Module 8
Food Chemistry, Subsistence Webs, and Nutrition

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Key Terms and Concepts

- adenosine diphosphate (ADP)
- adenosine triphosphate (ATP)
- amino acid
- anabolic steroids
- antioxidant
- ascorbic acid (vitamin C)
- basal metabolic rate (BMR)
- basal metabolism
- biochemistry
- body mass index (BMI)
- bond
- butylated hydroxyanisole (BHA)
- butylated hydroxytoluene (BHT)
- calcium
- calorie
- carbohydrates
- cellulose
- cholesterol
- coenzyme
- collagen
- complete proteins

- copper
- dioxins
- disaccharide
- endocrine disruptor
- enzyme
- essential amino acids
- estrogen
- ethylene diamine tetraacetic acid (EDTA)
- fats
- fatty acid
- fibre
- food additives
- free radicals
- fructose
- glucose
- glycogen
- hormone
- iodine
- iron
- lactase
- lactose
- lipids
- lipoproteins
- magnesium
- major minerals
- monosaccharide
- niacin (vitamin B_3)
- nutrients
- nutrition
- oils
- pepsin
- peptide bond

- polysaccharides
- potassium
- progesterone
- prostaglandins
- protease
- protein
- Retin-A (vitamin A)
- scurvy
- selenium
- sodium
- starches
- steroids
- substrate
- sucrose
- tocopherol (vitamin E)
- triglycerides
- unsaturated
- vitamin B complex
- vitamins
- zinc

Learning Objectives/Outcomes

Upon completion of this module, you should be able to

1. identify the structure and properties of carbohydrates, proteins, and fats.
2. outline the dietary needs for carbohydrates, fats, proteins, and vitamins.
3. explain the laws of energy, caloric intake, and energy storage.
4. describe the value of subsistence food.
5. describe the potential danger of contaminants and food additives.

Overview

Sustainability and stewardship directly relate to maintaining life. Life comes in a variety of forms, from bacteria to plants and fish and mammals. But there is a unity within this variation; these different organisms are made up of the same basic biomolecules: proteins, carbohydrates, and fats. All organisms also use and need vitamins, salts, and minerals. These molecules provide the organism with energy and raw materials to grow or renew their own molecular structures; for example, proteins supply the biological catalysts—that is, enzymes—that control the chemical reactions of the cell.

Foods are the source of these molecules; and the way an organism uses food is known as *nutrition*. Our bodies are composed of the atoms and molecules obtained from foods: you are what you eat. For humans, a nutritional diet should supply a balance of carbohydrates, fats, proteins, vitamins, minerals, and water. Research has shown that ideal proportions of these nutrients are about 60% carbohydrate, 10% protein and 30% or less fat. These **nutrients** provide energy for the performance of essential metabolic processes and supply materials for building cellular structures and body tissues. Nutrients also can provide molecules or their precursors needed for regulation of metabolic and physiological process.

Lecture

Composition and Molecules of Foods

Food does not bring only nourishment to the table; it also brings a variety of pleasures and traditions. Whatever the reason for selecting a diet, whether it is environmental, spiritual, or for convenience, everyone needs to eat in order to gain the energy necessary to maintain the physiological order that is life. Contained in the chemical bonding structure of our food is the energy needed to move, think, breathe, and even replenish tissues. This energy is measured in calories (cal); and 1 kilocalorie is called a "Calorie" (Cal). The amount of calories in a food sample is determined by measuring the amount of heat that is released when the sample is completely oxidized in an apparatus called a bomb calorimeter. This, however, is not the same as the energy that is available for our bodies to use. Some of the energy from food is lost in feces from undigested food or in urine because some nitrogen-containing compounds are not fully oxidized. Some energy is lost as waste heat in metabolic processes—a heat tax. The smallest amount of energy needed for normal function is the **basal metabolic rate (BMR)**, the resting rate. This is the energy required to stay alive while sleeping—to maintain **basal metabolism**. Basal metabolism requires about 0.5 Cal/hour per 0.5 kg (1 lb.) of body weight.

Different foods provide varying amounts of energy (see table 8.1). Fats are the highest source of energy, providing 9 Cal/g, whereas carbohydrates and proteins supply 4 Cal/g. Every person has a different basal metabolic rate, based on age, sex, size, and activity. The average young adult male of about 82 kg (180 lbs.) requires about 3,000 Cal per day and a young adult female of about 54 kg (120 lbs.) requires 2,100 Cal per day. In Arctic regions, fat provides the bulk of energy; while in temperate and tropical areas, carbohydrates are more available for energy use.

Table 8.1 Caloric Content of Several Food Types

Food Type	Caloric Content (Cal/g)	% Recommended Caloric Intake
Fats and Oils	9	30
Carbohydrates	4	58
Proteins	4	10

Besides providing us with energy, food supplies nutrients in the form of vitamins, minerals, and fibre. These compounds contain little or no calories but are still essential for growth, maintenance, and tissue repair. Food also contains non-nutrients such as colouring agents, pigments, preservatives, and even contaminants. While some non-nutrients turn out to be beneficial for human health or for food preservation, others can be harmful. Long-term effects of theses non-nutrients on overall health, when ingested in small amounts or infrequently, are being questioned. Eating something bad for you once in a while will probably have little, if any, impact, but continuous bad habits could have a lasting consequence.

Carbohydrates

Carbohydrates are comprised of carbon, oxygen, and hydrogen and are the primary source of immediate energy for humans. This energy is obtained from the **monosaccharide** glucose ($C_6H_{12}O_6$), a simple sugar that is the building block of **complex carbohydrates**, such as starch and cellulose (fibre). Other common sugars are the monosaccharide fructose (found in berries and honey), the **disaccharide** lactose (found in milk), and **sucrose** (found in sugar cane and sugar beet). Monosaccharides and disaccharides are called simple carbohydrates (see fig. 8.1).

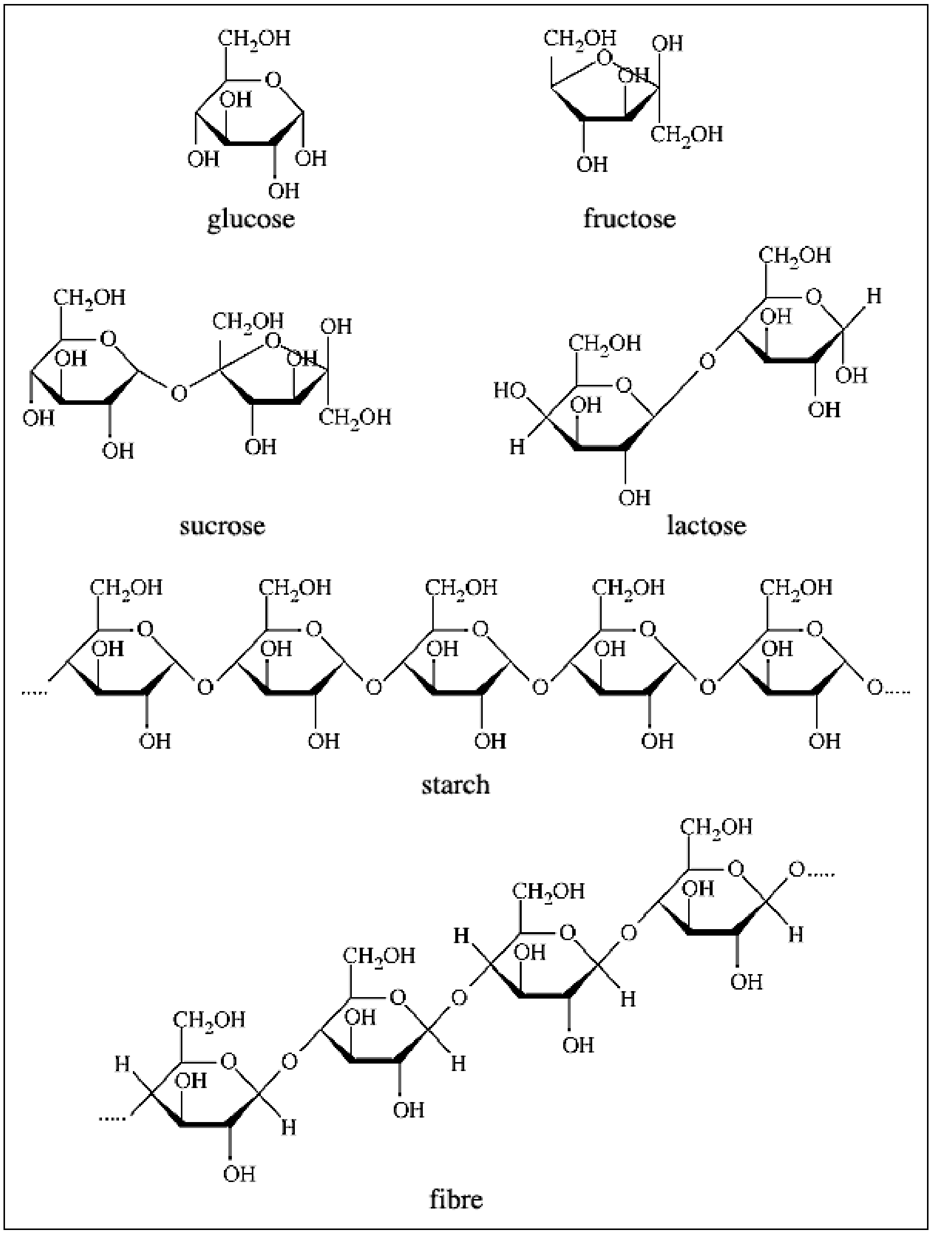

Fig. 8.1 Carbohydrates

Monosaccharides like glucose, fructose, and galactose cannot be broken down into smaller carbohydrates. They are the monomers that form the large polysaccharides composed of hundreds to thousands of these simple sugar units linked together by a glycosidic bond. Each monosaccharide contains alcohol (C—H), ketone (C=O), or aldehyde groups (H—C=O). Monosaccharides usually exist as a ring structure in solution, and they are very soluble in water. A disaccharide consists of two monosaccharides formed by a glycosidic bond after the loss of water:

