CHAPTER SCOPE

Why do we eat? This simple question, posed in our last chapter scope, actually has a two-part answer. First, in the digestive system chapter we learned how the larger fuel food polymers are digested by specific enzyme reactions into smaller molecules that are absorbed into the blood and distributed to all cells of the body. The second part of the answer is provided as the topic of this chapter—the regulation of metabolism. We eat to provide all body cells with absorbed fuel foods, such as *carbohydrates*, *lipids*, and *proteins* that release energy when combusted along specific **metabolic pathways**. This energy is transferred to make molecules of **ATP** and used immediately by the cell for various functions such as active transport, or is stored for future use as glycogen or fat. Energy that is not directly applied to activities in the cell or stored, is lost as *heat*. Still more of these absorbed raw materials are required for the synthesis of new molecules to replace those that routinely wear out or are broken down.

These carbohydrate, lipid, and protein fuel molecules are continuously built up (*anabolism*) or broken down (*catabolism*) by tissue cells. **Metabolism** refers to both of these processes occurring simultaneously throughout all body tissues. In chapter 2, anabolic processes were discussed in which these fuel molecules were assembled by *dehydration synthesis*. The catabolic, or hydrolytic, processes were covered in chapter 5. Chapter 5 discussed how (1) carbohydrates were combusted during glycolysis, the Krebs cycle, and oxidative phosphorylation reactions; (2) lipids were dismantled during beta-oxidation to acetyl-CoA; and (3) proteins were disassembled during transamination and oxidative deamination reactions. If your memory of these pathways is hazy it should be, because these complicated reactions were described very early in the text. If you have the time, this would be an ideal opportunity to review these concepts.

Most of this chapter is devoted to the **endocrine** and **neural** control over these metabolic pathways and the problems that can develop when these control systems malfunction, such as in **diabetes mellitus**. The organs and hormones featured will include the (1) *pancreas*, which releases insulin (beta cells) and glucagon (alpha cells); (2) the *adrenal glands*, which release epinephrine (from the medulla) and glucocorticoids (from the cortex); (3) the *anterior pituitary gland*, which releases growth hormone; (4) the *thyroid gland*, which releases thyroxine (follicle cells) and calcitonin (parafollicular cells); and (5) the *parathyroid glands*, which release parathyroid hormone (PTH) from chief cells. (Please review chapter 11, for further descriptions of these endocrine glands, the general properties of their hormones, and the operation of their second messenger systems.)

I. NUTRITIONAL REQUIREMENTS

The body's energy requirements must be met by the caloric value of food to prevent catabolism of the body's own fat, carbohydrates, and protein. Additionally, food molecules — particularly the essential amino acids and fatty acids — are needed for replacement of molecules in the body that are continuously degraded. Vitamins and minerals do not directly provide energy but instead are required for diverse enzymatic reactions.

A. Multiple Choice

___ 1. Which statement about the total rate of body metabolism, or metabolic rate, is *false*?
   a. The metabolic rate can be measured by the amount of heat generated by the body.
   b. The metabolic rate can be measured by the amount of oxygen consumed by the body per minute.
   c. The metabolic rate is increased both by eating and by physical exercise.
   d. The metabolic rate is decreased when the ambient temperature is lowered (as in hypothermia).
   e. All of these statements regarding the metabolic rate are true.

___ 2. Which factor is *not* involved in the *direct* determination of the *basal metabolic rate* (BMR)?
   a. male or female gender
   b. age
   c. level of thyroid hormone secretions
   d. body frame size
   e. body surface area

___ 3. Which of the following molecules is *not* either an essential fatty acid or an essential amino acid?
   a. riboflavin
   b. methionine
   c. linolenic acid
   d. tryptophan
   e. linoleic acid

___ 4. Which of the following is *not* a *fat-soluble* vitamin?
   a. vitamin A
   b. vitamin D
   c. vitamin C
   d. vitamin E
   e. vitamin K

___ 5. The vitamin that is converted into a hormone with the help of the sun, serving to regulate calcium levels in the blood, is
   a. vitamin D.
   b. vitamin K.
   c. vitamin C.
   d. thiamine.
   e. pyridoxine.

___ 6. Of the following elements, which one is needed in relatively *large* amounts to function as a cofactor for specific enzymes, and therefore, is not a trace element?
   a. fluorine
   b. zinc
   c. magnesium
   d. iron
   e. selenium

___ 7. Which statement about free radicals is *false*?
   a. Free radical molecules have an unpaired electron in their outermost orbital.
   b. Free radicals are highly reactive in the body, sometimes resulting in the oxidation of or sometimes resulting in the reduction of other atoms.
   c. Free radicals are waste products of metabolism and are always damaging to body tissues.
   d. Free radicals may have either an unpaired nitrogen atom (reactive nitrogen species) or an unpaired oxygen (reactive oxygen species) atom.
   e. Free radicals include the superoxide radical, the hydroxyl radical, and the nitric oxide radical, among others.

___ 8. Which of the following molecules is *not* known to have antioxidant properties?
   a. vitamin D
   b. glutathione
   c. vitamin C (ascorbic acid)
   d. vitamin E (alpha-tocopherol)

B. True or False/Edit

___ 9. A *kilocalorie* is equal to 1,000 calories and can also be written as 1 kcal, or 1 C.

___ 10. A person with *hyperthyroidism* would be expected to have an abnormally high BMR, and a person with *hypothyroidism* to have an abnormally low BMR.

___ 11. A higher than normal BMR in certain obese people may be due to genetic factors that have been inherited.

___ 12. When the intake of carbohydrates, protein, or fat exceeds the energy output, the excess calories are stored in the body primarily as fat.

___ 13. Weight loss can be achieved by dieting alone or in combination with an exercise program to raise the metabolic rate.

___ 14. Anabolism (the assembly of polymers) and catabolism (the breakdown of polymers) are processes that normally occur simultaneously within cells of the body.

___ 15. Since fat can be made from excess carbohydrates, only a small amount of fat is necessary in the diet to supply the body with the essential fatty acids and adequate quantities of fat-soluble vitamins.

___ 16. There are more essential fatty acids required by the body than there are essential amino acids required by the body.
___ 17. Derivatives of the water-soluble vitamins primarily serve as cofactors for specific enzymes involved in the metabolism of carbohydrates, lipids, and proteins.
___ 18. The vitamins thiamine (B1), riboflavin (B2), and niacin (B3) are examples of vitamins required for the normal metabolism of carbohydrate, lipid, and protein molecules.
___ 19. The vitamin most required for the production of prothrombin and for clotting factors VII, IX, and X, is vitamin A.
___ 20. Beta-carotene is a vitamin found only in plants that can be eaten and digested in the intestine into two molecules of retinal, a precursor of vitamin E.
___ 21. Thyroxine, vitamin D, and vitamin A have overlapping cellular functions in the regulation of gene expression and the promotion of tissue differentiation because all three interact together at the receptors of target cell nuclei.
___ 22. Although the formation of some free radical molecules like superoxide and nitric oxide radicals is important in normal physiology, it is the excessive production of free radicals that causes damage to lipids, proteins, and DNA and thereby exerts oxidative stress on the body.

II. REGULATION OF ENERGY METABOLISM

The blood plasma contains circulating glucose, fatty acids, amino acids, and other molecules that can be used by the body tissues for cell respiration. These circulating molecules may be derived from food or from the breakdown of the body's own glycogen, fat, and protein. The building of the body's energy reserves following a meal and the utilization of these reserves between meals are regulated by the action of a number of hormones that act to promote either anabolism or catabolism.

