Biology: The Scientific Study of Life

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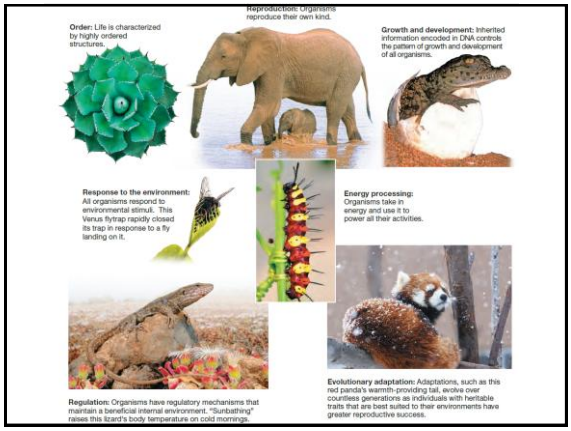
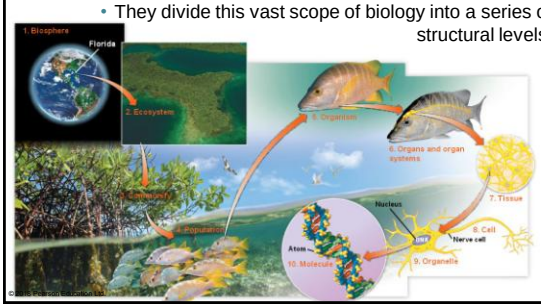

Reproduction: Organisms reproduce their own kind.
Order: Life is characterized by highly ordered structures.
Growth and development: Inherited information encoded in DNA controls the pattern of growth and development of all organisms.
Response to the environment: All organisms respond to environmental stimuli. This Venus flytrap rapidly closed its trap in response to a fly landing on it.
Energy processing: Organisms take in energy and use it to power all their activities.
Regulation: Organisms have regulatory mechanisms that maintain a beneficial internal environment. "Sunbathing" raises this lizard's body temperature on cold mornings.
Evolutionary adaptation: Adaptations, such as this red panda's warmth-providing tail, evolve over countless generations as individuals with heritable traits that are best suited to their environments have greater reproductive success.

In life's hierarchy of organization, new properties emerge at each level

- Biologists study life across a very broad range of scales, from the molecules in a cell to the entire living planet.
- They divide this vast scope of biology into a series of structural levels.


1. Biosphere
Florida
2. Ecosystem
3. Community
4. Population
5. Organism
6. Organs and organ systems
7. Tissue
8. Cell
Nerve cell
9. Organelle
Nucleus
DNA
Atom
10. Molecule

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Elements, Atoms, and Compounds

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Introduction

- Life's chemistry is tied to water.
  - Life first evolved in water.
  - All living organisms require water.
  - Cells consist of about 70% water.

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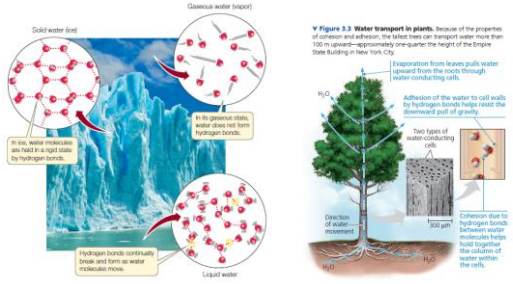
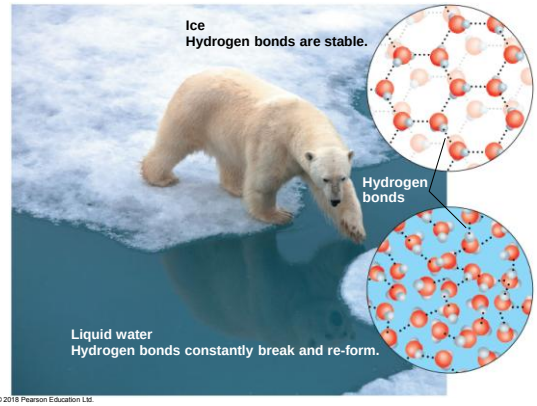
Water

