Chapter One: An Introduction to Cells

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Chapter outline

I. **Cells and their history**
   A. Cells
      1. All living things are made of cells.
      2. Cells are microscopic.
   B. Unicellular organisms
      1. Unicellular organisms are just one cell.
      2. Unicellular organisms can still perform all of the functions necessary for life.
   C. History of the discovery of cells
      1. Robert Hooke observed dead cork cells under a simple microscope in 1665.
      2. In 1838, Matthias Schleiden proposed that plant tissues are composed of cells.
      3. In 1839, Theodore Schwann suggested that animal tissues are also made of cells.
      4. Rudolf Virchow proposed in 1858 that all cells come from preexisting cells.
   D. Cell theory
      1. All living things are composed of cells.
      2. The chemical reactions which occur in organisms occur in cells.
      3. Cells come from preexisting cells.

II. **The meaning of "life"**
   A. Characteristics of all living things
      1. They have a greater organization than nonliving things.
      2. They reproduce.
      3. They can grow.
      4. They respond to changes in the environment.
      5. They tend to keep their internal environment unchanged despite changes in the external environment.
   B. Some things, like fire, may satisfy some of these requirements, but only things which satisfy all five conditions are considered to be alive.

III. **The origin of life**
   A. Life first formed 3.5 billion years ago.
   B. A. I. Oparin first theorized how life originated.
      1. There was very little oxygen freely floating in the atmosphere.
      2. Nitrogen, carbon, oxygen, and hydrogen were all present on the primitive Earth.
      3. Energy from lightning, volcanoes, and ultraviolet rays forged the first organic molecules.

C. Stanley Miller tested Oparin's hypothesis in the 1950s.
    1. Miller constructed an apparatus which simulated the conditions on Earth 3.5 billion years ago.
    2. Within 24 hours, amino acids had formed.

IV. **How cells work**
  A. Cell organelles
    1. Organelles are structures within cells which perform specific functions. In this way, they are similar to organs in animals and humans.
    2. The cytoplasm is the jelly-like solution in cells in which all of the organelles float.
  B. Cell processes
    1. Like all organisms, cells must have ways of eating, breathing, and reproducing.
    2. These processes are often the basis for the corresponding processes in large organisms.
  C. DNA
    1. DNA stands for deoxyribonucleic acid.
    2. DNA is a long molecule which directs the production of proteins in a cell.
    3. Proteins affect many of the processes which a cell performs.

V. **Types of unicellular organisms**
  A. Prokaryotes
    1. Prokaryotes are also known as bacteria.
    2. They evolved before the more complex class of organisms, eukaryotes.
    3. Prokaryotes do not have any membrane-bound organelles.
    4. The DNA in prokaryotes is arranged in a circular shape.
  B. Eukaryotes
    1. Eukaryotes are more complex than prokaryotes because they have membrane-bound organelles.
    2. The DNA in eukaryotes is linear and is wrapped around special proteins called histones.
  C. Heterotrophs versus autotrophs
    1. Any organism which consumes food from the environment is a heterotroph.
    2. Organisms which produce their own food are called autotrophs.
  D. Aerobes versus anaerobes
    1. Organisms which require oxygen to survive are aerobes.
    2. Anaerobes are organisms which do not need oxygen.

Terms to know

- aerobe - An organism which uses oxygen during respiration as an acceptor of hydrogen atoms to form water.
- anaerobe - An organism which does not use oxygen during respiration.

- autotroph - An organism which producec its own food through a method of autotrophic nutrition (such as photosynthesis).
- cell - The unit of structure, function, and reproduction of every living organism. Cells perform all of the necessary functions for life, including respiration, reproduction, and responses to changes in the environment.
- cytology - The scientific study of cells.
- cytoplasm - The fluidic substance inside of all cells.
- eukaryote - Cells which contain membrane-bound organelles and are generally more complex than prokaryotes.
- DNA - Deoxyribonucleic acid. DNA is a long molecule composed of deoxyribose, phosphate groups, and nitrogenous bases which indirectly dictates the production of proteins in a cell.
- heterotroph - An organism which must obtain its food from the environment.
- organelle - Specialized structures within cells which perform specific functions.
- prokaryote - Cells which do not contain membrane-bound organelles and are in general less complex than eukaryotes. They are also referred to as bacteria.
- unicellular - A unicellular organism is one which has only a single cell. The two main types of unicellular organisms are prokaryotes and eukaryotes.

Chapter Two: The Chemistry of Biology

Chapter outline

I. **Elements and atoms**
   A. Matter
      1. Matter refers to the "stuff" that everything, living or nonliving, is made of.
      2. The special type of matter which cannot be broken down is called an element.
   B. Elements
      1. Elements cannot be broken down by chemical reactions.
      2. Carbon, hydrogen, and oxygen are examples of elements.
      3. Each element has a one or two letter symbol which is used to identify it.
      4. Over one hundred elements have currently been discovered.
      5. Any amount of an element will exhibit that element's chemical properties.
   C. Atoms
      1. The nucleus
         a. At the center of every atom is a ball consisting of two particles, protons and neutrons.
         b. Protons have a positive charge.
         c. Neutrons have a neutral charge.
      2. Electrons are tiny negatively charged particles which orbit the nucleus.
      3. The positive charge of a proton is equal to the negative charge of an electron.
      4. Atoms normally have the same number of protons as electrons, so the overall charge is neutral.
   D. Atomic mass and atomic number
      1. An element's atomic number is the number of protons in an atom of that element.
      2. An element's atomic mass is the number of protons plus the number of neutrons in an atom of that element.
   E. Isotopes
      1. All isotopes of an element have the same number of protons and electrons, but they have a different number of neutrons.
      2. Different isotopes of the same element may have different chemical properties.

II. **Molecules and their formation**
   A. Molecules

1. Molecules are collections of atoms formed through chemical reactions.
2. The atoms in a molecule are held together by a bond.

B. Ionic bonds
1. An ionic bond occurs when one atom donates one or more electrons to another atom.
2. As a result, one atom becomes becomes positively charged, and the other becomes negatively charged, so they attract to one another and stay together.

C. Covalent bonds
1. A covalent bond occurs when two atoms share one or more electrons to become more stable.
2. Since atoms always tend to become more stable, the bond is not broken easily.

D. Nonpolar molecules and polar molecules
1. In molecules where all of the electrons are shared equally, the charge is neutral everywhere in the molecule. These molecules are nonpolar.
2. Polar molecules are those in which the electrons are not shared equally, to some areas have a slight positive charge, and some have a slight negative charge.

III. **Molecular and structural formulas**

A. Molecular and structural formulas are used to describe the composition and structure of a molecule.

B. Molecular formulas
1. Molecular formulas are simply a list of the symbol of each element in the molecule followed by the number of atoms of that element in the molecule.
2. For example, the molecular formula for glucose is $C_6H_{12}O_6$.
3. When writing chemical reactions, scientists indicate that more than one of a molecule was present by adding a number before the molecular formula. Eight molecules of glucose would be written as $8C_6H_{12}O_6$.

C. Structural formulas
1. Structural formulas are actual sketches of the bonds between the atoms in a molecule.
2. In a structural formula, the atoms are represented by their symbols, and the bonds are indicated by lines between the symbols.
3. If two molecules have an identical molecular formula, only their structural formula can be used to tell the difference.

