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The Way Food Works: Analyzing the Short and Long Term Effects of What We Eat

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Introduction

Why eat? And what? Given our plentiful resources and inventive minds, we have access to nearly every type of food imaginable. However, my students seem to have their own construed version of the food pyramid, consisting of the pizza, cheeseburger, and fried potato groups, topped off by sugar in all shapes and forms. Food fuels our bodies and minds and shapes our health in countless ways, yet we often pay little attention to the nutrients that we put into our bodies. Most people, including my students, are perplexed about what to eat and why. Challenges of convenience, food access, persuasive advertisements and conflicting media messages only contribute to this confusion. This unit is designed to be a powerful educational tool, teaching the complexities of digestion and metabolism on a human cellular level, while pushing a message of health and responsibility.

Objectives

This unit is designed to fit into the International Baccalaureate (IB) program for biology, which is a two-year course taught to juniors and seniors. The course follows a strict and well-defined scientific curriculum but also has the flexibility to provide relevant and meaningful connections to students. Students should have already had a year of "pre-IB" biology and therefore have a superficial understanding of most of the topics in the unit. They should know the building blocks and function of carbohydrates, proteins, and lipids, that plants produce energy for all living organisms through the process of photosynthesis, that energy is released from sugars through the process of cellular respiration, and a general understanding of nutrition (i.e. that you should generally follow a diet low in saturated and trans fats, high in whole grains, fruits, and vegetables, etc.) They should also recall basic biochemistry, such as elements and molecules, and cellular structures.

International Baccalaureate is a rigorous and demanding program and the objectives I am trying to achieve are quite complex. While I have high expectations for this unit and for my students, I feel that it is important to mention that these children are *not* in a magnet high school and are working at something of an academic deficit.

The course will provide greater detail and broader connections across other areas of science as well as issues in society. By the end of the unit, students should have an understanding of each of the macronutrients (molecular structure, synthesis and catabolism, specific functions), the human digestive process (different organs and their functions, how each nutrient is broken down and released to the bloodstream), metabolism and the release of energy from food molecules (aerobic respiration and anaerobic fermentation), the importance of energy and nutrient balance, and the consequences of food choice on our health.

Students should emerge from the course with an applicable knowledge of what foods will best nourish their bodies, which should be avoided, and how these choices (as well as other factors) will shape their health. The ultimate goal of this unit is to create a lasting impression of these ideas and to have students share them with their friends and family so as to improve the community overall.

Rationale

I teach regular, honors, and International Baccalaureate (IB) biology at Hubbard High School, a neighborhood (non-magnet) school on the south side of Chicago. The school is about eighty percent Hispanic, twelve percent African-American, and the remaining eight percent white and Asian. Ninety two percent of the school's approximately 1,600 students are defined as being low-income. My students face issues of violence, gangs, and substance abuse on a frequent basis. Many of them live in unusual and often unsupportive household situations, and a fair number of them work to support their families. If you ask them, my students will tell you that they want to go to college, but they often lack the academic skills, motivation, or understanding of what it takes to get to and succeed in college. Because this unit is designed primarily for the IB classes, one of its goals is to provide knowledge and experiences that will help them overcome these challenges and prepare them for college.

Everyone must eat. Knowledge of food is therefore essential to survival, and, as we have learned through decades of research, a key factor in the quality of our health and longevity. Students therefore should be able to gain an understanding of how their food choices affect the way their body works at present, as well as how it will function in the future.

Additionally, my students are primarily of Hispanic or African American ethnic backgrounds, two groups that are at a higher risk of diabetes and heart disease. They should therefore be given the opportunity to learn specific concepts about how variations in different nutrients lead to these results. From my experience in general biology, students usually have a poor understanding of food's role in the body and the causes of various nutrition-related disorders. They have a further skewed vision of what energy is, having been confused by the various "energy drinks" and other products that are so heavily advertised today.

Many of my students claim that their parents do not offer them healthy choices, likely due to a combination of factors. The majority of my students' parents lack a solid education and work multiple jobs, leading to the increasingly common solution of fast-food or take-out for one or more meals a day. Therefore, an important part of this unit is to also provide education to the parents through the students so that the entire household can make healthier choices together. My students are also quick to speak up about the lack of choices they have in the school cafeteria. My observations have revealed that most students consume something along the lines of pizza, a fried chicken patty sandwich or burger, fries or tater tots, and (often chocolate) milk. They frequently supplement their meals with items from the so-called "new and improved" vending machines, such as Rice Krispy Treats, PopTarts, or Otis Spunkmeyer muffins, topped off with a can of Snapple or a Powerade. These meals are highly processed, contain few vitamins, minerals, or fiber, and are high in kilocalories, sugar, sodium, and fat. The students complain that there is no fresh fruit, that vegetables are generally overcooked and unappealing, and that salads are less than appetizing. There are some things that cannot be changed, or will be slow to change in my students' diets. However, I want to empower them and help them make better choices even when their options are few. They need to be able to construct an eating plan that is both healthy and realistic.

Strategies

The content in the following section will be covered in a variety of ways. Because this is an advanced course, much of the information will presented in lecture using Power Point, supplemented with diagrams, videos, examples, and animations. These additions to the presentations will help visualize the information for students. I feel this is particularly beneficial when dealing with concepts on a cellular or molecular level, as it is hard to imagine processes that cannot be seen. I always encourage my students to ask questions, and anticipate many in this unit since eating is something that everyone consciously does each day.

I have students take notes in the Cornell style to ensure that they go back through their notes at least once and think about what they are learning. When taking Cornell notes, students draw a line a third of the way from the left side of the paper and leave this section blank. At the conclusion of the lecture, students go back through their notes and add questions that can be answered by the information present. For example, if a student wrote "all carbohydrates are constructed by small units called monosaccharides (simple sugars)," they could write "what are the building blocks of carbohydrates?" or "what are monosaccharides?" as well as several other questions. This forces them to go back through their notes and analyze the information covered, and in addition, gives them a useful study tool to use (they may cover the notes and ask themselves the questions).

In addition to lectures, students will learn information through supplemental and textbook reading assignments, classroom discussions and group/pair sharing. Labs are also an important part of any science curriculum, and these are listed in the classroom activities section that follows. There will be a major activity or lab for each of the five sections of content. These laboratory exercises will allow students to explore and practice the concepts that they learn in lecture. They are additionally valuable because they challenge students to be investigative and creatively apply their science skills. One of the labs is designed to be an open inquiry lab, meaning that students are given a general concept (in this case, digestion) and asked to design a procedure that will yield results confirming or expanding upon the concept at hand.

