

Contents

Preface to the Third Edition	<i>xxvii</i>
Preface to the Second Edition	<i>xxix</i>
Preface to the First Edition	<i>xxxi</i>
About the Companion Website	<i>xxxiii</i>

1 Introduction to Anatomy and Physiology 1

Anatomy and Physiology	1
Levels of Organization	2
Homeostasis	3
Homeostatic Regulatory Mechanisms	4
Feedback Systems	5
Negative Feedback System	5
Positive Feedback System	7
Anatomical Nomenclature	7
Directional and Positional Terms	7
Body Planes	8
Body Cavities and Membranes	9
References	9

2 The Cell: The Common Physiological Denominator 11

Cells: A Common Denominator	11
Water: The Universal Solvent	12
Cellular Organelles	14
Fluid Mosaic Model	14
Microscopy Techniques	16
Organelles of the Cytoplasm	20
Mitochondria	21
Ribosomes	21
Endoplasmic Reticulum and Golgi Apparatus	22
Lysosomes and Peroxisomes	24
Microfilaments, Microtubules, and Intermediate Filaments	24
Centrioles	26
Nuclear Structure	27
Nucleoli	28
Chromatin Structure	28
Cell Growth and Differentiation	29
Stages of the Cell Cycle	32
Stages of Mitosis	32
Regulators of Cell Division	33
Macromolecules and Cellular Physiology	35
Proteins	35

Carbohydrates	39
Lipids	40
Nucleic Acids	43
Cellular Biochemistry	44
Chemical Bonds	44
Chemical Reactions	46
Significance of Enzymes	47
Extracellular Environment and Cell Function	48
Osmosis	49
Transport Mechanisms	52
Chapter Summary	56
Cells and Organelles	56
Macromolecules and Cell Function	57
References	58

3 Fundamental Biochemical Pathways and Processes in Cellular Physiology 61

Metabolism and Energetic Definitions	61
Production of ATP	64
Glycolysis	65
The Cori Cycle	68
Krebs Cycle	69
Intermediary Metabolism: Processing and Pathways	72
Glycogenesis, Gluconeogenesis, and Glycolysis	72
Lipogenesis and Lipolysis	75
Interconversions and Catabolism of Proteins	85
Structure and Function of DNA and RNA	86
Protein Synthesis	87
Food for Thought	90
Chapter Summary	91
References	92

4 Tissue Structure and Organization 95

Introduction	95
Microscope General Points	95
Examining Prepared Slides	95
Terminology and Definitions	97
Epithelial Tissue	98
Epithelial Tissue Characteristics	101
Simple Epithelium	102
Stratified Epithelium	107
Epithelial Cell Junctions	113
Glandular Epithelial Types	115
Connective Tissue	117
Classification of Connective Tissue	117
Specialized Connective Tissues	122
Muscle Tissue	127
Skeletal Muscle	129
Cardiac Muscle	132
Smooth Muscle	133
Nervous Tissue	135
Chapter Summary	136
References	138

5	Integumentary System	139
	Overview of Skin Structure	139
	Epidermis	139
	Dermis	142
	Specialized Structures	143
	Sweat Glands	143
	Sebaceous Glands	145
	Other Skin Glands	145
	Hair	146
	Biochemical Properties of Skin	149
	Skin and Coat Color	149
	Vitamin D Metabolism	150
	Nails, Claws, Hoofs, and Feathers	151
	Horns	152
	Feathers	154
	Leather	155
	Food for Thought	155
	Chapter Summary	156
	References	157
6	Bones and Skeletal System	159
	Bones	159
	Introduction	159
	Classification of Bones	159
	Bone Structure	159
	Gross Anatomy	159
	Long Bones	159
	Short, Irregular, and Flat Bones	161
	Microscopic Anatomy of Bone	161
	Compact Bone	162
	Cancellous or Spongy Bone	163
	Chemical Composition of Bone	163
	Hematopoietic Tissue in Bones	163
	Bone Development	164
	Intramembranous Ossification	164
	Endochondral Ossification	165
	Bone Growth, Remodeling, and Repair	166
	Bone Growth	166
	Bone Remodeling and Repair	167
	Hormonal Control	167
	Repair of Fractures	167
	Response to Mechanical Stress	168
	Nutrients Necessary for Bone Deposition	168
	Homeostatic Imbalances of Bone	169
	Osteomalacia and Rickets	169
	Parturient Paresis (Milk Fever)	169
	Egg-Laying Fatigue in Birds	169
	Bones and Skeleton	169
	Markings on Bones	169
	Skeleton	169
	Functions of the Skeletal System	172
	Skeletal Cartilage	172

