Nutrition, Metabolism, and Body Temperature Regulation Outline

PART 1: NUTRIENTS (pp. 915–922; Figs. 24.1–24.3; Table 24.1)

24.1 Carbohydrates, lipids, and proteins supply energy and are used as building blocks (pp. 915–919; Figs. 24.1–24.2; Table 24.1)

A. A nutrient is used by the body to promote normal growth and development.
   1. Major nutrients are carbohydrates, lipids, and proteins; vitamins and minerals are micronutrients. (p. 915; Fig. 24.1)
   2. According to current "MyPlate" guidelines, a healthy diet can be illustrated by a plate, divided, so that it contains roughly half fruits and vegetables and half grains and proteins with dairy represented as a glass of milk with the meal.
   3. There are 45–50 essential nutrients that cannot be made in adequate quantities by the body, so we must consume them in our diet.

B. Carbohydrates consist of sugars (monosaccharides and disaccharides) from fruits, sugarcane, sugar beets, honey, and milk; and polysaccharides from grains, fruits, and vegetables. (pp. 915–916; Table 24.1)
   1. Glucose is used by the body as fuel for the reactions that synthesize ATP and is required by neurons and red blood cells.
   2. Polysaccharides, such as insoluble cellulose and other soluble polysaccharides, provide fiber in the diet.

C. The most abundant dietary lipids are triglycerides, or neutral fats, and may be saturated–derived from animal sources, coconut oils, and hydrogenated shortenings (trans fats)–or unsaturated–derived from plant sources. (p. 916; Table 24.1)
   1. Essential fatty acids linoleic acid and linolenic acid cannot be made by the body, so these must be consumed in the diet.
   2. Cholesterol is found in egg yolk, meats, organ meats, shellfish, and milk, but about 85% of the body's cholesterol is made by the liver.
   3. Lipids help the body absorb fat-soluble vitamins, serve as a cellular fuel, are an integral component of myelin sheaths and cell membranes, form adipose tissues, and serve as regulatory molecules.

D. Proteins that have all essential amino acids are complete proteins, and are found in eggs, milk, fish, and meats; proteins that are low or lacking in one or more of the essential amino acids are incomplete, and are found in legumes, nuts, and cereals. (pp. 916–919; Fig. 24.2; Table 24.1).)
   1. Proteins are important structural and functional molecules in the body.
   2. The amino acids from proteins may be used for synthesis of new molecules or may be burned for energy, depending on:
      a. The presence of all necessary amino acids needed for a particular protein.
      b. Adequate caloric intake.
      c. Whether the body is in a positive nitrogen balance, in which proteins are built into tissues faster than they are broken down, or a negative

nitrogen balance, existing when breakdown of protein exceeds incorporation into tissues.

d. Effects of anabolic hormones, such as pituitary growth hormone, sex hormones, or glucocorticoids.

24.2 Most vitamins act as coenzymes; minerals have many roles in the body (pp. 919–921; Tables 24.2–24.3)

A. Vitamins mostly serve as coenzymes, many of which are not made by the body and must be consumed. (p. 919; Table 24.2)

1. Vitamins A, D, E, and K are fat-soluble and are absorbed when bound to ingested lipids.
2. Water-soluble vitamins, such as B-complex vitamins and vitamin C, are absorbed along with water in the GI tract.

B. Minerals are used by the body to work with other molecules, may be incorporated into tissues to give added strength, may be ionized in body fluids, or may be bound to organic compounds. (p. 919–920; Table 24.3)

PART 2: METABOLISM (pp. 922–945; Figs. 24.3–24.24; focus Figure 24.1; Tables 24.4–24.6)

24.3 Metabolism is the sum of all biochemical reactions in the body (pp. 922–924; Figs. 24.3–24.5; Focus Figure 24.1)

A. Metabolic processes are either anabolic, in which larger molecules are synthesized from smaller ones, or catabolic, in which large molecules are broken down to simpler ones. (p. 922; Fig. 24.3)

1. In cellular respiration, food molecules are broken down in cells, with some of the energy released used to power ATP synthesis, manufacture of the body's primary energy currency.
2. Three stages are involved in processing energy-containing nutrients: digestion in the GI tract, anabolic or catabolic processing of nutrients within cells, and final breakdown of nutrients to form ATP.

B. Oxidation-reduction reactions are coupled reactions that involve the transfer of electrons from one molecule to another, resulting in a transfer of energy between molecules. (pp. 922–923)

1. In the body, oxidation-reduction reactions are enzyme-catalyzed reactions requiring specific coenzymes that transfer the energy contained in food fuels to other molecules, ultimately leading to the synthesis of ATP from ADP.

