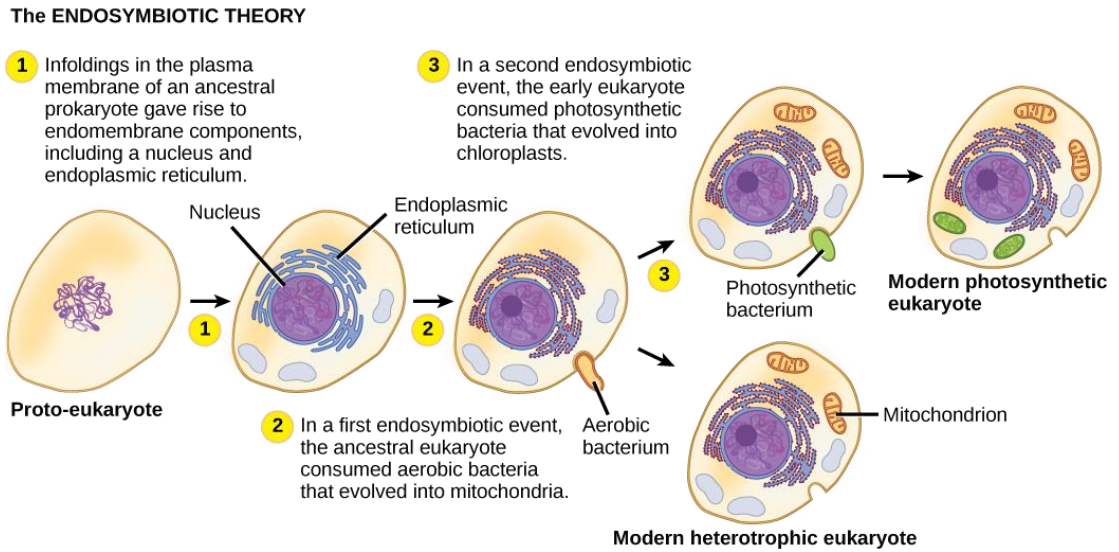


PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

- Function of various organelles
  - The **nucleus** contains the genetic information of the cell in the form of deoxyribonucleic acid (DNA)
  - The **cytoplasm** includes all of the membrane-enclosed organelles
  - The **mitochondria** is the powerhouse of the cell. It oxidizes food molecules and produces ATP
    - It has an inner & outer membrane, as well as its own copies of circular DNA
  - The **endoplasmic reticulum** & **Golgi apparatus** synthesize molecules to be exported from the cell or inserted into cell membranes via transport vesicles
  - The **lysosomes** digest large molecules using various enzymes
  - The **peroxisomes** perform fatty acid oxidation & decomposition of reactive oxygen species
  - **Chloroplasts** perform photosynthesis

PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

- **Endosymbiotic Theory**
  - Explains how eukaryotic cells could have evolved from prokaryotic cells
  - Mitochondria were single-celled bacteria (prokaryotes) that were likely absorbed by an ancestral eukaryotic cell
    - Benefit for ancient mitochondria = protected by eukaryote cell
    - Benefit for ancient eukaryote = receives energy from mitochondria to perform other, more complex tasks
    - It's likely that chloroplasts were photosynthetic bacteria that were engulfed <u>after the mitochondria</u> by the first plant-like cells
  - Evidence that argues the validity of this theory
    - Mitochondria & chloroplasts have their own DNA which are arranged in a similar way to bacteria
    - Mitochondria & chloroplasts can divide on their own in a similar way to bacteria



PRE-MIDTERM 1 – CHAPTER 1 – CELLS: THE FUNDAMENTAL UNITS OF LIFE

- Model Organisms
  - Examples: *E. coli, Saccharomyces cerevisiae, Arabidopsis thaliana, Drosophila melanogaster, Caenorhabditis elegans,* the zebrafish, the lab mouse, human cells
  - Know certain advantages for these specific examples

- Why do we study them?
  - They grow under controlled conditions
  - They reproduce rapidly
  - They are convenient for genetic manipulations
  - Note: Since all cells come from a common ancestor, many fundamental biological properties have been evolutionary conserved

PRE-MIDTERM 1 – CHAPTER 4 – PROTEIN STRUCTURE AND FUNCTION

- Proteins represent most of the cell's dry mass and perform MANY functions
  - Examples: enzymes, structure, transport, motor, storage, signal, receptor, transcription, special purposes (antibodies, hormones,…)
- The shape of a protein and its biological activity are defined by its **amino acid sequence**
- These amino acids are linked together by **peptide bonds**
  - Carboxyl carbon links to amino nitrogen and this forms the backbone of the protein
  - The side chains are what give rise to different chemical properties among amino acids

Can interact with water = hydrophilic

Do not interact with water = hydrophobic

AMINO ACID			SIDE CHAIN
Aspartic acid	Asp	D	negatively charged
Glutamic acid	Glu	E	negatively charged
Arginine	Arg	R	positively charged
Lysine	Lys	K	positively charged
Histidine	His	H	positively charged
Asparagine	Asn	N	uncharged polar
Glutamine	Gln	Q	uncharged polar
Serine	Ser	S	uncharged polar
Threonine	Thr	T	uncharged polar
Tyrosine	Tyr	Y	uncharged polar

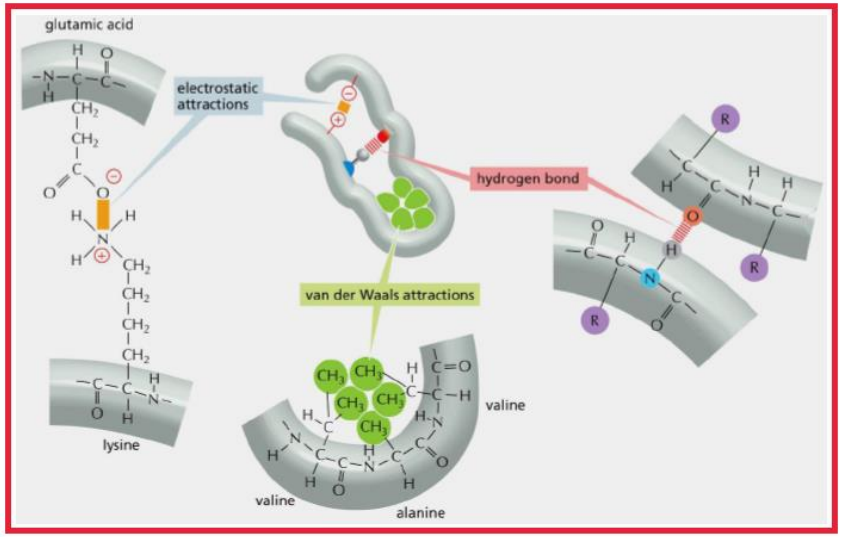
POLAR AMINO ACIDS

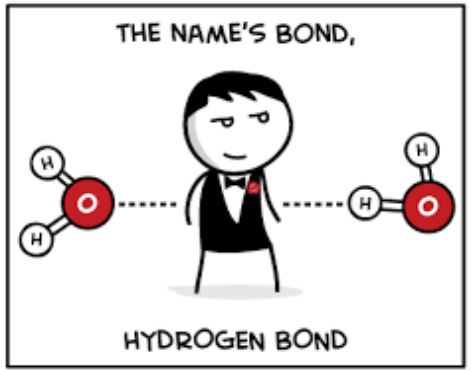
AMINO ACID			SIDE CHAIN
Alanine	Ala	A	nonpolar
Glycine	Gly	G	nonpolar
Valine	Val	V	nonpolar
Leucine	Leu	L	nonpolar
Isoleucine	Ile	I	nonpolar
Proline	Pro	P	nonpolar
Phenylalanine	Phe	F	nonpolar
Methionine	Met	M	nonpolar
Tryptophan	Trp	W	nonpolar
Cysteine	Cys	C	nonpolar

NONPOLAR AMINO ACIDS

PRE-MIDTERM 1 – CHAPTER 4 – PROTEIN STRUCTURE AND FUNCTION

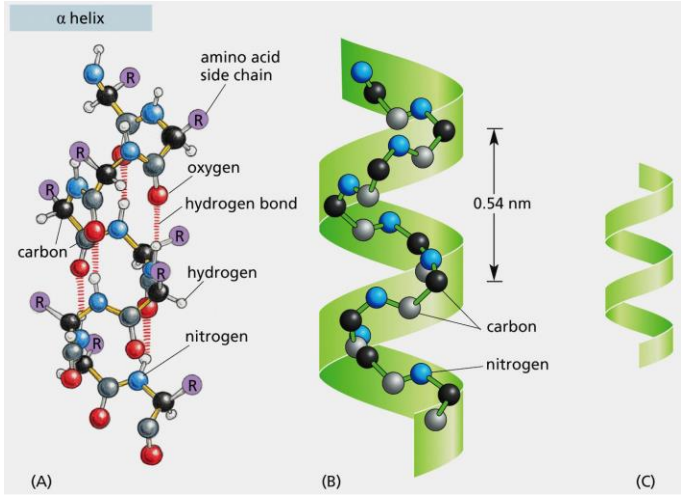
- Types of **noncovalent bonds** which are quite weak individually, but relatively strong as a whole
  - Hydrogen bonds help stabilize the folded protein shape by interacting with the protein backbone and/or side chain
  - Electrostatic Interactions between charged amino acids
  - Van der Waal forces
  - Hydrophobic forces pack non-polar amino acids inside the protein, away from water
- These interactions can be disrupted with certain solvents (i.e. urea), but can refold spontaneously when the denaturing solvent is removed
- Protein folding can be assisted by **chaperone proteins** (this requires ATP binding & hydrolysis)

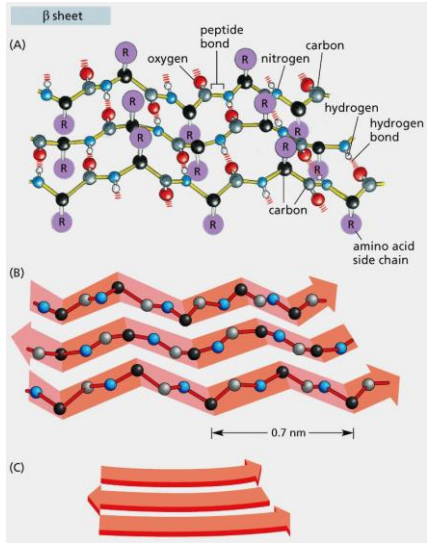




PRE-MIDTERM 1 – CHAPTER 4 – PROTEIN STRUCTURE AND FUNCTION

- **Secondary protein structures**
  - **α-helix** is a type of secondary protein structure in which the polypeptide chain turns around itself to make a rigid cylindrical shape. Every amino group of an amino acid is hydrogen bonded to a carboxyl group located **4 amino acids** away.
    - Membrane bound proteins typically cross the lipid bilayer as α-helices
    - Coiled-coil refers to the structure when 2 or 3 α-helices wrap around one another
  - **β-sheet** organizes the polypeptide chain in parallel or antiparallel strands that are also held together by hydrogen bonds between peptide bonds in adjacent strands.
    - Amyloid structure refers to rows of β-sheets in the form of teeth of a zipper



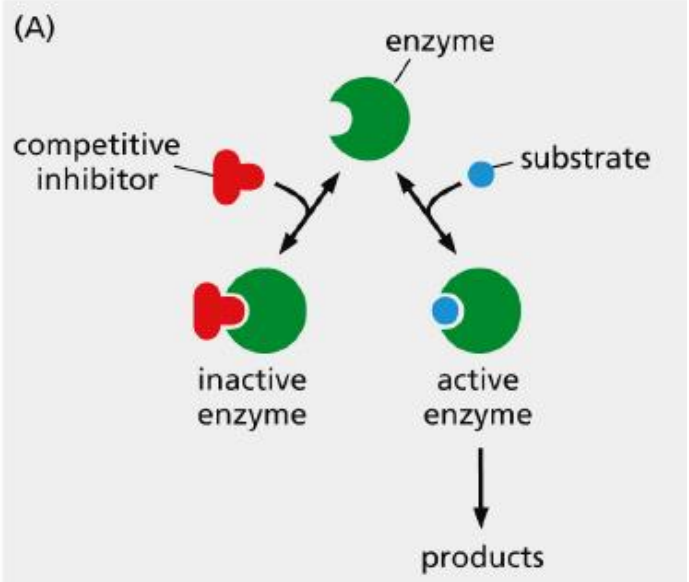


PRE-MIDTERM 1 – CHAPTER 4 – PROTEIN STRUCTURE AND FUNCTION

- Protein level of organization
  - Primary structure: amino acid sequence
  - Secondary structure: α-helices & β-sheets
  - Tertiary structure: 3D conformation of polypeptide chain (includes domains)
    - Domains: segments of the polypeptide chain that typically have their own function
  - Quaternary structure (not always present): Complex from multiple polypeptide chains
- Misfolded proteins can form amyloid structure that contribute to neurodegenerative diseases such as Alzheimer's, Huntington's, "mad cow"/Creutzfeldt-Jakob disease (from misfolded prions)
  - Prions can misfold normally folded proteins making them infectious

PRE-MIDTERM 1 – CHAPTER 4 – PROTEIN STRUCTURE AND FUNCTION

- Proteins can be globular or fibrous
  - Globular: actin, tubulin, hemoglobin, insulin
  - Fibrous: collagen, elastin, keratin, myosin
- Protein binding is **highly selective**
  - The ligand must fit precisely into the binding site so that a large number of noncovalent interactions can be formed
  - Enzymes are a prime example of this as they convert substrates to products very quickly (they greatly increase the rate of a chemical reaction) by making or breaking covalent bonds
    - A way to recognize enzymes: they typically end with –ase and are preceded by what they catalyze (i.e. proteases catalyze the breakdown of proteins)
    - As you increase the substrate concentration ([S]) you will increase the rate of the reaction until a point of saturation.
    - A competitive inhibitor can prevent substrate binding, as it binds to the same active site, but this can be overcome by increasing [S]



PROTEIN BINDING QUESTION

Which of the following is NOT an example of protein binding?

A) Hexokinase interacts with glucose to create glucose-1-phosphate

B) GPCR recognizes a survival signal

C) Antibodies recognize a specific foreign antigen on a human epithelial cell

D) These are all examples of protein binding

PRE-MIDTERM 1 – CHAPTER 4 – PROTEIN STRUCTURE AND FUNCTION

- Enzymes must be regulated to control the reactions they catalyze
  - Feedback inhibition: a large quantity of product will inhibit an enzyme earlier in the pathway (negative regulation)
    - Inhibition will trigger a conformation change in the enzyme once the product binds to the **regulatory site**
  - Covalent modifications (more than one may be present to influence the protein's function/behavior)
    - Phosphorylation causing a conformational change which can activate or inactivate an enzyme
    - Acetylation
    - Ubiquitination
    - Addition of fatty acids

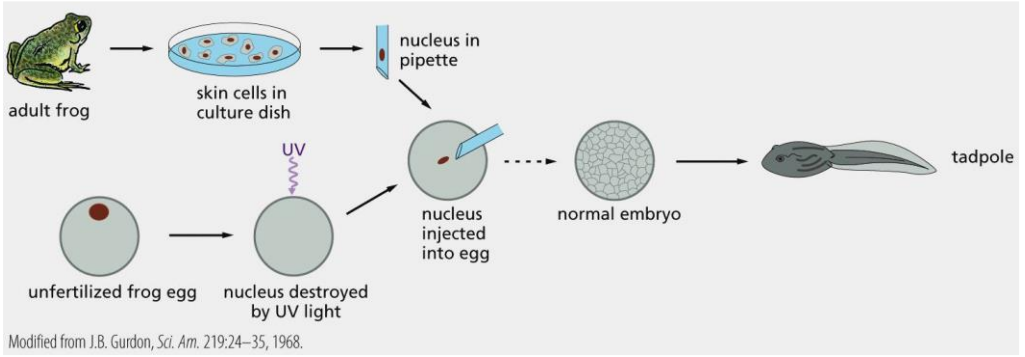
PRE-MIDTERM 1 – CHAPTER 4 – PROTEIN STRUCTURE AND FUNCTION

- Breaking cells and separating cell components
  - Homogenization: gentle mechanical procedures that can rupture the plasma membrane and release the cell's contents
    - High-frequency sound, mild detergents, high pressure, shearing
  - Centrifugation can separate various components depending on centrifugation speed
    - Low-speed: nuclei & cytoskeleton
    - Medium-speed: mitochondria, lysosomes, peroxisomes
    - High-speed: ER, other small vesicles
    - Ultra high-speed: ribosomes, viruses, large macromolecules
- Protein separation
  - Column chromatography
  - Gel Electrophoresis
  - Isoelectric Focusing
  - 2D Polyacrylamide Gel Electrophoresis
- Protein structure determination
  - X-Ray Crystallography
  - NMR Spectroscopy
  - Cryoelectron Microscopy

Review pages 164-169 in textbook or slides 91-95

PRE-MIDTERM 1 – CHAPTER 8 – CONTROL OF GENE EXPRESSION

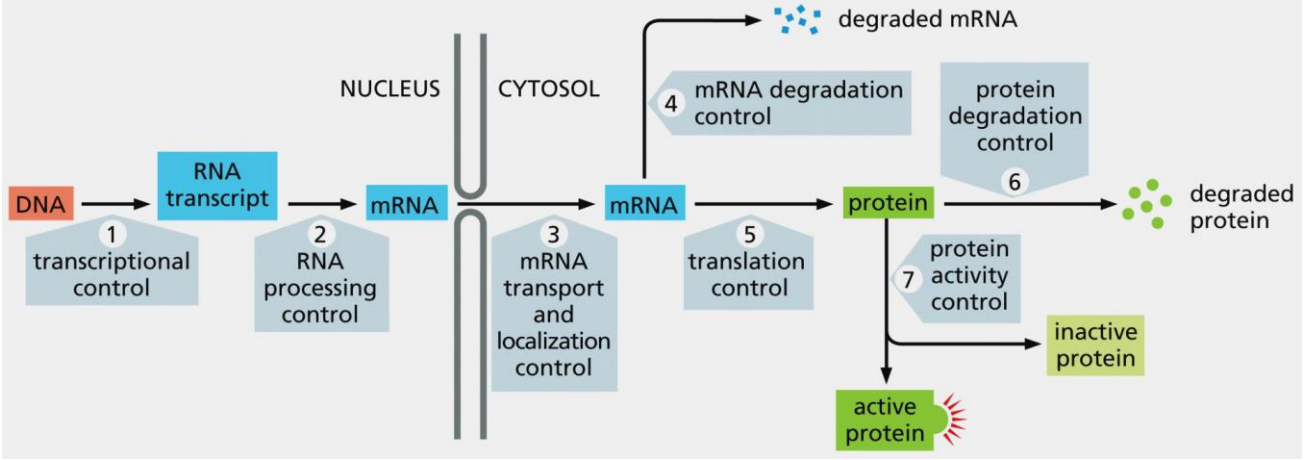
- Although all our cells in our bodies have **identical genomes**, they express only **a fraction** of it which will determine the cell's size, shape and function
- Cells have the ability to change which genes they express via external signals
  - Frog experiment, taking a differentiated skin cell nucleus and injecting it into an enucleated egg gave rise to a tadpole
  - This suggests that the DNA in differentiated cells still contains the **entire genome** since it gives rise to an entire organism



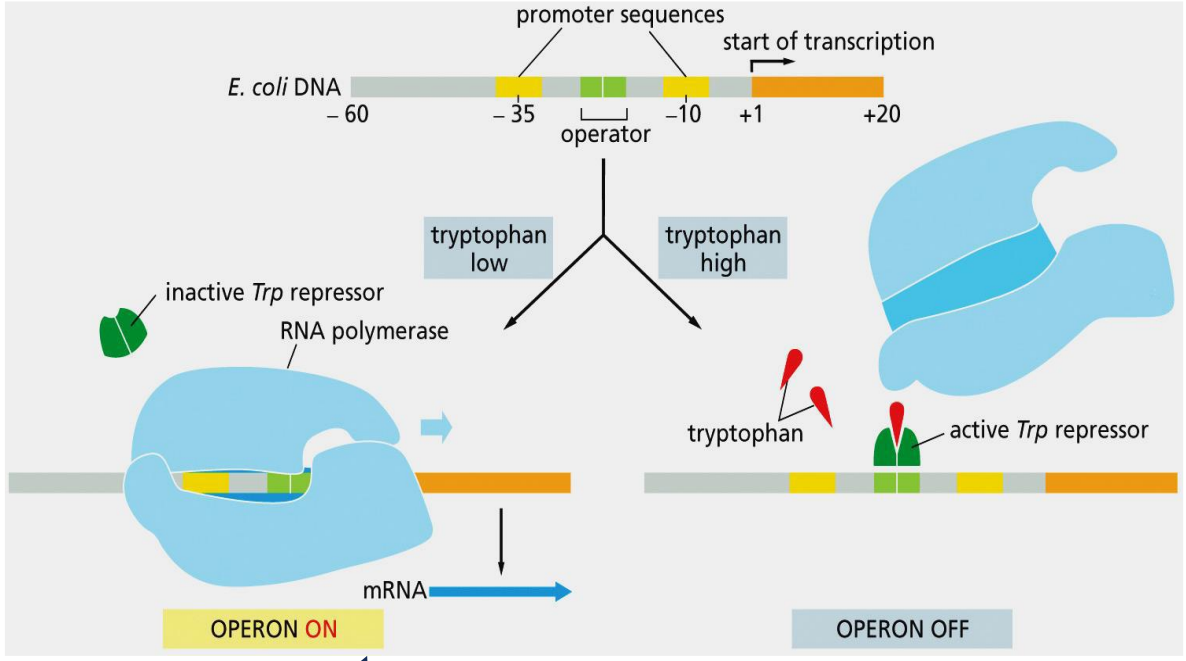
- The difference is not in the genes, but the RNAs & proteins produced in specialized cells
  - Note: housekeeping proteins (DNA/RNA polymerases, ribosomal proteins, …) are common to all cell types

