2

Body Tissues and Basic Physiology

CHAPTER OUTLINE

TYPES OF TISSUE

CONNECTIVE TISSUE

Bones
- *Bone Tissue*
- *Shapes of Bones*
- *Axial vs. Appendicular Skeleton*
- *Bone Markings*

Cartilage

Dense Connective Tissue

Loose Connective Tissue

Blood

Lymph

JOINTS

Functional Classification
- *Synarthrotic*
- *Amphiarthrotic*
- *Diarthrotic*

Structural Classification
- *Fibrous*
- *Cartilaginous*
- *Synovial*

MUSCLES

Muscle Tissue

Structure of a Skeletal Muscle

Skeletal Muscle Cell Components

Skeletal Muscle Contraction
- *Sliding Filament Mechanism*
- *Motor Units*
- *All-or-Nothing Principle*
- *Motor Unit Recruitment*
- *Muscle Tone*
- *Muscle Fatigue*
- *Types of Skeletal Muscle Fibers*

Origin, Insertion, Action

Concentric, Eccentric, and Isometric Contractions

Synergists and Antagonists

Shortened and Lengthened Muscles

Palpation and Massage of Muscles

NERVE SUPPLY TO MUSCLES

ARTERIAL SUPPLY TO MUSCLES
- *Chapter Summary*
- *Workbook*

KEY TERMS

Epithelial tissue: tissue that covers surfaces, and lines cavities and hollow organs.

Connective tissue: abundant and continuous tissue that supports, binds, and protects the body and structures within the body

Compact bone tissue: the dense type of bone tissue that comprises the entire outer surface of bones

Spongy bone tissue: the lighter type of bone tissue, formed by thin slivers of bone arranged in an irregular pattern and located deep to compact bone tissue

Axial skeleton: includes the bones that generally run along the vertical axis of the body, including the bones of the skull and spine, as well as the ribs, sternum (breast bone), and hyoid bone, which is a small curved bone in the anterior neck

Appendicular skeleton: includes all the bones of the upper and lower limbs, as well as the bones that hold the limbs to the axial skeleton, including the clavicle (collar bone) scapula (shoulder blade), and hip bones

Bone markings: special projections, shapes, and textures on bones that serve varied anatomical functions

Synarthrotic: immovable

Amphiarthrotic: slightly movable

Diarthrotic: freely movable

Synovial joint: a freely movable, diarthrotic joint in which the ends of the joining bones are covered with cartilage and held together by a synovial joint capsule containing synovial fluid

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

Endomysium: sheet-like connective tissue structure that surrounds each muscle

Perimysium: sheet-like connective tissue structure that surrounds each fascicle or group of muscle cells

Epimysium: sheet-like connective tissue structure that surrounds each individual muscle cell

Sarcolemma: cell membrane of a skeletal muscle cell

Myofibril: a basic structure that forms skeletal muscle cells and that contains multilayered rows of alternating protein fibers called myofilaments

Myosin: thicker myofilament or protein fibers that overlap with actin when a muscle shortens

Actin: thinner myofilament or protein fibers that overlap with myosin when a muscle shortens

Sarcoplasmic reticulum: a network of sacs and tubules that surround each myofibril

Sliding filament mechanism: the process by which myosin and actin are pulled closer together, resulting in muscle shortening

Motor units: a single motor neuron (nerve cell designed to allow movement) and the set of skeletal muscle cells innervated by that single neuron

Motor unit recruitment: the use of additional motor units to accomplish a muscle contraction or movement

Muscle tone: continuous contraction of alternating motor units, which causes muscles to have tension or firmness during rest

Muscle fatigue: exhaustion of muscle cells, so that they can no longer contract

Origin: muscles typically connect to two or more locations on at least two different bones; the stable or less movable location is called the origin

Insertion: muscles typically connect to two or more locations on at least two different bones; the more movable, less stable location is called the insertion

Action: movement that occurs at a joint when a muscle's insertion moves closer to the muscle's origin

Concentric contraction: a muscle contraction resulting in shortening of the muscle

Eccentric contraction: a muscle contraction resulting in lengthening of the muscle

Isometric contraction: a muscle contraction in which the length of the muscle does not change, yet muscle tension occurs

Synergists: muscles that perform one or more of the same actions

Antagonists: muscles that perform one or more opposite actions

Shortened muscle: a muscle that remains in a shortened position, with origin and insertion closer together than typical

Lengthened muscle: a muscle that remains in a lengthened position, with origin and insertion farther apart than typical

This chapter provides an introduction to the physiology of bones, joints, and muscles, and a brief overview of nerve and arterial supply to muscles. This information provides a framework for the understanding of myology and kinesiology, as these studies relate to massage therapy. We begin this chapter by discussing the types of tissue and the particular categories and functions of connective tissue. Within this discussion, we explore the bones and bone markings of the body, many of which serve as muscle attachment sites. Next, we explore joints of the body, including the different categorizations of joints and the movement permitted at each. Then, we move on to muscles, including their structure and functions and how they contract to allow us to move. We conclude this chapter with a look at shortened and lengthened muscles, how they impact posture and function, as well as the importance of muscles' innervation and arterial supply. Understanding these concepts prepares you for the study of myology and assists you in designing treatment plans for your clients.

TYPES OF TISSUE

A brief description of tissues can help create a context for learning about muscles, bones, and joints. *Tissue* is a mass of the same type of cells that form a particular kind of structure, for a particular purpose. There are four types of tissue in the body. **Epithelial tissue** lines the cavities, vessels, and hollow organs of the body and forms the outer covering of the body. It also comprises various glands. **Nervous system tissue** forms the brain, spinal cord, peripheral nervous system, and all supporting nerve tissue. Nervous system tissue is designed to sense stimuli and respond to it by generating nerve impulses. **Muscle tissue** is designed to contract, which enables it to shorten and lengthen and thus allow movement. **Connective tissue** includes all other tissue in the body and is the most abundant type of tissue we have. Connective tissue protects, supports, and binds together other tissue. Of these four types, this chapter will focus primarily on connective tissue and muscle tissue.

CONNECTIVE TISSUE

It is just as important for massage therapists to understand and address connective tissue as it is to address muscles. In fact, it is impossible to differentiate the massage of muscle from the massage of connective tissue. As we will see later in this chapter, muscles are infused with and surrounded by connective tissue. Restrictions in a client's connective tissue can cause pain, limited range of motion, and postural abnormalities, all of which can be addressed with massage therapy.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

Connective tissue is made up of cells and matrix. The matrix, which is secreted by the cells, gives connective tissue its unique properties. The matrix is made of ground substance and fibers, and depending upon its composition, may be fluid, gel-like, fibrous and flexible, or solid.

Connective tissue includes bone, cartilage, fascia (dense and loose connective tissue), blood, and lymph. Each of these is described below.

Bones

It is important for you, as a massage therapist, to understand bones and bony landmarks, as they are attachment sites for muscles. In addition, an understanding of the exact location of muscles and their position relative to bones and joints is needed to understand the movements muscles allow us to perform. You will also benefit from understanding the exact location of a muscle's connection to bone, as it is often helpful to massage this area to enhance muscle relaxation, or to treat or prevent tendonitis.

Bones are a rigid form of connective tissue that provide the overall structure of the body. They have several important functions, including protecting organs, producing blood cells, and storing fats and minerals. In addition, bones provide attachment sites for muscles and act as levers, or solid structures that move when muscles contract.

Bone Tissue

There are two types of bone tissue: compact and spongy (Fig. 2-1). **Compact bone tissue** forms the outer layer of bones and is more solid in structure. **Spongy bone tissue** is deep to compact bone and is porous. Spongy bone tissue is composed of thin beams of bone, called *trabeculae*, which are patterned in a criss-cross or latticelike structure. The space between the beams of bone are filled with red bone marrow, which produces blood cells.

Shapes of Bones

Bones are classified by shape: long, short, flat, irregular, or sesamoid. Long bones are longer than they are wide. The bones of the arm, forearm, fingers, thigh, leg, and toes are all long bones. Typical adult long bones contain spongy bone only on the proximal and distal ends of the bone and a hollow space called the *medullary canal* in the shaft of the bone. The medullary canal is filled with yellow marrow and contains fat cells.

Short bones are small and somewhat square-shaped and contain an outer layer of compact bone and an inner layer of spongy bones. Most of the carpal bones (most proximal bones in the hand) and the tarsal bones of the foot are short bones. Flat bones are as named: They are flat. Flat bones consist of two outer layers of compact bone with an inner layer of spongy bone between them. Examples include the ribs, sternum, scapula, and many bones of the skull. Irregular-shaped bones have unusual shapes. They include the vertebrae and some facial bones. Sesamoid bones are shaped like sesame seeds. The patella is the most famous. Other sesamoid bones are present in varying numbers and are generally imbedded in tendons.

Axial vs. Appendicular Skeleton

The human skeleton contains 206 bones and is divided into the axial and appendicular skeletons (Fig. 2-2).The bones of the axial skeleton form somewhat of a vertical axis through the center of the body. The **axial skeleton** includes the 22 bones of the skull, six auditory ossicles, 26 bones that make up the vertebral column, the hyoid bone, 24 ribs, and the sternum. The **appendicular skeleton** consists of the bones of the appendages or limbs and the girdles that hold the limbs to the axial skeleton.

The bones of the appendicular skeleton include the shoulder girdle bones: two clavicles and two scapulae. The appendicular skeleton also contains the bones of the upper limb: two humerus, two ulna, and two radius bones, 16 carpal bones (which include two each of the following bones: scaphoid, lunate, triquetrum, pisiform, trapezium, trapezoid, capitate, and hamate), ten metacarpals, and 28 phalanges in the hands. The appendicular skeleton also contains the pelvic girdle, or two coxal or hip bones, and the bones of the lower limb, which include two femurs, two patellae, two tibia, two fibula bones, 14 tarsals (which include two each of the following bones: calcaneus, talus, navicular, medial cuneiform, intermediate cuneiform, lateral cuneiform, and cuboid), ten metatarsals, and 28 phalanges in the feet.

Bone Markings

Bone markings are specific markings and textures on the surface of bones that serve many purposes. Most relevant to myology is the fact that bone makings serve as muscle attachment sites and provide the particular shapes that allow the bones to articulate (join) with other bones, thus creating joints. The list below describes the common markings that are relevant to the joints and muscles covered later in this book (Fig. 2-3).