A. Multiple Choice

___ 23. Which of the following is *not* a *circulating energy substrate*?
a. vitamins
b. fatty acids
c. glucose
d. amino acids
e. ketone bodies

___ 24. Which statement about *preferred energy sources* is *false*?
a. The brain has an almost absolute requirement for blood glucose for energy.
b. Resting skeletal muscles use fatty acids as their preferred energy source.
c. Ketone bodies are derived from fatty acid metabolism.
d. Ketone bodies, lactic acid, and amino acids can be used to different degrees as energy sources by various organs in the body.
e. All of these statements regarding preferred energy sources are true.

___ 25. Which statement about *adipose cells* (*adipocytes*) is *false*?
a. Adipocytes store fat in large vacuoles, releasing primarily free fatty acids during times of fasting.
b. Adipocytes are very active cells, and may themselves secrete hormones that play a pivotal role in the regulation of metabolism.
c. A rise in circulating fatty acid levels promotes the conversion of preadipocytes (derived from fibroblasts) into new adipocytes.
d. The differentiation of adipocytes requires the action a specific prostaglandin ligand on a nuclear receptor protein known as PPARγ (peroxisome proliferator activated receptor).
e. All of these statements regarding adipocytes are true.

___ 26. The regulatory molecule secreted by adipose cells (and other cell types) of obese people that reduces the ability of skeletal muscles to remove glucose from the blood in response to insulin, is called
a. leptin.
b. resistin.
c. TNFα (tumor necrosis factor-alpha).
d. adiponectin.

___ 27. The hormone secreted by adipocytes that acts on the hypothalamus to decrease appetite an food intake, is
a. leptin.
b. resistin.
c. TNFα (tumor necrosis factor-alpha).
d. adiponectin.

___ 28. Which of the following substances may explain why people who are starving get more infections and why excessively thin adolescent girls may have delayed onset of menarche (menstrual cycle)?
a. leptin
b. resistin
c. TNFα (tumor necrosis factor-alpha).
d. adiponectin

___ 29. In which of the following conditions is *obesity not* considered a risk factor?
a. some malignancies (especially endometrium cancer and breast cancer)
b. gallbladder disease
c. Parkinson's disease
d. diabetes mellitus
e. cardiovascular diseases

___ 30. The **arcuate nucleus** of the brain that receives neurotransmitters and hormone regulators from the blood in the important regulation of hunger, is located in the
a. anterior pituitary gland.
b. limbic system.
c. cerebellum.
d. hypothalamus.
e. medulla oblongata.

___ 31. Which statement about the regulation of hunger by the arcuate nucleus is *false*?
a. Melanocyte stimulating hormone (MSH) and other melanocortins, work to suppress hunger.
b. Neuropeptide Y stimulates hunger directly.
c. Agouti-related protein stimulates hunger indirectly by inhibiting MSH.
d. Hunger and appetite are responsive to signals from the digestive tract and from adipose tissue.
e. All of these statements about hunger are true.

___ 32. The recently discovered hormone secreted by the small intestine that regulates hunger on a more intermediate-time basis (over a 12-hour period), is
a. ghrelin.
b. cholecystokinin (CCK).
c. PYY.
d. leptin.
e. insulin.

___ 33. The circulating satiety factor (appetite suppressant) secreted by adipose tissue, best describes
a. ghrelin.
b. cholecystokinin (CCK).
c. PYY.
d. leptin.
e. insulin.

___ 34. The energy expenditure of a relaxed, resting person who is at a neutral ambient temperature and who has not eaten in 8-12 hours, best describes
a. adaptive thermogenesis.
b. diet-induced thermogenesis.
c. basal metabolic rate (BMR).
d. nonshivering thermogenesis.
e. body mass index (BMI).

___ 35. Which of the following statements about the "thermic effect of food" is *false*?
a. Heat energy is expended by the digestion and absorption of food.
b. Starvation increases the metabolic rate by as much as 40%.
c. The act of eating (feeding) increases the metabolic rate by about 25-40% in adults.
d. Body temperature usually rises during a meal.
e. This thermic effect of food is an important part of adaptive thermogenesis.

___ 36. During starvation,
a. adipose tissue increases its secretion of leptin.
b. there is a rise in the secretion of both TRH and thyroxine hormones to raise BMR.
c. there is a decline in the sympathetic stimulation of brown fat uncoupling proteins.
d. the net effect is to cause an increase in the metabolic rate and burn energy.

___ 37. Which two hormones have *both* anabolic and catabolic effects? [*Hint*: See table 19.5.]
a. insulin and glucagon
b. epinephrine and glucocorticoids
c. growth hormone and thyroxine
d. glucagon and thyroxine

B. True or False/Edit

___ 38. Protein is combusted as a secondary, or an emergency, energy source only after glycogen and fat primary *energy reserves* have been utilized.

___ 39. Resting skeletal muscles have an almost absolute requirement for blood glucose as its primary energy source.

___ 40. Another hormone secreted by adipocytes called *adiponectin* has an insulin-sensitizing, antidiabetic effect since it stimulates glucose utilization and fatty acid oxidation in muscle cells.

___ 41. Thiazolidinediones are a new class of drugs for the treatment of type 2 diabetes that specifically activate the PPARγ receptors, ultimately make skeletal muscle and other tissues more sensitive to the glucose-lowering effects of insulin.

___ 42. According to a study by the Rand Corporation, obesity is a greater risk factor to chronic diseases than either smoking or drinking.

___ 43. The increase in the release of leptin hormones from adipocytes in those who are starving or have low body fat appears to be related both to the lowering of immune competence (more susceptible to infections) and to the early onset of puberty (regulation of the menstrual cycle).

___ 44. Obesity in childhood is due to an increase in both adipocyte size and number; whereas weight gain in adults is due mainly to an increase in adipocyte size.

___ 45. The "pear shape" distribution of body fat places more intra-abdominal fat in the mesenteries and greater omentum, and thus, is a better predictor of cardiovascular disease than is an increase in subcutaneous fat seen in the "apple shape"

___ 46. Obesity is often diagnosed using a measurement derived from body weight (in kilograms) and height (in meters, squared) called the *body mass index* (BMI).

___ 47. Every day, about 60% of the total calories in the average, sedentary adult is spent just to keep the body tissue functioning, which is just to stay alive.

___ 48. In humans, the production of uncoupling proteins in the mitochondria of brown fat cells results in an increase in the production of ATP and a decrease in heat production.

___ 49. Adaptive thermogenesis is largely maintained by sympathetic innervation of skeletal muscles and brown fat, together with the effects of circulating epinephrine from the adrenal medulla, regulating overall metabolism in these tissues.

___ 50. The *postabsorptive* state starts about 4 hours after a meal and continues until the next meal; and is generally referred to as the fasting state.

___ 51. Glucagon, growth hormone, glucocorticoids, and epinephrine are all catabolic hormones that break down larger lipid energy reserves into simpler circulating free fatty acid substrates (lipolysis). [*Hint:* See table 19.5.]

C. Label the Figure — The Regulation of Metabolic Balance

Study figure 19.1 carefully. In the spaces provided, write the proper *metabolic process, fuel molecule,* or the *name of the hormone* that is involved in the balanced regulation of anabolism (buildup) and catabolism (breakdown) of carbohydrates, lipids, and protein. Notice the direction of the arrows. Can you name the two hormones that are active in *both* anabolism and catabolism? If you get stuck, sneak a peak at figure 19.5 in your text.

