4.3 Epithelial Tissue 79
General Features of Epithelial Tissue 80
Covering and Lining Epithelium 80
Glandular Epithelium 88

4.4 Connective Tissue 89
General Features of Connective Tissue 90
Connective Tissue Cells 90
Connective Tissue Extracellular Matrix 91
Classification of Connective Tissues 92
Types of Mature Connective Tissue 92
Connective Tissues: Diverse and Dynamic 100

4.5 Membranes 101
Mucous Membranes 101
Serous Membranes 101
Synovial Membranes 101

4.6 Muscular Tissue 102

4.7 Nervous Tissue 104

4.8 Tissue Repair: Restoring Homeostasis 105

4.9 Aging and Tissues 106
Excess Adiposity 106

Key Medical Terms Associated with Tissues 106

MANUAL THERAPY APPLICATION
How Massage Affects Connective Tissues 100

• CLINICAL CONNECTIONS
Pap Smear 82  Marfan Syndrome 91  Tissue Engineering 99
Adhesions 105

Study Outline 106  Self-Quiz Questions 108
Critical Thinking Questions 110
Answers to Figure Questions 110

5  THE INTEGUMENTARY SYSTEM 111

5.1 Structure of the Skin 112
Epidermis 113
Keratinization and Growth of the Epidermis 116
Dermis 116
Skin Color 117

5.2 Accessory Structures of the Skin 118
Hair 118
Skin Glands 121
Nails 122

5.3 Types of Skin 123

5.4 Functions of the Skin 124

5.5 Maintaining Homeostasis: Skin Wound Healing 125
Epidermal Wound Healing 125
Dermal Wound Healing 125

5.6 Skin Conditions Important to Therapists 127
Skin Cancer 127
Burns 128
Pressure Ulcers 129

5.7 Aging and the Integumentary System 130
Key Medical Terms Associated with the Integumentary System 130
Exhibit 5.1 The Integumentary System and Homeostasis 131

MANUAL THERAPY APPLICATIONS
Physiological Effects of Massage 127
Assessing Skin Lesions 129

• CLINICAL CONNECTIONS
Skin Grafts 115
Skin and Mucous Membrane Color as a Diagnostic Clue 118

Study Outline 132  Self-Quiz Questions 133
Critical Thinking Questions 134  Answers to Figure Questions 134

6  BONE TISSUE 135

6.1 Functions of Bone and the Skeletal System 136

6.2 Structure of Bone 136

6.3 Histology of Bone Tissue 138
Compact Bone Tissue 139
Spongy Bone Tissue 139

6.4 Blood and Nerve Supply of Bone 141

6.5 Bone Formation 142
Intramembranous Ossification 142
Endochondral Ossification 142

6.6 Bone Growth 145
Growth in Length 145
Growth in Thickness 146

6.7 Bones and Homeostasis 147
Bone Remodeling 147
Factors Affecting Bone Growth and Bone Remodeling 148
Fracture and Repair of Bone 148
Bone’s Role in Calcium Homeostasis 151

6.8 Aging and Bone Tissue 152
Key Medical Terms Associated with Bone Tissue 154

MANUAL THERAPY APPLICATIONS
Treatments for Fractures 151
Effects of Exercise on Bone 152

• CLINICAL CONNECTIONS
Bone Scan 141
Remodeling and Orthodontics 147
Rickets and Osteomalacia 148
Hormonal Abnormalities that Affect Height 148
Osteoporosis 153

Study Outline 154  Self-Quiz Questions 155
Critical Thinking Questions 157  Answers to Figure Questions 158

7  THE SKELETAL SYSTEM: THE AXIAL SKELETON 159

7.1 Divisions of the Skeletal System 160

7.2 Types of Bones 160

7.3 Bone Surface Markings 162

7.4 Skull 162
General Features and Functions 163
Cranial Bones 164
Facial Bones 170
Nasal Septum 173
Orbits 174
Foramina 174
Unique Features of the Skull 174

7.5 Hyoid Bone 177

7.6 Vertebral Column 177
Normal Curves of the Vertebral Column 179
Intervertebral Discs 179
Parts of a Typical Vertebra 179
Regions of the Vertebral Column 180