1. The *head* of a bone is generally rounded and appears at either the distal or the proximal end of many bones. Just distal or proximal to the head is a narrow portion of bone called a *neck*. A head may fit nicely into a socket to form a ball-and-socket joint. Other heads articulate with curved bone markings at joints that permit less movement. Note the heads of the humerus and radius in Figure 2-3, the ulna in Figure 5-2B, and the fibula in Figure 5-3A.
2. A *condyle* (which means knuckle) is also a rounded bone marking at the distal or proximal end of a bone. (The condyles of the occiput, a skull bone, are on the inferior aspect of the bone.) Condyles come in pairs.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

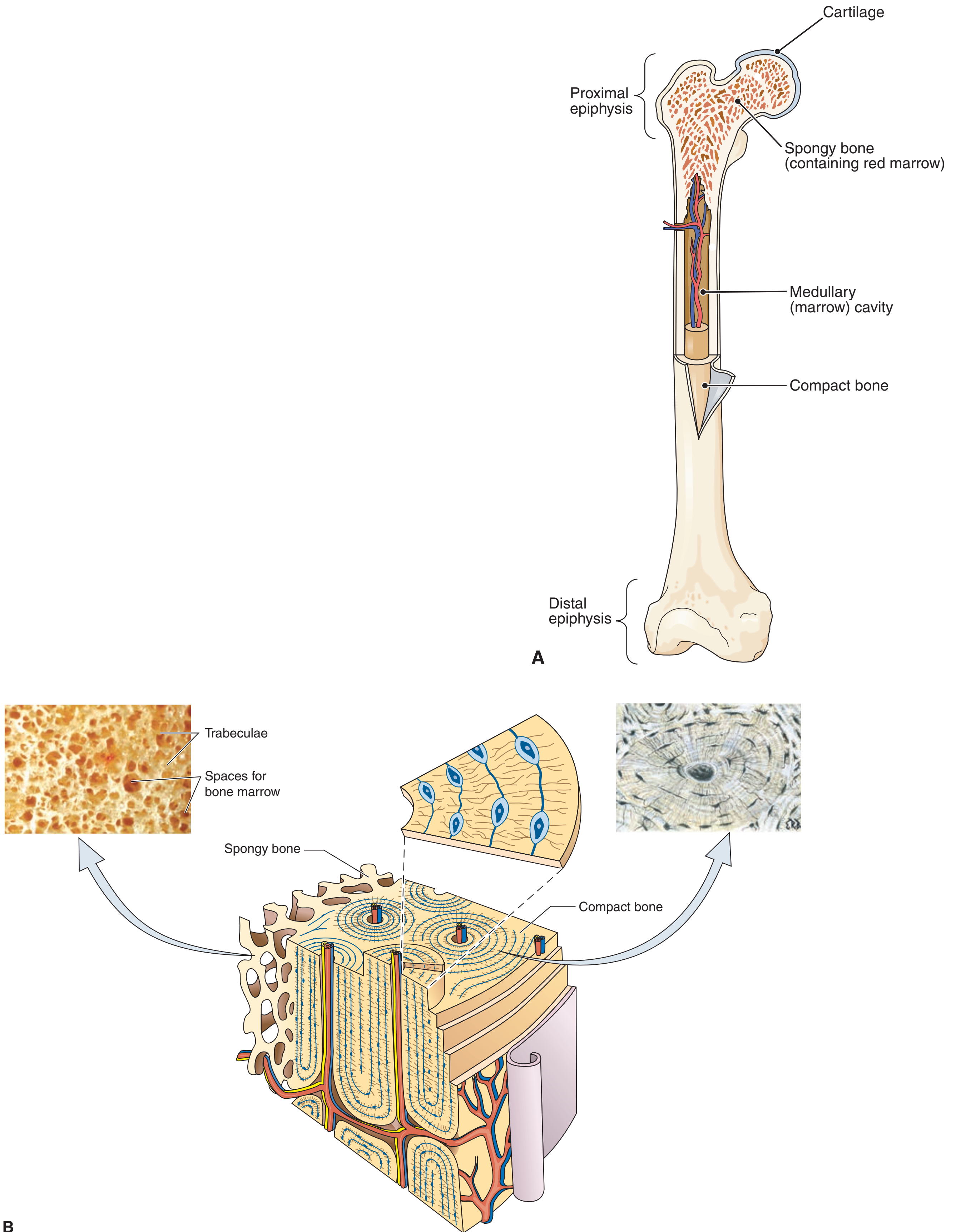


FIGURE 2-1 · Spongy and compact bone.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

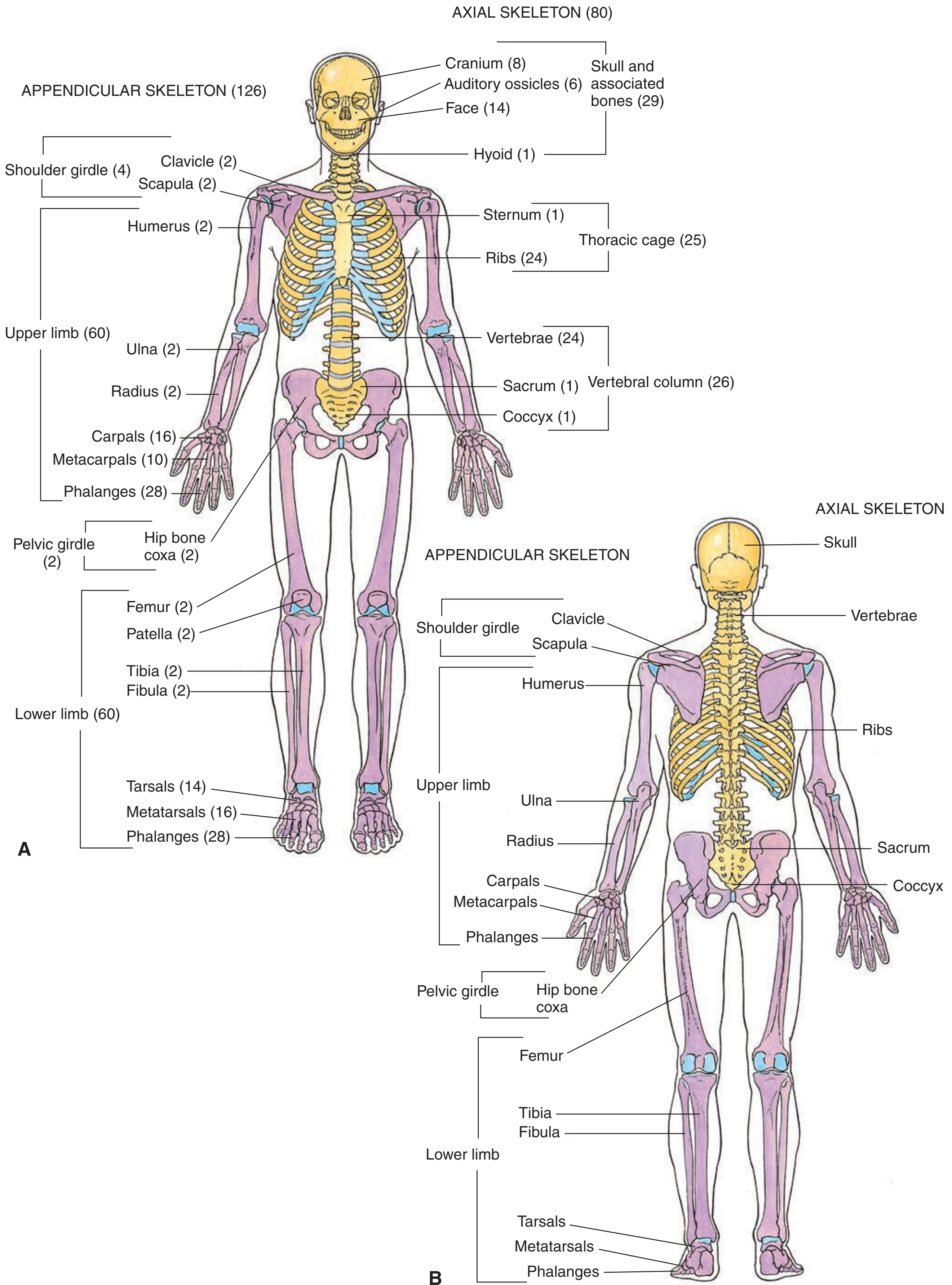


FIGURE 2-2 · Axial and appendicular skeleton.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

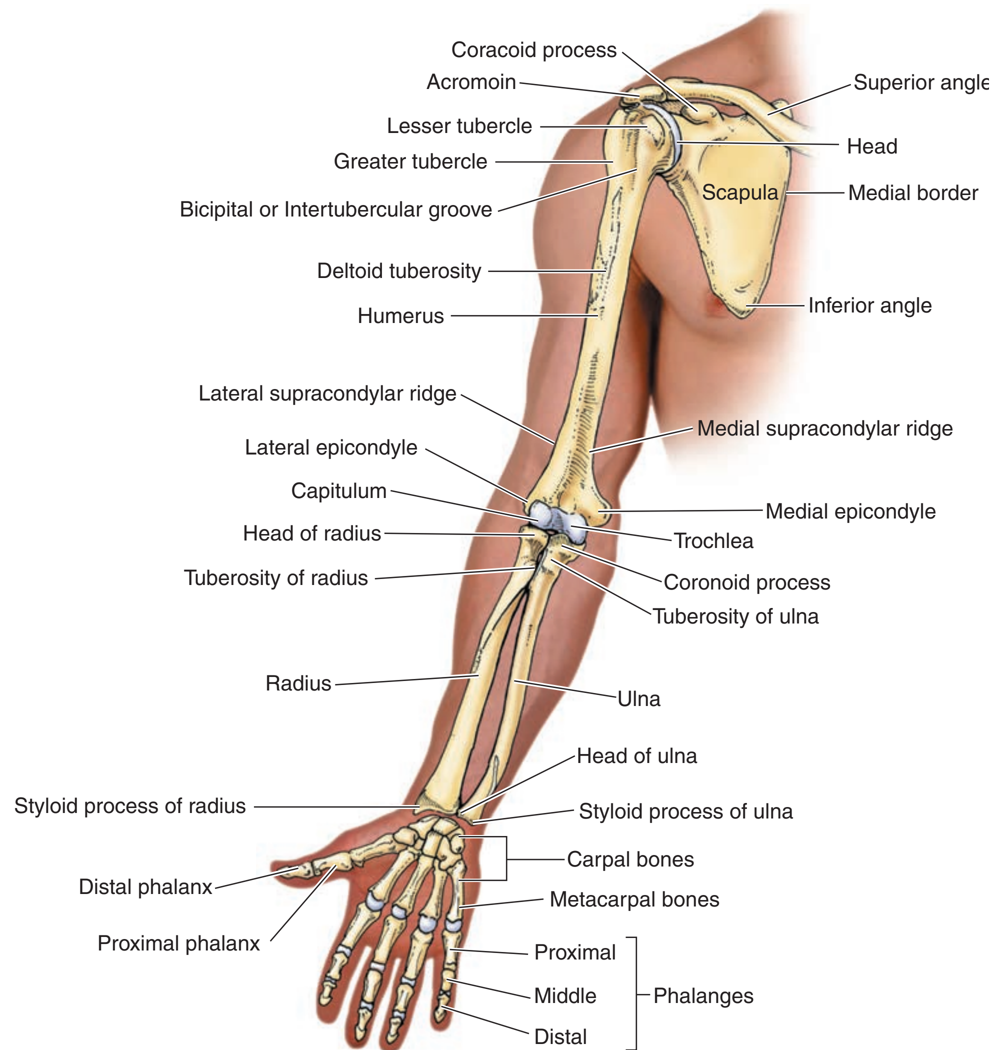


FIGURE 2-3 · Bone markings.