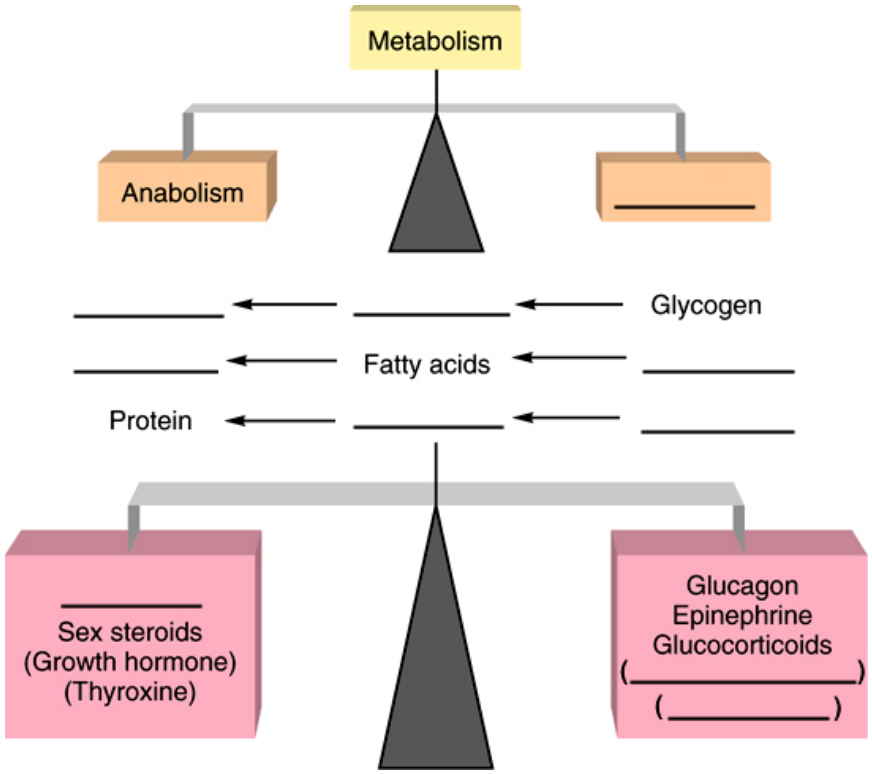


Figure 19.1 The regulation of metabolic balance.

III. ENERGY REGULATION BY THE PANCREATIC ISLETS

Insulin secretion is stimulated by a rise in blood glucose concentration, and insulin promotes the entry of blood glucose into tissue cells. Insulin thus increases the storage of glycogen and fat while causing the blood glucose concentration to fall. Glucagon secretion is stimulated by a fall in blood glucose, and glucagon acts to raise the blood glucose concentration by promoting glycogenolysis in the liver.

A. Multiple Choice

___ 52. The hormone secreted by the delta cells of the pancreatic islets (of Langerhans) that is identical to that produced by the hypothalamus and the intestine, is
a. insulin.
b. glucagons.
c. somatostatin.

___ 53. The most numerous cells of the pancreatic islets of Langerhans are the _____ cells that secrete the hormone _____.
a. alpha; insulin
b. beta; insulin
c. delta; glucagon
d. beta; glucagon
e. delta; insulin

___ 54. Which statement about the regulation of insulin and glucagon from the pancreatic islets of Langerhans is *false*?
a. Alpha and beta cells respond to changes in both the glucose and the amino acid concentrations in the plasma.
b. Homeostasis regulates insulin and glucagon levels by negative feedback loops.
c. Alpha and beta cells act both as sensors and effectors in regulation of their secretion of hormones.
d. After a meal, the rise in plasma glucose levels stimulates the release of insulin.
e. All of these statements about the regulation of insulin and glucagon from the islets of Langerhans are true.

___ 55. Which response to stimulation of the autonomic nervous system is *not* correct?
a. Both sympathetic and parasympathetic nerves innervate the islets of Langerhans.
b. Parasympathetic stimulation decreases insulin secretion.
c. Sympathetic stimulation increases glucagon secretion.
d. Together with epinephrine, glucagon is involved in stress hyperglycemia, when the sympathetic nerves are stimulated.
e. During meals, parasympathetic nerve activity stimulates gastrointestinal motility and secretion.

___ 56. Which of the following effects does the hormone, insulin, *not* promote?
a. increase in the entry of glucose into skeletal and cardiac muscles, adipose tissue, and liver
b. increase in the production of glycogen in liver and muscle cells (glycogenesis)
c. increase in the production of triglycerides (fat) in adipose cells (lipogenesis)
d. increase in overall body catabolism
e. lowering of the plasma glucose levels

___ 57. Which statement about the *postabsorptive*, or fasting state, is *false*?
a. Glucagon secretion is high and insulin secretion is low.
b. Glucose-6-phosphatase enzymes in the liver stimulate hydrolysis of liver glycogen to free glucose molecules (glycogenolysis).
c. Only muscle cells can use muscle glycogen stores for energy.
d. Only liver cells can use liver glycogen stores for energy.
e. Hormones promote the formation of glucose from noncarbohydrate molecules (gluconeogenesis).

___ 58. The enzyme, hormone-sensitive lipase
a. is found only in liver cells.
b. is sensitive to, and activated by, the hormone insulin.
c. promotes the hydrolysis of stored triglycerides, releasing free fatty acids and glycerol into the blood.
d. converts triglycerides into ketone bodies as an alternative energy source.
e. is most active immediately following ingestion of a meal.

B. True or False/Edit

___ 59. In the islets of Langerhans of the pancreas, the alpha and beta cells act as both the sensors and effectors in the negative feedback regulation (homeostasis) of plasma glucose levels.

___ 60. In general, insulin is considered an anabolic hormone because it not only permits the facilitated diffusion of glucose into cells but it also inhibits the breakdown of fat and muscle proteins while stimulating the production of fat-forming enzymes.

___ 61. During the absorption of a carbohydrate meal, stimulation of the alpha cells causes the secretion of *glucagon*, which acts to lower blood glucose levels by promoting its uptake by the tissues.

___ 62. A fall in plasma glucose will stimulate the alpha cells to secrete glucagon and inhibit the release of insulin from beta cells.

___ 63. One effect of glucagon is to lower the concentration of glucose in the blood by promoting the synthesis of glucose by the liver (gluconeogenesis).

___ 64. The *oral glucose tolerance test* is a clinical procedure in which a high glucose solution is drunk that challenges the ability of the beta cells to secrete insulin and lower the subsequent rise in blood glucose levels.

___ 65. Meals rich in protein and low in carbohydrates can stimulate the secretion of both insulin and glucagon from the pancreas — promoting amino acid entry into tissue cells and a rise in blood glucose.

___ 66. Relaxed eating environments will encourage parasympathetic stimulation of the pancreas and the subsequent increase in insulin secretion.

___ 67. *Gastric inhibitory peptide (GIP*) is also known as *glucose-dependent insulinotropic peptide* since it is released by the presence of glucose in the intestinal chyme to stimulate insulin secretion from the pancreas, even before plasma glucose levels begin to rise.

___ 68. The overall effect of glucagon is to lower blood *glucose* and *amino acid* levels by promoting their cellular uptake and incorporation into glycogen and proteins, respectively.

___ 69. One anabolic effect of insulin is the synthesis of triglycerides (lipogenesis) from glucose transported into adipose cells following a meal.

___ 70. There is a maximum of about 100 g of stored glycogen in the skeletal muscles, whereas the liver can store approximately 375-400 g of glycogen.

