

BRS

BOARD REVIEW SERIES

Gross Anatomy

NINTH EDITION

Nancy L. Halliday

Harold M. Chung



Wolters Kluwer

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Special Dedication to Kyung Won Chung, PhD

Dr. Kyung Won Chung was the original author of the first eight editions of *BRS Gross Anatomy*. He was proud of this work, which represented his vast knowledge of anatomy and his passion for teaching.

Dr. Nancy Halliday considered Kyung Chung to be a mentor who had a great impact on her development, both as a graduate student and later in her professional career. When invited to be an author for the eighth edition of *BRS Gross Anatomy*, she considered it a distinct honor and privilege to join her mentor in this, his life's, work. Her desire going forward is to continue his legacy by being a careful steward of his work represented in *BRS Gross Anatomy*.

Dr. Harold Chung grew up with a very close relationship with his father, Kyung Chung. He has collaborated with him since the fourth edition of *BRS Gross Anatomy* in 2000 in adding to the clinical aspect of the book. As he spent countless hours working with him for the last five editions, he experienced firsthand his father's incredible patience and work ethic, which he hopes he continues with his lessons in his own life, his work, and most importantly his family.

We lost a great father, teacher, mentor, and friend with the passing of Kyung Won Chung, PhD.



Dedication

To Frank, my husband and best friend, with deep gratitude for his unwavering support and encouragement. And to my students (past, present, and future) who inspire me.

—*Nancy L. Halliday*

To Kathie, my wife, best friend, and soul partner, and to my daughters Kira, Liah, and Maia, for their love, support, and understanding.

—*Harold M. Chung*



Preface

Anatomy is the science of studying and understanding the structure and organization of the body. The art of medicine requires a strong foundation in the basic medical sciences, and anatomy is a keystone in that foundation. This concise review of human anatomy is designed for medical, dental, graduate, physician associate, nursing, physical therapy, and other health science students. It is intended to help students prepare for the United States Medical Licensing Examination (USMLE), the National Board Dental Examination, as well as other board examinations for students in health-related professions. It presents the essentials of human anatomy in the form of condensed descriptions and simple illustrations. The book is concisely outlined with related board-type questions following each section. It is not intended to substitute for comprehensive textbooks or for course syllabi, although the student may find it a useful adjunct to gross anatomy courses.

The first chapter reviews general concepts of gross anatomy. The remaining chapters are organized by anatomical regions. Numerous clinical correlations are included in each chapter to emphasize the clinical applications of anatomy. The cranial and autonomic nervous system are separated from the head and neck chapter and are described more extensively with high-quality illustrations to facilitate thorough understanding of cranial and autonomic nerve functions.

The chapter review tests and comprehensive examination at the end of the book consist of questions and answers that reflect the guidelines set forth by the National Board of Medical Examiners and the current USMLE format. The questions reinforce the key information and test basic anatomic knowledge and the students' clinical problem-solving ability. The tests are useful in identifying knowledge gaps to guide independent study. Clear, concise explanations accompany the questions. The questions can be used as a pretest to identify areas of weakness or as a posttest to determine mastery.

New to this edition:

- Addition of updated and new full-color figures
- Updated text and tables
- Updated clinical correlations

It is the authors' intention to invite feedback comments, constructive criticisms, and valuable suggestions from students and colleagues who choose this book as an aid to learning and teaching basic and clinical anatomy.

*Nancy L. Halliday
Harold M. Chung*



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We express our sincere thanks to the many students, colleagues, and friends who have made valuable suggestions that have led to the improvement of the ninth edition. We are particularly grateful to Rob Jackson, PhD, for providing his invaluable criticism of the text as well as for his copyediting during the preparation phase of this current edition. Our grateful appreciation is also extended to John M. Chung, MD, for providing his invaluable criticism of the text and clinically oriented test questions as well as for his copyediting during the preparation phases of previous editions. We are also grateful to Daniel O'Donoghue, PhD, for his encouragement, constructive criticism of the text and clinical notes, and helpful suggestions during the preparation of this current edition, as well as previous editions. Finally, we greatly appreciate and enjoy the privilege of working with the Wolters Kluwer staff, including Crystal Taylor, Acquisitions Editor; Kerry McShane, Editorial Coordinator; Andrea Vosburgh, Development Editor; Jennifer Clements, Art Director; Jeethu Abraham, Senior Project Manager; and Alicia Jackson, Senior Production Project Manager. We thank the staff for their constant guidance, enthusiasm, and unfailing support throughout the preparation, production, and completion of this new edition.

Contents

Preface vii

Acknowledgments viii

1. INTRODUCTION

1

Skeletal System 1

- I. Bones 1
- II. Joints 2

Muscular System 4

- I. Muscle 4
- II. Structures Associated With Skeletal Muscles 5

Nervous System 5

- I. Nervous System 5
- II. Neurons 6
- III. Central Nervous System 7
- IV. Peripheral Nervous System 7
- V. Autonomic Nervous System 9

Circulatory System 11

- I. Vascular System 11
- II. Lymphatic System 12

Organ Systems 13

- I. Digestive System 13
- II. Respiratory System 14
- III. Urinary System 14
- IV. Reproductive System 14
- V. Endocrine System 15
- VI. Integumentary System 15
- High-Yield Topics 15

Review Test 18

2. BACK

22

Vertebral Column 22

- I. General Characteristics 22
- II. Typical Vertebra 24
- III. Intervertebral Disks 26
- IV. Regional Characteristics of Vertebrae 27
- V. Ligaments of the Vertebral Column 29
- VI. Vertebral Venous System 30

Structures of the Back 31

- I. Superficial Back 31
- II. Structures of the Deep Back 33
- III. Suboccipital Region 34

Spinal Cord and Associated Structures 36

- I. Spinal Cord 36
- II. Spinal Nerves 37
- III. Meninges 38
- IV. Structures Associated With the Spinal Cord 40
- V. Dermatome, Myotome, and Sclerotome 41
- VI. Development of Back Structures 42
- High-Yield Topics 42

Review Test 45**3. THORAX****52****Thoracic Wall 52**

- I. Skeleton of the Thorax 52
- II. Articulations of the Thorax 54
- III. Breasts and Mammary Glands 55
- IV. Muscles of the Thoracic Wall 55
- V. Nerves and Blood Vessels of the Thoracic Wall 55
- VI. Lymphatic Drainage of the Thorax 56
- VII. Thymus 56
- VIII. Diaphragm and Its Openings 57

Mediastinum, Pleura, and Organs of Respiration 57

- I. Mediastinum 57
- II. Trachea and Bronchi 58
- III. Pleurae and Pleural Cavities 59
- IV. Lungs 62
- V. Respiration 64
- VI. Lymphatic Vessels of the Lung 65
- VII. Blood Vessels of the Lung 65
- VIII. Nerve Supply to the Lung 67
- IX. Development of the Respiratory System 68

Pericardium and Heart 69

- I. Pericardium 69
- II. Heart 70
- III. Great Vessels 79
- IV. Development of the Heart 80
- V. Development of the Arterial System 83
- VI. Development of the Venous System 84
- VII. Fetal Circulation 84

Structures in the Posterior Mediastinum 85

- I. Esophagus 85
- II. Blood Vessels and Lymphatic Vessels 86
- III. Autonomic Nervous System in the Thorax 89
- High-Yield Topics 91

Review Test 97

4. ABDOMEN

109

Anterior Abdominal Wall 109

- I. Abdomen 109
- II. Muscles of the Anterior Abdominal Wall 110
- III. Fasciae and Ligaments of the Anterior Abdominal Wall 110
- IV. Inguinal Region 112
- V. Spermatic Cord, Scrotum, and Testis 113
- VI. Inner Surface of the Anterior Abdominal Wall 114
- VII. Nerves of the Anterior Abdominal Wall 115
- VIII. Lymphatic Drainage of the Anterior Abdominal Wall 116
- IX. Blood Vessels of the Anterior Abdominal Wall 116

Peritoneum and Peritoneal Cavity 117

- I. Peritoneum 117
- II. Peritoneal Reflections 117
- III. Peritoneal Cavity 119

Gastrointestinal (GI) Viscera 120

- I. Esophagus (Abdominal Portion) 120
- II. Stomach 121
- III. Small Intestine 123
- IV. Large Intestine 124
- V. Accessory Organs of the Digestive System 126
- VI. Spleen 130
- VII. Development of Digestive System 131
- VIII. Celiac and Mesenteric Arteries 133
- IX. Hepatic Portal Venous System 137