Types of Cartilage	172
Growth of Cartilage	172
Skeleton Classification	173
Axial Skeleton	173
The Skull	173
Cranium	173
Species Differences	175
The Vertebral Column	176
Thorax	179
Appendicular Skeleton	180
Thoracic Limb	180
Pelvic Limb	185
Avian Skeleton	188
Joints	189
Anatomical Types of Joints	189
Synovial Joints	191
Anatomy of Synovial Joints	191
Classification of Synovial Joints	192
Movements of Synovial Joints	192
Specific Joints	193
Intervertebral Articulations	193
Costovertebral Joints	193
Sternocostal Joints	193
Costochondral Joints	193
Thoracic Limb	194
Shoulder Joint	194
Elbow Joint	194
Carpal Joint	194
Pelvis	195
Pelvic Symphysis	195
Sacroiliac Joint	195
Hip Joint	195
Pelvic Limb	195
Knee (Stifle Joint)	195
Tarsus	196
Chapter Summary	196
Classification of Bones	196
Bone Structure	196
Gross Anatomy	196
Microscopic Anatomy of Bone	197
Chemical Composition of Bone	197
Bone Development	197
Bone Growth, Remodeling, and Repair	197
Bone Repair	198
Homeostatic Imbalances of Bone	198
Bones and Skeleton	198
Markings on Bones	198
Skeleton	198
Skeleton Classification	198
Axial Skeleton	199
The Vertebral Column	199
Thoracic	199

Appendicular Skeleton	199
Thoracic Limb	199
The Pelvic (Hip) Girdle	199
References	200

7 Muscular Tissue 201

Muscle Tissue Overview	201
Introduction	201
Properties of Muscles	201
Functions of Muscles	201
Skeletal Muscle	202
Connective Tissues	202
Blood Vessels and Nerves	203
Skeletal Muscle Fibers	203
Myofibrils	203
Sarcoplasmic Reticulum	204
Sarcomeres	204
Thin Filaments	206
Thick Filaments	206
Contraction of Skeletal Muscle	207
Neuromuscular Junction	208
Pharmacology of the Neuromuscular Junction	208
Excitation-Contraction Coupling	209
Sliding Filament Theory	209
Rigor Mortis	211
Summary of Skeletal Muscle Contraction	211
Length-Tension Relationships	212
A Muscle Twitch	212
Treppe	213
Summation	213
Wave Summation	213
Multiple Motor Unit Summation	214
Muscle Tone	214
Isometric Versus Isotonic Contraction	214
Metabolism of Skeletal Muscle	215
Aerobic Mechanism	216
Creatine Phosphate	216
Anaerobic Mechanism	216
Muscle Fatigue and Oxygen Consumption	217
Heat Production	217
Types of Muscle Fibers	217
Effects of Exercise on Muscles	218
Cardiac Muscle	219
Cardiac Versus Skeletal Muscle Cells	219
Functional Characteristics	219
Smooth Muscle	219
Structure	219
Types of Smooth Muscle	220
Neural Innervation of Smooth Muscle	221
Contraction of Smooth Muscle	221
Muscle System	222
Naming Muscles	222