At the conclusion of the unit, after having learned about the long term effects of nutrition, students will select an effect (such as diabetes), research it, and prepare a webpage presenting information on what nutrition choices cause that condition, how it can be prevented and treated, and the effect on the body. These webpages will then be linked to the class webpage, which is used to maintain communication with parents as well as students.

Content

Sources of Energy

Cellular Energy—ATP, Glucose, and Glycogen

Energy is one of the requirements of life—no living organism can survive without energy to power its daily functions. The ultimate source of nearly all energy is the sun, the energy from which plants are able to capture and transform into a stored and usable form, sugars. Other organisms, such as animals, lack the ability to acquire energy directly from the sun and must consume food, the energy in which is transferred into a powerful molecule called adenosine triphosphate, or ATP (McArdle et al. 2006). The ATP molecule consists of a nitrogenous ring (adenine), a five-carbon sugar (ribose), and a three-phosphate "tail." The potential energy from food is transferred to ATP, where it remains trapped in the bond between the middle and outer phosphates; the breaking of this bond releases the cellular energy used to fuel life. When this bond is broken, the molecule is reduced to ADP (adenosine diphohsphate) and an inorganic phosphate ion. ADP and P_i can in turn be converted back to ATP to store and release energy again (Boron and Boulpaep 2005).

ATP is typically generated from the simple sugar glucose, which the body obtains from foods that contain various carbohydrates. Only a small amount of ATP remains in the cell at any given time so it is continually regenerated as needed. Therefore, glucose serves as a storage molecule for energy. When the human body has excess glucose, such as from a surplus of food molecules, then these glucose molecules can be linked together in branched structures called glycogen, which is then stored in the liver and muscles (Thompson and Manore 2005).

During digestion, food is broken down into its component molecules; however, only three types of molecules yield energy that can be converted to ATP and used by cells. These energy-producing molecules are the macronutrients: carbohydrates, proteins, and fats. Most foods contain a variety of these compounds, each of which has specific uses by cells in the human body.

Anabolism and Catabolism

Cells are tiny machines that are constantly breaking down molecules and building new ones as they are needed. This overall process of breaking down and rebuilding of molecules is called metabolism. Anabolism is the process of assembling the monomers or building blocks of different molecules into a finished end product. This process is endergonic, meaning that it absorbs or requires energy. The other half of the energy cycle is catabolism, where larger molecules, such as carbohydrates, fats, and proteins, are broken down to release energy (therefore making it an exergonic process) and raw products necessary for anabolism. Both energy and these molecular building blocks are obtained through our diet and are absolutely vital components to our survival (McArdle et al. 2006).

Carbohydrates

Carbohydrates are the primary source of energy for animals. Carbohydrates are built and converted from the simple sugar glucose, which is synthesized by plants in the process of photosynthesis. Plant cells contain a specialized organelle called the chloroplast, which uses the sun's light energy to break and reform bonds, rearranging the atoms in carbon dioxide and water to create glucose and oxygen as a waste product. These carbohydrates are broken down in digestion and used almost exclusively for energy, for both immediate and storage purposes.

Monosaccharides, meaning single sugar, are the building blocks of carbohydrates. Carbohydrates are broadly classified into simple (sugars) and complex (starches, glycogen, and fiber) molecules. Monosaccharides (mono- meaning one or single, saccharide meaning sugar) are made of carbon, hydrogen, and oxygen molecules in a ratio of 1:2:1, and form long chains or rings. Glucose, galactose, and fructose are all important monosaccharides. Glucose is the most abundant in nature, but it generally does not exist by itself; rather it combines with other monosaccharides to form more complex molecules. Galactose also does not generally occur alone but is a component (along with glucose) of the disaccharide lactose. Fructose is the sweetest natural sugar and is found in fruits and vegetables. Often we now see sugar alcohols listed under carbohydrates on food labels. These are a modified form of monosaccharides where the aldehyde group is reduced to a hydroxyl group. The most common of these is sorbitol, a reduction of glucose. Sugar alcohols are not well absorbed in the digestive tract and therefore have a reduced effect on blood sugar, making them ideal for sweets formulated for diabetics. These compounds are still metabolized as fuel but yield about half the energy of the other monosaccharides.

When two monosaccharides bond together they connect with a glycoside bond and form a disaccharide (meaning two sugars). The two join through a condensation reaction, meaning that water is lost as a result of the bond being formed. Lactose is the sugar that is found in milk and consists of a glucose bound to a galactose. Table sugar, the kind isolated from sugar cane or beets, is sucrose: one glucose bound to one fructose. Maltose consists of two glucose molecules and does not commonly occur in plants, but is a product of starch digestion in animals (Bender 2007).

When more than two monosaccharides are linked together, they are classified as a polysaccharide, or a complex carbohydrate. Starches are polymers of glucose that are synthesized as carbohydrate storage in plants. About 20-25% of plant starches occur as amylose, a straight chain of glucose molecules bound by glycoside bonds. The remaining percentage is predominantly amylopectin, which has a branched structure. Animals store glucose in a different branched polysaccharide structure called glycogen. As mentioned in the beginning of the section, it is crucial that animals have access to energy in both immediate and stored capacities. When animals are consuming and breaking down food, the liver links together glucose molecules and synthesizes glycogen, and similarly breaks it down in times of fasting. Other polysaccharides include soluble and insoluble plant fibers (Thompson and Manore 2005).

Proteins

Though proteins can yield energy like carbohydrates, they are not generally utilized in that capacity. Instead, their most important roles are in cell growth, repair, and maintenance, where they act as enzymes and hormones, to maintain fluid, electrolyte, and acid-base balance, uphold the immune system, among other functions. Unlike carbohydrates, proteins contain nitrogen as well as carbon, hydrogen, and oxygen. Proteins are built from different combinations of the 20 amino acids, allowing for a nearly infinite variety of combinations and chain lengths. Each amino acid has a central carbon with an amine group (NH_2) bound to one side, a hydrogen (H) on another, a carboxyl group (COOH) opposite the amine group, and a fourth group called the side chain. The side chain consists of a combination of atoms that is unique to each amino acid. Amino acids link together with peptide bonds to form proteins, which are constructed by the ribosomes in the cytoplasm of the cell. The construction of proteins is entirely regulated by the DNA of each cell; this genetic code provides the order in which the amino acids are to be linked for each protein. When a protein is released, it folds into a secondary, tertiary and sometimes quaternary structure, which creates the shape that is specific to its function. Therefore, the primary purpose for consuming protein is to provide the raw materials necessary to construct new proteins (Thompson and Manore 2005).

