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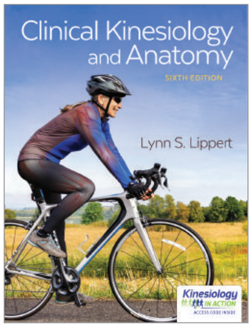

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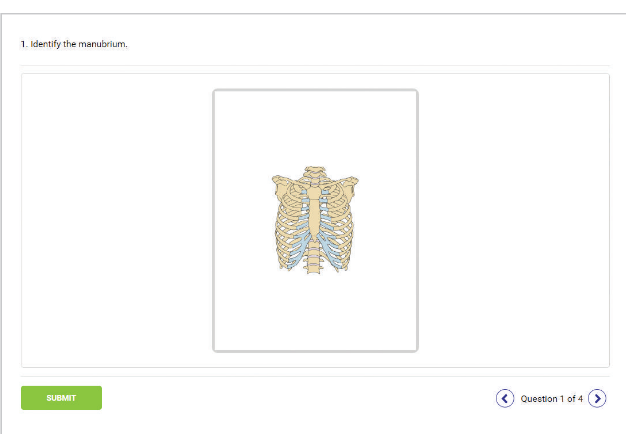

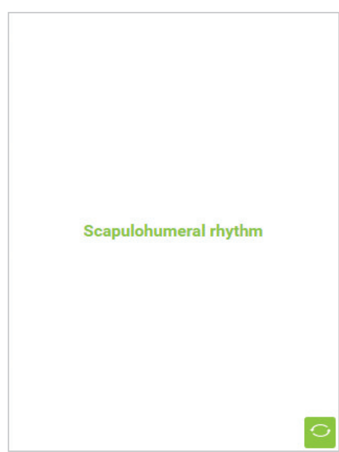

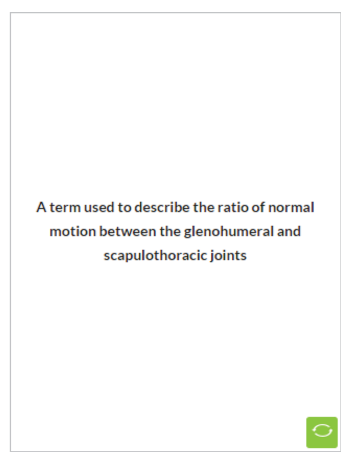

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1. An individual experienced a distal humerus fracture and was immobilized for 6 weeks. The person now presents with limited range of motion. When planning how to help this person improve elbow flexion, the arthrokinematic motion that would be most helpful is:

- **A.** glide radius anterior on the humerus
- **B.** glide radius posterior on the humerus
- **C.** glide ulna anterior on the humerus
- **D.** glide ulna posterior on the humerus

SUBMIT

3. What muscle groups attach to the medial epicondyle of the elbow?

- **A.** Wrist extensors and forearm pronators
- **B.** Wrist extensors and forearm supinators
- **C.** Wrist flexors and forearm pronators
- **D.** Wrist flexors and forearm supinators

SUBMIT

Question 3 of 10

Lesson 4: Shoulder Assessment

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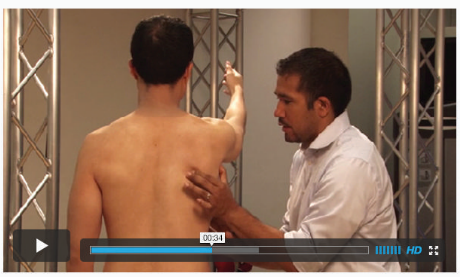

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Clinical Kinesiology and Anatomy

SIXTH EDITION

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To Sal Jepson, who for over 27 years and six editions has provided invaluable support, advice, and wisdom. Your contribution is immeasurable. Thank you from the bottom of my heart.

Acknowledgments

As Hillary Clinton made us so aptly aware that it takes a village to raise a child, the same can be said of the creation or revision of a book. My village includes so many individuals. Sal Jepson, who drew the original art for the first edition, and whose influence continues through to this edition, also donned Lycra and smiled while riding her bicycle for the cover shot. Mark Fitzgerald, with his knowledge of photography and helpful, easy-to-work-with style allowed the photo shoot for the cover to be accomplished to everyone's satisfaction. Don Davis has continued to make my explanations of physics simple, yet accurate. Shelby Clayson again has applied her eagle eyes to proofreading so I might accomplish my dream of an error-proof edition. Jennifer Hurrell somehow found enough time and energy while teaching full time, going to graduate school, and raising two teenage daughters to contribute some writing in this edition.

My appreciation goes out to Rob Craven, President, and the many individuals at F.A. Davis for their commitment to making this textbook one that will continue to make us all proud. Melissa Duffield, Senior Acquisitions Editor has maintained her support of this text, while juggling more projects than seemingly possible, and still kept her sense of humor. Margaret Biblis, publisher, has maintained her long history with, and support of, me and this book. Jennifer Pine, Senior Developmental Editor, whose expertise, wonderful communication skills, and calm demeanor has made the project move quite smoothly. Carolyn O'Brien, Design Manager, used her artistic eye and expertise in the creation of the book cover, and provided suggestions for improvement to the inside art.

Preface to the Sixth Edition

For over 25 years *Clinical Kinesiology and Anatomy* has provided a fundamental understanding of kinesiology and anatomy from a clinical perspective. The sixth edition continues to provide this basic information. Simple, easy-to-follow explanations continue to be the hallmark of this book.

As with previous editions, the book is written so that instructors can omit information not needed for their particular discipline without putting the student at a disadvantage in terms of understanding other subject matter. For example, some disciplines may not need to study arthrokinematics, the temporomandibular joint, or gait. The joint-specific chapters are essentially self-standing, so the order in which they are read can be easily changed. Instead of beginning with joints of the upper extremity, one could begin with the lower extremity or axial skeleton, and not lose understanding.

Emphasis remains on basic understanding. To make the arthrokinematics chapter more clinically relevant, steps have been provided to perform a motion analysis.

A brief explanation at the cellular level has been provided for greater understanding of how force is produced during muscle contraction.

To provide a greater link between foundational knowledge and clinical application, several box features have been added throughout the joint-specific chapters. Many illustrations have been updated to provide uniformity and consistency across the text. To enhance clarity, consistent color-coding has been applied to several illustrations.

