Contents

Uses of Different-Energy Sowides at soubago

	The Symapse 178 PST 200thonetri			
	Review Activities 126 energeny2 lasiment2		Cranial Nerves 234 Sections	
Preface	Vicetylcholine as a Neurotransmitter /182	2.3	Proteins 40	
			Structure of Proteins 40	
1	The Study of Body		Functions of Proteins 43	
		2.4	Nucleic Acids 44	
	Function 1		Deoxyribonucleic Acid 44	
	Introduction to Physiology 2		Ribonucleic Acid 45	
	Scientific Method 2	Summ	ary 46	
1.2	Homeostasis and Feedback Control 4	Reviev	v Activities 47	
. 2				
	History of Physiology 4 Negative Feedback Loops 5	2	Cell Structure and	
	Positive Feedback 8			
	Neural and Endocrine Regulation 8		Genetic Control 49	
	Feedback Control of Hormone Secretion 8	3.1	Plasma Membrane and Associated Structures	5
1.3	The Primary Tissues 10		Structure of the Plasma Membrane 51	
	Muscle Tissue 10		Phagocytosis 53	
	Nerve Tissue 11		Endocytosis 53	
	Epithelial Tissue 12		Exocytosis 54	
	Connective Tissue 15		Cilia and Flagella 54	
1.4	Organs and Systems 17		Microvilli 55	
Revieti	An Example of an Organ: The Skin 18	3.2	Cytoplasm and its Organelles 55	
	Systems 19		Cytoplasm and Cytoskeleton 56	
	Body-Fluid Compartments 20		Lysosomes 57	
Summa			Peroxisomes 57	
	Activities 22		Mitochondria 58	
CVICVV	Second Messengers 152		Ribosomes 59	
			Endoplasmic Reticulum 59	
	Chemical Composition		Golgi Complex 60	
	of the Body 24	3.3	Cell Nucleus and Gene Expression 61	
			Genome and Proteome 62	
2.1	Atoms, Ions, and Chemical Bonds 25		Chromatin 63	
	Atoms 25		RNA Synthesis 63	
	Chemical Bonds, Molecules, and Ionic		RNA Interference 66	
	Compounds 26	3.4	Protein Synthesis and Secretion 67	
	Acids, Bases, and the pH Scale 28		Transfer RNA 67	
	Organic Molecules 30		Formation of a Polypeptide 68	
2.2	Carbohydrates and Lipids 32		Functions of the Endoplasmic Reticulum and Golgi	
	Carbohydrates 33		Complex 69	
	Lipids 36		Protein Degradation 69	

3.5

	DNA Replication 71	
	The Cell Cycle 72	
	Mitosis 75	
	Meiosis 77	
	Epigenetic Inheritance 78	
Interac	tions 82	
	ary 83	
	Activities 84	
Keview	ACTIVITIES 04	
4	Enzymes and Energy 86	
4.1	Enzymes as Catalysts 87	
	Mechanism of Enzyme Action 87	
	Naming of Enzymes 89	
4.2	Control of Enzyme Activity 90	
	Effects of Temperature and pH 90	
	Cofactors and Coenzymes 91	
	Enzyme Activation 91	
	Substrate Concentration and Reversible Reactions	92
	Metabolic Pathways 92	
4.3	Bioenergetics 95	
	Endergonic and Exergonic Reactions 96	
	Coupled Reactions: ATP 96	
	Coupled Reactions: Oxidation-Reduction 98	
Summe		
Summo		
Review	v Activities 102	
5	Cell Respiration and	
	Metabolism 104	
5.1	Glycolysis and the Lactic Acid Pathway 105	
	Glycolysis 105	
	Lactic Acid Pathway 107	
5.2	Aerobic Respiration 109	
	Citric Acid Cycle 109	
		10
	Coupling of Electron Transport to ATP Production 110	
	ATP Balance Sheet 113	
E 2		
5.3	Interconversion of Glucose, Lactic Acid, and Glycogen 115	
	Glycogenesis and Glycogenolysis 115	
	Cori Cycle 115	