PRE-MIDTERM 1 – CHAPTER 8 – CONTROL OF GENE EXPRESSION

- The main site of control is **transcription of DNA to RNA** via transcription regulators
  - Other points of control involve points where intermediates (RNA or proteins) are synthesized
    - mRNA transport and degradation, translation, protein activity and degradation
- A cluster of genes on a single mRNA molecule is called an **operon** that is controlled by a regulatory sequence known as the **operator**
  - Ex: the Trp operon & the Lac operon

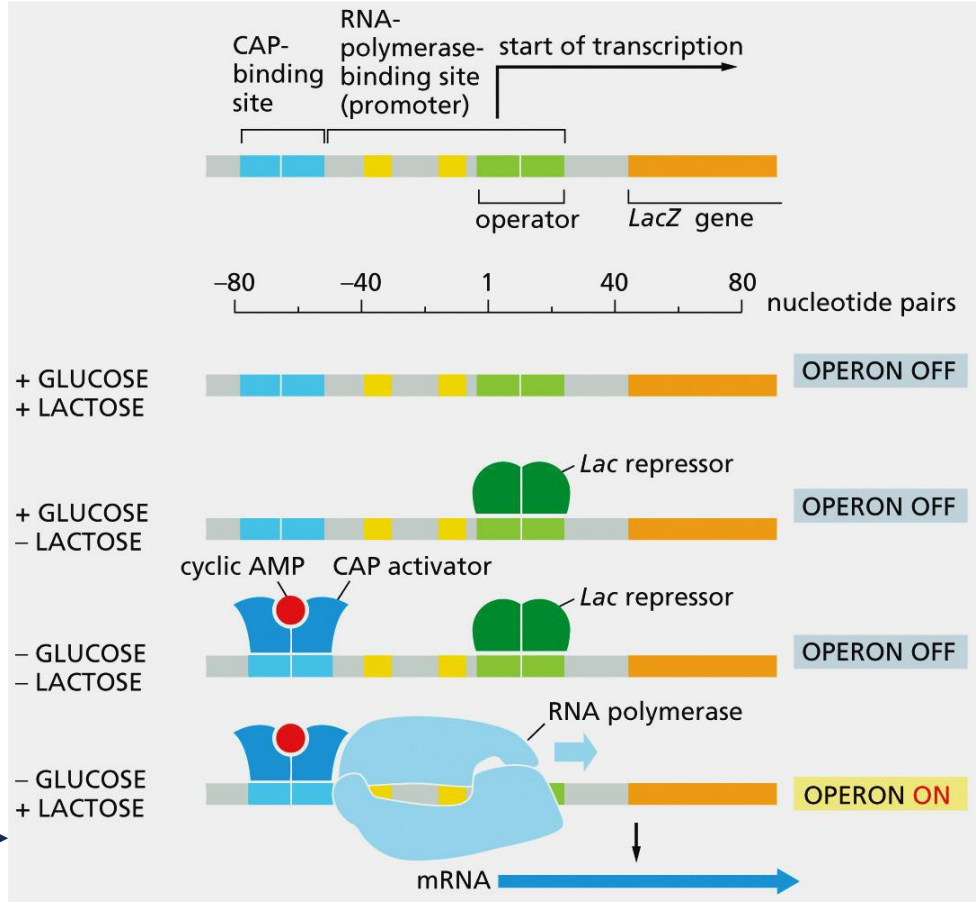


PRE-MIDTERM 1 – CHAPTER 8 – CONTROL OF GENE EXPRESSION



The Trp Operon: 5 genes that encode for enzymes required for tryptophan biosynthesis

The Lac Operon: LacZ gene that encodes β-galactosidase which breaks down lactose



LAC OPERON QUESTION

If the CAP activator protein was mutated in the presence of lactose and the absence of glucose, the Lac operon would…

A) Be turned ON because the CAP activator protein is not required for proper transcription when lactose is present.

B) Be turned ON because there is no repressor preventing transcription since glucose is absent.

C) Be turned OFF because the Lac operon cannot properly transcribe its genes without the CAP activator protein regardless if lactose is present.

D) Be turned OFF because the repressor is preventing transcription under these conditions.

PRE-MIDTERM 1 – CHAPTER 8 – CONTROL OF GENE EXPRESSION

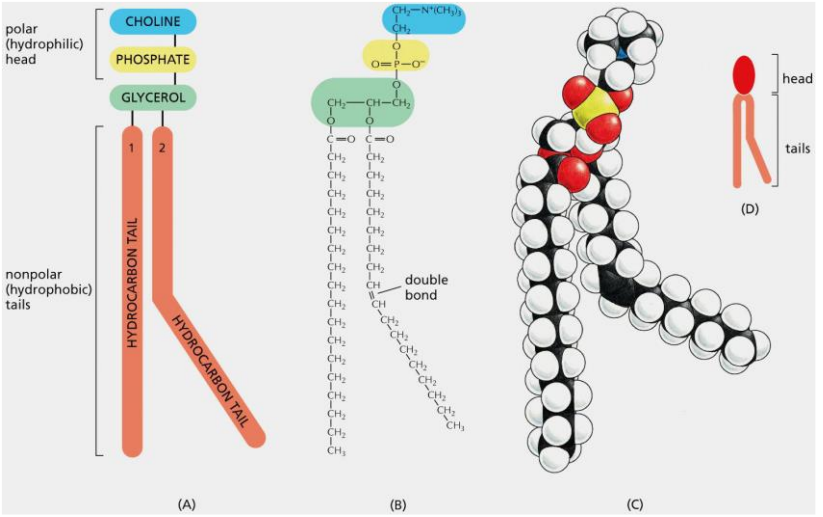
- Modifying the assembly process of RNA polymerase and other transcription factors via repressors and activators is not the only way to regulate gene expression
- Modifying the chromatin structure of the promoter region via covalent modifications can help expose or hide that sequence of DNA
- Certain regulators can maintain cells in an undifferentiated state, others can give rise to entire organs (Ey, a master regulator that creates the eye in Drosophila), convert a differentiated cell into another or de-differentiate a cell into an undifferentiated cell
- The ability for a differentiated cell to maintain its identity is known as **cell memory**, a positive feedback loop that activates the transcription of the cell's own gene
- A specific population of cells, known as **pluripotent cells** can give rise to all specialized cell types
  - Our embryonic stem cells are examples of undifferentiated cells exhibiting pluripotency

PRE-MIDTERM 1 – CHAPTER 11 – MEMBRANE STRUCTURE

- The **plasma membrane** acts as a semi-permeable barrier between the intracellular & extracellular space and has multiple functions such as:
  - Importing nutrients
  - Exporting waste
  - Receive information
  - Movement & expansion
- Other organelles such as the ER, Golgi, mitochondria,…also contain their own internal membranes that contain their unique sets of lipids & proteins, giving each organelle a unique function

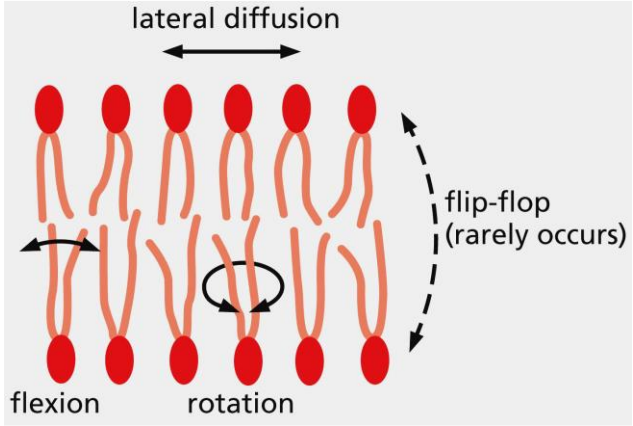
PRE-MIDTERM 1 – CHAPTER 11 – MEMBRANE STRUCTURE

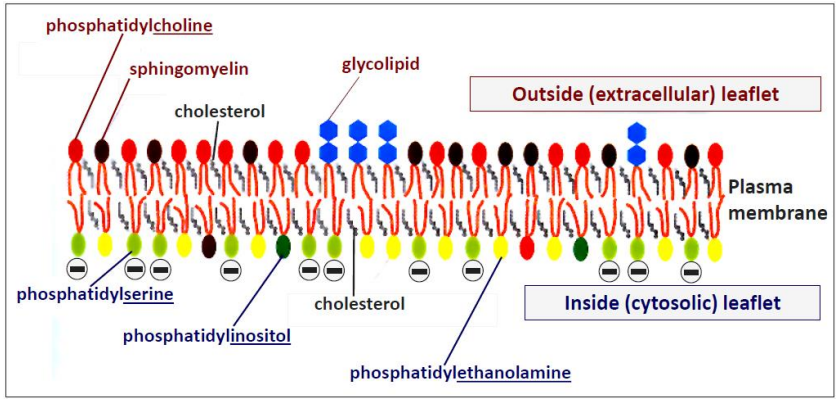
- The lipid bilayer consists of **amphipathic** molecules called phospholipids which typically have a hydrophilic head facing the outside of the membrane and two hydrophobic tails on the inside of the bilayer
- Creating this cage structure costs energy, but the cost is minimized if the hydrophobic tails cluster together (it is energetically most favorable)
  - Phosphatidylcholine (PC) is the most common phospholipid in cell membranes
    - It is made up of choline (unique to this phospholipid), a phosphate group, glycerol and two fatty acid chains, one saturated and one unsaturated (contains a double bond; kink)



PRE-MIDTERM 1 – CHAPTER 11 – MEMBRANE STRUCTURE

- Membrane phospholipids can move in different ways:
  - Lateral diffusion, which occurs rapidly
  - Flexion which occurs very rapidly
  - Rotation which also occurs very rapidly
  - Flip-Flop, which rarely occurs and if it does, it is very slow and requires proteins
    - Ex: Scramblases for random transfers in the ER membrane, Flippases for specific transfers in the Golgi
- Fluidity, which is important because it is crucial in rapid cell signaling (among other things), depends on:
  - Length of hydrocarbon tails (the shorter the chain, the less interaction between the tails, the more fluid the membrane)
  - Level of saturation (the more double bonds, the more unsaturated, the more fluid the membrane)
  - Presence of cholesterol typically stiffens the membrane





LIPID BILAYER QUESTION

Which of the following to you NOT expect to find in the lipid bilayer?

A) Phosphatidylserine

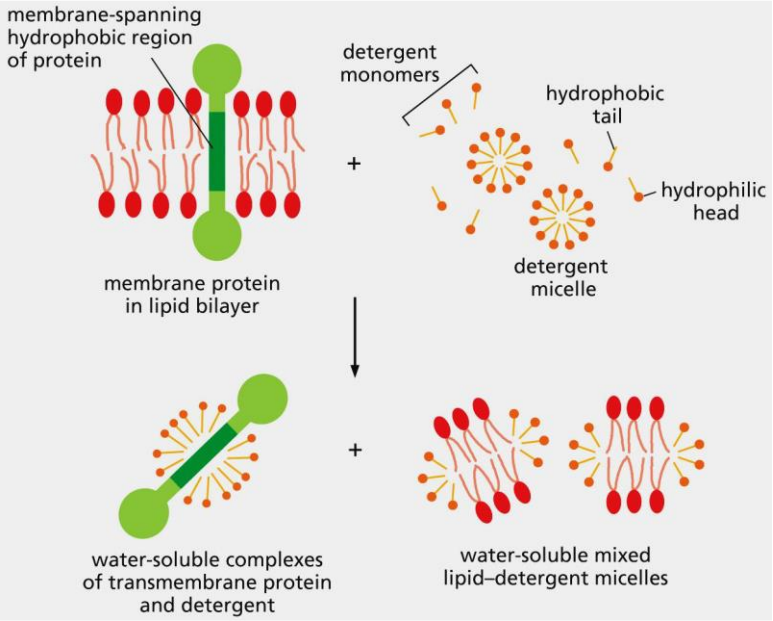
B) Cholesterol

C) Sphingolipids

D) All of the above can be found in the lipid bilayer

PRE-MIDTERM 1 – CHAPTER 11 – MEMBRANE STRUCTURE

- Plasma membrane proteins can have many different functions
  - Transporters/channels
  - Anchors
  - Receptors (typically α-helix transmembrane proteins that span the lipid bilayer)
  - Enzymes
- Detergents are cone-shaped amphipathic molecules (since they only contain a single hydrophobic tail) that can solubilize transmembrane proteins by forming micelles
  - SDS is a strong ionic detergent that can displace lipid molecules AND unfold proteins
  - Triton X-100 is a mild non-ionic detergent that can displace lipid molecules

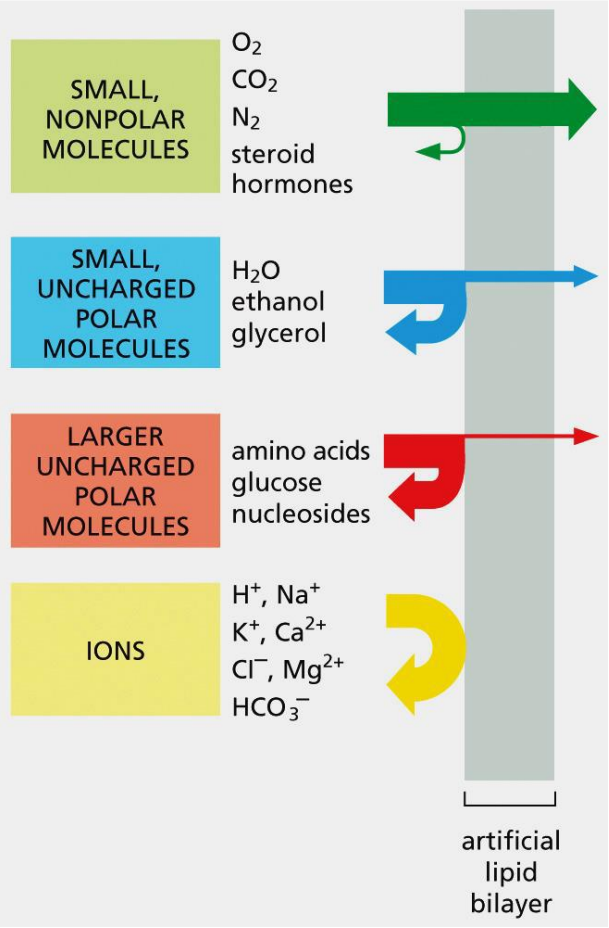


MIDTERM I - SUMMARY

- Cell components & function
- The Endosymbiotic Theory
- Amino Acids & Respective Side Chains + Properties
- Levels of Protein Structure
- Protein Regulation
- Laboratory techniques for Rupturing the plasma membrane, separating proteins and visualizing protein structure
- Operons
- Gene Expression Regulation
- The Lipid Bilayer & Components
- Types and Functions of Membrane Proteins
- Detergents and ability to confine transmembrane proteins to specific domains (Last 10 slides of Chapter 11)

PRE-MIDTERM 2 – CHAPTER 12 – TRANSPORT ACROSS CELL MEMBRANES

- What is permeable across the lipid bilayer?
  - The smaller the molecule, the easier it is to diffuse through the lipid bilayer
  - Nonpolar molecules will pass through more easily than polar molecules
  - The lipid bilayer is impermeable to ions
- Inside the cell, K^+ is the main cation and negatively charged proteins are the main anions
- Outside the cell, Na^+ is the main cation whereas Cl^- is the main anion
- It is important for positive and negative charges inside and outside the cell are balanced so the cell is not torn apart by electrical forces.
- The **membrane potential** is the difference in voltage across the plasma membrane



TRANSPORT QUESTION

Which of the following are MOST likely to cross the lipid bilayer?

A) H_2O & testosterone

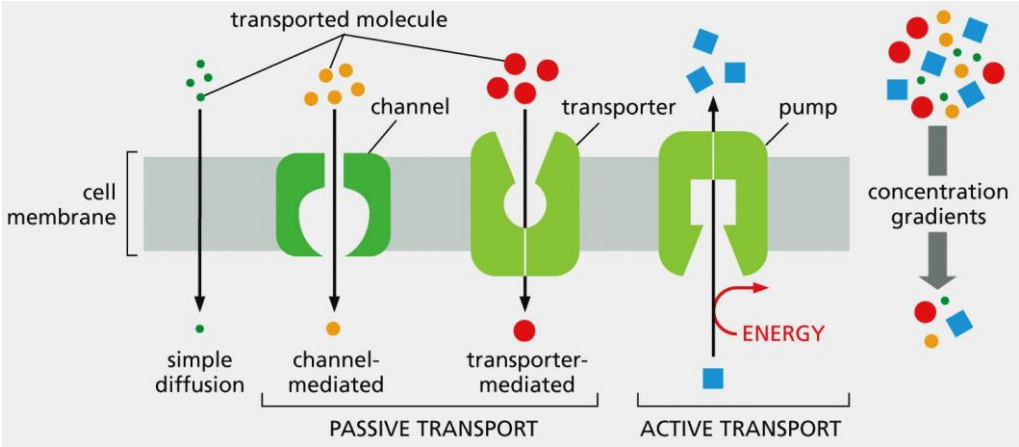
B) serine & CO_2

C) Ca^{2+} & N_2

D) adenosine & estrogen

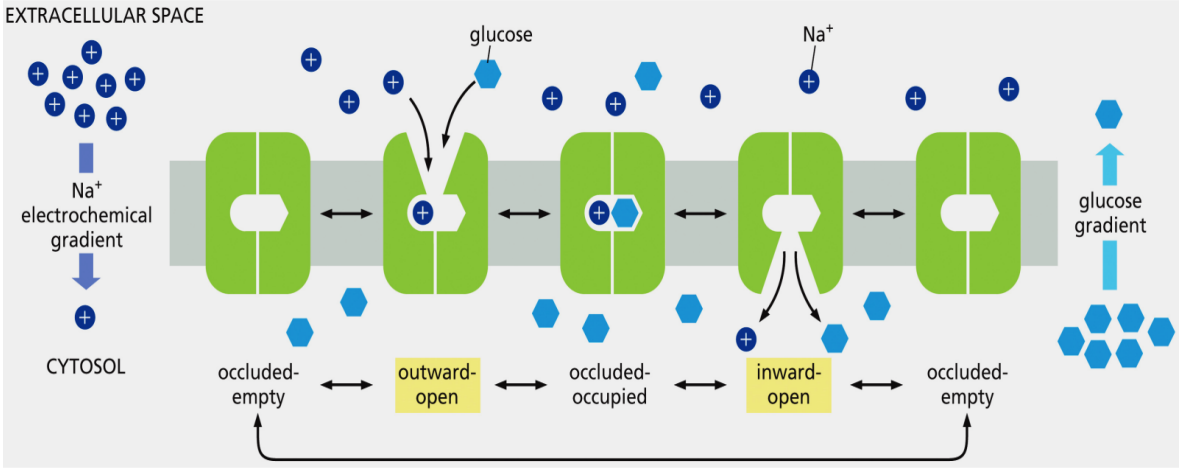
PRE-MIDTERM 2 – CHAPTER 12 – TRANSPORT ACROSS CELL MEMBRANES

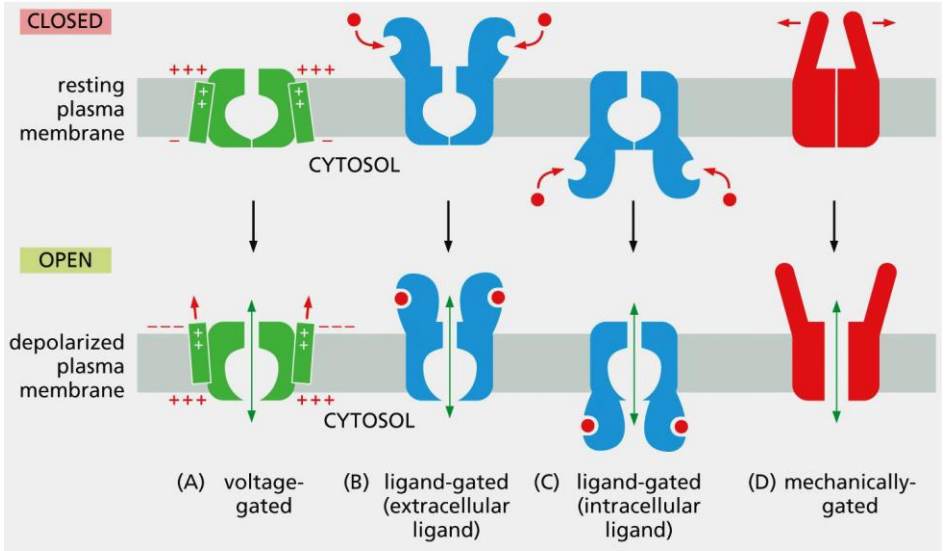
- Types of Transport
  - Simple Diffusion
    - Small non-polar molecules can simply diffuse through the membrane without the help of proteins
  - Passive Transport
    - Channels allow ions or polar molecules to diffuse down their concentration gradient
    - Transporters are very selective and require conformational changes to transfer solutes across the bilayer
  - Active Transport
    - Requires an input of energy since solutes move against their concentration gradient
    - These transporters are called pumps (Ex: Na^+-K^+ pump uses ATP to pump 3 Na^+ out and 2 K^+ in)