Lynn S. Lippert

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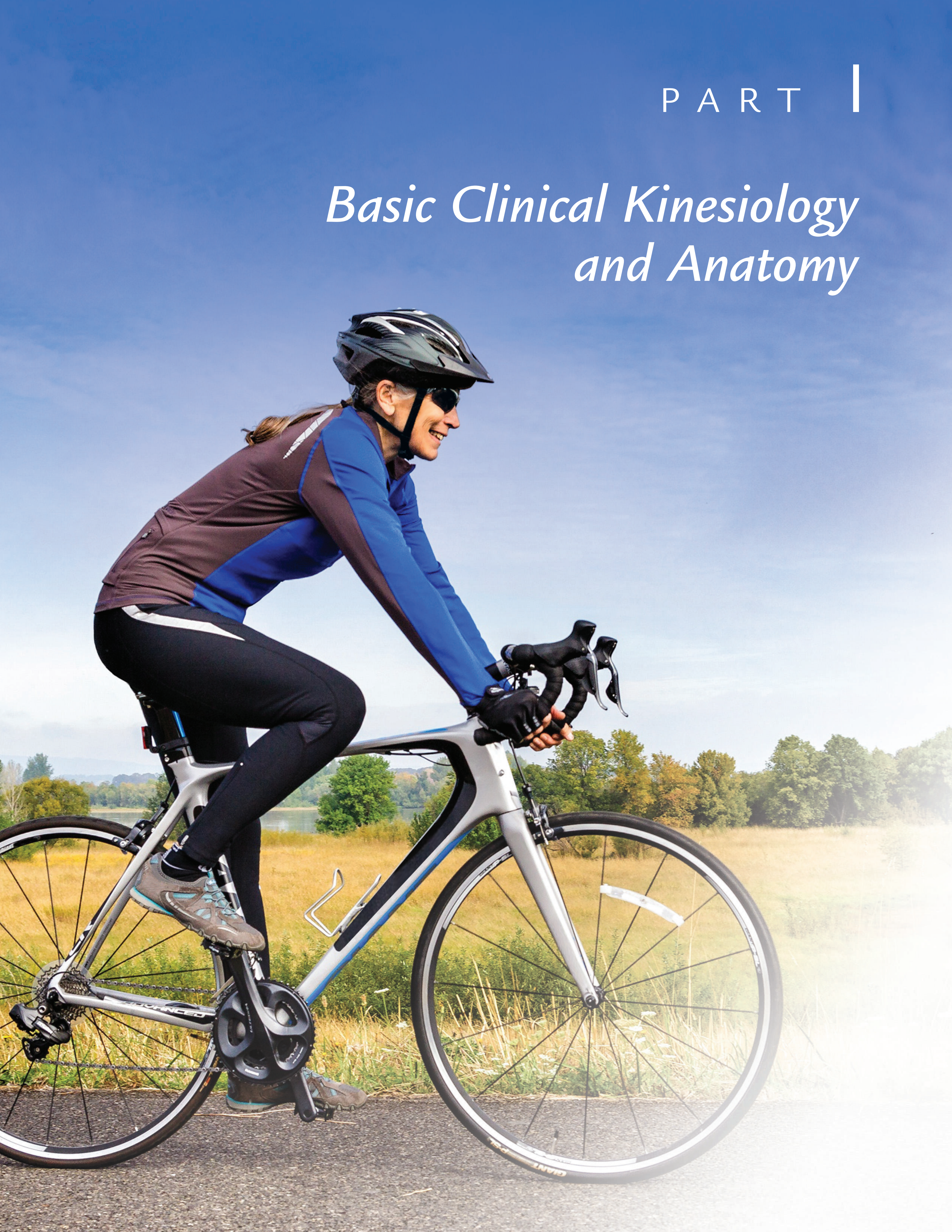
PART I

Basic Clinical Kinesiology and Anatomy



CHAPTER 1
Basic Information

Segments of the Body

Descriptive Terminology

Types of Motion

Joint Movements (Osteokinematics)

Review Questions

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By definition, **kinesiology** is the study of movement. However, this definition is too general to be of much use. Kinesiology brings together the fields of anatomy, physiology, physics, and geometry and relates them to human movement. Thus, kinesiology utilizes principles of mechanics, musculoskeletal anatomy, and neuromuscular physiology.

Mechanical principles that relate directly to the human body are used in the study of **biomechanics.** Because we may use a ball, racket, crutch, prosthesis, or some other implement, we must consider our biomechanical interaction with them as well. This may involve looking at the *static* (nonmoving) and/or *dynamic* (moving) *systems* associated with various activities. Dynamic systems can be divided into kinetics and kinematics. **Kinetics** are those forces causing movement, whereas **kinematics** is the time, space, and mass aspects of a moving system. These and other basic biomechanical concepts will be discussed in Chapter 8.

This text will give most emphasis to the musculoskeletal anatomy components, which are considered the key to understanding and being able to apply the other components. Many students have negative thoughts at the mere mention of the word *kinesiology.* Their eyes glaze over and their brains freeze. Perhaps, based on past experience with anatomy, they feel that their only hope is mass memorization. However, this may prove to be an overwhelming task with no long-term memory gain.

As you proceed through this text, keep in mind a few simple concepts. First, the human body is arranged in a very logical way. Like all aspects of life, there are exceptions. Sometimes the logic of these exceptions is apparent, and sometimes the logic may be apparent only to some higher being. Whichever is the case, you should note the exception and move on. Second, if you have a good grasp of descriptive terminology and can visualize the concept or feature, strict memorization is not necessary. For example, if you know generally where the patella is located and what the structures are around it, you can accurately describe its location using your own words. You do not need to memorize someone else's words to be correct.

By keeping in mind some of the basic principles affecting muscles, understanding individual muscle function need not be so mind-boggling. If you know (1) what motions a particular joint allows, (2) that a muscle must span a particular side of a joint surface to cause a certain motion, and (3) what that muscle's line of pull is, then you will know the particular action(s) of a specific muscle. For example, (1) the elbow allows only flexion and extension, (2) a muscle must span the elbow joint anteriorly to flex and posteriorly to extend, and (3) the biceps brachii is a vertical muscle on the anterior surface of the arm; (conclusion) therefore, the biceps muscle flexes the elbow.

Yes, kinesiology *can* be understood by mere mortals. Its study can even be enjoyable. However, a word of caution should be given: Like exercising, it is better to study in small amounts several times a week than to study for a long period in one session before an exam.

Segments of the Body

The body is divided into segments according to bones (Fig. 1-1). In the upper extremity, the **arm** is the bone (humerus) between the shoulder and the elbow joint.

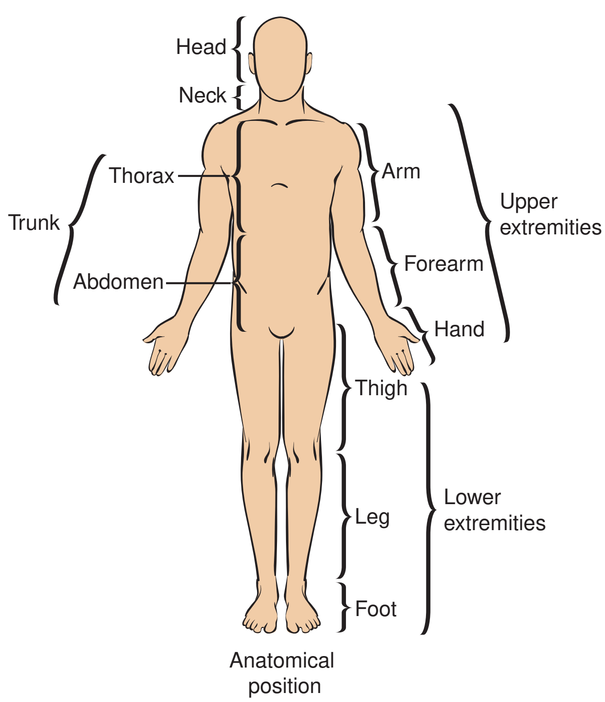

Figure 1-1. Body segments.

Next, the **forearm** (radius and ulna) is between the elbow and the wrist. The **hand** is distal to the wrist.

The lower extremity is made up of three similar segments. The **thigh** (femur) is between the hip and knee joints. The **leg** (tibia and fibula) is between the knee and ankle joints, and the **foot** is distal to the ankle.

The trunk has two segments: the thorax and the abdomen. The **thorax,** or chest, is made up primarily of the ribs, sternum, and thoracic vertebrae. The **abdomen,** or lower trunk, is made up primarily of the pelvis, stomach, and lumbar vertebrae. The **neck** (cervical vertebrae) and **head** (cranium) are separate segments.

Body segments are rarely used to describe joint motion. For example, flexion occurs at the shoulder, not the arm. The motion occurs at the joint (shoulder), and the body segment (arm) just goes along for the ride! An exception to this concept is the forearm. It is a body segment but functions as a joint as well. Technically, joint motion occurs at the proximal and distal radioulnar joints; however, common practice refers to this as *forearm pronation* and *supination.*

Descriptive Terminology

The human body is active and constantly moving; therefore, it is subject to frequent changes in position. The relationship of the various body parts to each other also changes. To be able to describe the organization of the human body, it is necessary to use some arbitrary position as a starting point from which movement or location of structures can be described. This is known as the **anatomical position** (Fig. 1-2) and is described as the human body standing in an upright position, eyes facing forward, feet parallel and close together, and arms at the sides of the body with the palms facing forward. Although the position of the forearm and hands is not a natural one, it does allow for accurate description.