Arrangements of Fascicles	223
Muscles as Levers	223
Muscle Terminology	224
Origins and Insertions	224
Actions	224
Muscle Attachments	225
Major Skeletal Muscles	225
Muscles of the Head and Neck	226
Muscles of the Pectoral Limb and Lateral Thorax	227
Muscles of the Pelvic Limb and Body Wall	229
Stay Apparatus of a Horse	231
Food for Thought	232
Chapter Summary	236
Overview of Muscle Tissues	236
Properties and Functions of Muscle	236
Types of Muscle Tissue	236
Skeletal Muscle	236
Gross Anatomy of a Skeletal Muscle	236
Microscopic Anatomy of a Skeletal Muscle Fiber	236
Excitation-Coupling and Sliding Filament Theory	237
Contraction of a Skeletal Muscle	237
Muscle Metabolism	237
Smooth Muscle	237
Structure of Smooth Muscle Fibers	237
Contraction of Smooth Muscle	238
Muscle Systems	238
Naming Muscles	238
Arrangement of Fascicles	238
Muscles as Levers	238
Muscle Terminology	238
Stay Apparatus of the Horse	238
References	239
8 Introduction to the Nervous System	241
Organization of the Nervous System	241
The Neuron	242
Cell Body	243
Dendrites	243
Axon	243
Synapse	244
Classification of Neurons	245
Classification Based on Neurite Number	246
Classification Based on Axon Length	246
Classification Based on Function	246
Classification Based on Neurotransmitter	247
Supportive Cells	247
Ependymal Cells	247
Astrocytes	248
Oligodendrocytes	248
Microglia	248
Satellite Cells and Schwann Cells	248
Neurophysiology	248

The Resting Membrane Potential	248
Membrane Channels	251
Chemically Gated Channels	251
Voltage-Gated Channels	252
Mechanically Gated Channels	253
Postsynaptic Potentials	253
Excitatory Postsynaptic Potentials	253
Inhibitory Postsynaptic Potential	253
Generation of an Action Potential	253
Propagation of the Action Potential	255
Conduction Velocity	255
Coding of Stimulus Intensity	257
Synaptic Transmission	257
Electrical Transmission	257
Chemical Transmission	257
Modulation of the Synaptic Signal	258
Neurotransmitters	259
Amines	260
Amino Acids	262
Peptides	262
Unconventional Neurotransmitters	262
Neurotransmitter Receptors	264
Chapter Summary	266
Organization of the Nervous System	266
The Neuron	266
Supportive Cells	266
Neurophysiology	266
The Resting Membrane Potential	266
Membrane Channels	267
Postsynaptic Potentials	267
Generation of an Action Potential	267
Propagation of the Action Potential	268
Synaptic Transmission	268
Neurotransmitters and Their Receptors	268
Modulation of the Synaptic Signal	268
Neurotransmitters	268
Neurotransmitter Receptors	269
9 Central Nervous System	271
Embryonic Development	271
Three Brain Vesicles	272
Organization of the Brain	273
The Cerebral Hemispheres	273
Ventricles of the Brain	275
Cerebral Cortex	276
Motor Areas	277
Sensory Areas	278
Cerebral White Matter	278
Basal Ganglion	278
Limbic System	279
Diencephalon	280
Thalamus	280

Hypothalamus	281
Epithalamus	283
Mesencephalon	283
Metencephalon	284
Medulla Oblongata	285
Functional Systems	285
The Reticular Activating System	285
Sleep	286
Cranial Nerves	287
Organization of the Spinal Cord	289
Protection of the Central Nervous System	292
Meninges	292
Cerebrospinal Fluid	293
Blood–Brain Barrier	293
Blood–Cerebrospinal Fluid Barrier	294
Food for Thought Chapter 9	294
Chapter Summary	294
Embryonic Development	294
Organization of the Brain	295
Cerebral Hemispheres	295
Ventricles of the Brain	295
Cerebral Cortex	295
Cerebral White Matter	295
Diencephalon	296
Epithalamus	296
Thalamus	296
Mesencephalon	296
Metencephalon	296
Medulla Oblongata	296
Functional Systems	296
Reticular Activating System (RAS)	296
Cranial Nerves	296
Organization of the Spinal Cord	296
Protection of the Central Nervous System	297
Meninges	297
Cerebrospinal fluid (CSF)	297
Blood–Brain Barrier	297
References	297
10 The Peripheral and Autonomic Nervous System	299
Nerves and Ganglia	299
Nerves	299
Classification of Nerves	299
Spinal Nerves	299
Degeneration and Regeneration of Nerves	301
Ganglia	301
Sensory Receptors	302
Classes of Sensory Receptors	302
General Senses	303
Mechanoreceptors	303
Tactile Receptors	303
Baroreceptors	304

