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Eat to Live: The Connection between Food, Digestion and Diabetes

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Introduction

Everyday we make choices about what to eat. The choices we make are affected by cost, availability, culture and personal taste. Our choices are also influenced by our ideas about the nutritional value in foods. In today's society, we are constantly bombarded with the latest information about healthy nutrients and new diets. This information is continuously updated, often conflicting, and may be based on a single research study. It is not surprising that young people are confused about what they should eat, or apathetic to the recommendations, simply relying on the nutritional offerings that are convenient, cheap, tasty and similar to what their peers are choosing.

As a high-school biology teacher, a large part of my curriculum focuses on the major biomolecules that make up our bodies: carbohydrates, fats, protein and nucleic acids. These molecules, in large part, come from or are synthesized from the food that we eat. Yet, students have difficulty realizing the connection between these chemical compounds, their diet and the composition of their bodies. Students need to understand how these nutrients are digested and what their role is in the body. Further, it is essential that students understand how eating certain foods in excess, can lead to obesity, and potentially to diseases like diabetes.

Objectives

I will begin teaching this unit at the molecular level—by discussing the chemistry of food macronutrients—and then I will progress to a human system focus, including the digestion process and a study of diabetes. My standards-based objectives for the molecular portion of the unit include: students will study and identify the structures of the macromolecules; they will learn the building block (monomer) and the cellular function of the macromolecule; and they will learn the process by which these molecules are synthesized (condensation) and broken down (hydrolysis). Further, I want students to link their learning about the molecules to foods that they eat every day.

My objectives for the systems portion of the unit are: students will learn the role of the digestive organs; they will explain how each type of macromolecule is digested, including the location(s) of digestion and the type of enzymes involved; they will learn the role of insulin in regulating blood glucose levels, and compare the insulin response to refined and whole grain carbohydrates; they will learn the causes, symptoms and treatment of diabetes; and they will research the characteristics of a healthy diet.

Rationale

My goal for this curriculum unit is to help students understand the link between nutrition and diabetes. For many of my students, their connection to this topic is personal. Many of the students in my classes have family members that have diabetes and other health problems associated with obesity. Further, many of them are making their own decisions about what to eat for breakfast, lunch and dinner. The easiest choices, in terms of cost and convenience, are found at fast food restaurants and corner stores. Educators must teach students about good nutrition at all grade levels; the eating habits that they develop as teenagers are likely to continue throughout adulthood. The evidence is clear that the Western diet, which includes abundant fast food, contributes to heart disease and diabetes, among other illnesses. Obesity rates and diabetes incidence is especially high in African-American, Native American and Hispanic populations. Accurate knowledge and familiarity with a diversity of foods will ultimately have a positive impact on our life span and the quality of life of us all.

The major macronutrients of our food are commonplace in daily language: carbohydrates (carbs), proteins and fats. Unfortunately, we have developed vast misconceptions about these nutrients, because of media, fad diets and influential food marketing. All of these nutrients are essential for life. Fats are essential components of cell membranes; proteins have structural, defense and enzymatic roles in the body; and carbohydrates are the basic fuel for the body, providing energy to all the cells. In many popular diets, both fat and carbohydrates are largely forbidden, while some diets consider animal protein to be detrimental to health. The bottom-line for those who want to lose weight is a simple fact; the input of calories must be less than your output of calories. A low-fat high carb diet can contribute to weight gain, because carbohydrates (specifically glucose molecules) that are not burned are converted into fat and stored in the fat cells. In the same way, when glucose stores are in short supply, protein and fat can be converted to glucose, to satisfy the bodies' needs.

Through this curriculum unit, students will learn about healthy eating and research healthy recipes that they will enjoy cooking and eating. In this way, students can be empowered to change their eating and learn some of the tools for cooking foods that taste good and are healthy. Evidence suggests that encouraging students to add more fruits and vegetables in their diet is more successful than negative messages telling students not to eat certain foods [1] . Further, by educating students with information that links nutrition directly to health, I believe that students are more likely to make dietary changes that endure.

Background Knowledge

Energy in Food

Food is crucial because it provides the compounds necessary for life and stores chemical energy that allows our body to function. Metabolism is the term that encompasses all of the chemical reactions that occur in the body, including growth and development, movement, and releasing the energy in our food. The amount of energy contained in foods is called calories. This term is ubiquitous, but the term has a very specific meaning in science. A calorie is the amount of energy it takes to raise 1 gram of water 1°C. One thousand calories is equal to one Calorie, as defined by nutritionists. For example, a candy bar that has 200 calories according to the nutritional label actually contains 200,000 calories as defined by scientists. Calorimetry is a method used to determine the number of calories in food (see Strategies).

Macronutrients

Three of the numerous biological molecules in food, protein, carbohydrates, and fats, are considered the macronutrients. These carbon-containing (organic) compounds are large polymers and found in abundance in foods. Each of the polymers is made of several monomers that are bonded together by a process called condensation or dehydration synthesis. The polymers are broken down by a process called hydrolysis. These processes are occurring continually in the body. Consider just two examples. Hydrolysis occurs during the digestive process as the large molecules are broken down into smaller monomers, so that they can be absorbed into the body. Condensation occurs in liver, fat and muscle cells when excess glucose is converted into the polysaccharide, glycogen.

Each of the macronutrients is discussed below in depth.

Protein

Proteins are a group of organic molecules with very diverse functions; proteins are polymers that are composed of a group of twenty related but different molecules called amino acids. The order of amino acids in a protein is coded by DNA in the cell's nucleus, though the protein is assembled in the cytoplasm of the cell. The twenty amino acids are combined in various arrangement and length to make the thousands of proteins that are present in the body. Amino acids are composed of a central carbon, which is surrounded by an amino group, a carboxyl group, an atom of hydrogen, and one or more atoms called an R group. [2] The bonds between each amino acid are called peptide bonds, and a complete amino acids chain is called a polypeptide.