Retroperitoneal Viscera, Diaphragm, and Posterior Abdominal Wall 140

- I. Kidney, Ureter, and Suprarenal Gland 140
 - II. Development of Kidney, Urinary Bladder, and Suprarenal Gland 143
 - III. Posterior Abdominal Blood Vessels and Lymphatics 144
 - IV. Nerves of the Posterior Abdominal Wall 145
 - V. The Diaphragm and Its Openings 148
 - VI. Muscles of the Posterior Abdominal Wall 150
- High-Yield Topics 150

Review Test 156

5. PERINEUM AND PELVIS

170

Perineal Region 170

- I. Perineum 170
- II. Urogenital Triangle 170
- III. Anal Triangle 174
- IV. External Genitalia and Associated Structures 175
- V. Nerve Supply of the Perineal Region 178
- VI. Blood Supply of the Perineal Region 180

Pelvis 181

- I. Bony Pelvis 181
- II. Joints of the Pelvis 184
- III. Pelvic Diaphragm 184

- IV. Ligaments or Folds and Pouches of the Pelvis 184
- V. Ureter and Urinary Bladder 186
- VI. Male Genital Organs 190
- VII. Female Genital Organs 194
- VIII. Rectum and Anal Canal 197
- IX. Blood Vessels of the Pelvis 199
- X. Nerve Supply to the Pelvis 202
- XI. Development of the Lower Gastrointestinal Tract and Urinary Organs 203
- XII. Development of the Reproductive System 205

Review Test 211

6. LOWER LIMB

224

Bones of the Lower Limb 224

- I. Hip (Coxal) Bone (Os Coxa) 224
- II. Bones of the Thigh and Leg 226
- III. Bones of the Ankle and Foot 228

Joints and Ligaments of the Lower Limb 230

- I. Hip (Coxal) Joint 230
- II. Knee Joint 232
- III. Tibiofibular Joints 236
- IV. Ankle (Talocrural) Joint 236
- V. Tarsal Joints 237

Cutaneous Nerves, Superficial Veins, and Lymphatics 238

- I. Cutaneous Nerves of the Lower Limb 238
- II. Superficial Veins of the Lower Limb 240
- III. Lymphatics of the Lower Limb 240

Muscles of the Lower Limb 241

- I. Muscles of the Gluteal Region 241
- II. Posterior Muscles of the Thigh 242
- III. Muscles of the Anterior and Medial Thigh 243
- IV. Anterior and Lateral Muscles of the Leg 245
- V. Posterior Muscles of the Leg 246
- VI. Muscles of the Foot 247

Nerves of the Lower Limb 250

- I. Branches of the Lumbar and Sacral Plexuses 250

Blood Vessels of the Lower Limb 254

- I. Arteries of the Lower Limb 254
- II. Deep Veins of the Lower Limb 258
- III. Development of the Lower Limb 259
- High-Yield Topics 259
- Summary 263

Review Test 265

7. UPPER LIMB 280

Bones and Joints of the Upper Limb 280

- I. Bones of the Shoulder Girdle 280
- II. Bones of the Arm and Forearm 282
- III. Bones of the Hand 285
- IV. Joints and Ligaments of the Upper Limb 286

Cutaneous Nerves, Superficial Veins, and Lymphatics 288

- I. Cutaneous Nerves of the Upper Limb 288
- II. Superficial Veins of the Upper Limb 290
- III. Superficial Lymphatics of the Upper Limb 291

Axilla and Breast 291

- I. Fasciae of the Axilla and Pectoral Regions 291
- II. Axilla (Armpit) 292
- III. Breast and Mammary Gland 295

Muscles of the Upper Limb 298

- I. Muscles of the Pectoral Region and Axilla 298
- II. Muscles of the Shoulder Region 299
- III. Muscles of the Arm and Forearm 301
- IV. Muscles of the Hand 303

Nerves of the Upper Limb 308

- I. Brachial Plexus 308
- II. Nerves of the Arm, Forearm, and Hand 311
- III. Functional Components of the Peripheral Upper Limb Nerves 314

Blood Vessels of the Upper Limb 315

- I. Branches of the Subclavian Artery 315
- II. Axillary Artery 315
- III. Brachial Artery 316
- IV. Radial Artery 317
- V. Ulnar Artery 318
- VI. Veins of the Upper Limb 319
- VII. Development of the Limbs 320
- High-Yield Topics 321
- Summary 323

Review Test 327

8. HEAD AND NECK

345

Structures of the Neck 345

- I. Major Divisions and Bones 345
- II. Muscles 347
- III. Nerves 348
- IV. Blood Vessels 350
- V. Lymphatics 356

Deep Neck and Prevertebral Region 357

- I. Deep Structures of the Neck 357
- II. Deep Cervical Fasciae 360
- III. Prevertebral or Deep Neck Muscles 362
- IV. Development of Thyroid and Parathyroid Gland 362

Face and Scalp 363

- I. Muscles of Facial Expression 363
- II. Nerve Supply to the Face and Scalp 364
- III. Blood Vessels of the Face and Scalp 366
- IV. Scalp 368

Temporal and Infratemporal Fossae 369

- I. Introduction 369
- II. Muscles of Mastication 371
- III. Nerves of the Infratemporal Region 372
- IV. Blood Vessels of the Infratemporal Region 373
- V. Parotid Gland 375
- VI. Joints and Ligaments of the Infratemporal Region 376

Skull and Cranial Cavity 377

- I. Skull 377
- II. Bones of the Cranium 377
- III. Sutures of the Skull 378
- IV. Foramina in the Skull 379
- V. Structures in the Cranial Fossae 382
- VI. Meninges of the Brain 383
- VII. Cranial Venous Channels 385
- VIII. Blood Supply of the Brain 386
- IX. Nerves of the Head and Neck 388
- X. Development of the Skull 388

Orbit 389

- I. Bony Orbit 389
- II. Nerves 391
- III. Blood Vessels 393
- IV. Muscles of Eye Movement 395
- V. Lacrimal Apparatus 397
- VI. Eyeball 398
- VII. Development of the Eye 401

Oral Cavity and Palate 401

- I. Oral Cavity 401
- II. Palate 402
- III. Tongue 404
- IV. Teeth and Gums or Gingivae 405
- V. Salivary Glands 407
- VI. Development of the Palate 408
- VII. Development of the Tongue 408
- VIII. Development of Teeth 408
- IX. Development of Salivary Glands 409

Pharynx and Tonsils 409

- I. Pharynx 409
- II. Subdivisions of the Pharynx 409
- III. Innervation and Blood Supply of the Pharynx 410
- IV. Muscles of the Pharynx 411
- V. Swallowing (Deglutition) 412
- VI. Tonsils 412
- VII. Fascia and Space of the Pharynx 413
- VIII. Pharyngeal (Branchial) Apparatus 414

Nasal Cavity and Paranasal Sinuses 415

- I. Nasal Cavity 415
- II. Subdivisions and Mucous Membranes 417
- III. Blood Supply to the Nasal Cavity 417
- IV. Nerve Supply to the Nasal Cavity 418
- V. Paranasal Sinuses 418
- VI. Development of the Nasal Cavity 419

Pterygopalatine Fossa 420

- I. Boundaries and Openings 420
- II. Contents 420

Larynx 422

- I. Introduction 422
- II. Cartilages 422
- III. Ligaments of the Larynx 423
- IV. Cavities and Folds 424
- V. Muscles 425
- VI. Innervation 426
- VII. Development of the Larynx 427

Ear 427

- I. External Ear 427
- II. Middle Ear 429
- III. Inner Ear 432
- IV. Hearing and Equilibrium 433
- V. Development of the Ear 433
- High-Yield Topics 434

Review Test 446**9. CRANIAL AND AUTONOMIC NERVES 463**

- I. Cranial Nerves 463
- II. Autonomic Nerves of the Head 476
- High-Yield Topics 480

Review Test 483**Comprehensive Examination 489****Index 510**

2. Metaphysis

- Is the broadened region of the diaphysis adjacent to the epiphysis. Growth plates are located between the metaphysis and epiphysis during bone development.

3. Epiphyses

- Are **expanded articular ends**, separated from the shaft by the epiphyseal plate during bone growth and composed of a **spongy bone** surrounded by a thin layer of **compact bone**.

