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The refractory period also limits the frequency of action potentials.

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Synaptic ribbons are found in sensory neurons that are involved in sustained activity.
Rods provide indistinct gray vision at night, whereas cones provide sharp color vision during the day.

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To secrete thyroid hormone, the follicular cells phagocytize thyroglobulin-laden colloid.

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Most of the secreted T_4 is converted into T_3 outside the thyroid.

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Glucocorticoid secretion is directly regulated by the hypothalamic–pituitary–adrenal axis.

The adrenal cortex secretes both male and female sex hormones in both sexes.

The catecholamine-secreting adrenal medulla is a modified sympathetic postganglionic neuron.

Epinephrine and norepinephrine vary in their affinities for the different adrenergic receptor types.

Epinephrine reinforces the sympathetic nervous system in "fight-or-flight" short-term stress, and exerts additional metabolic effects.

Sympathetic stimulation of the adrenal medulla is solely responsible for epinephrine release.

The stress response is a generalized, nonspecific pattern of neural and hormonal reactions to any situation that threatens homeostasis.

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Because food intake is intermittent, nutrients must be stored for use between meals, primarily as adipose tissue.

Glucose is homeostatically regulated to supply the brain and to prevent damaging processes at high concentrations.

Metabolic fuels are stored during the absorptive state and are mobilized during the postabsorptive state.

Lesser energy sources are tapped as needed.

The pancreatic hormones, insulin and glucagon, are most important in regulating fuel metabolism.

Insulin lowers blood glucose, amino acid, and fatty acid levels and promotes their storage.

The primary stimulus for increased insulin secretion is an increase in blood glucose concentration.

Glucagon in general opposes the actions of insulin.

Glucagon secretion is increased during the postabsorptive state.

Insulin and glucagon work as a team to maintain blood glucose and fatty acid levels.

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Control of calcium metabolism includes regulation of both calcium homeostasis and calcium balance.

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Bone continuously undergoes remodeling.

PTH's immediate effect is to promote the transfer of Ca^{++} from bone fluid into plasma.

PTH's chronic effect is to promote localized dissolution of bone to release Ca^{++} into plasma.

PTH acts on the kidneys to conserve Ca^{++} and to eliminate PO_4^{3-}.

PTH indirectly promotes absorption of Ca^{++} and PO_4^{3-} by the intestine.

The primary signal for regulating PTH secretion is the plasma concentration of free Ca^{++}.

Calcitonin lowers the plasma Ca^{++} concentration, but may not be essential.

Vitamin D actually is a hormone that increases calcium absorption in the intestine.

Phosphate metabolism is controlled by the same mechanisms that regulate Ca^{++} metabolism.

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The number of fibers contracting within vertebrate muscle depends on the extent of motor unit recruitment.

The frequency of stimulation can influence the tension developed by each vertebrate skeletal muscle fiber.

Twitch summation results from a sustained elevation in cytosolic calcium.

Arthropod muscle tension is controlled by gradation of contraction within a motor unit.

There is an optimal muscle length at which maximal tension can be developed on a subsequent contraction.

Muscle tension is transmitted to skeletal elements as the contractile component tightens the series-elastic component.

The two primary types of contraction are isotonic and isometric.

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Single-unit smooth muscle is myogenic.

Gradation of single-unit smooth muscle contraction differs considerably from that of skeletal muscle.

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The medullary cardiovascular control center and several hormones regulate blood pressure.

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Water-filled pores in the capillary wall permit passage of small, water-soluble substances that cannot cross the endothelial cells themselves.

Many capillaries are not open under resting conditions.

Interstitial fluid is a passive intermediary between the blood and cells.

Diffusion across the capillary walls is important in solute exchange.

Bulk flow across the capillary wall is important in extracellular fluid distribution.

The lymphatic system is an accessory route by which interstitial fluid can be returned to the blood.

Vessels: Veins 416

Veins serve as a blood reservoir as well as passageways back to the heart.

Venous return is enhanced by a number of extrinsic factors.