Note the condyles of the femur and tibia in Figure 5-2B. Note also that the distal end of the humerus has bone markings named *trochlea* (which means pulley) and *capitulum* (which means little head), rather than condyles.

3. *Epicondyles* ("epi" means upon) are raised areas on or near condyles. In Figure 2-3, note the medial and lateral epicondyles of the humerus.
4. A *tubercle* is a small, rounded projection. Note the tubercles on the humerus and scapula in Figure 2-3.
5. A *tuberosity* is a rounded, roughened area on a bone. Tuberosities tend to be larger than tubercles. Note the deltoid tuberosity on the humerus and the radial tuberosity in Figure 2-3.
6. A *trochanter* is a large projection on the femur. There are two trochanters on each femur, the greater trochanter and the lesser trochanter. See Figure 5-2A.
7. Many bone markings are called *processes*, each with a descriptive name, such as the acromion process, the coracoid process, and the coronoid process. In Figure 2-3, look for these three processes.
8. A *crest* is a prominent, narrow ridge of bone. An example of a crest is the iliac crest. See iliac crest in Figure 5-1A.
9. A *spine* is a thin, sharp projection. The spine of the scapula can be seen in Figure 2-3.
10. A *fossa* is a shallow indentation in a bone. See Figure 5-1A to see the iliac fossa.
11. A *groove* is a narrow, linear indentation in a bone. Locate the bicipital groove, also called the intertubercular groove, in the proximal, anterior humerus in Figure 2-3.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

12. A *facet* is a smooth, flat, articular surface on a bone. Facets are located on the ribs and vertebrae.
13. A *foramen* is a rounded opening in a bone. Typically, nerves or vessels pass through a foramen. Examples include the foramen magnum in the occiput and the obturator foramen in the hip or coxal bones.

Cartilage

Cartilage is made of a dense arrangement of collagen and elastic fibers within a rubbery ground substance that contains chondroitin sulfate. Cartilage has no blood or nerve supply. There are several types of cartilage, distinguished by the arrangement and composition of fibers and ground substance. *Hyaline* is the most common type of cartilage and covers the articular surfaces of most bones, providing them with smooth surfaces where they form joints. Hyaline cartilage forms the nose and parts of larynx. The function of hyaline cartilage is to provide flexibility and support.

Elastic cartilage has a matrix containing thin elastic fibers. The external ear is elastic cartilage. The function of elastic cartilage is to provide support and shape.

Fibrous cartilage has a matrix with abundant collagen fibers, making it the strongest type of cartilage. Fibrous cartilage is located in the intervertebral discs and at the pubic symphysis and is the cartilage of the knee joint. The function of fibrous cartilage is to provide support and attach structures.

Dense Connective Tissue

Dense connective tissue contains numerous, thick, densely packed fibers. There are several types of dense connective tissue. Dense regular connective tissue contains many collagen fibers organized in parallel groupings. Its function is attachment. Examples include *tendons*, which attach muscle to bone; *ligaments*, which attach bone to bone; and *aponeuroses,* which are flat, sheet-like tendons.

Dense irregular connective tissue also contains primarily collagen fibers, randomly arranged. Its function is to add strength. Examples include fascial membranes that cover, support, and separate muscles, deep layers of dermis of skin, membrane capsules around organs, and joint capsules.

Elastic connective tissue is made of elastic fibers that contain the protein elastin, and have the function of allowing elasticity (stretching). Examples of elastic connective tissue include lung tissue and the walls of arteries.

Loose Connective Tissue

Loose connective tissue contains fewer fibers and more cells than dense connective tissue, thus there is more space between fibers. There are several types of loose connective tissue. *Areolar* is soft, flexible tissue made of many types of fibers in semifluid ground substance. Its function is to cushion, protect, and give strength and elasticity. Areolar tissue also absorbs extra fluid when edema is present. An example of areolar tissue is the tissue surrounding organs.

Adipose tissue is dominated by fat cells. It functions as a temperature insulator and protector. Examples of adipose tissue include the tissue that protects and holds the eyeballs in their sockets, provides padding around the kidneys and heart, and makes up fat deposits.

Reticular connective tissue is composed of a fine, fibrous network, providing the framework of some organs such as the liver and spleen. An additional function of reticular connective tissue is to bind smooth muscle cells together. Examples include the framework of the liver, spleen, and lymph nodes.

Blood

Blood comprises blood cells and platelets in plasma. The function of blood is to transport oxygen, carbon dioxide, white blood cells, platelets, and many other substances needed for our body's health and homeostasis.

Lymph

Lymph is interstitial fluid that has passed into lymphatic vessels. Lymph assists in our body's immune response by transporting lymphocytes to areas where they are needed. Lymph also transports lipids and vitamins from the digestive tract to the blood.

The portion of connective tissue most relevant to massage therapists is the body's dense and loose connective tissue, which is collectively termed *fascia*. Fascia creates a continuous three-dimensional web around and within every structure of the human body, right down to the cellular level. Fascia is made of collagen and elastin fibers in a gel-like ground substance. Again, this web surrounds and connects every cell of the body, creating space between our cells while nourishing and protecting them.

Tears, adhesions, or other disruptions in the fascia are called *restrictions*, and these have a major impact on our health. Such restrictions can be caused by trauma, infection, or posture imbalances. In turn, fascial restrictions cause pain and limits in movement. Certain bodywork techniques directly impact the fascia, thus reducing pain and improving mobility. These techniques may lengthen the elastic components of fascia, leading to greater mobility, and/or they may change the viscosity of the ground substance, enhancing the overall health and function of the fascia.

JOINTS

It is important for massage therapists to have an understanding of joints and how different joints permit different movements. Massage therapy clients frequently have treatment goals related to the functioning of their joints. For many people, their

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

sense of health is directly related to their ability to move, and movement occurs at joints. A common reason for clients to seek massage therapy is to improve their range of motion or reduce pain that occurs during movement. Many clients present with joint injuries and joint problems they would like addressed. To satisfy these clients, we need to understand the structure and function of the joints we have in our bodies.

An *articulation*, or a joint, is a point where bones come together. Joints are necessary to allow our bodies to move. The surfaces of bones that contact other bones are called *articular surfaces*, and bones are said to *articulate* with each other at joints. Joints are classified in two ways, functionally and structurally.

Functional Classification

Classifying joints functionally means placing joints into categories based on the amount of movement they allow. The three functional categories are listed below.

Synarthrotic

Synarthrotic joints are considered "immovable" joints. The joints between the skull bones are classified as synarthrotic joints. Many bodywork practitioners, however, recognize that movement is possible between the skull bones, and this movement is one of the cornerstone beliefs of craniosacral therapy. Other examples include the joints between the roots of the teeth and their sockets in the mandible and maxillae.

Amphiarthrotic

Amphiarthrotic joints are considered "slightly movable" joints. The joints between the bodies of the vertebrae are examples of amphiarthrotic joints. The bodies make up the anterior aspects of the vertebrae and are joined together by fibrocartilaginous discs. Other examples include the pubic symphysis, which is the joint between the two pubic bones, and the joint between the ribs and the sternum.

Diarthrotic

Diarthrotic joints are considered "freely movable" joints. Freely movable may appear to be a misnomer in some instances, as in the case of the intercarpal joints, which are located in the very proximal aspect of the hand. The joints between the eight tiny carpal bones do not permit a wide range of motion, but they are classified as diarthrotic. More obvious diarthrotic joints include the elbow, the shoulder or glenohumeral joint, the hip and the knee.

Structural Classification

The second way to categorize joints is structurally. Structural classification is based on whether joints have a synovial cavity and the type of connective tissue that holds the bones together. The three structural categories are listed below.

Fibrous

Fibrous joints are connected by fibrous tissue with plentiful collagen fibers and can be synarthrotic or amphiarthrotic. They do not have a synovial cavity. *Sutures*, the joints between our skull bones and *gomphoses*, which are joints between our teeth and their sockets, are classified as fibrous joints. Another type of fibrous joint is a *syndesmosis*, such as the distal tibiofibular joint of the leg. This joint is classified as amphiarthrotic.

Cartilaginous

Cartilaginous joints have no synovial cavity and are united either by hyaline cartilage, fibrous cartilage, or both. They allow little or no movement. The two types of cartilaginous joints are synchondroses and symphyses. *Synchondroses* are synarthrotic joints that are joined by hyaline cartilage. An example is the joint between the rib 1 and the sternum. *Symphyses*, such as the pubic symphysis, are amphiarthrotic joints in which hyaline cartilage covers the surfaces of the articulating bones, and the bones are united by strong fibrous tissue. The joints between the bodies of the vertebrae are also symphyses, as they are united by fibrocartilaginous discs. The joints between the ribs and the sternum are also symphyses.

Synovial

Synovial joints have four basic components. Articular cartilage (generally hyaline cartilage, although sometimes fibrocartilage) covers the ends of both bones forming the joint. An articular capsule or sleeve encloses the joint surfaces. This sleeve contains an outer layer of fibrous connective tissue and an inner layer called the *synovial membrane*. Inside the sleeve is a joint cavity filled with synovial fluid. In addition, most synovial joints contain reinforcing ligaments (either inside or outside of the joint capsule), which add strength to the fibrous capsule. Some synovial joints also contain discs or *menisci* (pads of fibrocartilage) to support and cushion the joint.

There are six types of synovial joints, described below (Fig. 2-4). It is important to understand the movement permitted at each type of synovial joint. This allows us to properly assess range of motion. The movement permitted at each joint is determined by the shapes of the articulating surfaces of the bones that come together to form the joint. The movement permitted at each joint is also influenced by the ligaments that stabilize the joints and the soft tissue located in the area.

Plane or Gliding

Plane or gliding joints permit the least movement of all the types of synovial joints. Usually, they are joints between two flat surfaces of bone and permit only a small amount of back-and-forth or gliding movement. Examples include the intercarpal joints, the joint between the sternum and clavicle, and the joint between the acromion of the scapula and the clavicle (AC joint).