Dna Synthesis and Cell Division 71

5.4 Metabolism of Lipids and Proteins 117 Lipid Metabolism 117 Amino Acid Metabolism 120 Uses of Different Energy Sources 121

Interactions 124
Summary 125
Review Activities 126

6 Interactions Between Cells and the Extracellular Environment 128

6.1 Extracellular Environment 129

Body Fluids 129

Extracellular Matrix 129

Categories of Transport Across the Plasma
Membrane 130

Diffusion and Osmosis 131

Diffusion Through the Plasma Membrane 133

Rate of Diffusion 134

Osmosis 134

Regulation of Blood Osmolality 139

6.3 Carrier-Mediated Transport 140
Facilitated Diffusion 141
Active Transport 142
Bulk Transport 146

6.4 The Membrane Potential 147
Equilibrium Potentials 148
Resting Membrane Potential 150

6.5 Cell Signaling 151
Second Messengers 152
G-Proteins 153

Interactions 155
Summary 156
Review Activities 158

The Nervous System 160

Neurons and Supporting Cells 161

Neurons 161

Classification of Neurons and Nerves 162

Neuroglia 164

Neurilemma and Myelin Sheath 165

Functions of Astrocytes 168

	0 0		0 0	
		0 0	. 0 0	0
			0 0	0

Summ

7.2	Electrical Activity in Axons 170
	Ion Gating in Axons 171
	Action Potentials 172
	Conduction of Nerve Impulses 175
7.3	The Synapse 178
	Electrical Synapses: Gap Junctions 179
	Chemical Synapses 179
7.4	Acetylcholine as a Neurotransmitter 182
	Chemically Regulated Channels 183
	Acetylcholinesterase (AChE) 186
	Acetylcholine in the PNS 187
	Acetylcholine in the CNS 188
7.5	Monoamines as Neurotransmitters 188
	Serotonin as a Neurotransmitter 190
	Dopamine as a Neurotransmitter 191
	Norepinephrine as a Neurotransmitter 191
7.6	Other Neurotransmitters 192
	Amino Acids as Neurotransmitters 192
13.2	Polypeptides as Neurotransmitters 194
	Endocannabinoids as Neurotransmitters 195
	Gases as Neurotransmitters 196
	ATP and Adenosine as Neurotransmitters 196
7.7	Synaptic Integration 197
	Synaptic Plasticity 197
	Synaptic Inhibition 198
Summa	iry 199
Review	Activities 201

8 The Central Nervous System 204

8.1 Structural Organization of the Brain 205

Cerebrum 207

Cerebral Cortex 207

Basal Nuclei 213

Cerebral Lateralization 214

Language 216

Limbic System and Emotion 217

Memory 218

Emotion and Memory 223

8.3 Diencephalon 224

Thalamus and Epithalamus 224

Hypothalamus and Pituitary Gland 224

8.4 Midbrain and Hindbrain 227
Midbrain 227

Reticular Activating System in Sleep and Arousal 230

8.5 Spinal Cord Tracts 231
 Ascending Tracts 231
 Descending Tracts 232

8.6 Cranial and Spinal Nerves 234
 Cranial Nerves 234
 Spinal Nerves 235

Summary 238
Review Activities 239

9 The Autonomic Nervous System 242

9.1 Neural Control of Involuntary Effectors 243

Autonomic Neurons 243

Visceral Effector Organs 244

9.2 Divisions of the Autonomic Nervous System 245
Sympathetic Division 245
Parasympathetic Division 246

Adrenergic and Cholinergic Synaptic
Transmission 250
Responses to Adrenergic Stimulation 251
Responses to Cholinergic Stimulation 255
Other Autonomic Neurotransmitters 256
Organs With Dual Innervation 257
Organs Without Dual Innervation 258
Control of the Autonomic Nervous System by Higher Brain Centers 259

Interactions 261
Summary 262
Review Activities 263

10) Sensory Physiology 265

10.1 Characteristics of Sensory Receptors 266
Categories of Sensory Receptors 266
Law of Specific Nerve Energies 267
Generator (Receptor) Potential 267