Integrated Cardiovascular Function 418

Regulation of gas transport and mean arterial blood pressure is accomplished by controlling cardiac output, total peripheral resistance, and blood volume.

Gas transport and blood pressure are monitored by arterial sensors.

The baroreceptor reflex is the most important mechanism for short-term regulation of blood pressure.

Regulation of gas transport and blood pressure are coordinated during locomotory activity.

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CHAPTER 10

Defense Systems 427

Evolution of Defense Systems 427

Pathogenic bacteria, viruses, and internal parasites are the major targets of the immune defense system.

In most vertebrates, immune responses can be either innate or acquired.

Immune responses in any organism depend on ability to distinguish "self" from "non-self."

Some animals behaviorally acquire defense components from other organisms.

The Vertebrate Immune System 429

Active immune responses are regulated by feedback systems with sensors, integrators, and effectors.

Innate Immunity 431

Barrier tissues are the first line of defense, using passive and active mechanisms.

Inflammation, a second line of defense, is a nonspecific response to foreign invasion or tissue damage.

Salicylates and glucocorticoids suppress the inflammatory response.

The complement system kills microorganisms directly, both on its own and in conjunction with antibodies and also augments the inflammatory response.

Interferon transiently inhibits multiplication of viruses in most cells.

Natural killer cells destroy virus-infected cells and cancer cells on first exposure to them.

Acquired (Adaptive) Immunity 441

Acquired immunity includes cell-mediated and antibody-mediated responses.

An antigen induces an immune response against itself.

B Lymphocytes: Antibody-Mediated Immunity 442

Antibodies are Y-shaped and classified according to properties of their tail portion.

Antibodies largely amplify innate immune responses to promote antigen destruction.

Clonal selection accounts for the specificity of antibody production.

Selected clones differentiate into active plasma cells and dormant memory cells.

The huge repertoire of B-cells is built by reshuffling a small set of gene fragments.

Active immunity is self-generated; passive immunity is "borrowed."

Lymphocytes respond only to antigens presented to them by antigen-presenting cells.

T Lymphocytes: Cell-Mediated Immunity 449

The two types of T-cells are cytotoxic and helper T-cells.

Helper T-cells secrete chemicals that regulate other immune cells.

Cytotoxic T-cells secrete chemicals that destroy target cells.

The immune system is normally tolerant of self-antigens.

The major histocompatibility complex is the code for self-antigens.

Immune surveillance against cancer cells involves an interplay among immune cells and interferon.

A regulatory loop links the immune system with the nervous and endocrine systems.

Acquired Immunity in Other Vertebrates 456

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An Accidental Origin for Adaptive Immunity? 457

Innate (and Acquired?) Immunity in Other Animals 458

Phagocytotic cells and an inflammation-like response are the major form of cell-mediated innate immunity in most animals.

Antimicrobial peptides are common noncellular defenses in barrier tissues and immune cells of animals.

Lectins and Ig-fold proteins act as opsonins in many invertebrates.

The proPO system encapsulates large foreign materials in arthropods.

Invertebrate immune cells communicate with cytokines such as IL-1.

Some forms of acquired immunity may occur in some arthropods.

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CHAPTER 11

Respiratory Systems 462

Evolutionary Solutions to Gas Demands 462

General Principles 462

External respiratory processes must meet the demands of size, metabolism, and habitat through diffusion and bulk transport.

Evolutionary Forces 463

Breathing as a form of bulk flow can be tidal or flow-through.

External respiration can involve up to four major steps.

Water Respirers 466

Water is a more difficult medium than air for gas exchange

The limitations of diffusion in water are overcome with thin, high-surface-area structures and bulk transport.

Breathing muscles provide consistent and often fast bulk transport.
Aquatic respiratory systems can perform numerous nonrespiratory functions.