PRE-MIDTERM 2 – CHAPTER 12 – TRANSPORT ACROSS CELL MEMBRANES

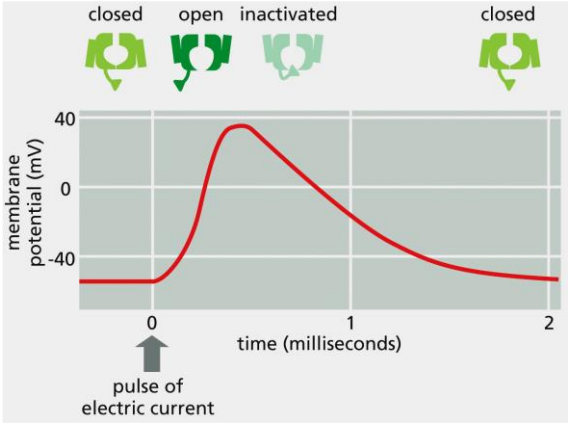
- Gradient-driven pumps couple the movement of one ion to another
  - Symports
    - Glucose-Na^+ symport uses the electrochemical gradient of sodium to power the movement of glucose into the cytosol of gut epithelial cells
  - Antiports
    - Na^+-K^+ ATPase
- Different types of channels that can either be in open or closed conformations
  - Voltage-gated (open if there is a change in voltage across the membrane)
    - Action potentials
  - Ligand-gated (open when chemical ligand binds)
    - Acetylcholine receptors in skeletal muscle cells
  - Mechanically-gated (opens in response to a mechanical stress)
    - Sound vibrations in the ear open channels that ultimately send auditory signals to the brain

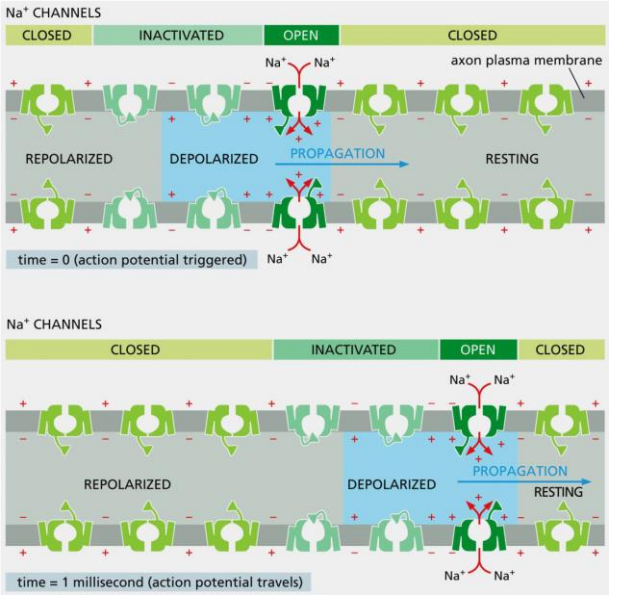




PRE-MIDTERM 2 – CHAPTER 12 – TRANSPORT ACROSS CELL MEMBRANES

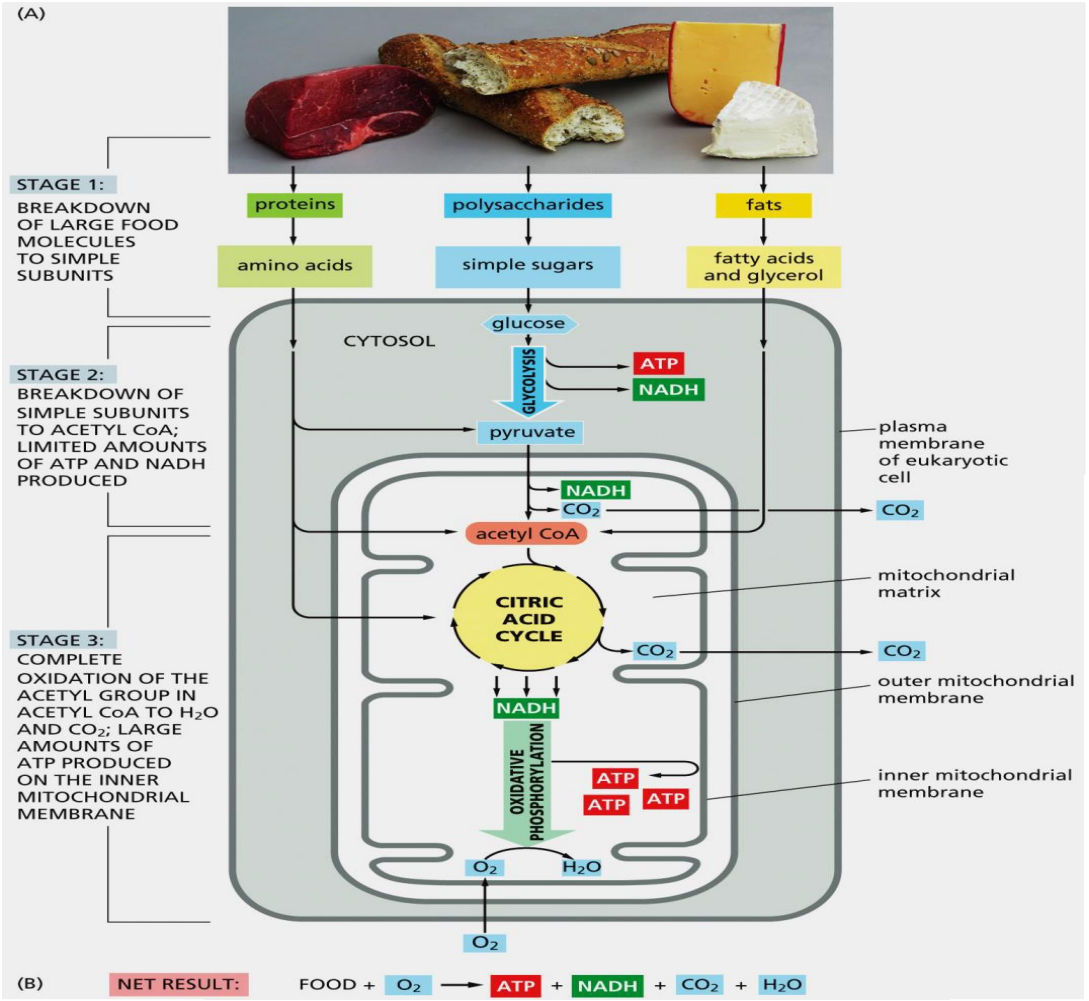
- In a neuron, the resting membrane potential is -60 mV
- When stimulated to about -40 mV, the threshold potential is reached which opens voltage-gated Na^+ channels
- The rapid influx of Na^+ ions into the cell will depolarize the membrane (action potential) until about +40mV which will temporarily inactivate the sodium channels, thus preventing the membrane from being re-stimulated and the signal will only move forward because the sodium channels behind the signal have been inactivated





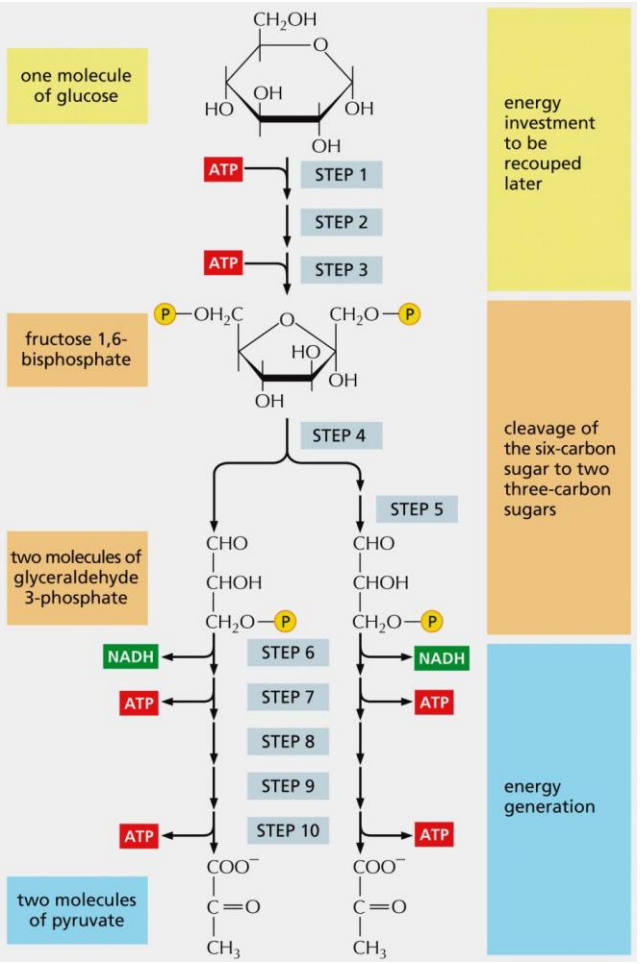
PRE-MIDTERM 2 – CHAPTER 13 – HOW CELLS OBTAIN ENERGY FROM FOOD

- Cells catalyze the breakdown of sugars in a series of small steps which allows a portion of the free energy to be stored in carrier molecules such as ATP & NADH. In a non-living system, the direct burning of sugar releases all the energy in the form of heat
- ATP can be synthesized by coupling the energetically favorable breakdown of food* and the unfavorable addition of an inorganic phosphate group to ADP to make ATP OR it can be made via oxidative phosphorylation in the inner mitochondrial membrane
- *Breakdown of Food
  - Step 1: large food molecules get broken down into simpler subunits (proteins to amino acids,…)
  - Step 2: Glycolysis & the conversion of pyruvate to acetyl CoA in the mitochondrial matrix
  - Step 3: Citric Acid Cycle in the matrix & oxidative phosphorylation in the inner membrane that uses NADH to produce large amounts of ATP



PRE-MIDTERM 2 – CHAPTER 13 – HOW CELLS OBTAIN ENERGY FROM FOOD

- Process of Glycolysis (does not require oxygen)
  - Input: 1 molecule of glucose, 2 molecules of ATP
  - Output: 2 molecules of pyruvate, 4 molecules of ATP, 2 molecules of NADH
  - Net result: glucose → 2 ATP + 2 NADH
- Step 1: **Hexokinase** requires ATP to produce glucose-6-phosphate from glucose
- Step 3: **Phosphofructokinase (PFK)** uses ATP to produce fructose 1,6-bisphosphate from fructose-6-phosphate
- Step 4 is characterized by the cleavage of a 6-carbon sugar to two 3-carbon intermediates (explains how 1 molecule creates 2 products)
- Steps 6 & 7 are energy generation steps, producing NADH & ATP respectively (2x since there are two intermediates)
- Step 10: **Pyruvate kinase** produces pyruvate & ATP (again 2x)
- **Note: the enzymes in green are the KEY regulatory enzymes in glycolysis as they are tightly regulated**
- **Gluconeogenesis** is the opposite process of glycolysis



GLYCOLYSIS QUESTION

If citrate is present in high concentrations in a cell, how will it interact with the enzyme phosphofructokinase (PFK) in glycolysis?

A) It will activate PFK, thus promoting glycolysis

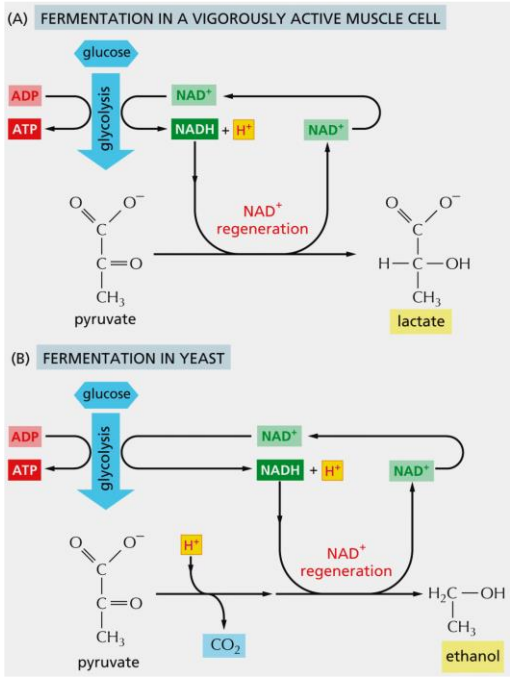
B) It will activate PFK, thus inhibiting glycolysis

C) It will inhibit PFK, thus promoting glycolysis

D) It will inhibit PFK, thus inhibiting glycolysis

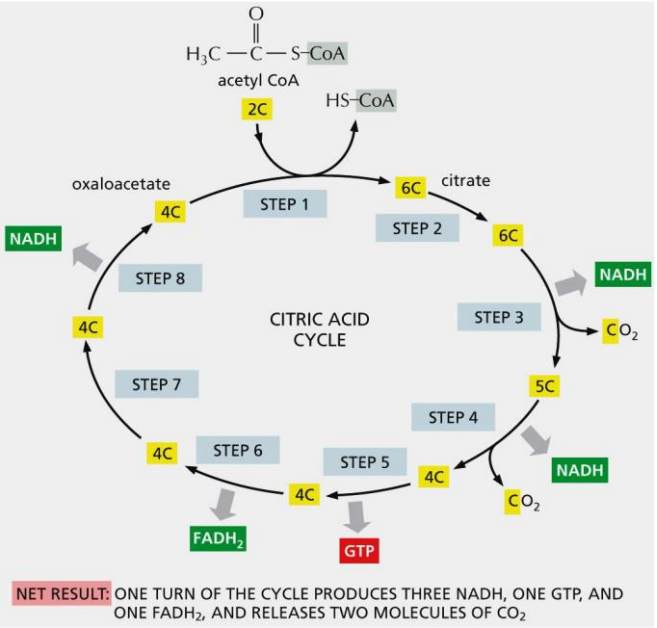
PRE-MIDTERM 2 – CHAPTER 13 – HOW CELLS OBTAIN ENERGY FROM FOOD

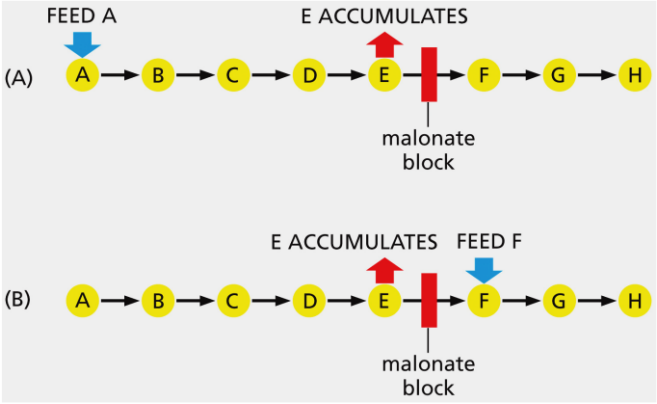
- Roles of different types of enzymes
  - Kinases: add a phosphate group
  - Phosphatases: remove a phosphate group
  - Isomerases: rearrange the bonds within a molecule
  - Dehydrogenases: catalyze the oxidation of a molecule (removes H^-)
  - Mutases: shift a chemical group from one position to another
- In the absence of oxygen, pyruvate gets broken down via fermentation
  - Pyruvate becomes lactate in an active muscle cell
  - Pyruvate becomes ethanol in yeast
- In the presence of oxygen, pyruvate + fatty acids in the mitochondrial matrix are converted to acetyl CoA



PRE-MIDTERM 2 – CHAPTER 13 – HOW CELLS OBTAIN ENERGY FROM FOOD

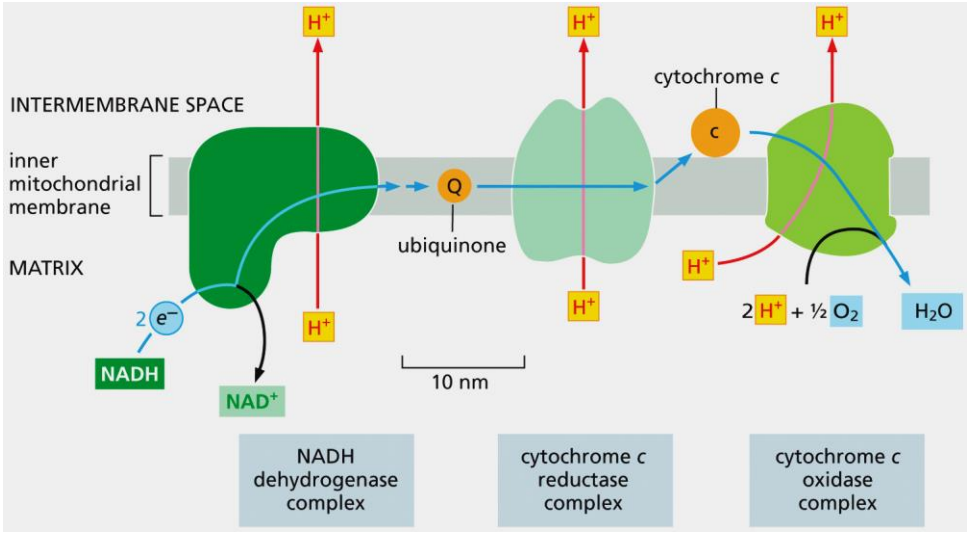
- Acetyl CoA will enter the **Citric Acid Cycle/Tricarboxylic Acid Cycle/Krebs Cycle**
  - The two carbons from Acetyl CoA will interact with oxaloacetate to ultimately make **3 NADH, 1 GTP, 1 $FADH_2$ and 2 CO_2**
  - Malonate, a competitive inhibitor of the enzyme succinate dehydrogenase, provides evidence suggesting the TCA cycle is indeed circular
    - Adding A (located before the block) or F (located after the block) both lead to an accumulation of E suggesting that these all make a circle

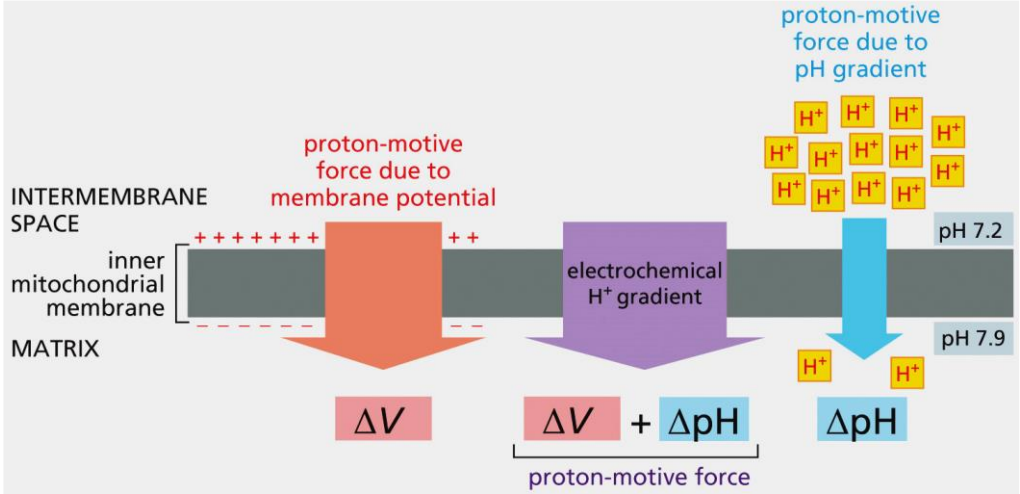




PRE-MIDTERM 2 – CHAPTER 14 – ENERGY GENERATION IN MITOCHONDRIA AND CHLOROPLASTS

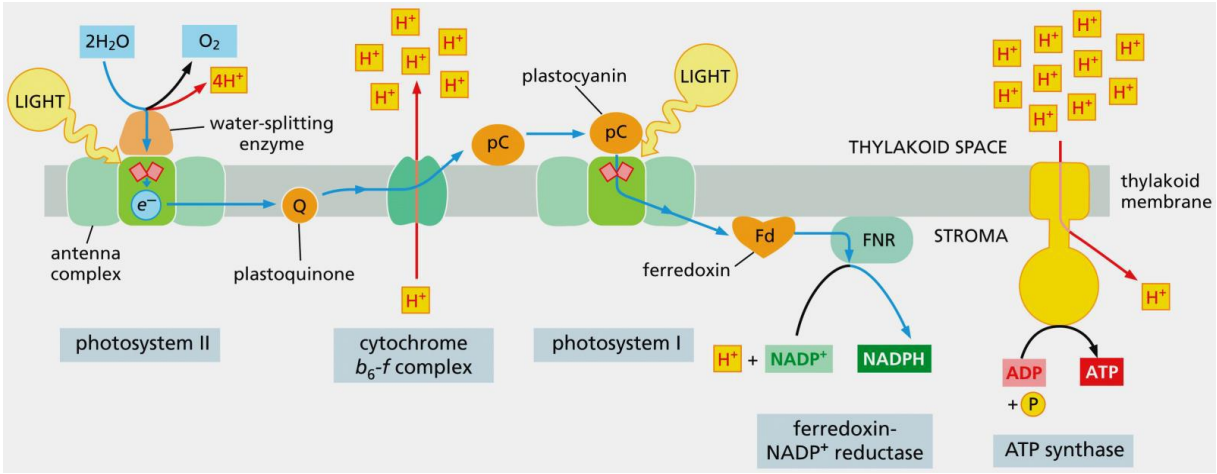
- NADH (as well as $FADH_2$) carry electrons from the TCA cycle to oxygen by going through the electron transport chain (ETC) causing protons to be pumped across the membrane (from the matrix to the intermembrane space)
- The electrons enter complex I, are passed to ubiquinone, complex III, cytochrome c, complex IV and handed off to oxygen
- Each complex listed pumps protons, creating an **electrochemical gradient** which drives the proton motive force
- The generated proton gradient drives the production of about 30 ATP by ATP synthase (the last complex in the ETC)





PRE-MIDTERM 2 – CHAPTER 14 – ENERGY GENERATION IN MITOCHONDRIA AND CHLOROPLASTS

- In chloroplasts, two types of reactions take place: light reactions and light-independent (dark) reactions
  - In light reactions, which occur in the thylakoid membrane, ATP & NADPH are produced
    - Sunlight energy is captured by chlorophylls embedded in photosystems (II then I) which produces a high-energy electron from hydrolysis
    - In photosystem II, the electron is transferred to plastoquinone which carries it to a proton pump called the cytochrome b_6-f complex (pumps protons from the stroma to the thylakoid space)
    - In photosystem I, the electrons are carried over via plastocyanin and a second energy boost is provided, allowing the electron to be passed to ferredoxin which carries it to FNR which reduces $NADP^+$ to NADPH
    - Just like in the mitochondria, the electrochemical proton gradient is used to produce ATP via ATP synthase



PLANT CELLS QUESTION

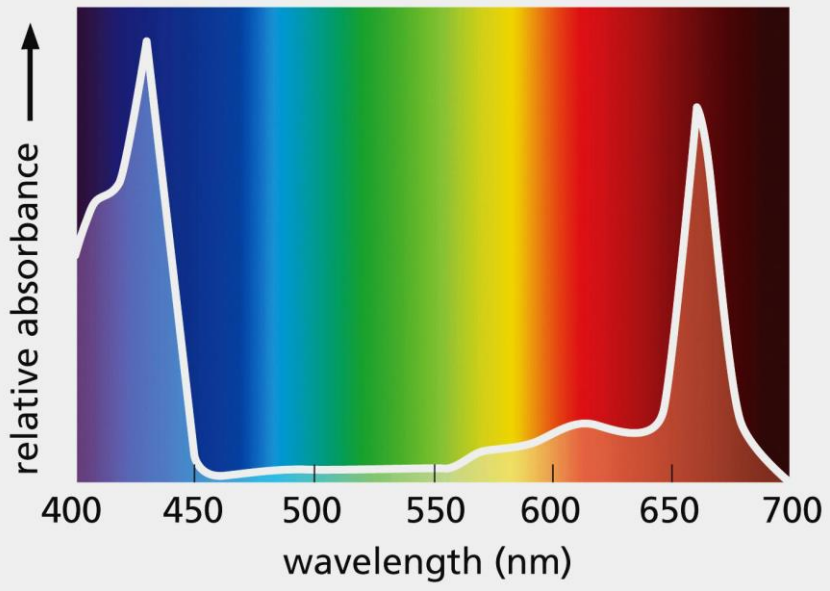
Why do plant cells that perform photosynthesis exhibit a green color?