___ 71. Glycogen stores in liver and skeletal muscle have a maximum, in that once these stores are filled, continued ingestion of excess calories will increase the production of fat.

___ 72. During fasting, gluconeogenesis promotes the synthesis of new glucose molecules from noncarbohydrate substrates such as certain amino acids and pyruvic acid molecules derived from muscle tissue.

___ 73. During fasting or starvation, several organs in the body can use ketone bodies derived from fatty acid metabolism as an alternative energy source; and thus spare glucose for use by the brain.

___ 74. Insulin is active primarily after eating (absorption), whereas glucagon is most active between meals (fasting).

C. Label the Figure — Insulin and Glucagon Effects on Glucose Metabolism

Study figure 19.2 carefully. In the spaces provided, write the name of the hormone (*insulin* or *glucagon*) or the terms *cellular uptake*, *glycogenolysis*, or *gluconeogenesis*. Notice the upward (increase) and downward (decrease) direction on all arrows. Can you explain why the effects of these hormones are said to be *antagonistic*? If you need help, refer to figure 19.7 in the text.

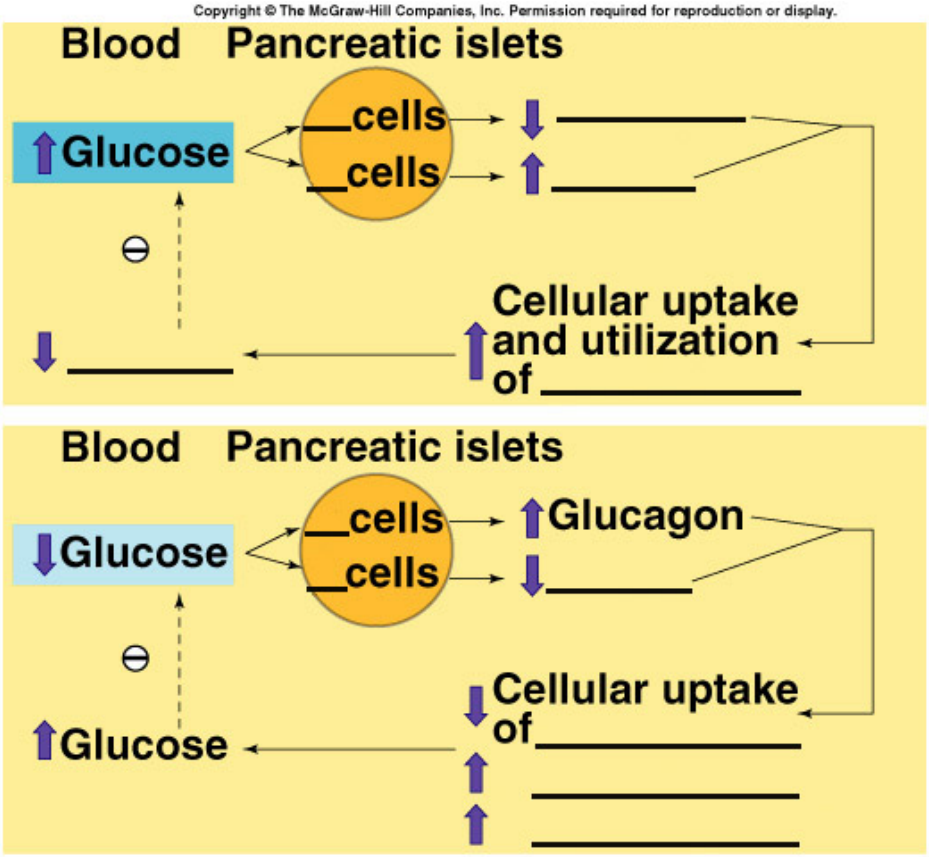


Figure 19.2 The regulation of insulin and glucagon secretion.

IV. DIABETES MELLITUS AND HYPOGLYCEMIA

Inadequate secretion of insulin, or defects in the action of insulin, produce metabolic disturbances that are characteristic of diabetes mellitus. A person with type 1 diabetes requires injections of insulin; a person with type 2 diabetes can control this condition by other methods. In both types, hyperglycemia and glycosuria result from a deficiency and/or inadequate action of insulin. A person with reactive hypoglycemia, by contrast, secretes excessive amounts of insulin and thus experiences hypoglycemia in response to the stimulus of a carbohydrate meal.

A. Multiple Choice

___ 75. Which general statement about **diabetes mellitus** is *false*?
- a. Diabetes mellitus is characterized by low blood sugar levels (hypoglycemia).
- b. Diabetes mellitus can result from inadequate insulin release when beta cells are destroyed.
- c. Diabetes mellitus can result from target cells not responding to insulin (increased resistance).
- d. Glucose usually "spills over" into the urine (glycosuria).
- e. There are two basic forms of diabetes mellitus, type 1 and type 2.

___ 76. *Type 2* (non-insulin dependent) *diabetes mellitus* is characterized by
- a. destruction of the beta cells by an autoimmune attack or by viruses, for example.
- b. absence of the hormone insulin in the plasma.
- c. diagnosis in people over age 40; once called *maturity-onset diabetes* and represents 90% of the people with diabetes mellitus.
- d. diagnosis in people under age 20; once was called *juvenile-onset diabetes*.
- e. abnormally high plasma levels of the hormone, glucagon.

___ 77. In people with type 1 *diabetes mellitus*,
- a. large amounts of free fatty acids are released from adipose cells (lipolysis).
- b. the liver raises the blood levels of ketone bodies (ketosis).
- c. the pH of the blood may go down (become more acidic) as more acids are made.
- d. osmotic diuresis may cause dehydration and thirst as water follows the excess solute into the urine.
- e. All of these occur in people with type 1 diabetes mellitus.

___ 78. *Reactive hypoglycemia* is a condition characterized by
- a. inadequate insulin secretion from the beta cells.
- b. being genetically predisposed to type 1 diabetes (insulin-dependent).
- c. an exaggerated response of beta cells to a rise in blood glucose levels.
- d. diagnosis when the oral glucose tolerance test results in blood glucose levels that rise sharply and stay elevated for 5 hours.
- e. treatment consisting of two or three large, high-carbohydrate meals a day.

B. True or False/Edit

___ 79. Type 1 diabetes mellitus is insulin-dependent diabetes mellitus, formerly called juvenile-onset diabetes, occurring in about 10% of the patients with diabetes in this country.

___ 80. Type 2 diabetes mellitus is non-insulin-dependent diabetes mellitus; usually occurs in adults over thirty years of age (maturity-onset diabetes) and is commonly associated with obesity.

___ 81. Type 1 diabetic patients may actually secrete normal or slightly elevated amounts of the hormone insulin from the beta cells of the pancreatic islets of Langerhans.

___ 82. Obesity seems to increase the sensitivity of target cells to insulin and thereby increasing the efficiency of glucose uptake by these tissue cells.

___ 83. People with type 2 diabetes have abnormally high tissue sensitivity to insulin which means a lowered insulin resistance.

___ 84. Exercise helps diabetics lose weight, decrease the size of the adipocytes and make them more insulin sensitive while also increasing both insulin sensitivity and glucose uptake in skeletal muscles.

___ 85. People with type 2 diabetes do not usually develop ketoacidosis; but are at risk of blindness, kidney failure, and amputation of the lower extremities due to prolonged exposure to high blood glucose levels.

___ 86. Hypoglycemia and possibly a coma can result in patients with type 1 diabetes who inject themselves with an overdose of insulin to prevent hyperglycemia and ketoacidosis.