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

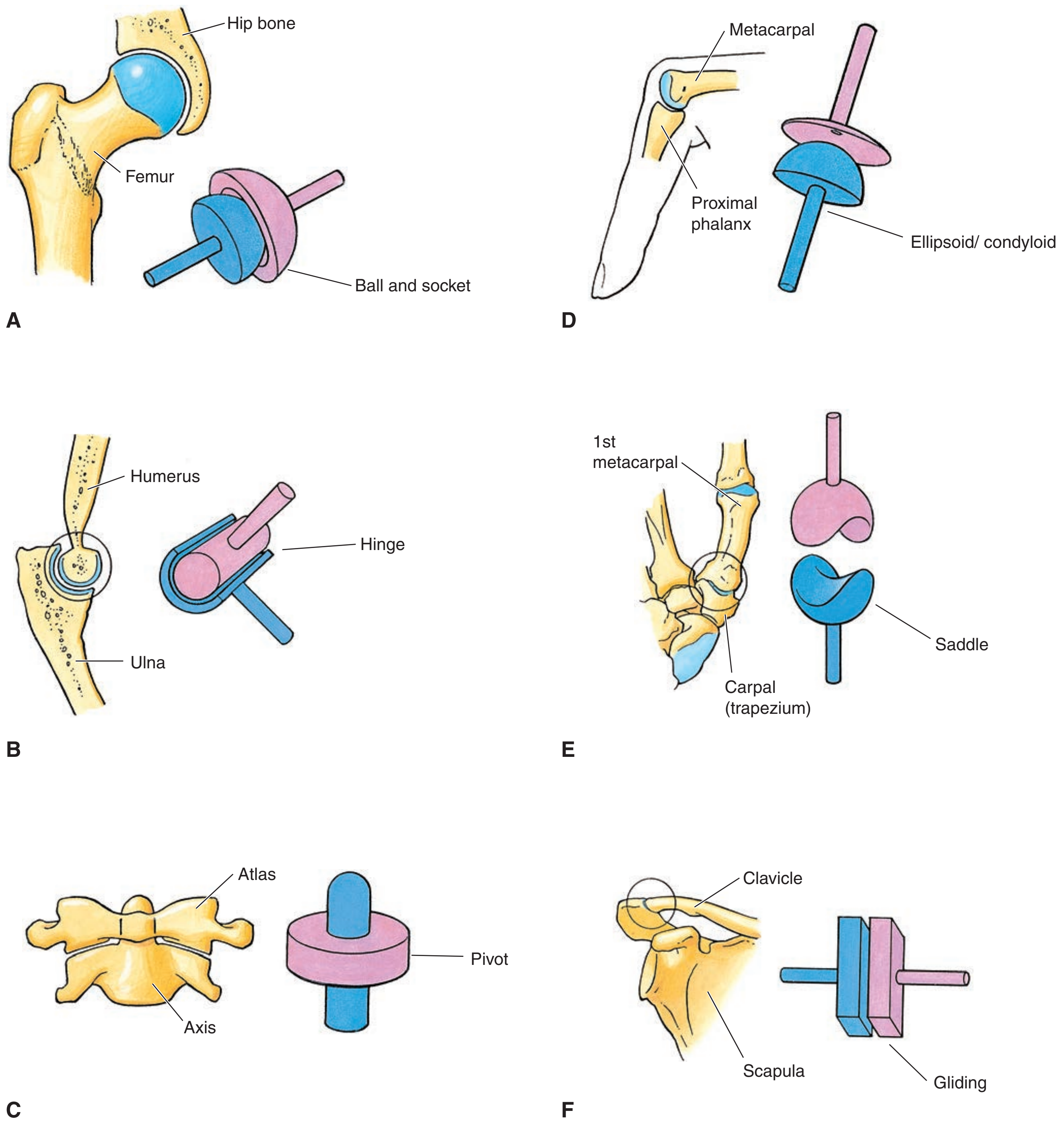


FIGURE 2-4 · Types of synovial joints.

Condyloid or Ellipsoidal

Condyloid or ellipsoidal joints permit flexion, extension, abduction, and adduction, or in other words, circumduction. Condyloid joints bring together convex and concave surfaces. You could perhaps picture an egg in an oval bowl. The egg can roll in two directions but cannot turn or spin. Examples of condyloid joints include the wrist, the joint between the occiput and C1 (atlanto-occipital joint), and the metacarpophalangeal joints.

Saddle

The saddle joint brings together the trapezium bone in the proximal hand with the metacarpal of the thumb. Saddle joints permit a greater range of circumduction than do condyloid joints.

Pivot

Pivot joints allow rotation only. They are formed by the articulation between a rounded surface on a bone and a

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

concave surface on a bone. They may also be formed by a ring of bone articulating with an axis of bone. Examples of pivot joints include the joints between the radius and ulna within the forearm and the atlantoaxial joint between C1 and C2.

Hinge

Hinge joints permit flexion and extension only and mimic a door opening and closing. Examples of hinge joints in the body include the elbow, the knee, and the ankle.

Ball-and-Socket

Ball-and-socket joints permit the most movement of any synovial joint. There are only two ball-and-socket joints in the body, the shoulder and the hip. The articulating surfaces of this type of joint are shaped like a ball and a socket.

MUSCLES

As massage therapists, we must know and understand the muscles we touch so we can provide the most effective massage and achieve the goals our clients seek. In addition, educating our clients about their bodies and potential postural or functional imbalances requires an understanding of and ability to communicate about our muscles.

Muscles are organs, composed of fiber-like cells, which are specialized to contract and thus allow movement. Muscles move not only our bones, but also food, fluids, and other substances through the body. In addition, muscle contraction generates 85% of our body's heat and allows us to maintain our body's internal temperature, despite a colder external environment. Muscles also help us to maintain our posture, such as standing up or holding our head up. Finally, muscles cross our joints and thus help to stabilize them. Muscles make up 40% to 50% of our body's weight.

Muscle Tissue

There are three types of muscle tissue: skeletal, smooth, and cardiac. Skeletal muscle attaches to our bones and moves them. It contracts voluntarily, meaning it is generally under our conscious control. Skeletal muscles also appear striated or striped when viewed under an electron microscope. The stripes are caused by alternating bands of thin and thick myofilaments, as will be discussed later.

Smooth muscle lines many of our body's organs and vessels and contracts to move food, fluids, and other substances along their pathways. Smooth muscle is considered involuntary, as it is not generally under conscious control. Cardiac muscle is the muscle of the heart. It contracts to push blood throughout our body. Cardiac muscle is also considered involuntary, although we have some capacity to control our heart rate through breathing and imagery.

Structure of a Skeletal Muscle

A typical skeletal muscle contains hundreds to thousands of long, thin muscle cells called muscle fibers. The gastrocnemius muscle contains roughly one million muscle fibers, whereas the first dorsal interosseus muscle contains roughly 80,000. Muscle cells line up next to each other. Each muscle fiber is encased in a thin, areolar connective tissue covering called an **endomysium**. Within each muscle, fibers are grouped together into bundles called *fascicles*. Each fascicle is wrapped in a dense regular connective sheet covering called a **perimysium**. Many fascicles are bundled together to make a muscle. The most superficial connective tissue wrapping around each muscle is called an **epimysium**. Epimysium is also made of dense regular connective tissue.

Skeletal Muscle Cell Components

Each muscle fiber or cell contains many components that are necessary for muscle contraction. The **sarcolemma** is the cell membrane, surrounding the muscle cell. The sarcolemma is responsible for controlling what enters and exits the cell. **Myofibrils** are the structural components of the muscle cell, which actually contract and shorten. Myofibrils are cylindrical in shape and contain thousands of thread-like protein structures beautifully positioned in organized rows and segments. These thread-like protein structures are called *myofilaments*.

Myofilaments are classified as thick or thin. There are alternating rows of thick and thin myofilaments, lying next to each other within each myofibril. Thick myofilaments appear darker on an electron micrograph and are primarily composed of the protein **myosin**. Thin myofilaments appear lighter on an electron micrograph and are composed primarily of the protein **actin**. Although myofibrils run the full length of each muscle fiber, the myofilaments do not. The shorter myofilaments of myosin and actin line up end to end along the length of a muscle cell, as well as next to each other. The lineup of myosin and actin is such that an actin myofilament extends beyond each end of the myosin. This lineup permits the actin myofilaments to slide toward the center of each myofibril segment. Each segment of a myofibril, which includes the myosin and the actin myofilaments that extend beyond the myosin, is called a *sarcomere*. Figure 2-5 illustrates the lineup of actin and myosin and the length of a sarcomere.

Myosin myofilaments have projections called *crossbridges*, which connect to the actin. During concentric contraction, myosin's crossbridges swivel and pull or slide the actin myofilaments toward the center of the sarcomere. Bringing the actin myofilaments toward the center of the sarcomere literally shortens the muscle. Myosin uses adenosine triphosphate (ATP) (energy) to do the work of pulling the actin.

The thin actin myofilaments have two regulatory proteins, tropomyosin and troponin, which can prevent myosin's crossbridges from pulling the actin myofilaments toward the center

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

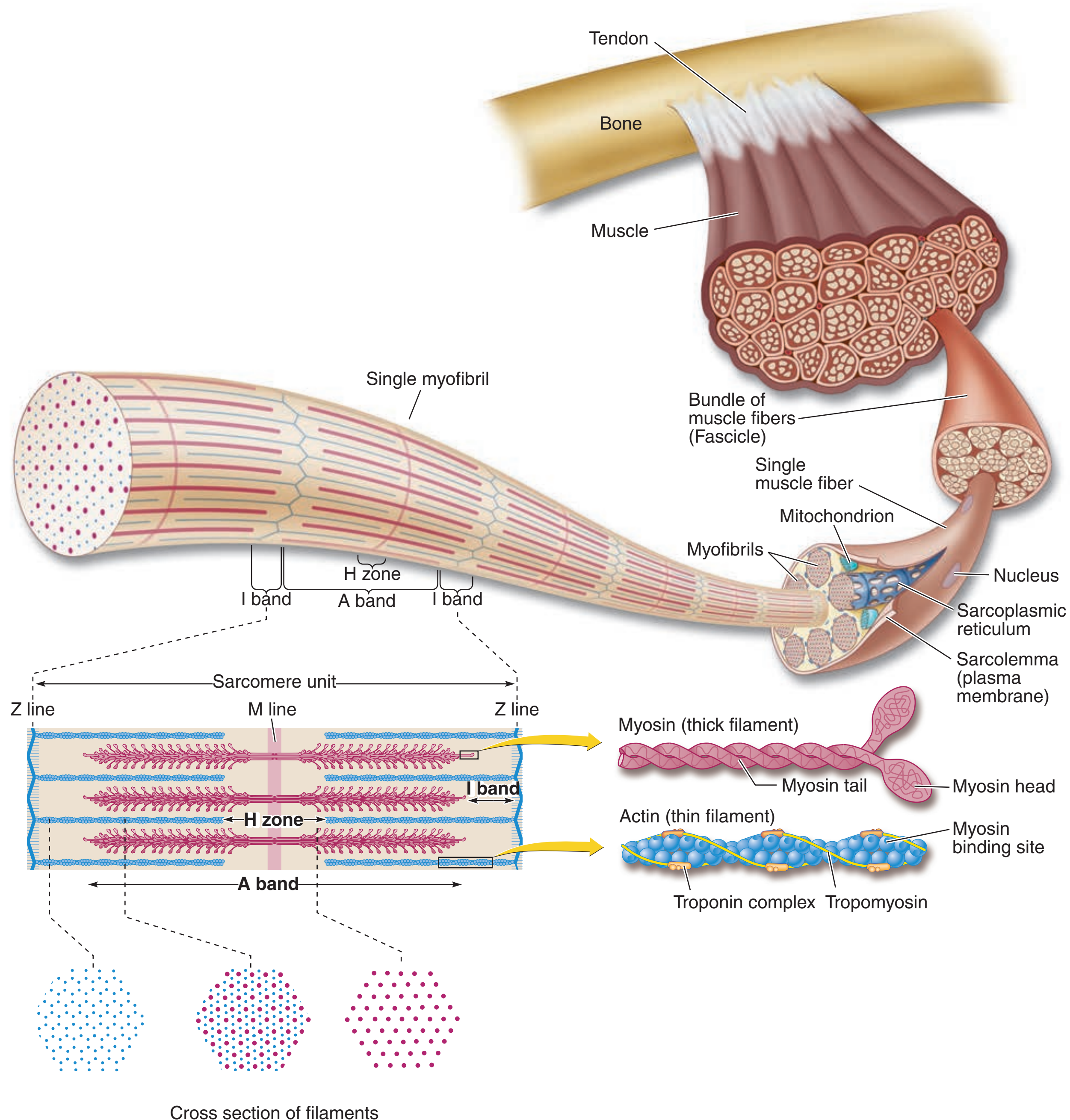


FIGURE 2-5 · **Skeletal muscle and the myofilaments within a skeletal muscle cell.**

of the sarcomere. When troponin and tropomyosin cover the myosin binding sites on the actin, contraction is impossible. However, as soon as the troponin and tropomyosin are removed from the actin, the myosin crossbridges are free to swivel and pull the actin toward the center of the sarcomere.