B. Short bones

- Include the carpal and tarsal bones and are approximately cuboid shaped.
- Are composed of **spongy bone** and **marrow** surrounded by a thin outer layer of **compact bone**.

C. Flat bones

- Include the ribs, sternum, scapulae, and bones of the cranial vault.
- Consist of **two layers of compact bone** enclosing **spongy bone** with a **marrow space (diploë)**.
- Have articular surfaces that are covered with fibrocartilage and grow by the replacement of connective tissue.

D. Irregular bones

- Include bones of mixed shapes, such as bones of the face, vertebrae, and coxa.
- Contain mostly **spongy bone** enveloped by a thin outer layer of **compact bone**.

E. Sesamoid bones

- **Develop** in certain **tendons** and reduce friction on the tendon and shift the mechanical advantage, thus protecting it from excessive wear.
- Are commonly found where certain tendons cross synovial articulations at the ends of long bones in the limbs, as in the wrist (i.e., pisiform) and the knee (i.e., patella).

CLINICAL CORRELATES

Osteoblasts synthesize new bone, and **osteoclasts** function in resorption (break down bone matrix and release calcium and minerals). Bone remodeling is a normal metabolic process and includes both processes. Parathyroid hormone causes mobilization of calcium by promoting bone resorption, whereas calcitonin and bisphosphonates suppress mobilization of calcium from bone. **Osteoid** is the organic matrix of bone prior to calcification.

Osteomyelitis is an infection of the bone with organisms such as *Staphylococcus* or *Streptococcus* (from penetrating trauma), *Salmonella*, or tuberculosis (Pott disease).

Osteomalacia is a gradual softening of a bone caused by mechanical forces or metabolic issues such as failure of the bone to calcify because of lack of vitamin D or renal tubular dysfunction. **Osteopenia** is a decreased calcification of bone or a reduced bone mass caused by inadequate osteoid synthesis. **Osteopenia** is an age-related disorder characterized by decreased bone mass and increased susceptibility to pathologic fractures (**osteoporosis**) of the hip, vertebra, and wrist. When bone resorption outpaces bone formation during bone remodeling, the bones weaken. Normal bone metabolism is characterized by constant cycles of resorption and formation (remodeling) to maintain the concentration of calcium and phosphate in the extracellular fluid. The pathologic signs of osteoporosis are vertebral compression, loss of body height, development of kyphosis, and hip fracture. **Osteopetrosis** is a disease that makes bones abnormally dense and prone to fracture, because of defective resorption of bone.

II. JOINTS

- Are places of union between two or more bones.
- Are innervated as follows: the nerve supplying a joint also supplies the muscles that move the joint and the skin covering the insertion of such muscles (**Hilton law**).
- Are classified on the basis of their structural features into fibrous, cartilaginous, and synovial types.

A. Fibrous joints (synarthroses)

- Are joined by fibrous tissue, have **no joint cavities**, and permit little movement.
 1. **Sutures**
 - Are connected by fibrous connective tissue, such as the fibrous continuities between the flat bones of the skull.
 2. **Syndesmoses**
 - Are connected by dense fibrous connective tissue.
 - Occur as the inferior tibiofibular syndesmoses and tympanostapedial syndesmoses (between the foot plate of the stapes and the oval window in the middle ear).

B. Cartilaginous joints

- Are united by **cartilage** and have **no joint cavity**.
 1. **Primary cartilaginous joints (synchondroses)**
 - Are united by **hyaline cartilage** and permit little to no movement but allow for growth in length during childhood and adolescence.
 - Include epiphyseal cartilage plates (the union between the epiphysis and the diaphysis of a growing bone) and sphenoid-occipital and manubriosternal synchondroses.
 2. **Secondary cartilaginous joints (symphyses)**
 - Are joined by **fibrocartilage** and are slightly movable joints.
 - Are all located in the median plane and include the pubic symphysis and the intervertebral disks.

C. Synovial (diarthrodial) joints

- Are found between two separate skeletal elements and permit certain degrees of movement according to the shape of the articulation and/or the type of movement.
- Are characterized by four structural features: joint cavity or space, articular (hyaline) cartilage, synovial membrane, which produces synovial fluid, and articular capsule.
 1. **Plane (gliding) joints**
 - Have flat articular surfaces and allow a simple back-and-forth **gliding** or sliding of one bone over the other.
 - Occur in the proximal tibiofibular, intertarsal, intercarpal, intermetacarpal, carpometacarpal, sternoclavicular, and acromioclavicular joints.
 2. **Hinge (ginglymus) joints**
 - Resemble **door hinges** and allow only flexion and extension.
 - Occur in the elbow, ankle, and interphalangeal joints.
 3. **Pivot (trochoid) joints**
 - Are formed by a central bony pivot turning within a bony ring and allow **only rotation** (movement around a single longitudinal axis).
 - Occur in the superior and inferior radioulnar joints and in the atlantoaxial joint.
 4. **Condylar (ellipsoidal) joints**
 - Have two convex condyles articulating with two concave condyles. (The shape of the articulation is **ellipsoidal**.)
 - Allow flexion and extension and occur in the wrist (radiocarpal), metacarpophalangeal, knee (tibiofemoral), and atlanto-occipital joints.
 5. **Saddle (sellar) joints**
 - Resemble the shape of a horse's **saddle** and allow flexion/extension, abduction/adduction, and circumduction, but no axial rotation.
 - Occur in the carpometacarpal joint of the thumb and between the femur and patella.
 6. **Ball-and-socket (spheroidal or cotyloid) joints**
 - Are formed by the reception of a globular (ball-like) head into a cup-shaped cavity and allow movement in many directions.
 - Allow flexion and extension, abduction and adduction, medial and lateral rotations, and circumduction and occur in the shoulder and hip joints.

CLINICAL CORRELATES

Osteoarthritis is a degenerative joint disease driven by inflammatory mediators produced by bone cells, chondrocytes, and synovial membranes. Osteoarthritis results in the degeneration of the articular cartilage and osseous outgrowth at the synovial margins. There are a number of predisposing factors including injury and obesity. It commonly affects the hands, fingers, hips, knees, feet, and spine and is accompanied by pain and stiffness. **Rheumatoid arthritis** is an inflammatory disease driven by immunologic attack primarily of the joints. Antibodies directed at the synovial membranes and articular structures lead to deformities and disability. While no cure is known, there are several disease-modifying options. The most common symptoms are joint swelling, stiffness, and pain. **Gout** is a painful form of crystalline arthritis and is caused by uric acid crystal deposits into joint spaces from the blood. These deposits cause inflammation and pain, heat, redness, stiffness, tenderness, and swelling of the first toe or thumb, characteristically, but can impact other joints as well. **Pseudogout** has similar clinical presentation but is related to calcium crystal deposits usually after chronic injury.

MUSCULAR SYSTEM

I. MUSCLE

- Consists predominantly of **contractile cells**, produces the **movements** of various parts of the body by contraction, and occurs in three types:

A. Skeletal muscle

- Is considered voluntary and has a striated histologic structure to its component myofibrils.
- Makes up approximately 40% of the total body mass and functions to produce movement of the body, generate body heat, and maintain body posture.
- Has two attachments: an **origin**, which is usually defined by a more fixed and proximal attachment, and an **insertion**, which is typically defined as the more movable and distal attachment.
- Is enclosed by fascia, the **epimysium**, which is a thin but tough layer of connective tissue surrounding the entire muscle. Within the muscle, smaller bundles of muscle fibers are surrounded by **perimysium**. Each individual muscle fiber is enclosed by **endomysium**.

CLINICAL CORRELATES

Amyotrophic lateral sclerosis (ALS, or Lou Gehrig disease) is a disease that attacks the motor neurons that control voluntary muscles. The muscles weaken and atrophy. Ultimately, the brain is unable to control voluntary movement of the arms, legs, and body, and patients lose the ability to breath, swallow, and speak. The earliest symptoms may include cramping, twitching, and muscle weakness.

B. Cardiac muscle

- Is striated muscle fibers found in the wall of the heart, the **myocardium**.
- Cardiac muscle contractions are autonomous, but the rate can be modulated by the autonomic nervous system (ANS).
- Includes subendocardial specialized myocardial fibers that form the cardiac **conducting system**.