V. METABOLIC REGULATION BY ADRENAL HORMONES, THYROXINE, AND GROWTH HORMONE

Epinephrine, the glucocorticoids, thyroxine, and growth hormone stimulate the catabolism of carbohydrates and lipids. These hormones are thus antagonistic to insulin in their regulation of carbohydrate and lipid metabolism. Thyroxine and growth hormone promote protein synthesis, however, and are needed for body growth and proper development of the central nervous system. The stimulatory effect of these hormones on protein synthesis is complementary to that of insulin.

A. Multiple Choice

___ 87. Which statement about the *adrenal gland* is *false*?
- a. The adrenal *medulla* secretes the catecholamine hormones, epinephrine, and norepinephrine.
- b. The adrenal *cortex* secretes mineralocorticoids, such as aldosterone, and glucocorticoids, such as cortisol.
- c. The adrenal medulla responds to sympathetic nerve activity.
- d. The adrenal cortex secretes adrenocorticotropic hormone (ACTH).
- e. The adrenal cortex and medulla have different embryonic origins.

___ 88. Which statement about the hormone, *thyroxine* is *false*?
- a. Thyroxine is also called tetraiodothyronine, or T_4.
- b. Thyroxine is released from the thyroid follicles when stimulated by TSH from the anterior pituitary.
- c. Thyroxine has target cells in almost every organ of the body.
- d. Thyroxine is a prehormone that must first be converted to T_3 within the target cells to be active.
- e. All of these statements about thyroxine are true.

___ 89. Which action of *thyroxine* is *false*?
- a. Thyroxine stimulates the rate of cell respiration in almost all cells of the body.
- b. Thyroxine reduces the concentration of ATP in target cells.
- c. Thyroxine reduces body heat production during cold adaptation.
- d. Thyroxine concentration is directly related to the basal metabolic rate (BMR).
- e. All of these statements about thyroxine are true.

___ 90. Which statement about *growth hormone* (GH) is *false*?
- a. GH is secreted in adults as well as in children.
- b. GH is also known as *somatotropic* hormone.
- c. GH is inhibited by *somatostatin* from the hypothalamus.
- d. GH is synthesized and released by the posterior pituitary.
- e. GH secretion follows a *circadian* rhythm, rising during sleep.

___ 91. Which statement about *growth hormone* (GH) is *false*?
- a. GH secretion increases after absorbing a high protein meal.
- b. GH secretion falls during prolonged fasting.
- c. GH secretion rises when plasma glucose levels fall.
- d. GH stimulates the catabolism of fat and release of fatty acids from adipose tissue.
- e. GH has both anabolic (protein) and catabolic (fat) effects.

___ 92. In adults, the oversecretion of *growth hormone* (GH) causes
- a. gigantism.
- b. Graves' disease.
- c. acromegaly.
- d. dwarfism.
- e. cretinism.

B. True or False/Edit

___ 93. The metabolic effects of epinephrine on its target cells are similar to those of the hormone, insulin.

___ 94. Both glucagon and epinephrine stimulate glycogenolysis, with release of glucose from the liver; and lipolysis, with release of fatty acids from adipose cells.

___ 95. Epinephrine and glucagon hormones have similar mechanisms of action that are both mediated by cyclic AMP second messengers in their target cells.

___ 96. Prolonged fasting or exercise stimulates the release of ACTH from the anterior pituitary, which, in turn, stimulates an increase in the secretion of glucocorticoid hormones from the adrenal cortex.

___ 97. Stress-induced release of glucocorticoids such as hydrocortisone (cortisol), results in the release of amino acids, glucose, fatty acids, and ketone bodies into the blood to help compensate for the state of stress.

___ 98. Thyroxine inhibits the rate of cell respiration in almost all cells in the body.

___ 99. Thyroxine is also considered an anabolic hormone since it is necessary for normal growth of the skeleton and for proper development of the central nervous system (CNS).

___ 100. *Graves' disease* is a disorder in which autoantibodies are produced that have TSH-like effects, stimulating the thyroid gland and forming a goiter.

___ 101. Blood levels of growth hormone fluctuate each day (circadian), with highest levels reached when awake (daytime).

___ 102. Growth hormone has both *anabolic* (protein synthesis) and *catabolic* (fat breakdown) effects on various target cells.
___ 103. Since recombinant growth hormone can be produced by genetically engineered cells in larger quantities, children of short stature, but do not have pituitary dwarfism, can receive injections and can grow to taller than expected heights.
___ 104. The skeleton growth-promoting effects of growth hormone seem to be mediated by the *somatomedins*, IGF-1 and IGF-2 proteins, which stimulate the chondrocytes (cartilage cells) to divide and secrete more matrix and exhibit insulin-like actions.
___ 105. An inadequate secretion of growth hormone during the growing years results in *dwarfism*.

VI. REGULATION OF CALCIUM AND PHOSPHATE BALANCE

A normal blood Ca^{2+} concentration is critically important for contraction of muscles and maintenance of proper membrane permeability. Parathyroid hormone promotes an elevation in blood Ca^{2+} by stimulating resorption of the calcium phosphate crystals from bone and renal excretion of phosphate. A derivative of vitamin D produced in the body, 1,25-dihydroxyvitamin D_3, promotes the intestinal absorption of calcium and phosphate.

A. Multiple Choice

___ 106. Which statement about *bone* is *false*?
a. Bone serves as a large store of calcium and carbonate
b. Calcium is stored as *calcium phosphate* in the form of hydroxyapatite crystals in bone.
c. *Osteoblasts* (bone-forming cells) secrete an organic matrix of collagen protein that becomes hardened by deposits of hydroxyapatite.
d. *Osteoclast* cells routinely dissolve hydroxyapatite crystals, a process called *resorption*.
e. Hormones determine bone formation and resorption rates.

___ 107. Which statement about *bone resorption* is *false*?
a. It begins when osteoclasts attach to the bone matrix and forms a "ruffled membrane."
b. Osteoclasts must secrete chemicals that both dissolve calcium phosphate and digest the proteins of the bone matrix.
c. Bone matrix is acidified by transport of H^+ (by a H^+-ATPase pump) in the ruffled membrane and a Cl^-/HCO_3^- pump on the opposite membranes of the osteoclast.
d. Cathepsin K is an enzyme released by the osteoclast to digest the protein portion of the bone matrix.
e. All of the statements about bone resorption are true.

___ 108. Which effect is *not* mediated by calcium ion (Ca^{2+})?
a. required for blood clotting
b. as the second messenger in the action of certain hormones
c. oxygen-binding ion within heme groups of hemoglobin
d. maintain proper membrane permeability to Na^+ and to other ions
e. combines with phosphate to harden bone

___ 109. Which bone disorder is due to excessive secretion of *parathyroid hormone* (PTH)?
a. rickets
b. osteomalacia
c. osteoporosis
d. steitis fibrosa cystica

___ 110. Which statement about *parathyroid hormone* (PTH) is *false*?
a. PTH is released when blood Ca^{2+} levels fall.
b. PTH stimulates the resorption of bone by osteoclasts.
c. PTH increases Ca^{2+} (but not phosphate) reabsorption from the glomerular filtrate of the kidney nephrons.
d. PTH promotes the formation of *1,25-dihydroxyvitamin D_3* in the kidneys.
e. All of these statements about PTH are true.

___ 111. The synthesis of 1,25-dihydroxyvitamin D_3
a. begins when sunlight strikes the skin.
b. requires activity of hydroxylation enzymes made in liver cells.
c. requires activity of hydroxylation enzymes made in the kidneys.
d. is promoted by parathyroid hormone (PTH) stimulating the enzymes involved synthesis of the vitamin.
e. All of these statements about the synthesis of *1,25-dihydroxyvitamin D_3* are true.