The **sarcoplasmic reticulum** is a specialized network of smooth tubules and sacs that surround each and every myofibril like a loosely knit sweater. The sacs in the sarcoplasmic reticulum store calcium ions, which are essential for contraction. Figure 2-5 illustrates a skeletal muscle and the myofilaments within a skeletal muscle cell.

Skeletal Muscle Contraction

The contraction of skeletal muscle is complex and involves many components and factors. These are discussed below.

Sliding Filament Mechanism

The concept of the **sliding filament mechanism** was first introduced in 1954 and was called *sliding filament theory*. Since that time, researchers have refined their knowledge of muscle contraction, allowing us to have a more detailed understanding of the process. As time passes, it is likely that our

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

understanding of how muscles contract and allow us to move will be developed even further.

The sliding filament mechanism is the means by which muscles contract or shorten. For a muscle to contract, a nerve impulse or electrical signal is required. As an illustration, we will follow the path of a nerve impulse toward the biceps brachii muscle, located in the superficial anterior arm. Biceps brachii helps us to flex our elbow. For biceps brachii to contract and for us to flex our elbow, a nerve impulse must be sent from the brain, travel down the spinal cord, and move out a spinal nerve heading toward the anterior arm. The nerve cell that carries the impulse required for muscle contraction is called a *motor neuron*. The particular fiber within the motor neuron that carries the nerve impulse toward a muscle is called a *motor axon*. At the end of the motor axon, the axon branches into axon terminals. At the end of each axon terminal, there are synaptic end bulbs, which house acetylcholine (ACh).

When a nerve impulse travels down a motor axon, then down the axon terminals, it reaches the synaptic end bulbs. The synaptic end bulbs do not touch the muscle; there is a space between the axon terminal and the muscle cell called a *synaptic cleft*. The nerve impulse must reach the skeletal muscle cell to cause contraction. If the impulse is strong enough, it will stimulate the release of ACh from the synaptic end bulbs. Acetylcholine is a neurotransmitter that carries the nerve impulse across the synaptic cleft and attaches to particular receptor sites on the sarcolemma. These receptor sites on the sarcolemma are called *motor end plates*.

Once the ACh has carried the nerve impulse and attached to its receptor sites on the sarcolemma, the sarcolemma becomes temporarily permeable to sodium ions. The interstitial fluid surrounding muscle cells contains a high concentration of positively charged sodium ions. When the sarcolemma becomes permeable to sodium, sodium ions rush into the cell. The entry of positive sodium ions alters the electrical charge within the cell and causes an electrical signal (called an *action potential*) to travel along the sarcoplasmic reticulum. The action potential causes the sarcoplasmic reticulum to release calcium from its storage sacs. The calcium travels to the troponin and tropomyosin, which is resting on actin, the thin myofilament. Calcium and the troponin–tropomyosin unit react chemically, causing the troponin–tropomyosin units to move away from the actin, thus revealing the myosin binding sites. With the myosin binding site exposed, the myosin crossbridges automatically attach to the actin and pull the actin myofilaments from both ends of the muscle toward the center of the sarcomere, thus shortening the muscle. As the muscle shortens, the muscle's tendons pull the bones, causing them to move closer to each other. In the case of elbow flexion, the forearm is pulled closer to the anterior arm. As additional action potentials are produced, and enough ATP energy and calcium are available, myosin continues to pull the actin over and over to sustain the contraction. This type of muscle contraction, in which the muscle shortens, is called a *concentric contraction*.

Relaxation of a muscle fiber happens when the nerve impulse ends and ACh is no longer released. Acetylcholinesterase is released to break down the acetylcholine in the synaptic cleft. Without the continuation of nerve impulses reaching the sarcolemma, the chain of events needed for muscle contraction stops. Energy is used to return calcium to the sarcoplasmic reticulum and remove sodium from the cell. Troponin and tropomyosin also return to cover the myosin binding sites on the actin. At this point, the myosin no longer can pull the actin. Contraction stops, and the muscle relaxes and returns to its original length. Figures 2-6 and 2-7 illustrate the position of actin and myosin during muscle contraction and relaxation.

Motor Units

Some types of motor axons each carry nerve impulses to just a few muscle cells, as is the case with motor axons that serve the muscles that move our eyes. Other motor axons can carry impulses that reach roughly 750 muscle cells, as do the motor axons that bring impulses to the biceps brachii muscle. Some motor axons carry impulses to thousands of skeletal muscle cells. The single motor axon and all the skeletal muscle cells it stimulates are together called a **motor unit**. The number of motor units that comprise and serve each muscle varies greatly. Some small muscles contain just a few motor units, whereas others have hundreds.

Because we have motor units, our bodies can move in many ways and in varying degrees. For instance, we can flex our elbow

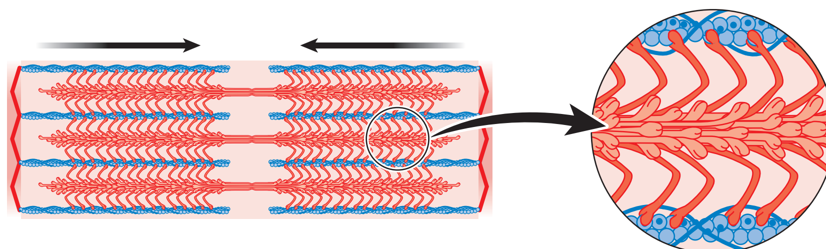


FIGURE 2-6 · Position of actin and myosin during muscle contraction.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

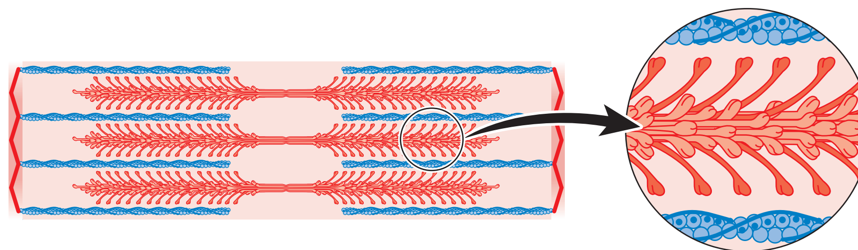


FIGURE 2-7 · Position of actin and myosin during muscle relaxation.

a little or a lot. We can flex our elbow when we have nothing in our hand, or we can flex it while carrying a 5-pound weight. A small movement with little force applied requires a smaller number of motor units. A larger movement with greater force applied requires the contraction of a greater number of motor units. Thus, the size and number of motor units contracting at any one time determines the amount of movement possible and the strength of the movement. In addition, motor units take turns contracting; some are engaged while others rest. This enables us to maintain contraction for a longer period of time.

All-or-Nothing Principle

When a motor unit does contract, every muscle cell within the motor unit contracts fully. This means that the entire set of actin and myosin myofilaments within each cell shorten to their full extent. In other words, there is no partial contraction within a muscle cell. This concept is called the *all-or-nothing principle*.

Motor Unit Recruitment

When we perform repetitive movements or use our muscles for a long time, we require more motor units to be activated. The generation of more nerve impulses to more skeletal muscle fibers to assist in muscle contraction is known as **motor unit recruitment**. When additional motor units are recruited, the ones in use initially can rest and get ready to contract again.

Muscle Tone

A small number of motor units are involuntarily activated to produce **muscle tone**. The motor units take turns being active to sustain these contractions, which create tone or firmness in our muscles.

Muscle Fatigue

When muscle fibers can contract for a prolonged period, they eventually fatigue and can no longer contract. Some factors that contribute to **muscle fatigue** are lack of calcium, insufficient oxygen, depletion of glycogen and other nutrients, and possibly the buildup of lactic acid.

Types of Skeletal Muscle Fibers

There are three main types of skeletal muscle fibers. *Slow oxidative* (SO) fibers are small in diameter and appear red because they have large amounts of myoglobin, a red protein that binds oxygen in muscle fibers. SO fibers have many large mitochondria, which generate ATP slowly. They contract slowly but are resistant to fatigue and can maintain sustained contraction for many hours. Muscles used in distance running and other endurance activities have higher concentrations of SO fibers.

A second type of skeletal muscle fiber is *fast oxidative glycolytic* (FOG). They are intermediate in diameter, are red because they contain much myoglobin, and can generate ATP by aerobic cellular respiration and glycolysis. Aerobic cellular respiration involves a series of oxygen-requiring mitochondrial reactions that produce ATP. Glycolysis is a series of ten reactions that break glucose into pyruvic acid and form ATP. The muscles in our lower limbs that we use for walking have a high concentration of FOG fibers.

Fast glycolytic (FG) fibers, the third type, are largest in diameter, and are white because they contain little myoglobin, and generate ATP by glycolysis. Muscles we use for weight lifting have a high concentration of FG fibers. They fatigue quickly. Most skeletal muscles have mixtures of these three types of fibers. Amazingly, we seem able to change the concentrations of these three types of fibers within our individual muscles to adapt to the type and level of activity we perform.

Origin, Insertion, and Action

Now that we have discussed muscle contraction in some depth, we can begin to prepare for the study of individual muscles. There are some terms we will need to understand to help us study the muscles. Recall that concentric skeletal muscle contraction involves a shortening of a muscle due to the sliding of myofilaments toward the center of the muscle's sarcomere. As a muscle shortens, a pull occurs on both ends of the muscle, and thus a pull, via the muscle's tendons, on both of the sites where the muscle connects to bones. The shortening of a muscle occurs when the more movable attachment site moves toward the more stable attachment site. The more stable attachment site of a muscle is called the **origin**. The more movable attachment site of a muscle is called the **insertion**.

For each muscle we will discuss in this text, we will name the origin and insertion. It is important for massage therapists to know and remember many origin and attachment sites, as this helps us know the exact location of a muscle. It is also helpful to remember the origin and insertion sites of muscles because these sites are useful places to provide massage, particularly friction, as we seek to help muscles relax.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

Practice will make it easier to determine origin and insertion sites of the muscles and to remember them. If we consider how our bodies typically move, we can determine which body parts are more movable (and thus contain insertion sites) and which are more stable (and contain origin sites). For example, the forearm is more movable that the arm. It is certainly easier to bring the forearm closer to the arm than it is to bring the arm closer to the forearm. Consider a muscle that flexes the elbow and that attaches to both the arm and forearm. The attachment on the humerus will be the origin and the attachment on the forearm will be the insertion.

