FOOD FOR 9 BILLION

The Challenge of Feeding the World

You Are What You Eat

Teacher Notes

Before You Start

Grade Level:
Grades 8-12

Concepts Covered:
Nutrition, Macronutrients, Micronutrients, Biological Molecules (Carbohydrates, Lipids, Protein), Digestion, Assimilation, Deficiencies/Disease, Cell Biology

Time Frame:
Class work or homework (20-30 minutes per fact sheet)
6 fact sheets:

- Metabolism
- Carbohydrates
- Protein
- Lipids
- Calcium, Phosphorus, and Vitamin D
- Vitamin A

Materials Needed:

- ***Fact Sheets:*** Teacher selects number of topics assigned (1-6)
- ***Student Worksheets*** for selected fact sheets, ***Teacher Worksheets*** with answers

Overview

Our food directly affects our bodies. This lesson encourages your students to think critically about what happens to the food they eat. ***You Are What You Eat*** includes a compilation of fact sheets outlining how macronutrients and micronutrients are ingested, digested, and assimilated by the human body and the consequences of nutritional deficiencies. Use the sheets with one of three types of activities that target different time frames and depth of content. These activities make an excellent introduction or wrap-up to a unit on digestion or biochemistry. This activity complements the ***Macronutrient Analysis*** and ***Mighty Micronutrients*** lessons in this unit, which include dietary self-study and comparisons between diets of teens from the United States and Haiti.

Objectives

1. Students will read for critical details.
2. Students will explain an integrated understanding of ingestion, digestion, and assimilation of carbohydrates, proteins, fats, water, and some micronutrients in the human body.

Prior Knowledge

Students need to have a basic understanding of the digestive system and biological molecules.

Teaching Tips/Activity Sequence

Consider listening to the Marketplace story, *Greece's Diet Crisis* at http://cironline.org/reports/greeces-diet-crisis-3953.

Beginning a unit with this lesson lends a powerful context for learning the structures of biological molecules or cellular structures. The ideas covered in this lesson could then be applied throughout the unit and/or reviewed at the end of the unit. The readings and questions can be completed as a jigsaw activity, or each student can read every sheet. Also see below for ideas about two other alternative teaching formats (diagramming concept maps and presentations).

Option 1: Reading/Jigsaw Assignment

1. Give a brief introduction explaining that the purposes of this activity are to understand how our food directly affects and constitutes the structures of our body, as well as to think critically about how proper nutrition can affect our bodies.
2. Hand out the ***Student Worksheets*** and review the discussion questions as a class before reading the ***Fact Sheets***. Ask students to rephrase the questions in their own words and guess what the answers may be.
3. Have students read the assigned ***Fact Sheets***.
4. Allow students to complete the ***Student Worksheets*** in pairs or groups.
5. Carefully monitor students' progress and understanding.

Option 2: Diagramming Concepts Activity

The Diagramming Concepts Activity can stand alone or be used as a reading tool to understand the ***Fact Sheets*** before students complete the ***Student Worksheets***. Teachers can choose to assign the Diagramming Concepts Activity as independent homework, group work, a jigsaw exercise, or a class activity. A group or class setting is most beneficial for students with lower reading levels. Poster or paper and different colored pens, pencils, or makers are needed for this activity.

1. Give a brief introduction explaining how food is broken down and used as components to help the body function. As students read and interpret the ***Fact Sheets***, they should draw a simple diagram (e.g. concept map, web, flowchart) of the following processes: ingestion, digestion, and assimilation.
2. The diagram should be made with three colors. In this example, information about ingestion could be black, digestion green, and assimilation blue. Students start by underlining information on the ***Fact Sheets*** in the appropriate color and then transferring these facts into a color-coded flowchart illustrating each process. See the ***Example Diagram*** at the end of the ***Teacher Notes***.

- *Note about **Example Diagram**:* The diagram could contain many more facts; the teacher decides how many facts students should include on their diagram. Let this number of facts be the goal of the activity: "By the time you are done reading, taking notes, and drawing your diagram, you should have at least _(#)_ facts included in your diagram."
- *Note about student assessment:* A straightforward way to grade this assignment is to give a point for every correctly placed and colored fact with the total points being the required number of facts. This assignment can either be checked by the teacher or by students using a peer-grading system. It is often learning-conducive to explain why points were taken away and to give students time to correct their graded work.

Option 3: Presentation Activity

1. After completing the reading or diagramming activity, students should work in groups of 2 or 3 to create a class presentation that will teach the class the process described on the fact sheet. There are many different media from which students can construct their presentations (poster, PowerPoint, short film, skit, etc.).
2. Allow time in class to formulate a solid idea of the product to be made, and appropriate time to complete the product. Motivated students can complete the product outside of class. This extensive activity may take several days to complete.
3. Groups present their creative products to the class.
4. *Note about student assessment:* Rubrics clarify creative assignments for students. Suggested categories to include in a rubric for this assignment: presentation was appropriate for topic; information was correct; process description was complete; presenters could be understood clearly; presentation was completed on time.

Tips for students who find the reading level a challenge

- Pass out highlighters and ask the students to highlight answers as they read the ***Fact Sheet***.
- Read the ***Fact Sheet*** to the class, stopping to answer questions about vocabulary.
- Ask student volunteers to summarize chunks of the text for the class. Ask them to define new vocabulary in their own words.
- For more interaction, pick a recurring vocabulary word from the ***Fact Sheet*** and teach it to the class in advance. Then teach them to perform a simple hand sign every time they hear the word. This could be something simple, such as the sign for "OK," "thumbs up," or crossed fingers (if the hand sign you choose relates in some way to the meaning of the vocabulary word, this is even better). Practice saying the vocabulary word and getting every student in the class to hold up the hand sign. As you read through the fact sheet for the class, pause briefly after every mention of the vocabulary word as students flash the hand sign. This method pulls the students' attention to the reading because they are being held accountable for actively listening. This also makes the repetition of a new word very apparent and memorable.

Extensions

- Another lesson, "Why Are People Hungry?" is available at http://www.ricediversity.org/outreach/educatorscorner/foodfor9billion
- Food Insecurity in the United States uses household budgeting to explore effects of rising food prices on food insecurity: http://www.pbs.org/newshour/extra/teachers/lessonplans/economics/july-dec11/food_11-18.html
- Malnutrition in India includes a reading comprehension exercise on the topic of nutrition: http://www.pbs.org/newshour/extra/features/world/jan-june12/india_01-20.html

Resources

Online Tutorials

- Wisc-Online: *The Biomolecules*
- Carbohydrates: http://www.wisc-online.com/objects/ViewObject.aspx?ID=AP13104
- Lipids: http://www.wisc-online.com/objects/ViewObject.aspx?ID=AP13204
- Protein: http://www.wisc-online.com/objects/ViewObject.aspx?ID=AP13304
- Life: The Science of Biology, 7th ed.
- Macromolecule Information: http://bcs.whfreeman.com/thelifewire/content/chp03/0302002.html
- University of Idaho
- Interactive Cell: http://www.sci.uidaho.edu/bionet/biol115/help/the_cell/animal_cell.htm
- Macromolecule Information: http://www.sci.uidaho.edu/bionet/biol115/t2_basics_of_life/lesson2.htm#Carbohydrates

You Are What You Eat

Standards

National Science Education Standards Grades 9-12	*Common Core State Standards for Literacy in History / Social Studies, Science and Technical Subjects 6-12*
Life Science	Reading Standards
The Cell 1.1, 1.2	Key Ideas and Details RST1
Matter, energy, and organization in living things 5.2, 5.3, 5.6	Integration of Knowledge and Ideas RST7, RST9
Science in Personal and Social Perspectives	Writing Standards
Personal and Community Health 1.5	Text Types and Purposes WHST2
	Production and Distribution of Writing WHST4
	Range of Writing WHST10

