Objectives:

1. Describe the roles of such cellular organelles as the endoplasmic reticulum, mitochondrion, Golgi body, ribosome and nucleus.
2. Use the fluid mosaic model to describe the general structure and function of a cell’s membrane.
3. Define the terms solute, solvent, and solution, and relate them to the concentration of a solution.
5. Distinguish those mechanisms by which substances move across the membrane passively (without the need of added energy) from active mechanisms (those requiring energy).

Video Synopsis:

This segment begins with an award-winning animated tour of the cell, where the viewer voyages through the cell membrane and encounters the major organelles. Dr. Robert Heath discusses the role of the cell membrane in the body as a barrier and transporter of the nutrient products of the remarkable factory.

Questions:

1. Identify and describe the activities of several cellular organelles.
   - Mitochondrion: Provides cell with useable energy in form of ATP.
   - Golgi body: Modification and packaging of macromolecules such as proteins.
   - Endoplasmic reticulum: Channels for cellular transport; sites of protein synthesis (RER) and a lipid biosynthesis (SER).
   - Nucleus: Control center of cell containing the genetic material DNA.

2. Why is it appropriate to describe the cell membrane as a fluid mosaic?
   - There is lateral movement of molecules within the lipid bilayer, giving it a fluid quality.
   - The lipid bilayer is studded with proteins, glycoproteins, and glycolipids, giving it a patterned or mosaic quality.

3. Describe the composition of a solution.
   - A solution contains a solid dissolved in some solvent which, in living organisms, is usually water.
   - Solute is the term for a dissolved substance.
   - The liquid dissolving agent is termed the solvent.
4. Describe diffusion. Why is it so common in both the living and non-living world?
   • Movement of a substance from a region of greater concentration to a region of lesser concentration.
   • Random motion inherent in molecules as a function of temperature is responsible.
   • No additional energy needs to be provided.

5. Describe three mechanisms for membrane transport which require energy.
   • Pumping of solutes across a membrane using transport proteins. This movement is often from a lower to higher concentration and requires ATP energy.
   • Endocytosis carries large substances into the cell by enclosing them in a patch of the cell membrane.
   • Exocytosis is the reverse process whereby cellular vesicles fuse with the membrane and release their contents to the outside of the cell.

Follow-up Activities:

1. The analogy of the cell as a factory is often used. Develop a list of factory activities, and then identify which cell parts have matching functions.

2. Several factors, including temperature, affect the rate at which diffusion takes place. Develop a hypothesis regarding how temperature changes would affect the rate of diffusion. Using food coloring and water, design and carry out an experiment to obtain information to support or refute your hypothesis.

3. When compared to one another, solutions are classified as hypertonic, hypotonic or isotonic. First research the meaning of these terms, and then decide whether an IV you might receive in the hospital should be hypertonic, hypotonic or isotonic to your blood. Defend your choice.
Objectives:

1. Identify the major reasons for which cells use energy.
2. Describe the reorganization of atoms that occurs in a simple reversible reaction using equations and noting the role of catalysts (including enzymes), reactants (or substrates), products, and the principles of equilibrium.
3. Discuss the importance of maintaining balance in metabolism and note the roles of coenzymes and cofactors, including some vitamins and minerals.

Video Synopsis:

Peer pressure for teenagers can have serious effects, and for a female athlete, the pressure to perform can result in devastating consequences. In this segment, we meet Merete Stockmann, a teen tennis champion in her native Denmark, who fell into a battle with bulimia during her college career in the U.S. We hear from Cathy Rigby-McCoy, Olympic gymnast, who speaks about the pressures of competition and coaches, and how she, too, suffered from eating disorders far into her adult life. Professor Paul Saltman describes the body’s metabolic pathways and the role of enzymes, coenzymes and cofactors in supplying the chemical reactions of cells with their required ingredients.

Questions:

1. What forms of energy does the body require?
   - Heat, chemical synthesis, electrical, and mechanical i.e., movement and blood flow

2. How does the body get the energy it needs to fuel its chemical reactions?
   - Food, metabolism, chemical reactions are all valid answers

3. What is a reversible reaction and what must occur to achieve “equilibrium”?
   - Reactants or substrates form products... then products rearrange again to reform the original reactants.
   - Equilibrium occurs when the rate of forward reaction equals the rate of reverse reaction.

4. What is the role and function of enzymes in metabolism?
   - Enzymes speed up existing reactions, but do not change overall results (i.e. products). They hold, twist and tug at reactants making it easier for the bonds to rearrange.
   - The body can use enzymes to “regulate” metabolism because more, active enzymes for a given pathway would cause that set of reactions to occur more.
   - Similarly, fewer active enzymes for a different pathway would cause less activity of that pathway.
5. What factors might change enzyme activity and what causes these factors to alter enzyme function?
   • Anything that might alter the shape of an enzyme and its ability to hold the reactants.
   • Cofactors and coenzymes should be noted.
   • Hint: Enzymes are protein molecules so what makes proteins hold their 3D shape? pH, temperature, allosteric inhibitors are all possibilities.