Air Respirers 470
Land slugs and snails use skin, mantle tissue, or lungs.
In insects, internal air-filled tubes—tracheae—supply oxygen directly to the tissues.
Arachnids use book lungs or tracheae.
Vertebrate air breathers use respiratory airways to conduct air between the atmosphere and the gas exchange surfaces in the lung.
The first air-breathing vertebrates were bimodal.
Reptiles, birds, and mammals use lungs ranging from simple sacs to elaborate folds, inflated by negative pressure.
Mammalian airways terminate in alveoli.
Avian airways terminate in air capillaries.
Aerial respiratory systems can perform numerous nonrespiratory functions

Respiratory Mechanics 479

Principles of Airflow 480
Interrelationships among atmospheric, intra-alveolar, and intrapleural pressures are important in respiratory mechanics of mammals.
The lungs are normally stretched to fill the larger thorax.
Flow of air into and out of mammalian lungs occurs because of cyclical intra-alveolar pressure changes brought about indirectly by respiratory muscle activity.
Respiratory diseases often increase airway resistance.
Elasticity in mammalian lungs depends on connective tissue and alveolar surface tension, which is reduced by surfactant.

Mechanics: Lung Volumes and Respiratory Cycles 486
The respiratory cycle of mammals is similar between species.
Alveolar ventilation is less than pulmonary ventilation because of the presence of dead space.
Water breathers have relatively lower dead-space volumes.
Local controls act on the smooth muscle of the airways and arterioles to maximally match blood flow to airflow.
Bird respiration exhibits an efficient flow-through mechanism.

Mechanics: Water versus Air Respirers 493
The work of normal breathing requires as little as 2% of total energy expenditure in some mammals to as much as 50% in some fishes.

Gas Exchange 493
Gases move down partial pressure gradients.
In air breathers, oxygen enters and CO_2 leaves the blood in the lungs passively.
Flow-through breathing plus countercurrent blood flow enhances pressure gradients in fishes.
Flow-through breathing plus crosscurrent blood flow enhances pressure gradients in birds.
Skin breathing occurs in most vertebrates, but its contribution is variable.
Factors other than the partial pressure gradient influence the rate of gas transfer.
Gas exchange across the systemic capillaries also occurs down partial pressure gradients.

Gas Transport 498
Most O_2 in many animal circulatory systems is transported bound to respiratory pigments.
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Life in the Cold: The Hemoglobinless Icefish 499
Myoglobin stores oxygen in aerobic muscle and may facilitate diffusion from the blood to the mitochondria.
The P_{O_2} is the primary factor determining the percent hemoglobin saturation.
By acting as a storage depot, hemoglobin promotes the net transfer of O_2 from the alveoli to the blood.
Increased CO_2, acidity, temperature, and organic phosphates shift the O_2–Hb dissociation curve to the right, favoring unloading.
Evolutionary adaptation results in different hemoglobin P_{50} values.
Filling of the gas bladder is aided by the Root effect.
Most CO_2 in both vertebrates and invertebrates is transported in the blood as bicarbonate.
Various respiratory states are characterized by abnormal blood-gas levels.
Other unusual respiratory states are not necessarily pathological.

Control of Respiration 510
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Effects of Depths 510
Respiratory centers in the vertebrate brain stem establish a rhythmic breathing pattern.
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Effects of Heights 512
The magnitude of ventilation is adjusted in response to three chemical factors: P_{O_2}, P_{CO_2}, and H^+.
Adjustments in ventilation in response to changes in arterial H^+ are important in acid–base balance.
Activity profoundly increases ventilation, but the mechanisms involved are unclear.

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Excretory Systems 521

Introduction 521
Selective excretion is crucial to internal fluid homeostasis and involves several systems.
Nitrogen metabolism creates special stresses and produces three major end products: ammonia, urea, and uric acid.
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Osmolytes and Gene Regulation 525
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Renal Excretory Organs 526
Renal tubules produce urine using the processes of filtration, secretion, reabsorption, and osmoconcentration.

The Mammalian Urinary System 528
The kidneys form the urine; the remainder of the urinary system is the bladder and ductwork that carries the urine.