Proteins function in cell structure, chemical reactions, cell movement, chemical messages (some hormones), and in immune response. [3] The proper functioning of a protein is dependent on its shape. After an amino acid chain is formed, some interactions (hydrogen bonding) among the amino acids occur which can give the polypeptide a coiled or sheet-like structure, which is known as the secondary structure. Further interactions between the R-groups of the amino acids result in tertiary structure, and finally, more than one polypeptide can interact leading to the protein's quaternary structure. [4]

Proteins are found in all foods, but they are found in large quantities in meats, dairy products, eggs and legumes. Of the twenty amino acids, all but nine can be synthesized by the body. The nine essential (or indispensable) amino acids not made by the body must be ingested in foods, in order to maintain health. The essential amino acids are: leucine, isoleucine, valine, lysine, threonine, tryptophan, methionine, phenylalanine and histidine. [5] Generally, animal sources of protein are considered complete protein, although some studies have shown that beef is deficient in cystine and methionine. [6] Most vegetarian sources of protein are known as incomplete protein, because they don't contain all of the essential amino acids. Yet, millions of people from varied cultures acquire their protein from these sources. By combining plant proteins—for example, by eating combinations of beans and rice—vegetarians can acquire all the essential amino acids needed for protein synthesis. [7]

Fats

Fats are another class of organic compounds, which are also called lipids. Fats primarily function in energy storage, insulation and cell membrane composition. Fats are composed of carbon, hydrogen and oxygen atoms in various arrangements. The basic unit of fat structure is a chain, called a fatty acid. A fatty acid is a nonpolar molecule that is hydrophobic, meaning it does not dissolve in water.

A fatty acid chain can have as many as 36 carbons, a carboxyl group, and hydrogen atoms filling all remaining bonding sites. [8] Fatty acids can be saturated or unsaturated based on the type of bonding between carbon atoms. Fatty acids that have only single bonds are called saturated fats, because each carbon is saturated with hydrogen. Saturated fats, like animal fats, have straight fatty acids chains which allow the molecules to pack tightly, resulting in a solid state at room temperature. Fatty acids that have at least one double bond between carbon atoms are called unsaturated. The double bond causes a kink in the tail which keeps the molecules from packing tightly together. Therefore, unsaturated fats, like vegetable oils, are liquid at room temperature. Monounsaturated and polyunsaturated fats refer to fatty acids with one or more than one double bonds, respectively.

Trans fats are synthetic lipids that are produced by the industrial process of hydrogenation: unsaturated fats are partially hydrogenated to make them more stable and solid at room temperature. These fats replaced saturated fats in many packaged foods because they help prolong the shelf life of the products. These trans fats have been linked to higher cholesterol, increased low-density lipoprotein (see below), and increased incidence of heart disease. [9] In 2006, the Federal Drug Administration required that trans fats be labeled, which has led many companies to eliminate the fats. [10] The city of New York banned trans fats in all restaurants, bakeries and food carts as of July 2008. [11]

The two most common types of dietary lipids are triglycerides (90%) and phospholipids (6%). Triglycerides are composed of three fatty acid chains bonded to a glycerol backbone. [12] Triglycerides are the most common type of dietary fat, and they contain twice the energy of carbohydrates (9kcal/gram compared to 4kcal/gram). The higher density of energy is due to the large numbers of removable electrons in fats, which release energy as they are removed. [13] Unlike the triglyceride, the phospholipid has only two hydrophobic fatty acids chains; the third chain is replaced by a hydrophilic 'head' composed of a phosphate group and a polar molecule. The structure of this molecule is directly related to its function as the primary component of the cell membrane. The phospholipids form a double layered cell membrane; the water-loving heads of the phospholipids face the watery inside and outside of the cell, while the water-hating tails of the phospholipids attract together, forming an fairly impermeable oily layer around the cell. Other well known lipids are the sterols which include cholesterol, vitamin D, bile salts, estrogen and testosterone. [14]

Lipoproteins

Lipoproteins are proteins that bond with cholesterol, triglycerides, and phospholipids that are derived from food (how they get into the body is described below). Lipoproteins are essential for the movement of fats within the body. Two types of lipoprotein are low-density lipoprotein (LDL) and high-density lipoprotein (HDL). Low density lipoprotein takes up triglycerides and cholesterol and binds to receptors on body cells. LDL can lead to atherosclerosis, the thickening of the arteries. High density lipoproteins also bind cholesterol, but these molecules move to the liver where the cholesterol is broken down, mixed with bile and excreted. This lipoprotein is beneficial because it is an essential part of the pathway that removes cholesterol from the body.

The lipoproteins, LDL and HDL, are used as a measurement for health in blood tests. The American Heart Association recommends that everyone 20 years of age and older have their LDL, HDL and cholesterol levels checked every five years. [15] However, teenagers that have family history or high risk factors can benefit by lipid screenings as well. [16] The recommended levels of LDL are 100mg/dL or less, HDL levels should be above 60mg/DL and total cholesterol should be less than 200mg/dL. See Appendix for complete table.

Carbohydrates

Carbohydrates are the class of organic compounds that primarily function as an energy source. The three classes of carbohydrates are monosaccharides, oligosaccharides, and polysaccharides. Glucose is a monosaccharide that is used directly in the production of cellular energy, ATP or adenosine triphosphate. ATP is an organic compound that stores chemical energy that is used to carry out various activities throughout cells. Many of the foods that we eat are broken down into glucose by the digestive system: fruits, vegetables, bread, and pasta. Fructose, fruit sugar, is also a common monosaccharide that we eat. Glucose can combine with one or a few other monosaccharides to form oligosaccharides, which include the disaccharide, sucrose, which is glucose bonded to fructose. Polysaccharides—such as starch, glycogen and cellulose—are large carbohydrate molecules that contain hundreds to thousands of glucose molecules joined together. Starch is the molecule that plants use to store glucose, and glycogen is the molecule that animals use to store glucose. Cellulose is an indigestible carbohydrate which contributes fiber to our diet.

Digestive System

The digestive system is a network of organs that takes in food, breaks the food down into its component parts for transport throughout the body, and eliminates food waste. The digestion process begins in the mouth, and food passes through the esophagus into the stomach for storage and continued digestion. Food is moved into the small intestine where nutrients are absorbed and indigestible matter moves into the large intestine. After water is removed and final breakdown of digestible material is completed, the remaining material moves into the rectum and out the anus. Many organs contribute to the digestive process even though food does not pass directly through them. The pancreas and the gall bladder release different kinds of digestive fluids into the small intestine. The blood vessels that surround the intestines—and receives all of the nutrient molecules as they are absorbed in the intestines—flows directly into the liver, so that cells in the liver can begin the process of using and storing the nutrients.