IV. **Chemical reactions**

A. A chemical reaction is the breaking of bonds and/or the formation of new bonds between atoms.

B. The substances which existed before a chemical reaction are called the reactants, and the substances produced by the reaction are called the products.

C. The number of atoms of an element which existed before a chemical reaction always equals the number of atoms of that element which existed after the chemical reaction was completed.
D. Cells use various chemical reactions to break down food, store it, and use it to drive other processes.

V. **Acids, bases, and buffers**
A. Acids and bases are a way of classifying compounds based upon what happens to them when they are placed in water.
B. Acids
1. When placed in water, acids release H+ ions.
2. On the pH scale, acids have a pH less than 7.
C. Bases
1. Bases release OH- ions when placed in water.
2. Bases have a pH greater than 7 on the pH scale.
D. Buffers
1. Buffers can neutralize the pH of a solution by combining with either H+ ions or OH- ions.
2. They are helpful in unicellular organisms, since many reactions can occur only at pH's which are not too acidic or basic.

VI. **Organic compounds and the importance of carbon**
A. Organic molecules are those which contain carbon, oxygen, and hydrogen.
B. Carbon is the "backbone" of these molecules because it can form four bonds with other atoms.
C. Functional groups
1. Organic molecules have functional groups where bonding with other molecules generally occurs.
2. Molecules with the same functional groups usually have similar chemical properties.
3. Organic molecules are often classified based on their functional groups.

VII. **Different types of organic compounds**
A. Carbohydrates
1. Carbohydrates are formed by joining sugar molecules. Sugars are characterized by having the same number of carbon atoms as oxygen atoms and having twice as many hydrogen atoms.
2. Disaccharides are carbohydrates with two sugars, and polysaccharides are carbohydrates with more than two sugars.
3. Cells use carbohydrates to store energy and as components of many cellular structures.
B. Lipids
1. Lipids are composed of molecules called fatty acids.
2. Lipids do not dissolve in water, so they are said to be hydrophobic.
3. Phospholipids
a. Phospholipids consist of two nonpolar fatty acid molecules, a polar phosphate ion, and a glycerol molecule.

b. Phospholipids are a very important part of the cell membrane because the phosphate ion is polar and the fatty acids are nonpolar.

C. Proteins
1. Proteins are long chains of amino acids.
2. All amino acids have an amino group (NH_2) and a carboxyl group (COOH).
3. The variable group differs between amino acids, giving them certain properties.
4. Amino acids bond together to form proteins through what is called a peptide bond.

VIII. **Enzymes and coenzymes**

A. Enzymes
1. Enzymes are catalysts: molecules which increase the rate of a chemical reaction.
2. All enzymes are complex protein molecules folded upon themselves to form a three-dimensional shape.
3. The area of the enzyme at which the substrate joins is called the active site.

B. Substrates
1. A subtrate is the molecule to which an enzyme attaches.
2. Enzymes attach only to specific substrates which fit into the enzyme's active site.
3. The induced-fit hypothesis states that an enzymes active site can change slightly so that a substrate which does not match perfectly can still fit.

C. Coenzymes
1. Coenzymes are organic molecules which aid in enzyme-catalyzed reaction, but they are not proteins.
2. Often, coenzymes bond with electrons which are released from the reaction catalyzed by the enzyme.

IX. **Factors which affect the efficiency of an enzyme**

A. Inhibitors
1. Competitive inhibitors
a. Competitive inhibitors have a structure to the enzyme's substrate.
b. The enzyme may bond with the competitive inhibitor instead of the substrate, so the reaction catalyzed by the enzyme will occur at a much slower rate.
2. Noncompetitive inhibitors
a. Noncompetitive do not bond to the active site of an enzyme and block the subtrate.
b. They react with portions of the active site, thus changing its shape so that the substrate cannot fit.

B. Allosteric factors

1. Many enzymes have an area called its regulatory site. Molecules which attach to the regulatory site are called allosteric factors.
2. By joining to the regulatory site, allosteric factors can change the shape of the active site, which may either help or harm the enzyme.

C. pH
1. Acids and bases release H+ and OH- ions when dissolved in water.
2. These ions are charged, so they can stretch and pull the enzyme's three-dimensional structure.
3. Solutions with very high or very low pH's have many ions, enough to pull the enzyme's active site completely out of shape so that it can no longer function.
4. Certain enzymes can function best at somewhat acidic or basic pHs.

D. Temperature
1. At higher temperatures, molecules move around faster, so it becomes more likely that an enzyme will come in contact with its substrate.
2. When the temperature is too high, the enzyme may be ripped apart (denatured) so that it loses all function.
3. At very low temperatures, the enzymes and substrates move around very slowly, so they do not come in contact very often and the reaction proceeds slowly.

X. **Diffusion**

A. Diffusion
1. Diffusion is the movement of molecules from an area of high concentration to an area of low concentration.
2. A concentration gradient is a difference in concentration between two areas. Molecules move "down" a concentration gradient; that is, toward the area with a lower concentration.

B. Osmosis
1. Osmosis is the diffusion of water.
2. Water potential is synonymous with water concentration; areas with a high concentration of water have a high water potential.
3. Osmotic potential is the likelihood for osmosis to occur toward a particular area. Areas with a low concentration of water have a high osmotic potential.

Terms to know

- acid - A substance which, when dissolved in water, release H+ ions.
- allosteric factor - A molecule which attaches to the regulatory site of an enzyme, causing a change in the enzymes structure.
- atom - The smallest amount of an element which still exhibits the properties of that element. An atom consists of a nucleus composed of protons and neutrons with electrons orbiting around it.

- atomic mass - The number of protons plus the number of neutrons in an atom of a particular element.
- atomic number - The number of protons in an atom of a particular element.
- base - A substance which, when dissolved in water, release OH- (hydroxide) ions.
- buffer - Compound which tends to neutralize the pH of a solution by combining with either H+ or OH- ions.
- carbohydrate - An organic molecule which is formed through the joining of sugar molecules. All carbohydrates have an equal number of carbon atoms and oxygen atoms, and they have twice as many hydrogen atoms.
- chemical reaction - When substances (the reactants) come together and react by rearranging their bonds to form new substances (the products).
- coenzyme - Organic molecules which are not proteins but still aide in reactions catalyzed by enzymes.
- covalent bond - A bond between two atoms in which the electrons are shared.
- diffusion - The movement of molecules from an area of high concentration to an area of low concentration.
- element - Matter which cannot be further broken down by chemical reactions.
- enzyme - Protein molecules which catalyze chemical reactions by joining to specific reactants in the reaction called substrates.
- ionic bond - A bond formed as a result of the jumping of electrons from one atom to another. Since the atoms either gained or lost electrons, they became ions, and the force of attraction between oppositely charged ions holds the bond together.
- isotope - A form of an element with a different number of neutrons in the nucleus than normal.
- lipid - An organic molecules which consists of fatty acids. Lipids do not dissolve in water.
- matter - The "stuff" that everything is made of.
- molecular formula - A way of describing a molecule by writing the symbol for each element in the molecule followed by a subscript indicating the number of atoms of that element in the molecule.
- molecule - A combination of atoms through chemical bonds.
- organic molecule - Any molecule which contains atoms of carbon, hydrogen, and oxygen. Its carbon backbone allows for a complex structure, and its functional groups allows it to form bonds to other molecules.
- osmosis - A special name for the diffusion of water.
- product - Any molecule formed as a result of a chemical reaction.
- protein - A type of organic molecule which consists of a long chain of amino acid molecules. They are synthesized by ribosomes based on the cell's genetic code.
- reactant - A substance which existed before a chemical reaction.
- structural formula - A method of writing a molecule by actually sketching its physical structure. Atoms are represented by their abbreviation, and bonds between atoms are indicated by lines.
- substrate - The substance to which an enzyme binds in catalyzing a chemical reaction.