7.7 Thorax 186
Sternum 186
Ribs 186

7.8 Disorders of the Axial Skeleton 189
Abnormal Curves of the Vertebral Column 189
Spina Bifida 190

Key Medical Terms Associated with Axial Skeleton 191
11 THE MUSCULAR SYSTEM: THE MUSCLES OF THE HEAD AND NECK 284

11.1 How Skeletal Muscles Produce Movement 285
Muscle Attachment Sites: Origin and Insertion 285
Lever Systems and Leverage 285  Effects of Fascicle Arrangement 288  Coordination within Muscle Groups 288
11.2 How Skeletal Muscles Are Named 289
11.3 Principal Skeletal Muscles of the Head and Neck 289
Exhibit 11.1 Muscles of Facial Expression 294
Exhibit 11.2 Muscles that Move the Eyeballs and Upper Eyelids (Extrinsic Eye Muscles) 300
Exhibit 11.3 Muscles that Move the Mandible and Assist in Mastication (Chewing) and Speech 302
Exhibit 11.4 Muscles of the Anterior Neck that Assist in Deglutition (Swallowing) and Speech 304
Exhibit 11.5 Muscles of the Anterior Neck that Assist in Elevating the Ribs or Flexing the Neck and Head 307
Exhibit 11.6 Muscles of the Lateral Neck that Move the Head 310

MANUAL THERAPY APPLICATIONS
Sternocleidomastoid (SCM) as an Example of Referred Trigger Points 310  Whiplash Injuries 312

• CLINICAL CONNECTIONS
Bell’s Palsy 298  Gravity and the Mandible 302

Study Outline 314  Self-Quiz Questions 314  Critical Thinking Questions 315  Answers to Figure Questions 315

12 THE MUSCULAR SYSTEM: THE MUSCLES OF THE TORSO 316

Exhibit 12.1 Muscles of the Abdomen that Act on the Abdominal Wall 317
Surface Features of the Abdomen and Pelvis 320
Exhibit 12.2 Muscles of the Thorax Used in Breathing 324
Exhibit 12.3 Muscles of the Pelvic Diaphragm and Perineum that Support the Pelvic Viscera 325
Exhibit 12.4 Muscles of the Neck and Back that Act on the Posterior Head, Posterior Neck, Back, and Vertebral Column 328
Suboccipital Muscles 332

MANUAL THERAPY APPLICATIONS
The Quadratus Lumborum and “Short Leg” Syndrome 319  Back Injuries and Heavy Lifting 332

• CLINICAL CONNECTIONS
Fibromyalgia 261  Muscular Dystrophy 261  Myasthenia Gravis 264
Abnormal Contractions of Skeletal Muscle 274

Study Outline 280  Self-Quiz Questions 282  Critical Thinking Questions 283  Answers to Figure Questions 283

13 THE MUSCULAR SYSTEM: THE MUSCLES OF THE UPPER LIMB 336

Exhibit 13.1 Muscles of the Thorax that Move the Pectoral Girdle 337
Movements of the Scapula 340
Exhibit 13.2 Muscles of the Thorax and Shoulder that Move the Humerus 341
Surface Features of the Shoulder 341  Surface Features of the Arm 341  Surface Features of the Back 346
Exhibit 13.3 Muscles of the Arm that Move the Radius and Ulna 347
Surface Features of the Arm and Elbow 352
Exhibit 13.4 Muscles of the Forearm that Move the Wrist, Hand, and Digits 354
Exhibit 13.5 Muscles of the Palm that Move the Digits–Intrinsic Muscles of the Hand 362
Surface Features of the Hand 366

MANUAL THERAPY APPLICATIONS
Structural and Functional Analysis 340  Tenosynovitis 352  Repetitive Strain Injuries 359

• CLINICAL CONNECTIONS
Rotator Cuff Injuries and Impingement Syndrome 345

Study Outline 367  Self-Quiz Questions 367  Critical Thinking Questions 368  Answers to Figure Questions 368