A) Chlorophyll absorbs and emits light of green wavelength

B) Chlorophyll absorbs light of blue and red wavelengths

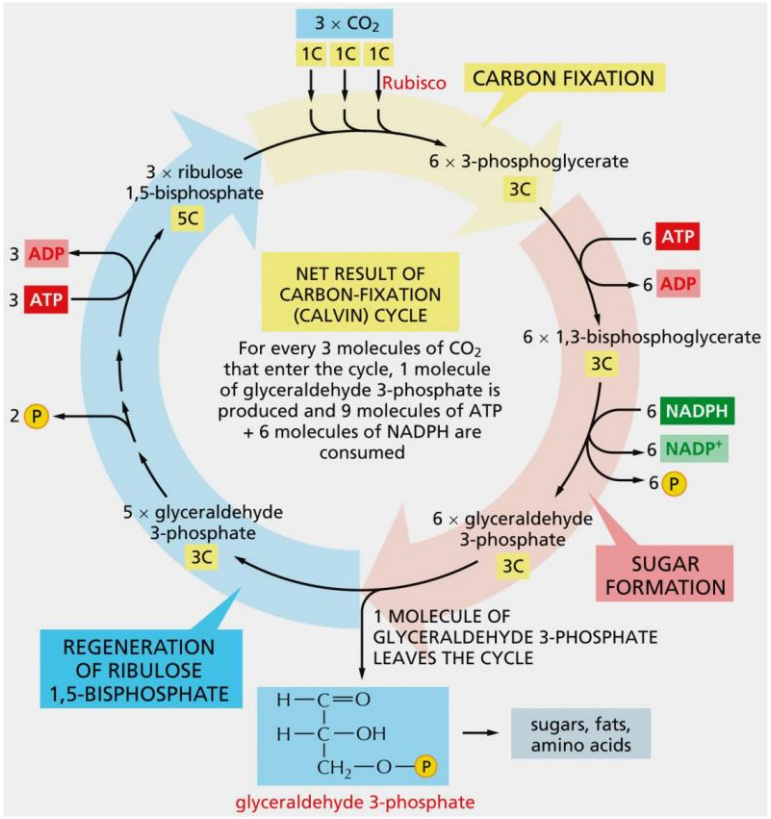
C) Green fluorescent protein is present in chlorophyll, giving it a green color

D) Chloroplasts, which are found in all plant cells, are naturally green



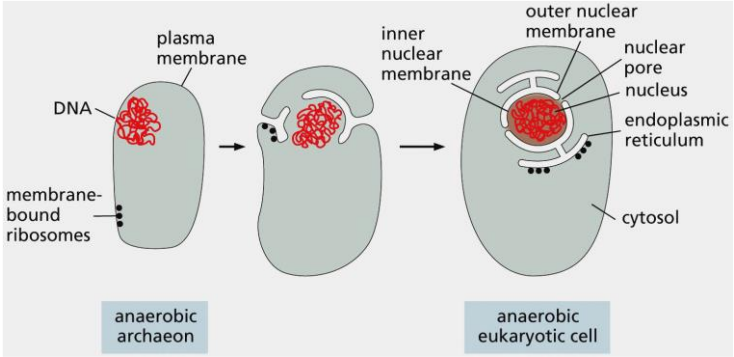
PRE-MIDTERM 2 – CHAPTER 14 – ENERGY GENERATION IN MITOCHONDRIA AND CHLOROPLASTS

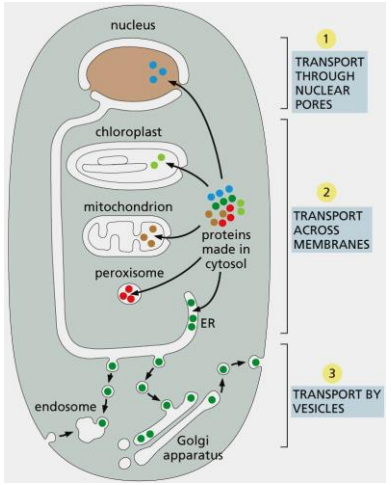
- In the dark reactions, which takes place in the stroma, carbon fixation is catalyzed by the enzyme **Rubisco** which converts CO_2 to 2 molecules of glyceraldehyde 3-phosphate (an intermediate of glycolysis)
- This molecule is then used to synthesize sugars which can be stored in the chloroplast as starch or exported to other parts of the plant cell



PRE-MIDTERM 2 – CHAPTER 15 – INTRACELLULAR COMPARTMENTS AND PROTEIN TRANSPORT

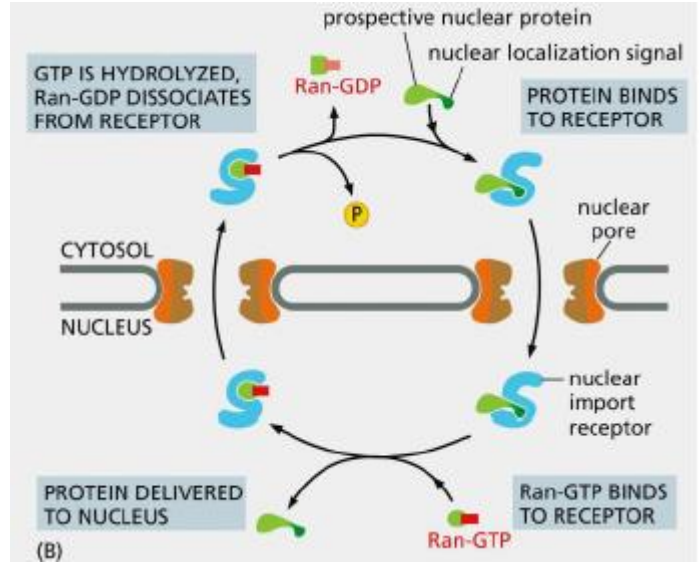
- Unlike the mitochondria and chloroplasts, it is believed that the nuclear membranes & the ER have evolved through invagination of the plasma membrane
  - This could explain why the space between the nuclear membranes is continuous with the ER
- Membrane-enclosed organelles import proteins by one of 3 energy-requiring mechanisms
  - Transport through nuclear pores
  - Transport across membranes
  - Transport by vesicles
- Proteins are directed through signal sequences located on the N-terminal of the protein
  - A lack of sequence suggests that these proteins are destined to remain in the cytosol

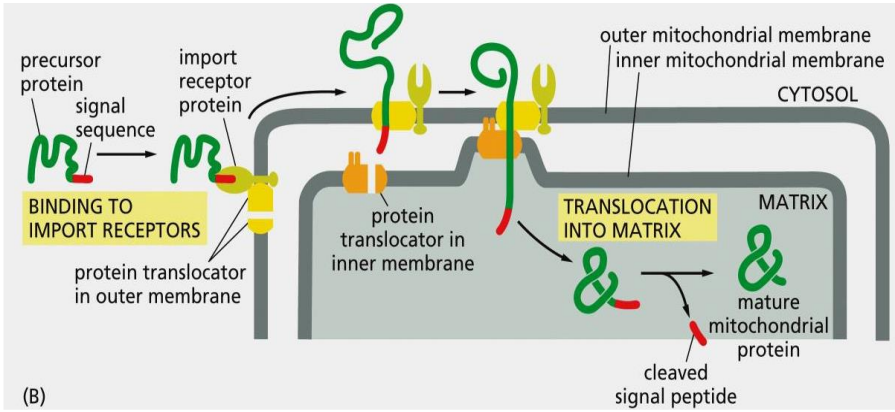




PRE-MIDTERM 2 – CHAPTER 15 – INTRACELLULAR COMPARTMENTS AND PROTEIN TRANSPORT

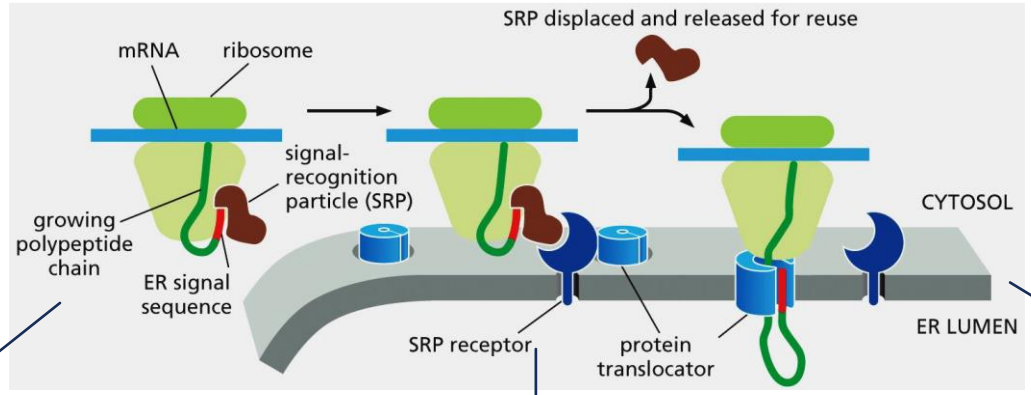
- A nuclear localization signal will interact with protruding fibrils on the cytosolic side of the pore which will capture the cargo protein
- Within the nucleus, Ran-GTP will bind to the nuclear import receptor after the cargo is released and will undergo GTP hydrolysis when it returns to the cytosol for reuse
- Ran-GDP falls off the receptor, allowing the receptor to bind to a new signal (bound to a protein) that is destined for import
- Proteins destined for the mitochondria contain a signal sequence that binds to a receptor on the outer mitochondrial membrane which is associated with a protein translocator
- The formed complex will diffuse laterally until the signal sequence is recognized by a 2nd translocator located in the inner mitochondrial membrane which will ultimately transport the protein through the membranes, unfolding it in the process





PRE-MIDTERM 2 – CHAPTER 15 – INTRACELLULAR COMPARTMENTS AND PROTEIN TRANSPORT

Within the ER, proteins may:
1- be soluble and enter the ER lumen
2- be retained in the bilayer as a single-pass transmembrane protein
3- be retained in the bilayer as a double-pass transmembrane protein



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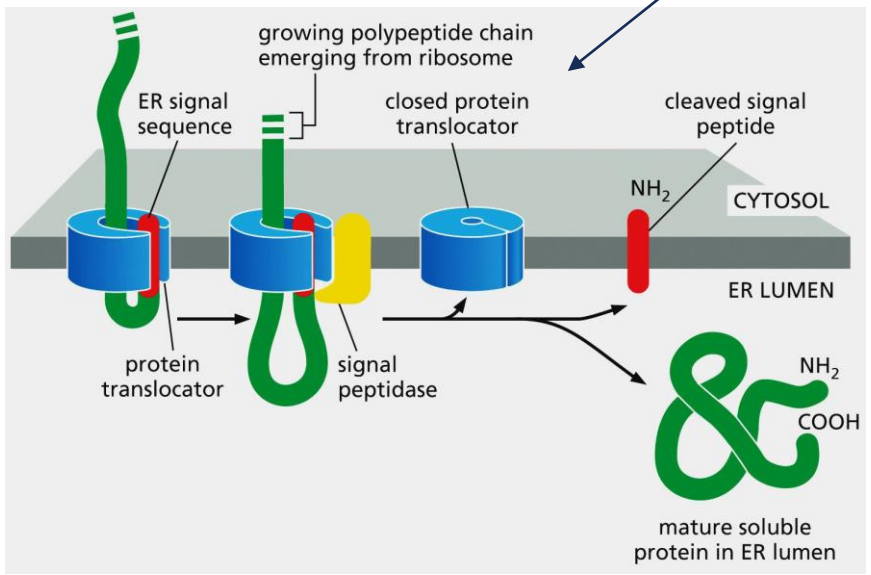

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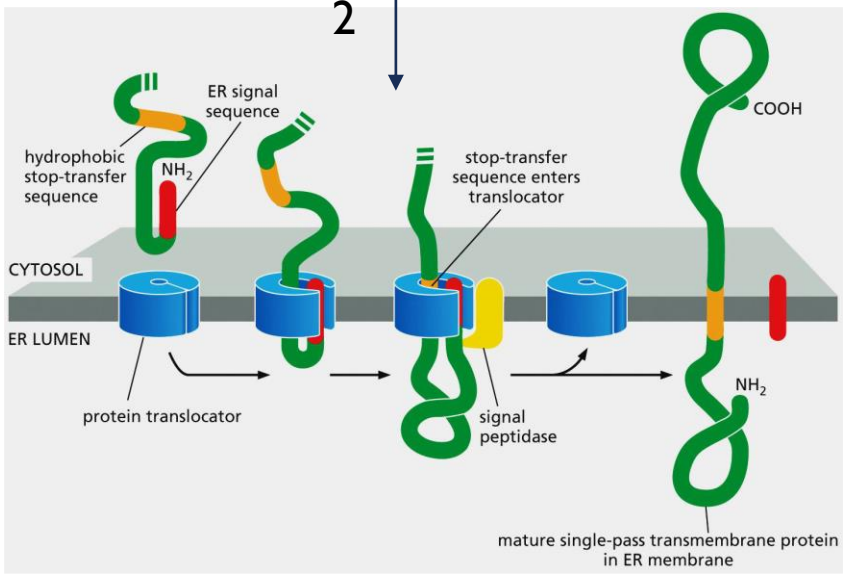

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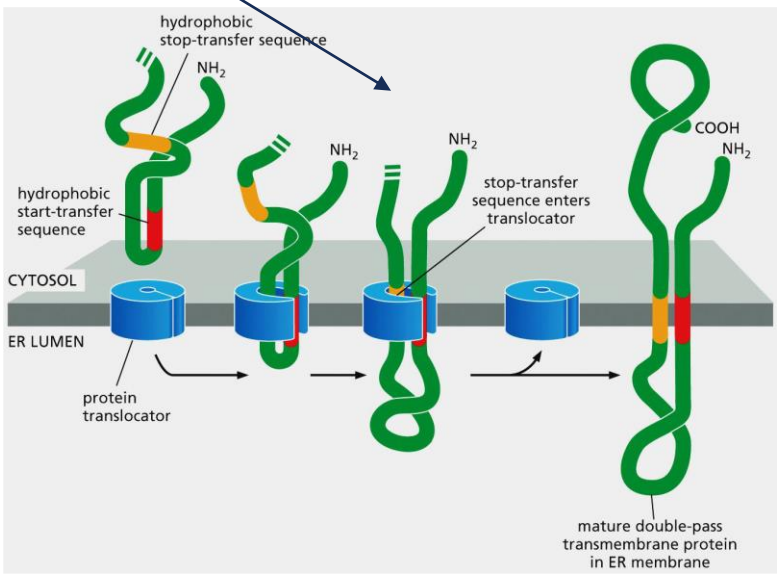


PROTEIN TRANSPORT QUESTION

Which of the following is an example of how protein X can be transported into the mitochondria?

A) Protein X containing the mitochondrial localization signal will interact with protruding fibrils on the cytosolic side of the mitochondria, which will capture and bring the protein into the mitochondrial matrix

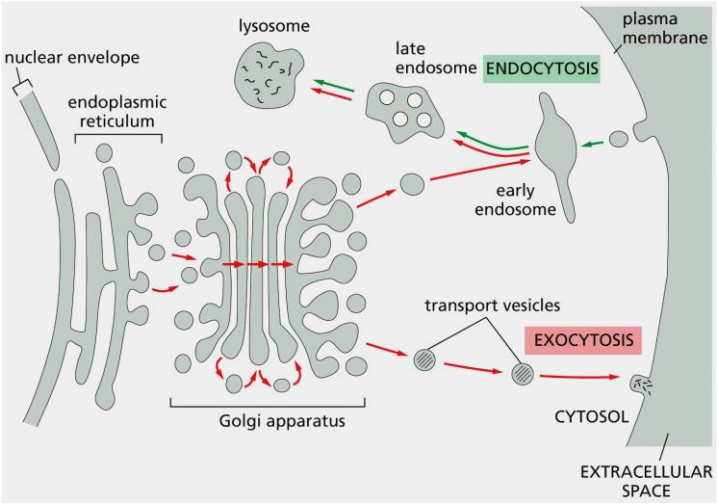
B) Protein X containing the mitochondrial localization signal will interact with an SRP receptor associated to a translocator which will bring the protein into the matrix and a signal peptidase will cleave the localization signal

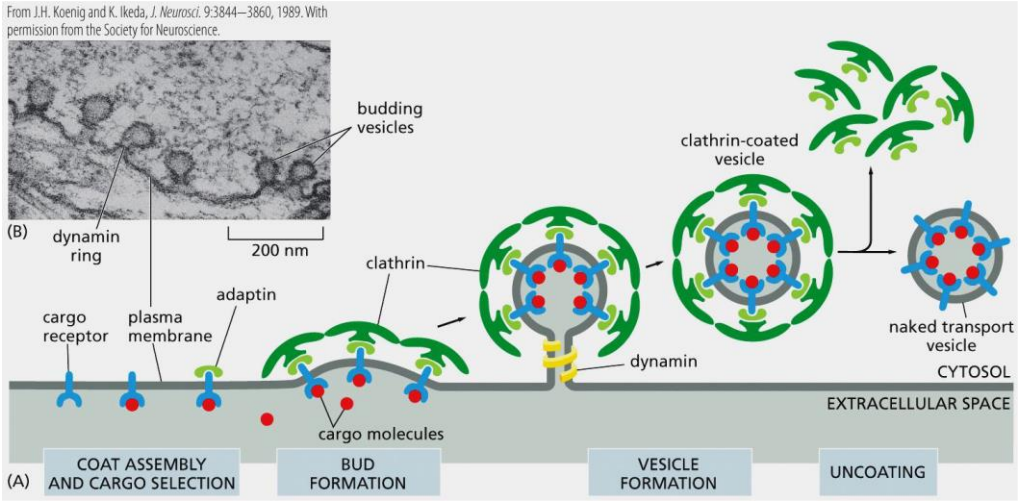
C) Protein X containing the mitochondrial localization signal will enter by binding to a receptor associated to a translocator and then subsequently binding to a second receptor that will allow the protein to become unfolded and enter the matrix

D) Protein X containing the mitochondrial localization signal will interact with an SRP receptor associated to a translocator which will bring the protein through the membrane until a stop sequence is reached, after which the protein will remain embedded in the mitochondrial outer membrane as a single-pass transmembrane protein