Chapter Three: Cell Structures

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Chapter outline

I. **The cell membrane and the cell wall**
   A. The cell membrane
      1. The cell membrane regulates the flow of materials into and out of a cell.
      2. It is selectively permeable, meaning that only certain materials can pass through the membrane.
      3. A cell membrane consists of a bilayer of phospholipids with protein molecules jutting through one or both layers.
   B. The cell wall
      1. Prokaryotic cell wall
         a. The prokaryotic cell wall consists of long polymers called peptidoglycans.
         b. Some prokaryotic cell walls have a second, outer layer composed of lipoproteins and lipopolysaccharides.
      2. Eukaryotic cell wall
         a. The eukaryotic cell wall has three parts: the primary cell wall, the middle lamella, and the secondary cell wall.
         b. The primary cell wall, composed mainly of cellulose, is the innermost layer of the wall.
         c. The middle lamella contains polysaccharides called pectins.
         d. The secondary cell wall is the outermost layer. It consists of cellulose and a strengthening material called lignin.

II. **Movement through the cell membrane**
   A. Simple diffusion
      1. Simple diffusion is when molecules simply pass through the phospholipids in the membrane.
      2. This only occurs for small, nonpolar molecules.
   B. Passive transport
      1. Protein channels
         a. Proteins can form tunnels through which molecules can diffuse.
         b. Since the molecules do not come in contact with the nonpolar fatty acids in the phosholipids, polar molecules can travel accross the membrane through a protein channel.
      2. Facilitated diffusion
         a. Carrier proteins bond to a molecule on one side of the membrane, travel accross, and then release it on the other side.

b. Carrier proteins usually bond with a specific molecule, like an enzyme bonds to a specific substrate.

C. Active transport
1. Active transport accross the cell membrane works against a concentration gradient, so it requires an input of energy.
2. A contractile vacuole is an example, as it forces excess water out of the cell, even if the water is more concentrated in the external environment.

III. **Vacuoles, vesicles, lysosomes, and peroxisomes**

A. Vacuoles and vesicles
1. Vacuoles are sacs within the cell often formed by the budding off of the cell membrane.
2. Vacuoles can hold food particles, water, enzymes, and other substances.
3. Vesicles are simply very small vacuoles, often formed by the budding off of parts of the Golgi bodies to hold protein molecules.

B. Lysosomes and peroxisomes
1. Lysosomes and peroxisomes are both sacs similar to vacuoles which contain enzymes.
2. Lysosomes contain digestive enzymes which can break down large food particles or damaged organelles.
3. Peroxisomes contain oxidizing enzymes which can neutralize many toxic substances, including hydrogen peroxide, by adding oxygen to them.

IV. **The nucleus, nucleolus, and ribosomes**

A. The nucleus
1. The nucleus contains a cell's DNA.
2. Since DNA controls the cell's production of proteins, and proteins affect the entire cell, the nucleus is sometimes called the cell's "brain."
3. The nucleus is surrounded by the nuclear membrane, which has pores which allow RNA to pass through into the endoplasmic reticulum.

B. The nucleolus
1. The nucleolus is a structure within the nucleus responsible for producing ribosomes.
2. Cells usually have several nucleoli.

C. Ribosomes
1. Ribosomes are tiny structures at which protein synthesis takes place.
2. Ribosomes are composed of a large and small subunit, each composed of ribosomal RNA and protein.
3. They are located in the endoplasmic reticulum and at the intersections of the microtrabeculae in the cytoplasm.

V. **The endoplasmic reticulum and the Golgi bodies**

A. The endoplasmic reticulum

1. The endoplasmic reticulum is a network of tunnels extending away from the nucleus to the Golgi bodies.
2. Rough endoplasmic reticulum looks "rough" under a microscope because it contains ribosomes; smooth endoplasmic reticulum does not contain ribosomes.
3. The endoplasmic reticulum is used to carry proteins to the Golgi bodies and synthesize new cell membrane.

B. The Golgi bodies
1. The Golgi bodies are stacks of membranous pouches found at the end of the endoplasmic reticulum.
2. They receive proteins from the endoplasmic reticulum and send them to other organelles in the cell by packaging them into tiny vesicles which bud off of the Golgi bodies.
3. The Golgi bodies can make changes to the proteins they receive before packaging them into vesicles.

VI. **The mitochondria**

A. Cellular respiration occurs in the mitochondria.
B. Most eukaryotic cells have thousands of mitochondria.
C. A mitochondrion's outer membrane separates it from the cytoplasm, and its folded inner membrane (the crystae) is where respiration actually occurs.
D. Mitochondria have their own DNA and can replicate themselves, so scientists believe that they were once separate organisms which were incorporated into eukaryotes.

VII. **The cytoskeleton**

A. The cytoskeleton is a network of fibers made of protein which allows the cell to change its shape. The four types are microtubules, intermediate filaments, microfilaments, and the microtrabeculae.
B. Microtubules
1. Microtubules are 20 to 25 nanometers in diameter.
2. They are involved in cell reproduction and are major components of cilia and flagella.

C. Intermediate filaments
1. Intermediate filaments are 7 to 10 nanometers in diameter.
2. They are made of fibrous protein which cannot be as easily broken down as the other fibers in the cytoskeleton.
3. Intermediate filaments help give the cell strength and shape.

D. Microfilaments
1. Microfilaments are 3 to 6 nanometers in diameter.
2. Microfilaments are involved in the locomotion of cells which do not have specializes structures (like cilia or flagella) for movement.

E. The microtrabeculae
1. The microtrabeculae are very tiny fibers which interconnect all of the cell's organelles to help give the cell shape.
2. Ribosomes are found at the intersections of the microtrabeculae.

VIII. **Cilia, flagella, and pseudopodia**

A. Cilia and flagella
    1. Cilia are tiny hairs on the outside of the cell membrane, and flagella are large hairs. they are both used for locomotion.
    2. Both cilia and flagella are composed of microtubules arranged in a circle of nine pairs around a tenth pair in the center.
    3. At the connection of the cilia and flagella with the cell membrane is a structure called the basal body. The basal body is composed of microtubles arranged in a circle of triplets.
B. Pseudopodia
    1. Pseudopodia are not true organelles; they are just extensions of the cytoplasm.
    2. The rest of the cytoplasm tends to flow toward a pseudopod, so pseudopodia can be used for movement.
    3. Pseudopopdia are also used to surround and capture prey.