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$

Glucose, the most biologically significant sugar and the body's primary fuel, is transported via the bloodstream to tissues and cells that need energy to function. Blood sugar refers to glucose levels (concentrations) in the blood and is absorbed into the blood from the digestive tract. Glucose mostly comes from the digestion (i.e., hydrolysis) of disaccharides and polysaccharides. A series of chemical reactions in the cell are involved in the release of energy from glucose: an anaerobic process (lacking oxygen) and an aerobic process (in the presence of oxygen). Glucose is easily transported to cells where it is oxidized in these reactions to form CO_2 and H_2O.

In anaerobic respiration, a phosphate (PO_4) group is put on glucose and this molecule is broken down via glycolysis to form three carbon organic acids, such as lactic acid. In this pathway, some of the energy from glucose is transferred to **adenosine diphosphate (ADP)**, making **adenosine triphospate (ATP)**. ATP is the universal energy currency of the cell. Phosphorus-oxygen-phosphorus bonds, in ADP and ATP, are high-energy bonds. ATP contains one more of these bonds than ADP, making it a more energy-rich compound. Energy will be released for biochemical work upon the hydrolysis of ATP to ADP. Overall, the anaerobic pathway produces two ATP molecules:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + 2ADP + 2H_3PO_4 \rightarrow \underset{\text{lactic acid}}{C_3H_6O_3} + 2ATP + 2H_2O$$

In aerobic respiration, pyruvic acid is converted to carbon dioxide and water with the formation of an additional 32 ATP molecules. Aerobic respiration releases more energy than anaerobic respiration. Without aerobic respiration, 90% of the energy stored in glucose would not be used, that is, would be lost.

Glucose is found in disaccharides such as sucrose, lactose, and maltose:

glucose + fructose → sucrose (table sugar)

glucose + galactose → lactose (milk sugar)

glucose + glucose → maltose

In digestion, the link (bond) between the monosaccharide units in lactose is broken by adding water (hydrolysis). Lactase is the enzyme that catalyzes the hydrolysis of lactose, and this enzyme is present in large quantities in the infant's intestine. Polysaccharides are long polymers of monosaccharides, which can form either straight or branched chains. These complex carbohydrates are called **starches** if digestible and **fibre** when indigestible. Glucose comes from the digestible complex carbohydrates: starch and glycogen (animal starch). Complex carbohydrates (polysaccharides) made from glucose can differ in the stereo-location of glycosidic bonds and the number of branches. Starch is a dietary carbohydrate that is found in a number of grains, potatoes, and pasta. It is composed of glucose bonded by alpha linkages. Catalysts, called **enzymes**, in the mouth, stomach, and intestine break down glycogen and starch into glucose for our body to use. Excess can be synthesized into glycogen (glycogenesis), a highly branched storage unit of glucose, and stored in the liver or muscle.

Fibre differs from starch by the stereochemistry of the bond that holds the units of glucose together (a beta linkage). Our body does not have an enzyme to break the beta bonds in cellulose down to glucose. Since fibre cannot pass through the intestinal wall, it has little caloric value. The same is true for the synthetic molecule, Olestra, which is a food additive. Some animals such as moose and caribou have bacteria in their gut that have the ability to break down fibre into glucose units for energy generation. This enables these animals to graze or browse on shrubbery and grasses. Also, fibre has another role in higher vertebrates, especially mammals. This indigestible carbohydrate passes through our digestive tract and absorbs water in our large intestine: a process that promotes proper bowel movement. Fibre can absorb other materials that our body wants to eliminate, such as cholesterol and bile. The pulp of fruits, wheat bran, and celery are all good sources of fibre.

In the Arctic, the increased use of commercially processed foods from outside the region is being questioned. Processing removes many important nutrients. For example, milled flour used in bread products is made by removing the germ and husks of the grain; both of which are good sources of fibre, proteins, vitamins, and minerals. Manufacturers repair this induced deficiency to some extent by reintroducing some of the lost nutrients or in this case enriching the flour with vitamins. Additives, however, cannot provide the diversity of nutrients found in whole grain or the fats and proteins found in subsistence fish and animals.

Nutrients and fibre are also removed in the process of refining sugar. Though eating a candy bar or another sugar-packed treat will provide a jolt of energy, it is not the healthiest approach. Glucose, in a refined sugar, like sucrose, is more rapidly fed into the bloodstream and is used less efficiently than glucose that is slowly derived from natural enzymatic digestion of complex carbohydrates. The rapid high levels of glucose in the blood results in refined sugar being more often transformed into fat. Eating a bowl of cereal or a piece of fruit is a healthier means of obtaining an energy boost, as well as resulting in the proper distribution of excess carbon between proteins, fats, and glycogen. The law of conservation of energy must be obeyed:

Energy intake = energy expended + energy stored

If our energy intake exceeds our energy expenditure, fat will be stored around our waistline. For every 3,500 Cal of excess energy, the body stores about 0.5 kg (1 lb.) of fat.

Lipids, Fats, and Fatty Acids

Lipids are large biological molecules that are diverse in their chemical composition (see fig. 8.2). They are insoluble in water and are grouped together based on their “non-polar” behaviour. Lipids are soluble in non-polar solvents such as benzene and chloroform; and lipids include compounds of widely different chemical structure such as fatty acids, waxes, **steroids**, prostaglandins and some vitamins. Many Arctic fish are rich in essential lipids, which are unsaturated. Lipids from plants also tend to be unsaturated, while fats from animals tend to be saturated.

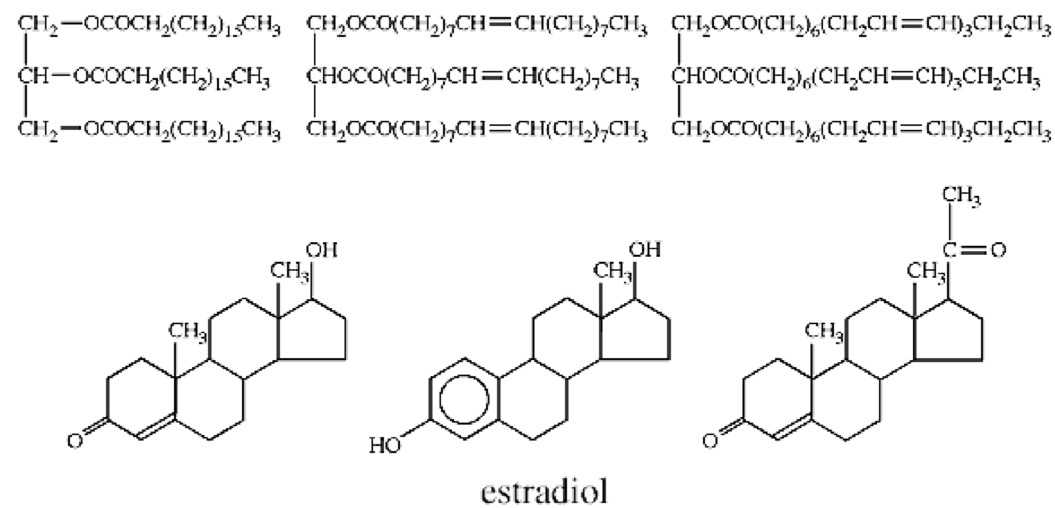

Fig. 8.2 Lipids

Fats and oils, also called triglycerides, make up the largest group in the lipid class. The term **fat**, however, is often used to refer to the entire class of lipids. Equally important in nutrition is the other subclasses in the family of lipids: **phospholipids** and sterols. Lipids have many roles in the body, but perhaps predominating is the role of providing energy. Because of metabolic design, carbohydrates supply immediate energy for the body’s use, while fats, which have a higher caloric nutrient, supply energy for sustained activity. A metabolic balance between carbohydrates and fats is hard to maintain; too much or too little fat can cause problems. **Obesity** (overweight is determined by the body mass index) and obesity-related problems like atherosclerosis (deposits of cholesterol in arteries) could ensue from a diet high in fat and could lead to strokes or heart attacks. Arctic diets are traditionally high in fat and protein. It is recommended that no more than 30% of the diet be comprised of fat, although a diet low in caloric energy may not be practical in the North, because of the physical demands brought on by living at extreme temperatures. The composition and type of **fatty acids** is also a critical factor in overall health. Our diet should be a balance of saturated, monounsaturated, and **polyunsaturated** fats.