14 THE MUSCULAR SYSTEM: THE MUSCLES OF THE LOWER LIMB 369

14.1 Introduction to the Muscles of the Lower Limb (Extremity) 370
Exhibit 14.1 Muscles of the Gluteal Region that Move the Femur 371
Surface Features of the Buttock 378
Exhibit 14.2 Muscles of the Thigh that Move on the Femur, Tibia, and Fibula 380
Surface Features of the Thigh and Knee 383
Exhibit 14.3 Muscles of the Leg that Move the Foot and Toes 386
Surface Features of the Leg, Ankle, and Foot 391
Exhibit 14.4 Muscles of the Foot that Move the Toes 393
14.2 Muscle Interactions 398
The Interconnectedness of the Whole Body 398  Posture and Interactions between Muscles 398
Exhibit 14.5 Contributions of the Muscular System to Homeostasis 400
15 NERVOUS TISSUE 403

15.1 Overview of the Nervous System 404
- Structures of the Nervous System 404
- Functions of the Nervous System 404
- Organization of the Nervous System 405

15.2 Histology of Nervous Tissue 407
- Neurons 407
- Myelination 409
- Gray and White Matter 411
- Neuroglia 411

15.3 Electrical Signals in Neurons 413
- Action Potentials 413
- Conduction of Nerve Impulses 417
- Effect of Axon Diameter 418

15.4 Synaptic Transmission 418
- Events at a Synapse 418
- Neurotransmitters 420

15.5 Regeneration and Repair of Nervous Tissue 421
- Neurogenesis in the CNS 421
- Damage and Repair in the PNS 421

Key Medical Terms Associated with Nervous Tissue 422

16 THE SPINAL CORD AND SPINAL NERVES 426

16.1 Spinal Cord Anatomy 427
- Protective Structures 427
- External Anatomy of the Spinal Cord 427
- Internal Anatomy of the Spinal Cord 429

16.2 Spinal Nerves 430
- Connective Tissue Coverings of Spinal Nerves 432
- Distribution of Spinal Nerves 433

Exhibit 16.1 Cervical Plexus 434
Exhibit 16.2 Brachial Plexus 436
Exhibit 16.3 Lumbar Plexus 440

16.3 Spinal Cord Physiology 444
- Sensory and Motor Tracts 445
- Reflexes and Reflex Arches 449
- Reflexes and Diagnosis 457

16.4 Traumatic Injuries of the Spinal Cord 458
- Key Medical Terms Associated with the Spinal Cord and Spinal Nerves 458

17 THE BRAIN AND CRANIAL NERVES 463

17.1 The Brain 464
- Major Parts and Protective Coverings 464
- Brain Blood Supply and the Blood-Brain Barrier 464
- Cerebrospinal Fluid 464
- Diencephalon 469
- Cerebellum 471
- Cerebrum 471
- Hemispheric Lateralization 476
- Memory 476
- Electroencephalogram (EEG) 476

17.2 Cranial Nerves 477

17.3 Aging and the Nervous System 479

Key Medical Terms Associated with the Brain 479

18 THE AUTONOMIC NERVOUS SYSTEM 483

18.1 Introduction to the Autonomic Nervous System 484
18.2 Comparison of Somatic and Autonomic Nervous Systems 484
18.3 Structure of the Autonomic Nervous System 486
Organization of the Sympathetic Division 486
Organization of the Parasympathetic Division 488
18.4 Functions of the Autonomic Nervous System 491
ANS Neurotransmitters 491
Activities of the ANS 491
18.5 Integration and Control of Autonomic Functions 492
Autonomic Reflexes 492
Autonomic Control by Higher Centers 494
Key Medical Terms Associated with the Autonomic Nervous System 494

MANUAL THERAPY APPLICATION
Mind-Body Exercise: An Antidote to Stress 492

• CLINICAL CONNECTIONS
Autonomic Dysreflexia 488
Raynaud Phenomenon 492
Study Outline 495
Self-Quiz Questions 495
Critical Thinking Questions 497
Answers to Figure Questions 497