Molecular structure of water and its capacity to form hydrogen bonds give it unique properties that are significant for life


Gaseous water (vapor)
Solid water (ice)
In ice, water molecules are held in a rigid state by hydrogen bonds.
In its gaseous state, water does not form hydrogen bonds.
Hydrogen bonds continually break and form as water molecules move.
Liquid water
Figure 3.3 Water transport in plants. Because of the properties of cohesion and adhesion, the tallest trees can transport water more than 100 m upward—approximately one-quarter the height of the Empire State Building in New York City.
Evaporation from leaves pulls water upward from the roots through water-conducting cells.
Adhesion of the water to cell walls by hydrogen bonds helps resist the downward pull of gravity.
Two types of water-conducting cells
Direction of water movement
300 µm
Cohesion due to hydrogen bonds between water molecules helps hold together the column of water within the cells.


Ice
Hydrogen bonds are stable.
Hydrogen bonds
Liquid water
Hydrogen bonds constantly break and re-form.
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Ice floats because it is less dense than liquid water

- Water can exist as a gas, liquid, or solid.
- Water is less dense as a solid than a liquid because of hydrogen bonding.
- When water freezes, each molecule forms a stable hydrogen bond with its neighbors.
  - As ice crystals form, the molecules are less densely packed than in liquid water.
  - Because ice is less dense than water, it floats.

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Sweating as a mechanism of evaporative cooling

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Water is the solvent of life

- A **solution** is a liquid consisting of a uniform mixture of two or more substances.
- Water's versatility as a **solvent** results from the polarity of its molecules.
- Polar or charged **solutes** dissolve when water molecules surround them, forming **aqueous solutions**.

Checkpoint question Why are blood and most other biological fluids classified as aqueous solutions?

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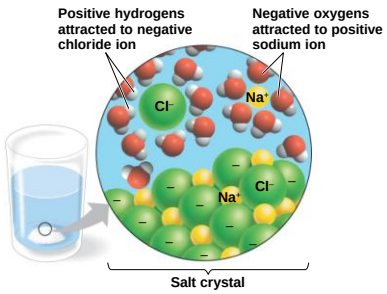
A crystal of salt (NaCl) dissolving in water


Positive hydrogens attracted to negative chloride ion
Negative oxygens attracted to positive sodium ion
Cl⁻
Na⁺
Cl⁻
Na⁺
Salt crystal

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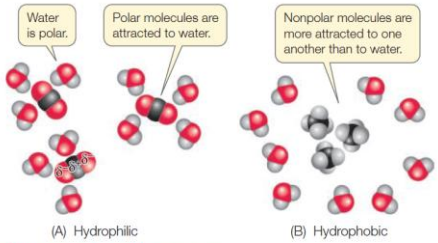
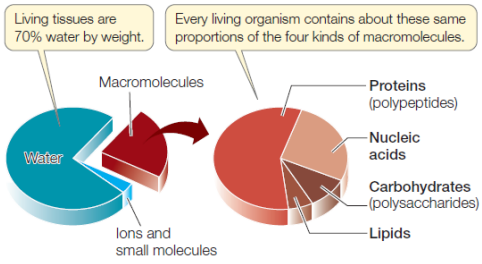
Polar and nonpolar substances


Water is polar.
Polar molecules are attracted to water.
Nonpolar molecules are more attracted to one another than to water.
(A) Hydrophilic
(B) Hydrophobic

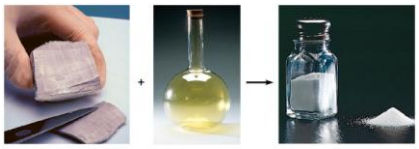
2.12 Hydrophilic and Hydrophobic (A) Molecules with polar covalent bonds are attracted to polar water (they are hydrophilic). (B) Molecules with nonpolar covalent bonds show greater attraction to one another than to water (they are hydrophobic).