Frequently, manufacturers will boast of having a product that is high in unsaturated fat. The difference between saturated and unsaturated fat is that **unsaturated fat** has at least one carbon-carbon double bond, such as linoleic acid (see fig. 8.3). Fatty acids, the building blocks of triglycerides, are long chains of carbon with a methyl group (-CH_3) on one end—the omega end—and a carboxylic acid group (-COOH) on the other end. Triglycerides are three chains of fatty acids attached to a glycerol backbone. Glycerol is a three-carbon tri-alcohol that forms ester bonds with fatty acids.

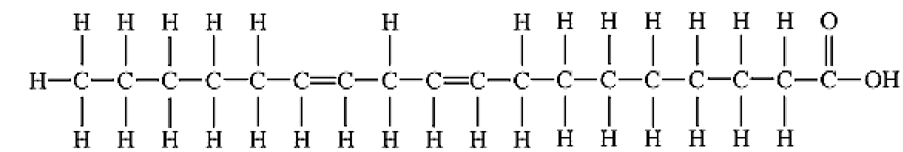

Fig. 8.3 Linoleic acid

The chemistry of fatty acids, like where the double bond is located or the length of the fatty acid chain, influences the characteristics of food, including the effects of fat on health. For example, higher unsaturation (more double bonds) increases the fluidity of fats and thus can affect cell membrane behaviour. Long-chain fatty acids (12 or more carbons) are abundant in meats and fish. Short-chain fatty acids (less than 10 carbons) are abundant in dairy products. All unsaturated fatty acids made by the body have a "cis-," or bent, configuration. Cooking can change the cis- shape to a more extended shape, "trans-."

Cold-water fish are rich in essential omega fatty acids. Fatty acids with a double bond on the third carbon, from the CH_3 end, are called **omega-3 unsaturated fatty acids**. Fatty acids with a double bond on the sixth carbon are called omega-6 fatty acids. Linolenic, an omega-3 fatty acid, and linoleic, an omega-6 fatty acid, are the only essential fatty acids for humans. An **essential nutrient** is one that our body cannot make so it must be acquired through the diet. All other omega fats that our body needs can be assembled from linolenic and linoleic. Salmon and other subsistence foods are high in omega-3 fatty acids. Interestingly, an omega-3 deficiency has been associated with mental depression.

Unsaturated fats, with their reactive double bonds, are more prone to react with oxygen, causing rancidity. Food spoilage can be delayed by placing food in airtight containers and keeping them refrigerated. Manufacturers often add hydrogen (hydrogenated fats) to decrease the number of double bonds, but this diminishes the health benefits associated with a diet rich in polyunsaturated fats. Another technique employed by manufacturers is including compounds that compete with oxygen, called **antioxidants**; butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), **vitamin C**, and **vitamin E** are common antioxidant additives. Many fruits and vegetables contain their own antioxidants, giving them the reputation for combating a number of unpleasant diseases. Blueberries, cranberries, and rosehips are among the richest sources of antioxidants. See figure 8.4.

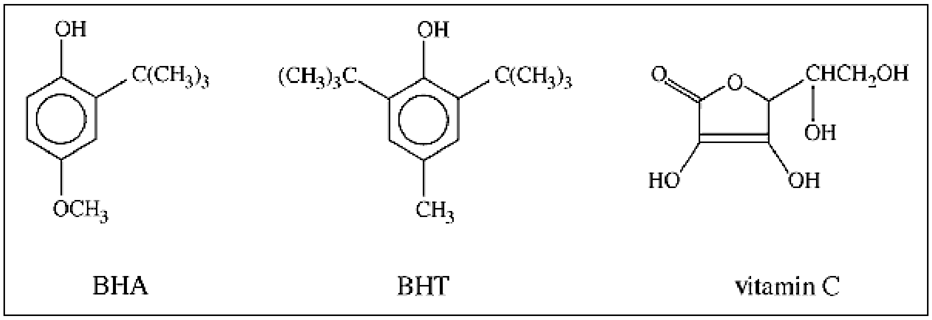

Fig. 8.4 Antioxidants

The other nutritionally significant classes of lipids, phospholipids and sterols, only make up 5% of total dietary lipids. Phospholipids differ in structure from triglycerides in that one of the fatty acid chains on the glycerol is replaced with a phosphate group and a small molecule like choline. The phosphate group makes one end of the phospholipids more soluble in water. This property has biological importance for cell membranes, establishing a semi-permeable barrier between the inside and outside of the cell. In the food industry, this quality of micelles helps emulsify mayonnaise and other products, like chocolate. Their polar and non-polar components would ordinarily tend to separate. We do not need to supplement our diet with phospholipids because our liver produces the phospholipid, lecithin.

The final group of lipids, the sterols, are composed of multiple rings of carbon. The best-known sterol is cholesterol, found only in animal by-products: meats, eggs, fish, poultry, and dairy products. Other important sterols include bile acids, hormones, and vitamin D. Cholesterol serves as the building block for all of the other important sterols and is an integral component of the cell wall.

Breakdown and absorption of lipids occurs in the intestine. The primary goals in fat digestion is to break down fats into the smaller units of glycerol and fatty acids so that our body can use them as synthetic starting materials or burn them for energy. Fats can provide energy; insulate us from the cold; cushion our vital organs; and protect against shock. Because cholesterol and triglycerides are non-polar, they need specialized proteins, called lipoproteins, to carry them in the bloodstream. Low-density lipoprotein (LDL) transports cholesterol from the liver to other tissues, while high-density lipoprotein (HDL) transports cholesterol from the vessels to the liver.

Proteins

Proteins (from "proteous," meaning first), are involved in every process that occurs in cells and tissues. Proteins are functionally diverse: they act as enzymes; hormones; regulators; molecular transporters; antibodies; building material for most structural units in the body; and even as energy. Like carbohydrates and lipids, all proteins are made up of carbon, hydrogen, and oxygen, but unlike them, proteins contain more nitrogen. Most deficiency diseases, other than vitamin-deficiencies, are owing to a diet lacking protein. Kwashiorkor is a disease that occurs when a child is weaned off of protein-rich milk to a diet low in protein. The diet may provide an adequate amount of calories, but protein synthesis is inhibited, leading to a buildup of fluid in tissues and limbs.

Amino acids are the building blocks of proteins. Each amino acid has four groups surrounding a central carbon: (1) a hydrogen (H); (2) an amine group (-NH_2); (3) an acid (-COOH); and (4) a specific functional group, called a side group. The side group for each amino acid varies, from the simplest amino acid, glycine, with a side group of one hydrogen (see fig. 8.5), to complex groups, with sulfur, oxygen, or benzene rings. The order of amino acid sequences creates a uniqueness that determines both the structure and the function of each protein. Amino acids are connected by a peptide bond, and a molecule of water is eliminated. Proteins are usually composed of a hundred or more amino acids. Because proteins serve such diverse functions, they differ from one another in both the length and the sequence of amino acids in the protein chain.

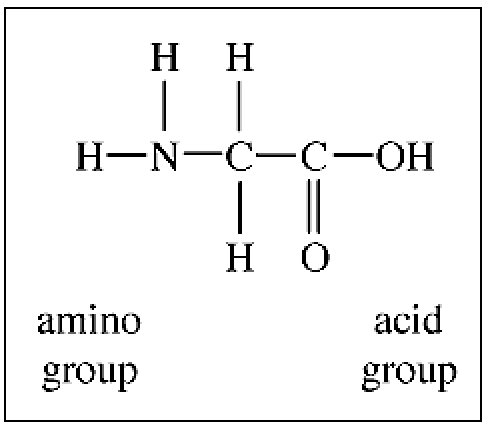

Fig. 8.5 Glycine

While there are many amino acids in nature, only 20 amino acids make up the vast array of proteins because these 20 amino acids are directed by the genetic code of DNA. Nine amino acids found in proteins are essential and must be provided by proteins in the diet. An essential amino acid that is lacking in the diet is commonly called a limiting amino acid. A complete protein source is one that provides the body with all the essential amino acids. Most proteins derived from animals are complete: meat, fish, poultry, cheese, eggs, and milk. Plant protein sources tend to be limiting in one or more amino acid, but all essential amino acids can be obtained from combinations of different plant proteins that have complementary amino acids, for example, peanut butter and bread. Eating muscle protein from caribou does not give you muscle protein, but it supplies the amino acids that your muscle proteins will contain. (See fig. 8.6.)