PRE-MIDTERM 2 – CHAPTER 15 – INTRACELLULAR COMPARTMENTS AND PROTEIN TRANSPORT

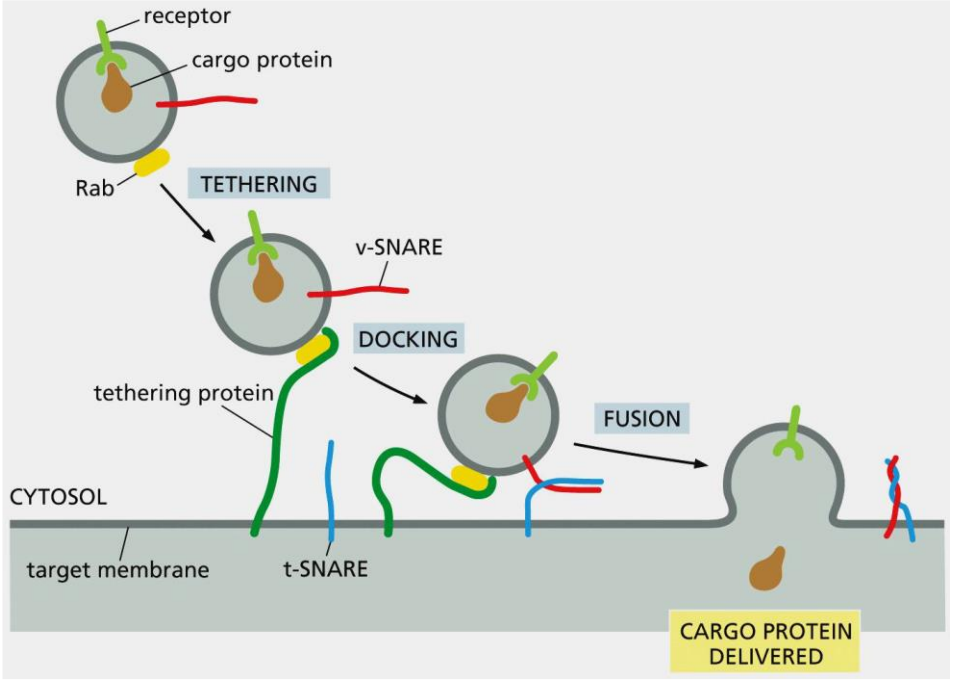
- Proteins may be transported through the cell via vesicles through
  - The inward endocytic pathway, where extracellular molecules are ingested and ultimately deliver to lysosomes
  - The outward secretory pathway, where proteins are transported from the ER to the Golgi, to the PM or lysosomes
- Vesicles are formed when cargo that is bound to cargo receptors are captured by adaptins which bind clathrin which forms a basketlike cage that helps shape the membrane into vesicles
- Dynamin proteins assemble around the neck of the budding vesicles and hydrolyze their GTP which pinches off the vesicle after which the clathrin-adaptin complex is removed





PRE-MIDTERM 2 – CHAPTER 15 – INTRACELLULAR COMPARTMENTS AND PROTEIN TRANSPORT

- Rab proteins, located on the surface of the vesicle containing the cargo protein will bind to a filamentous tethering protein, allowing the vesicle to dock on the target membrane
- A v-snare located on the vesicle will bind to its complementary t-snare located on the target membrane and together, these SNARE proteins catalyze the fusion of both membranes, allowing the cargo protein to be delivered

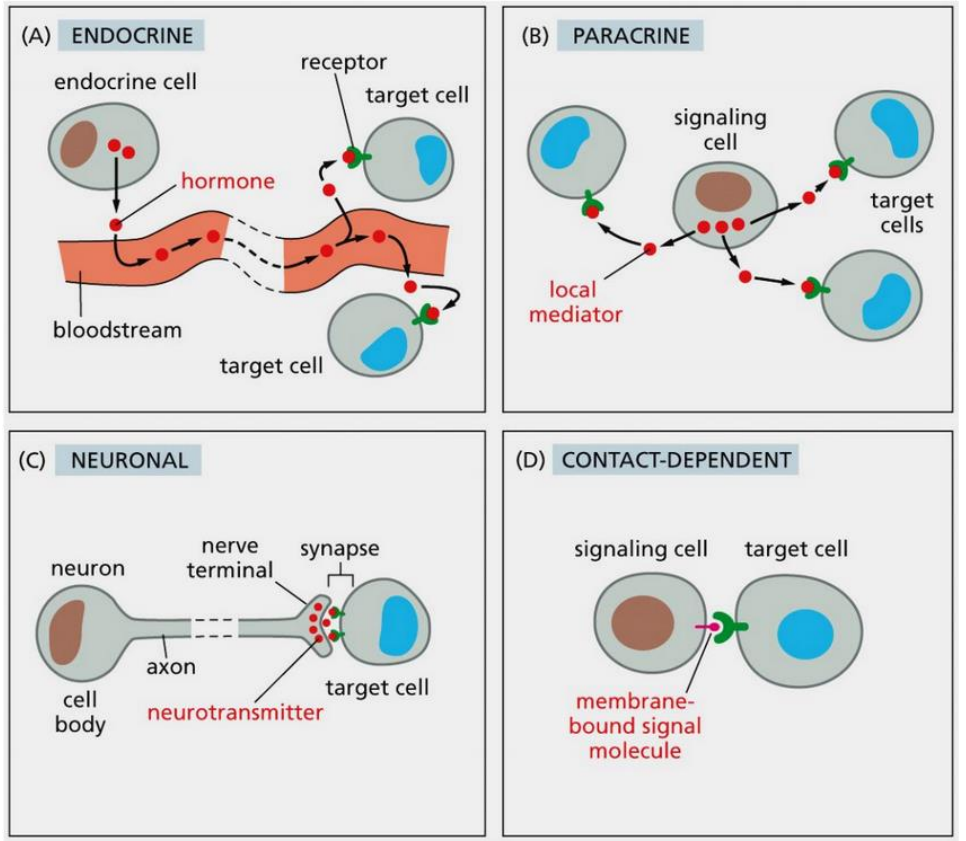


MIDTERM 2 - SUMMARY

- Lipid Bilayer Permeability
- Types of Transporters & Channels
- Action Potentials, Propagation of signals in the neuron and response in post-synaptic cells (Last few slides of Chapter 12)
- Glycolysis & Gluconeogenesis + Regulation
- TCA Cycle
- Oxidative Phosphorylation and the ETC
- Light & Dark Reactions in Chloroplasts
- Protein Transport into various compartments
- Vesicle Formation & Docking

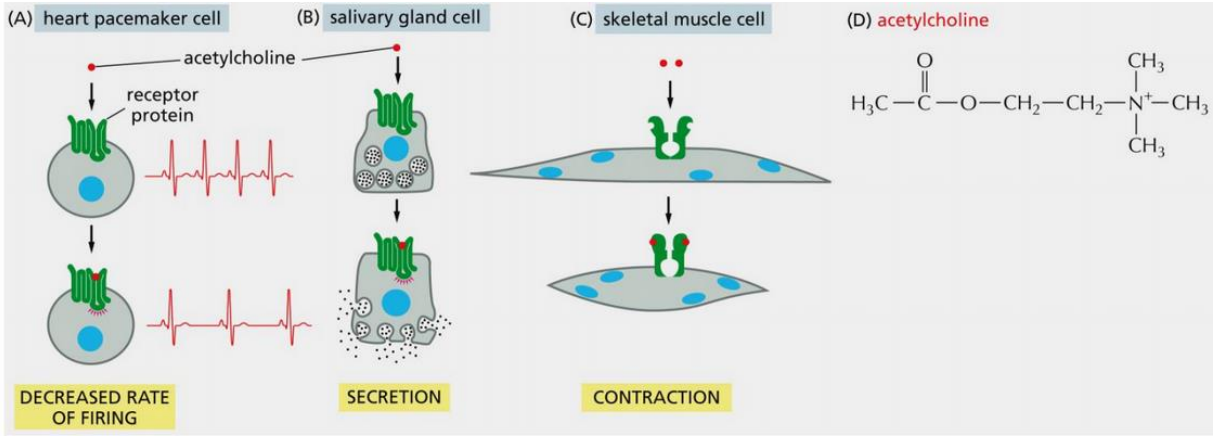
POST-MIDTERM 2 – CHAPTER 16 – CELL SIGNALING

- Different types of signaling includes:
  - Endocrine: Involves the use of hormones that are secreted into the bloodstream and distributed to the rest of the body
  - Paracrine: Signals are released by a cell to act on nearby neighboring cells
  - Autocrine: Cell responds to a signal it produces
  - Neuronal: Electrical signaling that is converted into a chemical signal (neurotransmitter) at the axon terminal of a nerve cell prior to interacting with its target cell
  - Contact-Dependent: Signaling molecule found on the surface of one cell interacts with a receptor protein on an adjacent cell producing a signal



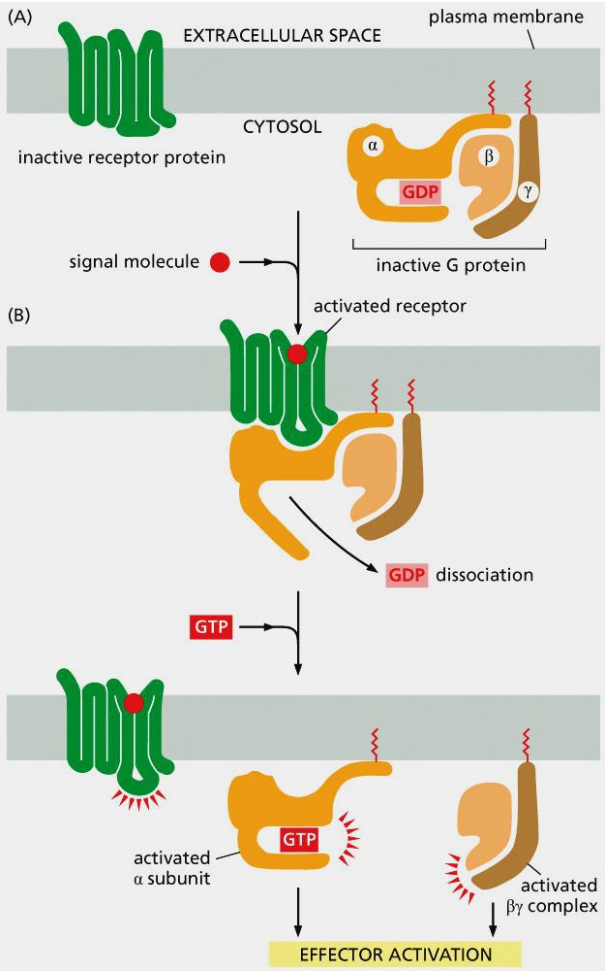
POST-MIDTERM 2 – CHAPTER 16 – CELL SIGNALING

- Role of acetylcholine (ACh) on various target cells
  - Heart pacemaker cells: Decreases the rate of action potential production, thus decreasing heart rate
  - Salivary gland cells: Promotes secretion of saliva components
  - Skeletal muscle cells: Causes muscle contraction via a different receptor protein
- What does this suggest?
  - ACh is not the message. Rather it is the way the signal is received (type of receptor) and the way the signal is interpreted that will ultimately determine the response/change in behavior of the cell



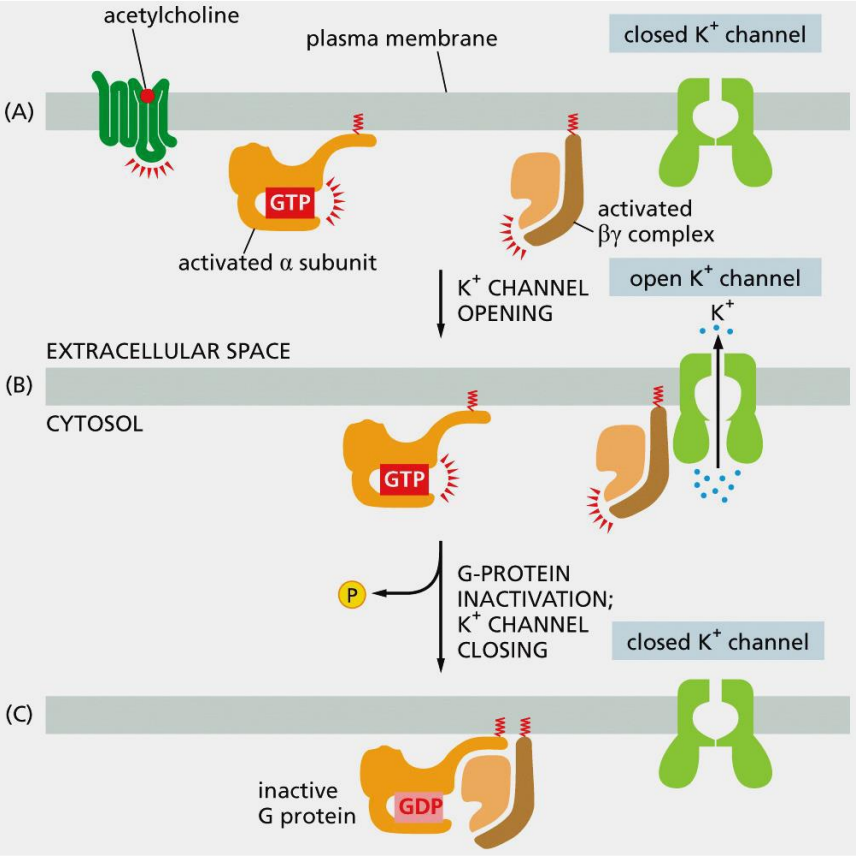
POST-MIDTERM 2 – CHAPTER 16 – CELL SIGNALING

- G-Protein-Coupled Receptors (GPCRs) possess a 7 α-helix transmembrane structure
- In heart pacemaker cells, when acetylcholine binds to the receptor, this causes a conformational change allowing it to bind to the inactive G protein
- The binding will cause a conformational change in the G protein, allowing it to exchange GDP for GTP, activating the protein
- The α-subunit will dissociate from the βγ-complex and both will perform their respective functions



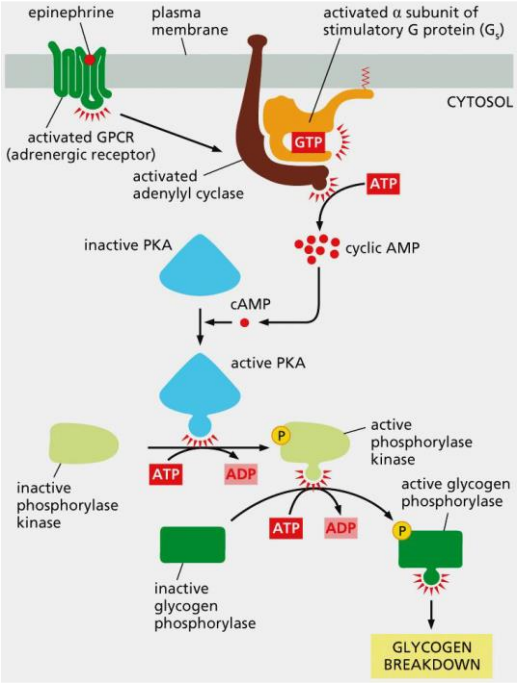
POST-MIDTERM 2 – CHAPTER 16 – CELL SIGNALING

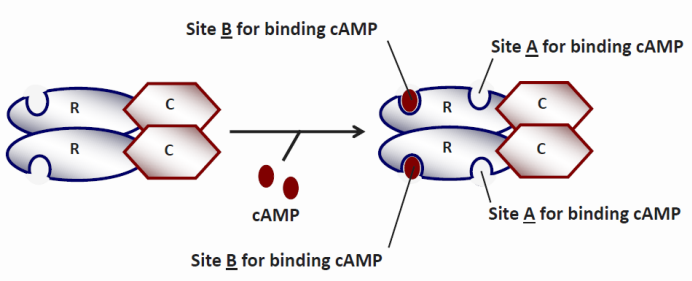
- The βγ-complex will open K^+ channels in the heart pacemaker cell, which will cause an efflux of potassium ions, making the membrane potential more negative (meaning that a greater signal is required to create an action potential)
- Less action potentials slows the heart rate
- The α-subunit will interact with its target protein and eventually hydrolyze its bound GTP, inactivating the subunit, which causes it to re-associate with the βγ-complex, rendering the G protein as a whole inactive
  - This closes the K^+ channels



POST-MIDTERM 2 – CHAPTER 16 – CELL SIGNALING

- In skeletal muscles, epinephrine (adrenaline) will cause a conformational change in the GPCR which will cause a conformational change to the α-subunit of its associated G protein
- This activates adenylyl cyclase, an enzyme that converts ATP to cyclic AMP, an important signaling molecule which will activate protein kinase A by binding to its B sites and then A sites (releasing the catalytic subunit)
- The catalytic portion of PKA will activate a phosphorylase kinase which activates glycogen phosphorylase, the enzyme responsible for glycogen breakdown





CELL SIGNALING QUESTION

Which of the following statements is TRUE about glycogen breakdown in skeletal muscle cells?

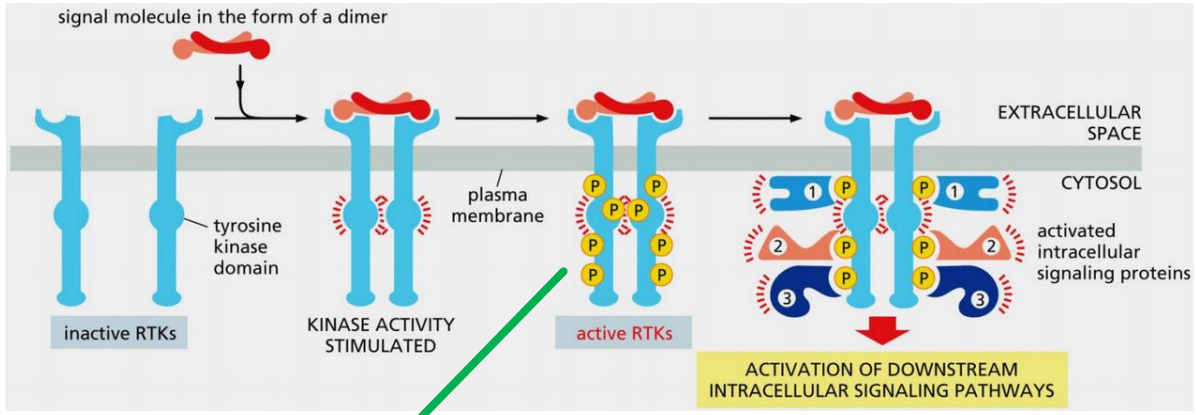
A) If the GPCR was mutated, but a hyperactive (always active) form of phosphorylase kinase was added to the cell, glycogen breakdown will constantly occur regardless of the presence of epinephrine

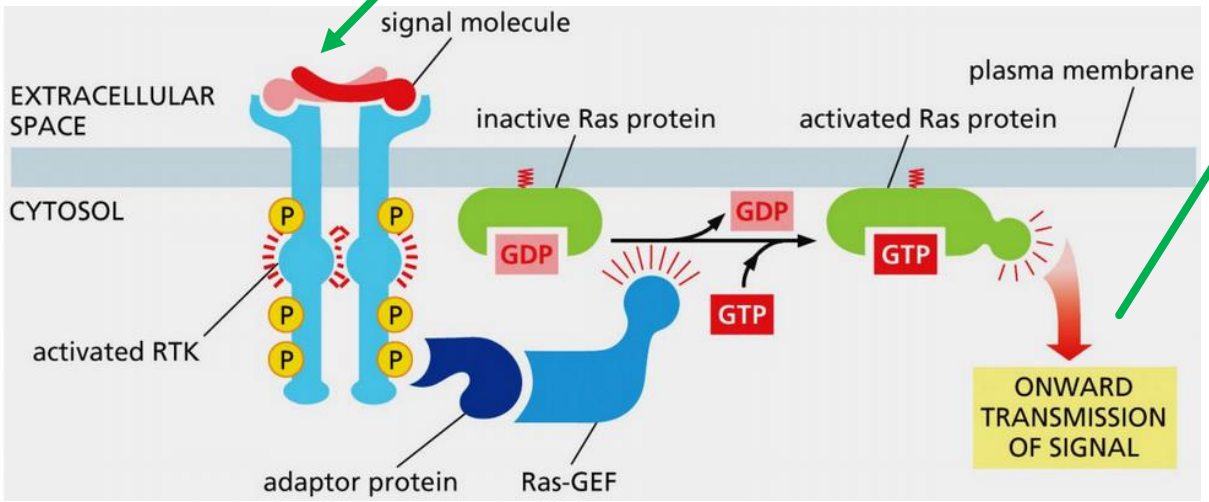
B) If PKA was mutated, but there was a constant and abundant influx of epinephrine, glycogen breakdown will constantly occur

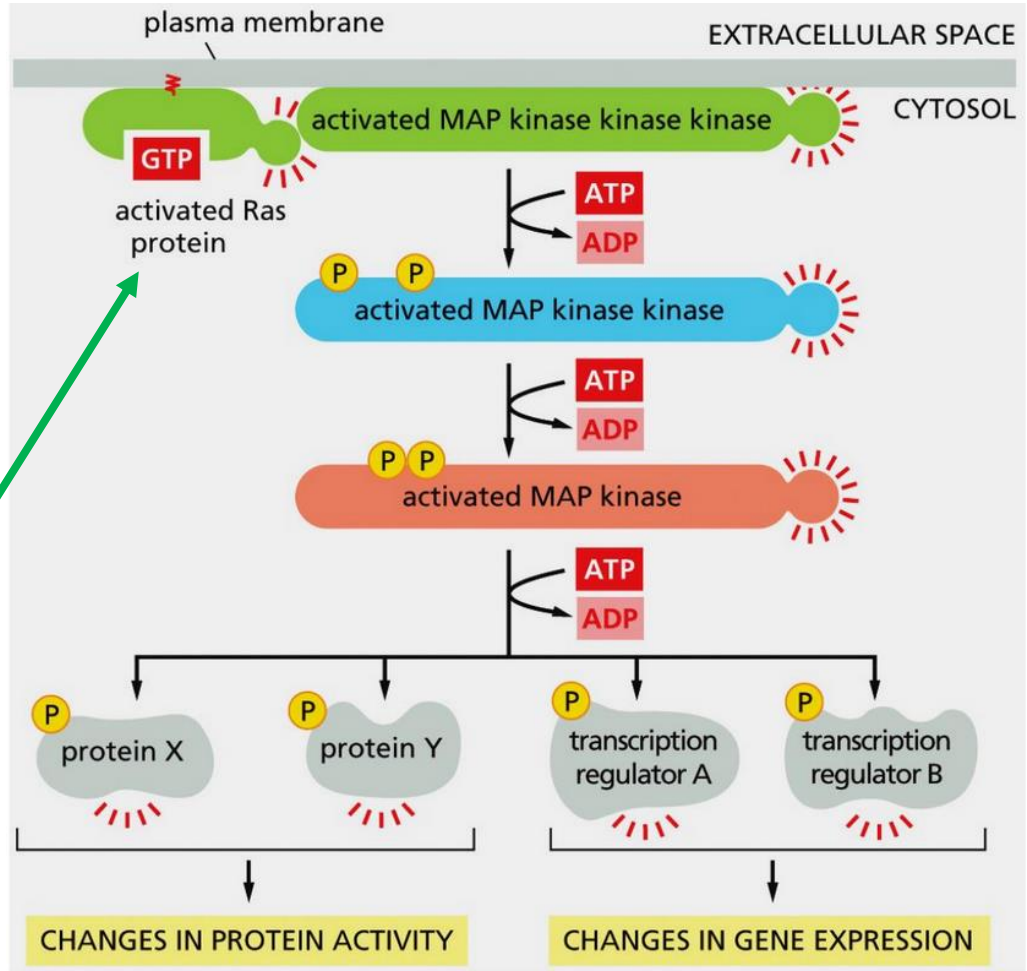
C) If PKA was mutated, there would be an excessive buildup of glucose in the cell