References

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2. *Carbohydrates in Human Nutrition.* Retrieved September, 2011, from Oregon State University, FAO Food and Nutrition Papers: http://www.fao.org/docrep/W8079E/W8079E00.htm
3. Cook, G. (1995). Cell-Cell Interactions. *Molecular Biology and Biotechnology: A Comprehensive Desk Reference.* Wiley-VCH.
4. Dusek, W. (1999-2012). *Carbohydrate Digestion.* Retrieved September, 2011, from Wisc-Online.com: http://www.wisc-online.com/objects/ViewObject.aspx?ID=AP15806
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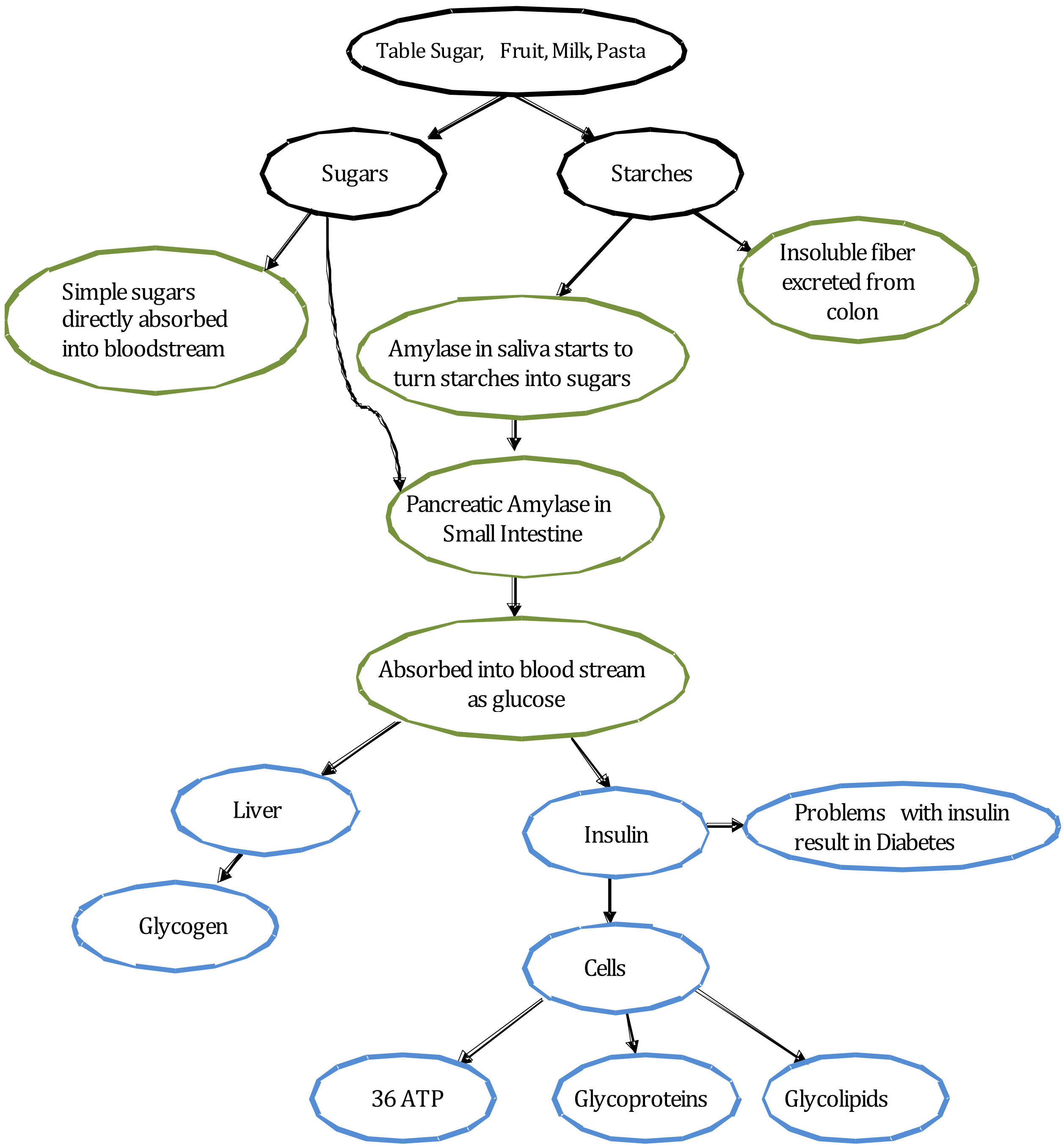
Acknowledgements

Molly Holden and Susan Dodge, M.S. Ed for Creative Curriculum, produced these teacher notes and resources in conjunction with the “Food for 9 Billion” project (http://FoodFor9Billion.org) with funding from the National Science Foundation (PGRP grant #1026555; http://ricediversity.org) and Cornell University.

Carbohydrate Diagramming Activity



Teacher Notes: Potentially Unfamiliar Terms for Students

Metabolism:
- Metabolism
- Catabolism
- Anabolism
- Digestion

Carbohydrates:
- Monosaccharides
- Disaccharides
- Amylase
- Hydrochloric acid
- Pepsin
- Chyme
- Duodenum
- Pancreatic amylase
- Glucose
- Glycogen
- Insulin
- Adenosine triphosphate/ATP
- Cellular respiration
- Aerobic respiration
- Anaerobic respiration
- Mitochondria
- Glycoprotein
- Glycolipids
- Ribose

Protein:
- Hemoglobin
- Amino acids
- Essential amino acids
- Proteases
- Oligopeptides
- Hepatic portal system
- Transamination
- Phenyketonuria
- Hydroxylase

Lipids:
- Duodenum
- Chyme
- Lipases
- Triglycerides
- Fatty acids
- Monoglycerides
- Chylomicrons
- Exocytosis
- Adipose tissue
- Phospholipids
- Lipidoses
- Fatty acid oxidation

Calcium, Phosphorus, and Vitamin D:
- Mineral
- Vitamins
- Coenzymes/cofactors
- Osteoporosis
- Cholecalciferol
- Ergosterol
- Osteomalacia

Vitamin A:
- Vitamins
- Coenzymes/cofactors
- Beta-carotene
- Retinol
- Retinal
- Retinoic acids

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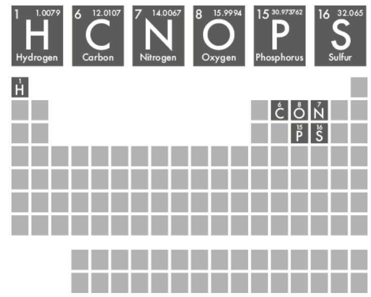
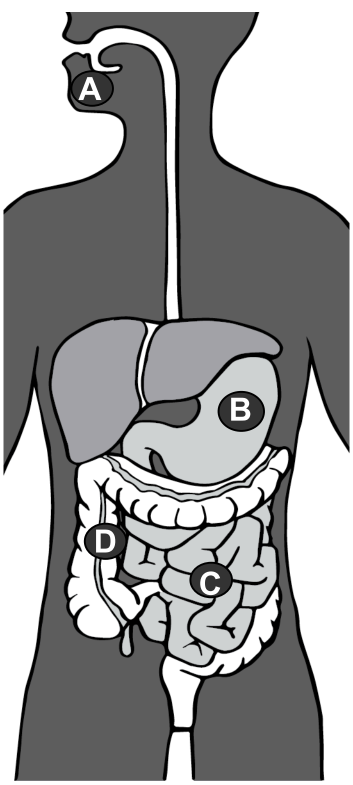
Metabolism Fact Sheet

A complete diet is necessary to supply all the elements and compounds that organisms need to maintain life. The elements are the building blocks of compounds that ultimately become structures, hormones, receptors, enzymes and many other compounds that sustain life. The foods humans eat are composed of proteins, carbohydrates, lipids, and nucleic acids that supply the major elements: carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, and many others. Water and at least 13 vitamins and 14 minerals are also necessary. Dietary deficiencies in these important nutrients can disrupt normal physiological processes and result in disease.