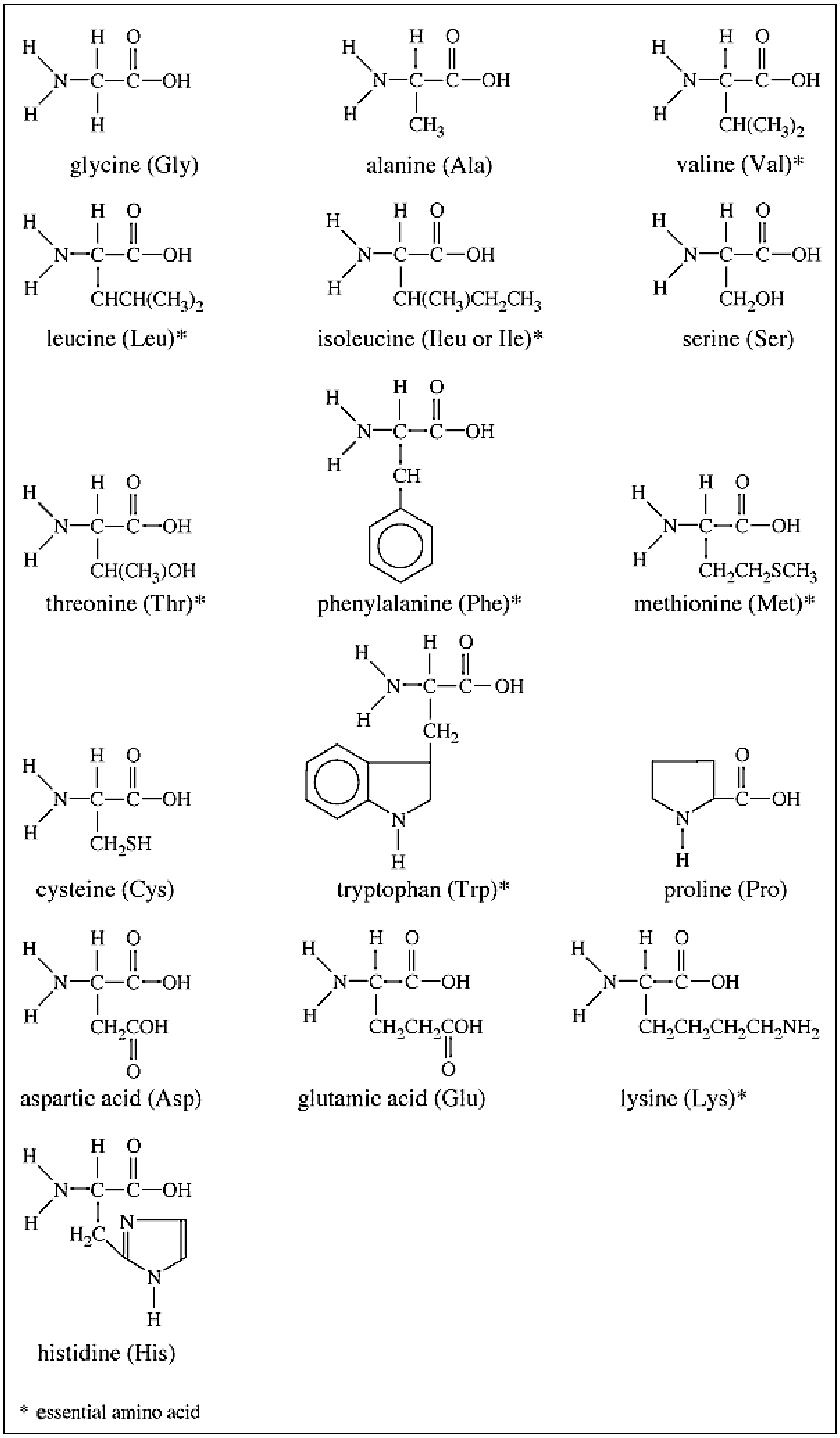

Fig. 8.6 Common amino acids

Proteins have a **primary** structure, the order of amino acids, which is based on the information from DNA. The sequence of amino acids, based on their chemical properties (polar, non-polar, hydrogen-bonding) directs the formation of a well-defined local shape in protein. These shapes are called either alpha helix or beta sheet, and they are considered the **secondary** structure. These secondary shapes come together to form the polypeptide chain's three-dimensional shape—the **tertiary** structure. If a protein has more than one polypeptide, each polypeptide chain is called a subunit. The three-dimensional shape of the combined subunits is called the **quaternary** structure. These different levels of structure depend on interactions between the side groups of the amino acids in the polypeptide chains. There are four major kinds of interactions:

- hydrogen bonding between –OH, $–NH_2$, –COOH, and $–CONH_2$ groups
- polar interactions between $–NH_3$+ and COO– groups
- hydrophobic interactions as CH_3 coalesce to avoid water
- –S–S– covalent bonds, called disulfide bonds

It is estimated that the human body consists of 10,000–50,000 different proteins. Even more astonishing is that our body contains the instructions in our DNA for making every single protein. Individual cells can encode for all the proteins necessary for their function. As mentioned previously, shape and the sequence of amino acids determine the function of the proteins. Sometimes an error can occur, either in copying the information from DNA or from a genetic defect passed on from previous generations. This error, called a mutation, can have devastating effects. One such genetic mutation is seen when the structure of **hemoglobin**, a protein that carries oxygen in the blood, is altered so that it no longer can perform that function; this is called sickle-cell anemia, named for the new shape of the cell. Anemia can also be caused by the lack of iron (Fe), which is also needed for a functionally active hemoglobin molecule.

Structural proteins make up bone, teeth, hair, and fingernails. The protein **collagen** is the material of tendons and ligaments and provides the strength of artery walls. Continuous synthesis of protein renews short-lived cells; skin cells and cells in the gastrointestinal tract need to be replaced frequently. Growing children and pregnant women have higher protein requirements because of the continuous building of tissue. Adults require 0.8 grams of protein per kilogram of body weight, whereas children and pregnant women require approximately 1.5 and 2.0 grams per kilogram of body weight, respectively.

All digestive processes involve enzymes, which act as catalysts. One **enzyme** can often perform billions of reactions before it loses its ability to function. Lipase breaks down lipids, trypsin breaks down proteins, and lactase breaks down lactose.

Some proteins act as **hormones** that are responsible for turning on or off other proteins and coordinating physiological functions. These protein hormones are transported from secretory glands to a target tissue. Examples are insulin and glucagon. The hormone insulin is excreted from the pancreas in response to elevated glucose levels; further excretion slows down as glucose levels drop. Diabetes is a disorder that is associated with low insulin production or poor insulin response. Glucagon functions in the opposite direction. Both together are needed to maintain homeostasis, that is, relatively stable levels of blood glucose.

Our immune system is a defensive system that is based on proteins called antibodies. Specific antibodies are made in our body in response to an invading virus. Once an antibody has been made, the body remembers how to make it. In this way, the body develops immunity against certain contagious agents. The immune system can be weakened by a poor diet lacking amino acids, vitamin K, or zinc. Contaminants in the diet can also interfere with the immune system.

Glycogen is a storage tank for glucose in muscle and liver, whereas adipose tissue is a storage tank for triglycerides. Proteins, on the other hand, exist only as functional or structural components of tissues. Though proteins can be used as energy (about 10% of the energy you need), it is not the most efficient use. A diet with adequate amounts of carbohydrates and fats will spare protein from excessive use in the production of energy. Proteins in food are rarely absorbed in our body in their native form; they are broken down into amino acids with the help of digestive enzymes, called proteases. The acidic environment of the stomach starts to dissociate complex protein structures with the help of the enzyme called pepsin. However, the enzymes in the small intestine, such as trypsin, complete the majority of the task of breaking down the strands of polypeptides into amino acids. Our body then absorbs and reassembles these amino acids into proteins based on metabolic demand. Fish are rich sources of protein in the Arctic and Subarctic.

Vitamins

Vitamins are essential organic compounds required in small quantities to ensure proper metabolism and, thus, good health. Unlike carbohydrates and proteins, vitamins have little caloric intake and are not macromolecules made up of building blocks. Their chemical composition is varied and they have unique structures of their own. Although vitamins do not supply energy, some act as **coenzymes**. A coenzyme is a non-protein part of an active enzyme. There are two classes of vitamins based on their polarity and solubility; water-soluble vitamins include vitamin B complex and vitamin C, while fat-soluble vitamins include vitamins A, D, E, and K. Water-soluble vitamins enter directly into the bloodstream, are excreted in urine, and need to be replenished daily. The B complex vitamins play a role in metabolism by acting as coenzymes, binding to their respective apoenzymes and creating an active enzyme complex. Fat-soluble vitamins, being largely non-polar, have to be transported by carrier proteins (transport proteins) and can build up in fatty tissues. Because of this trait, fat-soluble vitamins can reach toxic levels when over consumed or released from storage quickly. The bioavailability of vitamins is dependent on the amount in our diet, the amount the body is able to absorb, and metabolic activity. (See fig. 8.5.)