Likewise, the hand is more movable than the forearm. It is easier to bring the fingers closer to the forearm than it is to bring the forearm closer to the fingers. A finger flexor's attachment on the forearm will be the origin and the attachment on the fingers will be the insertion.

We could consider another muscle that attaches to the ribs and also to the humerus. The ribs are more stable than the humerus: it is easier to move the humerus toward the ribs than it is to move the ribs toward the humerus. Therefore, the origin of such a muscle would be on the ribs and the insertion would be on the humerus. The bone that moves when performing an action will be the bone that contains the insertion site. Muscles that are located in the extremities will have origin sites more proximal than their insertion sites, as the more proximal body parts in an extremity are more stable.

The **action** that a muscle performs is simply the name of the movement that occurs when insertion moves toward origin. Note that it is possible for muscles to contract and pull origin toward insertion. This is true if both muscle attachments are relatively equal in their mobility or if we fix the insertion, making it more stable. For instance, if we are hanging onto a chin-up bar, we have fixed our forearm, and when an elbow flexor contracts, the arm will actually move toward the forearm. It is essential for you to learn and remember the actions of muscles as the muscle's actions determine postural and functional problems. When a client presents with a postural or functional problem that he or she wishes to have addressed, you must determine the action he or she is having trouble with, or the action he or she is performing too much, so you can determine which muscle to address in your massage session. For this purpose, the actions of each muscle covered in this book are listed under that muscle as a reference for you.

Concentric, Eccentric, and Isometric Contractions

It is important to note that the above description of muscle contraction refers only to concentric contractions. **Concentric contractions** involve shortening of muscles. However, muscles may contract while lengthening or without any movement at all. A muscle contraction that occurs when a muscle lengthens is called an **eccentric contraction**. Eccentric contractions often occur when one moves to resist a force such as gravity. An example of eccentric contraction occurs when you slowly set a heavy stack of books down in front of you. Let us assume that you set the books down by slowly extending your elbows. In this instance, your elbow extensors are relaxing, and your elbow flexors are working or contracting. The elbow flexors contract to control the rate at which you set the books down, preventing gravity from pulling the books down quickly. Thus, the elbow flexors contract eccentrically. Another example to describe the difference between concentric and eccentric contractions can be illustrated as follows. Suppose you abduct your arm with a 5-pound weight in your hand. This action requires your arm abductors to contract concentrically. If you slowly lower the weight by adducting your arm, you are using your arm abductors eccentrically. Every muscle can be used concentrically and eccentrically, depending on the circumstances.

In addition, one can contract a muscle with no movement at all. This type of muscle contraction is described as an **isometric contraction**. Literally, isometric means "same length." A muscle contracting isometrically does not shorten or lengthen, so it remains the same length. An example of an isometric use of arm flexors is to hold your arms out in front of you in a position of flexion. If you hold your arms in a flexed position, you can notice that the arm flexors are working to allow you to maintain this position. Gravity would pull your arms back to your sides if you did not use muscles to hold your position. Another example of an isometric use of muscles is how the neck extensors contract to simply hold the head up. All muscle can be used isometrically, when they tighten, but do not cause movement.

Synergists and Antagonists

Synergists are muscles that work together to perform an action at a given joint. In the following chapters of the book, synergists will be listed for each muscle presented. Reviewing synergists helps you to remember the actions of muscles.

Antagonist or **opposing** muscles are ones that perform the opposite action from each other. Antagonist muscles must operate at the same joint. Antagonists will also be listed for each muscle presented in the following chapters. To have optimal health and posture, we need a balance between opposing muscle groups. If opposing muscle groups are in balance, we can have both strength and flexibility in all muscles. However, most of us have some imbalance between opposing muscles. We tend to have certain groups of muscles that are shortened and opposing muscle groups that are lengthened. For example, it is common for medial rotators of the arm to be shortened and lateral rotators of the arm to be lengthened. Typically, a lack of balance occurs because one group of muscles becomes shortened, resulting in the lengthening of the opposing muscles.

Shortened and Lengthened Muscles

Muscles frequently become shortened due to overuse. If your job requires continuous or frequent elbow flexion, your elbow flexors become shortened. If you perform elbow curls, flexing your elbows repetitively with weights in your hands, you will likely cause your elbow flexors to shorten. Muscles

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

also become shortened by being held in a position in which insertion has been moved toward origin. Wearing a sling that holds your elbow in a bent or flexed position for several weeks can cause shortened elbow flexors.

When muscles shorten, there are postural as well as functional implications. A **shortened muscle** causes one to hold the muscle in a contracted, shortened position. Perhaps you have noticed people who have slightly bent elbows, without intention to bend them. It is likely that such people have shortened elbow flexors.

In addition, shortened elbow flexors limit the ability to extend the elbow fully. In other words, a shortened muscle limits the range of motion of the opposite action. Shortened hip adductors result in limited hip abduction. Shortened knee extensors limit the ability to perform knee flexion fully. For many of the individual muscles covered in this text, we will explore the postural and functional implications of the muscle's shortening.

Muscles can also become weak and/or lengthened. Whenever a muscle shortens, its opposing muscle lengthens. Thus, muscles that remain in a shortened state cause their antagonists to remain in a lengthened state. Because shortened muscles receive continuous impulses to contract, the impulses to contract the opposing lengthened muscles may be inhibited, causing them to seem weak. These **lengthened muscles** that seem weak may be overworked, as they may need to contract eccentrically or isometrically to counteract the pull of a shortened muscle. For example, a muscle like the pectoralis minor, that pulls our scapulae (shoulder blades) forward and causes a posture of rounded shoulders, is commonly shortened and feels tight. Thus, the rhomboid muscles, which pull our scapulae back toward the spine, remain lengthened. A client with this particular muscular imbalance may experience pain in the area of the lengthened rhomboids. These rhomboids may feel tight and ropy to the massage practitioner. But the fact of the matter is that they are lengthened, so they will not benefit from lengthening massage strokes. The solution lies in lengthening the shortened muscles to restore balance. This solution is likely to restore strength to the weak muscles.

Muscles can also become weak when their nerve innervation is interrupted or when they have been injured. For many of the muscles covered in this text, we will discuss the implications of individual lengthened muscles.

Massage therapy techniques such as deep effleurage, friction, and range-of-motion work can literally lengthen muscles. Such massage applied to shortened muscles can help to restore the balance between opposing shortened and lengthened muscles. Circulatory massage to lengthened muscles can also assist their overall health. When approaching imbalances between muscle groups, it is commonly recommended to massage the shortened muscles first and with techniques designed to break adhesions and lengthen fibers. Afterward, it may appropriate to address the weaker, lengthened muscles with techniques that strengthen them. However, as mentioned in the example above, lengthening the shortened muscles can be enough to restore the strength of the lengthened muscles.

Palpation and Massage of Muscles

For each muscle discussed in this text, a suggestion for how to palpate the muscle and a list of appropriate massage strokes for the muscle are provided. Although the list of strokes is certainly not exhaustive, it gives you a sense of appropriate and helpful strokes to use to reduce muscle tension and adhesions in this muscle. Keep in mind that knowledge of each muscle's action keep allows you to use *reciprocal inhibition* to assist in muscle relaxation Reciprocal inhibition requires that you engage the opposing muscle isometrically. By causing the opposing muscle to contract, you limit the nerve impulse to contract to your target muscle and create an opportunity for lengthening the muscle. For example, if you wish to use reciprocal inhibition to relax the plantarflexors of the ankle, simply dorsiflex the ankle isometrically. Continued research and exploration allows our understanding of the nervous system to grow and change. We now know that reciprocal inhibition is much more complicated than the simple concept that our nervous system cannot simultaneously innervate opposing muscles. In fact, there are many instances when nerve impulses are sent to opposing muscles simultaneously, particularly muscles that cross more than one joint. However, it does seem that impulses to contract sent to a muscle can, at times, inhibit impulses to the antagonist. This is why reciprocal inhibition is such an effective cramp reduction technique.

For most muscles discussed, directions to stretch the muscle are offered. To stretch a muscle is to move the origin and insertion away from each other. This means that you can stretch muscles by performing the opposite action(s) of the muscle you wish to stretch. Sometimes you have to experiment with various combinations of opposite actions you perform when seeking a stretch. Remember that stretching should never hurt, and if you wish to stretch a client's muscles, you must give him or her a clear explanation of what you are doing before you begin a stretch. You must also tell your client to let you know as soon as he or she feels a good stretch and if any pain is experienced. Stretching is an excellent technique for lengthening a muscle and increasing range of motion at a joint.

NERVE SUPPLY TO MUSCLES

As described above in the section on the sliding filament mechanism, nerves are needed to carry impulses for contraction to all muscles. Any disruption in the process of bringing a nerve impulse to a muscle can cause mobility problems. Massage therapy clients may present with mobility problems, and thus it is important to have as full an understanding as possible of the physiology of movement. A brief overview of the nervous system, as well as information about which nerves innervate which muscles, is given below.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

The nervous system is divided into the *central nervous system,* which consists of the brain and the spinal cord, and the *peripheral nervous system,* which includes the nerves that extend from the brain and spinal cord and carry impulses to all parts of the body. There are two sets of nerves in the peripheral nervous system, the cranial nerves, which carry impulses to and from the brain, and the spinal nerves, which carry impulses to and from the spinal cord. There are 12 pairs of cranial nerves and 31 pairs of spinal nerves. The 31 pairs of spinal nerves are named according to the area of the spine from which they emerge (cervical, thoracic, lumbar, sacral, or coccygeal) and the level of the spine from which they emerge. The first pair of spinal nerves emerges between the occiput and C1 (C1 is the first vertebra and is also called the *atlas*). Each of the remaining spinal nerves emerges from a space between the vertebrae that is called the *intervertebral foramen.* The spinal nerves include eight pairs of cervical nerves, twelve pairs of thoracic nerves, five pairs of lumbar nerves, five pairs of sacral nerves, and one pair of coccygeal nerves.

The structure of spinal nerves is quite elaborate. Each spinal nerve has an anterior and a posterior root, which emerge directly from the spinal cord. These roots join together, pass through the intervertebral foramen, and divide immediately into two branches called rami (*rami* is the plural of *ramus*). The roots split into a ventral ramus, which innervates muscles of the extremities and the lateral and anterior trunk, and a dorsal ramus, which innervates deep muscles and the skin of the back. Most of the ventral rami form plexuses (Latin for *braid*), or networks of adjacent spinal nerves. The main plexuses are the cervical, brachial, lumbar, and sacral. The plexuses consist of spinal nerves that divide, join with other nerves, divide again, and rejoin other nerves to create a complex configuration of nerve pathways. The plexuses eventually become individual nerves that innervate particular body areas and muscle groups.

The cervical plexus comprises the ventral rami of spinal nerves C1 to C4, and a portion of C5. The cervical plexus innervates some muscles of the head, neck, and the diaphragm.