IX. **Plastids**
A. Plastids are found only in eukaryotic autotrophs. The three different types are chloroplasts, chromoplasts, and leucoplasts.
B. Chloroplasts
    1. Chloroplasts are green organelles (because they contain the green pigment chlorophyll) which have an outer membrane and a folded inner membrane.
    2. A solution called the stroma fills the space inside of the inner membrane.
    3. Within the chloroplast are stacks of flattened vesicles. The stacks are called grana, and the vesicles are known as thylakoids.
    4. Photosynthesis occurs within the thylakoids of a chloroplast.
C. Chromoplasts
    1. Chromoplasts are like chloroplasts, but they do not contain the green pigment chlorophyll.
    2. The colored pigments in chromoplasts absorb different colors of light than chlorophyll does, allowing photosynthesis to occur in different lightning conditions.
D. Leucoplasts
    1. Leucoplasts are colorless since they do not contain any pigments.
    2. They store starch, proteins, and lipids, releasing them when the cell requires them.

Terms to know

- active transport - Transport in which a cell must expend energy. Active transport occurs against a concentration gradient.
- basal body - A structure found at the connection of cilia and flagella with the cell membrane. It is composed of microtubules in a circular configuration of nine triplets.

- cell membrane - The structure which surrounds the cell and regulates the movement of materials into and out of the cell. It is composed mostly of phospholipids.
- cell wall - A structure found in most prokaryotes and some eukaryotes which gives the cell greater structure. In prokaryotes, it is composed of peptidoglycans, and in eukaryotes, it consists or polysaccharides, pectins, and lignin.
- cilia - Tiny hairs along the outside of the cell membrane which are used to move the cell and capture food particles.
- chloroplast - The organelle in which photosynthesis takes place. It contains chlorophyll.
- chromoplast - An organelle in which photosynthesis take place. It contains pigments other than chlorophyll, resulting in a color other than green.
- contractile vacuole - An organelle which pumps excess water of a cell to prevent it from bursting.
- endoplasmic reticulum - A network of tunnels which extend away from the nucleus, used for the transport of proteins.
- facilitated diffusion - A method of transport across the cell membrane by which carrier proteins bond to a molecule on one side of the membrane, move through the membrane, and then release it on the other side.
- flagella - Large hairs which can whip back and forth to propel a cell.
- Golgi body - Stacks of membranous pouches which act as a transport station, packaging proteins from the endoplasmic reticulum and placing them into tiny vesicles.
- intermediate filament - A part of the cytoskeleton with a strong, ropelike structure which gives the cell strength and helps it to maintain its shape.
- leucoplast - Colorless plastids in autotrophs which store starch, proteins, and lipids.
- lysosome - A sac similar to a vacuole which contains powerful digestive enzymes used to break down large food particles.
- microfilament - A part of the cytoskeleton which consists of actin and aids in cell movement.
- microtrabeculae - Tiny fibers which interconnect all of the structures within the cell and help to give the cell shape.
- microtubule - Fibers which extend from the center of the cell to the cell membrane. They are involved in cell reproduction and are part of the composition of cilia and flagella.
- mitochondria - The organelle in which cellular respiration occurs.
- nucleolus - A structure within the nucleus at which ribosomes are created.
- nucleus - The organelle in eukaryotes which contains the cells DNA and thus indirectly controls protein production and the rest of the cell.
- passive transport - A form of transport which allows highly polar molecules to move through the cell membrane without the expenditure of energy. This may occur either through protein channels or facilitated diffusion.
- peroxisome - An organelle similar to a vacuole which contains oxidizing enzymes which can help neutralize toxic substances.

- pseudopod - Extensions of the cytoplasm toward which the rest of the cytoplasm tends to flow. Pseudopodia can be used for movement and the capture of prey.
- ribosome - Structures found mainly in the endoplasmic reticulum whose function is to synthesize protein based upon the code of a messenger RNA molecule.
- vacuole - Membrane-bound sacs within a cell used to hold food particles, water, etc.
- vesicle - A tiny vacuole, often used to carry protein molecules packaged at the Golgi bodies.

Chapter Four: Cell Nutrition and Respiration

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Chapter outline

I. **Endocytosis and exocytosis**
   A. Endocytosis
      1. Large particles cannot diffuse accross the cell membrane. They enter the cell through a process called endocytosis.
      2. The particle pushes against the membrane and forms an indentation. The cell membrane wraps around the particle and engulfs it into a vacuole.
   B. Exocytosis
      1. Exocytosis is a process by which the cell expels the contents of a vacuole.
      2. The vacuole fuses with the cell membrane and the contents (usually waste products) are pushed into the external environment.
   C. Phagocytosis refers to the endocytosis of a solid particle.
   D. Pinocytosis refers to teh endocytosis of a liquid and its dissolved molecules.

II. **Energy, exergonic, and endergonic reactions**
   A. Energy is the ability to cause a change.
   B. Energy comes in many forms and can easily change from one form to another.
   C. To perform processes, cells must use energy. They store this energy in molecular bonds; it is called chemical energy.
   D. When molecular bonds are broken, energy is released which can be used to power various reactions.
   E. Exergonic reactions
      1. Exergonic reactions result in the release of energy.
      2. They usually occur spontaneously since only a minimal input of energy (the activation energy) is required to start the reaction.
   F. Endergonic reactions
      1. Endergonic reactions absorb energy, so they do not occur spontaneously.
      2. They can only occur when enough energy is available to fulfill the reaction's activation energy.

III. **How cells store energy: ATP**
   A. Cells store chemical energy in a molecule called adenosine triphosphate (ATP).
   B. An ATP molecule has three phosphate groups. Energy which can power an endergonic reaction is released as the bonds which hold the phosphate groups together are broken.

C. When food molecules are broken down, energy is released which cells use to form ATP molecules. In this way, energy is stored for later use.
D. Aerobic organisms create ATP much more efficiently than do anaerobes.

IV. **Glycolysis**
A. Glycolysis occurs in the cytoplasm of all cells.
B. The reactants of glycolysis are a molecule of glucose, two molecules of NAD-, and two molecules of ATP.
C. The products of glycolysis are two molecules of pyruvic acid, two molecules of NADH, and four molecules of ATP.
D. In anaerobes, the pyruvic acid enters fermentation, whereas it enters the Krebs cycle in aerobes.

V. **Anaerobic processes**
A. Anerobic processes occur in anaerobes all the time and in aerobes when there is not sufficient oxygen for an aerobic process.
B. Fermentation
1. Carbon dioxide is removed from the pyruvic acid molecules, forming acetaldehyde.
2. NADH (formed during glycolysis) releases its hydrogen atom to the acetaldehyde. The NADH molecule becomes NAD+, and the acetaldehyde becomes ethyl alcohol.
3. The NAD+ molecule formed is then used in glycolysis so that more ATP can be synthesized.
C. In a second anaerobic process, the NADH releases its hydrogen directly to the pyruvic acid molecule, forming lactic acid.

VI. **The Krebs cycle and electron transport chain**
A. The Krebs cycle
1. The Krebs cycle occurs in the mitochondria of aerobes.
2. A molecule of carbon dioxide is removed from each pyruvic acid molecule (forming acetyl coenzyme A) before they enter the Krebs cycle.
3. The cycle begins when the acetyl coenzyme A bonds with oxaloacetic acid.
4. A series of reactions ensue, producing ATP, NADH, $FADH_2$, and oxaloacetic acid.
5. The oxaloacetic acid formed is used in the next turn of the Krebs cycle.
B. The electron transport chain
1. The molecules of NADH $FADH_2$ were given high energy electrons during glycolysis and the Krebs cycle.
2. The electrons are passed to carrier molecules, releasing energy during the process.
3. At some steps in the chain, more energy is released than in others. This energy is used to power chemiosmosis.