___ 112. In a normal diet, *1,25-dihydroxyvitamin D_3* stimulates the
a. intestinal absorption of calcium and phosphate.
b. deposition of calcium and phosphate into bone.
c. body's loss of calcium and phosphate in the urine.
d. fall in both calcium and phosphate levels in the blood.
e. distribution of the pigment, *melanin*, in the skin following sun exposure (a tan).

___ 113. Which statement about *calcitonin* is *false*?
a. Calcitonin is secreted by the *parafollicular* cells or *C cells* of the thyroid gland.
b. Calcitonin acts to lower blood Ca^{2+} levels by inhibiting the activity of *osteoclasts*, thus reducing bone resorption.
c. Calcitonin inhibits the reabsorption of calcium and phosphate in the kidney nephrons, thus increasing the urinary excretion of these minerals.
d. Calcitonin action is clearly antagonistic to that of parathyroid hormone and is, therefore, required to maintain calcium homeostasis.
e. Very large doses (pharmacological doses) of calcitonin are clinically useful in the treatment of Paget's disease of the bone.

B. True or False/Edit

___ 114. Continuously throughout life the bone-forming cells or *osteoclasts*, serve to construct bone while simultaneously the bone-dissolving cells or *osteoblasts* work to resorb bone.

___ 115. The use of estrogen to treat osteoporosis in postmenopausal women is partly due to the hormone stimulating the apoptosis (cell suicide) of osteoclasts.

___ 116. By the age of fifty or sixty, the rate of bone resorption often exceeds the rate of bone deposition.

___ 117. The three hormones most involved in the endocrine regulation of calcium and phosphate balance are parathyroid hormone (PTH), 1,25-hydroxyvitamin D3, and calcitonin.

___ 118. Many cancers secrete a hormone known as parathyroid hormone-related protein that raises blood Ca2+ levels by activating the target cell PTH receptors in bone.

___ 119. The thyroid gland secretes a hormone called calcitonin that has questionable physiological significance but when taken in large doses (pharmacological effect), seems to inhibit the resorption of bone (opposes PTH).

___ 120. Compared to postmenopausal women, men are less prone to the demineralizing effects of osteoporosis because they have higher blood levels of testosterone (androgen) that can be converted locally within bones into estrogen.

___ 121. Parathyroid hormone (PTH) is released when the plasma Ca2+ levels rise, stimulating the resorption activity of osteoblast cells in bone.

___ 122. Surgical removal of the parathyroid glands results in a rise in calcium levels in the plasma (hypercalcemia) that can cause severe muscle tetany.

___ 123. Men are less prone to osteoporosis than postmenopausal women because men continue to form estrogen (from blood androgens) in their bones, whereas in women, estrogen secretion from the ovaries declines at menopause.

___ 124. Estrogen promotes bone mineralization partly because it stimulates the new matrix formation by osteoblasts while suppressing the formation of osteoclasts.

___ 125. People who are hypothyroid are more prone to osteoporosis since both osteoblasts and osteocytes have receptors for thyroxine (T3).

___ 126. Vitamin D3 functions as a prehormone that must be chemically changed in order to become biologically active.

___ 127. The primary function of 1,25-dihydroxyvitamin D3 is to raise the blood levels of calcium and phosphate, by promoting their absorption in the intestine from food.

___ 128. Low blood calcium levels can be raised by the combined actions of parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D3.

VII. CHAPTER REVIEW

A. Completion

129. Your metabolic rate is influenced by a number of factors, including _____, _____, and _____ _____; and is often measured as the rate of _____ consumption. 130. Chemical energy, or potential energy, in food we eat is measured in units of hear called _____. Excess energy from carbohydrates, protein, and fat that is not combusted will be stored primarily as _____. 131. The fat-soluble vitamins are _____, _____, _____, and _____, with the remaining vitamins soluble in the solvent _____. 132. In the body, the three main energy reserves (stores) available for use by the tissues are _____, _____, and _____,which are broken down into simpler energy substrates for combustion in cell respiration. 133. Eating behavior seems to be controlled by the _____ region of the brain, stimulating overeating (hyperphagia) or under eating _____. Four neurotransmitters (neurohormones?) have also been associated with eating behavior, including _____, _____, _____, and _____. 134. Hormones also regulate the distribution of energy through specific actions on metabolism. The islets of _____ in the _____ secrete two important hormones: _____ from the alpha cells and insulin from the _____ cells. 135. A rise in plasma glucose concentration stimulates the secretion of _____ and inhibits the secretion of _____ from the islets; whereas a rise in plasma amino acids _____ (stimulates/inhibits) secretion of both insulin and glucagon. Both parasympathetic stimulation and enterogastrone or gastric inhibitory peptide (GIP) from the intestine _____ (increase/decrease) the release of insulin, which _____ (raises/lowers) blood glucose levels and _____ (stimulate/inhibits) the synthesis of fat within adipose cells. 136. Fasting _____ (increases/decreases) glucagon secretion, which stimulates the breakdown _____ (anabolism/catabolism) of stored _____ and _____, thus increasing blood glucose levels. 137. Type 1, or _____ (IDDM/NIDDM) diabetes mellitus results when pancreatic _____ (alpha/beta) cells are destroyed such that plasma insulin levels _____ (rise/fall) and plasma glucagon levels _____ (rise/fall). 138. In Type 2, or _____ (IDDM/NIDDM), diabetes, the target cells are _____ (more/less) responsive to the insulin present and are associated with _____ (obesity/leanness). Type _____ diabetes mellitus is the more common form. 139. Epinephrine from the adrenal _____ (cortex/medulla) has effects that are similar to those of the hormone _____ from the pancreas, whereas _____ is a glucocorticoid from the adrenal _____ (cortex/medulla) that promotes muscle protein _____ (anabolism/catabolism) and conversion of amino acids to _____ (gluconeogenesis) in the liver. 140. The basal metabolic rate (BMR) is set by the hormone _____, which _____ (increases/decreases) the rate of cell respiration in most body cells. Thyroxine is especially important in synthesis of _____ during normal growth and development of the _____ nervous system. 141. Growth hormone (GH) is synthesized by the _____ _____ (2 words) gland, where it is released and inhibited by hormones from the _____. Growth hormone is secreted following a high- _____ meal and when blood glucose levels _____ during fasting. The promotion of body growth by growth hormone occurs indirectly through polypeptides such as IGF-1 and IGF-2, known as _____. 142. Hydroxyapatite crystals in bone contain the minerals _____ and _____. Bone formation is performed by _____ (osteoblasts/osteoclasts), whereas bone resorption is done by _____. 143. Parathyroid hormone (PTH) is released when plasma Ca^{2+} levels are _____ (high/low), thus stimulating bone _____ (deposition/resorption) and _____ (increasing/decreasing) reabsorption of Ca^{2+} from the kidney. PTH also activates a kidney hydroxylation enzyme, which adds a hydroxyl group (OH) to the number 25 carbon of vitamin _____, forming _____. 144. This vitamin _____ (increases/decreases) the intestinal absorption of calcium and phosphate, _____ (increases/decreases) bone resorption, and _____ (increases/decreases) the reabsorption of phosphate from the kidney tubules. This overall effect results in a rise in both Ca^{2+} and phosphate levels when Ca^{2+} concentrations in the blood fall. 145. Calcitonin is a hormone secreted by the _____ cells of the _____ gland when plasma Ca^{2+} levels are too _____ (high/low). Calcitonin _____ (raises/lowers) blood Ca^{2+} by inhibiting bone _____ (resorption/deposition) and _____ (increasing/decreasing) urinary excretion of calcium and phosphate.