C. ATP synthesis may occur through two mechanisms: (p. 924; Figs. 24.4–24.5)

1. Substrate-level phosphorylation, in which high-energy phosphate groups are transferred directly from phosphorylated substrates to ADP.
2. Oxidative phosphorylation, in which some energy from food fuels is used to create a proton gradient that is used to attach phosphates to ADP.

24.4 Carbohydrate metabolism is the central player in ATP production (pp. 924–933; Figs. 24.6–24.14; Focus Figure 24.1)

A. Oxidation of Glucose (pp. 924–932; Figs. 24.6–24.11; Focus Figure 24.1)

1. Glucose enters the cell by facilitated diffusion and is phosphorylated to glucose-6-phosphate, essentially trapping glucose within the cell.

2. Glucose enters glycolysis, an anaerobic process that occurs in the cytosol.
   a. In phase 1 of glycolysis, sugar activation, glucose is phosphorylated in a series of steps to fructose-6-phosphate to provide the activation energy for events that occur later in the pathway.
   b. In phase 2 of glycolysis, sugar cleavage, fructose-6-phosphate is split into two three-carbon fragments: glyceraldehyde-3-phosphate and dihydroxyacetone phosphate.
   c. In phase 3 of glycolysis, sugar oxidation and ATP formation, the pair of 3-carbon fragments produced in phase 2 are oxidized to transfer hydrogen to NAD^+, and the oxidized fragments are phosphorylated, creating bonds that can be used to transfer energy to ATP synthesis.
   d. The final products of this series of reactions are two pyruvic acid molecules, two molecules of NADH, and four molecules of ATP, although two ATPs were consumed at the beginning of the process.
3. The two pyruvic acid molecules can follow two distinct pathways, depending on the availability of oxygen.
   a. If adequate oxygen is present in the cell, glycolysis continues, and NADH delivers its electrons to the electron transport chain.
   b. If there is not adequate oxygen available, NADH returns its hydrogen to pyruvic acid, forming lactic acid, which allows NAD^+ to continue to act as an electron acceptor.
   c. Once enough oxygen is available within the cell, lactic acid is oxidized back to pyruvic acid and enters aerobic pathways.
4. In aerobic pathways, pyruvic acid is transported into the mitochondrion, where it enters the Krebs cycle.
   a. Pyruvic acid is first converted to acetyl CoA by removing a carbon, oxidizing the acetic acid fragment, and adding coenzyme A.
   b. Acetyl CoA enters the Krebs cycle, where it proceeds through eight successive steps that produce a series of keto acids, ultimately ending at the production of oxaloacetic acid.
   c. The net yield of the Krebs cycle is four molecules of CO_2, six molecules of NADH, two molecules of $FADH_2$, and two molecules of ATP per pair of acetyl CoA molecules that were produced from glucose.
5. The electron transport chain is the oxygen-requiring process of aerobic respiration involving the pickup of hydrogens removed from food fuels during oxidation by O_2, resulting in the formation of water, a process called oxidative phosphorylation.
   a. In the electron transport chain, hydrogens from NADH and $FADH_2$ are shuttled through a series of coenzymes, which results in the transport of H^+ from the mitochondrial matrix to the intermembrane space.
   b. H^+ diffuses back to the mitochondrial membrane through an enzyme, ATP synthase, which phosphorylates ADP to ATP as the H^+ diffuses.
6. The net energy gain from one glucose molecule is 30 ATP.
7. Because the cell cannot store large amounts of ATP, other processes are used to handle glucose in excess of what can be used in ATP synthetic pathways.

B. Glycogenesis, Glycogenolysis, and Gluconeogenesis (pp. 932–933; Figs. 24.12–24.13)
   1. Glycogenesis is a process that forms glycogen from glucose when high cellular ATP begins to inhibit glycolysis; this process occurs mostly in the liver and skeletal muscle.
   2. Glycogenolysis is a process that breaks down glycogen; in most body cells, it is broken down to glucose-6-phosphate, which enters glycolysis, but in the liver, glycogen is broken down to glucose and transported to the blood when blood glucose levels begin to fall.
   3. Gluconeogenesis is a process that forms glucose from nonglucose molecules to maintain blood glucose when dietary sources and glucose reserves begin to be depleted.