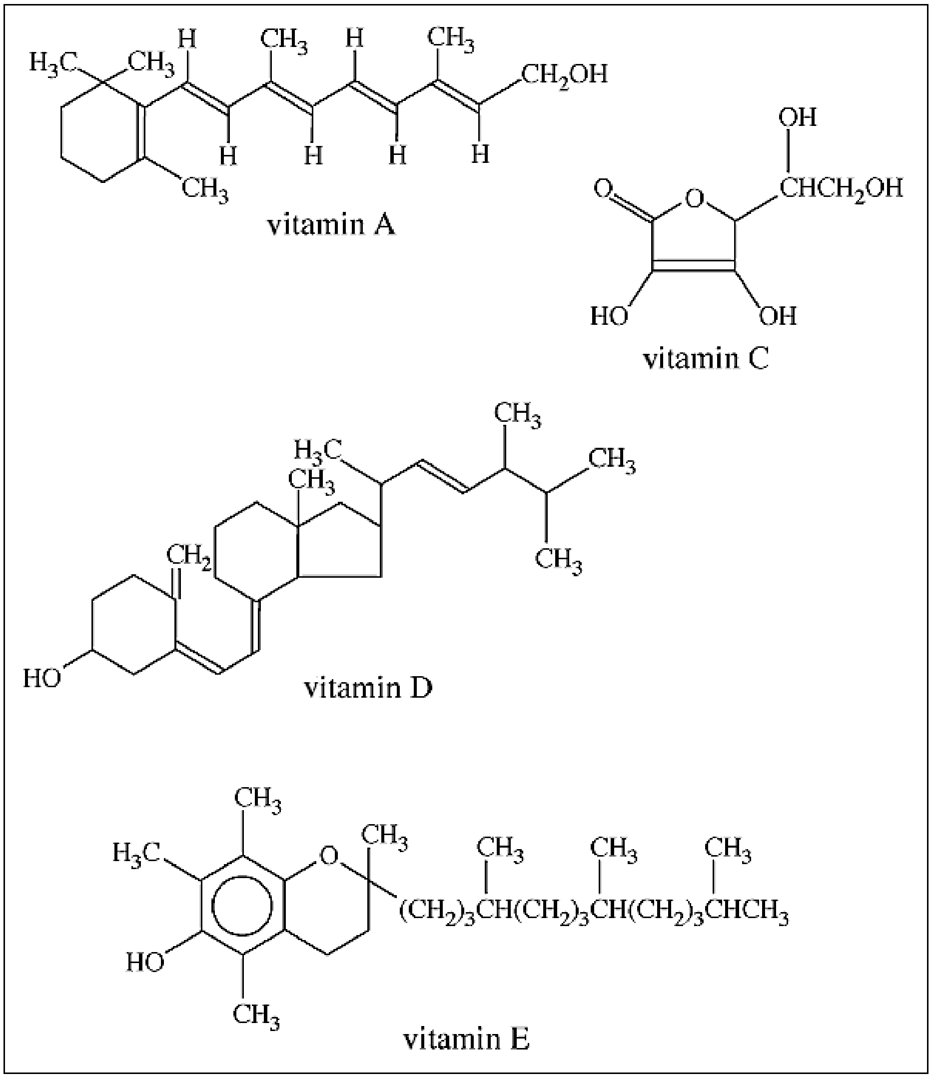

Fig. 8.7 Vitamins

Several diseases are associated with the absence of vitamins in food (vitamin deficiencies). A deficiency in vitamin C, also known as ascorbic acid, results in a disease called scurvy, in which blood vessels are weakened. Symptoms of scurvy include bleeding gums, loss of teeth, and anemia. Vitamin C is involved in the synthesis of collagen and absorption of iron through the intestines. Vitamin C is also an antioxidant protection against oxidation in water-soluble cellular components. The disease beriberi is a consequence of a deficiency in one of the B complex vitamins: vitamin B_1 (thiamine). Signs of beriberi are loss of appetite, stiff limbs, and eventual limb paralysis. A deficiency in niacin (vitamin B_3) causes pellagra. The amino acid tryptophan can be connected to niacin. Symptoms include dry, red skin and, in extreme cases, exhaustion and nervous system disorders. Deficiencies in the B complex vitamins result in the inability to extract energy from foods.

Deficiencies in fat-soluble vitamins can also produce disease. Vitamin A, also known as retinol, is essential for proper vision, regeneration of epithelial cells, and proper immune function. Diets that lack vitamin A may lead to night blindness in humans, a condition in which vision recovers slowly from bright flashes. Many animal-based foods provide vitamin A: milk, eggs, liver, and fish. Spinach, carrots, and sweet potatoes also provide vitamin A in a different form, beta carotene. The absorption of minerals, such as **calcium** and **phosphorus**, and their deposition in bone and teeth is dependent on vitamin D, which promotes calcium absorption through the intestine. Various skeletal abnormalities, such as rickets in children and osteomalacia (soft bones) in adults, result from vitamin D deficiencies. While not all required vitamin D must be provided in the diet, since it can be made from cholesterol-like molecules in the skin when exposed to light, lack of light in the North makes vitamin D in the diet important. Because infants and children are growing bones, they need high levels of vitamin D, so it is often added to milk.

Vitamin K is necessary for the synthesis of four proteins involved in blood clotting. A deficiency in vitamin K causes excess bleeding. It is found in mild and green vegetables. By protecting from free radicals, vitamin E acts as an antioxidant, helping maintain the proper structure and function of cell membranes and organs.

Minerals

Minerals are inorganic elements that maintain their chemical identity in and out of the body. Often minerals occur as ions in the body; but other elements or compounds can bind to minerals and alter their bioavailability. In this way minerals are similar to vitamins; some minerals bound to carbon compounds are sequestered in the body, while free minerals pass through. Minerals can be toxic when taken in excess. Their required levels usually classify minerals. Each mineral is found in different levels in the body because it has different dietary requirements. Macrominerals, the major minerals, are present in the body in large quantities, for example, calcium, phosphorus, magnesium, sodium, potassium, chloride and sulfur. Trace minerals are present in the body in very small quantities, though this does not signify their importance. For example, the trace, or minor minerals copper, manganese, molybdenum, iron, and zinc are important as cofactors for enzymes, while cobalt is a component of vitamin B_{12} (cobalamin). Selenium, iodine, and flurosine are also minor minerals.

The presence or absence of one mineral can affect the performance of another. Interaction exists between magnesium and phosphorus, where the absorption of one is limited by the levels of the other. Both magnesium and phosphorus are stored in the bone. Magnesium is a crucial part of different enzyme systems. Phosphorus, the second most abundant mineral in the body, is also a component of DNA and adenosine triphosphate (ATP). Proper development of bone and teeth is dependent on both calcium—the most abundant mineral—and phosphorus levels. Calcium is also important for transporting ions in and out of the cells, coagulating blood, and maintaining heart rhythm, and it can act as a chemical messenger inside the cell. Growing children and pregnant women have calcium and phosphorus requirements of 1.5 grams of each per day, whereas for other adults the requirements are about 1.0 gram of each per day. Milk is an excellent source of calcium and phosphorus. The breast-feeding of infants is highly recommended in the Arctic to ensure proper nutrition of newborns. A diet high in calcium and phosphorus is also recommended to women around menses as well as elders in general. Sodium is the main element involved in fluid-level regulation, while potassium and magnesium are necessary in maintaining electrolyte balance.

Sodium, chloride, potassium, and bicarbonate ions are most noted for their role in maintaining proper fluid balance in the body. A diet high in salt ($NaCl$) can alter this balance and cause water retention, or edema, and high blood pressure. Unlike subsistence foods, processed foods are frequently high in salt but low in potassium because $NaCl$ is added to replace the sodium and potassium that is lost in the manufacturing process.

Iron is a mineral that is needed by many proteins, including cytochromes, myoglobins, and hemoglobins. These proteins are important both for the transport of oxygen and the oxidation of food for energy. Anemia is a condition that develops as a result of an iron deficiency in which red blood cell numbers and hemoglobin concentrations are low. Menstruating women are at high risk for anemia because of increased blood loss. Meat and eggs in a subsistence diet are good sources of iron.

Thyroid hormones are important for regulating growth, development, and basal metabolic rate. Iodine plays an important role in the synthesis of the hormone thyroxine, which is secreted by the thyroid gland. Children with an iodine deficiency develop cretinism; symptoms include mental retardation and stunted growth. In adults, an iodine deficiency leads to a cellular response, causing a swelling of the thyroid gland, called a goiter. Milk, fish, and other seafood, common to a subsistence diet, are good sources of iodine. Zinc is essential to the function of many enzymes and is found in meat and shellfish. Copper is needed for enzymes that form hemoglobin and collagen. Selenium, a minor mineral, can act as an antioxidant.

Student Activity

1. What are you eating? Pick a common food that you eat and describe what the food is composed of in terms of proteins, fats, fibre, and carbohydrates.