In order for an organism to stay alive, its cells must constantly do many chemical reactions, both to utilize energy and to make new compounds. **Metabolism** is all the chemical reactions that happen in cells to maintain life. The chemical reactions in the living cells are divided into two main categories: *catabolism* and *anabolism*. Catabolism is the breakdown of macromolecules or macronutrients such as proteins, carbohydrates, and lipids to obtain both energy and the building blocks for the cells' own compounds. Anabolism is the synthesis or production of all compounds needed by the cells.



Human bodies require food as our "fuel" and building blocks. The digestive system breaks down the food so that the body can metabolize it. The food we eat travels through the digestive system, which breaks down the complex food into simpler and simpler particles.

For some macromolecules, digestion starts in the mouth (**A**). Acid and enzymes in the stomach (**B**) contribute to further breakdown of the macromolecules. Other chemicals – from the liver, pancreas, and the small intestine itself – are added into the small intestine (**C**) continue digestion. Most nutrients are absorbed in the small intestine. The waste material, which our bodies can't absorb, travels into the large intestine (**D**) where water and vitamins are absorbed into the bloodstream. The waste is compacted and eventually expelled from our bodies.

Carbohydrates, proteins, lipids, vitamins, and minerals—the various macromolecules—are all digested and metabolized in different ways.

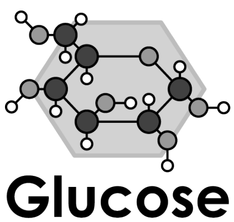
You Are What You Eat

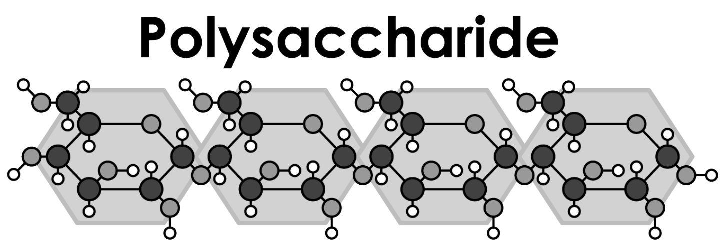
Introduction

Carbohydrates are the main energy source for human bodies. Our bodies either use the energy from carbohydrates immediately or store the energy for later use. Energy-rich carbohydrate macromolecules are a staple in every diet around the world. Milk, fruit, bread and pasta are excellent sources of carbohydrates. Energy is stored in the chemical bonds of glucose, fructose, or starch within fruits, seeds, and other plant parts. Humans harvest and process plant crops into diverse products that contain sugar or starch such as breads and cereals.

Carbohydrates are built of units called monosaccharides (simple sugars); glucose and fructose are examples. From two to thousands of monosaccharides can be linked together. Sucrose is a disaccharide; it is made of one glucose and one fructose. Starch (in plants) and glycogen (in animals) are polysaccharides consisting of hundreds of thousands of glucose units. Cellulose, found in wood and other plant fibers, is glucose-based polysaccharide that we cannot digest.

Mono=one
Di = two
Poly = many

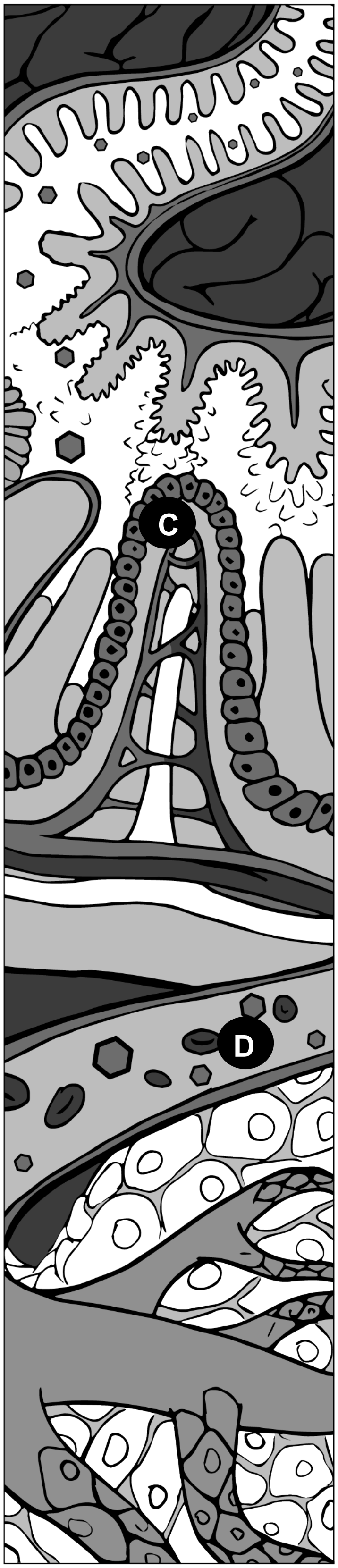




Digestion

Digestion of carbohydrates begins in the mouth. As the teeth and tongue mash the food, *amylase*, an enzyme found in saliva, breaks down some of the polysaccharides into shorter molecules. The chewed and moistened food is then swallowed, and the amylase enzyme from saliva breaks down in the acidic environment of the stomach (**A**). The stomach helps further digest the food by mechanically mixing it with *hydrochloric acid*, resulting in a mixture called *chyme*. The chyme then leaves the stomach and enters the beginning of the small intestine called the *duodenum*.

In the duodenum (**B**), *pancreatic amylase*, an enzyme from the pancreas, will mix with the chyme to continue the breakdown of polysaccharides into simple sugars. The small intestine also has enzymes in its lining that help break down disaccharides into monosaccharides. The broken-down carbohydrates are now small enough (as monosaccharides) to be absorbed through the wall of the small intestine into the blood stream (**C**).

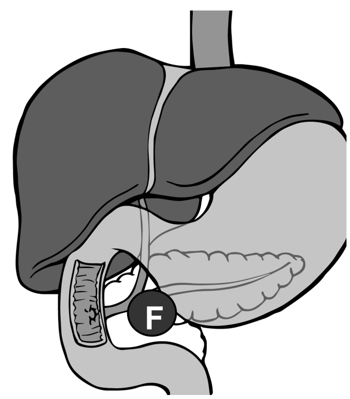


The body does not make enzymes for the breakdown of all carbohydrates; the human body relies on bacteria to help break down certain types of carbohydrates. There are hundreds of different species of bacteria in the intestine! Many types of bacteria in the digestive tract can digest small amounts of fiber, which then produces gas in our lower digestive tracts. The body is able to obtain some energy from the bacterial breakdown of fiber.