Digestive Processes

The mouth is the beginning of the digestive system, where the teeth begin to grind up food, and salivary glands release saliva and mucin to soften food. Saliva contains salivary amylase, an enzyme that breaks down on the digestion of carbohydrates. Food moves down the esophagus due to the muscular contraction of smooth muscle in a process called peristalsis. Food is pushed by peristalsis into the stomach, passing through the lower esophageal sphincter, which is a ring of muscle that opens to allow the passage of food and closes to keep the stomach acids from damaging the esophagus.

The stomach is a muscular pouch that mixes and digests food. In the stomach, the cells of the stomach lining release gastric juice into the stomach's interior, or the lumen. The gastric juice consists of mucus, hydrochloric acid, and pepsinogen, which is converted into pepsin in an acid environment. [17] The acid causes proteins to denature, or unravel, and pepsin, an enzyme, breaks the peptide bonds between the amino acids of proteins. The acid environment also kills microorganisms that may be present in food. The muscular wall of the stomach contracts, churning and grinding food into a watery fluid called chyme. The chyme is slowly moved on through the pyloric sphincter to the small intestine where digestion continues and nutrient absorption occurs.

The small intestine is 20 feet long with a diameter of 1.5 inches. It is divided into three segments: the duodenum, the ileum and the jejunum. The small intestine's job of digestion is done in conjunction with three accessory organs, the liver, the pancreas, and the gall bladder. As food enters the small intestine through the pyloric sphincter, the pancreas is triggered to release digestive enzymes that break down protein, carbohydrates, fats and nucleic acids. Among these enzymes are pancreatic amylase to break down carbohydrates, lipase to digest fats, proteases (for example, trypsin) to digest proteins, and nuclease to digest nucleic acids. The pancreas also releases bicarbonate to neutralize the acid within the liquid food coming from the stomach. This is important since the enzymes trypsin and chymotrypsin that break down protein can only function in a neutral pH. The liver has multiple functions in the body, several of which are involved in digestion. The liver produces bile, which is used to breakdown fat globules into smaller and smaller droplets. The bile salts act to surround the hydrophobic fat molecules. The gall bladder's function is to store excess bile before it is excreted into the intestine.

The small intestine is designed for absorption. Its wall is covered with millions of tiny folds, called villi that project out into the lumen of the small intestine. The villi increase the surface area for absorption, allowing the small intestine to absorb nutrients into the blood stream efficiently. As food passes to the jejunum and the ileum, the small monomers of nutrients are absorbed from the lumen, through the endothelial cells of the intestinal walls into the blood stream.

After food has passed through the small intestine, most of the digestible nutrients have been absorbed into the bloodstream. The indigestible food moves into the large intestine, which is approximately 5 feet long. However, some remaining nutrients are broken down by bacteria in the large intestine. These organisms are responsible for the production of Vitamin K in the body. Excess water in the indigestible material is absorbed and the waste is excreted through the rectum and anus.

Digestion and Absorption of Protein, Fats and Carbohydrates

In the digestive system, proteins are primarily digested in the stomach and small intestine, in the presence of protease enzymes like pepsin in the stomach and trypsin and chymotrypsin in the small intestine. Proteins are broken down into their component units, the amino acids, which are absorbed through the small intestine and enter the blood stream to be transported throughout the body. The amino acids enter cells so that cells can use the amino acids as raw material to make new proteins.

The breaking down of fat molecules begins in the stomach where the mechanical force of the stomach begins to break fats into smaller globules. Fat digestion continues in the small intestine due to the action of enzymes from the pancreas and bile from the liver. The bile salts surround the small fat droplets to keep them from reforming large globules that can resist breakdown. Bile salts are negatively charged and therefore these negatively charged droplets repel each other. Enzymes that digest fats can act more efficiently on the small droplets, forming monoglycerides and fatty acids. [18] These hydrophobic molecules easily diffuse through the lipid-containing cell membrane of the epithelial cells. Inside the epithelial cells of the small intestine, triglycerides reform from monoglycerides and fatty acids, and the triglycerides are transported into lymph vessels and then blood vessels. [19] These triglycerides are stored in adipose (fat) tissue until needed by cells as an energy source when glucose levels are depleted.

The digestion of carbohydrates begins in the mouth and continues in the small intestine. In the small intestine, digestion of carbohydrates occurs both in the lumen along the surface of the epithelial wall (brush border). Breaking starch molecules in the intestine requires multiple enzymes for the complete breakdown into glucose. Both salivary and pancreatic amylase can break the linkages between glucose molecules, except those at the terminal end or those proximal to a site of branching. The resulting molecules are disaccharides (maltose), oligosaccharides (maltotriose) and the small branched dextrins. These molecules move to the epithelium wall where an enzyme complex that consists of sucrase and isomaltase breaks the remaining molecules into monosaccharides. These monosaccharides move into the epithelial cells through specialized protein channels and enter the blood stream. [20] The glucose molecules are taken to cells that use glucose to produce cell energy, also known as adenosine triphosphate (ATP). Excess glucose is either stored as glycogen in the liver and in muscle cells or it is converted into lipid and stored in the adipose tissues in the body.

Pancreas and Insulin

The pancreas has a dual function in the body; it is a crucial part of both the digestive system and the endocrine system. As a digestive organ, the pancreas produces digestive enzymes that break down sugars, fats and proteins into their building blocks. The enzymes enter the duodenum through the pancreatic duct, and become fully functional in the duodenum. The nutrients that are broken down are absorbed through the intestinal wall and into the blood stream. These nutrients first pass through the liver for further metabolism and removal of toxins. The nutrient-rich blood then travels to the heart and is thus circulated throughout the body.

As an endocrine organ, the pancreas responds to the surge in glucose levels in the blood by producing insulin. Insulin is produced in the beta cells of the pancreas, which are found within tiny units called the islets of Langerhans. Glucose enters the beta cell, triggering a cascade of reactions that result in the release of insulin. Inside the beta cells, glucose is broken down in the mitochondria, releasing ATP. The production of ATP changes the voltage gradient of the cell, which results in an increase of calcium uptake by the cell. Insulin is then released from the beta cells through exocytosis.

The increased level of insulin in the blood stream triggers cells to take up glucose out of the blood stream. Insulin has effects throughout the body, primarily in the liver, in fat cells and in muscle cells. When glucose levels are high in the body, insulin levels increase and direct the storage of glucose as glycogen and the synthesis of lipids. When glucose levels are low, levels of insulin drop, causing lipids to be metabolized and proteins and amino acids are converted into glucose.