Specific terms are used to describe the location of a structure and its position relative to other structures (Fig. 1-3). **Medial** refers to a location or position toward the midline, and **lateral** refers to a location or position farther from the midline. For example, the ulna is on the medial side of the forearm, and the radius is lateral to the ulna.

Anterior refers to the front of the body or to a position closer to the front. **Posterior** refers to the back of the body or to a position more toward the back. For example, the sternum is located anteriorly on the chest wall, and the scapula is located posteriorly. **Ventral** is a synonym (a word with the same meaning) of *anterior,*

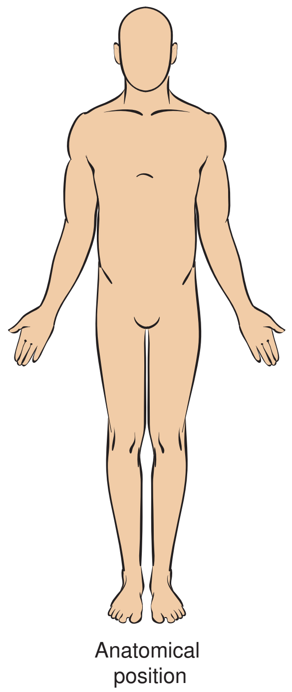

Figure 1-2. Descriptive position.

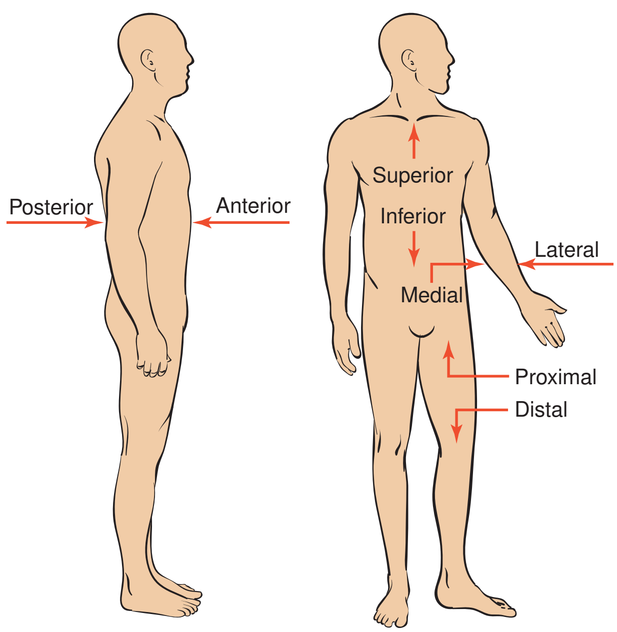

Figure 1-3. Descriptive terminology.

and **dorsal** is a synonym of *posterior; anterior* and *posterior* are more commonly used in kinesiology. *Front* and *back* also refer to the surfaces of the body, but these are considered lay terms and are not widely used by healthcare professionals.

Distal and *proximal* are used to describe locations on the extremities. **Distal** means away from the trunk, and **proximal** means toward the trunk. For example, the humeral head is located on the proximal end of the humerus. The elbow is proximal to the wrist but distal to the shoulder.

Superior is used to indicate the location of a body part that is above another or to refer to the upper surface of an organ or a structure. **Inferior** indicates that a body part is below another or refers to the lower surface of an organ or a structure. For example, the body of the sternum is superior to the xiphoid process but inferior to the manubrium. Sometimes people use **cranial** or *cephalad* (from the word root *cephal,* meaning "head") to refer to a position or structure close to the head. **Caudal** (from the word root *cauda,* meaning "tail") refers to a position or structure closer to the feet. For example, *cauda equina,* which means "horse's tail," is the bundle of spinal nerve roots descending from the inferior end of the spinal cord. Like *dorsal* and *ventral, cranial* and *caudal* are terms that are best used to describe positions on a quadruped (a four-legged animal). Humans are bipeds, or two-legged animals. You can see that if the dog in Figure 1-4 were to stand on its hind legs, dorsal would become posterior and cranial would become superior, and so on.

A structure may be described as **superficial** or **deep,** depending on its relative depth. For example, in describing the layers of the abdominal muscles, the external oblique is deep to the rectus abdominis but superficial to the internal oblique. Another example is the scalp being described as superficial to the skull.

Supine and *prone* are terms that describe body position while lying flat. When **supine,** a person is lying straight, with the face, or anterior surface, pointed upward. A person in the **prone** position is horizontal,

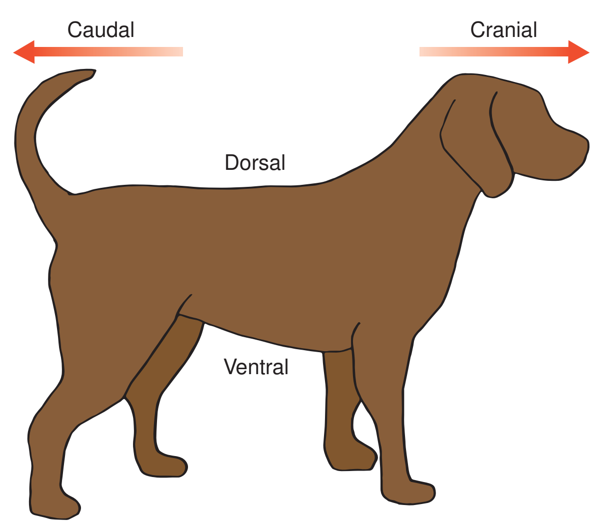

Figure 1-4. Descriptive terminology for a quadruped.

with the face, or anterior surface, pointed downward (the child in Fig. 1-5 is lying prone on the sled).

Bilateral refers to two, or both, sides. For example, bilateral above-knee amputations refer to both right and left legs being amputated above the knee. **Contralateral** refers to the opposite side. For example, a person who has had a stroke affecting the right side of the brain may have contralateral paralysis of the left arm and left leg. In contrast, **ipsilateral** refers to the same side of the body.

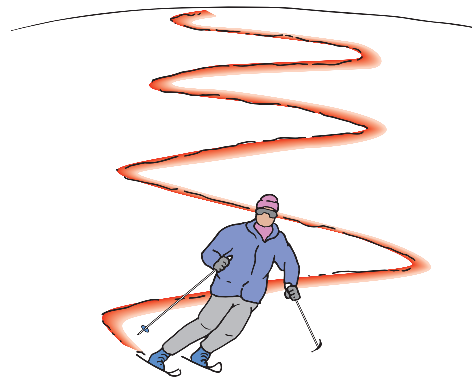

Figure 1-6. Curvilinear motion.

Types of Motion

Linear motion, also called *translatory motion,* occurs in a more or less straight line from one location to another. All parts of the object move the same distance, in the same direction, and at the same time. Movement that occurs in a straight line is called **rectilinear motion,** such as the motion of a child sledding down a hill (Fig. 1-5) or a sailboarder moving across the water. If movement occurs in a curved path that is not necessarily circular, it is called **curvilinear motion.** The path a diver takes after leaving the diving board until entering the water is curvilinear motion. Figure 1-6 demonstrates the curvilinear path a skier takes coming down a ski slope. Other examples of curvilinear motion are the path of a thrown ball, a javelin thrown across a field, or the earth's orbit around the sun.

Movement of an object around a fixed point (axis) is called **angular motion,** or *rotary motion* (Fig. 1-7). In the human body, our joints serve as the axis around which angular motion occurs. With angular motion, all parts of the object move through the same angle, in the same direction, and at the same time, but they do not move the same distance. When a person flexes his or her knee, the knee joint serves as the axis of rotation and the foot travels farther through space than does the ankle or leg.