VII. **Chemiosmosis**
A. Overview of chemiosmosis

1. The theory of chemiosmosis was proposed in 1961 by Peter Mitchell.
2. It explains how ATP is synthesized from the energy released in the electron transport chain.
3. Chemiosmosis occurs at the cell membrane in prokaryotes, at the crystae in heterotrophic eukaryotes, and at the thylakoid membrane in autotrophic eukaryotes.

B. Steps in chemiosmosis
1. Carrier molecules use the energy from the electron transport chain to separate H+ ions and electrons and to move the H+ ions accross the membrane.
2. A pH gradient and an electrical gradient forms accross the membrane as the H+ ions accumulate on one side.
3. Eventually, the H+ ions gush through the F_0 channel into the F_1 unit where ATP synthetase it located.
4. Using the energy from the movement of the H+ ions, ATP sythetase drives together ADP and a phosphate group to form ATP.

VIII. **Energy yield for aerobic respiration**

A. Glycolysis
1. For each molecule of glucose, glycolysis produces a net gain of 2 ATP molecules directly.
2. 2 NADH molecules are formed during glycolysis, providing the energy for the production of 3 ATP molecules each through the electron transport chain.
3. 8 molecules of ATP total are produced through glycolysis.

B. Oxidation of pyruvic acid
1. For each molecule of pyruvic acid which is oxidized, one molecule of NADH is formed, resulting in the production of 3 ATP.
2. Since two pyruvic acid molecules are formed for each molecule of glucose, 6 ATP molecules are formed through the oxidation of pyruvic acid.

C. The Krebs cycle
1. For each turn of the Krebs cycle, 1 molecule of ATP is formed directly.
2. 3 molecules of NADH are formed during one turn of the Krebs cycle, resulting in the production of 9 ATP molecules through the electron transport chain.
3. 1 molecule of $FADH_2$ is formed for each turn of the Krebs cycle, providing the energy for the synthesis of 2 ATP molecules.
4. The Krebs cycle occurs twice for each glucose molecule which enters glycolysis, so the total number of ATP formed through the Krebs cycle is 24.

D. The total number of ATP molecules formed from the breakdown of one glucose molecule is 38.

IX. **Overview of photosynthesis**

A. Photosynthesis is the process which autotrophs use to synthesize their own food.
B. The reaction requires light energy, carbon dioxide, and water.
C. The products of photosynthesis are oxygen and glyceraldehyde phosphate.

X. **Noncyclic electron flow and the Calvin cycle**

A. Noncyclic electron flow
1. Light energy enters a cluster of pigments called Photosystem II.
2. The energy is absorbed by a chlorophyll *a* molecule and passed to a carrier molecule.
3. The electron is passed down through several carrier molecules, releasing energy which is used to form ATP.
4. The electron transfers its remaining energy to Photosystem I. This and additional light energy is then transferred to another electron.
5. This electron is passed from carrier to carrier, eventually being accepted by an NADP+ molecule, forming NADPH.
6. Photosynthesis occurs within the thylakoids of a chloroplast.

B. The Calvin cycle
1. The Calvin cycle begins when a molecule of carbon dioxide bonds with the five-carbon sugar ribulose diphosphate.
2. A series of reactions ensue (which involve the NADPH molecule from noncyclic electron flow and convert it back to an NADP+ molecule), producing another molecule of ribulose diphosphate and a molecule of glyceraldehyde phosphate.
3. Glyceraldehyde phosphate can be used in the formation of sugars, proteins, and lipids.

Terms to know

- activation energy - The input of energy required for certain exergonic and all endergonic reactions to occur.
- ATP - Stands for adenosine triphosphate. Cells store energy used to power their processes in the high energy phosphate bonds of ATP molecules.
- chemiosmosis - A process which produces ATP for a cell by utilizing energy from a pH and electrical gradient formed from the transport of H+ ions across a membrane.
- electron transport chain - The passage of electrons from NADH and $FADH_2$ to carrier molecules. This process results in the release of energy which is harnessed to form ATP.
- endergonic reaction - A chemical reaction which requires energy to form chemical bonds.
- endocytosis - The engulfing of a large particle by the cell membrane.
- energy - The ability to cause a change. It can come in many forms and can easily change from one form to another.
- exergonic reaction - A chemical reaction which releases energy, usually by the breaking of molecular bonds.

- exocytosis - The fusion of a vacuole with the cell membrane, causing the expulsion of the contents of the vacuole into the external environment.
- fermentation - An anaerobic pathway following glycolysis which produces ethanol from glucose and provides NAD+ for glycolysis.
- glycolysis - The breaking down of glucose into two molecules of pyruvic acid. Glycolysis is the first step of cellular respiration.
- Krebs cycle - A series of reactions which occurs in the mitochondria, resulting in the formation of ATP. The cycle continually regenerates oxaloacetic acid, bonding it with acetyl coenzyme A at the start of each cycle.
- noncyclic electron flow - The first stage of photosynthesis, in which light energy is captured by a photosystem which is transmitted to an electron and eventually stored in the bond energy of an NADPH molecule.
- phagocytosis - Endocytosis of a solid particle into a vacuole.
- photophosphorylation - The chemiosmotic process utilized by autotrophs in the formation of ATP. It occurs at the membranes of the thylakoids.
- photosynthesis - The process by which autotrophs produce their own food. Light, carbon dioxide, and water are required for the reaction, resulting in the production of PGAL and oxygen.
- photosystem - A cluster of pigment molecules which transfer light energy to an electron.
- pinocytosis - Endocytosis of liquid and dissolved molecules into a vacuole.

Chapter Five: Cell Reproduction

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Chapter outline

I. **Organization of DNA**
   A. A cell's DNA is not simply cut in half during reproduction, because then each daughter cell would receive only half of the genetic code.
   B. DNA in prokaryotes
      1. In prokaryotes, the DNA is arranged in a large circle.
      2. The DNA is not wrapped around protein clusters called histones as it is in eukaryotes.
   C. DNA in eukaryotes
      1. In eukaryotes, the DNA is linear, and it is wrapped around histones.
      2. When a eukaryote is not dividing, its DNA appears as a large mass called chromatin.
      3. As the eukaryote prepares to divide, the chromatin condenses into structures called sister chromatids, attached together at a region called the centromere.

II. **Prokaryotic cell division**
   A. Division in prokaryotes is simpler than in eukaryotes because prokaryotes have shorter DNA and do not have many organelles.
   B. Before the cell divides, the DNA replicates, and each copy attaches to a point on the cell membrane.
   C. As the cell expands before dividing, each copy of DNA is pulled toward one side of the cell.
   D. When the cell is about double its original size, the cell membrane pinches inward in the middle of the cell, forming two new cells.

III. **The cell cycle**
   A. Mitosis
      1. The division of a cell's nucleus and its DNA.
      2. This stage is much shorter than the other stage of the cell cycle, interphase, which occurs between each cell division.
   B. Interphase
      1. G_1 phase
         a. The G_1 phase is a period of growth which follows a cell division.
         b. The cell grows to normal size and synthesizes new organelles.
      2. S phase
         a. The cell's DNA is replicated in preparation for a division.

b. It is currently unknown exactly what causes the transition between the G_1 phase and the S phase.

