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
Acknowledgments

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

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
3. **THORAX**

**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
## 4. **ABDOMEN**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Abdominal Wall</td>
<td>109</td>
</tr>
<tr>
<td>I. Abdomen</td>
<td>109</td>
</tr>
<tr>
<td>II. Muscles of the Anterior Abdominal Wall</td>
<td>110</td>
</tr>
<tr>
<td>III. Fasciae and Ligaments of the Anterior Abdominal Wall</td>
<td>110</td>
</tr>
<tr>
<td>IV. Inguinal Region</td>
<td>112</td>
</tr>
<tr>
<td>V. Spermatic Cord, Scrotum, and Testis</td>
<td>113</td>
</tr>
<tr>
<td>VI. Inner Surface of the Anterior Abdominal Wall</td>
<td>114</td>
</tr>
<tr>
<td>VII. Nerves of the Anterior Abdominal Wall</td>
<td>115</td>
</tr>
<tr>
<td>VIII. Lymphatic Drainage of the Anterior Abdominal Wall</td>
<td>116</td>
</tr>
<tr>
<td>IX. Blood Vessels of the Anterior Abdominal Wall</td>
<td>116</td>
</tr>
<tr>
<td>Peritoneum and Peritoneal Cavity</td>
<td>117</td>
</tr>
<tr>
<td>I. Peritoneum</td>
<td>117</td>
</tr>
<tr>
<td>II. Peritoneal Reflections</td>
<td>117</td>
</tr>
<tr>
<td>III. Peritoneal Cavity</td>
<td>119</td>
</tr>
<tr>
<td>Gastrointestinal (GI) Viscera</td>
<td>120</td>
</tr>
<tr>
<td>I. Esophagus (Abdominal Portion)</td>
<td>120</td>
</tr>
<tr>
<td>II. Stomach</td>
<td>121</td>
</tr>
<tr>
<td>III. Small Intestine</td>
<td>123</td>
</tr>
<tr>
<td>IV. Large Intestine</td>
<td>124</td>
</tr>
<tr>
<td>V. Accessory Organs of the Digestive System</td>
<td>126</td>
</tr>
<tr>
<td>VI. Spleen</td>
<td>130</td>
</tr>
<tr>
<td>VII. Development of Digestive System</td>
<td>131</td>
</tr>
<tr>
<td>VIII. Celiac and Mesenteric Arteries</td>
<td>133</td>
</tr>
<tr>
<td>IX. Hepatic Portal Venous System</td>
<td>137</td>
</tr>
<tr>
<td>Retroperitoneal Viscera, Diaphragm, and Posterior Abdominal Wall</td>
<td>140</td>
</tr>
<tr>
<td>I. Kidney, Ureter, and Suprarenal Gland</td>
<td>140</td>
</tr>
<tr>
<td>II. Development of Kidney, Urinary Bladder, and Suprarenal Gland</td>
<td>143</td>
</tr>
<tr>
<td>III. Posterior Abdominal Blood Vessels and Lymphatics</td>
<td>144</td>
</tr>
<tr>
<td>IV. Nerves of the Posterior Abdominal Wall</td>
<td>145</td>
</tr>
<tr>
<td>V. The Diaphragm and Its Openings</td>
<td>148</td>
</tr>
<tr>
<td>VI. Muscles of the Posterior Abdominal Wall</td>
<td>150</td>
</tr>
<tr>
<td>High-Yield Topics</td>
<td>150</td>
</tr>
<tr>
<td>Review Test</td>
<td>156</td>
</tr>
</tbody>
</table>

## 5. **PERINEUM AND PELVIS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perineal Region</td>
<td>170</td>
</tr>
<tr>
<td>I. Perineum</td>
<td>170</td>
</tr>
<tr>
<td>II. Urogenital Triangle</td>
<td>170</td>
</tr>
<tr>
<td>III. Anal Triangle</td>
<td>174</td>
</tr>
<tr>
<td>IV. External Genitalia and Associated Structures</td>
<td>175</td>
</tr>
<tr>
<td>V. Nerve Supply of the Perineal Region</td>
<td>178</td>
</tr>
<tr>
<td>VI. Blood Supply of the Perineal Region</td>
<td>180</td>
</tr>
<tr>
<td>Pelvis</td>
<td>181</td>
</tr>
<tr>
<td>I. Bony Pelvis</td>
<td>181</td>
</tr>
<tr>
<td>II. Joints of the Pelvis</td>
<td>184</td>
</tr>
<tr>
<td>III. Pelvic Diaphragm</td>
<td>184</td>
</tr>
</tbody>
</table>
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

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 tuberculous (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. **Osteoporosis** 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 (**Hill 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 (ellipsoid) joints
   - Have two convex condyles articulating with two concave condyles. (The shape of the articulation is ellipsoid.)
   - 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.
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.

  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.

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 breathe, swallow, and speak. The earliest symptoms may include cramping, twitching, and muscle weakness.
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 envelopes 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 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).
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

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

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 vena 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 breathe, 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 nervous system** 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 chilii; 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