Generally speaking, most movement within the body is angular; movement outside the body tends to be linear. It is not uncommon to see both types of movement occurring at the same time—the entire object moving in a linear fashion through space and the individual parts (within the body) moving in an angular fashion. In Figure 1-8, the skateboarder's whole body moves down the street (linear motion), whereas individual joints on the "pushing" leg (i.e., the hip, knee, and ankle) rotate around their axes (angular motion). Another example of combined motions is walking. The whole body

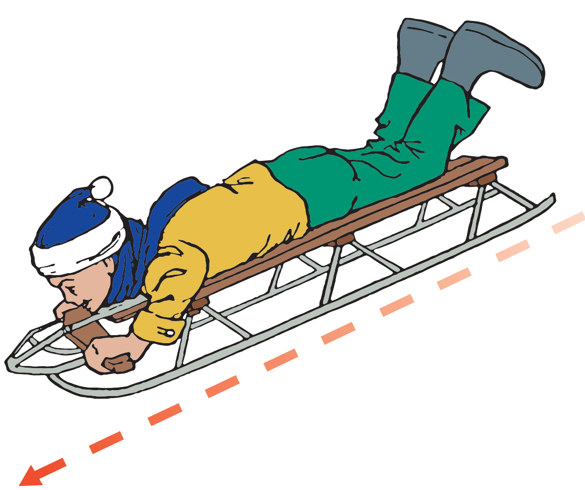

Figure 1-5. Rectilinear motion.

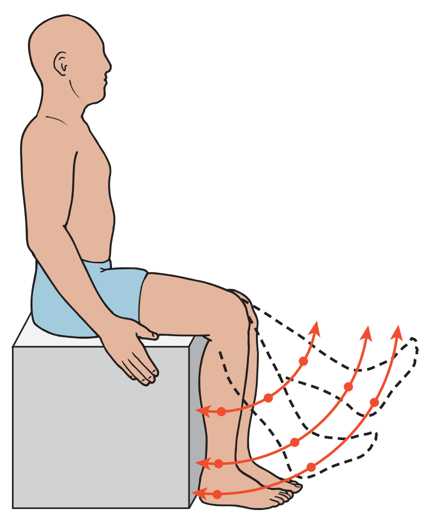

Figure 1-7. Angular motion.

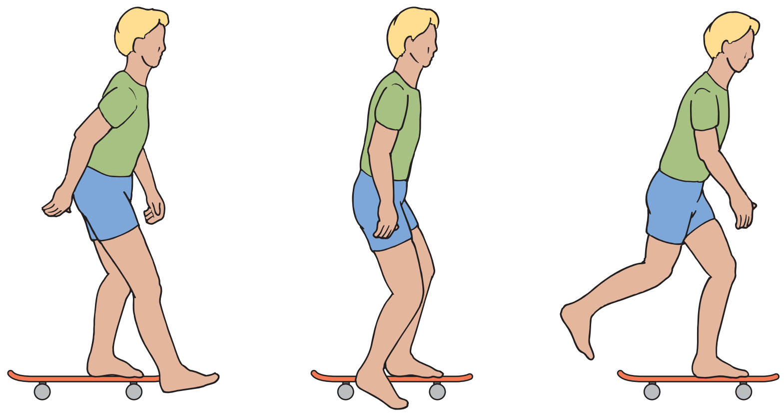

Figure 1-8. Combination of linear and angular motion.

exhibits linear motion when walking from point A to point B, whereas the hips, knees, and ankles exhibit angular motion. A person throwing a ball uses the upper extremity joints in an angular fashion, whereas the ball travels in a curvilinear path.

Exceptions to this statement can be found. For example, as will be described in Chapter 9, the movement of the scapula in elevation/depression and protraction/retraction is essentially linear. However, the movement of the clavicle, which is attached to the scapula, is angular and gets its angular motion from the sternoclavicular joint.

Joint Movements (Osteokinematics)

Joints move in many different directions. As will be discussed in Chapter 3, movement occurs around joint axes and through joint planes. *Flexion/extension, abduction/adduction,* and *rotation* are terms used to describe the various movements that occur at synovial joints. This type of joint motion is called **osteokinematics,** which deals with the relationship of the *movement of bones around a joint axis* (e.g., humerus moving on scapula). The relationship of *joint surface movement* (spin, glide, roll), called **arthrokinematic** motion, will be discussed in Chapter 4.

Flexion/extension, abduction/adduction, and *rotation* are general terms used to describe the osteokinematic movements that occur at synovial joints. *Inversion/eversion* and *protraction/retraction* are specific terms that apply only to specific synovial joints.

Flexion is the bending movement of one bone on another, bringing the two segments together and causing a decrease in the joint angle. Usually this occurs between anterior surfaces of adjacent bones, causing the anterior surfaces to move toward each other. In the case of the neck, flexion is a "bowing down" motion (Fig. 1-9A) in which the head moves toward the anterior chest. With elbow flexion, the anterior surfaces of the forearm and arm move toward each other. With hip flexion, the anterior thigh moves toward the anterior trunk. The knee is an exception in that flexion occurs when the posterior surfaces of the thigh and leg move toward each other. Flexion at the wrist may be called **palmar flexion** (Fig. 1-9F), and flexion at the ankle may be called **plantar flexion** (Fig. 1-9H).

Conversely, **extension** is the straightening movement of one bone away from another, causing an increase of the joint angle. This motion usually returns the body part to the anatomical position after it has been flexed (Fig. 1-9B, E). With extension, the anterior aspects of the joint surfaces tend to move away from each other. Extension occurs when the head moves up and away from the anterior chest, and the anterior thigh moves away from the trunk and returns to the anatomical position. **Hyperextension** is the continuation of extension beyond the anatomical position (Fig. 1-9C). The shoulder, hip, wrist, neck, and trunk can hyperextend. Extension at the wrist and ankle joints may be called **dorsiflexion** (Fig. 1-9G, I). Wrist or ankle **dorsiflexion** (Fig. 1-9G, I) refers to movement toward the dorsum (superior aspect) of the arm or foot.

Abduction is movement away from the midline of the body (Fig. 1-10A), and **adduction** (Fig. 1-10B) is movement toward the midline. The shoulder and hip can abduct *and* adduct. Exceptions to this midline definition are the fingers and toes. The reference point for the fingers is the middle finger. Movement away from the middle finger is abduction (see Fig. 13-5).