3. G_2 phase
   a. The cell synthesizes the structures required for cell division.
   b. After the G_2 phase, the cell undergoes mitosis.

IV. **Mitosis**

A. Mitosis is the process through which a cell gives each of its daughter cells identical copies of its DNA.

B. Prophase
   1. The chromatin in the nucleus condenses into sister chromatid structures.
   2. The nuclear membrane and the nucleolus disappear.
   3. The centrioles begin moving toward opposite ends of the nucleus, and the spindle fibers begin to form between them.

C. Metaphase
   1. The spindle fibers attach to the centromeres of the sister chromatid pairs.
   2. The sister chromatids are pulled to the center of the cell.

D. Anaphase
   1. The centromeres of all of the sister chromatids break simultaneously. Each chromatid is now called a chromosome.
   2. The spindle fibers pull one chromosome from each pair toward opposite ends of the cell.

E. Telophase
   1. The spindle fibers break apart.
   2. New nuclear membranes form around each set of chromosomes, and nucleoli form.
   3. The chromosomes begin to disperse back into the mass of chromatin.
   4. Each centriole replicates so that each daughter cell receives two centrioles.

V. **Cytokinesis**

A. Cytokinesis is the division of the cytoplasm into nearly equal halves. It begins in telophase.

B. Cytokinesis in cells without a cell wall
   1. The cell membrane begins to pinch inward, caused by a ring of contractile proteins called actin and myosin.
   2. The groove formed by the pinching inward is called the cleavage furrow.
   3. When the two sides of the furrow meet, the cell splits into two daughter cells.

C. Cytokinesis in cells with a cell wall
   1. Vesicles from the Golgi bodies fuse in the center of the cell, forming a structure called the cell plate.
   2. The cell plate is built outward as more vesicles are added.

3. When the cell plate reaches the cell membrane, the cell has been divided into two daughter cells.
4. The cell plate is used as a frame to build a cell wall for each daughter cell.

Terms to know

- anaphase - The third stage of mitosis during which all of the sister chromatid pairs break simultaneously and are tugged toward opposite ends of the cell by the spindle fibers.
- cell cycle - A description of the general stages of life of a eukaryotic cell. It is divided into mitosis and interphase.
- cell plate - A structure made of flattened vesicles which is built from the center toward the cell membrane during cytokinesis in cells which have a cell wall.
- centrioles - Two structures which, during mitosis, move to opposite ends of the cell and direct the action of the spindle fibers.
- centromere - A region at which a pair of sister chromatids are attached to one another.
- chromatin - The organization of a eukaroytic cell's DNA when it is not dividing. Chromatin is simply a large, dense mass of DNA.
- chromosome - A term which refers to each half of the sister chromatids after they split during mitosis.
- cleavage furrow - The deep groove formed when the cell membrane pinches inward during cytokinesis in cells without a cell wall.
- cytokinesis - The division of the cytoplasm after mitosis, resulting in an approximately equal distribution of organelles in each of the daughter cells.
- DNA - Deoxyribonucleic acid. DNA is a long molecule composed of deoxyribose, phosphate groups, and nitrogenous bases which indirectly dictates the production of proteins in a cell.
- interphase - The stage of the cell cycle between each cell division. Interphase is divided into three phases: the G_1 phase, the S phase, and the G_2 phase.
- metaphase - The second stage of mitosis during which the spindle fibers attach to the kinetochore of each sister chromatid structure and pull them to the center of the cell.
- mitosis - The process by which a cell's DNA is copied and then distributed so that each daughter cell receives an identical copy of the original DNA.
- prophase - The first stage of mitosis, during which the nuclear membrane and nucleolus disappear, the chromatin condenses into sister chromatid structures, the centrioles begin to move apart, and the spindle fibers begint to form.
- sister chromatids - The individual copies of portions of the DNA molecule formed after the chromatin condenses.
- spindle fibers - The structures which, during mitosis, direct the movement of the chromosomes for proper cell division.
- telophase - The final stage of mitosis during which the spindle fibers break apart, new membranes begin to form around each set of chromosomes, the nuclear

membrane and nucleoli reappear, and the chromosomes begin to disperse back into chromatin.

Chapter Six: DNA, RNA, and Protein Synthesis

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Chapter outline

I. **Early hypotheses regarding the genetic material**
   A. Genetic material is the substance in a cell which passes information from the parent cell to the daughter cell.
   B. Biologists realized that it was likely that chromosomes contain the genetic information because of the care a cell takes to provide each daughter cell with a full set of chromosomes.
   C. Chromosomes are made of protein and DNA, and scientists initially believed that protein was the genetic material because it comes in many varieties.

II. **The famous DNA experiments**
   A. Fred Griffith's experiment
      1. Griffith injected one group of mice with live virulent bacteria, another with live non-virulent bacteria, another with heat-killed virulent bacteria, and another with both heat-killed virulent bacteria and live non-virulent bacteria.
      2. Some of the mice which received heat-killed virulent bacteria and live non-virulent bacteria died, and live virulent bacteria was found in their blood.
      3. Griffith concluded that the genetic information in the heat-killed virulent bacteria was not destroyed by the heating and was taken in by some of the live non-virulent bacteria.
      4. Since heat denatures proteins, the genetic information had to be some other material.
   B. Oswald Avery's experiment
      1. Avery used heat to kill virulent bacteria and then extracted RNA, DNA, carbohydrates, lipids, and proteins from them.
      2. He placed each of these substances into different cultures of live non-virulent bacteria.
      3. Only the non-virulent bacteria which received DNA became virulent. This suggested that DNA is the genetic material.

III. **DNA's chemical composition and structure**
   A. Composition of DNA
      1. Nucleic acids (DNA and RNA) are composed of nucleotides: a phosphate group, a five-carbon sugar, and a nitrogenous base.
      2. The four bases in DNA are adenine, cytosine, guanine, and thymine. RNA has uracil in place of thymine.
      3. Adenine and guanine are called the purine bases; their structure has two rings of atoms.

4. Cytosine, thymine, and uracil are the pyrimidine bases; their atoms are arranged in a single ring.

B. Structure of DNA
   1. In the 1940s, Erwin Chargaff found that a DNA molecule has about the same amount of adenine as thymine, and of cytosine as guanine.
   2. In 1953, James Watson and Francis Crick published a paper suggesting that DNA is a double helix.
   3. The rungs of this twisted ladder are the nitrogenous bases, adenine bonding only with thymine and cytosine bonding only with guanine.
   4. The opposite sides of the helix are antiparallel, meaning that if one side ends in the phosphate group (the 5' end), then the other side ends with the sugar molecule (the 3' end).

IV. **The packing of DNA in eukaryotes**
   A. A single molecule of DNA from a human cell is actually about two meters long.
   B. A stretch of the DNA molecule is wrapped twice around a cluster of proteins called histones.
   C. A cluster of histones and the two loops of DNA around it is called a nucleosome.
   D. The nucleosomes are coiled together, and then this coil is packed into tight loops.
   E. This mass of loops is the chromatin seen in a eukaryotic cell's nucleus.