Carbohydrates and Blood Sugar

Carbohydrates contribute between 45 to 65% of the calories in the average diet. [21] Based on evidence from countries like China, that had both a relatively high carbohydrate diet and low rates for heart disease and diabetes, carbohydrates had been deemed healthy, compared to fat. As a result, doctors and nutritionists advised a low-fat and high carbohydrate diet. How successful was the advice? Today, sixty percent of adults are overweight and obese, and diabetes rates have tripled. [22] What went wrong? Evidently, the type of carbohydrate is crucial. The terms simple and complex carbohydrates refer to the size of the carbohydrate molecule, like monosaccharide and polysaccharide. Simple carbohydrates have been portrayed as bad and complex carbohydrates have been held as the good carbohydrates. [23] In fact, polysaccharides such as starch (complex carbs) are broken down into the monosaccharide glucose (simple carbs) in the small intestine.

Today, nutritionists recommend making whole grain carbohydrates an important part of the diet, and they warn against eating refined carbohydrates. Refined grains, such as bread made with white flour, white rice and potatoes, are easily and quickly digested. This rapid digestion results in a rapid rise of glucose in the blood and a corresponding flood of insulin to shuttle all of that glucose into cells for use and storage. The sudden release of large amounts of insulin can cause glucose levels to fall so low that the brain sends signals of hunger, leading us to find more sources of glucose. In contrast, whole grains take longer to be broken down, which ultimately leads to a more prolonged release of glucose and insulin response. This slower response keeps blood sugar levels in the blood from plummeting quickly, giving us the effect of feeling fuller longer. The fiber (indigestible cellulose) in whole grains plays an important role in these benefits, slowing the absorption of glucose.

Because of the physiological difference in insulin production of refined and whole grain carbohydrates, two values have been developed: Glycemic Index and Glycemic Load. Glycemic Index is a measure of the affect on blood sugar and insulin levels. Foods are ranked on the GI Scale, the highest value being 100, which is pure glucose. A Glycemic Load factors the amount of carbohydrate as well as the Glycemic index, thus giving a more compete picture of a food's effect on the body. [24]

Diabetes

Diabetes is a disease that causes high blood glucose levels in the bloodstream. There are two type of diabetes: Type 1 and Type 2. Type 1 diabetes results when the insulin secreting cells of the pancreas are destroyed and can no longer produce insulin. This attack on the beta cells in the pancreas is waged by the person's own immune system. It is not clear why this happens. Type 1 affects about 5% of those that have diabetes. Type 2 diabetes affects 95% of all diabetics. Type 2 diabetes is caused by a malfunction in the pancreas, in which insulin is either not produced in sufficient quantities or the cells have become resistant to insulin. Type 2 diabetes had been previously called adult-onset diabetes, but this type of diabetes is now common in young people as well. [25] I am focusing on Type 2 diabetes in this unit because of the prevalence of this disease, and its increasing importance among young people.

Type 2 Diabetes is characterized by blood glucose levels of 126 mg/dL and above (fasting test results). Elevated glucose levels are caused by insulin resistance, which may be caused by genetic susceptibility, but is made worse by lack of exercise, obesity and smoking. Insulin resistance, also known as Syndrome X, leads to high levels of insulin (hyperinsulinemia) in the blood because the pancreas pumps out more insulin in efforts to reduce glucose levels in the blood. [26] The high levels of glucose in the blood are removed by the kidneys, along with water, causing extreme thirst and frequent urination. Although there is plenty of glucose in the blood, cells cannot use the glucose because they do not respond to insulin properly. Therefore, cells are starved for glucose, which can cause feelings of fatigue in the individual.

The high glucose levels in the bloodstream that are characterized by diabetes can result is extensive damage to blood vessels, especially capillaries. If the areas of the body that are supplied by the capillaries don't get the nutrients and oxygen that they need, they eventually die. The areas most often affected are the lower legs and feet, the eyes and the kidneys. Blindness is also common in diabetics, each year 24,000 people become blind from the effects of diabetes. Amputation is even more common in this group; over 80,000 diabetics each year have a toe, foot or leg amputated due to gangrene. Heart disease is also extremely common in diabetics because of high triglyceride levels in the blood and high blood glucose levels which cause inflammation. [27]

Risk Factors

Diabetes affects almost 24 million people (7.8% of the population) in the United States. Of these, it is estimated that over 5 million people have yet to be diagnosed with this serious condition. While diabetes is ranked as the sixth leading cause of death, having diabetes is linked to other serious diseases such as heart disease, stroke, high blood pressure and kidney disease. [28] Obesity and lack of exercise are the primary risk factors for diabetes, though genetics plays a role as well. Peoples of Asian, African, Hispanic and Native American decent are more likely to develop diabetes. It is hypothesized that a trait, known as the "thrifty gene" may have enabled people to survive when food was scarce. [29] Cells may have had a natural insulin-resistance, breaking down fats rather than using glucose for energy. [30]

In addition to obesity, inactivity, and family history, there are other risk factors for diabetes. Individuals who are over the age of 45, have high blood pressure, and have high triglyceride and low HDL levels in the blood are at risk for diabetes. Prediabetes is a condition give to those that have one or more early indicators that may lead to diabetes. This condition affects approximately 54 million people, who may have elevated glucose levels in the blood (100 to 125 mg/dL) and urine. Early indicators for prediabetes also include a waist measuring more than 35 inches for males and more than 40 inches for females, blood pressure of 130/85 mmHg or higher, and low levels of HDL in the bloodstream. [31]

Obesity is clearly a risk factor for diabetes; approximately 80% of diabetics are obese. However, not all obese individuals develop diabetes, actually the percentage if fairly low, only 5-10%. How body fat is distributed influences diabetes risk; it is more common in individuals that carry most of their body fat in the central part of their abdomen. [32] Obesity increases the likelihood of insulin resistance, and it has been shown that weight-loss can reduce insulin resistance. [33] But how does obesity cause diabetes? One theory proposes that fat interferes with the body's ability to use insulin. [34] Specifically, excess lipid molecules in the bloodstream are taken up by muscle and liver cells interrupt the signals that would allow insulin into the cells. [35]