C. Smooth muscle

- Is involuntary and nonstriated and found in the walls of organs and blood vessels.
- In the walls of hollow organs, smooth muscle is arranged in two layers, **circular** and **longitudinal**, that allow rhythmic contractions called **peristaltic waves** in the walls of the gastrointestinal (GI) tract, uterine tubes, ureters, and other organs.
- Is innervated by the ANS, regulating the size of the lumen of a tubular structure.

II. STRUCTURES ASSOCIATED WITH SKELETAL MUSCLES

A. Tendons

- Are **fibrous bands** of dense connective tissue that **connect muscles to bones** or cartilage.
- Are supplied by sensory fibers extending from muscle nerves.

B. Ligaments

- Are **fibrous bands** that **connect bones to bones** or cartilage (the term is also used for folds of peritoneum serving to support visceral structures).

C. Raphe

- Is a seam of union of symmetrical structures by a fibrous or tendinous band, such as the pterygomandibular, pharyngeal, and scrotal raphes.

D. Aponeuroses

- Are **flat fibrous tendons of attachment** that serve as the means of origin or insertion of a muscle.

E. Retinaculum

- Is a fibrous thickening of the deep fascia that stabilizes tendons and neurovascular structures as they cross a joint in the distal limbs.

F. Bursae

- Are fluid-filled **flattened sacs of synovial membrane** that facilitate movement by minimizing friction between a bony joint and the surrounding soft tissue, such as skin, muscles, ligaments.

G. Synovial tendon sheaths

- Are synovial fluid-filled **tubular sacs** around **muscle tendons** that facilitate movement by reducing friction as tendons pass distally into the limbs.

H. Fascia

- Is a **fibrous sheet** that envelops the body under the skin and invests the muscles and may limit the spread of pus and extravasated fluids, such as urine and blood.

1. Superficial fascia

- Is a fatty connective tissue between the dermis and the deep muscular fascia and is considered the hypodermis with fat, cutaneous vessels, nerves, lymphatics, and glands. In a few locations, there may be a **membranous deep layer of superficial fascia (abdominal wall)**.

2. Deep fascia

- Is a sheet of fibrous tissue that **invests the muscles** and helps support them by serving as an elastic sheath or stocking.
- Provides origins or insertions for muscles, forms fibrous sheaths or retinacula for tendons, and forms potential pathways for spread of infection or extravasation of fluids.

NERVOUS SYSTEM

I. NERVOUS SYSTEM

- Is divided anatomically into the central nervous system (CNS), consisting of the brain and spinal cord, and the peripheral nervous system (PNS), consisting of 12 pairs of cranial nerves and 31 pairs of spinal nerves and their associated ganglia.
- Is divided functionally into the **somatic** nervous system, which controls primarily voluntary activities, and the **visceral (autonomic)** nervous system, which controls primarily involuntary activities.
- Is composed of **neurons** and **neuroglia** (non-neuronal cells such as astrocytes, oligodendrocytes, and microglia) and controls and integrates the body activity.

II. NEURONS

- Are the structural and functional units of the nervous system (neuron doctrine).
- Are specialized for the reception, integration, transformation, and transmission of information.

A. Components of neurons

1. Collections of neuronal **cell bodies** are termed **gray matter** or nuclei in the CNS, and collections of neuronal cell bodies are called ganglia in the PNS.
2. Dendrites (dendron means “tree”) are highly branched extensions from the cell body that carry impulses from local circuitry toward the cell body.
3. Axons are usually single and long, have fewer branches (collaterals), and carry impulses away from the cell body.

B. Classification of neurons based on shape

1. Unipolar (pseudounipolar) neurons

- Have **one process**, which divides into a branch directed at the CNS and a peripheral branch that brings information toward the cell body from peripheral receptors.
- Are called pseudounipolar because they were originally bipolar, but their two processes fuse during development to form a single process that bifurcates at a distance from the cell body.
- Are sensory neurons of the PNS and found in spinal and cranial nerve ganglia.

2. Bipolar neurons

- Have **two processes**: one proximal (CNS) and the other is distal (PNS).
- Are found in association with some of the special senses like olfaction, vision, and hearing.

3. Multipolar neurons

- Have **several dendrites** and **one axon** and are most common in the CNS (e.g., motor cells in the anterior and lateral horns of the spinal cord, autonomic ganglion cells).

C. Clusters of nerve cell bodies

- A **ganglion** is a collection of neuron cell bodies **outside the CNS** (e.g., dorsal root ganglion, autonomic ganglia).
- A collection of neuron cell bodies **within the CNS** is called a **nucleus**. An exception is the basal ganglia, which is a group of subcortical nuclei.

D. Other components of the nervous tissues/system

1. Cells that support neurons

- Include **Schwann cells** and **satellite cells** in the PNS.
- Are called **neuroglia** in the CNS and are composed mainly of three types: **astrocytes**; **oligodendrocytes**, which play a role in myelin formation and transport of material to neurons; and **microglia**, which phagocytose waste products of nerve tissue.

2. Myelin

- Is the membrane-wrapped sheath around certain nerve axons.
- Is formed by **Schwann cells in the PNS** and **oligodendrocytes in the CNS**.

3. Synapses

- Are the **sites of functional contact** of an axon terminal of one neuron with the cell body or dendrites of another neuron, or an effector (muscle and gland) cell, or a sensory receptor cell.
- Are classified by the site of contact as axodendritic, axoaxonic, or axosomatic.
- Are the sites of impulse transmission commonly from the axon terminals (presynaptic elements) to the plasma membranes (postsynaptic elements) of the receiving cell via a neural transmitter across the synaptic cleft.

III. CENTRAL NERVOUS SYSTEM

A. Brain

- Is enclosed within the cranial vault.
- Has a **cortex**, which is the **outer part** of the cerebral hemispheres, composed of **gray matter**. This matter consists largely of the **nerve cell bodies**, dendrites, and neuroglia.
- Has an interior part composed of **white matter**, which consists largely of **axons** forming tracts or pathways, and ventricles, which are filled with cerebrospinal fluid (CSF).

B. Spinal cord

- Is **cylindrical**, occupies approximately the upper two-thirds of the vertebral canal, and is enveloped by the meninges.
- Has cervical and lumbar enlargements for the nerve supply of the upper and lower limbs, respectively.
- Has centrally located **gray matter** and peripherally located **white matter**.
- The spinal cord is shorter than the vertebral canal, ending between L1 and L2 vertebral level because the cord grows more slowly than the surrounding vertebral column during fetal development.
- The conical end of the spinal cord is called the **conus medullaris** and is located near the level of L2 (or between L1 and L2) in the adult and at the level of L3 in the newborn.
- The conus medullaris attaches caudally to the coccyx through the sacral canal via the **filum terminale** located among the roots of the **cauda equina**.

C. Meninges

- Consist of three layers of connective tissue membranes (**pia**, **arachnoid**, and **dura mater**) that surround and protect the brain and the spinal cord.
- Contain the **subarachnoid space**, which is the interval between the arachnoid and pia mater, filled with CSF.
- The pia mater carries the vascular supply to the surface of the brain and spinal cord and is intimately invested with the external surfaces of these.

D. Cerebrospinal fluid

- Is produced by vascular choroid plexuses in the lateral ventricles, third ventricle, and fourth ventricle of the brain.
- Flows through the ventricles to drain into the subarachnoid space from the fourth ventricle.

CLINICAL CORRELATES

Multiple sclerosis (MS) is an autoimmune **destruction of myelin** found in the optic nerve, brain, brainstem, and spinal cord, leading to sensory disorders and muscle weakness. Signs and symptoms include numbness or tingling, visual disturbances because of optic nerve involvement, cognitive impairments, muscle weakness, difficulty with coordination and balance, slurred speech, bladder incontinence, fatigue, depression, and memory problems. MS is seen in individuals who have a genetic predisposition and some viral-associated trigger of autoimmunity. Destruction of myelin disrupting the conduction of nerve signals along the axons. MS affects women more often than men.

IV. PERIPHERAL NERVOUS SYSTEM

A. Cranial nerves

- Consist of **12 pairs** and are connected to the brain and brainstem.
- Have motor fibers with cell bodies located within the CNS and sensory fibers with cell bodies that form sensory ganglia located outside the CNS.
- Emerge from the ventral aspect of the brain (except for the trochlear nerve, or cranial nerve IV).
- Contain different functional components based on the cranial nerve functions.