Proprioceptors	305
Dorsal Column-Medial Lemniscal Pathway (Mechanoreceptor Pathway)	305
Nociceptors	305
Pain Pathway	306
Thermoreceptors	307
Thermoreceptor Pathway	308
Chemoreceptors	308
Detection of Sensory Stimuli	309
Reflexes	312
Classification of Reflexes	313
Development of Reflexes	313
Site of Information Processing	313
Resulting Motor Response	313
Spinal Reflexes	314
Monosynaptic Reflexes	314
Stretch Reflex	314
Anatomy of the Muscle Spindle	314
Muscle Spindle and Muscle Contraction	315
Function of the Gamma Motor Neurons	315
Gamma Motor Neuron Loop	316
Polysynaptic Reflexes	317
Tendon Reflex	317
Withdrawal Reflex	317
Crossed-Extensor Reflex	317
Use of Reflexes in Diagnostics	317
Autonomic Nervous System	318
Overview	318
Overlap of Somatic and Autonomic Functions	319
Divisions of the Autonomic Nervous System	320
Sympathetic Division	320
Parasympathetic Division	321
Anatomy of the Autonomic Nervous System	321
Sympathetic Division	321
Prevertebral Ganglia	321
Pathways to the Adrenal Medulla	322
Parasympathetic Division	322
Physiology of the Autonomic Nervous System	323
Neurotransmitters and Receptors	323
Cholinergic Fibers	323
Adrenergic Fibers	323
Other Neurotransmitters	325
Interactions of the Sympathetic and Parasympathetic Divisions	325
Central Nervous System Control of the Autonomic Nervous System	325
Visceral Reflexes	327
Ocular Reflexes	327
Cardiovascular Reflexes	327
Glandular Reflexes	327
Gastrointestinal Reflexes	327
Urogenital Reflexes	328
Chapter Summary	328
Nerves and Ganglia	328
Nerves	328

Classification of Nerves	328
Spinal Nerves	328
Degeneration and Regeneration of Nerves	328
Ganglia	329
Sensory Receptors	329
Classes of Sensory Receptors	329
General Senses	329
Mechanoreceptors	329
Nociceptors	329
Thermoreceptors	329
Chemoreceptors	330
Detection of Sensory Stimuli	330
Reflexes	330
Classification of Reflexes	330
Spinal Reflexes	330
Monosynaptic Reflex	330
Polysynaptic Reflexes	331
Use of Reflexes in Diagnostics	331
Autonomic Nervous System	331
Overview	331
Divisions of the Autonomic Nervous System	331
Role of the Sympathetic Division	331
Role of the Parasympathetic Division	332
Anatomy of the Autonomic Nervous System	332
Sympathetic Division	332
Parasympathetic Division	332
Physiology of the Autonomic Nervous System	332
Neurotransmitters and Receptors	332
Cholinergic Fibers	332
Adrenergic Fibers	332
Other Neurotransmitters	333
Central Nervous System Control of the Autonomic Nervous System	333
Visceral Reflexes	333
Ocular Reflexes	333
Cardiovascular Reflexes	333
Glandular Reflexes	333
Gastrointestinal Reflexes	333
Urogenital Reflexes	334
References	334
11 Special Senses	335
Olfaction: The Sense of Smell	335
Anatomy of Olfactory Receptors	335
Physiology of Olfaction	337
Olfactory Pathway	337
Gustation: The Sense of Taste	337
Tongue	337
Taste	338
Sweet Taste	339
Bitter Taste	340
Salty Taste	340
Sour Taste	340