High blood pressure, or hypertension, is also a risk factor for diabetes. Again, the mechanism that links blood pressure to diabetes is not well understood. High levels of insulin that would be present in a prediabetic or diabetic have been found to affect sodium retention, which could contribute to high blood pressure. [36] Also, insulin affects the endothelium (inner wall) of the blood vessels, causing dilation of blood vessels and capillary recruitment. Insulin resistance leads to dysfunction of the endothelium, which is related to hypertension, as well as coronary artery disease, and arteriosclerosis. [37]

Treating and Preventing Diabetes

Diabetes can be prevented by maintaining a healthy diet and getting proper exercise. The diet prescribed by Walter Willett, M.D. would be similar to a Mediterranean Diet, consisting predominantly of whole grain foods, unsaturated plant oils, fruits and vegetables, nuts and legumes and fish, poultry and eggs. [38] Refined carbohydrates, like white rice, white bread, white pasta, potatoes, soda and sweets, red meat, and butter should be eaten only sparingly. [39]

Diabetics also need to check their blood sugar regularly and take medicines as prescribed. Not all type 2 diabetics take insulin; some take medicines to increase the uptake of glucose into cells, to increase the amount of insulin produced by the pancreas, or to delay the uptake of glucose from the small intestine. [40] There are also medications to lower glucose levels in the blood. Most importantly, some people with type 2 diabetes can stop taking medications by losing weight and increasing their physical activity. The pancreas can make its own insulin and a careful diet can control their blood glucose levels. [41]

The most important routes to prevent diabetes are sustained exercise and healthy diet. The same diet that can help control diabetes is beneficial for preventing the occurrence of diabetes. That is, we all should be sure to eat plenty of fruits and vegetables and limit our intake of refined carbohydrates. As well, those over the age of 45 should have their glucose levels checked every three years, or younger if you have increased risk for getting diabetes.

Strategies

My plan for the curriculum unit is to explore the connection between diabetes and food. This topic is important to help students understand the connection between their eating habits and disease. My overall strategy in designing this curriculum unit is to use hands-on labs experiences that incorporate actual food items. Using food is a great way to stimulate student interest, to help them relate to the topic, and to see that science and biochemistry is not only important in the classroom; it is present in the kitchen as well. By starting at the molecular level of food macronutrients and then progressing to a human system focus, students learn the progressive nature of science, in which concepts continually build on each other.

The unit will start with a consideration of how we measure how much energy is in our food. Students will approach this concept in a lab in which students' burn various foods to determine their calorie content. This process is known as calorimetry. It can be done by putting a volume of water in a soda or tin can and elevating the can on a ring stand. The initial temperature of water is measured and the final temperature of water is measured after the food is burned beneath the water. The change in water temperature reflects the amount of energy in the food, which can be converted into the number of calories in the food. The definition of a calorie is the amount of energy it takes to raise one gram of water 1°C. The Calorie that is seen on nutrition labels is, in fact, a thousand calories or one kilocalorie. By doing this experiment, students should understand that foods with more fats have more calories, and thereby more energy, than less fattening foods.

Biology students have some background knowledge about the basic macronutrients: fats, carbohydrates and proteins that are obtained from food. Students will brainstorm what foods they think have protein, carbohydrates and fats, and then test several mystery foods with chemical indicators to determine which foods have which macronutrients. The chemical indicator solutions we will use are Benedict's solution for simple sugars, Lugol's solution for starch, and Biuret's solution for proteins. Benedict's solution is a chemical indicator that produces a color change from a blue solution to a red, green or yellow color in the presence of simple sugars like glucose. Lugol's iodine turns deep purple to black in the presence of starch. Biuret's solution changes from blue to pink/purple in the presence of protein. Sudan III solution is a chemical indicator that stains lipids a red color.

Following this activity, students will learn through readings and lecture the structure and function of the macronutrients (proteins, fats and carbohydrates). Each day, we will cover a different macronutrient and do an activity for that macronutrient. For protein, we will create a protein using "amino acid" pop beads. The students will continue their study of amino acids by analyzing different protein sources to see which amino acids they contain. Because vegetable sources of protein do not have all the essential amino acids (not synthesized in the body), the students will design a vegetarian meal that will supply all essential amino acids.

For lipids, we will observe the differences in color and viscosity of skim milk, 2% milk, whole milk, half and half and heavy cream and analyze the fat content of these milk products as well. Students will also observe the differences between oil, butter and lard. [42] After writing observations, I will introduce the molecular structures of saturated and unsaturated fats. They will connect the straight chain structure of saturated fats to their solid physical state at room temperature, and the kinky structure of unsaturated fats results in a liquid state at room temperature. I will bring in nutritional labels of certain candy bars so that students can see examples of fats on nutrition labels and learn about partially hydrogenated fats. Hydrogenation is a process to solidify unsaturated fats, in effort to avoid the less healthy saturated fats. Unfortunately, a by-product of this process is trans fats, which are dangerous to health. Most food companies have eliminated trans fats, and trans fats are now banned in New York City.

For carbohydrates, I will use powerpoint lecture to teach the variety of structures that carbohydrates can form from simple monosaccharides like glucose to large polysaccharides like starch and glycogen. Students will analyze different sweeteners like honey, table sugar and fruits for the presence of monosaccharides, disaccharides and polysaccharides using the chemical indicators, Benedict's solution and Lugol's Iodine. In this activity, students can make a direction connection between foods that they eat and enjoy and the study of molecular biology.

The systems portion of this unit will incorporate student research and projects. Students will initially learn the process of digestion through readings, lecture and the use of computer animations. We will focus specifically on the action of the stomach, small intestine, pancreas and liver. They will be able to trace the pathways that each of the nutrients follows through the human body. Specifically, they will be able to answer the questions: where are the nutrients broken down, where are they absorbed and where do the nutrients go in the body? Our focus will be on carbohydrate, in which students will study the physiological response of blood sugar and insulin production after eating carbohydrates (see Image Appendix). To compare how carbohydrates are digested in the body, we will conduct an amylase digestion lab that compares the activity of the enzyme amylase on refined and whole grain carbohydrates in the mouth and in test tubes.

I will use lecture, powerpoint and animations to introduce students to the types of diabetes, the symptoms of the disease, the treatments and the risk that diabetes conveys for other diseases. Each student will then conduct interviews of friends and family, finding out information about that person's individual experience with diabetes and the various treatments and health complications associated with the disease. Students will write the questions that they will ask ahead of time, and after conducting the interview, they will submit an essay about one person's account of living with diabetes.