B. Spinal nerves (Figure 1.1)

- Consist of **31 pairs**: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal.
- Are formed from dorsal and ventral roots; each dorsal root has a ganglion that is associated with each intervertebral foramen.
- Are connected with the sympathetic chain ganglia by white (T1–L2) and gray (all spinal nerves) **rami (communicantes)**.
- Contain sensory fibers with cell bodies in the dorsal root ganglion for somatic and visceral sensations.
- Contain motor fibers with cell bodies in the anterior horn of all levels of the spinal cord for stimulation of skeletal muscles and visceral motor fibers from cell bodies in the lateral horn of the spinal cord (T1 through L2, S2, S3, and S4).
- Branch into **ventral primary rami to supply for the body wall through major plexuses** (i.e., cervical, brachial, and lumbosacral) and **intercostal nerves**.
- Branch into the **dorsal primary rami** to innervate the skin and deep muscles of the back.

C. Functional components in peripheral nerves (Figures 1.2 and 1.3)

1. Somatic afferent fibers (formerly general somatic afferent)

- Transmit pain, temperature, touch, and proprioception from peripheral receptors or the skin of the body to the CNS.

2. Somatic efferent fibers (formerly general somatic efferent)

- Carry motor impulses from CNS motoneurons to the skeletal muscles of the body.

3. Visceral afferent fibers (formerly general visceral afferent)

- Convey sensory impulses from visceral organs and blood vessels to the CNS.

4. Visceral efferent fibers (autonomic nerves, formerly general visceral efferent)

- Transmit motor impulses from the CNS through a peripheral autonomic ganglion to smooth muscle of the viscera or blood vessels, cardiac muscle, and glandular tissues.

5. Special sensory fibers (formerly special somatic afferent and special visceral afferent)

- Convey special sensory impulses of the eye and ear for vision, hearing, and equilibration through cranial nerves to the CNS.

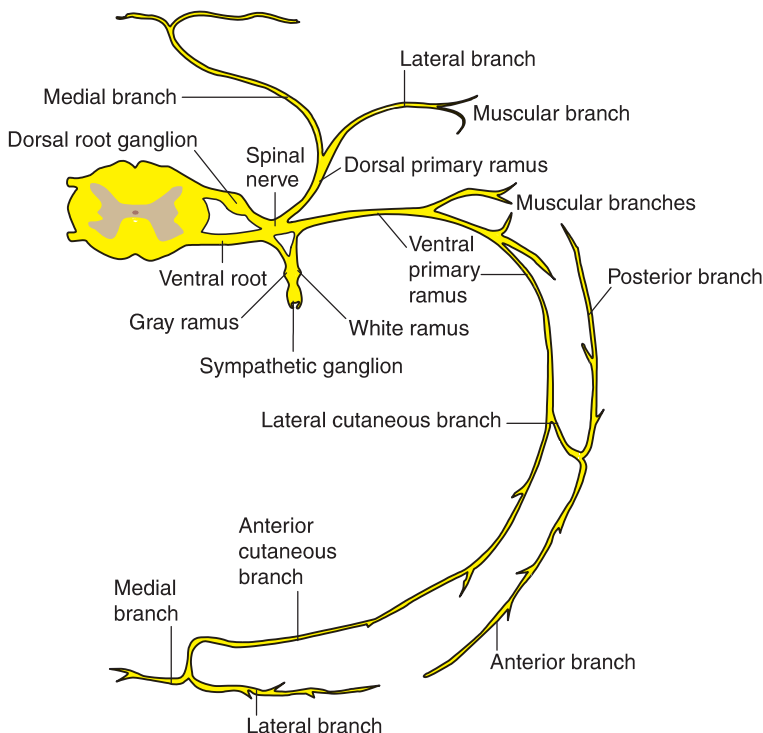


FIGURE 1.1. Typical spinal nerve (anterior, ventral; posterior, dorsal).

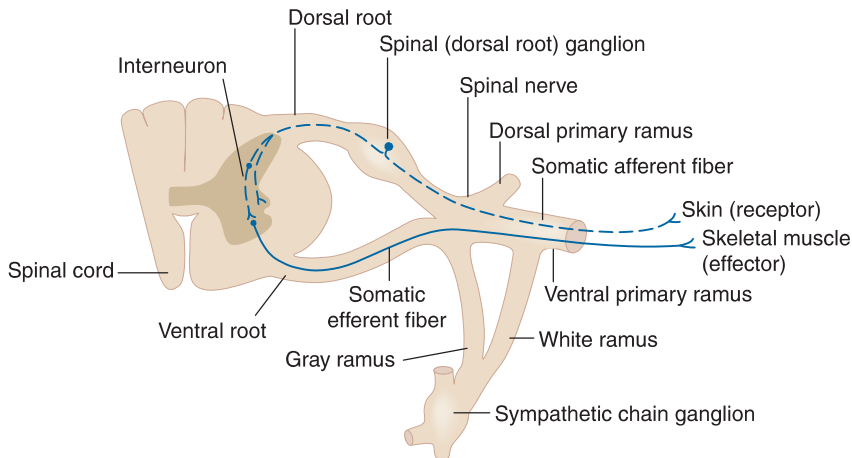


FIGURE 1.2. Somatic afferent and efferent nerves.

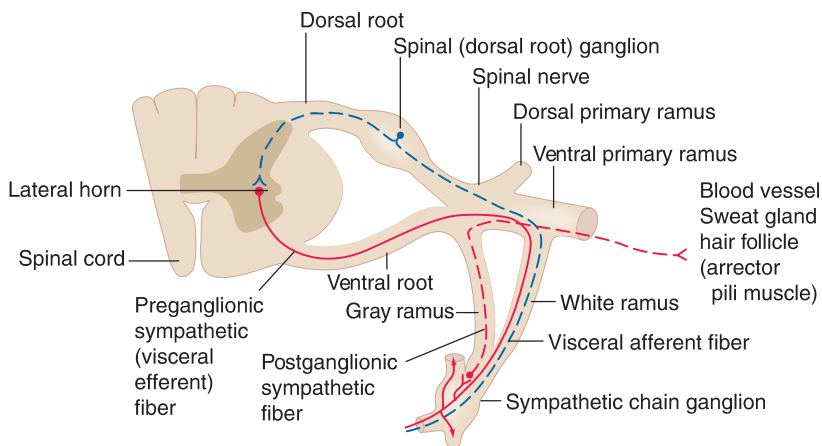


FIGURE 1.3. Visceral efferent (autonomic) and afferent nerves.

- Transmit senses of smell from the nasal cavity and taste sensations from the oral cavity through cranial nerves to the CNS.

6. Special visceral efferent fibers (old terminology)

- Conduct motor impulses to the muscles that develop in association with one of the branchiomeric arches: first arch—muscles for mastication; second arch—muscles for facial expression; third arch—stylopharyngeus muscle; fourth arch—palatal and pharyngeal muscles for elevation of the pharynx; or sixth arch—movement of the larynx.
- There is no fifth arch.
- This scheme is not used as widely as it was previously and will not show up on board examinations.

V. AUTONOMIC NERVOUS SYSTEM

- Is responsible for the motor innervation of smooth muscle, cardiac muscle, and glands (Table 1.1). It is divided into the **sympathetic** (thoracolumbar outflow), **parasympathetic** (craniosacral outflow), and **enteric divisions**.
- Is composed of two neurons, preganglionic and postganglionic, which are visceral efferent neurons. It has **cholinergic** fibers (sympathetic preganglionic, parasympathetic preganglionic, and

table 1.1 Functions of Autonomic Nerves

Organs	Sympathetic Nerve	Parasympathetic Nerve
Eyes	Dilates pupil	Constricts pupil; contracts ciliary muscle to thicken lens
Lacrimal gland	Slightly reduces secretion	Promotes secretion
Salivary gland	Reduces secretion and more viscid	Increases secretion and watery
Sweat gland	Stimulates secretion	No effect
Blood vessels	Constricts	No effect
Heart	Increases rate and ventricular contraction; dilates coronary vessels	Decreases rate and ventricular contraction; constricts coronary vessels
Bronchi	Dilates lumen; reduces bronchial secretion	Constricts lumen; promotes secretion
GI tract	Inhibits motility and secretion; constricts sphincters	Stimulates motility and secretion; relaxes sphincters
Liver	Promotes glycogen breakdown	Promotes glycogen formation and bile secretion
Suprarenal medulla	Secretes epinephrine and norepinephrine	No effect
Kidney	Reduces urine formation by constriction of renal vessels	May cause vasodilation of renal vascular bed
Urinary bladder	Contracts sphincter vesicae	Relaxes sphincter vesicae; contracts detrusor muscle, during urination
Genital organs	Causes vasoconstriction and the propulsion of ejaculation; sphincter vesicae is contracted to prevent retrograde ejaculation; contracts uterus	Causes vasodilation and erection; relaxes uterus

parasympathetic postganglionic) and **adrenergic** fibers (sympathetic postganglionic) except those to sweat glands (cholinergic).