10.2 Cutaneous Sensations 268
Neural Pathways for Somatesthetic Sensations 270
Receptive Fields and Sensory Acuity 271
Lateral Inhibition 272

Pituitary Hormones 330

10.3	Taste and Smell 273		Hypothalamic Control of the Posterior Pituitary 332
	Taste 273		Hypothalamic Control of the Anterior Pituitary 332
	Smell 275		Feedback Control of the Anterior Pituitary 334
10.4	Vestibular Apparatus and Equilibrium 277		Higher Brain Function and Pituitary Secretion 335
	Sensory Hair Cells of the Vestibular Apparatus 278	11.4	Adrenal Glands 336
	Utricle and Saccule 279		Functions of the Adrenal Cortex 337
	Semicircular Canals 279 as as as a langer		Functions of the Adrenal Medulla 338
10.5	The Ears and Hearing 281		Stress and the Adrenal Gland 339
	Outer Ear 282	11.5	Thyroid and Parathyroid Glands 340
	Middle Ear 282		Production and Action of Thyroid Hormones 341
	Cochlea 283		Parathyroid Glands 343
	Spiral Organ (Organ of Corti) 285	11.6	Pancreas and Other Endocrine Glands 344
10.6	The Eyes and Vision 289		Pancreatic Islets 344
	Refraction 293		Pineal Gland 346
	Accommodation 294		Gastrointestinal Tract 348
	Visual Acuity 295		Gonads and Placenta 348
10.7	Retina 296	11.7	Paracrine and Autocrine Regulation 348
	Effect of Light on the Rods 298		Examples of Paracrine and Autocrine
	Electrical Activity of Retinal Cells 299		Regulation 349
	Cones and Color Vision 300		Prostaglandins 350
	Visual Acuity and Sensitivity 302	Interac	ctions 353
	Neural Pathways from the Retina 303	Summo	
10.8	Neural Processing of Visual Information 306	Review	Activities 355
	Ganglion Cell Receptive Fields 306		Synaptic Plasticity 197 bestellbush-referr
	Lateral Geniculate Nuclei 307	10	Muscle 358
	Cerebral Cortex 307		IVIUSCIC 358
Intera	ctions 309 and moitevent leud di Wanegro	12.1	Skeletal Muscles 359
Summ	ary 310 ses notement laud tuodiff anagro		Structure of Skeletal Muscles 359
Revie	w Activities 313		Motor End Plates and Motor Units 360
		12.2	Mechanisms of Contraction 363
AA			Sliding Filament Theory of Contraction 366
11	Endocrine Glands 315		Regulation of Contraction 368
11.1	Endocrine Glands and Hormones 316	12.3	Contractions of Skeletal Muscles 373
	Common Aspects of Neural and Endocrine		Twitch, Summation, and Tetanus 373
	Regulation 316		Types of Muscle Contractions 374
	Chemical Classification of Hormones 318	Bertel	Series-Elastic Component 375
	Prohormones and Prehormones 319		Length-Tension Relationship 375
	Hormone Interactions 320	12.4	Energy Requirements of Skeletal Muscles 376
	Effects of Hormone Concentrations on Tissue		Metabolism of Skeletal Muscles 377
	Response 320		Slow- and Fast-Twitch Fibers 379
11.2	Mechanisms of Hormone Action 322		Muscle Fatigue 381
	Hormones That Bind to Nuclear Receptor		Adaptations of Muscles to Exercise Training 381
	Proteins 322		Muscle Damage and Repair 383
	Hormones That Use Second Messengers 325	12.5	Neural Control of Skeletal Muscles 383
11.3	Pituitary Gland 330		Muscle Spindle 384