To complete our study, students will research healthy eating habits that everyone should follow. Students will write what they think that they should eat, and then compare their ideas to Walter Willett's food pyramid.

Using the food pyramid, students will work on planning a week's worth of their meals, and research healthy recipes that they would like to eat and prepare. The student's recipes will be compiled into a healthy eating cookbook, and the entire biology class will plan, develop and coordinate a Healthy Food Festival for the entire school.

Classroom Activities

Activity 1: Amylase Digestion Lab

Objective: Students will do a digestion lab compares the activity of amylase on refined and whole grain carbohydrates in the mouth and in test tubes.

Materials:

Amylase Enzyme Solution

White and Whole Wheat Bread

Test tubes

Glucose Test Strips

Stop Watches

Audience: This activity will be used for a high school biology class, but it can be used at all levels.

Procedures:

Part 1

In this activity, students will the compare the digestion time for refined carbohydrates and whole-grain carbohydrates. In the first part of the lab, students will get a small piece of white bread and a small piece of whole-wheat bread. All students will get equal sized portions. Students will put the small piece of whole gain bread in their mouth, but not chew. As the starch (amylase) is broken down by the enzyme amylase in their saliva, they should taste a faint sweet taste. I will ask students to raise their hand when they detect the sweet taste. The students will repeat this process for the white bread. We will compare the average times for the wheat and white bread, and students will answer questions in their lab notebook about the activity.

Questions:

1. How long did it take white bread to taste faintly sweet in your mouth? How long did it take wheat bread to taste sweet in your mouth?
2. Which type of bread was broken down more quickly in your mouth? Why do you think this happened?
3. In addition to the sweet taste, what else was happening to the bread in your mouth? Why?
4. What is the difference in ingredients between white bread and wheat bread? How are these ingredients different?

5. Why do you think white bread was broken down more quickly in your mouth?

Part 2:

Students will measure and dispense equal amounts of amylase to two test tubes. With a stop watch and glucose test strips ready, students will add an equal amount of white and wheat bread to the test tube. Students will use glucose test strips to measure for the presence of the small sugar by-products (maltose and maltotriose) of the starch hydrolysis reaction. Students will test each test tube every thirty seconds. Students will compare their results and answer questions in their lab notebook.

(Note: Amylase in saliva and the pancreas breaks down starch into disaccharides (maltose), oligosaccharides (maltotriose) and small branched dextrins. These molecules are further broken down into monosaccharides (glucose and fructose) by a sucrase and isomaltase enzyme complex in the small intestine. Glucose test strips can be used, however, because they yield a false positive result in the presence of maltose and maltotriose).

Questions:

1. How long did it take for the white bread to test positive for the simple sugars? How long did it take the wheat bread to test positive for simple sugars?
2. Where is amylase produced in the body? What does amylase do?
3. What does the result tell you about blood sugar levels after eating white bread (refined carbohydrates) and wheat bread (whole grains)?
4. What is the response of the pancreas and the liver to the blood sugar spike caused by refined carbohydrates?

Activity 2: Mystery Foods Lab [43]

Objective: The objective for this lab is to relate the student's knowledge about the different types of macromolecules to common foods that they eat regularly.

Materials: For this experiment, I will use foods that contain only one of the macromolecules, and I will use foods that contain two or more of the macromolecules. The following is a list of foods and the nutrients that they predominantly contain:

Lentils - protein and carbohydrates

Eggs - protein and fats

Donut - carbohydrates and fats

Apple - carbohydrates

Tofu - protein

Olive oil - fat

Audience: This activity is for a high school biology class.

Procedures: For each food item, I will make a combine a small amount of the food with distilled water to make a food solution. The goal of the activity is for the students to conduct a carbohydrate (glucose and starch), protein and lipid tests for each mystery food solution. The students will report on the presence or absence of the three macromolecules, and they will try to match each mystery food to the list of know foods.

Glucose Test

To test for the presence of glucose, students will take 40 drops of liquid from the Mystery Food solution. The students will add 10 drops of Benedict's solution and place the test tube in a 40-50°C hot water bath for five minutes. The Benedict's solution will produce a color change from a blue solution to a red, green or yellow color in the presence of simple sugars like glucose.

Starch Test

To test for the presence of starch, students will take 40 drops of liquid from the Mystery Food solution. They will add 3 drops of Lugol's solution. If starch is present, a bluish-black color will appear.

Protein Test

To test for the presence of protein, students will take 40 drops of liquid from the Mystery Food solution. They will add 3 drops of Biuret's solution and swirl the test tube to mix well. The Biuret's solution will cause a color change from blue to pink/purple in the presence of protein.

Lipid Test

To test for lipids, students will add approximately 20 drops of the liquid from the Mystery Food solution and 20 drops of water to a test tube. The students will ass 3 drops of Sudan III solution. Sudan III solution will stain lipids a red color.

Students will use the following table to record positive and negative indicator tests.

Mystery Food	Sugar (+/-)	Starch (+/-)	Protein (+/-)	Lipid (+/-)
1				
2				
3				
4				
5				
6				

Activity 3: Assessing Patient Health through Blood Tests

Objective: Students will look at sample lab results and assess the health issues that each individual has in terms of blood sugar, triglycerides, total cholesterol and HDL and LDL.

Audience: This activity is intended for a high school Biology class.

Procedures: Students will study each of the four reports of blood glucose levels, total cholesterol, triglycerides, HDL and LDL. Students will research the healthy ranges for each test and fill in the chart below (the ranges are provided as a reference to the teacher). The students will review each of the patients' data, and they will be asked as a physician to comment on areas of concern and make recommendations to the individual on diet and exercise routine.

Individual #1

	Healthy Ranges	Individual Results
Glucose levels	(65-125)	89
Total Cholesterol	(120-233)	242
Triglycerides	50-200	206
HDL	60 and over	42
LDL	Less than 100	159

Individual #2

	Healthy Ranges	Individual Results
Glucose levels	(65-125)	178
Total Cholesterol	(120-233)	284
Triglycerides	50-200	228
HDL	60 and over	37
LDL	Less than 100	201

Individual #3

	Healthy Ranges	Individual Results
Glucose levels	(65-125)	92
Total Cholesterol	(120-233)	189
Triglycerides	50-200	147
HDL	60 and over	42
LDL	Less than 100	94

Individual #4

	Healthy Ranges	Individual Results
Glucose levels	(65-125)	209
Total Cholesterol	(120-233)	133
Triglycerides	50-200	161
HDL	60 and over	54
LDL	Less than 100	47

Questions:

1. What are the requirements that an individual must follow to obtain accurate data from the blood glucose and lipid test?
2. For which blood individuals is diabetes a concern?
3. As the physician for Individual #2, describe your concerns and explain your recommendations for that patient.
4. One of your patients admitted that she did not fast the required length of time before the blood test.