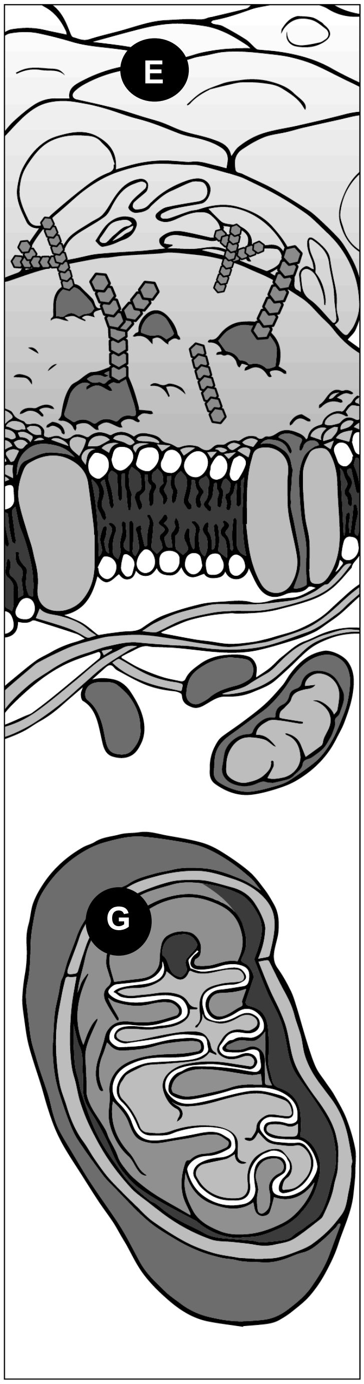
However, the majority of the fiber is not digested by bacteria, but forms a major component of stool, which is essentially made of the parts of our diet that our body cannot digest. Diets high in fiber from whole grains, beans, and fruits can relieve constipation. A high fiber diet may also lower the risk of developing heart disease and colon cancer.

Assimilation

As the monosaccharides in the small intestine flow into the blood stream (**D**), the liver picks up many microscopic sugars. One function of the liver is to store the monosaccharide *glucose* in large chains, polysaccharides called *glycogen*. Glycogen is used to pack and store glucose molecules in the liver and muscles until the body needs more energy. Most of these glucose molecules will be stored as glycogen for less than 24 hours. When glucose levels in the blood stream are lower than normal, the liver will use enzymes to break apart the glycogen chains and release the glucose molecules into the blood. The glucose then circulates through the body until cells absorb it (**E**).



Insulin, a protein made by the pancreas (**F**), is released into the blood stream. Insulin is required for glucose to enter certain cells. Without proper amounts of insulin in the body, glucose cannot enter cells.



Diabetes is a health condition related to insulin function. The bodies of people with Type 1 Diabetes do not produce enough insulin. The bodies of people with Type 2 Diabetes do not produce enough insulin, or they do not respond to insulin. A person with diabetes could have very high amounts of glucose in the blood, but the cells would receive little to no energy because the insulin system is not working properly. Symptoms of diabetes can include blurred vision, fatigue, increased urination, extreme thirst and hunger, and at worst, a coma.

Cellular Use

Cells break the bonds of glucose molecules to release energy that is used to make *adenosine triphosphate*, or *ATP*, the main energy currency of the cell. ATP produced by breaking down glucose is used for most jobs within the cell.

Humans mainly use the type of metabolism that occurs in the presence of oxygen called *aerobic respiration*, during regular daily activities and exercise such as running. Organelles called *mitochondria* (**G**) are devoted to this process, and ultimately make 36-38 ATP from each molecule of glucose. Humans use *anaerobic* metabolism when muscles need short bursts of energy, such as during weight lifting and sprinting.

Some jobs in the cell make or use carbohydrates for specific functions. The smooth and rough endoplasmic reticula synthesize *glycoproteins*, proteins with a carbohydrate tail. *Glycolipids*, also manufactured in the cell, are lipids with short chains of glucose or other sugars attached. Both glycoproteins and glycolipids are added into the cell membrane, where the carbohydrate tail helps with cell-to-cell interactions and cellular recognition. *Deoxyribose* and *ribose* are monosaccharides that are part of DNA and RNA, respectively. DNA and RNA are responsible for storing and relaying genetic information.

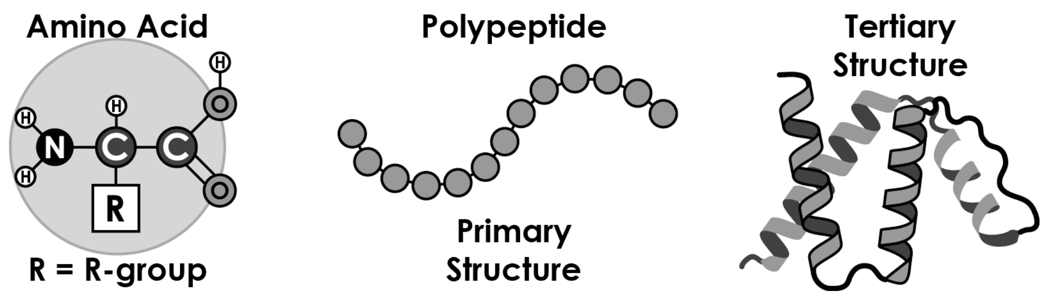
Carbohydrates are the main source of energy for our cells, but also play many other important roles in the body.

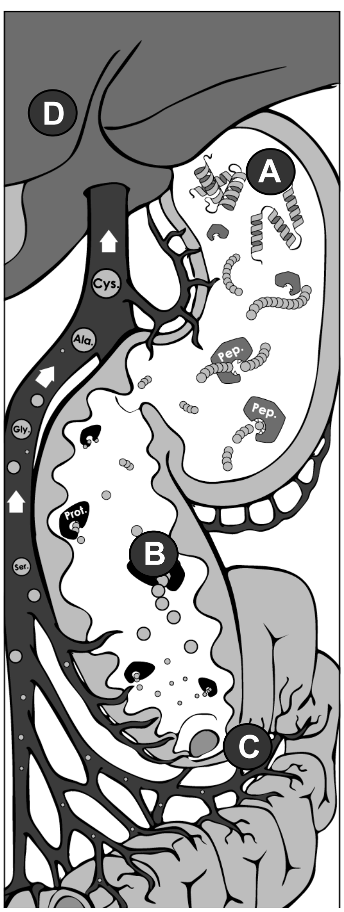
You Are What You Eat

Protein Fact Sheet

Introduction

Protein macromolecules play critical roles in cells and organisms. Proteins make up the structural tissue for muscles and tendons, compose part of hemoglobin (which transports oxygen), catalyze all biochemical reaction as enzymes, regulate reactions as hormones, form antibodies that fight infection, supply nitrogen for DNA and RNA genetic material, and can even be used in cellular respiration to form ATP. The building blocks of proteins are 20 *amino acids* that can be joined or linked together to form long strands, or polypeptides, that fold into specific 3-dimensional shapes. Of the 20 amino acids, 8 cannot be synthesized in the human body and are called the essential amino acids. Here, the word "essential" means that they must be provided in the diet in specific quantities each day. The remaining amino acids can be synthesized in the cell from other molecules.





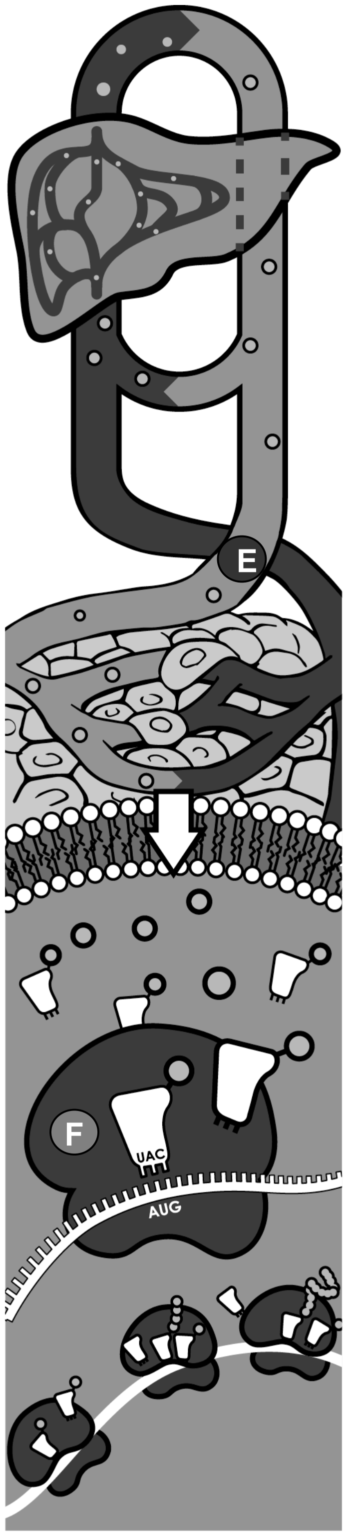
Digestion

When proteins are ingested, the proteins are broken down in the digestive system via physical and chemical processes. The motions of digestion physically break the protein into smaller pieces. A series of chemical reactions also break the large polymer into smaller subunits, which are eventually absorbed into the bloodstream and transported to the liver and cells.