19 SOMATIC AND SPECIAL SENSES 498
19.1 Overview of Sensations 499
Definition of Sensation 499
Characteristics of Sensations 499
Types of Sensory Receptors 499
19.2 Somatic Senses 500
Tactile Sensations 500
Thermal Sensations 501
Pain Sensations 502
Proprioceptive Sensations 503
19.3 Special Senses and Olfaction: Sense of Smell 504
Structure of the Olfactory Epithelium 504
Stimulation of Olfactory Receptors 505
The Olfactory Pathway 505
19.4 Gustation: Sense of Taste 506
Structure of Taste Buds 506
Stimulation of Gustatory Receptors 506
The Gustatory Pathway 506
19.5 Vision 507
Accessory Structures of the Eye 507
Layers of the Eyeball 509
Interior of the Eyeball 511
Image Formation and Binocular Vision 512
Stimulation of Photoreceptors 514
The Visual Pathway 514
19.6 Hearing and Equilibrium 515
Anatomy of the Ear 515
Physiology of Hearing 518
Auditory Pathway 519
Deafness 519
Physiology of Equilibrium 519
Equilibrium Pathways 519
Reflexology via the Ear 519
19.7 Aging and the Special Senses 521
Key Medical Terms Associated with Somatic and Special Senses 522
Exhibit 19.1 Contributions of the Nervous System to Homeostasis 523

MANUAL THERAPY APPLICATION
Reducing Pain through Massage 503

• CLINICAL CONNECTIONS
Phantom Limb Sensation 501
Analgesia 502
Night Blindness and Color Blindness 514
Study Outline 522
Self-Quiz Questions 525
Critical Thinking Questions 526
Answers to Figure Questions 526

20 THE ENDOCRINE SYSTEM 527
20.1 Endocrine Glands 528
20.2 Hormone Action 528
Target Cells and Hormone Receptors 528
Chemistry of Hormones 528
Mechanisms of Hormone Action 528
Control of Hormone Secretions 528
20.3 Hypothalamus and Pituitary Gland 530
Anterior Pituitary Hormones 531
Posterior Pituitary Hormones 533
20.4 Thyroid Gland 535
Actions of Thyroid Hormones 535
Control of Thyroid Hormone Secretion 536
Calcitonin 537
20.5 Parathyroid Glands 538
20.6 Pancreatic Islets 539
Actions of Glucagon and Insulin 540
20.7 Adrenal Glands 542
Adrenal Cortex Hormones 543
Adrenal Medulla Hormones 545
20.8 Ovaries and Testes 545
20.9 Pineal Gland 545
20.10 Other Hormones 546
Hormones from Other Endocrine Cells 546
Prostaglandins and Leukotrienes 546
20.11 The Stress Response 547
20.12 Aging and the Endocrine System 547
Key Medical Terms Associated with the Endocrine System 548
Exhibit 20.1 Contributions of the Endocrine System to Homeostasis 549

MANUAL THERAPY APPLICATIONS
Effects of Massage on the Diabetic Patient 542
Seasonal Affective Disorder 546

• CLINICAL CONNECTIONS
Pituitary Gland Disorders 532
Thyroid Disorders 537
Parathyroid Gland Disorders 539
Pancreatic Islet Disorders 541
Adrenal Gland Disorders 544
Congenital Adrenal Hyperplasia 545
Posttraumatic Stress Disorder 547
Study Outline 548
Self-Quiz Questions 551
Critical Thinking Questions 552
Answers to Figure Questions 552

21 THE CARDIOVASCULAR SYSTEM: THE BLOOD 553
21.1 Functions of Blood 554
21.2 Components of Whole Blood 554
Blood Plasma 554
Formed Elements 554
21.3 Hemostasis 563
Vascular Spasm 564
Platelet Plug Formation 564
Blood Clotting 564
Hemostatic Control Mechanisms 566
Clotting in Blood Vessels 566
21.4 Blood Groups and Blood Types 566
ABO Blood Group 567
Rh Blood Group 567
Transfusions 568
Key Medical Terms Associated with Blood 568
22 | THE CARDIOVASCULAR SYSTEM: THE HEART 571

22.1 Structure and Organization of the Heart 572
Location and Coverings of the Heart 572
Heart Wall 575  Chambers of the Heart 575
Great Vessels of the Heart 577
Valves of the Heart 577

22.2 Blood Flow and Blood Supply of the Heart 579
Blood Flow through the Heart 579
Blood Supply of the Heart 579
Myocardial Ischemia and Infarction 580