Which patient do you suspect? Explain why you suspect this patient.

5. Total cholesterol values are a result of dietary intake and biosynthesis in the body. What are the dangers of high cholesterol in the blood? What kinds of foods are high in cholesterol?
6. HDL and LDL are important lipoproteins in the body. What is the function of each? Which is the "good" cholesterol and which is the "bad" cholesterol?

Notes

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1. Leonard H. Epstein et al., "Increasing Healthy Eating vs. Reducing High Energy-dense Foods to Treat Pediatric Obesity," *Obesity* 16 (2008): 318-326.

2. Cecie Starr and Beverly McMillan, *Human Biology*, (6th ed. Pacific Grove: Brooks/Cole, 2005), 32.

3. Starr and McMillan, 32-36.

4. Starr and McMillan, 32-36.

5. "Protein and Amino Acid Requirements in Human Nutrition," *World Health Organization,* http://whqlibdoc.who.int/trs/WHO_TRS_935_eng.pdf> (July 15, 2008), 29.

6. "Supplemental Value of Certain Amino Acids for Beef Protein," *The Journal of Nutrition*, September 24, 1947, http://jn.nutrition.org/cgi/reprint/35/2/167.pdf> (July 15, 2008), 167.

7. Starr and McMillan, 134.

8. Starr and McMillan, 30.

9. Starr and McMillan, 30.

10. "Trans fats 101," *University of Maryland Medical Center*, May 4, 2007, http://www.umm.edu/features/transfats.htm> (July 15, 2008).

11. David Caruso, "NYC keeps the cannoli but drops the trans fats," *Associated Press,* http://ap.google.com/article/ALeqM5gVbpPWVeQDGQ2-c65c4xaSwlT8hwD91JRB100> (June 29, 2008).

12. Starr and McMillan, 30.

13. Starr and McMillan, 30.

14. Starr and McMillan, 30-31.

15. "What your Cholesterol Levels Mean," *American Heart Association,* April 7, 2008, http://www.americanheart.org/presenter.jhtml?identifier=183> (July 27, 2008).

16. Stephen R. Daniels et al., "Lipid Screening and Cardiovascular Health in Childhood," *Pediatrics,* 122 (2008): 198-208.

Stephen R. Daniels,

17. Starr and McMillan, 124.

18. Starr and McMillan, 126.

19. Starr and McMillan, 127.

20. Henry J. Binder and Adrian Reuben, "Nutrient Digestion and Absorption," *InMedical Physiology*, (Elsevier Saunders, 2003), 948-967.

21. "Healthy Diet: Do You know What to Eat," *Mayo Clinic*, February 16, 2007, http://www.mayoclinic.com/health/healthy-diet/NU00200> (July 29, 2008).

22. Walter C. Willett and Patrick J. Skerrett, *Eat, Drink, and be Healthy,* New York: Free Press, 2001, 35-38.

23. Willett and Skerrett, 35-38.

24. Willett and Skerrett, 85-100.

25. David E. Duncan, "The covert plague," *Discover,* December 1, 2005, http://discovermagazine.com/2005/dec/diabetes-inmsulin-resistance/article_view?searchterm=diabetes&b_start:int=1> (May 3, 2008).

26. Jane Brody, "Personal Health: Syndrome X and Its Dubious Distinction," *New York Times,* October 10, 2000, http://query.nytimes.com/gst/fullpage.html?res=9E06E0D7103CF933A25753C1A9669C8B63&sec=&spon=&pagewanted=all> (July 27, 2008).

27. Starr and McMillan, 285.

28. "Diabetes," *National Institute of Health*, http://diabetes.niddk.nih.gov/dm/pubs/statistics/#what> (July 30, 2008).

29. Duncan, "The covert plague."

30. Starr and McMillan, 284.

31. Starr and McMillan, 285.

32. Julia Steinberger and Stephen R. Daniels, "Obesity, Insulin Resistance, Diabetes, and Cardiovascular Risk in Children," *Circulation* 107 (2003): 1448.

33. Steinberger and Daniels, 1448.

34. "Health Guide: Diabetes," *New York Times,* http://health.nytimes.com/health/guides/disease/diabetes/overview.html#Complications> (July 15, 2008).

35. "How does Obesity cause ill health," *The Wellcome Trust*, http://www.wellcome.ac.uk/Professional-resources/Education-resources/Big-Picture/Obesity/Articles/WTX023503.htm> (July 27, 2008).

36. "Obesity, Insulin Resistance, Diabetes, and Cardiovascular Risk in Children," http://circ.ahajournals.org/cgi/content/full/107/10/1448#R26-125169> (July 27, 2008), 1448-1453.

37. *Ranganath Muniyappa et al, "Cardiovascular Actions of Insulin,"* Endocrine Reviews *28 (2007): 463-491http://edrv.endojournals.org/cgi/content/abstract/28/5/463 >.*

38. Willett and Skerrett, 85-100.

39. Willett and Skerrett, 85-100.

40. "Health Guide: Diabetes," *New York Times,* http://health.nytimes.com/health/guides/disease/diabetes/overview.html#Complications> (July 15, 2008).

41. "Health Guide: Diabetes."

42. Antonia Demas, "Food is Elementary: A Hands-on Curriculum for Young Students," (Ph.D. diss., Cornell University, 2001), 19-21.

43. Adapted from "Food Chemistry Testing for Sugar, Starch, Protein, or Fat," http://www.sciencecompany.com/sci-exper/food_chemistry.htm#1> and "Food Chemistry Testing," http://www.scribd.com/doc/3371524/Food-Chemistry-Testing-SUGAR-STARCH-ETC>

Annotated Bibliography

Pollan, Michael. *In Defense of Food: An Eater's Manifesto.* New York: The Penguin Press, 2008. The last two chapters are especially useful for students because of the simple and easy to follow guidelines for healthy eating.