Living tissues are 70% water by weight.
Every living organism contains about these same proportions of the four kinds of macromolecules.
Macromolecules
Water
Ions and small molecules
Proteins (polypeptides)
Nucleic acids
Carbohydrates (polysaccharides)
Lipids

3.3 Substances Found in Living Tissues The substances shown here make up the nonmineral components of living tissues (bone would be an example of a mineral component).

Organisms are composed of elements, usually combined into compounds

- Living organisms are composed of matter.
- Matter is composed of chemical elements.
  - About 25 elements are essential for human life.
  - Four elements make up about 96% of the weight of most living organisms.
- A **compound** is a substance consisting of two or more different elements in a fixed ratio.


Sodium (Na)
Chlorine (Cl)
Sodium chloride (NaCl)

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Elements of the human body as percentage of body weight

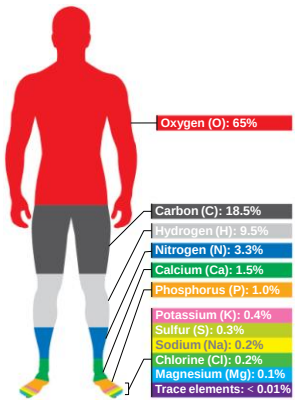
Oxygen (O): 65%
Carbon (C): 18.5%
Hydrogen (H): 9.5%
Nitrogen (N): 3.3%
Calcium (Ca): 1.5%
Phosphorus (P): 1.0%
Potassium (K): 0.4%
Sulfur (S): 0.3%
Sodium (Na): 0.2%
Chlorine (Cl): 0.2%
Magnesium (Mg): 0.1%
Trace elements: < 0.01%

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Table 2.1 Elements in the Human Body

Element	Symbol	Percentage of Body Mass (including water)	
Oxygen	O	65.0%	96.3%
Carbon	C	18.5%	
Hydrogen	H	9.5%	
Nitrogen	N	3.3%	
Calcium	Ca	1.5%	3.7%
Phosphorus	P	1.0%	
Potassium	K	0.4%	
Sulfur	S	0.3%	
Sodium	Na	0.2%	
Chlorine	Cl	0.2%	
Magnesium	Mg	0.1%	

Trace elements (less than 0.01% of mass): Boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), zinc (Zn)

- **Essential elements:** an organism needs to live a healthy life and reproduce.
- **Trace elements:** required by an organism in only minute quantities

Trace elements are common additives to food and water

- Some trace elements are required to prevent disease.
- Fluoride is usually added to municipal water and dental products to help reduce tooth decay.
- Several chemicals are added to food to
  - help preserve it,
  - make it more nutritious, and/or
  - make it look better.

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Goiter, a symptom of iodine deficiency

Too little iodine in the diet can lead to goiter—the condition afflicting this person. Goiter is not common in developing countries because iodine is added to salt and other foods.

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How much do you know about food?

Careful—one bite of my liver would kill you.

Can you find the hidden fat in this photo?

There's *how* much sugar in this yogurt??

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OVERVIEW

- What *is* food?
- What are macronutrients?
- What are micronutrients?
- How can I know exactly what I'm eating?

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Same food, different forms

Whole

Minimally processed

Many modern foods are so highly processed that the ingredients are unrecognizable

Highly processed

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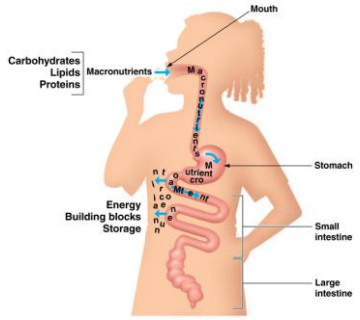
Macronutrients: organic molecules that we need to eat in relatively large amounts


Mouth
Carbohydrates
Lipids
Proteins
Macronutrients
Stomach
Energy
Building blocks
Storage
Small intestine
Large intestine

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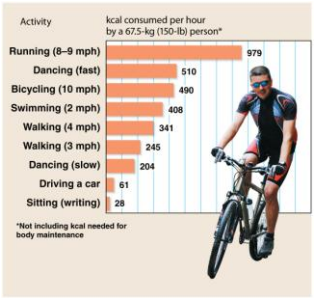
Energy for activities, basal metabolism