Lipids

Despite their generally negative association, lipids, or fats, as they are more commonly known in reference to food, are crucial molecules to our diet. The fats that we eat provide energy, especially at rest or during fasting. They also have the ability to store excess energy efficiently, provide essential fatty acids that have various cellular functions, enable the transport of fat-soluble vitamins, and maintain cell function and provide protection to the body. There are three different types of fat commonly found in our foods: triglycerides, phospholipids, and sterols, though nearly all (95%) of the fat that we consume is of the triglyceride type. Like carbohydrates, triglycerides consist of carbon, hydrogen, and oxygen. These atoms are arranged into three fatty acid tails, each consisting of long chains of carbons and hydrogens, attached to a three-carbon glycerol backbone. Triglycerides vary depending on different characteristics of the fatty acid chains: length, level of saturation, and their shape. Short-chain fatty acids contain fewer than six carbons, medium-chain between six and twelve carbons, and chains of a greater length are classified as long-chain fatty acids. If the fatty acid tails have no double bonds, then they contain the maximum number of hydrogen molecules, making them saturated fatty acids. Saturation, or complete carriage of hydrogen, also gives these fatty tails a straight shape. Monounsaturated fatty acids have a kinked shape due to the presence of a double bond—and two less hydrogen atoms—in one of the tails. Polyunsaturated fatty acids have more than one double bond, giving them a kinked shape as well. In the chemical structure of both these unsaturated fatty acids, the hydrogen bonds are in *cis* formation, creating a "C" shape with both hydrogens on the same side of the bond. Nearly all naturally existing unsaturated fatty acids take this shape, but in recent years food scientists have accidentally created fatty acids in the *trans* formation, where the hydrogens are on opposite sides of the bond. This was an attempt to make a healthier solid fat (such as margarine as a substitute for butter) by adding hydrogens to unsaturated oils. Unsaturated fats can also partially convert to *trans* fats at high temperatures, such as when deep-frying foods, though this occurs at a very low rate (Reeves, 2003).

Phospholipids are another important type of lipid, though the amounts that we consume are small. These fats are important because they contain a phosphate group attached to the glycerol, in place of one of the three fatty acids of the triglyceride, that makes them soluble in water. The other structural difference is that they have only two fatty acid tails instead of three. These fats transport substances in our bloodstream and form cell membranes. Because they can be synthesized by the body, they are not necessary in the diet. The third type of lipid, sterols, has an entirely different structure and instead has multiple rings. They are found in plants and animal food sources, but can also be synthesized by the body. An important and well-known sterol is cholesterol, which despite its negative connotation, is vital for life (Thompson and Manore 2005). Cholesterol in cell membranes enhances their fluidity and function; the body uses cholesterol as the starting material for synthesis of many hormones that are needed for regulation of body processes.

Digestion

Organization and Organs of the Digestive Tract

These macronutrients—protein, carbohydrate, and fat—exist in different combinations in the foods that we eat. In order for the body to have access to them for energy and raw materials, they must be broken down into smaller molecules and absorbed by the digestive system. This digestive systems contains a sequential set of organs, in linked in a path is as follows (in order): mouth, esophagus, stomach, small intestine, large intestine, and the rectum. Digestion is both mechanical and chemical, as the liver and pancreas release enzymes, acids, and salts to break bonds between the monomers of the macronutrients.

Digestion of some macronutrients begins in the mouth, which also mechanically breaks down chunks of food into smaller, more digestible fragments. This food moves through a muscular tube called the esophagus down to the stomach, where it combines with a variety of substances to continue digestion. In addition, the stomach mechanically contracts to grind and mix the food. It then moves to the small intestine, where more fluids enter and the digestive process continues. At this point, many of the molecules are small enough to be absorbed and are taken up through the villi along the intestinal walls. These villi greatly increase the surface area available for absorption, allowing more nutrients to enter the bloodstream at a greater rate. Whatever food remains at the end of the small intestine is not absorbed or digested and enters the large intestine, where the water is absorbed. Undigested food, including fiber, may be fermented by beneficial bacteria; any remaining substances leave the body through the rectum as solid waste (Damon et al. 2007).

Carbohydrate Digestion

The goal of carbohydrate digestion is to break polysaccharides and disaccharides (starches and sugars in the foods that we eat) into monosaccharides that can be converted to glucose and used for energy release or storage. Carbohydrate digestion begins in the mouth, where the enzyme amylase in the saliva breaks starch into smaller molecules. These carbohydrates enter the stomach, where they combine with hydrochloric acid, deactivating the amylase and pausing carbohydrate digestion. The pancreas secretes pancreatic amylase into the small intestine, digesting any remaining starch into the disaccharide maltose. At this point, all carbohydrates have been broken down into disaccharides: the disaccharides are cleaved by three substrate-specific enzymes, maltase, sucrase, and lactase into monosaccharides, which are absorbed into the bloodstream. In order to be used for energy, galactose and fructose must travel to the liver to be converted to glucose (Thompson and Manore 2005). As glucose enters the bloodstream, and the concentration of glucose in the blood rises, cells within the pancreas release the hormone insulin. Insulin lowers the blood glucose level by promoting the uptake of glucose into the cells, including into the liver for storage as glycogen. It is crucial to the body that the glucose level remain relatively constant; a concentration that is too high can damage blood vessels, and a low concentration will deprive cells—particularly cells of the brain—of the sugars necessary to generate ATP, the fuel of cellular activity (Campbell and Reece 2008).

Protein Digestion

As explained earlier, proteins are more important to the body in terms of their building blocks than energy. During digestion, proteins are broken down into their individual amino acids, which are then used to create new proteins. Protein digestion begins in the stomach, where the hydrochloric acid denatures the proteins and activates the enzyme pepsin, which breaks proteins into smaller polypeptide chains and single amino acids. When they enter the small intestine, the pancreas secretes protease enzymes to break larger polypeptides into smaller peptide chains and single amino acids, which are then absorbed into the blood stream and distributed to the liver and other cells as needed (Thompson and Manore 2005).