V. **DNA replication**
   A. The three hypothesis for DNA replication were called conservative replication, semiconservative replication, and dispersive replication.
   B. Scientists Matthew Meselson and Franklin Stahl rules out conservative and dispersive replication is possibilities, and semiconservative replication has since been proven to be correct.
   C. Steps in DNA replication
      1. The enzyme DNA helicase begins at the replication origin and runs down the DNA molecule, separating the bonds between the nitrogenous bases.
      2. DNA polymerase attaches new bases to each of the exposed bases as the DNA molecule is unzipped.
      3. In constructing a new strand of DNA, DNA polymerase can only work from the new strand's 5' end to its 3' end. On one side of the replication origin, the DNA polymerase follows the DNA helicase, but on the other side, it must move backwards for short intervals, creating small pieces of DNA called Okazaki fragments.
      4. The Okazaki fragments are linked together by the enzyme DNA ligase.

VI. **Transcription of RNA**
   A. Research by George Beadle and Edward Tatum suggested that DNA determines which proteins a cell produces.

B. Steps in RNA transcription
    1. The DNA molecule is unzipped as in DNA replication.
    2. The enzyme RNA polymerase attaches to a sequence of bases on the DNA molecule called the promoter, moves down the strand, and bonds the appropriate base to each exposed base on the DNA molecule.
    3. Instead of thymine, RNA polymerase bonds uracil to adenine.
    4. Transcription ends when the RNA polymerase reaches a sequence of bases called the termination signal.
C. In order to dictate the production of proteins, a molecule of messenger RNA must be transcribed. This molecule is then translated at the ribosomes into a protein molecule.

VII. **Types of RNA and the mRNA code**

A. Messenger RNA (mRNA)
    1. The mRNA molecule is the longest of the three types of RNA; it takes a copy of the DNA code to the ribosome for translation into a protein molecule.
    2. After exiting the nucleus, a 7-methylguanosine "head" is added which helps it attach to the ribosome.
    3. A poly-A "tail" consisting of adenosine residues is also added, which protects the mRNA molecule from enzymes in the cytoplasm.
B. Transfer RNA (tRNA)
    1. tRNA attaches to an amino acid and brings it to the ribosome when the mRNA code requires it in the construction of a protein molecule.
    2. One side of the tRNA molecule bonds to a specific amino acid, and the other side contains a sequence of bases which is complimentary to the sequence on the mRNA molecule which codes for the amino acid.
C. Ribosomal RNA (rRNA)
    1. Ribosomes have two components: proteins and rRNA.
    2. The large subunit of a ribosome contains an rRNA molecule 2904 nucleotides long, and the small subunit has an rRNA molecule 1542 nucleotides long.
D. The mRNA code
    1. Each triplet of bases on the mRNA molecule (and the DNA molecule) codes for a single amino acid.
    2. Many amino acids are associated with several codons.
    3. There are also special "stop" codons which end the process of translation.

VIII. **Translation**

A. Translation is the synthesis of a protein molecule based on the sequence of nitrogenous bases in an mRNA molecule.
B. The small ribosomal subunit attaches to the 5' end of the mRNA molecule. The first codon there is always AUG.

C. The tRNA molecule with the anticodon which matches AUG attaches to it. This tRNA molecule is bonded to the amino acid methionine.
D. The large ribosomal subunit attaches on top of the tRNA molecule, aligning it in the subunit's A site (the second site, called the P site, is used later).
E. The ribosome moves along the mRNA molecule so that the next codon is aligned in the A site. The previous codon and the tRNA attached to it are now in the P site.
F. A tRNA with the anticodon complimentary to the codon in the A site attaches there, lining up its amino acid with the one being held in the P site.
G. A peptide bond forms between the two amino acids, the tRNA molecule in the P site releases its bond to its amino acid, and the process repeats until the ribosome reaches a "stop" codon.

IX. **Mutations**
A. A mutation is a change in a cell's DNA.
B. Point mutations
1. A point mutation occurs when one base is substituted for another.
2. Point mutations affect only the codon in which they occur.
3. Proteins produced based on a code containing a point mutation are usually still functional, since they are only one amino acid different from what they should be.
C. Frame shift mutations
1. A frame-shift mutation occurs when a base is either added to or deleted from a sequence of bases.
2. Frame-shift mutations affect all of the codons after the mutation.
3. Proteins produced from a sequence of bases containing a frame-shift mutation are rarely functional, since all of the amino acids after the mutation are different than normal.

Terms to know

- codon - A sequence of three base pairs on the mRNA molecule which codes for a particular amino acid.
- conservative replication - A hypothesis for DNA replication whereby the original strand is unchanged and a completely new strand of DNA is synthesized.
- dispersive replication - A hypothesis for DNA replication whereby the DNA molecule is broken into many small segments alongside which new DNA strands are formed, after which the segments are reassembled into two molecules of DNA.
- DNA - Deoxyribonucleic acid. DNA is a long molecule composed of deoxyribose, phosphate groups, and nitrogenous bases which indirectly dictates the production of proteins in a cell.
- frame shift mutation - A mutation which occurs when a base is either added or deleted from the DNA molecule, resulting in a new reading of the triplet codons and a completely different amino acid being produced.

- histone - A protein molecule which exists in clusters around which DNA wraps so that it is condensed in the nucleus.
- mRNA - Messenger RNA. It carries large portions of the information contained in the DNA molecule to the ribosomes for protein synthesis.
- nucleosome - The fundamental packing unit of DNA. It consists of a cluster of histones with two loops of DNA around it.
- nucleotide - The unit of structure of a nucleic acid. It consists of a five carbon sugar, a phosphate group, and a nitrogenous base.
- Okazaki fragment - Small pieces of DNA which form during DNA replication since DNA polymerase must work backwards on some strands. The Okazaki fragments are joined together by the enzyme DNA ligase.
- point mutation - A mutation which occurs when one base in the DNA molecule is replaced by another. This results in the production of a protein only one amino acid different from normal, so it is usually not very harmful.
- promoter - A sequence of bases on the DNA molecule to which RNA polymerase must attach to begin the transcription of an RNA molecule.
- purine base - A nitrogenous base with two rings of atoms in its structure. This includes adenine and guanine.
- pyrimidine base - A nitrogenous base with one ring of atoms in its structure. This includes cytosine, thymine, and uracil.
- RNA - Ribonucleic acid. RNA is a molecule composed of ribose, phosphate groups, and nitrogenous bases used to transfer information from the DNA molecule to the ribosomes where proteins are produced.
- rRNA - Ribonucleic acid. RNA is a molecule composed of ribose, phosphate groups, and nitrogenous bases used to transfer information from the DNA molecule to the ribosomes where proteins are produced.
- semiconservative replication - A hypothesis for DNA replication whereby the DNA molecule "unzips" and a new strand of DNA is assembled on either side. The resulting DNA molecules are half from the original molecule and half newly synthesized.
- termination signal - A second sequence of bases on the DNA molecule which signals the RNA polymerase to end transcription.
- transcription - The process by which RNA is created off of a DNA template.
- translation - The process by which the code on an mRNA molecule is used to form a protein molecule at the ribosomes.
- tRNA - Transfer RNA. It transfers a specific amino acid to the ribosome when the appropriate codon on the mRNA molecule has been reached.