D) If the GPCR was mutated, but a hyperactive (always active) form of phosphorylase kinase was added to the cell, there would be an excessive buildup of glycogen in the cell

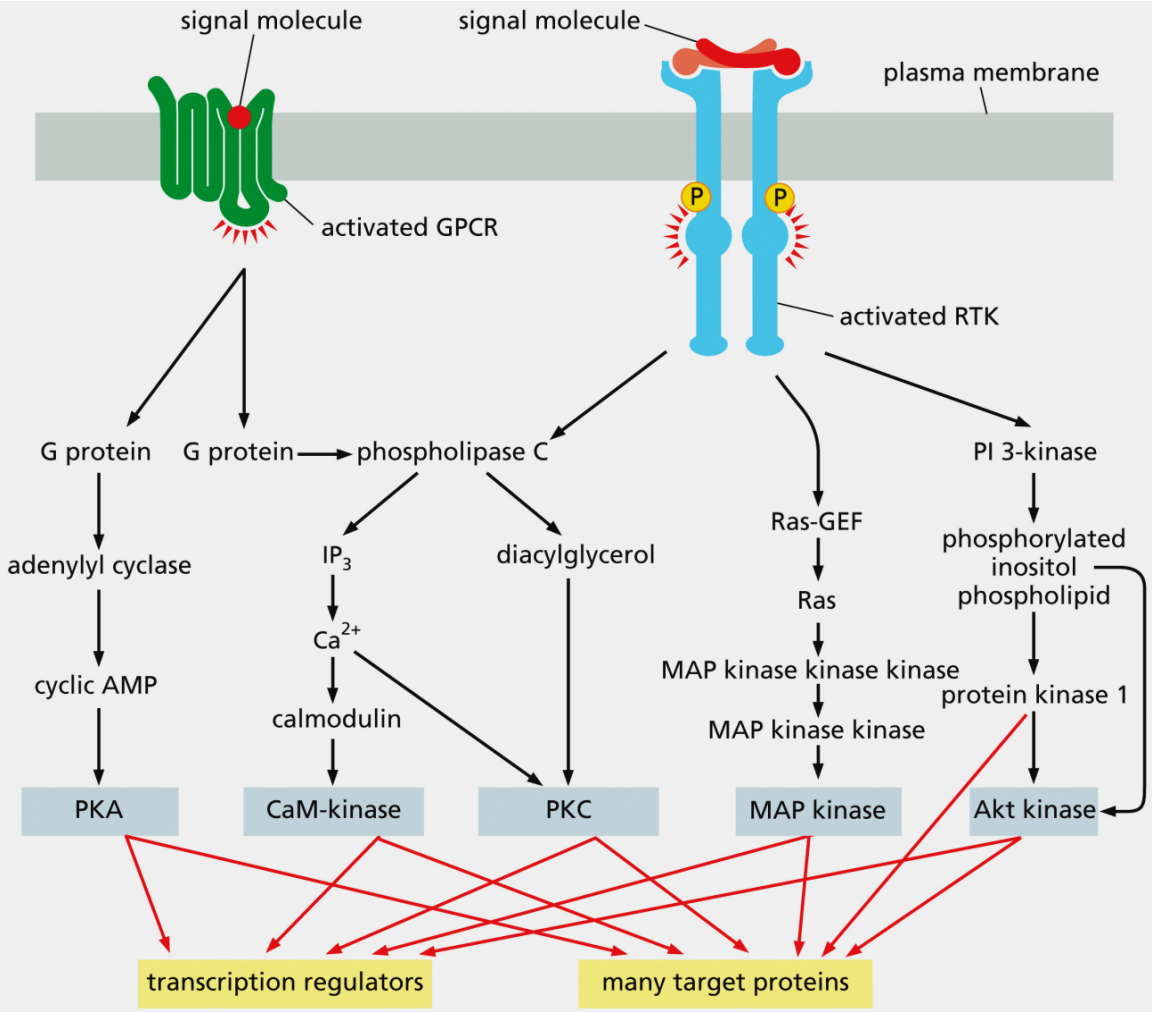
POST-MIDTERM 2 – CHAPTER 16 – CELL SIGNALING





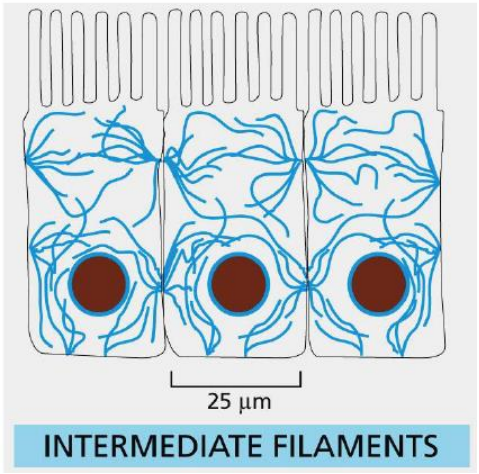


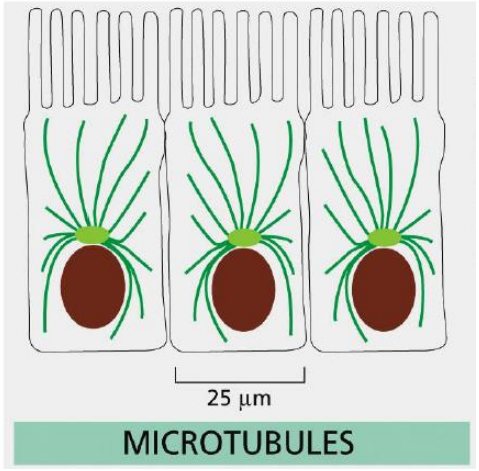
POST-MIDTERM 2 – CHAPTER 16 – CELL SIGNALING

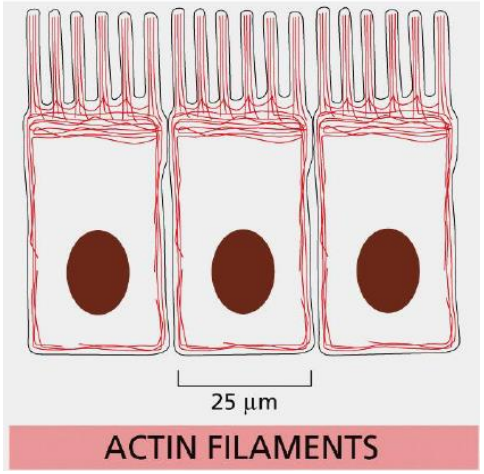


POST-MIDTERM 2 – CHAPTER 17 – CYTOSKELETON

- Three types of cytoskeletal filaments
  - **Intermediate filaments** have a diameter of 10nm and are able to withstand mechanical stress and are able to form a meshwork under the inner nuclear membrane known as the nuclear lamina
  - **Microtubules** have a diameter of 25nm and are able to rapidly assemble and disassemble (dynamic instability). They can create a system of tracks along which vesicles and organelles are transported. During mitosis, they form the mitotic spindle which is involved in segregating chromosomes during anaphase.
  - **Actin filaments (microfilaments)** have a diameter of 7 nm and are crucial for cell movement (crawling, phagocytosis & cell division)
- Intermediate filaments are linked to microtubules & actin filaments with the accessory protein **Plectin**

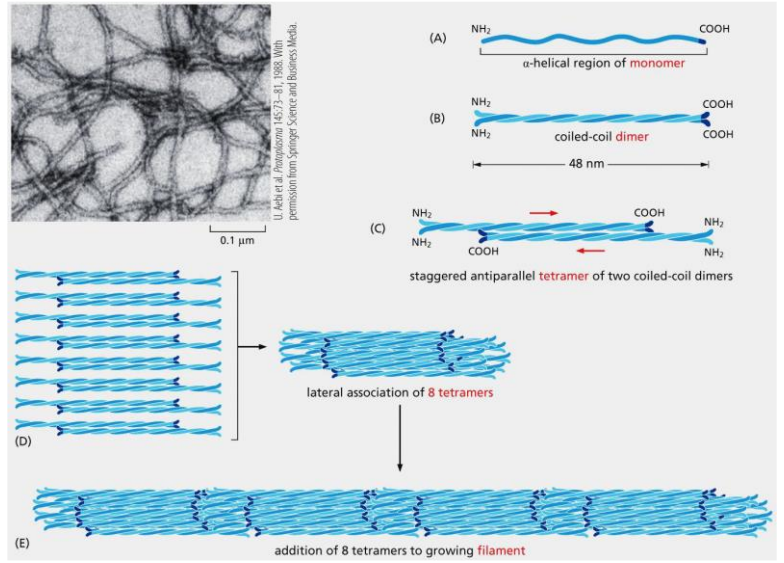


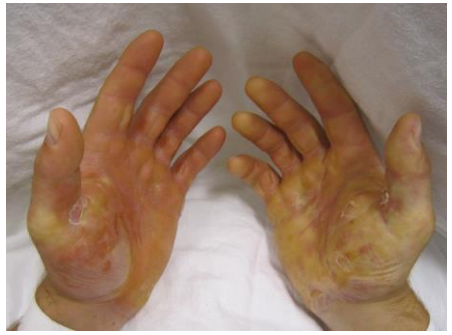




POST-MIDTERM 2 – CHAPTER 17 – CYTOSKELETON

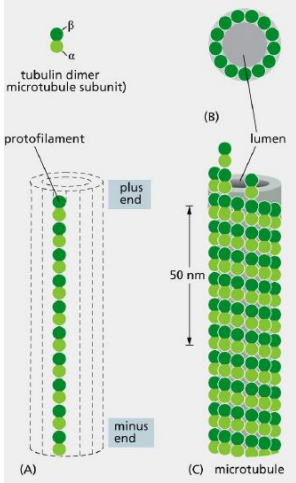
- Intermediate filaments are made up of long twisted strands of proteins
  - A monomer consists of an α-helical central rod domain
  - An α coiled-coiled dimer is formed when two monomers associate
  - Two antiparallel dimers will form a tetramer
  - 8 tetramers can pack together and associate to make the final rope-like intermediate filament
- They can be divided into four major classes: (cytoplasmic) keratin filaments, vimentin, & vimentin-related filaments neurofilaments and nuclear lamins (the latter being the only non-cytoplasmic filaments)
  - Epidermolysis bullosa simplex is a rare human genetic disease that makes the skin more prone to blistering since the keratin filament network in the skin is disrupted
  - Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease caused by an abnormal accumulation of neurofilaments
  - Progeria, a premature aging disorder, is caused by a defect in a nuclear lamin

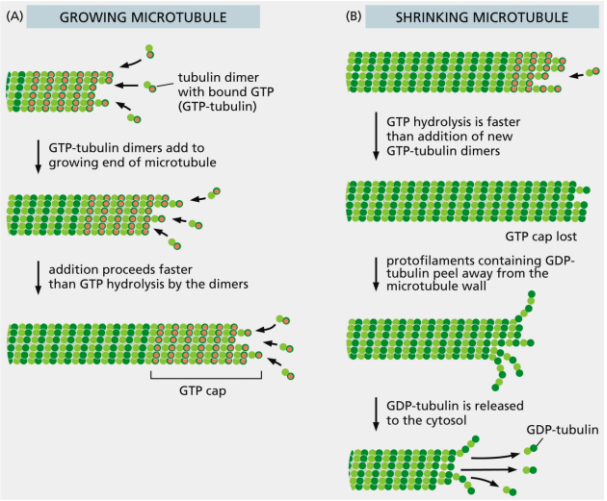




POST-MIDTERM 2 – CHAPTER 17 – CYTOSKELETON

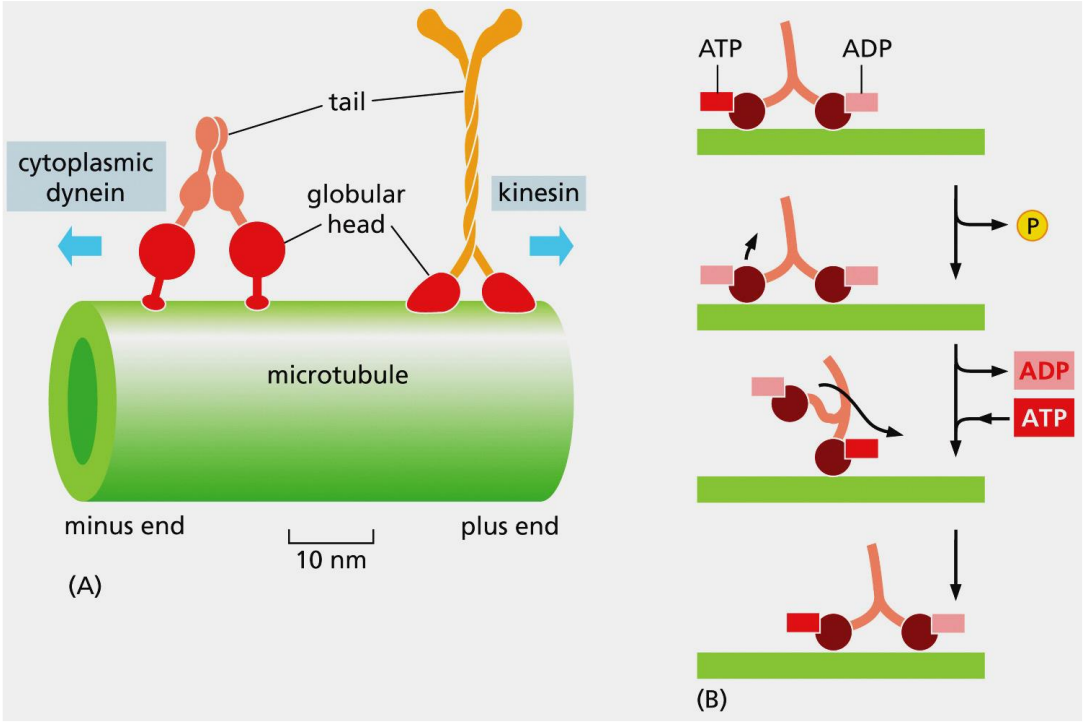
- Microtubules typically grow out from an organizing center such as the centrosome, the two poles of a mitotic spindle or the basal body of a cilium
- Microtubules consist of many αβ dimer containing protofilaments that are aligned together in the same orientation. This gives the microtubule a polarity with the α-end being the minus end and the β-end being the plus end (the fast-growing end).
  - The polarity is important for the assembly of microtubules and guiding the directional transport of vesicles and organelles
  - Capping proteins can help stabilize the plus ends of microtubules
  - Typically the minus ends are protected by the organizing centers
  - Microtubules will grow from the plus end when GTP-tubulin dimers are added faster than GTP hydrolysis occurs
  - When the opposite occurs, there will be no GTP cap and the GDP-tubulin dimers will peel away, causing the microtubules to shrink





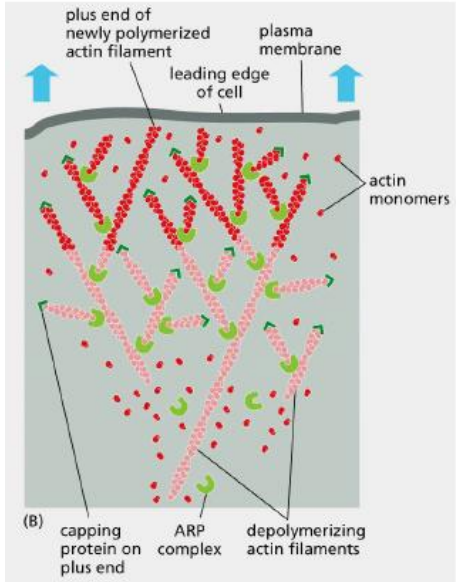
POST-MIDTERM 2 – CHAPTER 17 – CYTOSKELETON

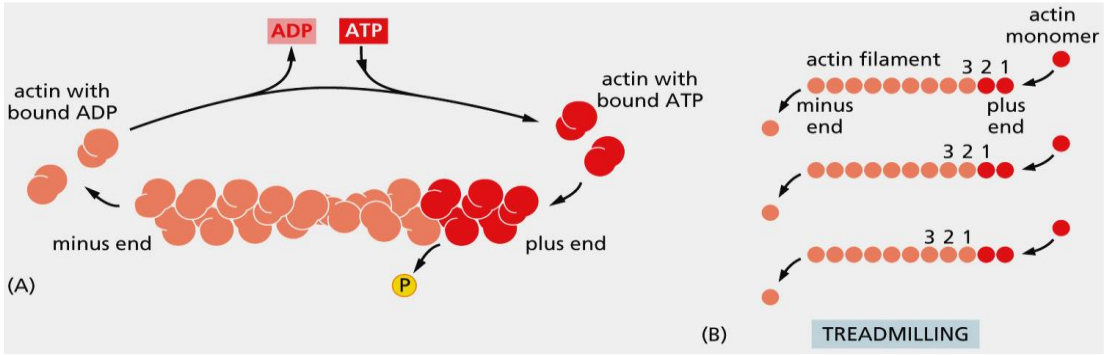
- Kinesins are microtubule motor proteins that move towards the plus end (towards the cell exterior)
- Dyneins are microtubule motor proteins that move towards the minus end (towards the cell interior)
  - Both contain **two globular heads that hydrolyze ATP and a single tail that interacts with the cargo**
  - They move using a "walking" hand-over-hand movement, using ATP binding & hydrolysis to move an individual head at a time
- Microtubules in a cilium create a power stroke motion to move
- Microtubules in a flagellum use repetitive wavelike motions to move



POST-MIDTERM 2 – CHAPTER 17 – CYTOSKELETON

- Actin filaments can associate in different structures:
  - Microvilli
  - Contractile bundles in the cytoplasm
  - Filopodia: actin protrusion at the leading edge pushes the plasma membrane forward and the rear end contracts after the cell anchors to a surface, moving the cell forward
  - Contractile ring during cell division
- Just like microtubules, actin filaments have a plus and minus end (polarity)
  - They can undergo **treadmilling** which is when the addition of ATP-bound actin is added to the plus end at the same rate as ADP-bound actin is lost from the minus end





CYTOSKELETAL FILAMENTS QUESTION

Which of the following about intermediate filaments is FALSE?