The brachial plexus primarily innervates muscles of the upper extremity (Fig. 2-8). The brachial plexus begins as the ventral rami of spinal nerves C5 to C8 and T1. The rami of spinal nerves C5 and C6 unite to form the superior (or upper)

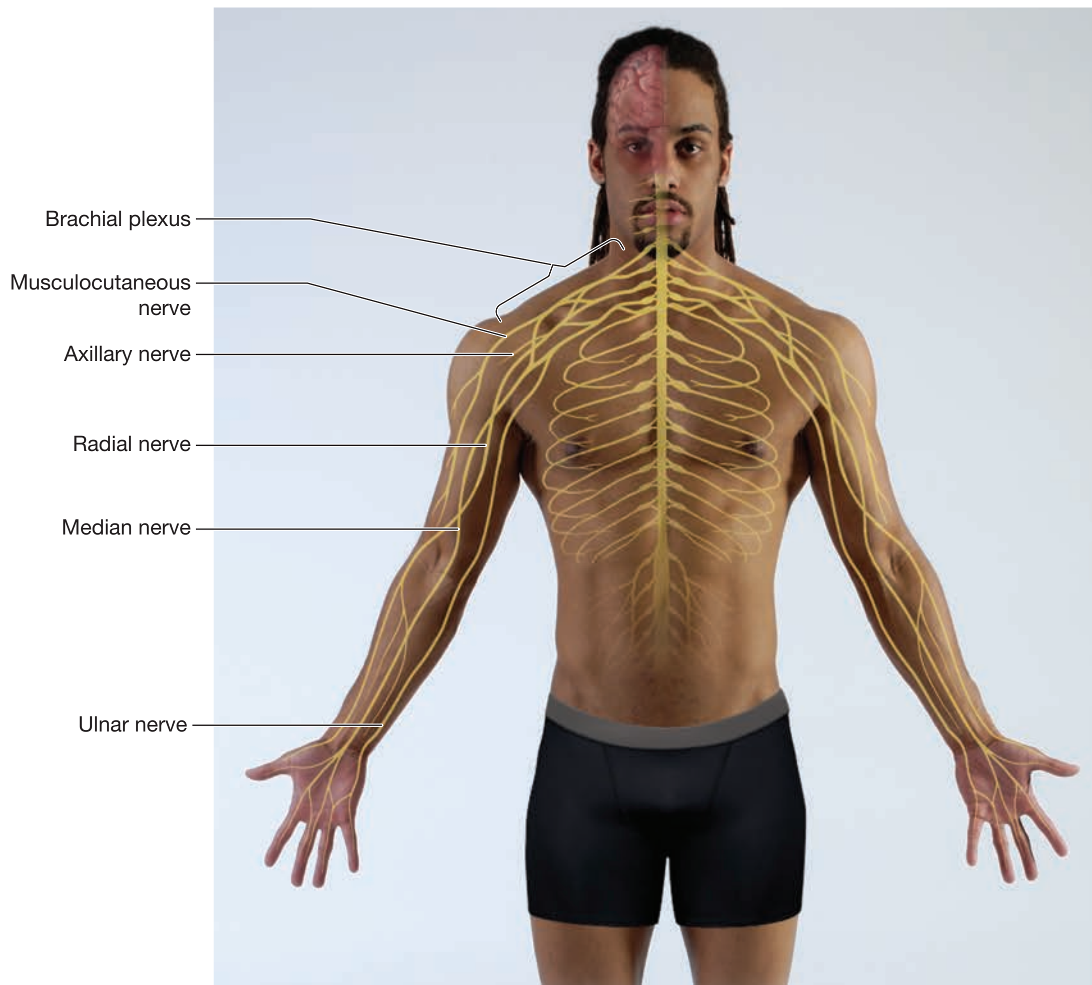


FIGURE 2-8 · Brachial plexus.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

trunk of the brachial plexus. The ventral ramus of C7 becomes the middle trunk. The ventral rami of C8 and T1 unite to form the inferior (or lower) trunk. The three trunks divide into anterior and posterior divisions. The anterior divisions from the superior and middle trunks unite to form the lateral cord. The anterior division of the inferior trunk continues on its own to become the medial cord. The posterior divisions from all three trunks unite to form the posterior cord. (The lateral cord runs more laterally, the posterior cord more posteriorly, and the medial cord more medially.) The cords branch into many specifically named nerves that innervate muscles of the upper extremity.

There are five major nerves that arise from the cords of the brachial plexus. They include the axillary nerve, which supplies the deltoid and teres minor muscles and thus is necessary for arm abduction. The musculocutaneus nerve supplies the coracobrachialis, biceps brachii, and brachialis and thus is largely responsible for elbow flexion. The radial nerve supplies muscles of the posterior arm and forearm and is thus responsible for elbow, wrist, and finger extension. The median nerve supplies most of the anterior forearm compartment and some muscles in the hand. The median nerve passes through the carpal tunnel and thus is the nerve that becomes irritated when one has carpal tunnel syndrome. Finally, the ulnar nerve supplies some anteromedial muscles of the forearm and most muscles of the hand.

Note the following regarding the source of certain nerve fibers:

- All axillary nerve fibers arise from the ventral rami of C5 and C6.
- All musculocutaneous nerve fibers arise from the ventral rami of C5 to C7.
- All radial nerve fibers arise from the ventral rami of C5 to C8 and T1.
- All median nerve fibers arise from the ventral rami of C5 to C7.
- All ulnar nerve fibers arise from the ventral rami of C8 and T1.

Other nerves that emerge from this plexus include the suprascapular nerve, which emerges from the superior trunk and supplies the supraspinatus and infraspinatus muscles. The nerve to the subclavius emerges from the superior trunk and supplies the subclavius muscle. The medial pectoral nerve emerges from the medial cord and supplies the pectoralis major and pectoralis minor. The subscapular nerve supplies the subscapularis and teres major. And the thoracodorsal nerve supplies the latissimus dorsi.

The thoracic nerves T2 to T12 are simply numbered and organized as singular nerves rather than a plexus. These spinal nerves innervate the intercostals muscles, some abdominal muscles, and some deep back muscles.

The nerves of the lumbar plexus, L1 to L4, innervate some abdominal muscles, some thigh flexors, all knee extensors, and all hip adductors.

The nerves of the sacral plexus, L4, L5, and S1 to S4, serve the gluteal muscles, hamstrings, and many muscles of the leg and foot.

ARTERIAL SUPPLY TO MUSCLES

Each muscle requires a blood supply to function. Blood is delivered to the muscles via arteries, which branch and narrow to arterioles. Massage therapy has long been credited with the enhancement of blood flow. While the exact effect of Swedish massage on the overall circulatory system is the subject of ongoing research and debate, it is commonly believed that massage enhances local circulation, reduces edema, and alters the interstitial fluid to enhance removal of metabolic waste and delivery of nutrients to the body's cells.

An understanding of the circulatory system enables massage therapists to better understand the effects of our work. A basic explanation of the structure and function of the system follows, including a list of the arterial supply to the major muscle groups of the body.

The cardiovascular system is comprised of the heart, blood vessels, and the blood. One of the main functions of the system includes delivery of nutrients to the cells of the body and removal of waste products from cells. Another function is maintenance of homeostasis in regards to temperature and pH. In addition, the blood allows clotting and the delivery of white blood cells to provide protection from pathogens.

The heart is a muscular pump that pushes our blood through 60,000 miles of blood vessels in our bodies. The healthy adult heart generally beats about 70 times per minute while at rest. The heart is located in the mediastinum, which is between our lungs and between the sternum and thoracic vertebrae. The heart is surrounded and protected by a three-layered membrane called the *pericardium*. Deep to the pericardium is the myocardium, the striated, involuntary cardiac muscle. The innermost layer of the heart is the endocardium, which provides a lining for the chambers of the heart.

The heart has four chambers, a right atrium, a left atrium, a right ventricle, and a left ventricle. Blood flows from the right atrium through the tricuspid valve into the right ventricle. From the right ventricle, blood is pumped into the pulmonary trunk, which splits into the pulmonary arteries that bring blood to the lungs via the pulmonary veins. Blood is oxygenated in the lungs and then flows into the left atrium. From the left atrium, blood passes through the bicuspid or mitral valve into the left ventricle and is pumped into the aorta.

The aorta is the largest artery of the body, with a width of close to 1 inch. The aorta contains four sections. The

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

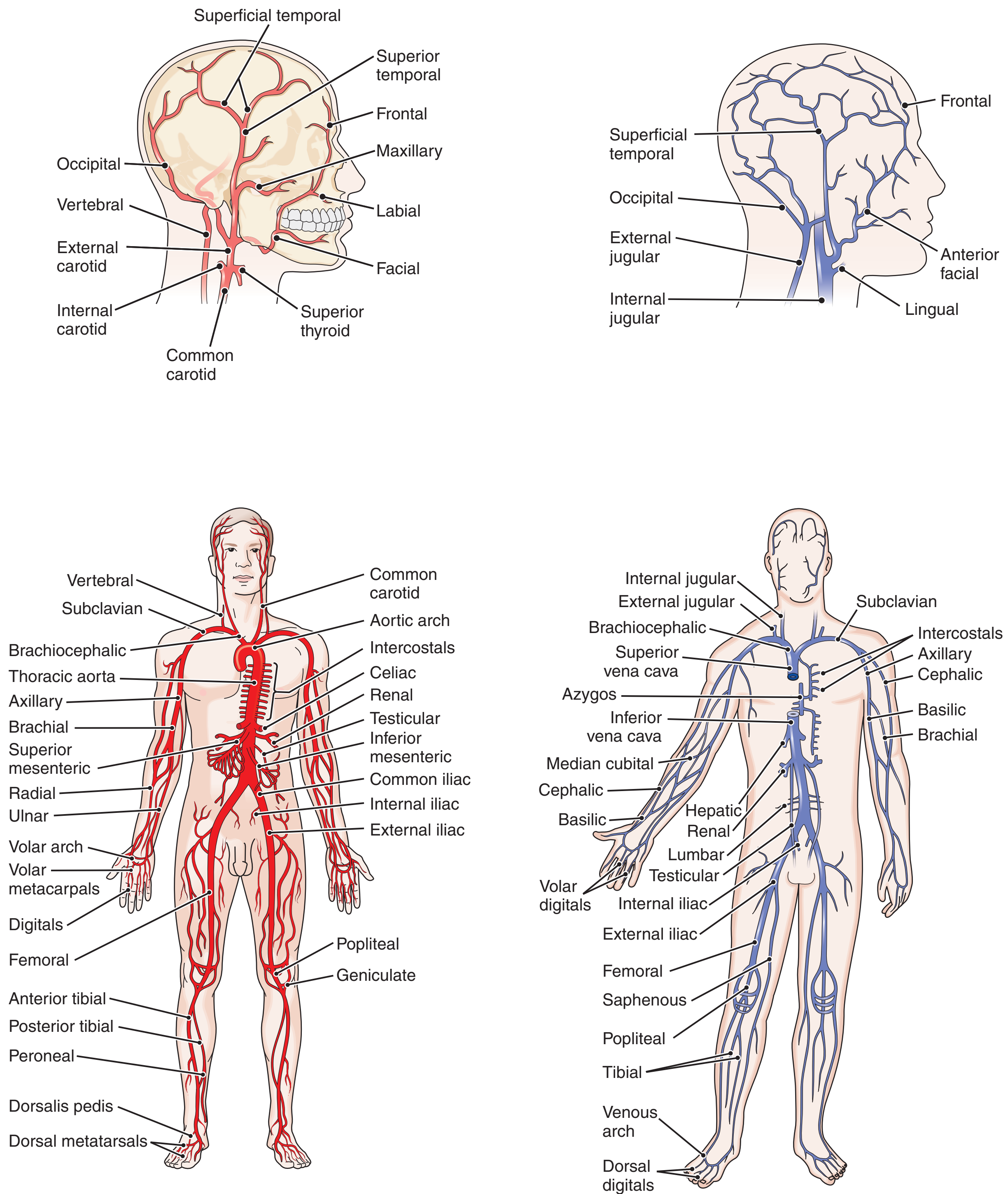


FIGURE 2-9 · **Arterial supply and venous return to various body areas.**

ascending aorta carries blood directly from the left ventricle of the heart. The right and left coronary arteries branch from the ascending aorta and bring blood to nourish the heart muscle. The ascending aorta becomes the *arch* of the aorta, which is aptly named for its curved shape. Three major arteries branch off of the arch of the aorta: the brachiocephalic trunk, the left common carotid artery, and the left subclavian artery. The brachiocephalic trunk divides into the right subclavian artery and the right common carotid artery. The right subclavian artery carries blood to the brain and spinal cord, as well as to muscles of the neck, shoulder, and scapula regions. The right common carotid artery carries blood to the right side of the head and neck. The left common carotid artery carries blood to the left side of the head

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

and neck. The left subclavian artery supplies the left upper extremity.