Muscle Spindle 384

Local Inflammation 499

ummo	Alpha and Gamma Motor Neurons 386 Coactivation of Alpha and Gamma Motor Neurons 386 Skeletal Muscle Reflexes 386 Upper Motor Neuron Control of Skeletal Muscles 389 Cardiac and Smooth Muscles 390 Cardiac Muscle 391 Smooth Muscle 392 tions 397 ary 398 Activities 400	14.1	Cardiac Output, Blood Flow, and Blood Pressure 449 Cardiac Output 450 Regulation of Cardiac Rate 450 Regulation of Stroke Volume 451 Venous Return 454 Blood Volume 455 Exchange of Fluid Between Capillaries and Tissues 456 Regulation of Blood Volume by the Kidneys 458	
13	Blood, Heart, and Circulation 403 Functions and Components of the	14.3	Vascular Resistance to Blood Flow 462 Physical Laws Describing Blood Flow 463 Extrinsic Regulation of Blood Flow 464 Paracrine Regulation of Blood Flow 465 Intrinsic Regulation of Blood Flow 466	
3.2	Circulatory System 404 Functions of the Circulatory System 404 Major Components of the Circulatory System 404 Composition of the Blood 405 Blood Plasma 405	14.4	Blood Flow to the Heart and Skeletal Muscles 467 Aerobic Requirements of the Heart 467 Regulation of Coronary Blood Flow 468 Regulation of Blood Flow Through Skeletal Muscles 469 Circulatory Changes During Exercise 469	
	The Formed Elements of Blood 406 Hematopoiesis 408 Red Blood Cell Antigens and Blood Typing 411	14.5	Blood Flow to the Brain and Skin 472 Cerebral Circulation 472 Cutaneous Blood Flow 473	
3.3	Blood Clotting 413 Dissolution of Clots 416 Structure of the Heart 417 Pulmonary and Systemic Circulations 417 Atrioventricular and Semilunar Valves 418	14.6	Blood Pressure 474 Baroreceptor Reflex 476 Atrial Stretch Reflexes 478 Measurement of Blood Pressure 478 Pulse Pressure and Mean Arterial Pressure 480	
3.4	Heart Sounds 419 Cardiac Cycle 421 Pressure Changes During the Cardiac Cycle 422	14.7	Hypertension, Shock, and Congestive Heart Failure 481 Hypertension 481	
3.5	Electrical Activity of the Heart and the Electrocardiogram 424 Electrical Activity of the Heart 424 The Electrocardiogram 427		Circulatory Shock 483 Congestive Heart Failure 485 tions 487	
3.6	Blood Vessels 430 Arteries 430	Summo	Activities 489	
3.7	Capillaries 432 Veins 434 Atherosclerosis and Cardiac Arrhythmias 435 Atherosclerosis 435	15.1	The Immune System 492 Defense Mechanisms 493 Innate (Nonspecific) Immunity 493	
3.8	Arrhythmias Detected by the Electrocardiograph 439 Lymphatic System 441		Adaptive (Specific) Immunity 496 Lymphocytes and Lymphoid Organs 498	