- We eat because we need energy.
- To maintain the same weight, caloric balance is necessary

Activity calculator

BMR calculator


Activity
kcal consumed per hour by a 67.5-kg (150-lb) person*
Running (8–9 mph) 979
Dancing (fast) 510
Bicycling (10 mph) 490
Swimming (2 mph) 408
Walking (4 mph) 341
Walking (3 mph) 245
Dancing (slow) 204
Driving a car 61
Sitting (writing) 28
*Not including kcal needed for body maintenance

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More than sugar

Protein
Fat
Vitamins
Minerals

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- What *is* food?
- What are macronutrients?
- What are micronutrients?
- How can I know exactly what I'm eating?

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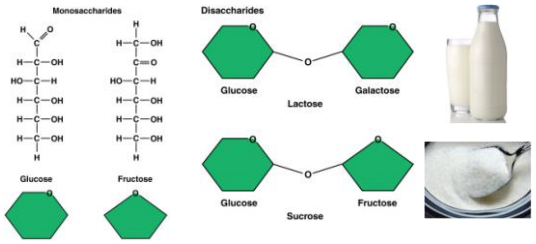
Carbohydrates—simple sugars


Monosaccharides
Glucose
Fructose
Disaccharides
Glucose
Galactose
Lactose
Glucose
Fructose
Sucrose

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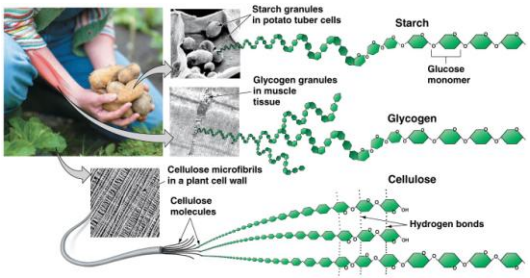
Carbohydrates—polysaccharides


Starch granules in potato tuber cells
Starch
Glucose monomer
Glycogen granules in muscle tissue
Glycogen
Cellulose microfibrils in a plant cell wall
Cellulose
Cellulose molecules
Hydrogen bonds

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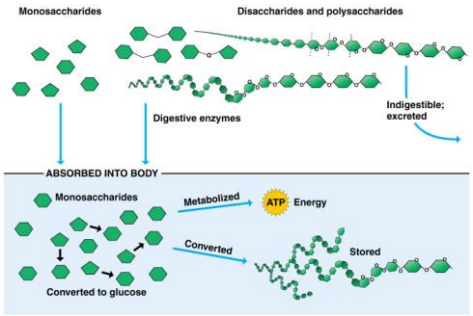
Digestion and use of carbohydrates


Monosaccharides
Disaccharides and polysaccharides
Digestive enzymes
Indigestible; excreted
ABSORBED INTO BODY
Monosaccharides
Metabolized
ATP
Energy
Converted
Stored
Converted to glucose

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Healthful carbohydrates

fiber, vitamins, minerals

This meal includes chickpeas, olives, tomatoes, basil, sprouts, and whole-grain bread.

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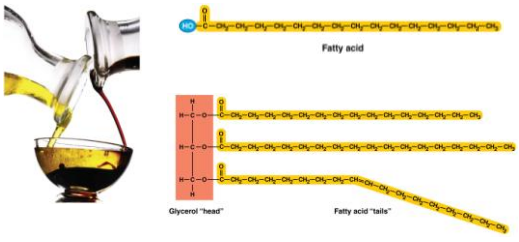
Lipids—fatty acids and fats


Fatty acid
Glycerol "head"
Fatty acid "tails"

Fat

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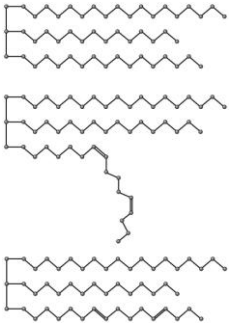
Saturated and unsaturated fats



Saturated fat

Polyunsaturated fat

Trans fat

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Essential fatty acids

Nutrients that our bodies need but are unable to make are called "essential" nutrients. Essential nutrients must be obtained from food.