2. How many calories are you getting from the food?

Energy, the Food Web, and Subsistence

Aboriginal people of the Arctic co-evolved with Arctic ecosystems for thousands of years; their social system and their land use were highly adapted to a sustainable relationship with the environment. Subsistence use implies a culture, values, and knowledge system that is in tune with nature. In a subsistence system, most of the resources are renewable because ecosystems supply them on a continual basis by processing the waste so it is again available for use by people.

First and Second Thermodynamic Laws

Materials cycle but energy does not cycle. Energy passes out of the ecosystem as it flows through it. The growth of plants provides the carbon chains that are used for the energy that drives metabolic "work." Energy has six basic forms: radiation, chemical, mechanical, electrical, nuclear, and heat. The first law of thermodynamics states that energy can be transformed from one form to another—but it cannon be created or destroyed. The second law of thermodynamics states that whenever energy is converted from one form to another, some of the energy is lost as heat. This heat cannot be used for metabolic work. All biological systems need energy input to continue functioning. Primary production, the growth of plants, is the source of energy, in the form of carbon chains, for the ecosystem. As consumers use the carbon chains from plants, there is a loss of energy as heat at each step of the food chain (at the trophic level) as a result of metabolic work. Food chain efficiency between steps varies between 10% and 50%. On a global scale, the sunlight that reaches the Earth is eventually converted by metabolism and by some physical processes to low-level heat, such as infrared radiation and the disorganized movement of molecules.

Subsistence Food Webs

People in traditional societies typically point out the fact that everything in nature is connected. Arctic people know that many events are either directly or indirectly a consequence of human activity (Gaia hypothesis). The subsistence food web or chain is damaged when people overestimate the sustainable harvest (catch) from an ecosystem. A sustainable food supply is possible only if the subsistence use is less than the maximum harvest—an application of the precautionary principle. Subsistence food is the most important way Arctic people receive energy and bodybuilding material—and, unfortunately, become exposed to toxins and contaminants. All northern plants and animals are exposed to contaminants that accumulate in the North. Worldwide air and water currents bring pollutants to the Arctic. The pollutants travel in clouds, fog, rain, and dust, and they settle on tundra, mountains, lakes, rivers, streams, ice and oceans. From soil and water, they move into plants, and from there into animals.

Plants and animals may accumulate contaminants—that is, they take them in faster than they can get rid of them. Some of these contaminants can build up "through the food chain," as one animal eats another, becoming more concentrated and dangerous at each step. This is called biomagnification. Not all contaminants biomagnify.

The contaminants that biomagnify are metals like mercury and persistent organic pollutants (POPs). POPs are PCBs, pesticides, and some chemicals—like dioxin released in incinerators. Toxin buildup in an animal depends on the "trophic level," which means where the animal eats on the food chain. For instance, see table 8.2.

Table 8.2

Algae is eaten by a duck which is eaten by a man.	→	2 steps
Plant is eaten by a reindeer which is eaten by a man.	→	2 steps
Phytoplankton eaten by small fish eaten by large fish eaten by seal eaten by man	→	4 steps
Phytoplankton eaten by small fish eaten by large fish eaten by seal eaten by bear eaten by man	→	5 steps

A duck or reindeer is considered to eat "low on the food chain." Plants are the lowest of all on the food chain. Plants and plant-eating animals generally have low levels of global contaminants, but they may still have high levels of contaminants if they are located where local spills of oil, solvents, and other chemicals have occurred. Polar bears tend to have the highest levels of contaminants, because they eat highest on the food chain. Some consider human newborns to have the same levels as polar bears.

The amount of contamination is not related to the size of an animal. For instance, a whale that eats mostly plants and zooplankton, like a bowhead, may have lower contaminants than a killer whale that eats seals, even though the bowhead is larger. Seals that eat clams have much lower levels of PCBs and pesticides than polar bears that eat seals and fish. People and animals that eat large amounts of marine mammals seem to be the most at risk for high contaminant levels.

Some animals may be experiencing subtle health effects that we are not able to see or measure easily—like a slightly lower production rate of antibodies. Beluga whales in a polluted river in northeastern Canada, called the St. Lawrence River, are definitely having health problems related to contamination. Seals in polluted areas of Europe died off in large numbers from viral infections; it is suspected that their immune systems did not work well because of the polluted water they lived in. New research on bears shows their immune systems are definitely lowered. In these examples, we can say that polar bears are affected by global contaminants that have biomagnified to dangerous levels.

Student Activity

What are the subsistence foods in your community? How are they acquired?

Contaminants and Additives

Mercury in the Arctic Environment

Mercury (Hg) is a natural element occurring in both terrestrial and aquatic ecosystems in the Arctic. Analysis of sediment cores indicates that the rate of Hg loading in Arctic lakes is increased when compared to pre-industrial times. Atmospherically deposited Hg resulting from air emissions has recently been documented by reports by the Arctic Monitoring and Assessment Programme (AMAP 2003). Major sources of the mercury emitted annually to the air from lower latitudes are coal-fired electric utilities and waste incinerators. Although most emitted mercury is deposited around the sources, the global background of atmospheric mercury is increasing each year. Mercury affects the circumpolar people through the fish in their diet. The United States Environmental Protection Agency (EPA, http://www.epa.gov/) believes that daily consumption of fish with mercury concentrations below 0.1 µg/kg body weight is safe. In the Arctic, some populations consume fish at higher levels. For example, approximately 21,000 Yukon-Kuskokwim Delta residents, 86% of whom are Yup'ik Eskimo and Alaskan Athabaskan Indian, rely on fish resources for about 60% of their subsistence. Analysis of stream-sediment samples collected from tributaries in Kukokwim River near legacy mining sites contained concentrations of mercury that were relatively high. In the Arctic National Wildlife Refuge, mercury was found in snow core samples, which were consistent with atmospheric deposition. In this case, municipal solid-waste incineration may have led to increased mercury.

When methyl mercury (CH_3Hg; MeHg) concentrations in fish samples are greater than or equal to US Food and Drug Administration (FDA) standards of 1.0 microgram (µg) for MeHg concentrations in food, Regional Health Corporations issue consumption advisories in their newsletters and discuss the benefits of omega-3 fatty acids. Similarly, if marine mammals have high levels in their fur and meat, the community is informed.

In the Arctic, mercury background levels of chronic exposure may be close to concentrations that can impose a slight increased risk to the health of newborns and the developing fetus. Hg is methylated by bacteria in fresh and marine water and concentrated through the food chain. Both Hg and MeHg are toxic, but MeHg has been associated with heart, neurological, and developmental disorders in humans. The risk of fetal brain impairment increases when the mercury concentration in maternal hair exceeds 10–20 µg/g. In Alaska, it has been reported that Alaskans rarely had maximum Hg concentrations in hair greater than 3 ppm. Although young women are a major concern when monitoring these low doses of Hg, it is known that lower intratesticular testosterone levels in rats occur after exposure to low levels of Hg. Mercury can be an **endocrine disruptor** and MeHg also impairs the immune response. Mercury can affect the health of subsistence species with damage to the sensory hair cells of the cochlea being reported in seals. (See table 8.3.)

Table 8.3 Total mercury (THg) concentrations in Yup'ik food (Rothschild and Duffy 2002)

Food Source (ng/g)	THg(ng/g) Mean	Standard Deviation
Red Salmon (*Oncorhynchus nerka*)		
Quaamalluq		
Half-dried, fermented (5 samples: 36.9, 109.8, 145.00, 66.2, 10.00)	73.58	54.44
Qiaganuk		
Half-dried (4 samples: 97.90, 95.00, 64.20, 225.80)	120.70	71.69
Red Roe	3.30	
Stinkhead, fermented	337.70	
Heads	40.80	
Boiled	36.30	
King Salmon (*Oncorhychus tshawytsha*)		
Qaamalluq		
Half-dried, fermented	115.60	
Qiaganuk		
Half-dried (2 samples: 72.80, 57.10)	64.90	11.10
King Roe (2 samples: 6.60, 7.70)	7.20	0.78
Smoked King (Strips)	113.20	
Smoked King (Strips) with Seal Oil	115.30	2.97
Pike (*Esox lucius*)		
Dried with Skin	443.80	
Blackfish (*Dallia pectoralis*)		
Dried	155.20	
Whitefish (*Coregonus nelsoni*)		
Dried	55.50	
Half-dried, with Potatoes	33.60	
Meat		
Reindeer Stew (*Rangifer tarandus*)	11.50	
Moose Stew (*Alces gigantus*)	12.30	
Dried Caribou (*Rangifer tarandus*)	55.80	
Marine Mammals		
Dried Seal (*Erignathus barbatus*) (4 samples: 347.10, 149.90, 62.90, 0.00)	140.00	151.10
Seal Stew	6.00	