22.3 Conduction System of the Heart 581

22.4 Electrocardiogram 583
Arrhythmias 583

22.5 The Cardiac Cycle 584
Pressure and Volume Changes during the Cardiac Cycle 584
Heart Sounds 586

22.6 Cardiac Output 586
Regulation of Stroke Volume 586  Regulation of Heart Rate 589

22.7 Exercise and the Heart 590
Key Medical Terms Associated with the Heart 590

23 | THE CARDIOVASCULAR SYSTEM: BLOOD VESSELS AND CIRCULATION 594

23.1 Blood Vessel Structure and Function 595
Arteries and Arterioles 595  Capillaries 595
Veins and Veins 597

23.2 Blood Flow Through Blood Vessels 599
Blood Pressure 599  Resistance 600
Regulation of Blood Pressure and Blood Flow 600

23.3 Checking Circulation 603
Pulse 603  Measurement of Blood Pressure 603

24 | THE LYMPHATIC SYSTEM AND IMMUNITY 627

24.1 Overview of Immunity 628

24.2 Lymphatic System Structure and Function 628
Lymphatic Vessels and Lymph Circulation 628
Lymphatic Organs and Tissues 631

24.3 Innate Immunity 634
First Line of Defense: Skin and Mucous Membranes 634
Second Line of Defense: Internal Defenses 634

24.4 Adaptive Immunity 636
Maturation of T cells and B cells 637
Types of Adaptive Immune Responses 637
Antigens and Antibodies 637
Processing and Presenting Antigens 638
T Cells and Cell-Mediated Immunity 639
B Cells and Antibody-Mediated Immunity 642
Immunological Memory 643

24.5 Aging and the Immune System 645
Exhibit 24.5 Contributions of the Lymphatic System and Immunity to Homeostasis 646
Key Medical Terms Associated with the Lymphatic System 647

Other sections and topics are also present in the document, covering various aspects of the cardiovascular and lymphatic systems, clinical connections, and manual therapy applications.
25  THE RESPIRATORY SYSTEM 651

25.1 Overview of the Respiratory System 652
25.2 Organs of the Respiratory System 653
Nose 653  Pharynx 654  Larynx 654  Trachea 656  Bronchi and Bronchioles 656  Lungs 657
25.3 Pulmonary Ventilation 660
Muscles of Inhalation and Exhalation 661  Pressure Changes During Ventilation 662  Lung Volumes and Capacities 662  Breathing Patterns and Modified Respiratory Movements 664
25.4 Exchange of Oxygen and Carbon Dioxide 664
External Respiration: Pulmonary Gas Exchange 665  Internal Respiration: Systemic Gas Exchange 665
25.5 Transport of Respiratory Gases 667
Oxygen Transport 667  Carbon Dioxide Transport 667
25.6 Control of Respiration 667
Respiratory Center 668  Regulation of the Respiratory Center 669
25.7 Exercise and the Respiratory System 671
25.8 Aging and the Respiratory System 671
Exhibit 25.1 Contributions of the Respiratory System to Homeostasis 672
Key Medical Terms Associated with the Respiratory System 673

MANUAL THERAPY APPLICATION
Abdominal Massage 657

• CLINICAL CONNECTIONS
Cough Reflex 654  Asthma 657  Cigarette Smoking 660
High Altitude Sickness 665  Carbon Monoxide Poisoning 667
Chronic Obstructive Pulmonary Disease 671

Study Outline 673  Self-Quiz Questions 675
Critical Thinking Questions 676  Answers to Figure Questions 676

26  THE DIGESTIVE SYSTEM 677

26.1 Overview of the Digestive System 678
26.2 Layers of the GI Tract and the Peritoneum 679
26.3 Mouth 681
Tongue 681  Salivary Glands 682  Teeth 682  Digestion in the Mouth 683
26.4 Pharynx and Esophagus 683
26.5 Stomach 685
Structure of the Stomach 686  Digestion and Absorption in the Stomach 687
26.6 Pancreas 688
Structure of the Pancreas 688  Pancreatic Juice 688
26.7 Liver and Gallbladder 688
Structure of the Liver and Gallbladder 688  Blood Supply of the Liver 690  Bile 690  Functions of the Liver 691
26.8 Small Intestine 692
Structure of the Small Intestine 692  Intestinal Juice 694  Mechanical Digestion in the Small Intestine 694  Chemical Digestion in the Small Intestine 694  Absorption in the Small Intestine 695
26.9 Large Intestine 697
Structure of the Large Intestine 697  Digestion and Absorption in the Large Intestine 700  The Defecation Reflex 700
26.10 Phases of Digestion 700
Cephalic Phase 700  Gastric Phase 700  Intestinal Phase 701
26.11 Aging and the Digestive System 701
Exhibit 26.1 The Digestive System and Homeostasis 702
Key Medical Terms Associated with the Digestive System 703