OH
Omega-3 carbon

Alpha-linolenic acid, an omega-3 fatty acid

Sources of linoleic acid

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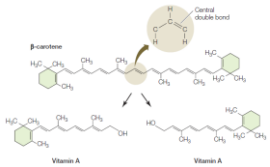
Vitamins A and D, **steroids** and **plant pigments** such as carotenoids are also lipids.

- The **carotenoids** are a family of light-absorbing pigments found in plants and animals. Beta-carotene (β-carotene) is one of the pigments that traps light energy in leaves during photosynthesis. In humans, a molecule of β-carotene can be broken down into two vitamin A molecules, from which we make the pigment *cis-retinal,* which is required for vision.

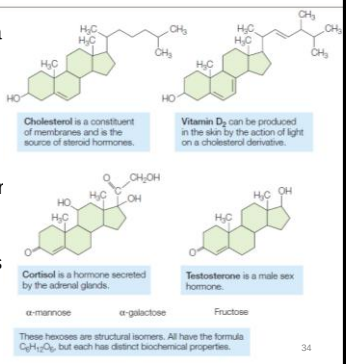

Central double bond
β-carotene
Vitamin A
Vitamin A

Carotenoids are responsible for the colors of carrots, tomatoes, pumpkins, egg yolks, and butter.

33

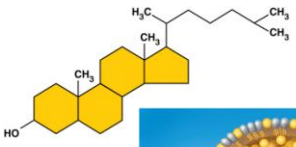
Steroids

- The **steroids** are a family of organic compounds whose multiple rings share carbons
- Cholesterol is synthesized in the liver and is the starting material for making testosterone and other steroid hormones, such as estrogen.

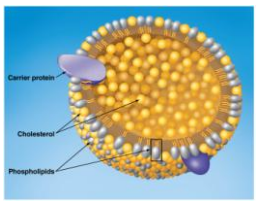

Cholesterol is a constituent of membranes and is the source of steroid hormones.
Vitamin D3 can be produced in the skin by the action of light on a cholesterol derivative.
Cortisol is a hormone secreted by the adrenal glands.
Testosterone is a male sex hormone.
α-mannose
α-galactose
Fructose
These hexoses are structural isomers. All have the formula C6H12O6, but each has distinct biochemical properties.

34

Lipids—steroids


HO

Cholesterol


Carrier protein
Cholesterol
Phospholipids

Low-density lipoprotein (LDL)

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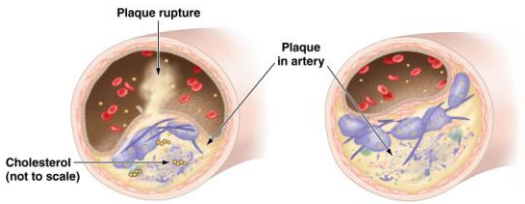
Lipids and cardiovascular disease


Plaque rupture
Plaque in artery
Cholesterol (not to scale)

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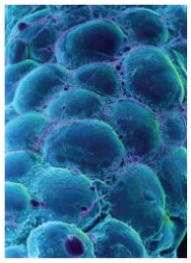
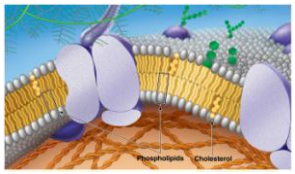
How lipids are used in the body



Fat cells=energy


Phospholipids
Cholesterol

Plasma membrane

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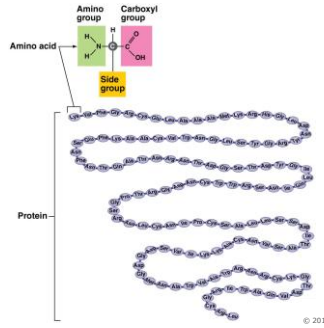
Protein structure


Amino group
Carboxyl group
Amino acid
Side group
Protein

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Complete protein

Animal sources

Meat

Dairy

Fish

Poultry

Plant sources

Soybeans

Soy products

Quinoa

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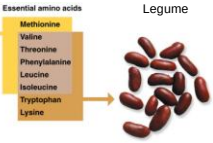
Complete protein