Summary 444

Review Activities 446

15.2	Functions of B Lymphocytes 502
	Antibodies 503
	The Complement System 505
15.3	Functions of T Lymphocytes 506
	Cytotoxic, Helper, and Regulatory T Lymphocytes 506
	Interactions Between Antigen-Presenting Cells and T
	Lymphocytes 510
15.4	Active and Passive Immunity 513
	Active Immunity and the Clonal Selection Theory 514
	Immunological Tolerance 516
	Passive Immunity 517
15.5	Tumor Immunology 518
	Innate Lymphoid Cells 519
	Effects of Aging and Stress 520
15.6	Diseases Caused by the Immune System 520
	Autoimmunity 520
	Immune Complex Diseases 522
	Allergy 522
Intera	
Summ	ary 527
Revie	v Activities 528
16	Respiratory Physiology 531
16.1	Respiratory Physiology 531 The Respiratory System 532
	The Respiratory System 532
	The Respiratory System 532 Structure of the Respiratory System 532
16.1	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535
16.1	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535
16.1	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536
16.1	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537
16.2	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539
16.2	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539
16.2	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540
16.2	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541
16.3	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541 Pulmonary Disorders 543
16.3	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541 Pulmonary Disorders 543 Gas Exchange in the Lungs 546
16.3	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541 Pulmonary Disorders 543 Gas Exchange in the Lungs 546 Calculation of Po2 546
16.3	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541 Pulmonary Disorders 543 Gas Exchange in the Lungs 546 Calculation of Po2 546 Partial Pressures of Gases in Blood 547
16.3	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541 Pulmonary Disorders 543 Gas Exchange in the Lungs 546 Calculation of Po2 546 Partial Pressures of Gases in Blood 547 Significance of Blood Po2 and Pco2 Measurements 549 Pulmonary Circulation and Ventilation/Perfusion
16.3	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541 Pulmonary Disorders 543 Gas Exchange in the Lungs 546 Calculation of Po ₂ 546 Partial Pressures of Gases in Blood 547 Significance of Blood Po ₂ and P _{CO2} Measurements 549 Pulmonary Circulation and Ventilation/Perfusion Ratios 549
16.2	The Respiratory System 532 Structure of the Respiratory System 532 Thoracic Cavity 535 Physical Aspects of Ventilation 535 Intrapulmonary and Intrapleural Pressures 536 Physical Properties of the Lungs 537 Surfactant and Respiratory Distress Syndrome 539 Mechanics of Breathing 539 Inspiration and Expiration 540 Pulmonary Function Tests 541 Pulmonary Disorders 543 Gas Exchange in the Lungs 546 Calculation of Po ₂ 546 Partial Pressures of Gases in Blood 547 Significance of Blood Po ₂ and Pco ₂ Measurements 549 Pulmonary Circulation and Ventilation/Perfusion Ratios 549 Disorders Caused by High Partial Pressures of Gases 551

Effects of Pulmonary Receptors on Ventilation 557

16.6 Hemoglobin and Oxygen Transport 558
Hemoglobin 558
The Oxyhemoglobin Dissociation Curve 560
Effect of pH and Temperature on Oxygen Transport 561
Effect of 2,3-DPG on Oxygen Transport 562
Inherited Defects in Hemoglobin Structure and Function 562
Muscle Myoglobin 563

Effects of Blood Po, on Ventilation 556

16.7 Carbon Dioxide Transport 564
The Chloride Shift 564
The Reverse Chloride Shift 565

16.8 Acid-Base Balance of the Blood 566
Principles of Acid-Base Balance 567
Ventilation and Acid-Base Balance 568

16.9 Effect of Exercise and High Altitude on Respiratory Function 569

Ventilation During Exercise 569

Acclimatization to High Altitude 570

Interactions 574

Summary 575

Review Activities 577

Physiology of the Kidneys 580

17.1 Structure and Function of the Kidneys 581
Gross Structure of the Urinary System 581
Control of Micturition 583
Microscopic Structure of the Kidney 583

17.2 Glomerular Filtration 586
Glomerular Ultrafiltrate 587
Regulation of Glomerular Filtration Rate 588

17.3 Reabsorption of Salt and Water 589

Reabsorption in the Proximal Tubule 590

The Countercurrent Multiplier System 591

Collecting Duct: Effect of Antidiuretic Hormone (ADH) 594

17.4 Renal Plasma Clearance 597

Transport Process Affecting Renal Clearance 598

Renal Clearance of Inulin: Measurement of GFR 599

Renal Clearance Measurements 600

Reabsorption of Glucose 601

17.5 Renal Control of Electrolyte and Acid-Base
Balance 603
Role of Aldosterone in Na⁺/K⁺ Balance 603

Control of Aldosterone Secretion 605

Natriuretic Peptides 606
Relationship Between Na⁺, K⁺, and H⁺ 607
Renal Acid-Base Regulation 607

17.6 Diuretics and Renal Function Tests 610
Use of Diuretics 610

Renal Function Tests and Kidney Disease 612

Interactions 613
Summary 614
Review Activities 61

18 The Digestive System 618

18.1 Introduction to the Digestive System 619
Layers of the Alimentary Tract 620
Regulation of the Alimentary Tract 622

18.2 From Mouth to Stomach 622
Esophagus 623
Stomach 624
Pepsin and Hydrochloric Acid Secretion 624

18.3 Small Intestine 628

Villi and Microvilli 628

Intestinal Enzymes 629

Intestinal Contractions and Motility 630

18.4 Large Intestine 632
Intestinal Microbiota 633
Fluid and Electrolyte Absorption in the Intestine 635
Defecation 636

Structure of the Liver 636
Functions of the Liver 639
Gallbladder 642
Pancreas 643