The chemical digestion of proteins begins in the stomach (**A**) with the aid of digestive acid and the enzyme pepsin. The resulting smaller peptides enter the small intestine (**B**) where pancreatic enzymes called *proteases* break down the peptide chains into even smaller chains called *oligopeptides*. The cells lining the small intestine contain peptidases that break down these small peptides into free amino acids that can be absorbed into the membrane (**C**) cells by active transport. Cells can also take in oligopeptides for intracellular digestion. From there, the free amino acids are moved into the bloodstream and are transported into the liver (**D**) via the *hepatic portal system*.

Assimilation

Once in the liver, amino acids can be used for a variety of functions. Some amino acids can be converted into glucose if the organism is



experiencing starvation. Other amino acids, like those essential to the ATP-producing citric acid cycle, can be changed by *transamination*. Transamination is the movement of an amine group from one molecule to another, thus creating one amino acid from another. The transamination process takes place in the liver and can synthesize certain amino acids not present in the diet. Amino acids in the liver are sent elsewhere via the bloodstream (**E**) to be utilized by other cells.

Cellular Use

The human body is dependent on proteins; all cells can synthesize necessary proteins from amino acids. The nucleolus of eukaryotic cells assembles ribosomes (**F**), which are then transported to the cytoplasm. Next, the ribosomes utilize the free amino acids (transported by tRNA) in the cytosol to translate the mRNA transcript (the intermediate carrier of information from DNA), creating proteins specific to each type of cell. For example proteins serve as hormone receptors in the cell membrane, structural components (cytoskeleton) in the cell, channel proteins in the membranes, and enzymes that catalyze each and every reaction in the cell.

Problems with Proteins

Because proteins have so many different critical roles in the body, amino acid deficiencies can lead to a variety of disorders. There are many causes of deficiency, but sometimes protein deficiency is due to malnutrition. Kwashiorkor results from an inadequate consumption of protein and leads to the reduction of proteins in internal organs. Reduced levels of protein in blood lead to accumulation of interstitial fluid, which can result in swelling (edema) in the extremities.

Some genetic mutations cause disorders by “breaking” an enzyme important for creating or degrading specific amino acids or for regulating proteins. *Phenyketonuria* (PKU) is caused by a mutation that results in a person not being able to produce the enzyme phenylalanine *hydroxylase*, which metabolizes phenylalanine into tyrosine. A person with PKU has elevated levels of phenylalanine and other compounds, which results in cognitive and behavioral abnormalities. Although dangerous, PKU is very rare and can be controlled by diet.

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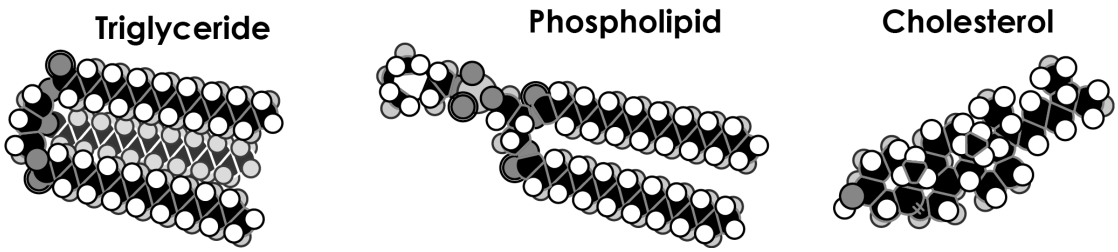
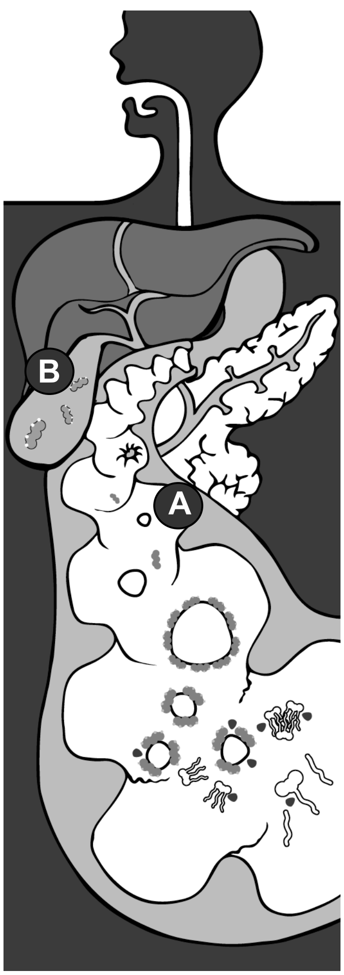
Lipids Fact Sheet

Introduction

Lipids are a broad category of molecules including fats, oils, and steroids. Plants and animals use these chains of carbon and hydrogen as a way to store energy for future use. One gram of fat has more than twice the energy packed into it than a gram of protein or carbohydrate. Lipids play essential roles as components of cell membranes, hormones, and other signaling molecules. Though the body can create many types of lipids, some essential fatty acids can only be obtained through food. Absorption of fat-soluble vitamins such as Vitamins A, D, E, and K requires some dietary fat intake.





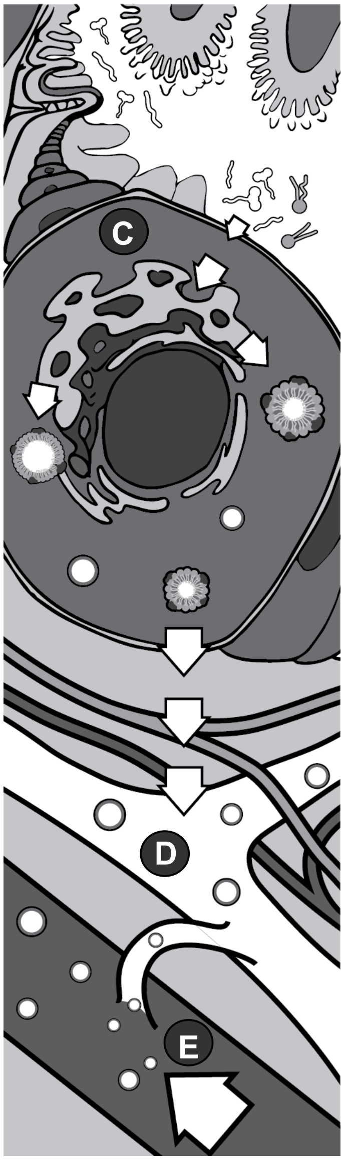
Digestion

Most of the lipids in the human diet are *triglycerides*, which are broken into *fatty acids* and *monoglycerides*. Lipid digestion begins in the mouth, but mostly occurs in the small intestine.