Grain


Essential amino acids
Methionine
Valine
Threonine
Phenylalanine
Leucine
Isoleucine
Tryptophan
Lysine

Legume

couscous (wheat) and falafel (chickpeas)

whole-grain bread and peanut butter

rice and black-eyed peas

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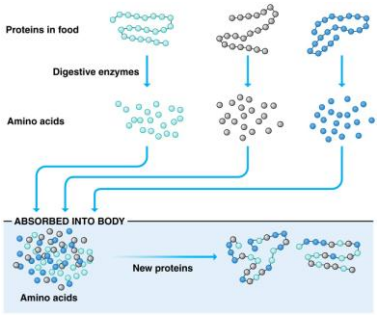
Digestion and use of proteins


Proteins in food
Digestive enzymes
Amino acids
ABSORBED INTO BODY
New proteins
Amino acids

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Protein functions

Enzymatic proteins

Function: Selective acceleration of chemical reactions

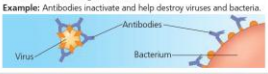
Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.


Enzyme

Defensive proteins

Function: Protection against disease

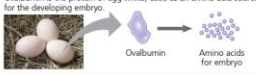
Example: Antibodies inactivate and help destroy viruses and bacteria.


Antibodies
Virus
Bacterium

Storage proteins

Function: Storage of amino acids

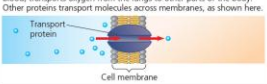
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.


Ovalbumin
Amino acids for embryo

Transport proteins

Function: Transport of substances

Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.


Transport protein
Cell membrane

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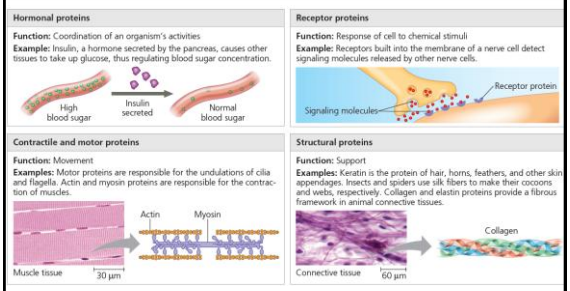
Protein functions


Hormonal proteins
Function: Coordination of an organism's activities
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.
High blood sugar
Insulin secreted
Normal blood sugar
Receptor proteins
Function: Response of cell to chemical stimuli
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.
Receptor protein
Signaling molecules
Contractile and motor proteins
Function: Movement
Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.
Actin
Myosin
Muscle tissue
30 µm
Structural proteins
Function: Support
Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.
Collagen
Connective tissue
60 µm

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- What *is* food?
- What are macronutrients?
- What are micronutrients?
- How can I know exactly what I'm eating?

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Micronutrients

Vitamins: Organic molecules
Fat-soluble
Vitamin A
Vitamin D
Vitamin E
Vitamin K
Water-soluble
B_1 (thiamine)
B_2 (riboflavin)
B_3 (niacin)
B_5 (pantothenic acid)
B_6 (pyridoxine)
B_7 (biotin)
B_9 (folic acid)
B_{12} (cobalamin)
Vitamin C

Minerals: Inorganic nutrients
Major minerals (>200 mg/day needed)
Calcium (Ca)
Phosphorus (P)
Sulfur (S)
Potassium (K)
Chlorine (Cl)
Sodium (Na)
Magnesium (Mg)
Trace minerals (<20 mg/day needed)
Iron (Fe)
Fluorine (F)
Iodine (I)
Selenium (Se)
Zinc (Zn)
Chromium (Cr)
Copper (Cu)
Manganese (Mn)

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Vitamins

- **Vitamins** are small molecules that are not synthesized by the human body and so must be acquired from the diet
- *Vitamin A* is formed from the β-carotene found in green and yellow vegetables. In humans, a deficiency of vitamin A leads to dry skin, eyes, and internal body surfaces, retarded growth and development, and night blindness, which is a diagnostic symptom for the deficiency. Vitamins D, E, and K are also lipids.