18.6 Regulation of the Digestive System 645
Regulation of Gastric Function 646
Regulation of Intestinal Function 648
Regulation of Pancreatic Juice and Bile Secretion 650
Trophic Effects of Gastrointestinal Hormones 650

Digestion and Absorption of Food 651
 Digestion and Absorption of Carbohydrates 651
 Digestion and Absorption of Proteins 652
 Digestion and Absorption of Lipids 653

Interactions 657
Summary 658
Review Activities 659

19 Regulation of Metabolism 662

19.1 Nutritional Requirements 663

Metabolic Rate and Caloric Requirements 663

Anabolic Requirements 665

Vitamins and Minerals 665

Free Radicals and Antioxidants 668

19.2 Regulation of Energy Metabolism 670
Regulatory Functions of Adipose Tissue 671
Regulation of Hunger and Metabolic Rate 673
Caloric Expenditures 675
Hormonal Regulation of Metabolism 676

19.3 Energy Regulation by the Pancreatic Islets 678
Regulation of Insulin and Glucagon Secretion 678
Insulin and Glucagon: Absorptive State 680
Insulin and Glucagon: Postabsorptive State 680

19.4 Diabetes Mellitus and Hypoglycemia 682
Type 1 Diabetes Mellitus 683
Type 2 Diabetes Mellitus 683
Hypoglycemia 686

19.5 Metabolic Regulation by Adrenal Hormones,
Thyroxine, and Growth Hormone 687

Adrenal Hormones 687

Thyroxine 688

Growth Hormone 689

19.6 Regulation of Calcium and Phosphate
Balance 691
Bone Deposition and Resorption 691

Hormonal Regulation of Bone 693

1,25-Dihydroxyvitamin D₃ 695

Negative Feedback Control of Calcium and Phosphate Balance 696

Summary 698
Review Activities 699

20 Reproduction 702

20.1 Sexual Reproduction 703

Sex Determination 703

Development of Accessory Sex Organs and External Genitalia 706

Disorders of Embryonic Sexual Development 707

20.2 Endocrine Regulation of Reproduction 709
Interactions Among the Hypothalamus,
Pituitary Gland, and Gonads 710

Onset of Puberty 711
Pineal Gland 713
Human Sexual Response 713

20.3 Male Reproductive System 713

Control of Gonadotropin Secretion 714
Endocrine Functions of the Testes 715
Spermatogenesis 716
Male Accessory Sex Organs 719
Erection, Emission, and Ejaculation 720
Male Fertility 722

20.4 Female Reproductive System 723

Pulmonary Disorders 543

THE PROPERTY OF THE PROPERTY O

State Indended the Land of the Contract of the

Ovarian Cycle 725

Ovulation 727

Hypothalamic-Pituitary-Ovarian Axis 728

20.5 Menstrual Cycle 729

Phases of the Menstrual Cycle: Cyclic Changes in the Ovaries 729

Cyclic Changes in the Endometrium 732

Effects of Pheromones, Stress, and Body Fat 733

Contraceptive Methods 734

Menopause 735

20.6 Fertilization, Pregnancy, and Parturition 735

Fertilization 736

Cleavage and Blastocyst Formation 738

Implantation of the Blastocyst and Formation of the Placenta 741

Exchange of Molecules Across the Placenta 744

Endocrine Functions of the Placenta 744

Labor and Parturition 746

Lactation 747

Regulation of the Allmentary Tray

Concluding Remarks 750

Interactions 751

Summary 752

Review Activities 753

Appendixes

Answers to Test Your Knowledge Questions A-1
Medical and Pharmacological Abbreviations B-1

Structure of the biver to squirouse and out to

Regulation of Intestinal Function areas and

oza notterbed elle bested bitsenned in antistues in des

Glossary G-1

Index 1-1