Chapter Seven: The Classification of Unicellular Organisms

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http://library.advanced.org/27819

Chapter outline

I. **General classification of organisms**
   A. Prokaryotes versus eukaryotes
      1. Prokaryotes, also called bacteria, do not have membrane-bound organelles. Their DNA is arranged in a circle.
      2. Since prokaryotes evolved before eukaryotes, they are much simpler.
      3. Eukaryotes have many specialized membrane-bound organelles. Their DNA is linear and is wrapped around histones.
   B. Heterotrophs versus autotrophs
      1. Heterotrophs are organisms which obtain their food from the environment.
      2. Organisms which produce their own food are autotrophs.
   C. Aerobes versus anaerobes
      1. Aerobes are organisms which require oxygen for respiration.
      2. Anaerobes are organisms which do not need oxygen to survive.
   D. Official classification of organisms
      1. Organisms are classified into five different kingdoms. Two of them, kingdom Monera and kingdom Protista, consist of unicellular organisms. The subcategory under a kingdom is called a phylum.
      2. Kingdom Monera consists only of prokaryotes.
      3. All unicellular eukaryotes are found in kingdom Protista.

II. **Spirochetes, Myxobacteria, and Cyanobacteria**
   A. Spirochetes
      1. Spirochetes are a class of bacteria which may be aerobic or anaerobic.
      2. All spirochetes have a spiral shape, formed by wrapping around special flagella called axial filaments.
      3. A spirochete can move by rotating its axial filaments.
      4. Since heat denatures proteins, the genetic information had to be some other material.
   B. Myxobacteria
      1. Myxobacteria are aerobic, heterotrophic bacteria which secrete a slimy mucus-like material.
      2. They do not have flagella but move using fibrils on the inside of the cell.

3. Myxobacteria reproduce by forming large clusters called fruiting bodies which release small clusters of cells called cysts.

C. Cyanobacteria
   1. Cyanobacteria are autotrophic bacteria, sometimes called blue-green algae. They may be aerobic or anaerobic.
   2. Unlike most prokaryotes, cyanobacteria have specialized membranes which help perform specific functions.
   3. Cyanobacteria do not normally have flagella.
   4. They may form large colonies in which certain cells take on specific roles.

III. **Algae**
   A. Algae refers informally to autotrophs in kingdom Protista.
   B. Algae usually live near the surface of large bodies of water where light (necessary for photosythesis) is abundant.
   C. They may form large colonies, and some varieties of algae are multicellular.

IV. **Euglenas**
   A. Euglenas are a type of algae, so they have chloroplasts in which photosynthesis occurs.
   B. They do not have a cell wall and can act as a heterotroph if the environment does not foster photosynthesis.
   C. The stigma is a light-sensitive structure which directs the euglena towards light for photosynthesis.
   D. The pyrenoid bodies store food in the form of paramylum, a type of starch.
   E. Euglenas can move using their long flagellum or their pellicle, a structure made of protein lying next to the cell membrane which can wiggle.

V. **Chrysophytes and Pyrrophytes**
   A. Both chrysophytes and pyrrophytes are types of algae.
   B. Chrysophytes
      1. Chrysophytes contain the green pigment chlorophyll and another pigment, fucoxanthin, which gives them a yellow-brown color.
      2. Chrysophytes store their food in the form of oils.
      3. The cell walls of chrysophytes are strengthened by silicon compounds.
      4. They usually live in marine environments.
   C. Pyrrophytes
      1. Pyrrophytes are also known as dinoflagellates.
      2. Most pyrrophytes have two flagella.
      3. Pyrrophytes are bioluminescent; they naturally give off a small amount of light, enough to glow in the dark.
      4. Pyrrophytes store their food as both starch and oils.
      5. Like chrysophytes, they usually are found in marine environments.

VI. **Protozoa**
   A. Protozoans informally refers to heterotrophs in kingdom Protista.
   B. Most protozoans reproduce asexually, but some types have complex sexual reproduction cycles.

VII. **Phyla Mastigophora and Sarcodina**

A. Mastigophores

1. Mastigophores are the most primitive protozoans.
2. They can have many flagella, and they also move using pseudopodia.
3. Most mastigophores reproduce asexually.
4. Mastigophores are usually parasites, living inside of another organism at that organism's expense.

B. Sarcodines

1. Sarcodines freely form pseudopodia to move and capture prey.
2. They are usually free-living, existing in both freshwater and marine environments.
3. Foraminiferans are sarcodines with calcerous shells (they are made of $CaCO_3$).
4. Radiolarians have shells containing silica. They live in marine environments.
5. Heliozoans have shells made of silica, and they lve in freshwater.

VIII. **Phyla Sporozoa and Ciliophora**

A. Sporozoans

1. Sporozoans are parasites; they obtain nutrients from their host organism.
2. They do not have cilia or flagella.
3. Sporozoans often have complex life cycles. The *Plasmodium vivax* finds itself in both a mosquito's stomach and a human liver during its lifetime.

B. Ciliates

1. Ciliates have great amounts of cilia.
2. They have trichocysts, organelles which can be discharged from the cell to anchor it or paralyze prey.
3. Ciliates can live in freshwater or marine environments.
4. They usually feed on bacteria or other protists.
5. Paramecia
    a. Paramecia, a type of ciliate, have a gullet to ingest large food particles.
    b. Most paramecia have a contractile vacuole.
    c. Paramecia can exchange DNA with one another through conjugation. This involves lining up their gullets and allowing DNA to pass through.

Terms to know

- aerobe - An organism which uses oxygen during respiration as an acceptor of hydrogen atoms to form water.
- algae - An informal term which refers to photosynthetic eukaryotes.
- anaerobe - An organism which does not use oxygen during respiration.

- autotroph - An organism which produces its own food through a method of autotrophic nutrition (such as photosynthesis).
- axial filaments - Special flagella found in spirochetes around which the cell wraps itself, resulting in a spiral shape. The rotation of the axial filaments can be used for locomotion.
- conjugation - A sharing of genetic information between two paramecia through their gullets.
- contractile vacuole - An organelle which pumps excess water of a cell to prevent it from bursting.
- eukaryote - Cells which contain membrane-bound organelles and are generally more complex than prokaryotes.
- fruiting body - A large cluster of cells of the phylum myxobacteria used in reproduction.
- heterotroph - An organism which must obtain its food from the environment.
- kingdom - One of five large categories into which all organisms can be classified. Prokaryotes are found in kingdom Monera, and kingdom Protista consists of unicellular eukaryotes.
- paramylum - The form of starch which euglenas store as a spare energy source.
- pellicle - A structure in euglenas made of protein lying just next to the cell membrane. The wiggling of the pellicle can be used for locomotion.
- phylum - A subcategory under the general category of kingdom.
- prokaryote - Cells which do not contain membrane-bound organelles and are in general less complex than eukaryotes. They are also referred to as bacteria.
- protozoan - An informal term which refers to a heterotrophic eukaryote.
- pseudopod - Extensions of the cytoplasm toward which the rest of the cytoplasm tends to flow. Pseudopodia can be used for movement and the capture of prey.
- pyrenoid body - A structure found in the euglena which stores starch in the form of paramylum.
- stigma - A light-sensitive structure found in the euglena which directs the euglena's movement toward light.