A) They have a plus & minus end just like actin filaments & microtubules

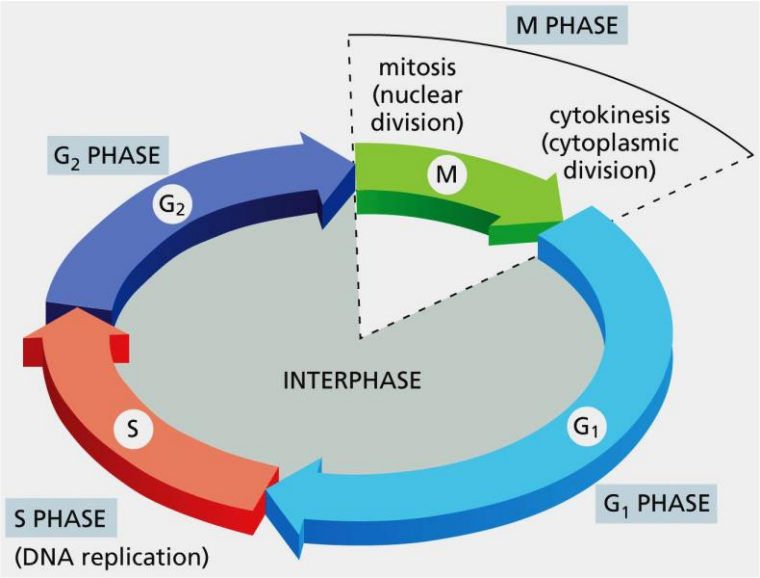
B) Certain mutations in various types of intermediate filaments can lead to progeria, ALS & epidermolysis bullosa simplex

C) They can form the nuclear lamina and withstand mechanical stress

D) They are called intermediate because their diameter is between that of actin & microtubules

POST-MIDTERM 2 – CHAPTER 18 – THE CELL-DIVISION CYCLE

- The four phases of the eukaryotic cell cycle are the following:
  - G_1 phase: The cell ensures its conditions are suitable for DNA replication
  - S phase: DNA replication occurs
  - G_2 phase: The cell ensures its conditions are suitable for mitotic division
  - M phase: Mitosis occurs
- Before entering the next phase, there is a checkpoint (part of the cell-cycle control system) that ensures that they key processes in the prior phase have occurred properly before moving on to the next phase
  - These checkpoint can halt the cell from progressing if the conditions are unfavorable
  - This control system depends on **cyclin-dependent protein kinases (Cdks)**



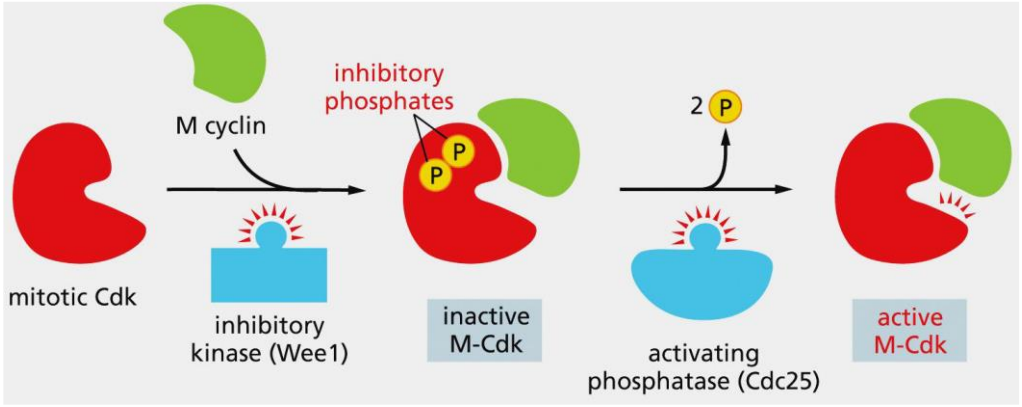
POST-MIDTERM 2 – CHAPTER 18 – THE CELL-DIVISION CYCLE

- Since Cdks depend on cyclin concentration, the change in cyclin concentration & Cdk activity are responsible for controlling entry to the next phase
- Some Cdks can be rendered inactive via the degradation of their associated cyclins by ubiquitylation (which targets them for destruction in proteasomes)
- Others can be rendered inactive by p27, an inhibitory protein
- M-Cdk needs Cdc25 (a phosphatase) which removes the inhibitory phosphate groups that are associated to the complex because of Wee1 in order to be activated
- Personally, I would learn which cyclins associate with which Cdks and what checkpoints they play a role in

TABLE 18–2 THE MAJOR CYCLINS AND CDKS OF VERTEBRATES

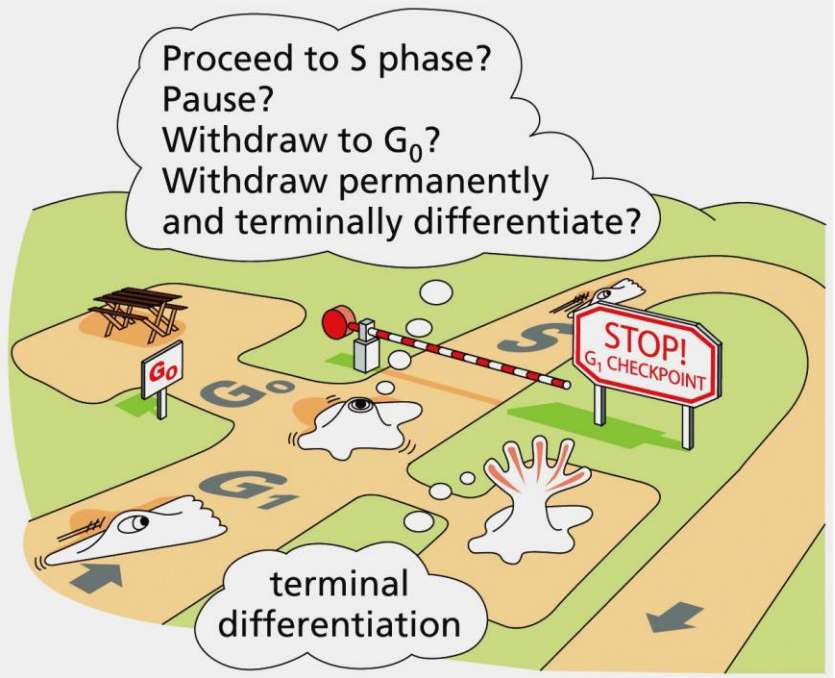
Cyclin–Cdk Complex	Cyclin	Cdk Partner
G_1-Cdk	cyclin D*	Cdk4, Cdk6
G_1/S-Cdk	cyclin E	Cdk2
S-Cdk	cyclin A	Cdk2
M-Cdk	cyclin B	Cdk1

*There are three forms of cyclin D in mammals (cyclins D1, D2, and D3).



POST-MIDTERM 2 – CHAPTER 18 – THE CELL-DIVISION CYCLE

- The G_1/S checkpoint will evaluate the size of the cell, as well as its environmental conditions (intra/extracellular signals) and then commit the cell to:
  - Proceed to S phase if all the conditions are favorable
    - Ex: Mitogens will activate an intracellular signaling pathway that will inactivate the Rb protein which will activate the transcription of genes required for entry to S phase
  - Pause temporarily until conditions are favorable
    - Ex: Damaged DNA will activate p53 which will transcribe & translate p21, which will render the S-Cdk inactive until DNA is repaired
  - Withdraw from the cell cycle (enter G_0) temporarily
    - The cell-cycle control system can be reassembled
  - Withdraw from the cell cycle permanently if cells have been fully differentiated (ex: nerve and muscle cells)
    - The cell-cycle control system is completely dismantled



G_1 VS G_0 QUESTION

What is the main molecular difference when a cell is arrested in G_1 or in G_0?

A) In G_0, a cell that has been arrested has not replicated its DNA. Thus, it has half the DNA of a cell arrested in G_1

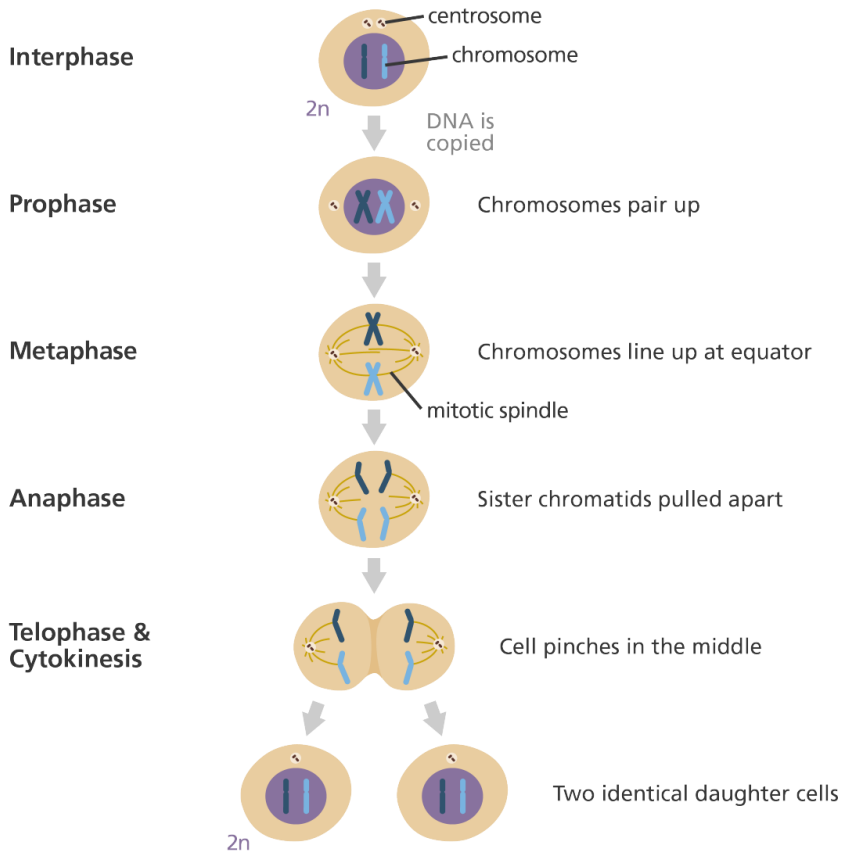
B) In G_0, not all the Cdks & cyclins are present since the cell-cycle control system has been partially dismantled

C) Nothing. A cell becomes arrested simply because it lacks the mitogens that would normally turn on cell signaling pathways that would allow the cell to re-enter the cell cycle

D) There is no molecular difference. Rather, the difference lies in how long the cell remains paused in that phase. Cells are paused for much longer in G_0 than only being temporarily paused in G_1

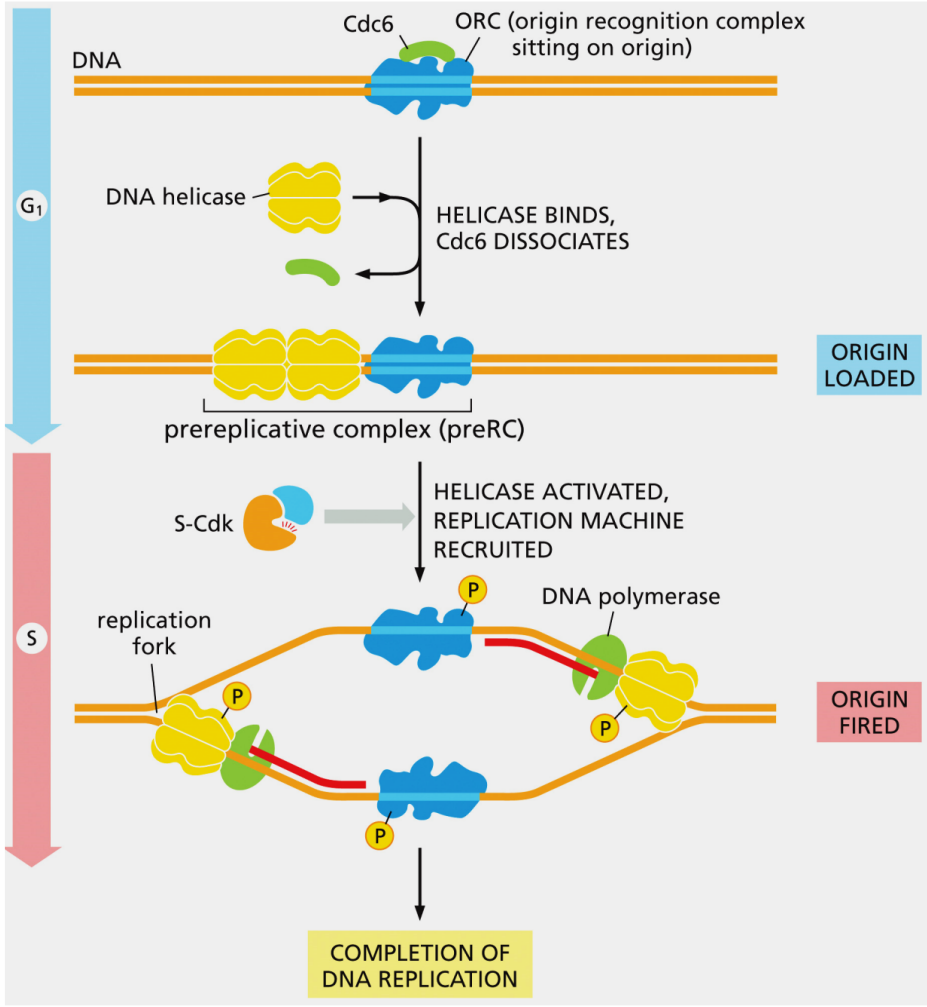
POST-MIDTERM 2 – CHAPTER 18 – THE CELL-DIVISION CYCLE

- Interphase
  - Centrosome duplication at the start of S phase and is completed by the end of G_2
- The steps in mitosis (PPMAT)
  - Prophase: Chromosomes condense, mitotic spindle assembles
  - Prometaphase: Breakdown of nuclear envelope (phosphorylation of nuclear pore proteins & lamina), chromosomes attach to spindle microtubules via kinetochores
  - Metaphase: Chromosomes align at the metaphase plate, midway between the poles
  - Anaphase: Sister chromatids are pulled apart to their respective poles
    - The APC/C triggers the cleavage of cohesins which hold the sister chromatids together via the ubiquitylation/destruction of securing which normally inhibits separase, the enzyme responsible for cleaving cohesin
  - Telophase: Chromosomes arrive at their respective poles, nuclear envelope reassembles (dephosphorylation of nuclear pore proteins & lamina), assembly of contractile ring
    - Cytokinesis: Cytoplasm divided in two by a contractile ring of actin & myosin filaments, creating two daughter cells
    - In plant cells, the phragmoplast is responsible for cytokinesis by forming a new cell wall between the two cells



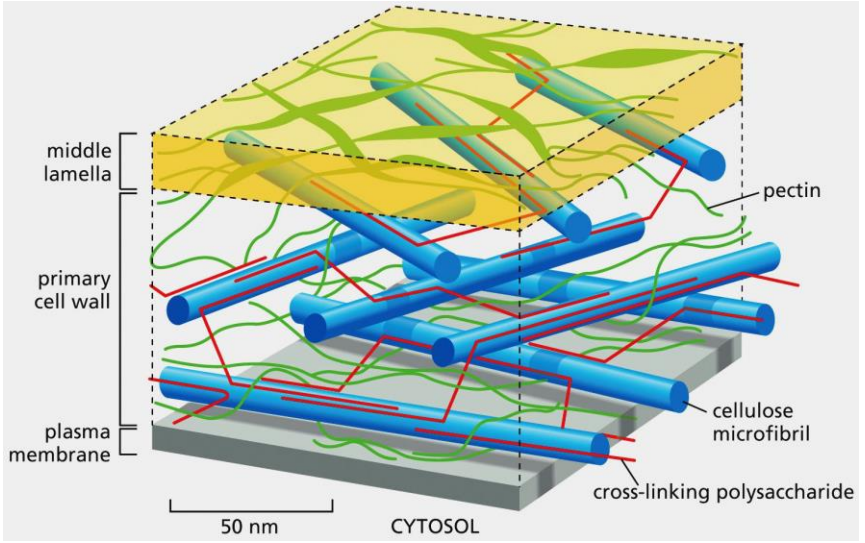
2n = diploid

POST-MIDTERM 2 – CHAPTER 18 – THE CELL-DIVISION CYCLE



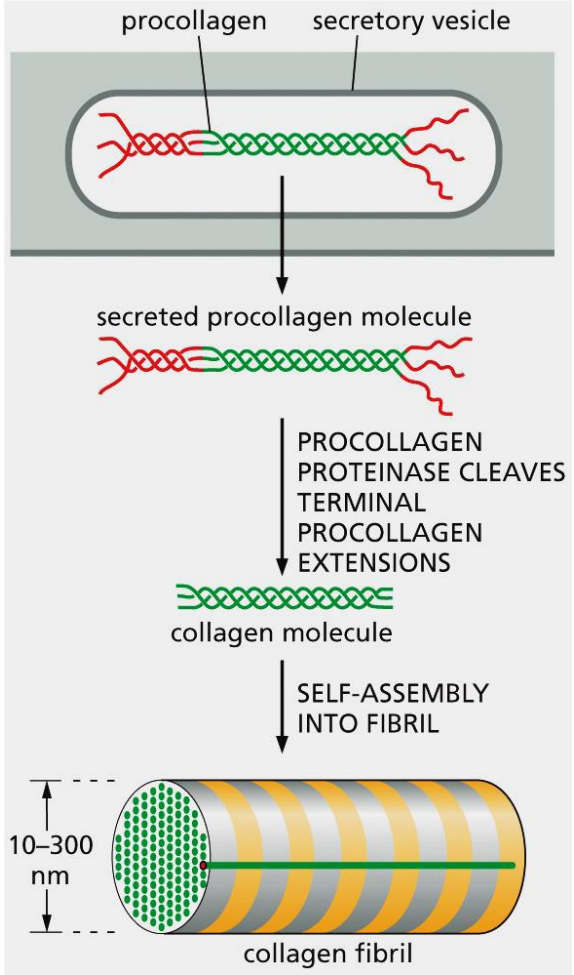
POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

- Cell walls in plant tissues are made up of two different polysaccharides:
  - Pectin is the main component in the outer layer (in the primary cell wall in a growing cell)
    - Pectin, as well as lignin, help resist compression through glycosaminoglycans (GAGs
  - Cellulose is the main component in the inner layer (in a more rigid, thicker secondary cell wall after cell growth has ceased)
    - Cellulose microfibrils are long chains of glucose linked via β1,4-linkages and provide tensile strength (resistance to break under tension)
    - The orientation of these microfibrils influence the direction in which plant cells grow
- Turgor pressure is the force that pushes the plasma membrane against the cell wall



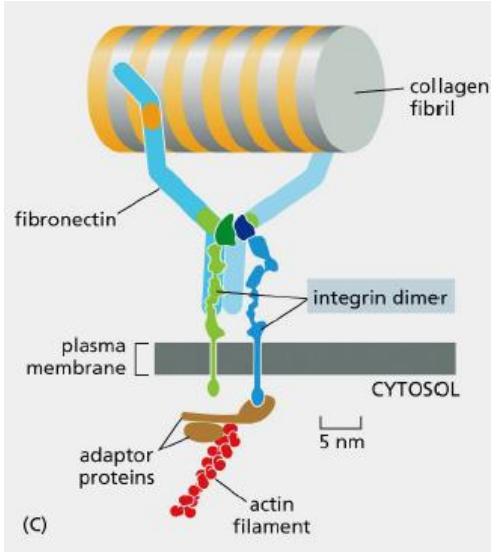
POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

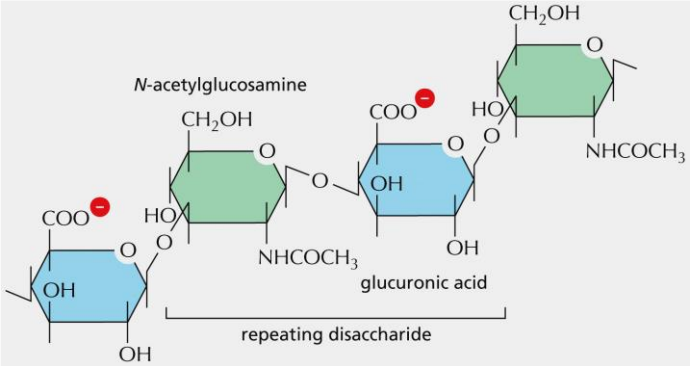
- Four major types of animal tissues:
  - Connective
    - Abundant extracellular matrix which carries the mechanical load (ex: bone matrix that consist almost entirely of collagen fibrils)
    - Procollagen contains unstructured peptides at both ends, preventing them from assembling inside skin, bone or other connective tissues
    - Procollagen is secreted by exocytosis and proteinases remove the terminal peptides; the molecules can self-assemble into fibrils
      - Incorrect collagen assembly via lack of proteinases or defects in procollagen can cause abnormally stretchable skin
  - Epithelial
  - Nervous
  - Muscular
    - Sparse extracellular matrix and cells carry the mechanical load themselves as they are directly joined to one-another (muscular, nervous & epithelial tissues)



POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

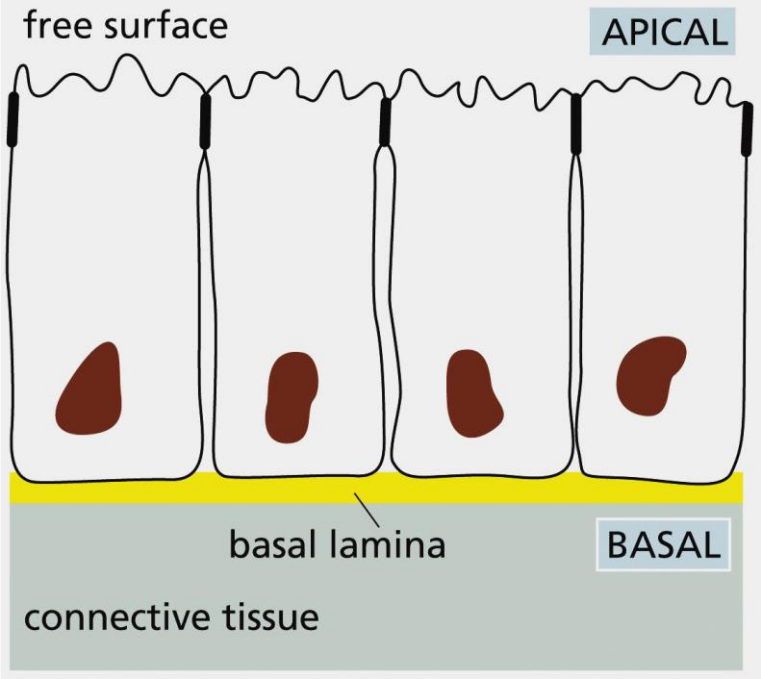
- Fibronectin proteins bind to collagen fibrils outside the cell and integrin proteins bind to the fibronectin and tether them to the actin cytoskeleton inside the cell via adaptor proteins
- Integrin proteins have two different subunits α & β which are inactive until they bind to fibronectin (extracellular matrix molecule) or the adaptor proteins (intracellular cytoskeleton)
- Glycosaminoglycans (GAGs) such as Hyaluronan, built from repeated disaccharide units help resist compression in the extracellular matrix of animal tissues
  - They contain many negative charges which allows them to adopt highly extended conformations, thus occupying a huge volume
  - When linked with proteins, they form proteoglycans which can regulate the passage of molecules through the extracellular medium, bind secreted growth factors that can act as signaling molecules and block or encourage cell migration through the matrix