The nephron is the functional unit of the kidney.
The basic renal processes are glomerular filtration, tubular reabsorption, tubular secretion, and osmoconcentration.

Glomerular Filtration 534
The glomerular membrane is more than 100 times more permeable than capillaries elsewhere.
The glomerular capillary blood pressure is the major force responsible for inducing glomerular ultrafiltration.
The most common factor resulting in a change in the GFR is an alteration in the glomerular capillary blood pressure.
The GFR can be influenced by changes in the filtration coefficient.

Tubular Reabsorption 540
Tubular reabsorption is tremendous, highly selective, and variable.
Tubular reabsorption involves transepithelial transport.
An energy-dependent Na^+–K^+ ATPase transport mechanism in the basolateral membrane is essential for Na^+ reabsorption.
Glucose and amino acids are reabsorbed by Na^+-dependent secondary active transport.
With the exception of Na^+, actively reabsorbed substances exhibit a tubular maximum.
Active Na^+ reabsorption is responsible for the passive reabsorption of Cl^-, H_2O, and urea.
In general, unwanted waste products except urea are not reabsorbed.
The renin-angiotensin-aldosterone system stimulates Na^+ reabsorption in the distal tubules, elevates blood pressure, and stimulates thirst and salt hunger.
Atrial natriuretic peptide antagonizes the renin-angiotensin-aldosterone system, inhibiting Na^+ reabsorption and reducing blood pressure.

Tubular Secretion 547
Hydrogen ion secretion is important in acid–base balance.
Potassium secretion is controlled by aldosterone.
Organic anion and cation secretion helps efficiently eliminate foreign compounds from the body.
Plasma clearance is the volume of plasma cleared of a particular substance per minute.

Osmoconcentration 551
The ability to excrete urine of varying concentrations depends on the medullary countercurrent-multiplier system and vasopressin.
Urea recycling in the renal medulla contributes to medullary hypertonicity and helps concentrate urea in the urine.
The medullary vertical osmotic gradient permits excretion of urine of differing concentrations by means of vasopressin-controlled, variable, H_2O reabsorption from the collecting duct.
Countercurrent exchange within the vasa recta enables the medulla to be supplied with blood while conserving the medullary vertical osmotic gradient.
Different osmoconcentrating abilities among species depend on nephron anatomy and metabolic rates.

Bladder Storage and Micturition 562
Urine is temporarily stored in the bladder, from which the process of micturition empties it.

Renal Diseases 563
Renal diseases are numerous and have wide-ranging consequences.

Other Vertebrate Urinary Systems and Extrarenal Organs 563
Freshwater bony fishes excrete water with their kidneys, and their gills excrete wastes and take up salts.
Marine bony fishes use gills for most excretion and retention processes.
Cartilaginous fishes retain urea and trimethylamine oxide, and use gills, kidneys, and rectal glands for excretion and retention.
Amphibians use kidneys and bladders for excretion and retention.
Reptiles use amphibian-like kidneys, hindguts, and (in marine and desert species) salt glands for excretion and retention.
Birds use mammalian-like kidneys, hindguts, and (in marine species) salt glands for excretion and retention.

Insect Malpighian Tubules 567
Malpighian tubules initiate filtration by ion secretion, which causes osmosis.
The tubules and hindgut modify the lumen fluid by specific secretion and reabsorption.

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Fluid and Acid–Base Balance 572

Introduction 572
If balance is to be maintained, input must equal output.
Body water is distributed between the intracellular and extracellular fluid compartments.
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The Sweet Solution to Desiccation 574
In vertebrates, the plasma and interstitial fluid are similar in composition; but the ECF and ICF are markedly different in all animals.

Osmotic and Volume Balance 576
Several osmotic problems threaten cells and animals.
Animals have evolved two strategies to cope with osmotic challenges.

Osmoconformers 578
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Osmoregulators 585
Osmoregulators rely on special transport mechanisms to maintain internal osmotic constancy.