- **Preganglionic neuron** cell bodies are located **in the CNS**, whereas **postganglionic neuron** cell bodies are in ganglia **in the PNS**.

A. Sympathetic nerve fibers (see Figure 1.3)

- Have preganglionic nerve cell bodies that are located in the lateral horn of the thoracic and upper lumbar levels (L2 or L1–L3) of the spinal cord.
- Have **preganglionic fibers** that pass out of the spinal cord through ventral roots, spinal nerves, and then enter the **white rami** (communicantes).
- Preganglionic fibers enter adjacent sympathetic chain ganglia, where they synapse or travel up or down the chain to synapse in remote chain ganglia for the autonomics of the body wall.
- **Postganglionic fibers** from the neurons in the chain ganglia return to spinal nerves by way of **gray rami** and supply the skin with secretory fibers to sweat glands, motor fibers to smooth muscles of the hair follicles (arrectores pilorum), and vasomotor fibers to the blood vessels of the body wall.
- Alternatively, **preganglionic fibers** run ventrally through to the splanchnic nerves to synapse in **preaortic** (collateral) **ganglia**.
- Postganglionic fibers from the preaortic ganglia travel with arteries to innervate the viscera of the abdomen and pelvis.
- Sympathetics function primarily in **emergencies** or catabolism (energy consumption), preparing individuals for **fight** or **flight**, and thus increase the heart rate, inhibit GI motility and secretion, and dilate pupils and bronchial lumen. They liberate norepinephrine (except sweat glands) and are classified as adrenergic.

B. Parasympathetic nerve fibers

- Comprise the preganglionic fibers that arise from the brainstem (cranial nerves III, VII, IX, and X) and the second, third, and fourth sacral spinal segments.
- Are distributed to the internal organs and walls of the viscera and glands of the digestive and respiratory systems *but not* to the skin or body wall and limbs.
- Decrease the heart rate, increase GI peristalsis, and stimulate secretory activity.

- Parasympathetics function primarily in **homeostasis** or anabolism (energy conservation), tending to promote quiet and orderly processes of the body. They liberate acetylcholine and are classified as cholinergic.

C. Enteric division

- Consists of a complex web of interconnecting neurons with multiple different neurotransmitters located in the walls of the GI tract.
- The enteric ganglia are parasympathetic postganglionic neuron cell bodies and plexuses of the GI tract that include the classically described myenteric (Auerbach) and submucosal (Meissner) plexuses.
- Plays an important role in the control of GI motility and secretion.

CIRCULATORY SYSTEM

I. VASCULAR SYSTEM

- Functions to circulate vital materials such as **oxygen, nutrients to the tissues, and waste products to the kidneys, liver, and lungs.**
- Other circulating elements are carbon dioxide, hormones, antibodies, and cells involved in inflammation, immunology, and wound healing.
- Consists of the **heart** and **vessels** (arteries, capillaries, and veins) that transport blood through all parts of the body.
- Also includes the **lymphatic vessels**, a set of channels that begin in the tissue spaces and return tissue fluid to the bloodstream.

A. Circulatory loops

1. Pulmonary circulation

- Pulmonary arteries transport blood away from the right ventricle to the lungs for the exchange of oxygen and carbon dioxide and return oxygenated blood to the heart, left atrium, via the pulmonary veins.

2. Systemic circulation

- Transports blood from the left ventricle through the aorta to all parts of the body and returns it to the right atrium through the superior and inferior venae cavae and the cardiac veins.

B. Heart

- Is a hollow, muscular, four-chambered organ that **pumps blood** to the two separate circulatory loops mentioned previously, the **pulmonary circulation** and the **systemic circulation.**
- Is regulated in its pumping rate and strength by the ANS, which controls the normal **pacemaker**, the sinoatrial node.
- Receives oxygenated blood from the right and left coronary arteries off the ascending aorta.

C. Blood vessels

- Carry blood to the lungs, where carbon dioxide is exchanged for oxygen.
- Carry blood to the intestines, where nutritive materials in fluid form are absorbed, and to the endocrine glands, where hormones pass through the vessel walls and are distributed to target cells.
- Transport waste products from tissue fluids to the kidneys, intestines, lungs, and skin, where they are excreted.
- Are of four types: arteries, veins, capillaries, and sinusoids.

1. Arteries

- Carry blood away from the heart to the capillary beds and have thicker walls than do their corresponding veins.
- Consist of three main types: the large **elastic arteries**; the distributive, named, **muscular arteries**; and the smallest are **arterioles** found before a capillary bed.
- The precapillary arterioles are vital to the maintenance of blood pressure.

2. Capillaries

- Are composed of endothelium and its basement membrane and connect the arterioles to venules.
- Are the **sites for the exchange** of carbon dioxide, oxygen, nutrients, and waste products between the tissues and the blood.
- Are absent in the cornea, epidermis, and hyaline cartilage and may be absent in some areas where the arterioles and venules have direct connections (**arteriovenous anastomoses** or **shunts**), which may occur in the skin of the nose, lips, fingers, and ears, where they conserve body heat.

CLINICAL CORRELATES

Aneurysm is a circumscribed dilatation of an artery or the heart as a result of breakdown of the wall and is caused by an atherosclerosis (accumulation of fat, cholesterol, and calcium that forms plaque in the arterial wall), changes in the formation of tissue layers within the arterial wall, or high blood pressure, giving a greater risk of rupture.

Atherosclerosis is a pathology of arteries caused by **narrowing** of the artery because of the deposition of fat, cholesterol, and calcium (atheroma) in the arterial walls. Narrowing and blockage of arteries in the brain cause ischemic **stroke**, and narrowed and blocked coronary arteries lead to **heart attacks**. Typically, myocardial infarctions occur when a clot blocks a narrowed artery.

Arteriosclerosis is a thickening and **hardening** of the arterial walls with resulting loss of elasticity. It may be caused by fibrosis and calcification of the arterial walls (the site of an atheroma) and develops with aging, high blood pressure, diabetes, and other conditions.

Varicose veins are enlarged and tortuous veins that develop most commonly in the superficial veins of the lower limb because of reduced elasticity and incompetent valves in the veins or thrombophlebitis of the deep veins.

3. Veins

- Return blood to the heart from the capillary beds and consist of the **pulmonary veins**, which return oxygenated blood to the left atrium of the heart from the lungs, and the **systemic veins**, which return deoxygenated blood to the right atrium of the heart from the rest of the body.
- Pulmonary veins feed the systemic outflow, and the systemic venous return is needed to produce pulmonary blood flow.
- Contain valves that prevent the reflux of blood, and each muscular artery may have two veins (**venae comitantes**) that closely accompany it into the limbs.

4. Sinusoids

- Are wider and more irregular than capillaries and substitute for capillaries in some organs, such as the liver, spleen, red bone marrow, adenohypophysis, suprarenal cortex, and parathyroid glands.
- Often contain phagocytic cells on their walls and form a part of the **reticuloendothelial system**, which is concerned chiefly with phagocytosis and antibody formation.

5. Portal system

- Is a system of vessels in which blood collected from one capillary network passes through a large vessel(s) and then a second capillary network before it returns to systemic circulation.
- Consists of the **hepatic portal system** in which blood from the intestinal capillary bed passes through the hepatic portal vein and then hepatic capillaries (sinusoids) to the hepatic veins, and the **hypophyseal portal system** in which blood from the hypothalamic capillaries passes through the hypophyseal portal veins and then the pituitary capillary sinusoids to the hypophyseal veins.

II. LYMPHATIC SYSTEM

- Provides an important **immune mechanism** for the body.
- Provides a route for transporting fat and large protein molecules absorbed from the intestine to the thoracic duct.