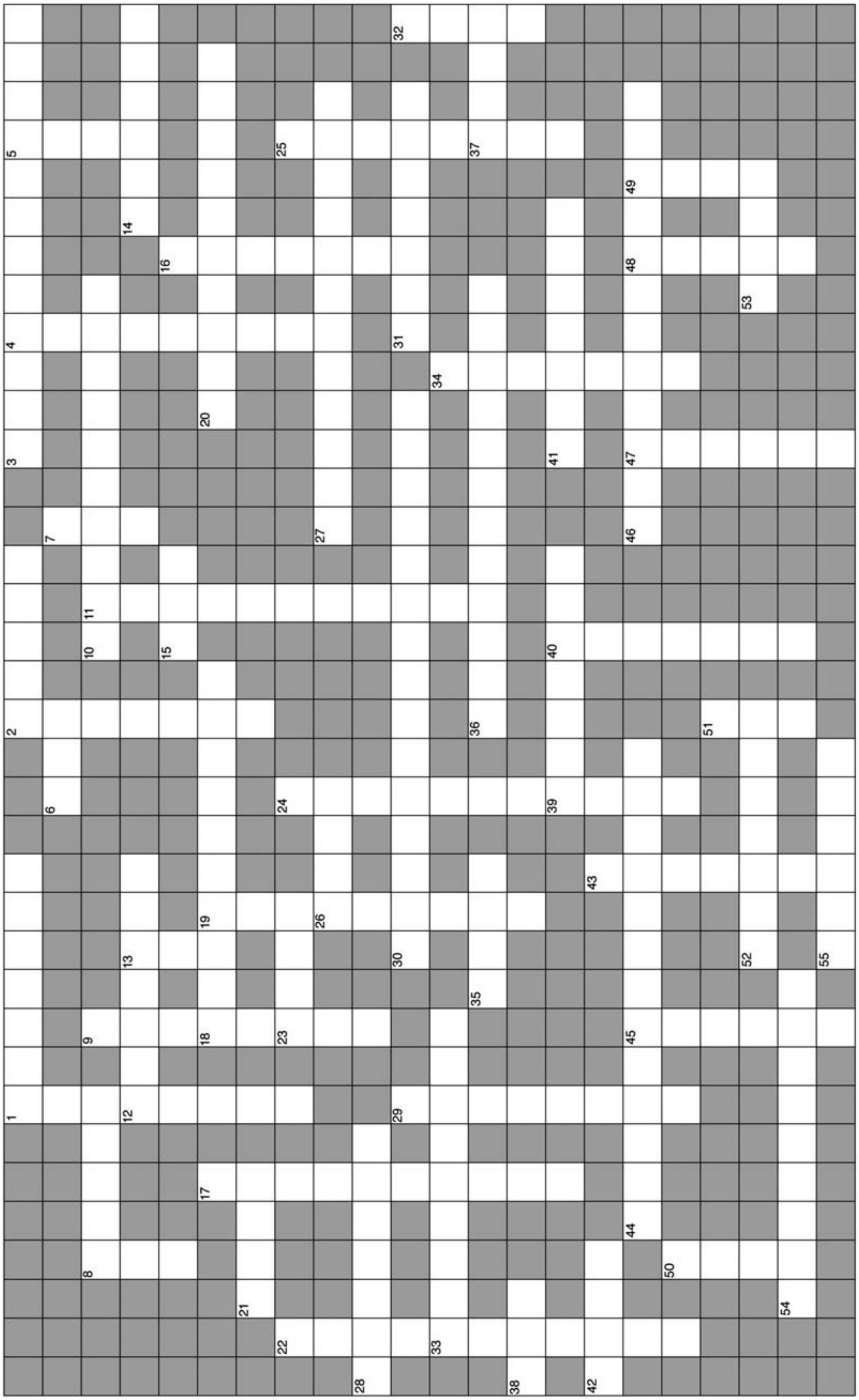
B. Crossword Puzzle — Regulation of Metabolism

Across

1. most available source of energy, especially for brain tissue
2. islet of Langerhans cells that secrete *glucagon*
3. _____ ism: glandular condition that results in an increase in BMR
6. coenzyme derived from the vitamin, *niacin* (B_3)
8. circulating energy substrate that can be stored in large quantity-known as a(an) _____ acid
10. the sum total of catabolism and anabolism
12. measure of energy provided in foods — unit of heat
14. person who suffered from hypothyroidism during the prenatal or early infant growth periods
15. hormone secreted by the intestine to stimulate insulin secretion
18. the process of hydrolysis and other chemical reactions that break down larger molecules
20. a property common to vitamins A, D, E, and K
21. islet of Langerhans cells that secrete *insulin*
23. a festive occasion; celebration
26. when not idle, you are _____
27. an abnormal blood glucose condition that may develop following excessive insulin injection by a diabetic
28. circulating energy substrate, other than carbohydrate or fat
30. hormones from the *adrenal cortex*, such as hydrocortisone
31. endocrine gland with a distinct cortex and medulla that secrete various hormones for regulating metabolism
33. hormone that stimulates the rate of cell respiration in almost all cells of the body
35. a period of time characterized by not eating
36. physical property common to vitamin C and other vitamins involved in cell respiration
37. an essential trace element, needed to assemble hemoglobin molecules
38. common expression when departing
39. disfiguring bone disease of children due to a lack of *1,25-dihydroxyvitamin* D_3
41. hormone most responsible for the uptake of blood glucose into tissue cells
42. a primary target tissue for *growth hormone*
44. abnormally high levels of glucose in the blood
46. part of the brain somewhat involved in regulating eating behavior
52. one component of hydroxyapatite crystals
53. insulin stimulates the uptake of glucose into the _____
54. another component of hydroxyapatite crystals
55. vitamin that, if deficient, causes *pellagra*

Down

1. storage form of carbohydrate in liver and muscle tissue
2. another name for fat cells
4. molecules that the body cannot make and therefore must be eaten as part of the diet
5. what happens to blood calcium levels in the presence of *parathyroid hormone* (PTH)
7. destination for excess calories that are not expended by activity
8. a *coenzyme* derived from the vitamin, riboflavin (B_2)
9. pancreatic hormone that raises blood glucose levels during periods of fasting
11. main "fight-or-flight" hormone released from the *adrenal medulla*
13. food that is not properly cared for or preserved will _____
16. hired enforcer at the door to your favorite dance hall
17. thyroid hormone secreted when blood calcium levels rise above normal
19. the buildup or assembly of larger molecules from smaller molecules
22. gland that secretes a hormone that stimulates bone *resorption* and kidney calcium *reabsorption*
24. glandular condition, _____ ism: with symptoms including *myxedema* and *goiter*
25. essential compounds that serve primarily as *coenzymes* to assist metabolic enzymes
29. disease often described as type 1 or type 2
32. an important *trace element* and enzyme *cofactor*
34. inappropriately high body weight; a risk factor in many disorders such as cardiovascular disease
40. the general name for any atom found in the periodic table
43. portion of the adrenal gland that secretes epinephrine and norepinephrine
45. hormone regulated by both releasing and inhibiting hormones from the *hypothalamus*
47. bone-softening disease caused by increased osteoclast activity
48. one important metabolic organ that hydroxylates vitamin D
49. the assemblage of food and drink consumed while eating
50. Mrs. _____, a former U.S. president's wife with Graves' disease
51. measured by oxygen consumption 12-14 hours after eating and comfortable



C. Essay

Essay Tutorial

This essay tutorial will answer the first essay question found in the "**Review Activities**" section of your *Human Physiology* textbook. Please read *Essay Question* 1 in the "**Test Your Understanding of Concepts and Principles**" section located at the end of chapter 19 and let me guide you through one possible answer. Watch for key terms in boldface type, helpful tips and general suggestions on writing the essay or short-answer questions. Enjoy!