Umami	340
Taste Pathway	340
Vision	342
Accessory Structures of the Eye	342
Lacrimal Apparatus	343
Extrinsic Eye Muscles	343
Anatomy of the Eyeball	344
Fibrous Tunic	344
Vascular Tunic	345
Retina (the Sensory Tunic)	346
Lens	347
Chambers of the Eye	347
Physiology of Vision	347
Refraction	347
Accommodation	347
Refraction Problems	348
Pupil Diameter	348
Field of Vision	349
Photoreception	349
Chemistry of Visual Pigments	349
Light Transduction by Photoreceptors	352
Retinal Processing of Visual Information	352
Light or Dark Adaptation	353
Visual Pathway	353
Hearing and Balance	354
Anatomy of the Ear	354
Outer (External) Ear	354
Middle Ear	355
Inner Ear	355
Physiology of Hearing	356
Physiology of Equilibrium	358
Otolithic Organs Within the Utricle and Saccule	358
The Crista Ampularis and Dynamic Equilibrium	358
Chapter Summary	359
Olfaction: The Sense of Smell	359
Anatomy of Olfactory Receptors	359
Physiology of Olfactory	359
Olfactory Pathway	359
Gustation: The Sense of Taste	359
Tongue	359
Taste	359
Vision	360
Accessory Structures of the Eye	360
Eyelids, Eyelashes, and Eyebrow	360
Lacrimal Apparatus	360
Extrinsic Eye Muscles	360
Anatomy of the Eyeball	360
Fibrous Tunic	360
Vascular Tunic	360
Retina (the Sensory Tunic)	361
Lens	361
Chambers of the Eye	361

Physiology of Vision	361
Refraction	361
Accommodation	361
Refraction Problems	362
Pupil Diameter	362
Field of Vision	362
Photoreception	362
Chemistry of Visual Pigments	362
Light Transduction by Photoreceptor	362
Retinal Processing of Visual Information	363
Light or Dark Adaptation	363
Visual Pathway	363
Hearing and Balance	363
Anatomy of the Ear	363
Outer (External) Ear	363
Middle Ear	363
Inner Ear	363
Sound	364
Physiology of Hearing	364
Physiology of Equilibrium	364
Otolithic Organs Within the Utricle and Saccule	364
The Crista Ampularis and Dynamic Equilibrium	364
References	364

12 Endocrine System 367

Introduction and Overview	367
Cell Signaling	367
Mechanisms for Signaling by Cell Surface Receptors	372
Mechanisms of Internal Hormone Cell Signaling	378
Receptors and Regulation	381
Measuring Circulating Hormone Concentrations	384
Endocrine and Growth Factor Signaling	387
The Hypophyseal-Pituitary Axis	388
Pituitary Overview	389
Negative Feedback Loops	393
Hormones and Cells of the Posterior Pituitary	393
Hormones of the Anterior Pituitary	397
Somatotropin (GH)	397
The Somatomedin Hypothesis	399
GH Secretion	400
Prolactin	401
Prolactin Secretion	403
Follicle-Stimulating Hormone and Luteinizing Hormone	403
Thyroid-Stimulating Hormone	405
Adrenocorticotrophic Hormone	406
Thyroid Gland	407
Biosynthesis of Triiodothyronine and Thyroxine	407
Biological Effects of Thyroid Hormones	407
Calcitonin	411
Parathyroid Hormone	411
Adrenal Gland	412
Endocrine Pancreas	416

Other Hormones and Growth Factors	418
IGF Family	419
EGF Family	422
FGF Family	424
TGF- β Family	425
Leptin	426
Chapter Summary	427
Cell Signaling	427
Major Hormones	428
References	429

13 Cardiovascular System 435

Functions and Composition of Blood	435
Functions of Blood	435
Transportation	435
Regulation	435
Protection	435
Physical Characteristics of Blood	435
Plasma	437
Formed Elements in Mammals	437
Types of Blood Cells in Mammals	438
Erythrocytes	438
Leukocytes	440
Granulocytes	440
Agranulocytes	441
Platelets	443
Formation of Blood Cells	443
Erythrocyte Formation	444
Leukocyte Formation	444
Platelet Formation	444
Formed Elements and Blood Cells in Birds	445
Thrombocytes	445
Heterophils	445
Hemostasis	445
Vascular Spasm	446
Platelet Plug Formation	446
Blood Clotting	446
Extrinsic Pathway	447
Intrinsic Pathway	447
Common Pathway	447
Role of Vitamin K	447
Clot Retraction and Repair	447
Fibrinolysis	447
Factors Limiting Clot Growth and Formation	447
Thrombolytic Agents	447
Blood Groups and Crossmatching	448
Blood Groups	448
Crossmatching	448
The Heart	448
Anatomy of the Heart	448
Location and Exterior Landmarks	448
Pericardium	448