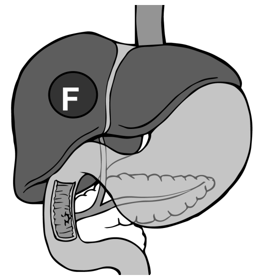
The digestion of fats and oils begins with the secretion of lingual lipase in the mouth. The fats move through the stomach into the first section of the small intestine, the *duodenum* (**A**). Intestinal movements break up globules of fat in acidic *chyme*, the mixture leaving the stomach. The gall bladder walls contract and release bile (which is made in the liver but stored in the gall bladder (**B**)) into the small intestine via the common bile duct. The droplets of fats then become coated with bile. The bile serves to break up or emulsify the large lipid droplets into smaller micelles that present more surface area for the pancreatic enzymes that are released into the small intestine.

Assimilation

The fatty acids and monoglycerides are lipid-soluble and are able to cross the mucosal membrane of the small intestine. Once inside the epithelial cells (**C**) that line the small intestine, the fatty acids and monoglycerides diffuse into the endoplasmic reticulum. There, they are re-synthesized into triglycerides and combined with cholesterol, phospholipids, and proteins to form *chylomicrons*, structures that transport lipids to other part of the body.

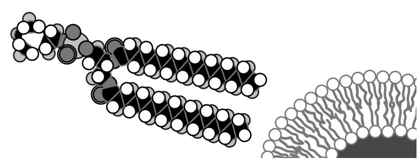


Because chylomicrons are water-soluble, they are able to exit cells via *exocytosis*. The chylomicrons enter the lymph system (**D**) through vessels in the submucosal layer of the small intestine. After traveling through the lymphatic system, the chylomicrons are released into the bloodstream (**E**) through the thoracic duct.



There is usually a constant supply of lipids in the blood, although the concentration increases immediately after a meal. The liver (**F**) regulates the proper concentration of lipids in the blood. The lipids are absorbed by liver cells, which process the lipids and release molecules that provide energy for cellular functions. Excess lipids in the bloodstream are transported to and stored in *adipose tissue*, or body fat. Adipose tissue serves as an extra layer of insulation and cushioning and can function as part of the endocrine system. The stored lipids can be used later for energy, if necessary. They can be transported from the adipose tissue to the other cells to be metabolized.

Cellular Use



Fatty acids that enter the cells become important building blocks for many different structures. Some of these fatty acids will be transformed into *phospholipids* and serve as the flexible and semi-permeable membrane for cells and the organelles; others serve as intermediates for the synthesis of compounds such as prostaglandins and leucotrienes, which play a role in physiological regulation; and, finally, some fatty acids are metabolized to form acetyl CoA, which in turn is converted into many types of compounds, including fatty acids. Acetyl CoA can also be broken down in the mitochondria to provide ATP.

Disorders

Because lipids are an important source of energy for the body, they are constantly broken down and reassembled to balance the body's needs with the food available to it. Any mutations or defects in the enzymes that catalyze the breakdown or synthesis of lipids can lead to the accumulation of specific fatty substances, which may harm various organs of the body. Disorders caused by the buildup of lipids are called *lipidoses*; Tay Sachs disease is an example. Abnormalities in enzymes that prevent lipids from being converted into energy are called *fatty acid oxidation* disorders.

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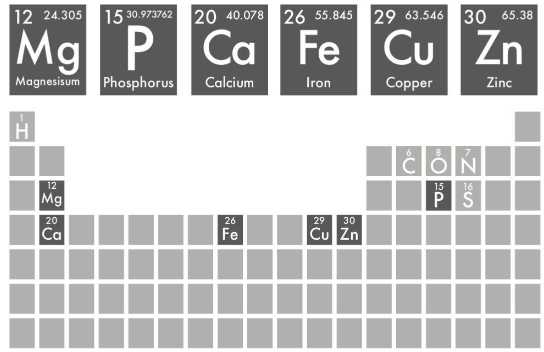
Vitamins & Minerals Fact Sheet

Vitamins and Minerals

A *mineral* is an inorganic substance that cannot be synthesized in living organisms. Therefore, the body can only obtain minerals such as iron, phosphorous, calcium, copper, zinc and magnesium through the diet. Living organisms must consume adequate amounts of minerals for structural reasons and cellular processes.

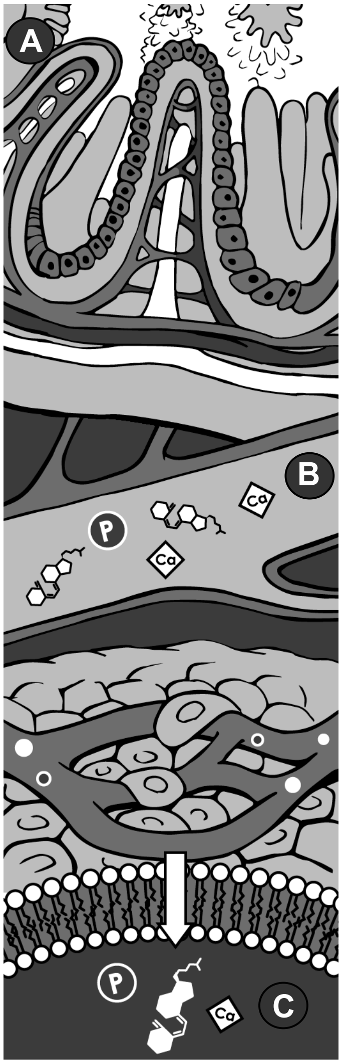


Vitamins are organic molecules either not made in the body or synthesized in amounts too small to meet the body's needs. As a result, vitamins must be obtained from the diet, and consumption of vitamins is necessary for normal metabolism. Fat-soluble vitamins (A, D, E, and K) are stored in the liver and fatty tissues and require dietary fat intake for absorption and metabolism. Excess amounts of fat-soluble vitamins are not easily excreted, posing a higher risk for toxicity. Water-soluble vitamins such as the B vitamins and Vitamin C are easily dissolved in water, easily excreted when in excess amounts, and therefore must be consumed regularly. Most vitamins function as *coenzymes* or *cofactors*, which must be present for particular enzymes to function properly. Both deficiencies and excessive intake may lead to many forms of disease.

Calcium

The mineral calcium (Ca^{2+}) is the most abundant mineral in the body. Calcium makes up 40% of all the minerals in the human body. The best source of calcium is dairy products and, to a lesser extent, dark, leafy vegetables. Many of the processed foods we eat such as cereal and orange juice have extra calcium added.

Calcium is absorbed in the small intestine (**A**) and travels through the blood stream (**B**) to the cells (**C**). Calcium is essential to many bodily functions, although 99% of the calcium in the body is used for structure of bones and teeth. The other 1% is needed for muscles to contract nerves to communicate, and blood to clot properly. Calcium also plays an important role in the dilation and contraction of blood vessels, the activation of some enzymes, and the secretion and regulation of hormones in the body. The accumulation of calcium can interfere with normal functioning of cells, including muscle cells in the heart. Conversely, calcium deficiency can lead to *osteoporosis*, or a decrease in bone density over time, making it easier for bones to break.



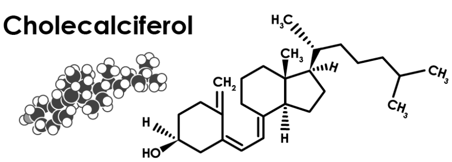
Phosphorus

Another abundant mineral in the human body is phosphorus, which composes 25% of total bodily minerals. Like calcium, phosphorus is absorbed in the small intestine (**A**). It is also critical to the structure of bones and teeth; roughly 80% of phosphorus in the body is devoted to the structure of bones and teeth. The other 20% is involved in building muscle tissue and other processes. At the cellular level, phosphorus is utilized as a component of DNA, RNA, some proteins, phospholipids, and ATP.