Fat Digestion

Because fats are not water soluble, they must be digested, absorbed, and transported differently than the other macronutrients. Fats reach the stomach intact, where they are mixed and broken into smaller droplets. The gallbladder releases bile into the small intestine where it assists in the breakup of larger fat molecules into tiny drops. The pancreas secretes enzymes to separate the fatty acid tails from each other and from the glycerol backbone. Small compounds called micelles form by trapping the fatty acids and monoglycerides in a bubble of bile and phospholipids. This allows the insoluble fats to be absorbed and transported out of the small intestine and into mucosal cells. They are then repackaged and transported in the bloodstream by structures called chylomicrons, which are a combination of lipids and lipoprotein. Fat can then be used for immediate energy, stored in adipose tissue for later energy use, or used to make lipid-containing compounds (Thompson and Manore 2005).

Vitamins, Minerals, and Water

In addition to carbohydrates, proteins, and fats, food also contains three other classes of compounds that are vital to our existence. Unlike the three macronutrients mentioned above, water, vitamins, and minerals do not contain energy. Water is contained in most foods and is necessary to maintain hydration in and between cells throughout the body. Minerals are inorganic ions; they do not contain carbon and are not made by living organisms so must instead be consumed. Their original sources are typically soil, rocks, and sea water, but are then taken up by plants or animals and carried through the food web to other consumers such as humans. On the other hand, vitamins are synthesized in living organisms and contain carbon, making them organic compounds. Vitamins are molecules that needed for life processes—for example, vitamin C is needed for metabolism in humans—but that the body is not capable of producing on its own. Therefore, vitamins are essential in the diet (Damon et al. 2007).

Energy Balance

Caloric and Nutrient Requirements

As explained earlier, humans require energy from external sources (food), as we cannot create it ourselves. Even at rest, our cells have a continual need for energy and so it is therefore vital that we have a system that allows us to consume, digest and absorb, and save energy from food. Though we generally associate the need for energy with voluntary activity such as movement and exercise, the majority (two thirds) of the energy used each day is for the body's internal functions and maintenance.

The amount of energy available in food is measured in kilocalories. One kilocalorie is the amount of heat required to raise one kilogram of water by one degree Celsius. Given that the average human uses between two and three thousand kilocalories each day, we require a great deal of energy in order to function. Each of the three macronutrients discussed earlier contains a certain amount of energy that may be released by the cells. Each gram of carbohydrates contains four kilocalories, each gram of protein four kilocalories, and each gram of fat, nine kilocalories. Fat is clearly a much denser form of energy than either carbohydrates or proteins. Structurally, fats have a higher ratio of carbon-hydrogen bonds to carbon-oxygen bonds, which can store more energy. Alcohol actually contains kilocalories as well (seven per gram), but because of its potentially toxic qualities and lack of nutritional value, it should be avoided as an energy source (Damon et al. 2007).

The amount of energy (number of kilocalories) used by a human each day varies greatly depending on factors such as age, gender, muscle and fat mass, and activity level. The rate of energy usage at rest is called the basal metabolic rate (BMR). Larger bodies have a higher BMR because there contain a greater amount of metabolically active cells. BMR declines with age because of the natural transgression of decreased muscle tissue and replacement with adipose (fat) tissue. Because muscle contains a much higher number of metabolically active cells, muscle uses more energy than fat tissue. Energy usage depends on gender because, on average, compared to men, women have a higher percent of adipose tissue and a lower percent of muscular body tissue, and therefore a lower BMR as well (Bender 2007).

In addition to having a certain requirement for energy consumption, humans also have needs for certain vitamins and minerals. Specific recommended values can be found through the USDA's Food and Nutrition Information Center, available online at http://fnic.nal.usda.gov/. Vitamins are tiny but important organic molecules that serve a variety of functions in the body, often as coenzymes in chemical reactions. There are 13 essential vitamins, essential because they cannot be synthesized by our bodies. Minerals are inorganic elements that have many functions. Vitamins and minerals occur naturally in many of our foods, especially in fruits and vegetables (Campbell and Reece 2008).

Maintaining a healthy weight is crucial to health. Being underweight is often a sign of another condition (such as illness) that may be detrimental rather than being unhealthy in and of itself. Being overweight or obese, however, pose serious health risks, including heart disease, stroke, high blood pressure, high cholesterol, certain cancers, diabetes, arthritis, infertility, gallstones, sleep apnea, and adult-onset asthma (Willett 2005).

Weight Gain and Loss

Despite the thousands of diets and weight-altering products on the market, weight change is a very simple concept. To maintain a certain body mass, the number of kilocalories consumed should be equal to the number of kilocalories used, meaning that the amount of energy taken in is the same as the amount of energy expended. The body is designed to store energy when excess is available, so if absorbed food molecules are not used, they are converted to fat and deposited throughout the body. This process occurs regardless of what type of molecule is in excess. Surplus kilocalories from carbohydrates, protein, fat, and alcohol can all be converted to fat. If too few kilocalories are consumed, or too many kilocalories are used, the body does not have enough energy and must rely upon these fat stores for energy. This results in an overall loss of mass, which may be achieved through either modifying the diet to consume fewer kilocalories, exercising more to use a greater number of kilocalories, or a combination thereof. It is important to ensure that the net kilocalories consumed is adequate to meet the BMR requirements, or over time the body will be forced to use muscle or other tissues to fuel its basic processes (Willett 2005).

Body Mass Index and Healthy Weight

The body mass index (BMI) is calculated from the ratio of height to weight and is a general indication of appropriate body mass. BMI may be calculated as follows: BMI = (mass in kg) / (height in m)^2. In American units, the conversion is BMI = [(weight in lbs) x 703)] / (height in in)^2. A BMI under 18.5 indicates that the individual is underweight, 18.5 to 24.9, normal weight, 25.0 to 29.9, overweight, and 30.0 or above obese. While the BMI system is generally accurate, it does not take into account the type of mass that is present. A cubic centimeter of muscle weighs more than a cubic centimeter of fat, so a person with a high concentration of muscle, such as a weightlifter or sprinter, can have a high BMI but be healthy, because of their low body fat percentage (Damon et al. 2007).