Birds		
Lesser Canadian Goose	6.20	
Dried Ptarmigan (*Lagopus lagopus*)	11.50	
Mallard Stew	357.20	
Plants		
Buttercup Greens	8.50	
Sourdock, Seal Oil and Sugar	3.90	
Tundra Tea	0.00	
Greens and Fish Stew	0.00	
Greens, raw	3.10	
Wild Celery	0.00	
Boiled Fiddlehead	4.30	
Treats		
Aqutaq (3 samples: 1.00, 0.00, 4.20)	1.70	2.20

Uptake of contaminants, like mercury, usually occurs via food. In the North, river otters and seals have been routinely used as an indicator of pollution. For example, Hg in river otter hair ranges from 2 ppm to as high as 18.8 ppm. The Alaska Section of Epidemiology has been collecting data on Hg in marine mammals for many years. They review the published literature and report concentrations for many Arctic species: bearded seal (*Erignathus barbatus*), bowhead whale (*Balaena mysticetus*), beluga whale (*Delphinapterus leucas*), northern fur seal (*Callorhinus ursinus*), harbour seal (*Phoca vitulina*), walrus (*Odobenus rosmarus*), and ringed seal (*Phoca hispida*). For bowhead whales, they report low levels of mercury, which may be related to the fact that their food comes from lower trophic levels, that is, less biomagnification. In general, mercury in the tissues examined in the bowhead whale was lower than levels reported for toothed whales, which eat at higher levels. The same pattern can be seen for sockeye salmon, which eat plankton and thus have lower mercury levels, on average, than chinook salmon. For freshwater fish, the mean levels of total Hg are usually higher than in salmon and show that the MeHg was the major Hg type in the muscle tissue analyzed. Mercury levels generally increase with the size of the fish. This was very noticeable in pike, a predatory fish feeding at a high trophic level and in which biomagnification with age would be expected. When species of fish were compared, Hg levels were highest in pike. However, there is a large variation in mercury levels in Arctic fish, and each individual local food web should be monitored. Other metals that can act as toxic contaminants in the subsistence diet are cadmium (Cd) and lead (Pb).

Organochlorines in the Arctic Environment

"PCBs" is short for polychlorinated biphenyls. These are chemicals that are no longer produced in the United States but were commonly used as lubricants in hydraulic fluid, transmission oil, and in electrical transformers. PCBs are still made in some developing countries. PCBs are one of the persistent organic pollutants, chemicals that stay in the environment for a long time and travel long distances. Because they move, we do not know automatically whether PCBs we find in soil, water, plants, animals, and people originated from somewhere close by or from far away. Congener analysis helps determine this. The term is often used when talking about PCBs. Congeners refer to specific chemical compounds; there are 209 different PCB compounds, which have slightly different structures. "Aroclors" were industrial mixtures of many congeners.

PCBs are of great concern because they biomagnify. In industrial accidents, PCBs discolour nails and skin; cause a rash called "chloracne"; cause chronic bronchitis; and may cause jaundice, vomiting or nausea, fatigue, and abdominal pains. At low levels in food, they affect the reproductive system and thyroid as well as damage the immune and nervous system. Prenatal infants exposed tend to have a higher incidence of upper respiratory-tract infections. Some kinds of PCBs are suspected of causing cancers in the liver, skin, and intestines. People who worked for the military may have had direct contact with PCBs while working with machine lubricants or electrical fluids. By doing specific tests, we can see how much of each congener is in a sample of soil, water, blood, plant tissue, muscle, and so on. This pattern is called a "fingerprint." If we find congeners that indicate several industrial Aroclor types, this would indicate more than just a local source.

Organochlorines can also be pesticides, which in the Arctic usually come from sources in the South. All countries around the world use pesticides when they are growing crops. In the United States, crop-dusting planes are often used to apply pesticides to huge agricultural farms. When the chemical is released from the plane, much of it travels into the air and gets into streams and lakes near the farm; but many of these chemicals rise up into the air and travel on prevailing winds to the Arctic.

Some pesticides—like DDT, aldrin, dieldrin, chlordane, and heptachlor—are banned or severely restricted in the United States and many other nations but continue to be used in some countries. DDT is still used in Africa to kill mosquitoes because mosquitoes carry malaria. Because some countries continue to use DDT, and wind and water carry it to the Arctic, DDT continues to be found in Arctic marine mammals. DDT and the toxic chemical it breaks down into (DDE) are also found in humans throughout the world, and in the breast milk of women worldwide.

Pesticides were found at low levels in the Arctic food chain. In these lesser amounts, pesticides can harm newborns, hormone systems, and immune systems. They can cause developmental problems in children. (See fig. 8.8.)

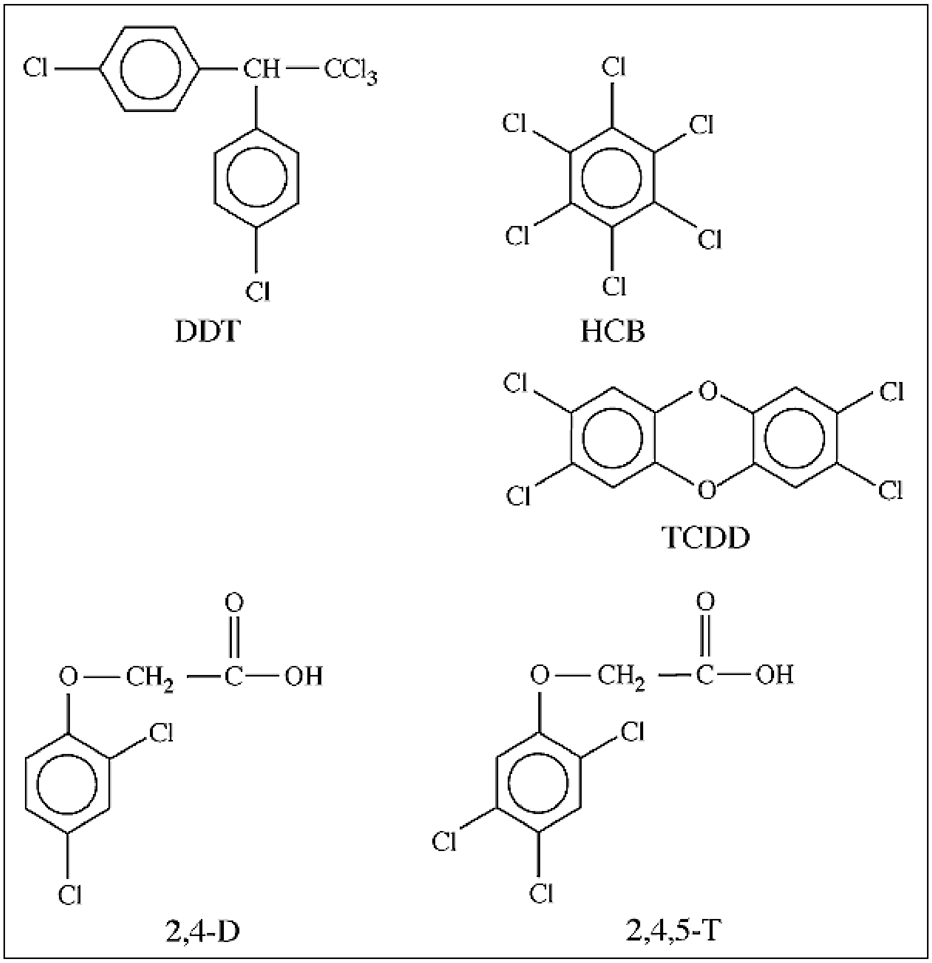

Fig. 8.8 Organochlorines

Food Additives

Starting with herbs and spices to improve flavour, and salt to preserve meat, humankind have added substances to food since ancient times. Several hundred current food additives are used to preserve food, enhance its flavour, and maintain its colour and physical appearance. These additives are generally recognized as safe by the US Department of Health and Services (according to the US Food and Drug Administration's list of food additives that are "generally recognized as safe," or GRAS). There are six types of additives: antioxidants, artificial colours, artificial flavours, flavour enhancers, stabilizers, and antimicrobial agents.

Antioxidants, similar to vitamin C and vitamin E, are compounds that are added to food to prevent oxidation. The addition of antioxidants to oils and juices prevents rancidity (foul odour and flavours) and browning by inhibiting oxidation and preventing the formation of volatile aldehydes, ketones, and acids. Some common antioxidants include butylated hydroxyanisole (BHA). Mice fed a diet fortified with BHA or butylated hydroxytoluene (BHT) have shown lower cancer rates than mice fed diets without these antioxidants.

Sulfites, which are also used as anti-browning agents in fruits, are also antioxidants. The chemical compound ethylene diamine tetraacetic acid (EDTA) can work as an antioxidant by binding and immobilizing metal ions like iron. Metal ions often catalyze oxidation reactions.

Artificial flavours are usually synthetic versions of the natural molecules. Artificial colours are also synthetic forms of natural plant pigments. Flavour enhancers, like monosodium glutamate (MSG) are molecules that have little or no flavour of their own but bring out the natural flavour of the food.