146. Compare the metabolic effects of **fasting** to the state of uncontrolled *type 1 diabetes mellitus*. Explain the hormonal *similarities* of these conditions.

Answer. Fasting results in lowered blood glucose concentrations as glucose is expended as fuel in cell respiration. In response, *glucagon* hormones are released from the alpha cells of the pancreas. Glucagon stimulates the hydrolysis of glycogen reserves (glycogenolysis) mainly in the liver, the breakdown of fat (lipolysis) from adipose tissue, the synthesis of glucose from amino acids (gluconeogenesis) in the liver, and the formation of ketone bodies (ketosis) — all in the effort to provide circulating *energy substrates* for use by the starving cells. Since plasma glucose and amino acid levels are low, insulin secretion is also low.

Type 1 diabetes mellitus (*IDDM*) is uncontrolled when insulin is not being provided (usually by injection) in response to a rise in blood sugar levels. Hormone levels during fasting conditions are similar to those during this type of uncontrolled diabetes in that the blood concentrations of glucagon are high and insulin concentrations are low. Without insulin yet with increased amounts of glucagon, type 1 diabetics have high blood glucose concentrations (hyperglycemia) in addition to an increased release of fatty acids from adipose cells. In the liver, newly released fatty acids are converted to ketone bodies causing blood levels of ketones to rise (ketosis). When the blood buffers such as bicarbonate are limited, *ketoacidosis* results, just as it does in fasting conditions. Therefore, both fasting and type 1 diabetic individuals are similar in that each is unable to utilize glucose molecules as a source of fuel, so that cells must depend on other circulating energy substrates such as fatty acids and ketone bodies (ketoacids) liberated by the actions of primarily glucagon for meeting metabolic demands.

Whew! This was a tough question. Again, don't be disappointed if your answer differs from mine. Your efforts will give you valuable practice in answering essay-formatted questions and help you understand concepts in physiology. Now, let's work on a few more.

147. Define the term **Calorie.** Describe how this unit of heat is used as a measure of the energy *content* of fuel food — such as carbohydrate, fat, and protein — and as a measure of energy *output* during physical activity.

148. Discuss the possible roles played by the *sex hormones*, *growth hormone*, and *somatomedins* (IGF-1 and IGF-2) in the growth and development that occur during puberty.

149. Distinguish between the target cell actions of *parathyroid hormone* (PTH), *1,25-dihydroxyvitamin* D_3, and *calcitonin* in the effort to maintain blood levels of calcium and phosphate constant (homeostasis).

150. Describe how a state of prolonged fasting or exercise can be partially compensated by synthesis of *corticosteroids* (e.g., hydrocortisone). Explain how these effects are similar to those of *glucagon*.

Answers — Chapter 19

I. Nutritional Requirements
   A. 1.e, 2.d, 3.a, 4.c, 5.a, 6.c, 7. c, 8. a
   B. 9. T, 10. T, 11. F—Replace "higher" with "lower," 12. T, 13. T, 14. T, 15. T, 16. F—Switch "fatty" and "amino," 17. F—Replace "cofactors" with "coenzymes," 18. T, 19. F—Replace "A" with "K," 20. F—Replace "E" with "A," 21. T, 22. T

II. Regulation of Energy Metabolism
   A. 23. a, 24. e, 25. e, 26. c, 27. a, 28. a, 29. c, 30. d, 31.e, 32. c, 33. d, 34. c, 35. b, 36. c, 37. c
   B. 38. T, 39. F—Replace "Skeletal muscle" with "The brain," 40. T, 41. T, 42. T, 43. F—Replace "decrease" with "increase," 44. T, 45. F—Switch "pear" with "apple," 46. T, 47. T, 48. F—Switch "increase" with "decrease," 49. T, 50. T, 51. T
   C. Label the Figure — Hormones That Balance Metabolism; See figure 19.5 in the text.

III. Energy Regulation by the Pancreatic Islets
   A. 52. c, 53. b, 54. e, 55. b, 56. d, 57. d, 58. c,
   B. 59. T, 60. T, 61.F—Replace "alpha" with "beta;" "glucagon" with "insulin," 62. T, 63. F—Replace "gluconeogenesis," with "glycogenolysis" 64. T, 65. T, 66. T, 67. T, 68. F—Replace "glucagon" with "insulin," 69. T, 70. F—Switch "liver" and "skeletal muscles," 71. T, 72. T, 73. T, 74. T
   C. Label the Figure — Regulation of Insulin and Glucagon Secretion. See figure 19.7 in the text.

IV. Diabetes Mellitus and Hypoglycemia
   A. 75. a, 76. c, 77. e, 78. c
   B. 79. T, 80. T, 81. F—Replace "1 (IDDM)" with "2 (NIDDM)," 82. F—Replace "obesity" with "exercise," 83. F—Replace "high" with "low," "lowered" with "raised," 84. T, 85. T, 86. T

V. Metabolic Regulation by Adrenal Hormones, Thyroxine, and Growth Hormone
   A. 87. d, 88. e, 89. c, 90. d, 91. b, 92. c
   B. 93. F—Replace "insulin" with "glucagon," 94. T, 95. T, 96. T, 97. T, 98. F—Replace "inhibits" with "stimulates," 99. T, 100. T, 101. F—Replace "awake (daytime)" with "asleep (nighttime)," 102. T, 103. T, 104. T, 105. T

VI. Regulation of Calcium and Phosphate Balance
   A. 106. a, 107. e, 108. c, 109. d, 110. e, 111. e, 112. a, 113. d
   B. 114. F—Switch "osteoclasts" and "osteoblasts," 115. T, 116. T, 117. T, 118. T, 119. T, 120. T, 121. F—Replace "rise" with "fall;" "osteoblast" with "osteoclast," 122. F—Replace "rise" with "fall;" hypercalcemia" with "hypocalcemia," 123. T, 124. T, 125. F—Replace "hypothyroid" with "hyperthyroid," 126. T, 127. T, 128. T

VII. Chapter Review
   A. 129. temperature, eating, physical activity, oxygen 130. kilocalories; fat; coenzymes, cofactors, 131. A, D, E, K, water, 132. glycogen, fat, protein, 133. hypothalamus, hypophagia; endorphins, norepinephrine, serotonin, CCK, 134. Langerhans, pancreas, glucagon, beta, 135. insulin, glucagon, stimulates; increase, lowers, stimulates, 136. increases, catabolism, glycogen, fat, 137. type 1, beta, fall, rise, 138. non-insulin dependent, less, obesity; 2, 139. medulla, glucagon, cortisol, cortex, anabolism, glucose, 140. thyroxine, increases; proteins, central, 141. anterior pituitary, hypothalamus; protein, fall; somatomedins, 142. calcium, phosphate; osteoblasts, osteoclasts, 143. low, resorption, increasing; D_3, 1,25-dihydroxyvitamin D_3, 144. increases, increases, increases, 145. parafollicular, thyroid, high; lowers, resorption, increasing.

B. Crossword Puzzle