Energy Pathways and Food Metabolism

Energy Pathways

There is no single method in which cells produces energy. Each cell of any organism produces energy using methods that depend on the types of organelles and enzymes they possess. Human cells are capable of breaking down any of the three macronutrients; the mode of breakdown in a cell depends on the type of activity the energy is needed for and whether or not oxygen is present in the environment. If energy is needed immediately, such as for an explosive motion, or oxygen is not present, the cell undergoes lactic acid fermentation. If time is less of a factor, and oxygen is available, the cell follows cellular respiration instead. Both pathways begin with a process called glycolysis. While carbohydrates are the preferred fuel of the body, fat may also be metabolized with a few extra steps, and proteins as well.

Glycolysis

Glycolysis is the first step of both fermentation and respiration when glucose is the molecule being metabolized. This process occurs in the cytoplasm rather than in a specialized organelle, and so is possible for even the simplest of organisms. Glycolysis produces energy quickly and without oxygen, but is inefficient and wastes much of the energy available in glucose's bonds.

To start glycolysis, glucose is first phosphorylated by two ATP molecules, which the cell must invest. The phosphorylated glucose is then split into two three-carbon molecules, each of which is phosphorylated at one carbon. Each of these is then oxidized by a cellular co-factor called NAD^+ and the energy from the reaction phosphorylates another carbon. Enzymes then remove the phosphates so that they can be added to ADP molecules to make ATP. There are two phosphates on each of the three-carbon molecules, so two ATP are produced from each one. This results in the production of four ATP, however, since two ATP were needed to begin the reaction, glycolysis nets only two ATP per glucose molecule. Two NADH molecules, an electron and energy carrier, are also produced in the reaction. In addition, two pyruvate molecules are produced for each glucose.

The entire glycolysis process is controlled by a series of enzymes. To regulate the amount of ATP being produced, feedback inhibition will block the first level of the pathway when ATP levels are high in the cell. Pyruvate cannot be stored in the cell and must continue down one of two energy pathways. In human cells, if oxygen is available, then the pyruvate will enter the mitochondria and begin the process of cellular respiration. However, if there is insufficient oxygen, the cell is forced to accept a smaller ATP yield and go through fermentation (Damon et al. 2007).

Fermentation

Fermentation, like glycolysis, occurs in the cytoplasm, and proceeds anaerobically. It does not produce any energy, but it does regenerate the NAD^+ molecules needed for another round of glycolysis. In the fermentation reaction, pyruvate is converted to lactate, another three-carbon molecule, and NADH is oxidized to NAD^+ . The reaction is reversible and if oxygen becomes available, lactate may be converted back into pyruvate for use in cellular respiration.

Respiration

When oxygen is present, pyruvate is actively transported into the mitochondria. Each pyruvate (3C or three carbons) first loses a carbon dioxide molecule and combines with the molecule called coenzyme A. This two-carbon molecule is also called acetyl CoA. If ATP levels are low, acetyl CoA enters the Krebs cycle in the matrix of the mitochondria to begin the energy release process. Acetyl CoA combines with a four-carbon molecule called oxaloacetate, creating citrate (6C). Coenzyme A is then released and is free to combine with another pyruvate.

Citrate is oxidized by NAD^+ and releases a molecule of carbon dioxide, making it a five-carbon compound.

This compound is then oxidized again and releases another carbon dioxide molecule. The resulting compound is the same four-carbon oxaloacetate that was present at the beginning of the cycle. This cycle produces two ATP, six molecules of the electron carrier NADH, two molecules of another electron carrier, $FADH_2$, and four molecules of CO_2, which are released as waste.

NADH and $FADH_2$ are needed to provide electrons for the next step of respiration, the electron transport chain. This occurs in the inner membrane of the mitochondria, where electrons are passed through a series of oxidation-reduction reactions. The final electron acceptor is the highly electronegative oxygen, which is what makes this process aerobic (Damon et al. 2007).

Chemiosmosis is the final part of respiration, in which a large amount of ATP is produced. The reactions of the electron transport chain cause a build-up of hydrogen ions in the intermembrane space, creating a concentration gradient. The flow of hydrogens through the ATP synthase, an enzyme embedded in the intermembrane, creates the energy necessary to combine ADP and phosphate into ATP (Campbell and Reece 2008).

Overall, the process of cellular respiration may be represented by the following equation: $C_6H_{12}O_6 + 6H_2O \longrightarrow 6CO_2 + 6H_2O$ + energy. Each molecule of glucose can create 36 ATP through respiration, two of which are produced in glycolysis, two in the Krebs cycle, and the rest from the electron transport chain. If oxygen is not available, only the two ATP from glycolysis are released and the rest of the energy store in the glucose molecule is wasted.

Energy from Non-carbohydrates

Proteins and fats contain energy as well. Even though carbohydrates are the body's preferred energy source, these other two macronutrients can be converted into metabolizable forms. Fats are actually an excellent energy source and yield more than twice as much ATP per gram than carbohydrates. After fats are split into glycerol and fatty acids, the glycerol is converted to an intermediate in glycolysis, where it can continue to be metabolized in the same manner as glucose. The majority of the energy in fats is contained within the carbon hydrogen bonds of the fatty acid tails, which are oxidized into two-carbon fragments that enter respiration at the Krebs cycle as acetyl CoA.

Proteins are not a preferred energy source, as the cell typically needs the amino acids to build other proteins. If necessary, however, the amino acids from a digested protein can be deaminated, meaning that the amine group (NH_3) is removed. The deaminated amino acid is essentially a carbon backbone and can be converted to pyruvate or acetyl CoA and processed through glycolysis and respiration (Campbell and Reece 2008).

Power vs. Efficiency

Because it is so much more efficient in terms of energy production, the cell will perform respiration over fermentation when at all possible. However, under some circumstances, fermentation is necessary. If blood does not circulate to a tissue fast enough—such as in a muscle that is producing short, explosive activity—the cells must rely on glycolysis and fermentation to produce energy, even though it comes at a cost. When oxygen is available, cells metabolize carbohydrates in the blood for energy, but will also break down fats for fasting or for extended activity.

Long-Term Effects of Food

Consequences of Diet

Though we often don't pay much attention to it, the foods and beverages that we put into our mouths have a great impact on our bodies. The section above explains the short-term effects of food—energy and building blocks. However, the choices we make with our nutrition have a cumulative effect on the systems in our bodies, increasing the risk for the conditions listed below. Some of the information listed below will be covered in lecture in class, and the rest will be done through independent research for the student webpage project.

Nutrient Deficiencies

Eating a balanced diet will generally provide all the nutrients necessary for cellular function. However, sometimes the diet may be insufficient in one or more ways. This is especially a problem in developing countries, though with the American diet becoming increasingly high in processed foods and fat, it may be an issue for us as well.