MANUAL THERAPY APPLICATION
Abdominal Massage 697

• CLINICAL CONNECTIONS
Heartburn 685  Peptic Ulcer Disease 686  Pancreatic Cancer 688  Gallstones 691  Hepatitis 691  Colon Pathologies 698

Study Outline 703  Self-Quiz Questions 705
Critical Thinking Questions 706  Answers to Figure Questions 706

27  NUTRITION AND METABOLISM 707

27.1 Nutrients 708
Guidelines for Healthy Eating 708  Minerals 709  Vitamins 710
27.2 Metabolism 711
Carbohydrate Metabolism 714  Lipid Metabolism 716  Protein Metabolism 718
27.3 Metabolism and Body Heat 719
Measuring Heat 719  Body Temperature Homeostasis 719  Regulation of Body Temperature 720
Key Medical Terms Associated with Nutrition and Metabolism 722

MANUAL THERAPY APPLICATION
Carbohydrate Loading: Great for Marathoners 716

• CLINICAL CONNECTIONS
Diets 709  Supplements 711  Ketosis 717  Exercise Training and Metabolism 722

Study Outline 723  Self-Quiz Questions 724
Critical Thinking Questions 725  Answers to Figure Questions 725

28  THE URINARY SYSTEM 726

28.1 Overview of the Urinary System 727
28.2 Structure of the Kidneys 728
External Anatomy of the Kidneys 728  Internal Anatomy of the Kidneys 728  Renal Blood Supply 728  Nephrons 729
28.3 Functions of the Nephron 732
Glomerular Filtration 732  Tubular Reabsorption and Secretion 734
Components of Urine 736
28.4 Transportation, Storage, and Elimination of Urine 737
   Ureters 737  Urinary Bladder 737
   Urethra 737  Micturition 738

28.5 Aging and the Urinary System 739
Key Medical Terms Associated with the Urinary System 739
Exhibit 28.1 The Urinary System and Homeostasis 740

MANUAL THERAPY APPLICATION
Massage and the Kidney 728

CLINICAL CONNECTIONS
Kidney Transplant 729  Number of Nephrons 730
Oliguria and Anuria 733  Glucosuria and Polyuria 734
Urinalysis 734  Diuretics 736

Study Outline 741  Self-Quiz Questions 741
Critical Thinking Questions 743  Answers to Figure Questions 743

29 THE REPRODUCTIVE SYSTEMS 744

29.1 Introduction to the Reproductive Systems 745

29.2 Male Reproductive System 745
   Scrotum 745  Testes 745
   Ducts 749  Accessory Sex Glands 750  Penis 752

29.3 Female Reproductive System 752
   Ovaries 752  Uterine Tubes 755
   Uterus 755  Vagina 756
   Perineum and Vulva 756
   Mammary Glands 758

29.4 Female Reproductive Cycle 759
   Hormonal Regulation of the Female Reproductive Cycle 759
   Phases of the Female Reproductive Cycle 759

29.5 Aging and the Reproductive Systems 763
Exhibit 29.1 The Reproductive Systems and Homeostasis 765
Key Medical Terms Associated with the Reproductive Systems 766

MANUAL THERAPY APPLICATION
Benefits of Massage During Pregnancy 764

CLINICAL CONNECTIONS
Cryptorchidism 745  Vasectomy 750  Prostate Disorders 750
Circumcision 752  Ovarian Cancer 754  Hysterectomy 755
Episiotomy 757  Breast Cancer 758  Premenstrual Syndrome 761
The Female Athlete Triad—Disordered Eating, Amenorrhea, and Premature Osteoporosis 763

Study Outline 766  Self-Quiz Questions 767
Critical Thinking Questions 769  Answers to Figure Questions 769

APPENDIX A: MEASUREMENTS A1
B: PERIODIC TABLE B3
C: ANSWERS C4

GLOSSARY G1
CREDITS CR1
INDEX I1