Layers of the Heart	449
Fibrous Skeleton of the Heart	449
Heart Chambers and Vessels	450
Pathways of Blood Through the Heart	451
Heart Valve Operation	452
Pulmonary, Systemic, and Coronary Circulation	452
Pulmonary Circulation	452
Systemic Circulation	453
Coronary Circulation	453
Cardiac Muscle and the Cardiac Conduction System	453
Cardiac Muscle	453
The Conduction System	453
Mechanisms of Heart Contraction	455
ATP Production	456
Electrocardiogram	456
Heart Sounds	457
The Cardiac Cycle	458
Cardiac Output	459
Regulation of Stroke Volume	459
Regulation of Heart Rate	460
Autonomic Nervous System Regulation	461
Chemical Regulation of Heart Rate	461
Blood Vessels and Hemodynamics	461
Structure and Function of Blood Vessels	461
Blood Vessel Walls	461
Arteries	462
Arterioles	462
Capillaries	462
Venules	464
Veins	464
Anastomoses	464
Portal Systems	464
Capillary Exchange	465
Diffusion	465
Bulk Flow	465
Factors Affecting Blood Flow	466
Flow, Pressure, and Resistance	466
Blood Pressure	466
Resistance	467
Venous Blood Return	467
Maintaining Blood Pressure	468
Neural Regulation	468
Chemical Regulation of Blood Pressure: Short-Term Control	468
Renal Regulation of Blood Pressure: Long-Term Control	470
Autoregulation of Blood Pressure	470
Shock and Homeostasis	471
Types of Shock	471
Circulatory Routes	471
Pulmonary Circulation	471
Systemic Circulation	471
Chapter Summary	474
Functions and Composition of Blood	474

Functions of Blood	474
Transportation	474
Regulation	474
Protection	474
Physical Characteristics of Blood	475
Plasma	475
Type of Blood Cells	475
Erythrocytes	475
Leukocytes	475
Granulocytes	475
Agranulocytes	475
Platelets	475
Formation of Blood Cells	476
Formed Elements and Blood Cells in Birds	476
Hemostasis	476
Vascular Spasm	476
Platelet Plug Formation	476
Blood Clotting	476
Clot Retraction and Repair	477
Fibrinolysis	477
Blood Groups and Cross Matching	477
The Heart	477
Coverings of the Heart	477
Layers of the Heart Wall	477
Heart Chambers and Vessels	478
Pathway of Blood Through the Heart	478
Systemic, Pulmonary, and Coronary Circulation	478
Pulmonary Circulation	478
Systemic Circulation	478
Coronary Circulation	478
Cardiac Muscle and the Cardiac Conduction System	479
Cardiac Muscle	479
The Conduction System	479
Mechanisms of Heart Contraction	479
ATP Production	479
Electrocardiogram	479
Heart Sounds	480
The Cardiac Cycle	480
Cardiac Output	480
Regulation of Stroke Volume	480
Regulation of Heart Rate	480
Autonomic Nervous System Regulation	480
Chemical Regulation of Heart Rate	481
Blood Vessels and Hemodynamics	481
Structure and Function of Blood Vessels	481
Arteries	481
Arterioles	481
Capillaries	481
Veins	481
Portal Systems	482
Capillary Exchange	482
Diffusion	482