A. Lymphatic vessels

- Serve as one-way drainage toward the heart and return lymph to the bloodstream through the **thoracic duct** (the largest lymphatic vessel) or the right lymphatic duct.
- Function to **absorb large protein molecules** and transport them to the bloodstream because the molecules cannot pass through the walls of the blood capillaries back into the blood.
- Carry lymphocytes from lymphatic tissues to the bloodstream.
- Have valves, which are constricted at the sites of valves; thus, vessels show a beaded appearance.
- Are absent in the brain, spinal cord, eyeballs, bone marrow, splenic pulp, hyaline cartilage, nails, and hair.
- Are not usually visible in dissections but are the major route by which cancer metastasizes.

B. Lymphatic capillaries

- Begin blindly in most tissues, collect tissue fluid, and join to form large collecting vessels that pass to regional lymph nodes.
- **Absorb lymph** from tissue spaces and transport it back to the venous system.
- Are called **lacteals** in the villi of the small intestine, where they absorb emulsified fat.

C. Lymph nodes

- Are organized collections of lymphatic tissue permeated by lymph channels.
- Contain **lymphocytes** and **plasma cells** and **filter the lymph**.
- Normally, not easily palpated. But can be palpable, hard, and painless with a metastasis or enlarged and tender when associated with infections.
- Trap **bacteria** and metastatic cells drained from an infected area or tumor and contain reticulo-endothelial cells and macrophages (phagocytic cells) that ingest and digest non-self-epitopes for presentation to lymphocytes.

D. Lymph

- Is a clear, straw-colored fluid that is collected from the intercellular spaces.
- Typically is acellular until lymphocytes are added in its passage through the lymph nodes.
- Its constituents are similar to blood plasma (e.g., proteins, fats, and lymphocytes).
- Often contains digested fat droplets (called **chyle**) that come from intestines.
- Is filtered by passing through several lymph nodes before entering the venous system.

ORGAN SYSTEMS

I. DIGESTIVE SYSTEM

- Consists of three divisions of the visceral tube, the **mouth**, the **pharynx**, and the **alimentary canal**, comprising the esophagus, the stomach, the small intestine, and the large intestine.
- Also contains accessory organs and glands to aid in digestion and nutrient storage, including the salivary glands, liver, gall bladder, and pancreas.
- Performs specific functions: essential food-processing activities. In the mouth, the food is moistened by saliva; is masticated and mixed by the mandible, teeth, and tongue; and is propelled by the pharynx and esophagus into the stomach, where it is mixed with the gastric juice and converted into chyme.
- Performs specific functions: in the **small intestine**, the food or chyme is **digested** by secretions from glands in the intestinal wall and from the liver, gallbladder, and pancreas; and digested end products are **absorbed** into the blood and lymph capillaries in the intestinal wall.
- Performs specific functions: in the **large intestine**, **water** and **electrolytes** are **absorbed**, and the waste products are transported to the rectum and anal canal, where they are eliminated as feces.
- Liver stores and releases glucose, breaks down toxins, and marshals cholesterol metabolism.

II. RESPIRATORY SYSTEM

- Consists of a **conducting portion that transports** filtered, humidified, and warmed air to the lungs. Includes the nose/nasal cavity and paranasal sinuses, pharynx, larynx, trachea, and bronchi.
- Consists of a respiratory portion in the **lungs**, which contain the terminal air sacs, or **alveoli**, where gas **exchange occurs**; oxygen in the air is exchanged for carbon dioxide in the blood.
- Air movements at rest are aided by the diaphragm and thoracic cage.
- Is concerned with speech, which involves the intermittent release of exhaled air and the opening and closing of the glottis.

III. URINARY SYSTEM

- **Kidneys** produce urine and are important in maintaining water and electrolyte balance, acid–base balance, regulating urine volume and composition, regulating blood volume, and in eliminating waste products from the blood.
- Also, through structures in the kidney, stimulates red blood cell production and helps in the control of blood pressure.
- **Ureters** carry urine from the kidney to the urinary bladder.
- **Bladder** stores urine and drains through the **urethra** out of the body.

IV. REPRODUCTIVE SYSTEM

A. Male reproductive system

- Includes **testes that** produce **spermatozoa** and androgenic hormones.
- Has **ducts** (epididymis, ductus deferens, and ejaculatory ducts) that transmit spermatozoa from the testis to the prostatic urethra.
- **Glands**, such as the seminal vesicles, prostate gland, and bulbourethral glands, contribute secretions to the seminal fluid as it passes through the urethra.
- The urethra passes the ejaculate to an opening at the tip of the external genital organ, the penis.

B. Female reproductive system

- Consists of ovaries, uterine tubes, uterus, vagina, and external genital organs. The **ovaries** produce steroid hormones and also **oocytes** (ova or eggs) that are conveyed from the ovaries through the uterine tubes to the cavity of the uterus. Each ovulated oocyte is released into the peritoneal cavity of the pelvis; one of the uterine tubes captures the oocyte, where it begins its journey toward the uterus. The **uterine tubes** transmit spermatozoa in the opposite direction, and **fertilization** of an oocyte usually occurs within the expanded **ampulla** of a uterine tube. A fertilized oocyte becomes embedded in the wall of the uterus, where it develops and grows into a fetus, which passes through the uterus and vagina (together called the birth canal). The **vagina** provides a passage for delivery of an infant; it also receives the penis and semen during sexual intercourse.
- Includes female external genitalia: the **mons pubis**, which is a fatty eminence anterior to the symphysis pubis; the **labia majora**, which are two large folds of the skin; the **labia minora**, which are two smaller skin folds that commence at the glans clitoris, lack hair, and contain no fat; the **vestibule**, which is an entrance of the vagina between the two labia minora; has the hymen at the vaginal orifice; and the **clitoris** (crura, body, and glans or head), which is composed largely of erectile tissue and is hooded by the prepuce of the clitoris.

V. ENDOCRINE SYSTEM

- Ductless endocrine glands secrete **hormones**, or messenger molecules, directly into the blood circulation and are carried to body cells.
- **Controls** and **integrates** the **functions** of other organ systems and plays a very important role in reproduction, growth, and metabolism.
- Functions tend to be slower processes compared to those controlled by the nervous system.
- Pure endocrine organs include the pituitary, pineal, thyroid, parathyroid, and suprarenal glands.
- Other endocrine cells are contained in the pancreas, thymus, gonads, hypothalamus, kidneys, liver, stomach, and the walls of the intestine.
- **Tropic hormones** are hormones that regulate the functions of other endocrine glands.

VI. INTEGUMENTARY SYSTEM

- Includes skin (integument) and its appendages, including sweat glands, sebaceous glands, hair, and nails.
- Contains **sensory receptors** associated with nerve endings for pain, temperature, touch, and pressure.
- Represents the largest single organ in the body.

A. Skin

- Consists of the avascular **epidermis** as the superficial, or surfacing, layer of stratified squamous epithelium that develops from ectoderm and has a keratinized layer on the outside of the body; it is thickest on the palms and the soles.
- The **dermis** is a deeper layer of connective tissue that develops largely from the mesoderm and contains downgrowths from the epidermis, such as hair follicles and glands.
- The **hypodermis** (subcutaneous tissue) is a fatty layer that lies deep to the dermis and is part of the superficial fascia. This layer is highly vascular and can serve as a route to administer medications via injection.
- The skin is a protective layer, an extensive sensory organ and is significant in body temperature regulation, fluid balance, production of vitamin D, and at least some absorption.

B. Appendages of the skin

- **Sweat glands** develop as epidermal downgrowths, have excretory functions, and regulate body temperature and fluid balance.
- **Sebaceous glands** develop from the epidermis (as downgrowths from hair follicles into the dermis) that empties their oily sebum into hair follicles to provide a lubricant to the hair and skin and protect the skin from drying.
- **Hairs** develop as epidermal downgrowths and function in protection, regulation of body temperature, and facilitate evaporation of perspiration.
- **Nails** develop as epidermal thickenings to protect the sensitive tips of the digits and function in delicate manipulations.

HIGH-YIELD TOPICS

- **Appendicular skeleton** includes the upper and lower limbs and the pectoral and pelvic girdles.
- **Axial skeleton** includes the skull, vertebral column, ribs, and sternum.
- **Bones** serve as a **reservoir for calcium and phosphorus** and act as biomechanical levers on which muscles act to produce the movements.