24.5 Lipid metabolism is key for long-term energy storage and release (pp. 933–935; Figs. 24.14–24.16)
A. Oxidation of Glycerol and Fatty Acids (p. 933; Fig. 24.15)
   1. Lipids are the body's most concentrated source of energy, producing approximately twice the energy of either carbohydrates or proteins.
   2. Catabolism of triglycerides involves the splitting of the molecule into glycerol and fatty acids: The glycerol portion is converted to glyceraldehyde phosphate, which enters into glycolysis, while the fatty acids are converted to acetyl CoA through beta oxidation, and directed into aerobic pathways.
B. Lipogenesis is stimulated when cellular ATP and glucose levels are high and involves combining excess glycerol and fatty acids into triglycerides to be stored in subcutaneous or adipose tissues. (p. 934; Figs. 24.14, 24.16)
C. Lipolysis breaks down stored triglycerides into glycerol and fatty acids to be directed into lipid catabolism. (pp. 934–935; Figs. 24.14, 24.16)

24.6 Amino acids are used to build proteins or for energy (pp. 936–937; Figs. 24.17–24.18)
A. Degradation of Amino Acids (pp. 936–937; Figs. 24.17–24.18)
   1. Transamination involves the transfer of the amine group from an amino acid to α-ketoglutaric acid.
   2. In the liver, the amine group is removed as ammonia, regenerating α-ketoglutaric acid: the ammonia is converted to urea, to be removed from the body in urine.
   3. Resulting keto acids are altered to be able to enter the citric acid cycle.
B. Amino acids are the most important anabolic nutrient and can be used to synthesize structural and functional proteins of the body. (p. 937)

24.7 Energy is stored in the absorptive state and released in the postabsorptive state (pp. 937–942; Figs. 24.19–24.23;Table 24.4)
A. Catabolic-Anabolic Balance of the Body (pp. 937–939; Fig. 24.19; Table 24.4)
   1. There is a dynamic catabolic-anabolic state of the body as molecules are broken down and rebuilt.
   2. The body draws molecules to meet these needs from various nutrient pools: amino acid, carbohydrate, and fat stores.
B. During the absorptive state, anabolism exceeds catabolism. (pp. 939–940; Figs. 24.20–24.21; Table 24.4)

1. All absorbed monosaccharides are made into glucose by the liver and released to the blood or converted to glycogen or fat.
2. Most fats enter the lymph as chylomicrons, which are broken down to glycerol and fatty acids to enable them to pass into capillaries.
   a. Adipose cells, skeletal and cardiac muscle cells, and the liver use triglycerides to synthesize plasma proteins, while most amino acids passing through the liver remain in the blood for uptake by other body cells.
3. Insulin is the hormone that directs all events of the absorptive state: increases glucose uptake, and oxidation within body cells, promotes storage of glycogen and fat, increases transport of amino acids into cells, promotes protein synthesis, and inhibits gluconeogensis.

C. In the postabsorptive state, net synthesis of fat, glycogen, and proteins ends, and the body shifts to catabolism of these molecules. (pp. 940–942; Figs. 24.22–24.23; Table 24.4)
1. Blood glucose is obtained by promoting glycogenolysis in the liver and skeletal muscle, lipolysis in the liver and adipose tissues, and catabolism of cellular protein.
2. If the body experiences prolonged fasting, it will enter glucose sparing, which is aimed at conservation of blood glucose by promoting increased use of noncarbohydrate fuel molecules, especially triglycerides.
   a. The brain continues to use glucose, unless fasting continues for longer than four or five days, at which time it begins to use ketone bodies as an alternate fuel source.
3. Hormonal and neural controls of the postabsorptive state:
   a. Insulin-promoted processes are inhibited as insulin levels fall.
   b. Declining blood glucose levels promote the release of glucagon, which targets the liver, causing enhanced glycogenolysis, lipolysis, and gluconeogenesis, in order to keep blood energy sources available to body cells.
   c. The sympathetic nervous system mobilizes fat and promotes glycogenolysis in order to make fuel available quickly.

24.8 The liver metabolizes, stores, and detoxifies (pp. 942–945; Fig. 24.24; Table 24.5)

A. Cholesterol Metabolism and Regulation of Blood Cholesterol Levels (pp. 943–945; Fig. 24.24; Table 24.5)
1. Cholesterol is transported in the blood bound to lipoprotein complexes, which solubilize lipids and regulate entry and exit at specific target cells.
2. Lipoprotein complexes vary in the percentage of lipid they contain, but all contain triglycerides, phospholipids, and cholesterol, in addition to protein.
3. The greater the proportion of lipid in the lipoprotein, the lower its density, and there are very-low-density lipoproteins (VLDLs), low-density lipoproteins (LDLs), and high-density lipoproteins (HDLs).
   a. VLDLs transport triglycerides from the liver to peripheral tissues, LDLs transport cholesterol to peripheral tissues, and HDLs transport excess cholesterol from peripheral tissues to the liver and provide cholesterol to steroid-producing organs.
4. High levels of HDL are considered beneficial, as the cholesterol they contain is bound for removal, but high levels of LDL are considered a

risk, because the cholesterol they contain may be laid down on vessel walls, forming plaques.

5. Blood levels of cholesterol are partly regulated through negative feedback, and a high intake of cholesterol will somewhat inhibit cholesterol synthesis by the liver.
6. Diets high in saturated fats stimulate liver synthesis of cholesterol and reduce its elimination from the body, while unsaturated fatty acids enhance excretion of cholesterol to bile for removal from the body.
   a. Trans fats are unsaturated fats that have been modified to make them more solid and have a worse effect on blood cholesterol than saturated fats, causing a greater increase in LDLs, and a greater reduction in HDLs.