Bulk Flow	482
Factors Affecting Blood Flow	482
Blood Pressure	482
Resistance	482
Venous Blood Return	483
Maintaining Blood Pressure	483
Neural Regulation	483
Chemical Regulation of Blood Pressure: Short-Term Control	483
Renal Regulation of Blood Pressure: Long-Term Control	483
Autoregulation of Blood Pressure	483
Shock and Homeostasis	484
Types of Shock	484
Circulatory Routes	484
Pulmonary Circulation	484
Systemic Circulation	484
References	484
14 Respiratory System	487
Introduction	487
Functional Anatomy: Nose and Paranasal Sinuses	487
Conducting Pathway Anatomy	489
Pharynx and Nasopharynx	489
Oropharynx and Laryngopharynx	489
Larynx	489
Trachea and Bronchi	490
Respiratory Anatomy of the Lungs and Pleural Membrane	491
Alveoli	491
Blood Supply to the Lungs	493
Pulmonary Ventilation	493
Pressure Changes During Respiration	493
Inspiration	493
Expiration	494
Other Factors Involved in Pulmonary Ventilation	494
Surface Tension of Alveolar Fluid	494
Compliance of the Lungs	495
Airway Resistance	495
Lung Volumes and Capacities	495
Exchange of Oxygen and Carbon Dioxide	496
Dalton's Law and Henry's Law	496
Dalton's Law	496
Henry's Law	497
External and Internal Respiration	497
Transport of Oxygen and Carbon Dioxide	497
Hemoglobin and Oxygen Transport	497
Other Factors Affecting the Oxygen–Hemoglobin Dissociation Curve	498
Hemoglobin–Nitric Oxide	499
Carbon Dioxide Transport	499
Control of Respiration: Neural Mechanisms	500
Pneumotaxic and Apneustic Area	500
Chemoreceptors	501
Pulmonary and Airway Receptors	501
Avian Respiration	501

Anatomy of the Avian Respiratory System	501
Air Sacs	502
Avian Ventilation and Gas Exchange	502
Prehatching Respiration in Birds	503
Defense Mechanisms of the Respiratory System	505
Nonspecific Defense Mechanisms	505
Specific Defense Mechanisms	506
Chapter Summary	506
Respiratory System	506
Functional Anatomy	507
Nose	507
The Pharynx	507
Larynx	507
Trachea	507
Bronchi	507
Lungs	507
Pleural Membrane	508
Alveoli	508
Blood Supply to the Lungs	508
Pulmonary Ventilation	508
Pressure Changes During Respiration	508
Inspiration	508
Expiration	508
Other Factors Involved in Pulmonary Ventilation	509
Lung Volumes and Capacities	509
Respiratory Volumes	509
Exchange of Oxygen and Carbon Dioxide	509
Dalton's Law and Henry's Law	509
External and Internal Respiration	510
Transport of Oxygen and Carbon Dioxide	510
Oxygen Transport	510
Other Factors Affecting the Oxygen–Hemoglobin Dissociation Curve	510
Hemoglobin–Nitric Oxide	511
Carbon Dioxide Transport	511
Control of Respiration-Neural Mechanisms	511
Pneumotaxic and Apneustic Area	511
Chemoreceptors	511
Pulmonary and Airway Receptors	512
Avian Respiration	512
Anatomy of the Avian Respiratory System	512
Air Sacs	512
Avian Ventilation and Gas Exchange	512
References	513

15 Immunity 515

Introduction	515
Innate or Nonspecific Defenses	518
Specific Immunity	528
Antibody Structure and Function	529
B Cell Selection and Antibody Secretion	530
Cell-Mediated Immunity	531
Avian Versus Mammalian Systems	534

Lymphatic System	535
Chapter Summary	536
Introduction	536
Specific Immunity	536
Antibodies	536
Leukocytes, Lymphocytes, and Others	536
Cytokines	537
Passive Immunity	537
Lymphatic System	537
References	537

16 Urinary System 539

Anatomy of the Urinary System	539
Nephron Structure	542
Mechanisms of Urine Formation	545
Factors Affecting Filtration	545
Proximal Convoluted Tubule	546
Countercurrent Mechanisms and Medullary Osmotic Gradient	550
Renal Clearance	554
Kidney Excretion of Wastes and Control of pH	555
Excretion of Nitrogenous Wastes	560
Comparative Urinary Physiology and Function	560
Avian Nitrogen Excretion	562
Avian Salt Glands	563
Chapter Summary	563
Introduction	563
Urinary System	564
Anatomy and Function	564
The Nephron	564
Kidney Blood Flow	564
Blood Pressure, Hormones, and Regulation	564
References	565

17 Digestive System 567

Digestive System Overview	567
Functions of the Digestive Tract	567
Peritoneal Cavity	567
Mesenteries	569
Blood Supply of the Digestive Organs	570
Histology of the Digestive Tract	570
Mucosa	570
Submucosa	571
Muscularis Externa	571
Serosa	571
Enteric Nervous System	571
Functional Anatomy of the Digestive System	571
Mouth	572
Lips, Cheeks, and Gums	572
Tongue	573
Salivary Glands and Saliva	573
Teeth	575
Pharynx	578