Osmotic and Volume Balance in Mammals 588
Osmotic balance is maintained by regulating ECF volume and ECF osmolarity.
Control of ECF osmolarity prevents changes in ICF volume.
Control of water balance by means of vasopressin and thirst is of primary importance in regulating ECF osmolarity.

Control of ECF volume is important in the long-term regulation of blood pressure.

During hemorrhagic shock, circulatory functions and fluid balance are coordinately regulated.

Acid–Base Balance 595

Acids liberate free hydrogen ions, whereas bases accept them.

The pH designation is used to express hydrogen ion concentration.

Fluctuations in hydrogen ion concentration have profound effects on body chemistry.

Hydrogen ions are continually being added to body fluids as a result of metabolic activities.

pH Regulation: Buffers 599

Chemical buffer systems act as the first line of defense against changes in hydrogen ion concentration.

pH Regulation: Respiration 601

Respiratory systems regulates hydrogen ion concentration through adjustments in ventilation and (in gills) membrane transport.

pH Regulation: Excretion 602

Excretory systems contribute powerfully to control of acid–base balance by controlling both hydrogen ion and bicarbonate concentrations in the ECF.

Acid–base imbalances can arise from either respiratory dysfunction or metabolic disturbances.

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CHAPTER 14

Digestive Systems 612

Introduction: Feeding Strategies and Evolution 612

Animal digestion evolved from an intracellular to an extracellular process in a specialized sac or tube connected to the environment.

Animals can be classified according to their primary feeding methods.

Digestive systems perform four basic digestive processes.

The digestive tract and accessory digestive organs make up digestive systems.

Regulation of digestive function is complex and synergistic.

Receptor activation alters digestive activity through neural reflexes and hormonal pathways.

Mouth 620

Saliva aids in mastication but plays a more important role in lubricating food boluses before swallowing.

The continuous low level of salivary secretion can be increased by simple and conditioned reflexes.

Digestion in the mouth is minimal, and no absorption of nutrients occurs.

Pharynx, Esophagus, and Crop 623

Swallowing in vertebrates is a sequentially programmed all-or-none reflex.

During the oropharyngeal stage of swallowing, food is directed into the esophagus and prevented from entering the wrong passageways.

Esophagus 624

The esophagus is a muscular tube guarded by sphincters at both ends.

The pharyngoesophageal sphincter keeps air from entering the gut.

Peristaltic waves push the food through the esophagus.

CHALLENGES AND CONTROVERSIES

Global Warming and the Rumen 625

The gastroesophageal sphincter prevents reflux of gastric contents.

Esophageal secretion is entirely protective.

Crop 626

The crop is a modified section of the esophagus and functions mainly as a storage organ.

Stomach or Midgut 626

The midgut stores food and begins nonsalivary digestion.

The stomach stores food and begins protein digestion.

Gastric filling involves receptive relaxation.

Gastric storage takes place in the body of the stomach.

Gastric mixing takes place in the antrum of the stomach.

Gastric emptying is largely controlled by factors in the duodenum.

Peristaltic contractions occur in the empty stomach before the next meal.

Stress can influence gastric motility.

The body of the stomach does not actively participate in the act of vomiting.

Gastric digestive juice is secreted by glands located at the base of gastric pits.

Pepsinogen, once activated, begins protein digestion.

Intrinsic factor is essential for absorption of vitamin B_{12}.

Multiple regulatory pathways influence the parietal and chief cells.

Control of gastric secretion involves three phases.

Gastric secretion gradually decreases as food empties from the stomach into the intestine.

The stomach lining is protected from gastric secretions by the gastric mucosal barrier.

Carbohydrate digestion continues in the body of the stomach, whereas protein digestion begins in the antrum.

Proventriculus-gizzard processes begin the process of digestion in birds and insects.

Pancreas, Liver, and Fat Body 638

The pancreas is a mixture of exocrine and endocrine tissue.

The exocrine pancreas secretes digestive enzymes and an aqueous alkaline fluid.