PART 3: ENERGY BALANCE (pp. 945–956; Figs. 24.25–24.29)

24.9 Neural and hormonal factors regulate food intake (pp. 946–949; Fig. 24.25)

A. There is a balance between the body's energy intake, defined as the energy produced during food oxidation, and energy output, which includes energy lost as heat, used to do work, or stored as fat or glycogen. (p. 946)
   1. When energy intake and energy output are balanced, body weight remains stable, but when they are not, weight is gained or lost.

B. Obesity is defined as an individual having a body mass index (BMI) greater than 30, and places individuals at higher risk for atherosclerosis, diabetes mellitus, hypertension, heart disease, and osteoarthritis. (p. 946)
   1. BMI = weight (lb) x 705/height (inches)^2

C. Regulation of Food Intake (pp. 946–949; Fig. 24.25)
   1. The hypothalamus produces several peptides controlling feeding behavior, which ultimately reflect two sets of neurons: one set promoting hunger and the other set promoting satiety.
   2. Short-term regulation of food intake involves neural signals from the digestive tract, blood levels of nutrients, and GI hormones.
   3. Long-term regulation of food intake relies on the hormone leptin, secreted by adipose cells.
      a. Leptin is a hormone that is secreted in response to an increase in the body's fat mass and suppresses activity of the neurons that promote hunger while increasing activity of neurons that promote satiety.
   4. Other factors that may affect food-seeking behaviors are changes in ambient temperature, stress, other psychological factors, infections, sleep deprivation, or composition of gut bacteria.

24.10 Thyroxine is the major hormone that controls basal metabolic rate (pp. 950–951)

A. Basal Metabolic Rate (p. 950)
   1. The basal metabolic rate reflects the amount of energy required for performance of only the essential activities of the body and is expressed as kilocalories per square meter of body surface area.
   2. Basal metabolic rate is higher if the individual is younger or male and tends to rise and fall with body temperature.
   3. The most important hormonal factor affecting basal metabolic rate is thyroxine, which increases O_2 consumption and heat production.

B. Total metabolic rate is the rate of kilocalorie consumption needed to power all activities, and can increase with an increase in muscle activity, or food-induced thermogenesis. (p. 950)

24.11 The hypothalamus acts as the body's thermostat (pp. 951–954; Figs. 24.26–24.28)

A. Core and Shell Temperature (pp. 951)
   1. The core of the body, which includes organs within the skull, thoracic, and abdominal cavities, has the highest body temperature, while the shell (mostly the skin) has the lowest temperature.
   2. Core temperature is closely regulated: blood is an agent of exchange between the core and shell, allowing heat to be lost through increased flow to skin, or retained by bypassing vessels in the skin.

B. Mechanisms of Heat Exchange (pp. 951–952; Figs. 24.26–24.27)
   1. Heat exchange between our skin and the external environment occurs through radiant flow of heat, conductive flow of warmth from warmer to cooler objects, convective movement of warm air away from the body, and heat loss due to evaporation of fluids from the lungs, oral mucosa, and the skin.

C. The hypothalamus contains the heat-loss and heat-promoting centers that aid in the regulation of behavioral and physiological mechanisms to maintain normal body temperature. (p. 952)

D. Heat-promoting mechanisms maintain or increase body core temperature and include constriction of cutaneous blood vessels, shivering, increase in metabolic rate, and increased release of thyroxine. (pp. 952–954; Fig. 24.28)

E. Heat-loss mechanisms protect the body from excessively high temperatures and include dilation of cutaneous blood vessels, enhanced sweating, and behaviors that promote heat loss or reduce heat gain. (p. 954; Fig. 24.28)

F. Fever results when macrophages and other cells release cytokines that act as pyrogens, causing the hypothalamus to reset to a higher than normal temperature. (p. 954)

Developmental Aspects of Nutrition and Metabolism (pp. 954–956; Fig. 24.29)

A. Inadequate nutrition during pregnancy and in the first three years of life seriously compromises brain growth and development, as well as muscle and bone development. (p. 954)

B. Several genetic disorders affect metabolism, such as cystic fibrosis, phenylketonuria, and glycogen storage disease. (p. 955)

C. By middle age, Type II diabetes mellitus becomes a significant problem. (p. 955)

D. Metabolic syndrome is characterized by a group of risk factors that includes accumulation of visceral fat that dramatically increases the risk of heart disease and stroke. (p. 955; Fig. 24.29)

E. Metabolic rate declines throughout life, and this decline may affect the body's ability to digest and absorb nutrients (p. 955)