Follow-Up Activity:

1. Analyze your diet for a day and compare your intake with that suggested by the classic “food pyramid”. Where do you obtain the energy? The cofactors and coenzymes? The reactants?
Objectives:

1. Summarize the *two laws of thermodynamics* that govern energy and its conversion from one form to another.
2. Describe the energy flow that occurs when energy-requiring reactions and energy-releasing reactions are coupled.
3. Use the *ATP/ADP cycle* as an example to explain how a cell can use a molecule to temporarily hold and transport energy for use in later reactions.

Video Synopsis:

The need for energy is common to all of us. Those who work out, as we will see in the opening montage, have their own special ways to “power up.” Beginning our segment, Dr. Paul Saltman and Dr. Magro Haygood summarize the first two laws of thermodynamics. As various animals, including humans, give a display of energy expenditure, the experts discuss the concepts of changing energy from one form to another and constantly using ATP to maintain order in metabolic systems.

Questions:

1. Why does the human body need a constant input of energy?
   - All living things need energy to stay alive because they need to maintain the organization that makes them different from the non-living environment.
   - Similarly, organisms require energy to function... movement, maintaining body heat, building more structures, electrical activity, reproduction, all require energy.

2. Define the first and second laws of thermodynamics.
   - Thermodynamics refers to the movement of energy.
   - The first law states that energy is neither created nor destroyed... it merely changes form.
   - The second law states that entropy or “randomness” is increasing as transformations occur.
   - With each conversion or use of energy, the total system becomes more disordered, so energy is converted at a price.

3. Do these laws hold true for metabolic processes? Explain.
   - Of course. For example, an organism is highly ordered, but it requires constant energy input from its environment to maintain that order and perform life’s processes.
   - The constant energy input and transformations result in an entropy increase in the surrounding environment.
   - In this case, the “spent” energy dissipates back to the surrounding environment as heat.
4. What are coupled reactions and why are they important to metabolism?
   - Coupled reactions are two or more reactions linked in such a manner that the second reaction can only occur if the first reaction occurs simultaneously. Usually, the first reaction results in a release of energy because the total energy remaining in the products is less than the energy that was contained in the reactants. Once begun, this energy releasing reaction can continue to occur spontaneously.
   - On the other hand, the second reaction is usually an energy requiring reaction: the products contain more energy that is in the original reactants. This reaction cannot continue spontaneously because it requires energy input. Coupling uses the energy released from reaction #1 to drive reaction #2. Without coupling, all building of body structures and other reactions requiring energy would be impossible.

5. What is ATP and why is the ATP/ADP cycle so significant?
   - ATP is often called the energy currency of the cell. It is a molecule with relatively high energy content for its small size.
   - The reaction sequence that converts ATP to ADP and inorganic phosphate, and then back again, is especially significant because it is readily coupled to key reactions in most metabolic pathways.
   - When ATP is split to ADP and P, energy is released that can drive another reaction. But the sequence recombining ADP and P requires energy and is therefore an important acceptor of energy from metabolism of food byproducts.
   - The ATP/ADP cycle is especially important because it is the energy intermediary for almost all reaction sequences of all organisms on earth, effectively handing energy from one reaction to another.

Follow-Up Activities:

1. Make a diagram showing how energy is converted from one form to another in everyday activities such as cooking, doing laundry, etc. Are these conversions perfect? If not, where does the extra energy go?

2. In broad terms, outline how the human body extracts the energy it needs from a ham-and-cheese sandwich and how is that energy used to build a muscle and then contract it? Basically indicate all the locations where the ATP/ADP cycle would fit into this process.
Objectives:

1. Outline the general flow of energy and matter in the living world, noting the relationship between photosynthesis and aerobic cellular respiration that cycles carbon dioxide, oxygen and water.
2. Describe basic leaf structure and the functional advantages it offers plants.
3. Describe the key steps of the light-dependent and light-independent reactions of photosynthesis, noting the raw materials required, the end products, and the location of each phase.

Video Synopsis:

Dr. Jeanne Erikson, who studies photosynthetic reactions of single celled algae, describes the passage of carbon dioxide and sunlight through the surface layer of plant leaves. Here, they become the source materials for the photosynthetic factories in the chloroplasts. Dr. Erikson explains how light triggers special trap pigments to release energized electrons and how these electrons are passed through a series of biological reactions to produce NADPH and ATP. These light-dependent reactions are followed by the light-independent reactions of the Calvin-Benson cycle, where six-carbon sugar glucose is ultimately formed.

Questions:

1. What is the meaning of the bumper sticker that says “Have you thanked a green plant today?”
   - All organisms require a supply of energy, usually, but not always, from photosynthesis.
   - Most of the energy entering the biosphere is solar energy trapped by green plants during photosynthesis.
   - In addition to the production of energetic sugar molecules, photosynthesis also produces the oxygen used by most organisms for respiration.