Pancreatic exocrine secretion is hormonally regulated to maintain neutrality of the duodenal contents and to optimize digestion.

Liver and Gallbladder 640

The vertebrate liver performs various important functions, including bile production.

The liver lobules are delineated by vascular and bile channels.

Bile is continuously secreted by the vertebrate liver and is diverted to the gallbladder between meals.

Bile salts are recycled through the enterohepatic circulation.

Bile salts aid fat digestion and absorption through their detergent action and micellar formation, respectively.
Bilirubin is a waste product excreted in the bile.

Small Intestine 645

The digestive tract wall has four layers.
Segmentation contractions mix and slowly propel the chyme.
The migrating motility complex sweeps the intestine clean between meals.
The ileocecal juncture prevents contamination of the small intestine by colonic bacteria.
Small-intestine secretions in vertebrates do not contain any digestive enzymes.
Small-intestine enzymes complete the process of digestion at the brush border membrane.
The small intestine is highly adaptable for its primary role in absorption.
The mucosal lining experiences rapid turnover.
Energy-dependent Na^+ absorption drives passive H_2O absorption.
Carbohydrate and protein are both absorbed by secondary active transport and enter the blood.
Most absorbed nutrients immediately pass through the liver for processing.
Extensive absorption by the small intestine keeps pace with secretion.
Biochemical balance among the stomach, pancreas, and small intestine is normally maintained.
Diarrhea results in loss of fluid and electrolytes.

Large Intestine 657

The large intestine functions in electrolyte and fluid balance, harbors microbes for fermentation and VFA production, and serves as a temporary storage site for excreta.
Diet composition governs the variation in structure of the large intestine.
Haustral contractions prolong the retention of digesta.
Postgastric fermentation is not as efficient as pregastric fermentation in obtaining nutrients.
Mass movements propel colonic contents long distances.
Feces are eliminated by the defecation reflex.
Large-intestine secretion is protective in nature.
The large intestine absorbs primarily salt and water, converting the luminal contents into feces.
MOLECULAR BIOLOGY AND GENOMICS
Big Bugs Have Little Bugs . . . 660
The large intestine of birds and hindgut of insects actively transports glucose and amino acids.

Ruminant Digestion 661

The rumen is divided into separate compartments.
The abomasum is similar in function to the stomachs of nonruminants.
Neonatal ruminants rely only on the abomasum.
Motility of the ruminant stomach is predominantly regulated by central nervous system reflex mechanisms.
Rumination is the regurgitation, remastication, and reswallowing of ingesta.
The environment of the rumen fosters the growth of anaerobic microbes.
Nutrients for the host ruminant are generated by anaerobic microbes.
Rumen microbes synthesize vitamins for their host and detoxify some ingested toxins.
Some ruminants are selective in what they eat, whereas others simply graze the available forage.

Overview of the Gastrointestinal Hormones 666

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Energy Balance and Thermal Physiology 670

Introduction 670

Life follows the laws of thermodynamics.

Energy Balance 671

Animals require food intake to compensate for entropy.
Metabolic rate is scaled to body mass.
Aerobic locomotory energy reflects the limits of oxygen delivery and is also scaled to body mass.
CHALLENGES AND CONTROVERSIES:
A Universal Scale of Life? 675
Diet-induced thermogenesis occurs after eating in most animals.
Energy input must equal energy output to maintain a neutral energy balance.
Many mammals maintain long-term neutral energy balance.
Some animals undergo periods of positive or negative energy balance.
Food intake in mammals is controlled primarily by the hypothalamus in response to numerous inputs.
MOLECULAR BIOLOGY AND GENOMICS
Discovering the Obesity Gene 681

Thermal Physiology: General Principles 682

Temperature is one of the most important habitat factors.
Biomolecules can be altered to work optimally at different temperatures.
The thermal adaptation strategies of animals depend on their primary source of heat.
Heat exchange between the body and the environment takes place by radiation, conduction, convection, and evaporation.
Heat gain versus heat loss determines core body temperature.