- **Long bones** have a shaft (**diaphysis**) and two ends (**epiphyses**). The **metaphysis** is a part of the diaphysis and is the **growth zone** between the diaphysis and epiphysis during bone development.
- **Sesamoid bones** develop in certain tendons and muscles and reduce friction as well as increase ability to transmit muscular force.
- **Osteoblasts** synthesize new bone and **osteoclasts** function in the resorption and remodeling of bone.
- **Osteomalacia** is a gradual softening of the bone caused by failure of the bone to calcify.
- **Osteopenia** is a decreased calcification of bone or a reduced bone mass.
- **Osteoporosis** is an age-related disorder characterized by decreased bone mass and increased susceptibility to fractures. It occurs when bone resorption outpaces bone formation (osteoclastic activity is greater than osteoblastic activity).
- **Osteopetrosis** is an abnormally dense bone, obliterating the marrow cavity, because of defective resorption of immature bone (osteoblastic activity is greater than osteoclastic activity).
- The nerve supplying a joint also supplies the muscles that move the joint and the skin covering the insertion of such muscles (**Hilton law**).
- **Osteoarthritis** is a noninflammatory degenerative joint disease characterized by degeneration of the articular cartilage and osseous outgrowth at the margins.
- **Rheumatoid arthritis** is an inflammatory disease of the joints. It is an autoimmune disease in which the immune system attacks the synovial membranes and articular structures, leading to deformities and disability.
- **Gout** is a painful form of arthritis and is caused by too much uric acid in the blood. Uric acid crystals are deposited in and around the joints, causing inflammation and pain, stiffness, and swelling of the joint tissues.
- **Lou Gehrig disease (amyotrophic lateral sclerosis/ALS)** is a fatal neurologic disease that attacks the neurons responsible for controlling voluntary muscles. The **muscles gradually weaken and atrophy**; the brain is unable to control voluntary movement of the body; and patients lose the ability to breath, swallow, and speak.
- **Nervous system** is divided into the central nervous system (**CNS**), consisting of the brain and spinal cord, and the peripheral nervous system (**PNS**), consisting of 12 pairs of cranial nerves and 31 pairs of spinal nerves and their associated ganglia. It is divided functionally into the somatic and visceral (autonomic) nervous system.
- **Ganglion is a collection of neuron cell bodies outside the CNS**, and a **nucleus is a collection of neuron cell bodies within the CNS**.
- **Neurons** in cranial or spinal ganglia are **unipolar (pseudounipolar)** types.
- **Axons carry impulses away from the cell body**, whereas the **dendrites carry impulses toward the cell body**.
- **Myelin** is the fatlike substance forming a sheath around certain nerve fibers and is formed by **Schwann cells in the PNS** and **oligodendrocytes in the CNS**.
- The **autonomic nervous system (ANS)** is responsible for the motor innervation of smooth muscle, cardiac muscle, and glands and is divided into the sympathetic, parasympathetic, and enteric divisions. Preganglionic neuron cell bodies are in the CNS, and postganglionic neuron cell bodies are in ganglia in the PNS. ANS consists of **cholinergic** fibers (sympathetic preganglionic, parasympathetic preganglionic, and parasympathetic postganglionic) and **adrenergic** fibers (sympathetic postganglionic) except those to **sweat glands (cholinergic)**.
- **Sympathetic nervous system** functions in **emergencies** or catabolism (energy consumption), preparing for fight or flight, whereas the **parasympathetic nerves** function in homeostasis or anabolism (energy conservation), tending to promote quiet and orderly processes of the body.
- **Cerebrospinal fluid (CSF)** is produced by vascular choroid plexuses in the brain ventricles and found in the subarachnoid space.
- Multiple sclerosis (**MS**) is a nervous system disease that causes **destruction of myelin in the CNS** (spinal cord and brain), leading to sensory disorders and muscle weakness. Symptoms also include numbness, visual and cognitive impairments, loss of coordination and balance, slurred speech, bladder incontinence, fatigue, and depression.
- **Coronary arteries** arise from the ascending aorta and supply blood to the **heart**.
- **Portal venous system** consists of the **hepatic portal system** in which blood from the intestinal capillary bed passes through the hepatic portal vein and then hepatic capillaries (sinusoids) to the hepatic veins, and the **hypophyseal portal system** in which blood from the hypothalamic

capillaries passes through the hypophyseal portal veins and then the pituitary capillary sinusoids to the hypophyseal veins.

- **Varicose veins** are dilated veins that develop in the superficial veins of the lower limb because of reduced elasticity and incompetent valves in the veins or thrombophlebitis of the deep veins.
- **Aneurysm** is a circumscribed dilation of the wall of an artery or the heart and caused by a **weakness of the arterial wall**, an atherosclerosis (accumulation of fat, cholesterol, and calcium which form plaque in the arterial wall), or high blood pressure, giving a greater risk of rupture.
- **Atherosclerosis** is a **narrowing** of the artery because of fatty **plaque** formation in the arterial wall. Narrowing and blockage of arteries in the brain cause **stroke**, and narrowed and blocked coronary arteries lead to **heart attacks**. **Arteriosclerosis** is a thickening and **hardening** of the arterial wall.
- **Lymphatic system** provides an important immune mechanism including clearing infections from the bloodstream, provides a route for transporting fat and large protein molecules, and is involved in the metastasis of cancer cells.
- **Thoracic duct** begins in the abdomen at the cisterna chili; drains the lower limbs, pelvis, abdomen, left thorax, left upper limb, and left side of the head and neck; and empties into the junction of the left internal jugular and subclavian veins.
- **Right lymphatic duct** drains the right sides of the thorax, upper limb, head, and neck and empties into the junction of the right internal jugular and subclavian veins.
- **Lymph nodes** are organized collections of lymphatic tissue and are an important part of the immune system. Lymph nodes are the main source of lymphocytes of the peripheral blood, play a role in antibody production, and as part of the reticuloendothelial system, serve as a defense mechanism by removing noxious agents, such as bacteria and toxins.

Review Test

Directions: Each of the numbered items or incomplete statements in this section is followed by answers or by completions of the statement. Select the **one**-lettered answer or completion that is **best** in each case.

1. A 22-year-old man presented to his family physician with a laceration of the fibrous sheets or bands that cover his body under the skin and surround the muscles. Which of the following structures would most likely be injured?

 - (A) Tendon
 - (B) Fascia
 - (C) Synovial tendon sheath
 - (D) Aponeurosis
 - (E) Ligament
2. After examination by her neurologist, a patient is told that her parasympathetic nerves are damaged. Which of the following muscles would most likely be affected?

 - (A) Muscles in the hair follicles
 - (B) Muscles in blood vessels
 - (C) Muscles that act at the elbow joint
 - (D) Muscles in the gastrointestinal (GI) tract
 - (E) Muscles enclosed by epimysium
3. A 46-year-old male patient with high blood pressure was seen in the emergency department and found to have leakage of blood from the blood vessel that normally carries richly oxygenated blood. Which of the following vessels would most likely be damaged?

 - (A) Superior vena cava
 - (B) Pulmonary arteries
 - (C) Pulmonary veins
 - (D) Portal vein
 - (E) Coronary sinus
4. A 26-year-old man was stabbed in a bar fight. Axons of the general somatic efferent (GSE) neurons to the shoulder muscles were severed. The damaged axons:

 - (A) Would carry impulses toward the cell bodies
 - (B) Would carry impulses away from the cell bodies
 - (C) Would carry pain impulses
 - (D) Are several in numbers for multipolar neurons
 - (E) Are found primarily in the gray matter
5. A 76-year-old homicide victim suffered a laceration of the posterior intercostal nerves by a penetrating knife wound. Under microscopy, the pathologist observed numerous degenerated cell bodies of the unipolar or pseudounipolar neurons. Which of the following structures would most likely provide the abnormal cell morphology?

 - (A) Ventral horn of the spinal cord
 - (B) Lateral horn of the spinal cord
 - (C) Dorsal horn of the spinal cord
 - (D) Dorsal root ganglion
 - (E) Sympathetic chain ganglion
6. A 59-year-old anatomy professor came to her doctor's office for a neurologic examination. Her physician told her that synapses are normally absent in or on which of the following structures?

 - (A) Anterior horn of the spinal cord
 - (B) Dorsal root ganglia
 - (C) Sympathetic chain ganglia
 - (D) Dendrites
 - (E) Cell bodies
7. A 27-year-old woman involved in a car accident is brought into the emergency department. Her magnetic resonance imaging reveals that she has laceration of the spinal cord at the L4 spinal cord level. Which of the following structures would you expect to be intact?

 - (A) Dorsal horn
 - (B) Lateral horn
 - (C) Ventral horn
 - (D) Gray matter
 - (E) White matter