The arch of the aorta becomes the thoracic aorta. Many smaller vessels branch off from the thoracic aorta as it descends and provide blood to the bronchial tubes, esophagus, and muscles of the chest wall and rib cage, as well as to the diaphragm.

Finally, the thoracic aorta becomes the abdominal aorta. Many arteries branch off from the abdominal aorta, including the celiac trunk, and the superior and inferior mesenteric branches, as well as other branches serving glands and organs in the abdominal region. The celiac trunk serves some digestive organs including the stomach, gall bladder, liver, pancreas, and spleen. The superior mesenteric trunk supplies the small and large intestines. The inferior mesenteric branch delivers blood to portions of the colon and rectum.

The abdominal aorta branches into the right and left common iliac arteries. These vessels divide further into the femoral arteries, which serve the muscles of the thigh; the popliteal artery, which serves muscles of the posterior knee; and the anterior and posterior tibial arteries, which serve muscles of the leg.

When blood is brought to a muscle, it must enter the smallest vessels, called *capillaries*, which are structures to allow the exchange of oxygen and carbon dioxide between blood and muscle cells. Oxygen is diffused through capillary walls, into the interstitial fluid, where it can be accessed by our cells. Carbon dioxide is diffused into the capillaries, and the blood carries it into venules (small veins), then veins, and then back into the right atrium.

We have two types of circulation: systemic and pulmonary. Systemic circulation refers to the delivery of oxygenated blood from the left ventricle to the body's tissues and organs. Pulmonary circulation is the delivery of deoxygenated blood to the lungs, where it gains oxygen, and delivery of this oxygenated blood from the lungs to the heart.

The blood is a liquid connective tissue that contains plasma (about 91% water and some dissolved substances) and formed elements (red blood cells, white blood cells, and platelets). *Hematocrit* is the percentage of blood volume that is red blood cells. Average hematocrit is 38%–46% of blood volume. Red blood cells contain hemoglobin, which carries oxygen and carbon dioxide, and helps regulate blood pressure. White blood cells help fight infections and inflammation. Platelets are needed for clotting.

Figure 2-9 illustrates the arterial and venous supplies to the various body areas.

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

CHAPTER SUMMARY

Chapter 2 has provided a basic introduction to the physiology of connective tissue (including bones, cartilage, fascia, blood, and lymph), joints, and muscles, and an introduction to the nerve and blood supplies to muscles. This information should equip you to begin a comprehensive study of the muscles of the body.

WORKBOOK

Review Exercises

Connective Tissue

1. What are bones?

____

____

2. List five functions of bones:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

3. Two main types of bone tissue are:

a. ______________________________

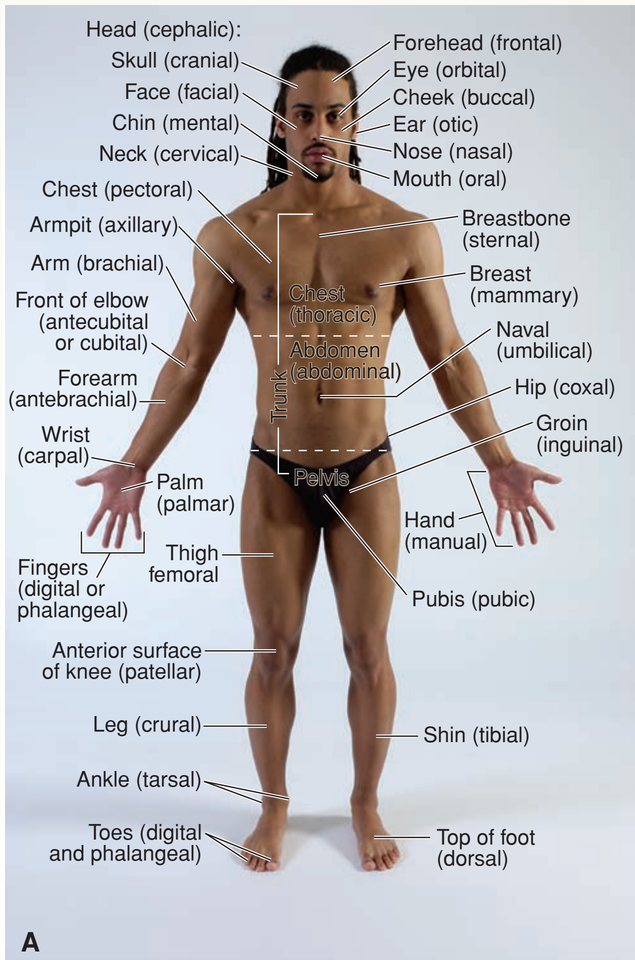
b. ______________________________

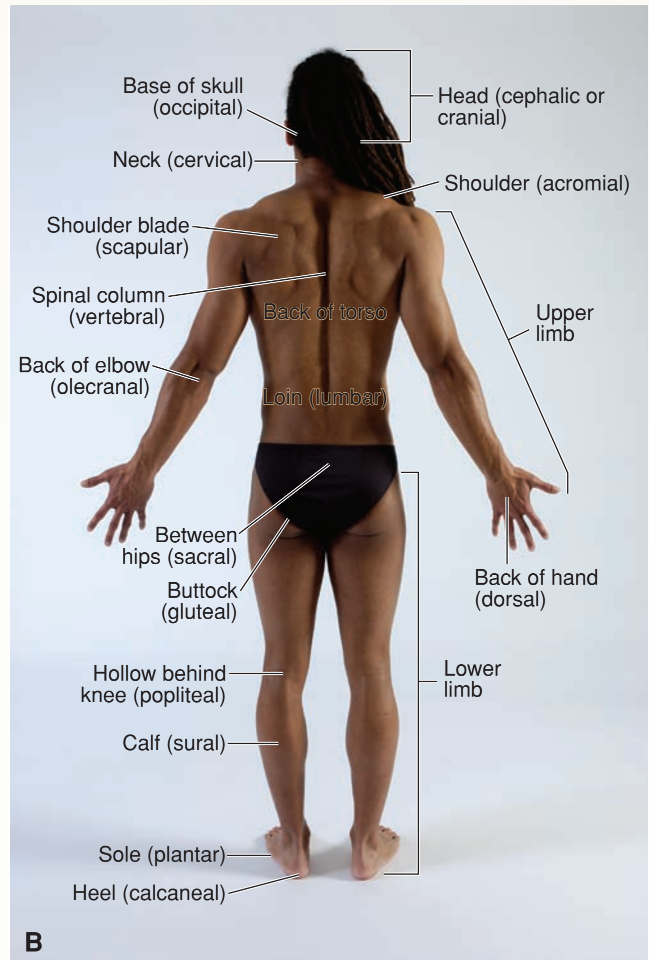
4. List the five shapes of bones:

a. ______________________________

b. ______________________________

c. ______________________________





© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

d. ______________________________

e. ______________________________

5. Skeleton is divided into axial and appendicular segments.
   a. The axial skeleton consists of:

   ____
   ____
   ____

   b. The appendicular skeleton consists of:

   ____
   ____
   ____

6. Define fascia, and give four examples of connective tissue structures that are called fascia:

   ____
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________

Joints

1. Fill in the appropriate functional classifications of joints:
   a. ____________________ = immovable joint
   b. ____________________ = slightly movable joint
   c. ____________________ = freely movable joint

2. Structural classifications of joint use the following terms:
   a. ____________________ joints are held together by fiber.
   b. ____________________ joints are held together by cartilage.
   c. ____________________ joints contain all the components of synovial joints.

3. List the four components of a synovial joint:
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________

4. For each type of synovial joint listed below, please fill in the following: a., the movement permitted at this joint; b., the shape of the articulating surfaces; and c., an example of where this joint is in the body.

1. Plane or gliding
   a. ______________________________
   b. ______________________________
   c. ______________________________

2. Condyloid or ellipsoidal
   a. ______________________________
   b. ______________________________
   c. ______________________________

3. Saddle
   a. ______________________________
   b. ______________________________
   c. ______________________________

4. Pivot
   a. ______________________________
   b. ______________________________
   c. ______________________________

5. Hinge
   a. ______________________________
   b. ______________________________
   c ______________________________

6. Ball-and-socket
   a. ______________________________
   b. ______________________________
   c. ______________________________

Muscles

1. What are muscles?

   ____
   ____
   ____

2. Three types of muscle tissue include:
   a. __________, which is __________, __________, and ______________________________
   b. __________, which is __________, __________, and ______________________________
   c. __________, which is __________, __________, and ______________________________

3. Functions of muscles include:
   a. ______________________________
   b. ______________________________
   c. ______________________________

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.

d. ______________________________

e. ______________________________

4. Structure of a skeletal muscle:
   a. Each individual muscle cell is enclosed in a connective tissue sheath called an ______________________________.
   b. Each fascicle, or group of muscle cells, is wrapped in a connective tissue sheath called a ______________________________.
   c. Many fascicles, bound together to form a muscle, are wrapped in a covering called a ______________________________.
   d. The epimysium blends into a tendon or aponeurosis, attaching muscles to bone.

5. List and define the components of a skeletal muscle cell:

____

____

____

6. Write out the steps involved in the sliding filament mechanism:

____

____

____

____

____

____

____

____

____

7. Define a motor unit, and explain the relationship between motor units and the all-or-nothing principle.

____

____

____

8. What is the difference between origin and insertion?

____

____

9. Give an example of a concentric contraction and an example of an eccentric contraction:

____

____

____

____

© Jones & Bartlett Learning, LLC. NOT FOR SALE OR DISTRIBUTION.