Ectotherms 688

Body temperatures of ectotherms may follow the environment, or may be regulated by external exchanges.
Some ectotherms can metabolically compensate for changes in body temperatures.
Ectotherms survive extreme cold by metabolic dormancy and by either freeze avoidance or freeze tolerance.
Ectotherms may survive extreme heat with the heat shock response.

Endotherms 692

Birds and mammals homeostatically maintain internal core temperature, whereas other endotherms heat selected body regions.

To maintain a stable core temperature, heat gain must balance heat loss.
The hypothalamus integrates a multitude of thermosensory inputs from both the core and the surface of the body.
To regulate core temperature homeostatically, the hypothalamus simultaneously coordinates heat—production, heat—loss, and heat conservation mechanisms.
During a fever, the hypothalamic thermostat is "reset" to an elevated temperature.

Heterotherms 701
Heterotherms are endotherms that are not fully homeothermic.

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SECTION V: REPRODUCTION

CHAPTER 16

Reproductive Systems 707

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Reproductive Processes 707
Animals employ a variety of reproductive strategies to ensure survival of the species.

Reproductive Systems and Genetics 710
The reproductive system of vertebrates includes the hypothalamus, gonads, and reproductive tract.
Reproduction systems in insects includes neuroendocrine organs, gonads, and reproductive tract.
Gametogenesis is accomplished by meiosis.
The sex of an individual is determined by the combination of sex chromosomes by environmental stimuli.
Sex differentiation in mammals depends on the presence or absence of masculinizing determinants during critical periods of embryonic development.

Vertebrate Male Reproductive Physiology 718
Spermatogenesis in most mammals is temperature sensitive and cannot occur at normal body temperatures.
The testicular Leydig cells secrete masculinizing testosterone during the breeding season.
Spermatogenesis yields an abundance of highly specialized, mobile sperm.
Throughout their development, vertebrate sperm remain intimately associated with Sertoli cells.
LH and FSH from the anterior pituitary control testosterone secretion and spermatogenesis.
Gonadotropin-releasing hormone activity increases at puberty.
The ducts of the reproductive tract stores and concentrates sperm and increases their fertility.
The accessory sex glands contribute the bulk of the semen.
Prostaglandins are ubiquitous, locally acting chemical messengers.
The male sex act is characterized by erection and ejaculation.
Erection is accomplished by penis vasocongestion.
Ejaculation includes emission and expulsion.

Vertebrate Female Reproductive Physiology 729
Complex cycling characterizes female reproductive physiology in many vertebrates.
The steps of gametogenesis are the same in both sexes, but the timing and outcome differ sharply.
CONCEPTS AND CONTROVERSIES
Environmental Estrogens: Bad News for Reproduction 731
The ovarian cycle of mammals consists of alternating follicular and luteal phases.
The follicular phase is characterized by the development of maturing follicles.
The luteal phase is characterized by the presence of a corpus luteum.
The mammalian estrous cycle is regulated by complex hormonal interactions among the hypothalamus, anterior pituitary, and ovarian endocrine units.
The uterine changes that occur during the estrous cycle reflect hormonal changes during the ovarian cycle.
Fluctuating concentrations of estrogens and progesterone produce cyclic changes in cervical mucus.
The reproductive cycles of nonviviparous vertebrates are fundamentally similar but have some unique differences.
Sexual maturity events in mammalian females are similar to those in males.
The oviduct is the site of fertilization.
The mammalian blastocyst implants in the endometrium through the action of its trophoblastic enzymes.
The placenta is the organ of exchange between maternal and fetal blood.
Hormones secreted by the corpus luteum and placenta play a critical role in the maintenance of pregnancy.
Maternal body systems respond to the increased demands of gestation.
Changes during late gestation prepare for parturition.
The factors that trigger the onset of parturition are only partially characterized.
Parturition is accomplished by a positive-feedback cycle.
Lactation requires multiple hormonal inputs.
Mammary gland feeding is advantageous to both the infant and the female.
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The end is a new beginning.

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