Stabilizers preserve the physical characteristics of food. They are used to keep some foods moist (e.g., glycerin) or to keep food dry and prevent caking (e.g., silicon dioxide, or calcium silicate). Emulsifiers, such as glycerol monostearate, are added to keep mixtures of non-polar and polar food components from separating. (See fig. 8.9.)

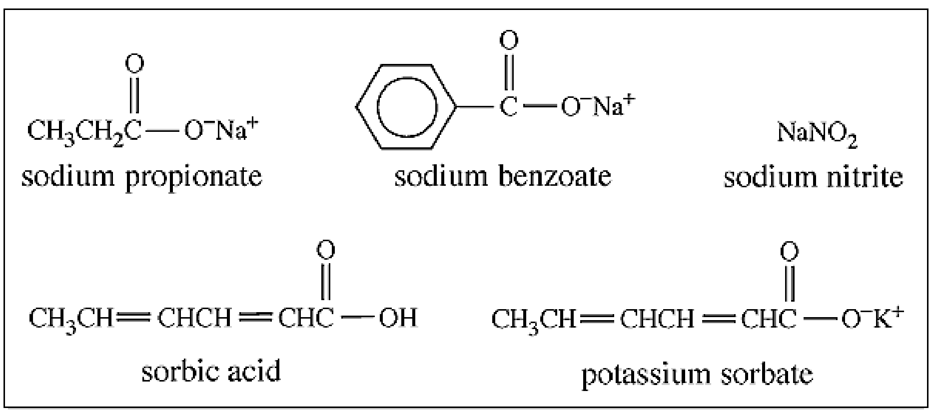

Fig. 8.9 Food Additives

Lastly, antimicrobial agents are added to food to prevent the growth of bacteria and moulds. For example, the bacterium responsible for botulism produces a toxin of which a thousandth of a microgram can kill an animal. Antimicrobial agents include salt, which is often used in drying meat and fish, and even sugar. High concentrations of salt or sugar prevent bacteria or mould growth by producing dehydration of the micro-organisms. Sodium benzoate, potassium sorbate, and sodium nitrate also prevent bacteria growth by inhibiting their metabolic processes.

Student Activity

1. Are there concerns about a contaminant in the food of your community? What is the contaminant? Do you think it could biomagnify up the food web? Why?

2. Is there a local group in your community that monitors food quality?

Summary

Foods are composed of molecules and our diet should contain a proper balance of proteins, fats, carbohydrates, and minerals. Energy is obtained from food through a complex series of reactions generating ATP. The human body does not make all the required molecules for growth and metabolism, so essential amino acids, fats, and vitamins must come from food. Water-soluble vitamins can function as coenzymes. Conditions associated with a deficiency in minerals, vitamins, or essential fats and proteins can lead to diseases. A concern in the Arctic is that if there are contaminants in wild and traditional foods that can increase as the contaminants are passed up the food web, young children's health will be affected. Thus, people practising a subsistence lifestyle may be at risk. Organochlorines and mercury are contaminants of concern in the North.

Study Questions

1. What is the difference in structure between glucose and fructose?

2. What is a disaccharide? Give an example.

3. Why can enzymes break down glycogen but not cellulose (fibre)?

4. What is a common property of lipids?

5. What is a polyunsaturated fat?

6. Are fish important sources of essential fats? Explain.

7. Draw the structures of a triglyceride and the steroid estradiol.

8. In a dietary sense, what is meant by a "complete protein"?

9. What is the vitamin deficiency associated with ascorbic acid?

10. What do we mean by the term antioxidant? Give an example.

11. What two functional groups are present in amino acids?

12. What is the primary structure of a protein?

13. Why is energy lost between steps in the food chain (trophic levels)? In what form of energy is it lost?

14. What is the second law of thermodynamics? Give an example.

15. Make a diagram of your food chains.

16. Describe how mercury discharged into a body of water can be a threat to humans who eat fish.

17. Why is DDT dangerous as an endocrine disruptor?

Glossary of Terms

anabolic steroids	illegal drugs that are synthetic analogs of testosterone, the male sex hormone. When taken in high doses and coupled with exercise or weight lifting, they act to increase muscle mass.
antioxidants	a substance that is easily oxidized and therefore prevents the oxidation of other substances. Antioxidants are added to foods to prevent the browning associated with oxidation.
biochemistry	the study of the chemistry of living organisms.
calcium	a nutritional mineral; the most abundant mineral in the body and the main structural material of bones and teeth.
carbohydrates	polyhydroxyl aldehydes, or ketones, or their derivatives.
cholesterol	a non-polar compound with the four-ring structure characteristic of steroids. Cholesterol is found in animal foods like beef, eggs, fish, poultry, and milk products and is suspected of contributing to cardiovascular disease.
collagen	the synthesizer of connective tissue.
complete proteins	proteins that contain all the essential amino acids in the right proportions.
copper	a nutritional mineral needed to form Hb and collagen.

dioxins	a family of compounds with varying levels of toxicity.
disaccharides	carbohydrates, such as sucrose, with double-ringed structures.
enzyme	a biological substance that catalyzes or promotes a specific biochemical reaction.
essential amino acids	those amino acids that are necessary for the production of human proteins but are not synthesized by the body. Essential amino acids must be obtained from food.
estrogen	a female sex hormone.
fats	triglycerides.
fatty acids	a type of lipid consisting of an organic acid with a long hydrocarbon tail.
fibre	nondigestive carbohydrates composed of long chains of glucose units linked together via beta linkages.
food additives	substances added to food to preserve it, enhance its flavour or colour, and maintain its appearance or physical characteristics.
free radicals	atoms or molecules with unpaired electrons.
fructose	a simple sugar, consisting of a single saccharide group and found in fruits, plants, honey, and products sweetened with a high fructose corn sweetener (HFCS).
glucose	a simple carbohydrate that acts as the body's primary fuel source.
hemoglobin	the protein that carries oxygen in the blood.
hormone	a biochemical substance that regulates specific processes within an organism's body.
iodine	a trace mineral needed by the body in only very small quantities.
iron	composes a critical part of hemoglobin.
lactase	the enzyme that catalyzes the hydrolysis of lactose.
lactose	a disaccharide, consisting of the monosaccharides glucose and galactose and found primarily in milk and milk products.
lactose intolerance	a common condition in which adults have low lactase levels and therefore have trouble digesting milk or milk products.
lipids	those cellular components that are insoluble in water but extractable with non-polar solvents.

lipoproteins	specialized proteins that act as carriers of fat molecules and their derivatives in the bloodstream.
magnesium	a nutritional mineral involved in maintaining electrolyte balance in and around cells.
major minerals	compose about 4% of the body's weight and include Ca, P, Mg, Na, K, Cl, and S.
minerals (nutritional)	those elements—other than carbon, hydrogen, and oxygen—needed for good health.
minor minerals	present in the body in trace amounts and include Fe, Cu, Zn, I, Se, Mn, F, Cr, and Mo.
monosaccharides	carbohydrates, such as glucose or fructose, with a single-ring structure.
oil	triglycerides.
polysaccharides	carbohydrates composed of a long chain of monosaccharides linked together.
potassium	a nutritional mineral involved in maintaining electrolyte balance in and around cells.
progesterone	a female sex hormone.
prostaglandins	fatty acid derivatives involved in a number of physiological processes including the propagation of pain impulses along nerves and the formation of fevers.
protease	an enzyme that acts like molecular scissors to cut freshly made proteins to the correct size.
proteins	the substances that make up much of our structure.
scurvy	a condition in which bodily tissues and blood vessels become weakened.
selenium	an antioxidant.
starches	digestive carbohydrates composed of long chains of glucose units linked together via alpha linkages.
steroids	biochemical compounds characterized by their 17-carbon-atom, four-ring, skeletal structure.
sucrose	a disaccharide; two monosaccharide units (glucose and fructose) linked together; occurs naturally in sugar cane, sugar beets, and many plant nectars.
triglycerides	the combination of glycerol (a trihydroxy alcohol) with three fatty acids.
unsaturated hydrocarbons	hydrocarbons that contain at least one double or triple bond between carbon atoms.
vitamin A	important in vision, immune defences, and maintenance of body lining and skin.

vitamin B complex	a family of water-soluble vitamins that include thiamin, riboflavin, niacin, and vitamin B_6, folate, and vitamin B_{12}. B complex vitamins play central roles in metabolism, protein synthesis, and cell multiplication.
vitamin C	a water-soluble vitamin that serves several roles in the body, including the synthesis of collagen, protection against infection, and absorption of iron through the intestinal wall.
vitamin D	promotes absorption of Ca through the intestinal wall and into the blood.
vitamin E	serves as an antioxidant in the body, preventing oxidative damage to cellular components and especially cell membranes.
vitamin K	necessary for the synthesis of four proteins involved in blood clotting.
vitamins	those organic compounds essential in the diet in small amounts but with little or no caloric value.
zinc	a nutritional mineral essential to the function of more than 100 enzymes.

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