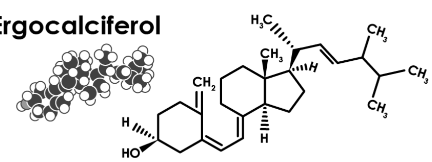
Vitamin D

Vitamin D, a fat-soluble vitamin, is the precursor for a steroid hormone involved in regulating body levels of calcium and phosphorus and in the hardening, or mineralization, of bone. Vitamin D facilitates the intestinal absorption of calcium, phosphorous, and magnesium. If there is a deficiency of Vitamin D, dietary calcium is not absorbed as efficiently. Because of the large number of Vitamin D receptors in many cells, it is possible that this hormone may have more biological effects beyond regulating calcium and phosphorus absorption and the mineralization of bone.

Cholecalciferol

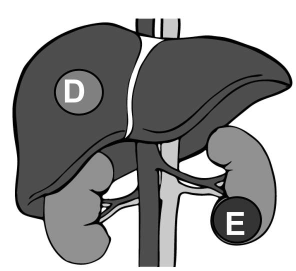


Ergocalciferol



There are several different forms of Vitamin D. One form is Vitamin D3, or *cholecalciferol*, which the body produces in the presence of sunlight. A precursor molecule (7-dehydrocholesterol) absorbs sunlight in the skin of animals and is converted into cholecalciferol. There are also several dietary sources of Vitamin D including egg yolk, fish oil, and a number of plants. The plant form of vitamin D is called Vitamin D2 or *ergocalciferol*. These forms can supplement the body's own production of cholecalciferol.

Vitamin D3 and D2 are not biologically active until they are transported to the liver (**D**) and kidney (**E**) and metabolized into one inactive form (25-hydrocholecalciferol) and the final biologically active form (1,25-dihydrocholecalciferol). Because these two substances are not water-soluble, they are bound to carrier proteins and transported in the bloodstream. The biologically active form binds to receptors that function as transcription factors to regulate gene expression.



The classical manifestation of Vitamin D deficiency is rickets, which can lead to bone deformity in children. Lack of Vitamin D can also cause softening of the bones in adults, also known as the disease *osteomalacia*. Rickets and osteomalacia both result from inadequate exposure to sunlight and decreased intake of dietary Vitamin D. A deficiency in the biologically active form of Vitamin D can result from genetic defects in Vitamin D receptors, disease of the liver or kidney that reduce the production of the active hormone, or insufficient exposure to sunlight to convert 7-dehydrocholesterol into cholecalciferol.

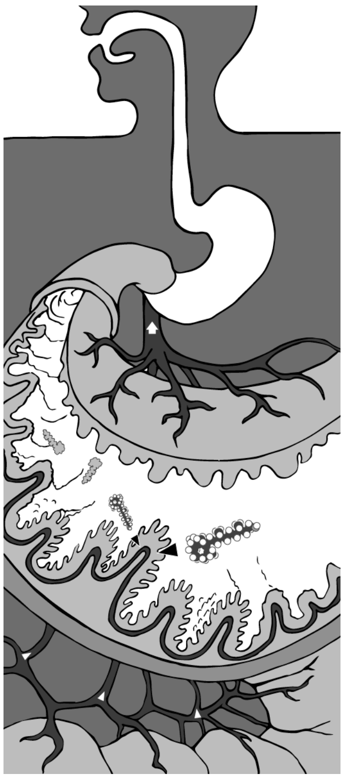
Exposure to extreme levels of Vitamin D is very toxic. Overexposure to sunlight does not result in the overproduction of Vitamin D; however, the overdosing of supplemental Vitamin D has proven severely toxic to humans and animals over time.

You Are What You Eat

FOOD FOR 9 BILLION

Vitamin A Fact Sheet

Vitamins are organic molecules needed for normal metabolism. Vitamins are not made in the body or are synthesized in amounts too small to meet the body's needs; therefore, vitamins must be obtained from the diet. Most vitamins function as *coenzymes* or *cofactors*, which must be present for enzymes to function properly. Both deficiencies and excessive intake of vitamins can result in many types of diseases.

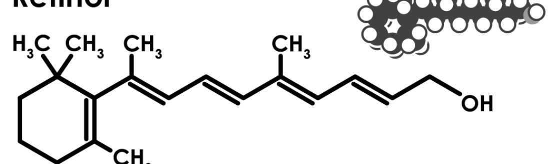


Fat-soluble vitamins such as Vitamin A are stored in the liver and other tissues. Because the body requires a moderate, regular intake of Vitamin A, a person must consume some fat in his or her diet in order to absorb and metabolize Vitamin A. However, because fat-soluble vitamins are not easily excreted, too much Vitamin A can result in accumulation and toxicity.

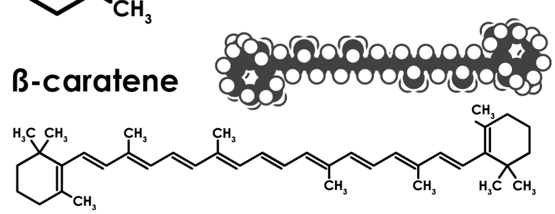
Vitamin A is present in many foods of animal origin and is readily absorbed by the small intestine. Once absorbed by the cells in the mucosal lining of the small intestine, Vitamin A is metabolized to an active form, retinol. Plant tissues do not contain Vitamin A, but they do contain carotenoid pigments that are found predominantly in dark green or dark yellow plant parts such as carrots. Some carotenoids, such as the abundant *beta-carotene*, are converted into retinol within the intestinal mucosa during absorption. Retinol is stored in the liver and released into the bloodstream, delivered to tissues by a protein transporter. Various cells either use retinol or convert it to other active forms, retinal or retinoic acid.

Each of the active forms of vitamin A (retinol, retinal, and retinoic acid) play some very significant roles in physiology, as evident in the case of deficiency or excess intake. Retinal is part of the light-absorbing molecule in our eyes. Retinoic acid is an important intracellular messenger that directly affects the transcription of several genes. In addition to their role as sources of vitamin A, there is some evidence that certain carotenoids may have physiological function themselves. There is much current research on their possible role in the immune system. A deficiency of vitamin A can affect vision, reduce resistance to infectious diseases, inhibit proper maintenance and differentiation of epithelial cells, impact bone growth, and inhibit the production of sperm cells. An excess of vitamin A can be very toxic and is generally caused by excessive supplementation. An excess intake of carotenoids from carrots, however, will generally not have toxic effects.

Retinol



ß-caratene



Name: _________________________

Date: ___________________ Class:__________

You Are What You Eat: Carbohydrates

1. Describe the pathway and the enzymes involved in the digestion of carbohydrates.

2. Describe the advantage of having indigestible carbohydrates in the digestive system.

3. The liver is one destination for digested monosaccharides. Describe how the liver utilizes monosaccharides.

4. Describe two ways that simple sugars are either incorporated or utilized within cells.

Name: _________________________

Date: ___________________ Class:__________

You Are What You Eat: Protein

1. Describe the pathway and the enzymes involved in the digestion of proteins.

2. Describe how the liver uses amino acids.

3. Describe how amino acids are incorporated or utilized within cells.

4. If certain amino acids were removed from the diet and other amino acids could not be transformed into those amino acids, how might the resulting deficit disrupt an organism or a cell?