2. How well is the structure of a leaf adapted for “doing” photosynthesis?
   - Often flattened to maximize surface area.
   - A waxy cuticle helps retain water.
   - Openings in epidermis called stomata allow for gas exchange including the CO₂ necessary for photosynthesis.
   - Light trapping pigments and transport proteins are efficiently arranged in the thylakoid membranes of the chloroplasts.
3. Identify the location, reactants and products of the light-dependent phase of photosynthesis.
   • The light dependent phase takes place on the thylakoid membranes of the chloroplasts.
   • This phase requires H₂O and light energy.
   • The trapped solar energy is used to form the energetic substances ATP and reduced NADPH. Along the way, oxygen is given off as a byproduct.

4. What are the events of the light-independent phase of photosynthesis and where does this process occur?
   • The light-independent, or dark phase occurs in the fluid-filled part of the chloroplast called the stroma. Enzymes necessary for the dark phase are found here.
   • Carbon dioxide is joined to existing molecules of the Calvin cycle and the energy of ATP and NADPH (reducing power) is used to drive the synthesis of six-carbon sugars such as glucose. ATP is also used to resynthesize the Calvin cycle intermediates.

**Follow-up Activities:**

1. Attempt to find some plans for the constructions of a simple green house. How does it work? Why isn’t it green?

2. Given your basic understanding of photosynthesis, discuss what might be some consequences of deforestation. Consulting a reference on global warming might help you formulate some thoughts.
Cycles of Life: EXPLORING BIOLOGY
Module 2: The Chemistry of Living Organisms
Segment 5: Respiration

Objectives:

1. Distinguish between autotrophic and heterotrophic organisms.
2. Identify the purpose of the process of cellular respiration.
3. Recognize ATP as the central energy exchange unit of the cell and state why ATP is well suited for this role.
4. Describe the three major stages of aerobic cellular respiration, noting the raw materials and products of each stage.

Video Synopsis:

Oxygen is a crucial ingredient that drives the metabolism of non-photosynthetic organisms like ourselves. Dr. Paul Saltman explains how chemical energy trapped in food particles is released through the chemical reactions of aerobic respiration. ATP is the “currency” of various energy deposits and withdrawals that characterize these transformations. Animated sequences show the release of ATP through a series of chemical reactions that occur in the cellular cytoplasm and mitochondria: glycolysis, Krebs cycle and electron transport phosphorylation.

Questions:

1. What is the characteristic common to all heterotrophs?
   - Heterotrophs utilize previously formed compounds as their energy source.
   - Such nutrients must be obtained from feeding on other organisms or their products.

2. What is accomplished by cellular respiration?
   - Respiration involves a series of energy-releasing reactions which are utilized to drive ATP synthesis.
   - Energy is transferred from fuel molecules to ATP.

3. Why is ATP termed the energy currency of the cell?
   - ATP is an energetic molecule whose bonds are easily broken to provide energy.
   - The energy released when ATP is degraded is just about the right amount needed to drive many cellular reactions without creating too much wasted heat energy.

4. What is glycolysis; where does it occur; what are its end products?
   - Glycolysis is the sequence of reactions whereby glucose is broken down to two molecules of pyruvate.
   - Glycolysis occurs in the cytoplasm.
   - Along with the two molecules of pyruvate, the initial breakdown of glucose yields a net of two ATP molecules and two molecules of the energy-rich reduced coenzyme NAD (NADH).
5. How is the glucose broken down in the mitochondrion? What are the end-products?
   • In the mitochondrion, pyruvate is broken down into a two-carbon fragment (acetyl-CoA) which enters the Krebs cycle.
   • In the Krebs cycle, the remaining carbohydrate is broken down to CO$_2$. An ATP molecule is also produced for each turn of the cycle along with three NADHs and an FADH$_2$.
   • The energetic electrons from the reduced coenzymes are passed along a set of carrier molecules called the electron transport system. Some of the energy released in passage is used to create a proton gradient across the inner mitochondrial membrane.
   • The energy derived for the dissolution of this gradient is used to drive much ATP synthesis (34-36 ATP/glucose molecule).
   • The electrons, devoid of much of their energy, eventually join with oxygen and protons to form the final product of respiration, H$_2$O.

Follow-up Activities:

1. Fats and proteins can also be burned along with carbohydrates to yield useable energy. Find a chart of metabolic reactions and identify those steps where fat and protein breakdown ties in with carbohydrate or sugar breakdown.

2. Aerobic respiration requires oxygen as the terminal electron acceptor. From your prior knowledge or a search of text material, determine if respiration can occur without oxygen. If so, what is the nature of the process and how good is the energy yield compared to aerobic respiration?

3. Rotenone is a fish poison and insecticide. Its mode of action is listed on container labels as “respiratory poison.” Exactly where and how does it disrupt cellular respiration?