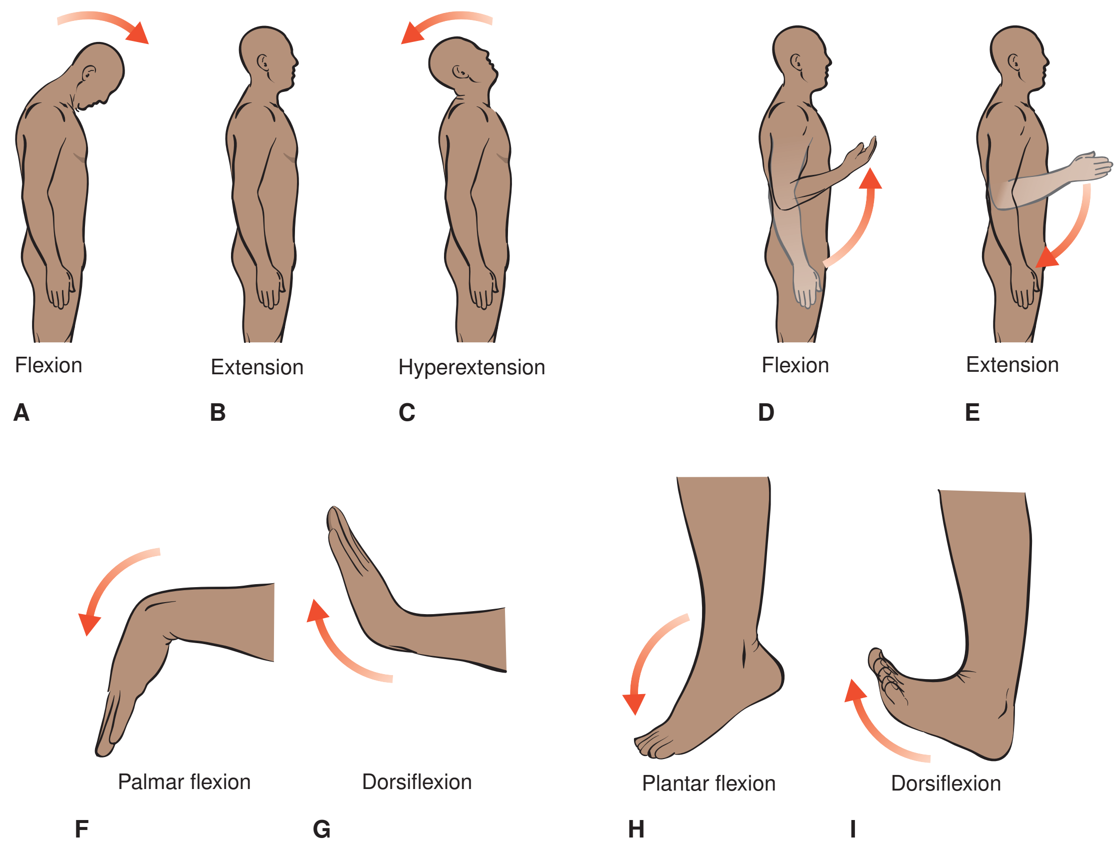

Figure 1-9. Joint motions of flexion and extension.

It should be noted that the middle finger abducts (to the right and to the left) but adducts only as a return movement from abduction to the midline. The point of reference for the toes is the second toe (see Fig. 20-14). Similar to the middle finger, the second toe abducts to the right and the left but does not adduct, except as a return movement from abduction. Horizontal abduction and adduction are motions that cannot occur from the anatomical position. They must be preceded by either flexion or abduction of the shoulder joint so that the arm is at shoulder level. From this position, shoulder movement backward is **horizontal abduction** (Fig. 1-10C) and movement forward is **horizontal adduction** (Fig. 1-10D). There are similar movements at the hip, but the ranges of motion are not usually as great.

Radial deviation and *ulnar deviation* are terms more commonly used to refer to wrist abduction and adduction. When the hand moves laterally, or toward the thumb side, it is **radial deviation** (Fig. 1-10E). When the hand moves medially from the anatomical position toward the little finger side at the wrist, it is **ulnar deviation** (Fig. 1-10F).

Lateral bending is the term used when the trunk moves sideways. The trunk can laterally bend to the right or the left (Fig. 1-10G, H). If the right side of the trunk bends, moving the shoulder toward the right hip, it is called *right lateral bending.* The neck also laterally bends in the same way. The term *lateral flexion* is sometimes used to describe this sideward motion. However, because this term is easily confused with *flexion,* it will not be used in this book.

Circumduction is motion that describes a circular, cone-shaped pattern. It involves a combination of four joint motions: (1) flexion, (2) abduction, (3) extension, and (4) adduction. For example, if the shoulder moves in a circle, the hand would move in a much larger circle. The entire arm would move in a cone-shaped sequential pattern of flexion to abduction to extension to adduction, bringing the arm back to its starting position (Fig. 1-11).

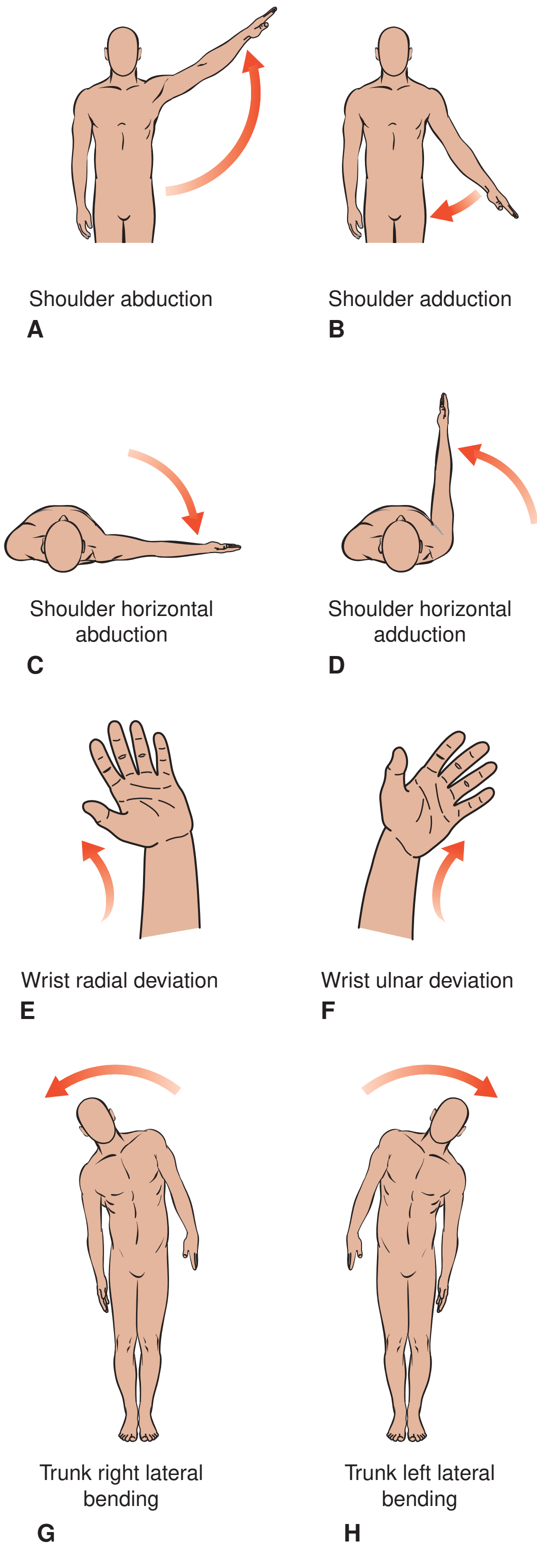

Figure 1-10. Joint motions of abduction and adduction.

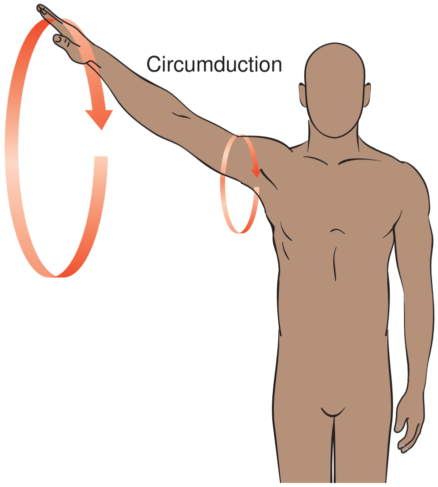

Figure 1-11. Circumduction motion.

Rotation is movement of a bone or part around its longitudinal axis. If the anterior surface rolls inward toward the midline, the motion is called **medial rotation** (Fig. 1-12A). This is sometimes referred to as *internal rotation*. Conversely, if the anterior surface rolls outward, away from the midline, the motion is called **lateral rotation** (Fig. 1-12B), or *external rotation*. Joints capable of performing medial and lateral rotation are the shoulder and the hip. The neck and trunk can also rotate to either the right or left side (Fig. 1-12C, D). Visualize the neck rotating as you look over your right shoulder. This would be "right neck rotation."

Rotation of the forearm is referred to as *supination* and *pronation*. In the anatomical position (see Fig. 1-2), the forearm is in **supination** (Fig. 1-12E). This faces the palm of the hand forward, or anteriorly. In **pronation** (Fig. 1-12F), the palm is facing backward, or posteriorly. When the elbow is flexed, the "palm up" position refers to supination and "palm down" refers to pronation.