Swallowing	580
Esophagus	580
Histology of the Esophagus	580
Stomach	581
Anatomy of the Monogastric Stomach	581
Histology of the Monogastric Stomach	582
Gastric Secretions	583
Gastric Motility	584
Vomiting and Egestion	584
Regulation of Gastric Secretions and Emptying	585
Anatomy of the Stomach of Ruminants	587
Anatomy of the Stomach of Birds	593
Small Intestine	593
Anatomy of the Small Intestine	593
Histology of the Small Intestine	596
Intestinal Juices and Brush-Border Enzymes	598
Mechanical Digestion and Motility in the Small Intestine	598
Chemical Digestion in the Small Intestine	598
Carbohydrate Digestion	599
Protein Digestion	599
Lipid Digestion	599
Nucleic Acid Digestion	599
Absorption in the Small Intestine	599
Accessory Organs	603
Pancreas	603
Liver and Gallbladder	605
Large Intestine	608
Anatomy of the Large Intestine	608
Histology of the Large Intestine	609
Mechanical Digestion in the Large Intestine	610
Chemical Digestion in the Large Intestine	610
Gut Microflora and Immunity	610
Chapter Summary	615
Introduction	615
Functions of the Digestive Tract	615
Peritoneal Cavity	615
Blood Supply of the Digestive Organs	615
Histology of the Digestive Tract	615
Enteric Nervous System	616
Functional Anatomy of the Digestive System	616
The Mouth	616
Tongue	616
Salivary Glands and Saliva	616
Teeth	616
Pharynx	617
Swallowing	617
Stomach	617
Gastric Motility	617
Vomiting and Egestion	617
Regulation of Gastric Secretions and Emptying	617
Anatomy of the Stomach of Ruminants	618
Anatomy of the Stomach of Birds	618

Small Intestine	618
Anatomy of the Small Intestine	618
Histology of the Small Intestine	618
Intestinal Juices and Brush-Border Enzymes	619
Mechanical Digestion and Motility in the Small Intestine	619
Chemical Digestion in the Small Intestine	619
Absorption in the Small Intestine	619
Accessory Organs	619
Pancreas	619
Liver and Gallbladder	620
Large Intestine	620
Anatomy of Large Intestine	620
Mechanical Digestion in the Large Intestine	620
Chemical Digestion in the Large Intestine	621
Gut Microflora	621
References	621

18 Lactation 623

Introduction	623
Overview of Mammary Development	624
Prepubertal and Postpubertal Mammary Development	625
Mammary Development During Pregnancy	629
Alveolar Cell Differentiation and Lactogenesis	633
Hormonal Control of Lactogenesis and Lactation	634
Milk Synthesis and Secretion	640
Colostrum	640
Lactation Curves	645
Galactopoiesis and bST	650
Mammary Involution	651
Chapter Summary	652
Introduction	652
Mammogenesis, Lactogenesis, and Galactopoiesis	653
Milk Composition	653
References	653

19 Reproduction 659

Introduction	659
Overview of the Female Reproductive Tract	659
Puberty in Females	666
Endocrinology of Female Puberty	666
Estrous Cycles, Estrus, and Ovulation	666
Fertilization and Pregnancy	671
Implantation and Placentation	672
Parturition	676
Overview of Male Reproductive Tract	677
Spermatogenesis	678
Sperm Storage, Maturation, and Delivery	681
Reproduction in Birds	682
Avian Female Reproductive System	683
Avian Male Reproductive System	685
Reproductive Technologies	685
Artificial Insemination	686

In Vitro Fertilization (IVF)	687
Embryo Transfer (ET)	687
Sexed Semen	688
Cloning	688
Transgenic Animals	689
Chapter Summary	691
Female Reproductive System	692
Estrous Cycles and Ovulation	692
Fertilization and Pregnancy	693
Male Reproductive System	694
Reproductive Technologies	695
References	695

Glossary	697
-----------------	------------

Index	745
--------------	------------