Willett, Walter C., and Patrick J. Skerrett. *Eat, Drink, and be Healthy*. New York: Free Press, 2001. This book is a great synopsis of some of the latest health research. It has chapters on carbohydrates, proteins, fats as well as water, vitamins and minerals. The last chapter includes great recipes that would be great for anyone who wants to eat healthy.

"Health Guide: Diabetes." *New York Times* http://health.nytimes.com/health/guides/disease/diabetes/overview.html#Complications> (July 15, 2008). This website is very complete and it has some excellent diagrams that I will use in my class.

Duncan, David E. "The covert plague." Discover. December 1, 2005. http://discovermagazine.com/2005/dec/diabetes-insulin-resistance/article_view?searchterm=diabetes&b_start:int=1> (May 3, 2008). This article discussed the theory of the "thrifty gene" that proposes that some human populations a more likely to become insulin resistant.

"Recipes for Teens" http://kidshealth.org/teen/recipes/> (July 15, 2008). This is a great list to get kids to start thinking about healthy eating and cooking. Includes recipes for vegetarians and teens with diabetes.

"Looking Past Blood Sugar to Survive With Diabetes" *New York Times* http://www.nytimes.com/2007/08/20/health/20diabetes.html> This article is an important reminder that blood sugar is not the only concern for diabetics. Cardiovascular disease is the most common cause of death for diabetics. Reading this article would go well with Activity #3.

Boyles, Salynn. "Just for Teens Cholesterol Analysis: New System Could Help Spot Risk for Future Heart Disease" *WebMD Health News Teacher Resources*. August 29, 2006. http://www.webmd.com/cholesterol-management/news/20060829/teens-cholesterol-analysis> (July 27, 2008). This article reinforces the importance that teens at-risk for health complications need to have their cholesterol checked.

Teacher Resources

These resources are a list of website and class activities that can also be used with this unit.

Calorimetry Lab

http://www.nohum.k12.ca.us/ahs/ebridge/images/uploads/larmin/Calorimetry_Lab_lah.pdf>

Carbohydrates: Simple and Complex http://www.uen.org/Lessonplan/preview?LPid=1264>

Carbohydrates: Chemistry & Identification Lab

www.csun.edu/science/courses/525/demonstrations/carbLabfordemo.pdf>

Fat: How modern life, biology and genetics influence our relationship with food.http://www.pbs.org/wgbh/pages/frontline/shows/fat/>

Food Chemistry Testing for Sugar, Starch, Protein or Fat

http://www.sciencecompany.com/sci-exper/food_chemistry.htm>

Peggy Brickman, "Sweet Indigestion: A Directed Case Study on Carbohydrates" *University of Georgia Digestive System Assignment* www.sciencecases.org/carbohydrates/carbohydrates.asp>

Merle Heidemann and Gerald Urquhart, "A Can of Bull? Do Energy Drinks Really Provide a Source of Energy?"*Michigan State University* http://www.sciencecases.org/energy_drinks/energy_drinks.asp>

Your Digestive System and How it Works

http://digestive.niddk.nih.gov/ddiseases/pubs/yrdd/index.htm>

Learn About Diabetes: Interactive Learning Center

http://onlineclasses.joslin.org/ape/CourseListing/OnLineCourseListing.asp>

Student Resources

Kid Health Teen Website www.kidshealth.org/teen>

This website includes three very useful sections: Food and Fitness, Recipes, and Diseases and Conditions (Diabetes). It is very accessible for the students and is a great resource for them.

Fitday www.fitday.com>

This website is an amazing way for students to keep track of their nutrition and exercise. It would be very time consuming to do year-round, but this could be a really great week or month-long activity.

Gmap Pedometer http://www.gmap-pedometer.com/>

If your students walk or run, this website is a great way for them to track their distance or work out good routes to take. Uses Google map technology.

Appendix

Image Resources

Carbohydrate Structures

http://www.accessexcellence.org/RC/VL/GG/sugarTypes1.php

http://www.accessexcellence.org/RC/VL/GG/sugarTypes2.php

Protein Structures

http://www.accessexcellence.org/RC/VL/GG/protein.php

Triglycerides and Phospholipids

http://www.accessexcellence.org/RC/VL/GG/garland_PDFs/Panel_2.04a.pdf

HDL and LDL http://www.nytimes.com/imagepages/2007/08/01/health/adam/19279HDLandLDL.html

Blood Glucose and Insulin

http://healthpsych.psy.vanderbilt.edu/Web2007/AtkinsBeware_files/image002.jpg

Blood Cholesterol and Triglyceride Tables

	Desirable	Low Risk	High Risk
Total Cholesterol	Less than 200 mg/dL	200 - 239 mg/dL	Greater than 240 mg/dL

	Optimal	Near Optimal-Above Optimal	Borderline High	High	Very High
LDL	Less than 100 mg/dL	100-129 mg/dL	130-159 mg/dL	160-189 mg/dL	190 mg/dL and above

	High Risk	Normal	Optimal
HDL for man	Less than 40 mg/dL	40 to 50 mg/dL	60 mg/dL and above
HDL for woman	Less than 50 mg/dL	50 to 60 mg/dL	60 mg/dL and above

	Normal	Borderline High	High	Very High
Triglyceride Levels	Less than 150 mg/dL	150-199 mg/dL	200-499 mg/dL	500 mg/dL and above

Related Virginia Standards of Learning for Biology

BIO.3 The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include

b. the structure and function of macromolecules;
c. the nature of enzymes; and
d. the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration

BIO.5The student will investigate and understand life functions of archaebacteria, monerans (eubacteria), protists, fungi, plants, and animals including humans. Key concepts include

a. how their structures and functions vary between and within the kingdoms;
b. comparison of their metabolic activities;
c. analyses of their responses to the environment;
d. maintenance of homeostasis;
e. human health issues, human anatomy, body systems, and life functions

Related National Standards 9-12

CONTENT STANDARD A: All Students should develop the abilities necessary to do scientific inquiry.

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: As a result of their activities in grades 9-12, all students should develop an understanding of

- Structure of atoms
- Structure and properties of matter
- Chemical reactions
- Conservation of energy and increase in disorder
- Interactions of energy and matter

CONTENT STANDARD C: All students should develop understanding of

- Matter, energy, and organization in living systems

CONTENT STANDARD F: As a result of activities in grades 9-12, all students should develop understanding of

- Personal and community health