The following are terms used to describe motions specific to certain joints. **Inversion** is moving the sole of the foot inward at the ankle (Fig. 1-13A), and **eversion** is the outward movement (Fig. 1-13B). **Protraction** is mostly a linear movement along a plane parallel to the ground and away from the posterior midline (Fig. 1-14A), and **retraction** is mostly a linear movement in the same plane but toward the posterior midline (Fig. 1-14B). Protraction of the shoulder girdle moves the scapula away from the posterior midline, as does protraction of the jaw, whereas retraction in both of these cases returns the body part toward the posterior midline, or back to the anatomical position.

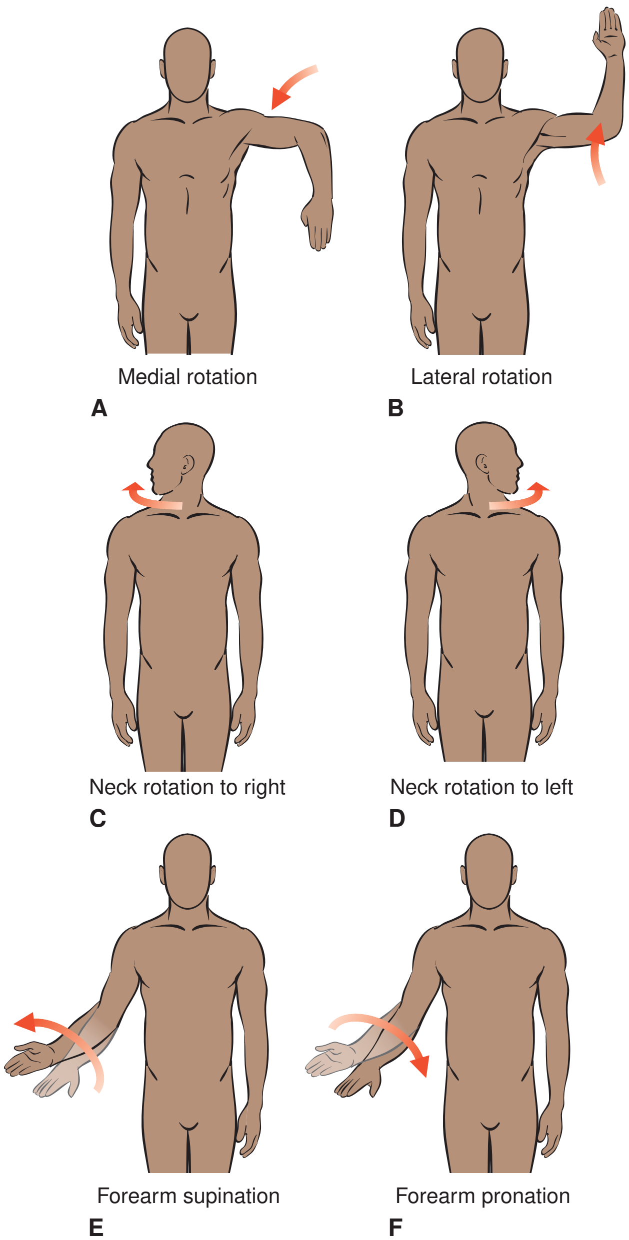

Figure 1-12. Joint rotation motions. In A & B, the shoulder is abducted to 90 degrees only to demonstrate the rotation more clearly.

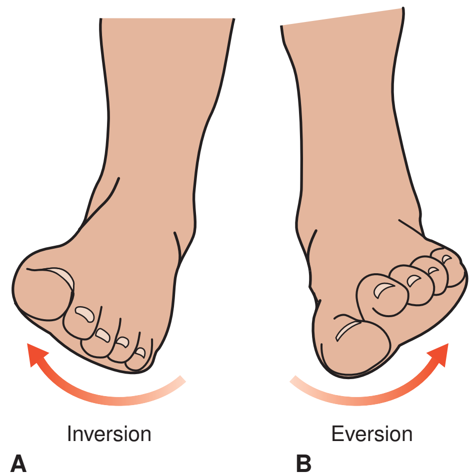

Figure 1-13. Inversion and eversion of left foot.

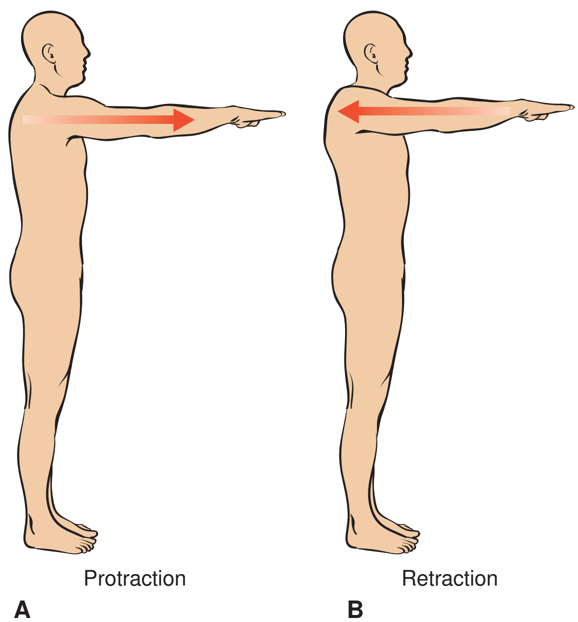

Figure 1-14. Protraction and retraction.

Review Questions

1. Using descriptive terminology, complete the following:
   a. The sternum is ____________________ to the vertebral column.
   b. The calcaneus is on the ____________________ portion of the foot.
   c. The hip is ____________________ to the chest.
   d. The femur is ____________________ to the tibia.
   e. The radius is on the ____________________ side of the forearm.
2. When a football is kicked through the goalposts, what type of motion is being demonstrated by the football? By the kicker?
3. Looking at a spot on the ceiling directly over your head involves what joint motion?
4. Putting your hand in your back pocket involves what shoulder joint rotation?
5. Picking up a pencil on the floor beside your chair involves what trunk joint motion?
6. Putting your right ankle on your left knee involves what type of hip rotation?
7. In the anatomical position, the forearms are in what position?
8. If you place your hand on the back of a dog, that is referred to as placing it on what surface? If you place your hand on the back of a person, that is referred to as placing it on what surface?
9. A person wheeling across a room in a wheelchair uses both linear and angular motion. Describe when each type of motion is being used.
10. A person lying on a bed staring at the ceiling is in what position?
11. When touching the left shoulder with the left hand, is a person using the contralateral or ipsilateral hand?

Refer to Figure 1-15 below.

12. Identify the three main positions of the left hip.
13. What is the position of the left knee?
14. What is the position of the right forearm?
15. Identify the two main positions of the neck (not the head).

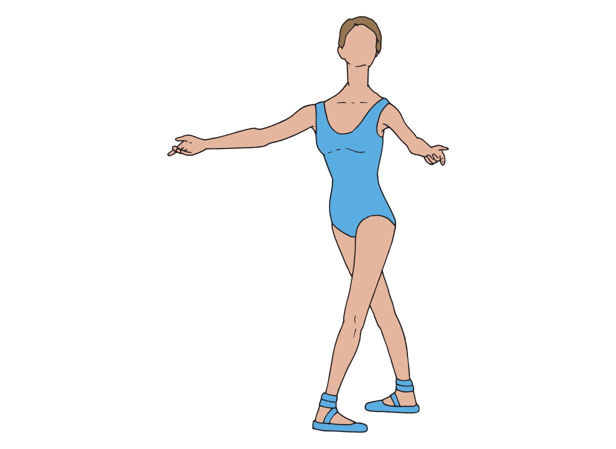

Figure 1-15. Ballet position.