Some of the more common deficiencies (and their symptoms) include: vitamin D (rickets), thiamin (beriberi), niacin (pellagra), vitamin C (scurvy), calcium (osteoporosis), iodine (goiter), and iron (anemia). Fruits and vegetables are excellent sources of many of these micronutrients (Bender 2007).

Obesity

As discussed earlier, a surplus of energy (kilocalories) will be stored as fat for later use. While this was useful in our evolution, when food was abundant at times and scarce at others, it has now become a major health issue. For most Americans, food is always abundant. More than two-thirds of Americans are now overweight or obese, which greatly increases the risk of several conditions. The major causes of death associated with obesity are certain types of cancer (breast, prostate, colon), atherosclerosis, coronary heart disease, high blood pressure, and stroke, type II diabetes, and respiratory diseases. Obesity obviously occurs because of an excess of ingested kilocalories over a period of time, and is becoming increasingly common in children, who are also then likely to be overweight or obese as adults (Bender 2007).

Diets high in kilocalories (often from excess sugar and/or fat), along with a sedentary lifestyle, are mostly to blame for the increase in overweight and obese individuals. Our diets now consist of more processed foods, restaurant foods (especially fast food), snacks, and sugared beverages than in the past. This results in an overall increase in energy consumption. As we have become busier, our diets are determined based on cost and convenience rather than on nutrition. In addition, jobs have shifted away from manual labor and towards a higher number of seated positions. Many people do not get much physical exercise, and recess and gym have been cut out of many children's school day. These two factors, an increase in the amount of energy available and a decrease in the energy used have led to what is now considered to be an epidemic of obesity.

Metabolic Syndrome

Recently, doctors have begun to cluster certain metabolic risk factors together under the label metabolic syndrome. These risk factors are: high blood pressure, insulin resistance (where cells are no longer responsive to the insulin), high LDL and low HDL cholesterol, high fasting glucose, obesity, especially in the central abdominal region, and high triglycerides. People with several of these factors are at a high risk for heart disease and type II diabetes (Bender 2007).

Diabetes

In addition to the obesity epidemic, there has also been a huge increase in the number of people developing diabetes type II (T2DM). Though it was originally referred to as adult or late-onset diabetes, this form of the disease is now commonly diagnosed in children and young adults as well. In this form of diabetes, the body receptors are resistant or no longer sensitive to insulin. The risk factors for this type of diabetes include being obese, having a family history, going through puberty, and being a minority. Obesity appears to be the greatest risk factor, especially for children and teenagers. When the receptors become resistant to insulin, the pancreas responds by secreting even greater amounts to keep the blood glucose low. This overstimulation has a cost, however, and even these higher levels of insulin become ineffective and blood glucose levels rise. After time, the beta cells in the pancreas that secrete insulin begin to lose functionality; this is the onset of type II diabetes (Dabelea and Klingensmith 2008).

Diabetes itself is not immediately life-threatening, but can lead to severe conditions such as nerve disease, kidney malfunction, eye damage, high blood pressure, and an increased risk of heart attack or stroke. Without treatment, it can be a fatal disease because when blood glucose levels are high, the energy stored within the sugars is not reaching the cells. Fortunately, type II diabetes is treatable without insulin most of the time. It can usually be controlled with the implementation of a healthy, well-balanced diet, exercise, and weight-loss program (Damon et al. 2007).

High Cholesterol and Atherosclerosis

It is not only the number of kilocalories that we consume, but also the type of food. Foods that are high in saturated fat, trans fats, and cholesterol can all contribute to the development of heart disease. If a person's diet is high in these types of lipids, they will begin to accumulate in the arteries of the heart, forming a hard plaque and a condition called atherosclerosis. Over time, these deposits may become large enough to trap blood clots, causing a heart attack or stroke (American Heart Association 2008).

It is therefore important to limit the amount of saturated and trans fats, as well as cholesterol, in the diet. While cholesterol is an important molecule with a role in the cell membrane and production of hormones and steroids, the body can synthesize adequate cholesterol without dietary consumption.

Classroom Activities

Sources of Energy: Building and Breaking Down Food Molecules

Purpose

Students will visualize the structure of the macromolecules and see how they are put together (such as two monosaccharides to create a disaccharide), as well as how they can be broken apart (such as the separation of the glycerol head from the fatty acid tail).

Materials

1 molecular model kit for each pair of students

Diagrams of carbohydrates, fats, and proteins

Directions

Briefly demonstrate how to construct molecules from the molecular kit. It may be valuable to mention that the colors of the molecules are important because the carbon should have four holes corresponding to its ability to form four bonds, the hydrogen one to form one bond, etc. Then provide molecular diagrams of glucose, oleic acid (a fatty acid found in olive oil), and several amino acids bound together (such as glycine and alanine, since they are small). Since proteins are generally more than fifty amino acids in length, it would be nearly impossible to construct a protein in a single class period.

Have the students work together to create two glucose molecules first, then have them join these molecules to make maltose by removing an oxygen and hydrogen from a group on one of the glucose molecules, removing a hydrogen from another, and then joining the two together at the oxygen. The two hydrogens and single oxygen should be bound together to show the release of water from the reaction (condensation). This may be reversed to show the breakdown (hydrolysis).

Next, students should construct oleic acid. Have them construct the glycerol head and then the three fatty acid tails. It may be necessary to shorten the tails if there are not enough materials. Then have them show a series of three hydrolysis reactions to separate the fatty acid tails from the glycerol head. At the attachment point for each fatty acid, add a water molecule so that both the glycerol and the fatty acid has a hydroxyl group where the bond was. The end product should be a glycerol molecule and three separate fatty acid tails. This may be reversed also, to show the formation reactions.

Finally, have the students construct the amino acids alanine and glycine according to the diagrams. They should then link them with a peptide bond; this is also a condensation reaction. Students should remove a hydroxyl group (OH) from one amino acid and a hydrogen to another and then connect the nitrogen of the amine group to the carbon of the former carboxyl group. Remember to have them form water from the hydroxyl and hydrogen that is lost from the amino acids. This will create a dipeptide, one tiny part of a large protein.

Evaluation

Students will show the instructor their molecules and explain the reactions that produced them.