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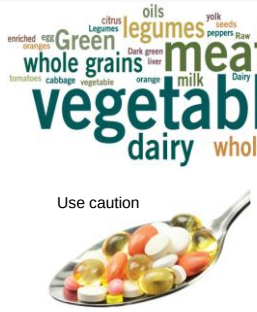
Vitamins


oils
citrus
legumes
yolk
seeds
fish
Legumes
enriched
egg
Green
peppers
Raw
egg yolks
oranges
Nuts
organ
Dark green
meats
eggs
strawberries
whole grains
liver
wheat germ
peanuts
tomatoes
cabbage
vegetable
orange
milk
Dairy
broccoli
fruits
leafy
green
nuts
vegetables
dairy
whole grains

Good sources of vitamins

Use caution

Don't eat the liver

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Photo credits: (Left) volkaFotolia, (Right) JackFFotolia

Three important minerals

Mineral	How much per day?	Why?	Sources
Limit intake			
Sodium	1,500–2,300 mg	Causes hypertension in some people	Processed foods: anything that tastes salty
Get enough			
Calcium	1,000 mg	Strong bones and teeth; adequate blood clotting; nerve and muscle function	Dairy, leafy green vegetables, fortified foods
Iron	8 mg for men, 18 mg for women	Hemoglobin for red blood cells	Meat, poultry, fish; legumes, whole grains

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Foods rich in iron

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How can I know what I'm eating?


Nutrition Facts
Serving Size 1 Bar (40g)
Amount Per Serving
Calories 170
Calories from Fat 60
% Daily Value*
Total Fat 7g 18%
Saturated Fat 3g 15%
Trans Fat 0g
Cholesterol 0mg 0%
Sodium 160mg 7%
Total Carbohydrate 24g 8%
Dietary Fiber 3g 12%
Sugars 10g
Protein 5g 10%
Vitamin A 2%
Vitamin C 2%
Calcium 20%
Iron 8%
*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs:
Calories: 2,000 2,500
Total Fat Less than 65g 80g
Sat. Fat Less than 20g 25g
Cholesterol Less than 300mg 300g
Sodium Less than 2,400mg 2,400g
Total Carbohydrate Less than 300g 375g
Dietary Fiber 25g 30g
Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4
Check calories
Limit these nutrients
Get enough of these nutrients
Footnote
Ingredients
Granola bar (Brown rice syrup, Granola [rolled oats, honey, canola oil], Dry roasted peanuts, Soy crisps [soy protein isolate, rice flour, malt extract, calcium carbonate], Crisp brown rice [organic brown rice flour, evaporated cane juice, molasses, rice bran extract, sea salt], Glycerine, Peanut butter [ground dry roasted peanuts], inulin, Whey protein isolate, Gold flax seeds, Quinoa flakes, Calcium carbonate, Salt, Natural flavors, Water, Soy lecithin [an emulsifier], Dark compound coating (evaporated cane juice, palm kernel oil, cocoa [processed with alkali], palm oil, soy lecithin [an emulsifier]).

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Source: USDA Dietary Guidelines for Americans, 2010, p. 73, appendix 4, www.cnpp.usda/DGA2010_PolicyDocument.htm

Check the label for hidden sugar

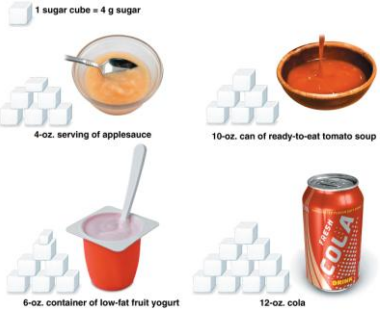
1 sugar cube = 4 g sugar
4-oz. serving of applesauce
10-oz. can of ready-to-eat tomato soup
6-oz. container of low-fat fruit yogurt
12-oz. cola

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Photo credits: (Applesauce) Mark Scott/Fotolia, (Soup) markcarper/Fotolia, (Yogurt) NikuP/Fotolia, (Cola Can) StramskiFotolia