CHAPTER 2

Skeletal System

Functions of the Skeleton

Types of Skeletons

Composition of Bone

Structure of Bone

Types of Bones

Common Skeletal Pathologies

Review Questions

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Functions of the Skeleton

The skeletal system, which is made up of numerous bones, is the rigid framework of the human body. It gives support and shape to the body; protects vital organs such as the brain, spinal cord, and heart; and assists in movement by providing a rigid structure for muscle attachment and leverage. The skeletal system also manufactures blood cells in various locations. The main sites of blood formation are the ilium, vertebrae, sternum, and ribs. This formation occurs mostly in flat bones. Calcium and other mineral salts are stored throughout all osseous tissue of the skeletal system.

Types of Skeletons

The bones of the body are grouped into two main categories: axial and appendicular (Fig. 2-1). The **axial skeleton** forms the upright part of the body. It consists of 80 bones of the head, thorax, and trunk. The **appendicular skeleton** attaches to the axial skeleton and contains the 126 bones of the extremities. There are 206 bones in the body. Individuals may have additional sesamoid bones, such as in the flexor tendons of the great toe and the thumb.

Table 2-1 lists the bones of the adult human body. The sacrum, coccyx, and innominate bones are each made up of several bones fused together. In the innominate bone, also called the os coxa or hip bone, these fused bones are known as the *ilium, ischium,* and *pubis.*

Composition of Bone

Bones can be considered organs because they are made up of several different types of tissue (fibrous,

Table 2-1 Bones of the Human Body

	Single	Paired	Multiple
Axial Skeleton			
Cranium (8)	Frontal Sphenoid Ethmoid Occipital	Parietal Temporal	None
Face (14)	Mandible Vomer	Maxilla Zygomatic Lacrimal Inferior concha Palatine Nasal	None
Other (7)	Hyoid	Ear ossicles (3)	None
Vertebral column (26)	Sacrum (5)* Coccyx (3)*	None	Cervical (7) Thoracic (12) Lumbar (5)
Thorax (25)	Sternum	Ribs (12 pairs = 24) True: 7 False: 3 Floating: 2	None
Appendicular Skeleton			
Upper extremity (64)	None	Scapula Clavicle Humerus Ulna Radius	Carpals (16) Metacarpals (10) Phalanges (28)
Lower extremity (62)	None	Innominate (3)* Femur Tibia Fibula Patella	Tarsals (14) Metatarsals (10) Phalanges (28)

*Denotes bones that are fused together.

cartilaginous, osseous, nervous, and vascular), and they function as integral parts of the skeletal system.

Bone is made up of one-third *organic* (living) material and two-thirds *inorganic* (nonliving) material. The organic material gives the bone elasticity, whereas the inorganic material provides hardness and strength, which makes bone opaque on an x-ray. Just how hard is bone? It has been estimated that if you took a human skull and slowly loaded weight onto it, the skull could support 3 tons before it broke!

Compact bone (Fig. 2-2A and Fig. 2-3) makes up the hard, dense outer layer of all bones. **Cancellous bone** (Fig. 2-2A and Fig. 2-3) is the porous and spongy inside portion made up of thin columns and plates called the *trabeculae,* which means "little beams" in Latin. The latticework network resists local stresses and strains (Fig. 2-2B). Trabeculae tend to be filled with marrow and make the bone lighter.

Structure of Bone

The **epiphysis** is the area at each end of a long bone. This area tends to be wider than the shaft (Fig. 2-3). In adult bone, the epiphysis is osseous; in growing bone, the epiphysis is cartilaginous material called the **epiphyseal plate.** Longitudinal growth occurs here through the manufacturing of new bone.

On an x-ray, a growing bone will show a distinct line between the epiphyseal plate and the rest of the bone (Fig. 2-4A). Because this line does not exist in the

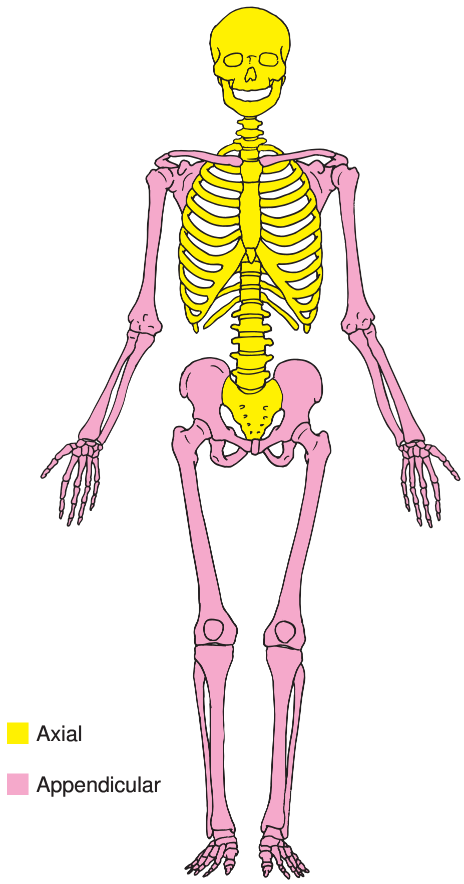

Figure 2-1. Axial and appendicular skeleton.

normal adult bone, its absence indicates that bone growth has stopped (Fig. 2-4B).

There are two types of epiphyses found in children whose bones are still growing (Fig. 2-5). A **pressure epiphysis** is located at the ends of long bones, where they receive pressure from the opposing bone making up that joint. This is where growth of long bones occurs. A **traction epiphysis** is located where tendons attach to bones and are subjected to a pulling, or traction, force.

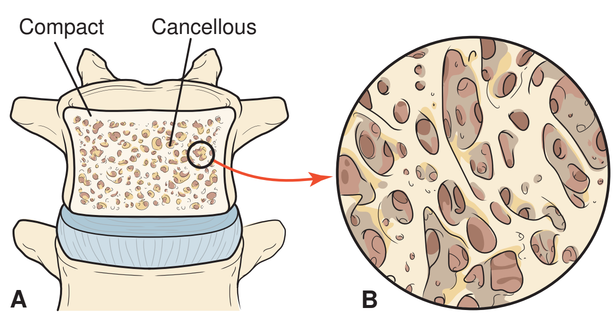

Figure 2-2. Normal bone structure: **(A)** compact and cancellous bone **(B)** trabeculae network within cancellous bone.

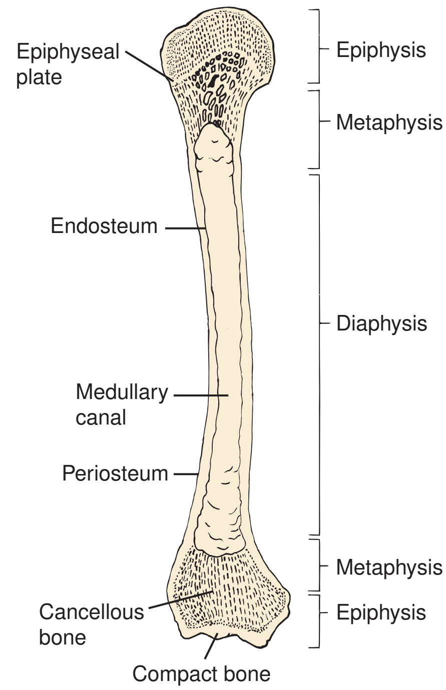

Figure 2-3. Longitudinal cross section of a long bone.

Examples would be the greater and lesser trochanters of the femur and tibial tuberosity.

The **diaphysis** (see Fig. 2-3) is the main shaft of bone. Its walls are made up mostly of compact bone, which gives it great strength. Its center, the **medullary canal,** is hollow, which, among other features, decreases the weight of the bone. This canal contains marrow and provides passage for nutrient arteries. The **endosteum** is a membrane that lines the medullary canal. It contains **osteoclasts,** which are mainly responsible for bone resorption—a process by which old bone is broken down so it can be replaced with new bone.

In long bones, the **metaphysis** is the flared part of the bone that serves as a transition from the end of each diaphysis to each epiphysis. It is made up mostly of cancellous bone and functions to support the epiphysis.