Digestion: Open Inquiry Digestion Lab

Purpose

Students will explore digestion of the different macromolecules through a loosely structured inquiry lab. They will use different digesting agents to visualize and collect data on the breakdown of different carbohydrates, proteins, and fats.

Materials

amylase

pepsin

lipase

hydrocholoric acid (this material and the first three are available through Carolina Biological Company)

whole grain bread (no refined flour)

white bread

hard-boiled egg white

canned tuna

olive oil

butter

test tubes

pipettes

Directions

This is a student-designed inquiry lab, so directions should be brief. Students will be provided with a variety of carbohydrates (two types of bread), proteins (two animal-based sources), and fats (one plant and one animal source). They may bring in additional sources or make requests if they wish. They will also be provided different digestive agents (amylase, pepsin, lipase, hydrochloric acid). Instruct students to design a lab where they can both qualitatively and quantitatively observe and record the digestion of different types of food. Students should take a day to decide on materials and procedure, then take one to two days further to complete the experiment. They will be expected to create a full lab report, including an introduction with background information, hypothesis, materials, procedure, data, analysis, and conclusion.

Evaluation

The lab report will be analyzed on a standard IB laboratory-grading rubric.

Energy Balance: Calculating BMI

Purpose

Students will learn how to calculate the body mass index so that they can have a better understanding whether or not they have a healthy weight. They will also learn that different weights are appropriate for different people and body types, and will understand the risks of being overweight or obese.

Materials

sample students heights and weights (Appendix 1)

calculator

Directions

Students will be given 5 sample student descriptions, including information on their lifestyle as well as their height and weight. Students will then calculate the BMI for each as follows: BMI = [(weight in lbs) x 703)] / (height in in) ^{2} Students will also provide suggestions on how to improve the sample students' diets. The assumption is that students will be able to make comparisons about their own BMI without asking them to directly calculate it and therefore being more sensitive to the issue of students' weight.

Evaluation

Students will turn in a completed sheet with the BMIs and suggestions recorded on it.

Long-Term Effects of Food: Health Complication Website Project

Purpose

Students will investigate different health conditions that are caused by the choices we make in our diets. This will stimulate thought and discussion on what we can do to make better food choices and how we can avoid these conditions. Students will also broadcast the information they have learned by creating webpages that will be linked to the class webpage. Parents and other students will be encouraged to read the information on these pages in order to make better and more informed nutrition choices.

Materials

laptop computers or computer lab access

access to class website (such as http://pages.google.com)

Directions

Students may choose one condition from the following: nutrient deficiencies (one specifically, such as vitamin B_6 deficiency), obesity, metabolic syndrome, diabetes, and high cholesterol and atherosclerosis. They will then spend two days researching their topic in class using the laptop computers and will be required to come up with the following information: what causes the disorder, what nutrition choices can help prevent the disorder, the effects of the disorder on the body, what the risk factors are (if any, besides diet), treatments or cures, current research, and resources for people at risk. Students should be careful to document exactly where they found their information and use several reliable sources. Students will then provide the information to the instructor, who will load the pages onto the class page, proving useful and applicable health information to other students, instructors, parents, members of the community, as well as general web users.

Evaluation

Students will be assessed in four areas on a rubric: completion, scientific accuracy, neatness and creativity, and documentation (sources).

Appendices

Appendix 1: Sample Student Descriptions (for "Energy Balance: Calculating BMIs")

Student 1: Amelia is fourteen years old and is 5'2" and weighs 145 pounds. Amelia usually skips breakfast, eats the school lunch, and snacks on hot chips and pop after school. In the evenings for dinner she usually eats at home, and her parents prepare traditional Mexican dishes, such as tacos or tamales.

Student 2: Darryl is eighteen years old and is 6'1 and weighs 200 pounds. He usually has cereal and milk for breakfast, has a can of juice and bag of chips for lunch, and grabs a double cheeseburger, fries, and soda after school with his friends. His mother works late at night so he usually eats frozen pizza for dinner, and cookies and ice cream for dessert.

Student 3: Sarah is fifteen years old and is 5'8" and weighs 112 pounds. She is very self-conscious about her weight and watches what she eats very carefully. She just drinks coffee for breakfast, eats an apple for lunch, and a small serving of dinner, usually chicken breast, rice, and vegetables.

Student 4: Nidia is seventeen years old and is 5'2" and weighs 120 pounds. She eats whole wheat toast with jam for breakfast, a sandwich and fruit for lunch, and has milk and cereal for a snack. For dinner, her grandfather usually prepares chicken or turkey, potatoes, and vegetables or salad. Sometimes Sharyn has a cookie or two for dessert.

Student 5: Jorge is fourteen years old and is 5'5" and weighs 175 pounds. For breakfast, his mother prepares scrambled eggs with cheese and toast. He eats the school lunch every day, usually pizza and fries, with a bottle of Gatorade, and often grabs a milkshake on the way home. Both his parents work, and usually grab take-out on the way home for dinner.

Appendix II: Implementing District Standards

This unit meets the following Illinois State Board of Education standards for high school (upper grades) science:

STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

11.A.5a Formulate hypotheses referencing prior research and knowledge.

11.A.5b Design procedures to test the selected hypotheses.

11.A.5c Conduct systematic controlled experi¬ments to test the selected hypotheses.

11.A.5d Apply statistical methods to make predictions and to test the accuracy of results.

11.A.5e Report, display and defend the results of investigations to audiences that may include professionals and technical experts.

STATE GOAL 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

12.A.5a Explain changes within cells and organisms in response to stimuli and changing environmental conditions (e.g., homeostasis, dormancy).

Appendix III: Implementing International Baccalaureate Standards

This unit meets the following objectives for International Baccalaureate Biology, Standard Level:

3.2: Carbohydrates, Proteins, and Lipids

-Distinguish between organic and inorganic compounds.

-Identify amino acids, glucose, ribose and fatty acids from diagrams showing their structure.

-List three examples each of monosaccharides, disaccharides and polysaccharides.

-State one function of glucose, lactose and glycogen in animals, and of fructose, sucrose and cellulose in plants.

-Outline the role of condensation and hydrolysis in the relationships between monosaccharides, disaccharides and polysaccharides; between fatty acids, glycerol and triglycerides; and between amino acids and polypeptides.

-State three functions of lipids.

-Compare the use of carbohydrates and lipids in energy storage.

A1: Components of Human Diet

-Define nutrient.

-List the type of nutrients that are essential in the human diet, including amino acids, fatty acids, minerals, vitamins and water.