Name: ________________________

Date: __________________ Class:__________

You Are What You Eat: Lipids

1. Describe the pathway and the enzymes involved in the digestion of lipids.

2. Describe the pathway of lipids between the digestive system and the bloodstream.

3. Besides long-term energy storage, what other functions do lipids serve in organisms and in cells?

4. How might a deficit or over-accumulation of fats be detrimental to organism?

Name: ________________________

Date: __________________ Class:__________

You Are What You Eat: Calcium, Phosphorous & Vitamin D

Calcium

1. Describe several important functions of calcium in living organisms.

2. How can the accumulation or deficiency of calcium be harmful to living things or cells?

Phosphorus

3. Discuss how the deficiency of phosphorus affects the ability of cells to continue with their regular functions.

Vitamin D

4. Describe several important functions of Vitamin D.

5. Discuss how Vitamin D deficiency affects organisms.

Name: ________________________

Date: __________________ Class:__________

You Are What You Eat: Vitamin A

1. Describe the pathway of Vitamin A from the food source to the destination cells.

2. Discuss how Vitamin A deficiency can be harmful to living organism.

Name: __TEACHER ANSWER KEY______________________

Date: __________________ Class:__________

You Are What You Eat: Carbohydrates

1. Describe the pathway and the enzymes involved in the digestion of carbohydrates.

   Mouth- amylase begins the breakdown of starch; Stomach- hydrochloric acid (HCl) contribute to further chemical and mechanical breakdown; Small intestine-pancreatic enzymes including pancreatic amylase continue the breakdown of carbohydrates. Simple sugars are absorbed in the small intestinal lining and enter the bloodstream and are transported to the liver and all cells of the organism

2. Describe the advantage of having indigestible carbohydrates in the digestive system.

   The undigested carbohydrates or fibers that are not broken down by bacteria are responsible for maintaining regular flow through the digestive tract. This reduces constipation and may reduce the risk of colon cancer.

3. The liver is one destination for digested monosaccharides. Describe how the liver utilizes monosaccharides.
   The monosaccharides or simple sugars are incorporated into long chains of glucose called glycogen in the liver. This polymer is used for very short-term storage. The liver monitors blood sugar levels. If sugar level is too low, the liver will release enzymes to hydrolyze the polymer to release glucose into the bloodstream.

4. Describe two ways that simple sugars are either incorporated or utilized within cells.

   Sugars that enter the cells can undergo the process of aerobic respiration that breaks down the organic compound to manufacture ATP in the matrix of the mitochondria, which will serve as an energy source for multitudes of chemical reactions and other activities. Sugars can also be used to manufacture glycolipids and glycoproteins in the endoplasmic reticulum (ER). These compounds become components of the cell membrane and are responsible for cell-to-cell interactions as well as cellular recognition.

Name: __TEACHER ANSWER KEY______________________

Date: __________________ Class:__________

You Are What You Eat: Protein

1. Describe the pathway and the enzymes involved in the digestion of proteins.

   Mouth and stomach- mechanical and chemical digestion - chemical digestion begins with the aid of hydrochloric acid (HCl) and pepsin; small intestine- pancreatic proteases break down the peptide chains into smaller peptides; intestinal epithelial cells contain peptidases that further break down the peptides into free amino acids that are readily absorbed into the membrane cells.

2. Describe how the liver uses amino acids.

   Free amino acids in the liver can be used for a variety of functions. Some amino acids can be converted into glucose if it is lacking in the organism. Other amino acids are used in the citric acid cycle to produce ATP and other amino acids. The liver essentially governs the production of necessary amino acids that may or may not be present in the diet. Amino acids unused in the liver are sent elsewhere to be utilized by other cells.

3. Describe how amino acids are incorporated or utilized within cells.

   In the cell, tRNA transports amino acids to ribosomes in the cytoplasm or endoplasmic reticulum to build polypeptides, as coded in the mRNA. The proteins created may either be exported to other cells or be incorporated into the cell's structures such as the cell membrane, cytoskeleton or become a variety of enzymes.

4. If certain amino acids are omitted from the diet and other amino acids cease to transform into those specific amino acids, how might this deficit disrupt life in an organism or a cell?

   If certain amino acids are left out of the diet and cannot be created by the liver, then certain key proteins cannot be synthesized during protein synthesis. This deficiency in proteins can severely affect development, the condition of visceral organs, or the production of enzymes that are essential for all the biochemical pathways in an organism.

Name: __TEACHER ANSWER KEY______________________

Date: __________________ Class:__________

You Are What You Eat: Lipids

1. Describe the pathway and the compounds involved in the digestion of lipids.

   The digestion of fats begins in the small intestine. The globules of fat are broken down into smaller droplets due to the action of the intestinal movements. The globules become coated with bile. The bile further breaks down or emulsifies the fat. The pancreatic enzymes called lipases in the small intestine can now further break down the smaller droplets or micelles.

2. Describe the pathway of lipids between the digestive system and the bloodstream.

   The fatty acids and monoglycerides, which are fat-soluble, are able to cross the mucosal lining of the small intestine. Once inside the epithelial cells, they diffuse into the endoplasmic reticulum and are re-synthesized into triglycerides, combined with cholesterol, phospholipids and coated with a protein to form a chylomicron. The water-soluble chylomicron exits the cells via exocytosis and enters the lymphatic vessels in the submucosa. The lymphatic system will dump the chylomicron into the bloodstream.

3. Besides long-term energy storage, what other functions do lipids serve in organisms and in cells?

   The fatty acids can become important building blocks for many different structures. Some will be transformed into phospholipids, which are the structural basis of cell membranes. Other fatty acids can become intermediates for compounds such as prostaglandins and leucotrienes.

4. How might a deficit or over-accumulation of fats be detrimental to organism?
   Any mutations in the enzymes responsible for the breakdown of lipids will result in the accumulation of lipids and this can be very harmful to many organs of the body.

Name: __TEACHER ANSWER KEY______________________

Date: __________________ Class:__________

You Are What You Eat: Calcium, Phosphorus, and Vitamin D

Calcium

1. Describe several important functions of calcium in living organisms.

Calcium is a major component of bones and teeth. Calcium is necessary for the contraction and relaxation of muscles. It permits nerve impulses to be transmitted and plays a role in blood clotting. Calcium is responsible for activating certain enzymes and regulates certain hormones in the body.

2. How can the accumulation or deficiency of calcium be harmful to living things or cells?

The accumulation of calcium can induce mechanical and chemical abnormalities in cardiac tissue. A deficiency in calcium can affect the integrity of bones and lead to osteoporosis.

Phosphorus

3. Discuss how the deficiency of phosphorus affects the ability of cells to continue with their regular functions.

A deficiency in phosphorus would impact bone growth, teeth, and muscles. Because phosphorus is a building block of DNA and RNA and is a major component of ATP, a deficiency of phosphorous might impact the cells' ability to synthesize the appropriate proteins, which regulate all activity and ATP.

Vitamin D

4. Describe several important functions of Vitamin D.

Vitamin D is important in regulating body levels of calcium and phosphorus. It also regulates the mineralization of bone. Vitamin D facilitates the absorption of calcium and stimulates the absorption of phosphorous and magnesium ions in the intestine.

5. Discuss how Vitamin D deficiency affects organisms.

A deficiency in Vitamin D will result in the weakening and softening of the bone called rickets. Lack of Vitamin D can also cause softening of the bones in adults, also known as the disease osteomalacia. Because Vitamin D facilitates the absorption of calcium, magnesium, and phosphorous, a deficiency of Vitamin D will effect levels of those minerals.

Name: TEACHER ANSWER KEY

Date: __________________ Class:__________

You Are What You Eat: Vitamin A

1. Describe the pathway of Vitamin A from the food source to the destination cells.

   Vitamin A enters the small intestine along with the food and is absorbed by the tissues in the mucosal lining. Once inside the epithelial cells, the vitamin is converted into its active form, retinol. Retinol moves to the liver to be stored, from which it is released into the bloodstream. Various cells either use retinol or convert it to other active forms, retinal or retinoic acid.

2. Discuss how Vitamin A deficiency can be harmful to living organism.

   Deficiency in Vitamin A can affect vision, reduce resistance to infectious diseases, inhibit proper maintenance and differentiation of epithelial cells, reduce the ability of osteoblasts and osteoclasts to regulate bone growth and inhibit the production of sperm cells.