Check the label for invisible fat


1 pat of butter = 1 teaspoon = 3 g saturated fat
Apple pie
Plain hot dog
1 package of ramen noodles
Cake donut
Cheesecake
Coconut chocolate donut

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Photo credits: (Apple Pie) SunnyS/Fotolia, (Hot Dog) Springfield Gallery/Fotolia, (Noodles) Xuejun Li/Fotolia, (Cake Donut) Bert Folsom/Fotolia, (Cheese Cake) Boris Ryzhkov/Fotolia, Chocolate Donut) JJAVA/Fotolia

Wheat grains

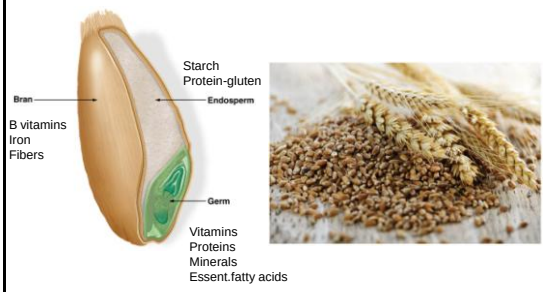
Bran
B vitamins
Iron
Fibers
Starch
Protein-gluten
Endosperm
Germ
Vitamins
Proteins
Minerals
Essent.fatty acids

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Photo credit: ElenaNeveselFotolia

ANCILLARY SLIDE

Vegetarian diets

Type of diet	Description	Micronutrient concerns
Vegan	Completely plant-based diet	Iron, calcium, zinc, vitamin B_2 (riboflavin), vitamin B_{12}
Lactovegetarian	Excludes all animal-based food except dairy products	Iron, vitamin B_{12}
Lacto-ovo-vegetarian	Includes both dairy products and eggs	Iron, vitamin B_{12}
Pescovegetarian	Excludes meat but eat seafood, eggs, and dairy products	Iron, vitamin B_{12}

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ANCILLARY SLIDE (1 of 2)

Can you match the food with its nutrition facts?

Food item	A	B	C	D	E	F
Serving size (g)	116	117	120	128	130	133
Calories	370	235	350	260	330	360
Total fat (g)	17	12	18	13	14	16
Saturated fat (g)	6	2	9	2.5	6	6
Cholesterol (mg)	0	17.5	50	70	30	65
Sodium (mg)	760	310	860	770	870	580
Total carbs (g)	49	22	32	13	37	31
Dietary fiber (g)	4	2.5	2	2	2	2
Sugars (g)	0	3	1	0	4	5
Protein (g)	4	10	16	25	13	24

Pepperoni pizza

3" of a tuna sub

Chicken tenders (3)

Plain hamburger

Cheese quesadilla

Medium fries

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Photo credits: (Pizza) Nicholas Piccillo/Fotolia, (Tuna Sub) JJAVA/Fotolia, (Chicken) Bert Folsom/Fotolia, (Hamburger) Springfield Gallery/Fotolia, (Quesadilla) Brooke Becker/Fotolia, (Fries) ntnatoly/Fotolia

ANCILLARY SLIDE (2 of 2)

Fast food facts

Food item	Medium French fries	3" of tuna sub	Cheese quesadilla	Chicken tenders (3)	Pepperoni pizza (1 slice)	Hamburger (no condiments)
Serving size (g)	116	117	120	128	130	133
Calories	370	235	350	260	330	360
Total fat (g)	17	12	18	13	14	16
Saturated fat (g)	6	2	9	2.5	6	6
Cholesterol (mg)	0	17.5	50	70	30	65
Sodium (mg)	760	310	860	770	870	580
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Protein (g)	4	10	16	25	13	24

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References

- ***On Food and Cooking: The Science and Lore of the Kitchen***
  Harold McGee, Scribner, 2004.
- **Links to Nutrition Resources**
  www.nutrition.gov/
- **Nutrition and Fitness Resources**
  www.livestrong.com/myplate/
- **USDA Food and Nutrition Information**
  www.choosemyplate.gov/

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