-State that non-essential amino acids can be synthesized in the body from other nutrients.

-Outline the consequences of protein deficiency malnutrition.

-Outline the variation in the molecular structure of fatty acids, including saturated fatty acids, cis and trans unsaturated fatty acids, monounsaturated and polyunsaturated fatty acids.

-Evaluate the health consequences of diets rich in the different types of fatty acid.

-Distinguish between minerals and vitamins in terms of their chemical nature.

-Discuss the amount of vitamin C that an adult should consume per day, including the level needed to prevent scurvy, claims that higher intakes give protection against upper respiratory tract infections, and the danger of rebound malnutrition.

-List the sources of vitamin D in human diets.

-Explain the benefits of artificial dietary supplementation as a means of preventing malnutrition, using iodine as an example.

-Outline the importance of fibre as a component of a balanced diet.

6.1 Digestion

-Explain why digestion of large food molecules is essential.

-Explain the need for enzymes in digestion.

-State the source, substrate, products and optimum pH conditions for one amylase, one protease and one lipase.

-Draw and label a diagram of the digestive system.

-Outline the function of the stomach, small intestine and large intestine.

-Distinguish between absorption and assimilation.

-Explain how the structure of the villus is related to its role in absorption and transport of the products of digestion.

A2: Energy in Human Diets

-Compare the energy content per 100 g of carbohydrate, fat and protein.

-Compare the main dietary sources of energy in different ethnic groups.

-Explain the possible health consequences of diets rich in carbohydrates, fats and proteins.

-Outline the function of the appetite control centre in the brain.

-Calculate body mass index (BMI) from the body mass and height of a person.

-Distinguish, using the body mass index, between being underweight, normal weight, overweight and obese.

-Outline the reasons for increasing rates of clinical obesity in some countries, including availability of cheap high-energy foods, large portion sizes, increasing use of vehicles for transport, and a change from active to sedentary occupations.

-Outline the consequences of anorexia nervosa.

3.7: Cell Respiration

-Define cell respiration.

-State that, in cell respiration, glucose in the cytoplasm is broken down by glycolysis into pyruvate, with a small yield of ATP.

-Explain that, during anaerobic cell respiration, pyruvate can be converted in the cytoplasm into lactate, or ethanol and carbon dioxide, with no further yield of ATP.

-Explain that, during aerobic cell respiration, pyruvate can be broken down in the mitochondrion into carbon dioxide and water with a large yield of ATP.

3.8: Photosynthesis

-State that photosynthesis involves the conversion of light energy into chemical energy.

-State that light energy is used to produce ATP, and to split water molecules (photolysis) to form oxygen and hydrogen.

A3: Special Topics in Human Nutrition

-Outline the causes and symptoms of type II diabetes.

-Explain the dietary advice that should be given to a patient who has developed type II diabetes.

-Evaluate the benefits of reducing dietary cholesterol in lowering the risk of coronary heart disease.

Teacher Resources

Bender, David A. *Introduction to nutrition and metabolism.* 2007. London: CRC Press.

This text contains useful diagrams, as well as a very thorough explanation of the structure, synthesis, digestion, and metabolism of each of the macronutrients. It contains information in more depth than is necessary for student knowledge but will be useful to the instructor to answer questions.

Campbell, Neil A., and Jane B. Reece. 2008. *Biology, 8 th edition.* San Francisco: Benjamin Cummings, Inc.

The text and its supporting resources will be the foundation of information for the unit.

Student Resources

Campbell, Neil A., and Jane B. Reece. 2008. *Biology, 8 th edition.* San Francisco: Benjamin Cummings, Inc.

Students will rely heavily on their text for background information, additional reading, and diagrams to further their understanding of the topics.

Pearson Education, Inc. 2008. The Biology Place. http://www.phschool.com/science/biology_place/index.html

This website will provide students with virtual labs and interactive demonstrations.

United States Department of Health and Human Services. 2008. Healthfinder. http://www.healthfinder.gov/

This government website is a good starting point for student research on their long-term effects website project.

References

American Heart Association, Inc. 2008. Atherosclerosis. http://www.americanheart.org/presenter.jhtml?identifier=4440

This site provides a description of what atherosclerosis is, what causes it and how it can be prevented, as well as helpful pictures and diagrams.

Bender, David A. *Introduction to nutrition and metabolism.* 2007. London: CRC Press.

This college text provides very detailed descriptions and diagrams of the various metabolism processes, as well on good background information on the macronutrients.

Boron, Walter F., and Emile L. Boulpaep. 2005. *Medical physiology: a molecular and cellular approach.* Philadelphia: Elsevier Saunders.

This text has some excellent diagrams, as well as thorough background information. A bit too technical for most uses, but a good reference to have.

Campbell, Neil A., and Jane B. Reece. 2007. *Biology, 8 th edition.* San Francisco: Benjamin Cummings, Inc.

This is the text that my class will be using. It is a good, solid standard biology text and an excellent reference with well-explained diagrams.

Dabelea, Dana, and Georgeanna J. Klingensmith, editors. 2008. *Epidimiology of pediatric and adolescent diabetes.* New York: Informa Healthcare, USA.

This source contained specific data on rates of diabetes as well as risk factors and the process through which Type II Diabetes develops.

Damon, Alan, Randy McGonegal, Patricia Totso, and William Ward. 2007. *Biology standard level.* Oxford: Heinemann International Literature and Textbooks.

This text closely follows the International Baccalaureate standards and provides clear information on the standards that matches these objectives.

McArdle, William D., Frank I. Katch, and Victor L. Katch. 2006. *Exercise physiology: energy, nutrition, and human performance.* Philadelphia: Lippincott Williams & Wilkins.

An excellent college text, this source contains many valuable diagrams that visualize the more complicated processes, such as the metabolism of non-carbohydrate molecules.

Reeves, Robert M. 2003. The skinny on trans fats. *The Washington Post,* August 30.

Thompson, Janice, and Melinda Manore. 2005. *Nutrition: an applied approach.* San Francisco: Benjamin Cummings, Inc.

This is another college text and contains clear information on the structure, function, and digestion of the macronutrients and specifications on vitamins and minerals.

Willett, Walter C. 2005. *Eat, drink, and be healthy.* New York: Free Press.

This source is a well-written and easy-to-read guide on general nutrition and healthy eating habits. It contains useful background research as well as a wealth of studies and data to support its statements.