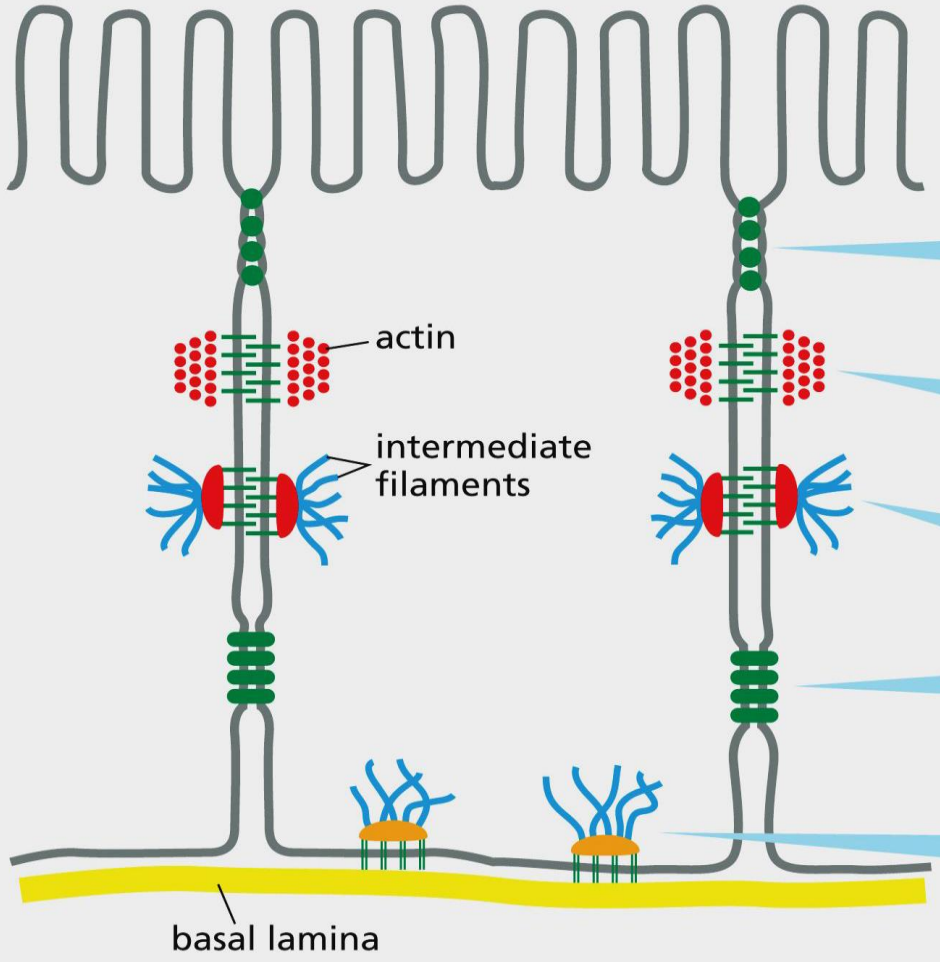


POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

- Various types of epithelial sheets
  - Simple epithelium (one cell thick)
    - Columnar
    - Cuboidal
    - Squamous
  - Many cells thick
    - Stratified
- Various functions of epithelia
  - Protective barrier (epithelial cells cover the external surface of the body and line all the body's internal cavities)
  - Secrete specialized products
  - Absorb nutrients
  - Detect signals



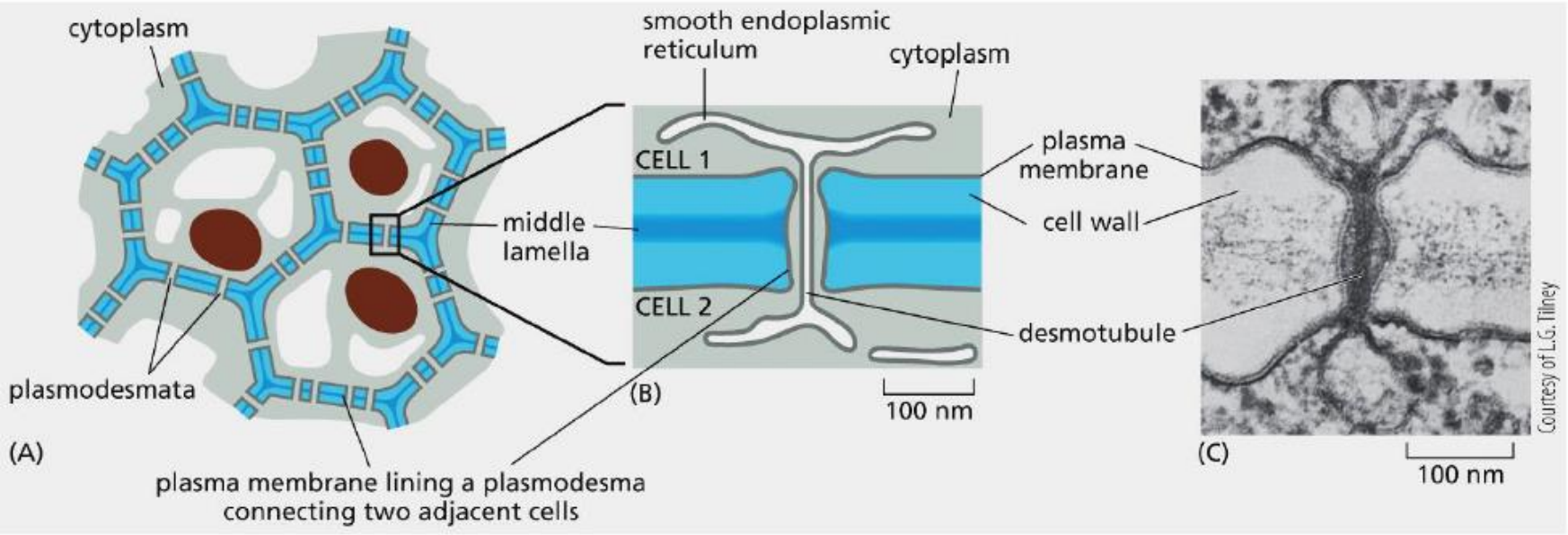
POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER



name	function
tight junction	seals neighboring cells together in an epithelial sheet to prevent leakage of extracellular molecules between them; helps polarize cells
adherens junction	joins an actin bundle in one cell to a similar bundle in a neighboring cell
desmosome	joins the intermediate filaments in one cell to those in a neighbor
gap junction	forms channels that allow small, intracellular, water-soluble molecules, including inorganic ions and metabolites, to pass from cell to cell
hemidesmosome	anchors intermediate filaments in a cell to the basal lamina

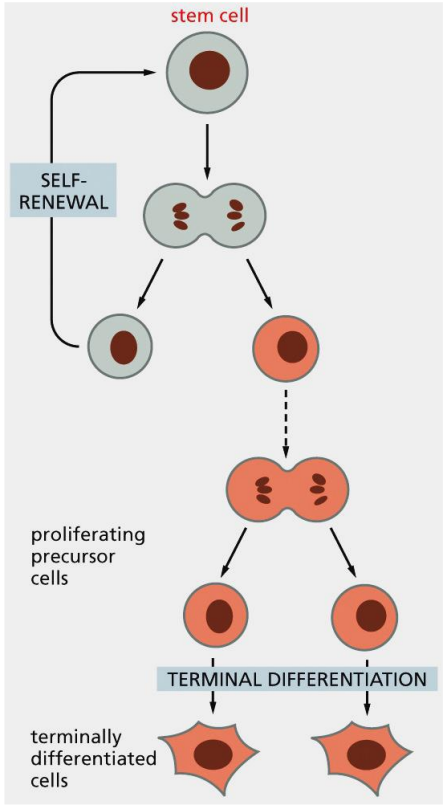
POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

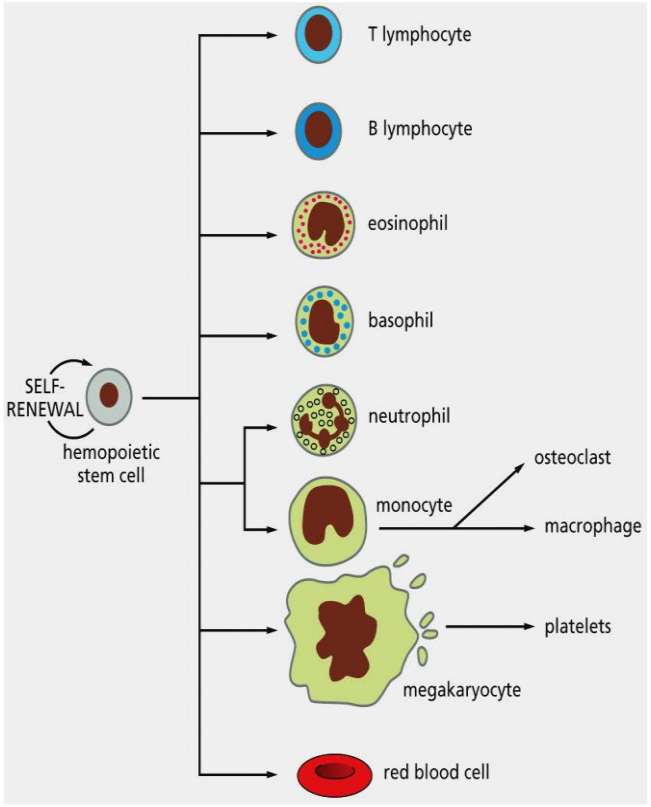
- In plant cells, plasmodesmata are cytoplasmic channels lined with plasma membrane that span the cell walls of two plant cells and allow both small & large molecules to pass from cell to cell in order to control transcription regulator proteins & regulatory RNAs which is crucial for plant development
- Plants lack the types of cell junctions in animal cells



POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

- How can an organism preserve the organization of a tissue?
  - Cell communication: Each specialized cell monitors for signals from other cells and adjusts its behavior accordingly
  - Selective cell adhesion: This keeps cells in their proper positions
  - Cell memory: Allows cells to preserve their differentiated character and pass this on to their progeny
- Stem cell division
  - Typically produces a stem cell and a cell that will ultimately become terminally differentiated and lose its ability to divide
  - The skin is a stratified epithelium that is renewed from stem cells in its basal layer
  - Likewise, a hemopoietic stem cell divides to make more stem cells and precursor cells that will differentiate into all the different types of blood cell types in our bodies using various extracellular signal molecules



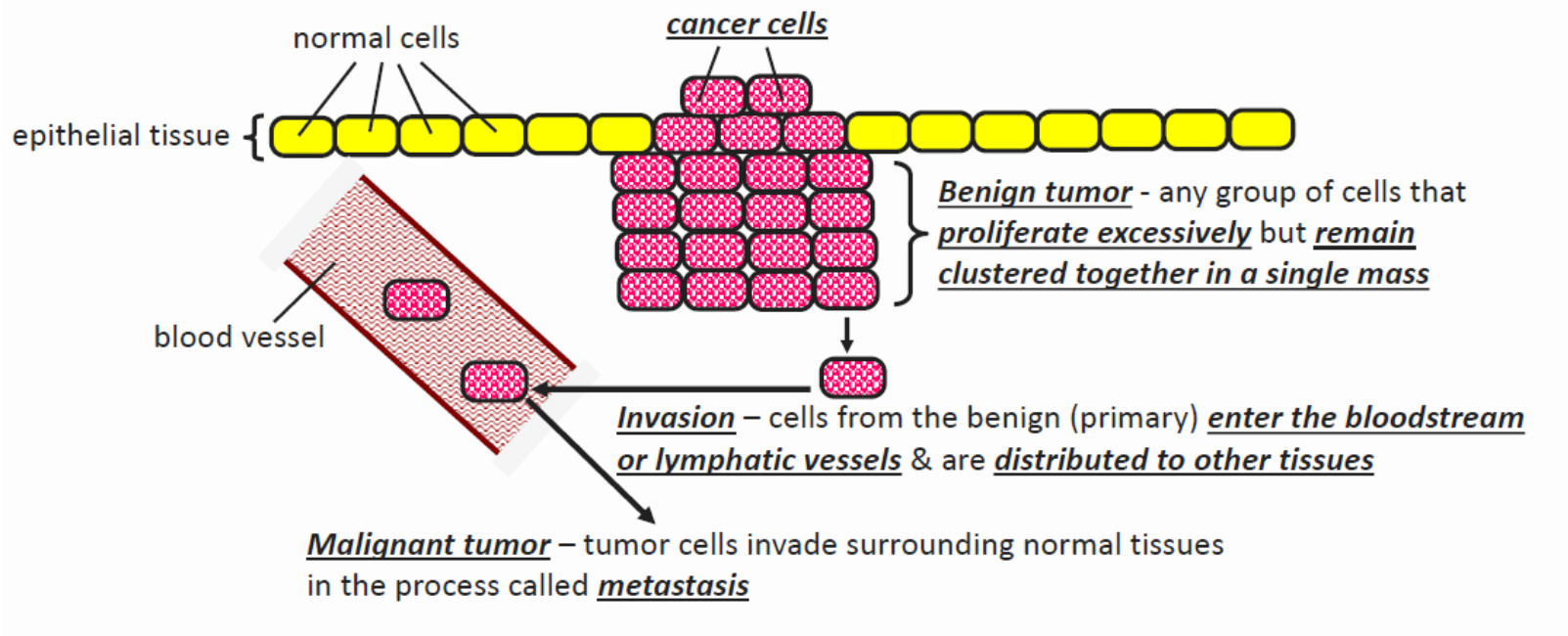


POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

- Mouse embryonic stem (ES) cells can be induced to differentiate into specific cell types in culture
  - This ability is known as **pluripotency:** cells that can give rise to all tissue and cell types
  - If exposed to the appropriate extracellular signal molecules, these cells can be induced to differentiate into specific cell types of interest
  - They can even form small organs known as organoids which is important in studying human development and genetic diseases
- Induced pluripotent stem (iPS) cells are human ES-like cells can be produced by reprogramming differentiated cells (such as fibroblasts) using **transcription regulator proteins** such as **Oct4, Sox2 & Klf4**

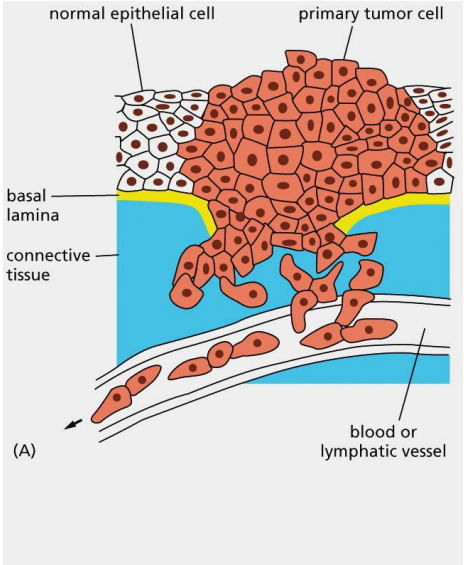
POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

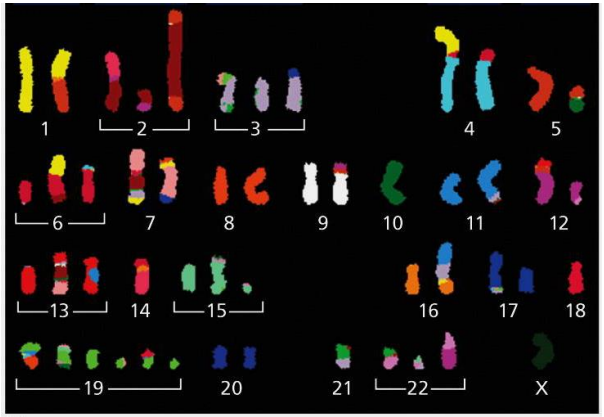
- The key abnormality that leads to the development of cancer is arguably the **continual excessive (unregulated) proliferation & inappropriate migration of cancer cells**



POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

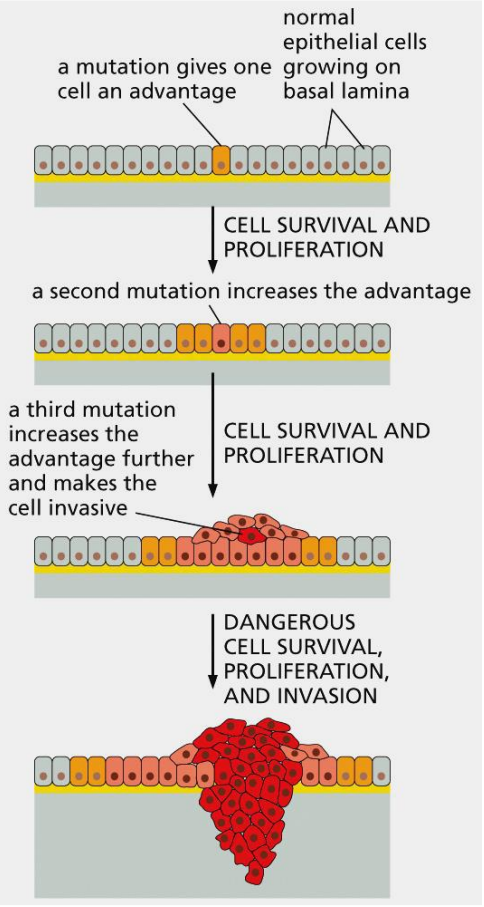
- Cancers can give rise to a secondary tumor by invading surrounding tissues or even metastasizing to distant sites by crossing the basal lamina, migrating through connective tissue and entering blood or lymphatic vessels, exit, settle, survive & proliferate in a new location
- Cancer incidence increases dramatically with age since cells are continuously experiencing spontaneous mutations, these mutations will accumulate over time and increase the chance that a cell will become cancerous
- Cancer can cause genetic instability by having an abnormal amount of chromosomes, leading to segregation errors





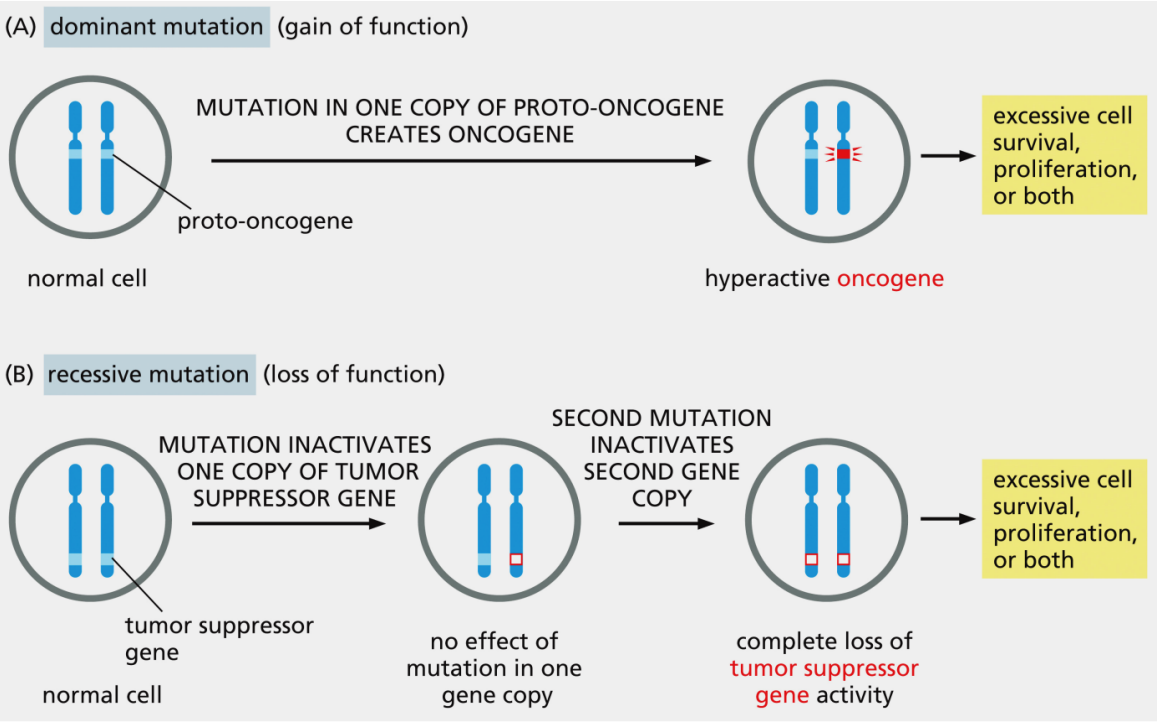
POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

- Distinguishing characteristics
  - Cancer cells do not require growth, division & survival signals in order to perform these tasks
  - Cancer cells can survive stress levels that would normally lead to apoptosis is healthy cells
  - Cancers can divide indefinitely
  - Cancer cells are genetically unstable, with an increased mutation rate & an abnormal amount of chromosomes
  - Cancer cells lack adhesion molecules, making them abnormally invasive especially since they secrete proteases that digest the basal lamina
  - Cancer cells generate most of their ATP by glycolysis since large tumors are typically oxygen-deprived
  - All of these are caused by mutations in key genes/proteins (Ras, p53, telomerase…)



POST-MIDTERM 2 – CHAPTER 20 – CELL COMMUNITIES: TISSUES, STEM CELLS, AND CANCER

- Proto-oncogenes are genes that, if mutated, will gain a function that can drive a cell towards cancer (ex: uncontrollable proliferation)
- Tumor suppressor genes are genes that, if mutated, can drive a cell towards cancer (ex: inability to perform apoptosis)
  - Both copies of the gene must be lost in order to eliminate the function



CANCER QUESTION

Which of the following is arguably the MOST significant mutation that can cause a cell to become cancerous?

A) Mutation that caused the formation of an additional pair of chromosome 4

B) Inability to produce clathrin in an epithelial cell, making the cell more loosely bound to its normal counterparts

C) A complete loss of function (deletion) of an important tumor suppressor gene in the paternal chromosome

D) A mutation in the p53 gene, preventing a cell to perform apoptosis or control cell proliferation

FINAL SUMMARY

- Types of signaling
- Key signaling molecules involving GPCR & RTKs
- Types and function of different cellular filaments
- Muscle contraction (non-discussed; Last 10 slides of Chapter 17)
- Various steps of mitosis
- What occurs at specific checkpoints
- Types of animal tissues
- Types & Function of cell junctions
- Stem cells
- Cancer

END OF REVIEW SESSION

- Thank you for a wonderful semester!
- Good luck with your studies!
- Do not wait until the last minute to review the material!
- Do not hesitate to email me at orfanosemmanuel@gmail.com if you have any questions about the course content, not the final content because I only know as much as you do.