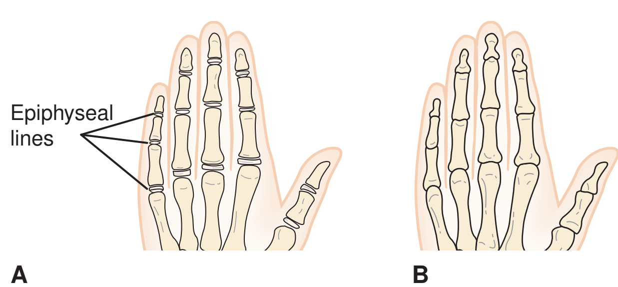

Figure 2-4. Epiphyseal lines in the hand bones of a child **(A)** and an adult **(B).**

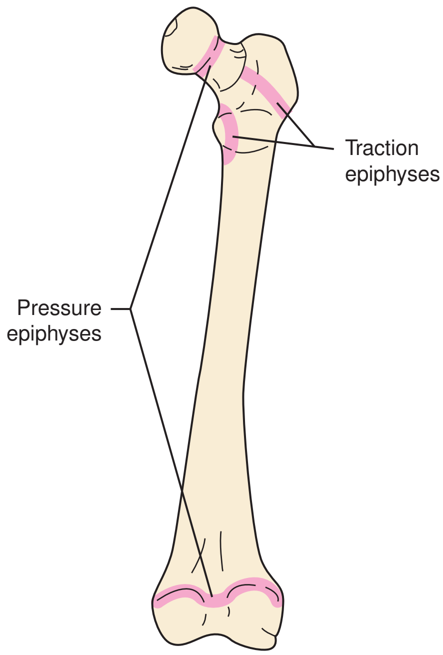

Figure 2-5. Types of epiphyses found in an immature bone.

Periosteum is the thin fibrous membrane covering all of the bone except the articular surfaces, which are covered with hyaline cartilage. The periosteum contains nerves as well as blood vessels that are important in providing nourishment, promoting growth in the diameter of immature bone, and repairing the bone. It also serves as an attachment point for tendons and ligaments. Compared with the surrounding bone tissue, the periosteum has a much greater number of pain receptors, which makes it exceedingly pain sensitive when it is overstressed, such as during a fracture or due to inflammation at the attachment site of a tendon.

Types of Bones

Long bones are so named because their length is greater than their width (Fig. 2-6A). They are the largest bones in the body and make up most of the appendicular skeleton. Long bones are basically tube-shaped, with a shaft (diaphysis) filled with bone marrow (medullary canal) and two bulbous ends (epiphysis). The wide part of the shaft nearest the epiphysis is called the *metaphysis* (see Fig. 2-3). As discussed previously, the diaphysis consists mainly of compact bone, whereas the metaphysis and epiphysis consist of cancellous bone covered by a thin layer of compact bone. While the body is still growing, bone growth occurs at the epiphyseal plate. Over the articular surfaces of the epiphysis is a thin layer of hyaline cartilage.

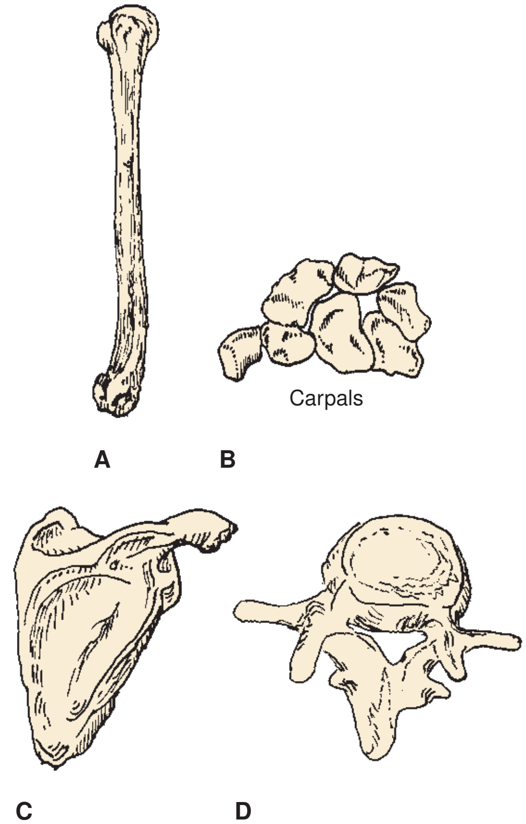

Figure 2-6. Types of bones.

Short bones tend to have more equal dimensions of height, length, and width, giving them a cube shape (Fig. 2-6B). They have a great deal of articular surface and, unlike long bones, usually articulate with more than one bone. Their composition is similar to long bones: a thin layer of compact bone covering cancellous bone, which has a marrow cavity in the middle. Examples of short bones include the bones of the wrist (carpals) and ankle (tarsals).

Flat bones have a very broad surface but are not very thick. They tend to have a curved surface rather than a flat one (Fig. 2-6C). These bones are made up of two layers of compact bone with cancellous bone and marrow in between. The ilium, scapula, and many of the cranial bones are good examples of flat bones.

As their name implies, **irregular bones** have a variety of mixed shapes that do not fit into the other categories (Fig. 2-6D). Their unique shapes allow them to fulfill a particular function. For example, the opening in the center of the vertebrae houses and protects the spinal cord. Other irregular bones include the sacrum and bones of the skull that are not flat. They are also composed of cancellous bone and marrow encased in a thin layer of compact bone.

Sesamoid bones, which resemble the shape of sesame seeds, are small bones located where tendons cross the ends of long bones in the extremities. They develop within the tendon and protect it from excessive wear. For example, the tendon of the flexor hallucis longus spans the bottom (plantar surface) of the foot and attaches on the great toe. If this tendon were not protected in some way at the ball of the foot, it would constantly be stepped on. Mother Nature is too clever to allow this to happen. Sesamoid bones are located on either side of the tendon near the head of the first metatarsal, providing a protective "groove" for the tendon to pass through this weight-bearing area.

Sesamoid bones also change the angle of a tendon's attachment, which can increase its ability to generate force at the joints it crosses. (Chapter 8 will present the biomechanical rationale for this.) The sesamoid bones just discussed (in the flexor hallucis longus) greatly enhance this muscle's ability to produce force at the great toe when pushing off to take a step. The patella can also be considered a sesamoid bone because it is encased in the quadriceps tendon, and it improves the mechanical advantage of the quadriceps muscle, allowing it to generate more force at the knee. As previously mentioned, sesamoid bones are also found in the flexor tendons that pass posteriorly into the foot on either side of the ankle. Other sesamoid bones are found in the flexor tendons of the thumb, near the metacarpophalangeal and interphalangeal joints as well as at the wrist. Occasionally, a sesamoid bone is located near the metacarpophalangeal joint of the index and little fingers.

Table 2-2 summarizes the types of bones of the axial and appendicular skeletons. It should be noted that there are no long or short bones in the axial skeleton, and there are no irregular bones in the appendicular skeleton. Except for the patella, sesamoid bones are not included in Table 2-2 because they are considered accessory bones, and their shape and number vary greatly.

When looking at various bones, you will see holes, depressions, ridges, bumps, grooves, and various other kinds of markings. Each of these markings serves a different purpose. Table 2-3 describes the different kinds of bone markings and their purposes.

Common Skeletal Pathologies

Fracture, *broken bone,* and *cracked bone* are all synonymous. It is a break in the continuity of the bony cortex caused by direct force, indirect force, or pathology. Fractures in children tend to be incomplete ("greenstick") or at the epiphysis. Fractures in the elderly mostly happen in the hip joint (proximal femur), resulting from a fall, or in the upper extremity from falling on the outstretched hand. Fractures are often described by type (e.g., closed), direction of fracture line (e.g., transverse), or position of the bone fragments (e.g., overriding).

Table 2-2 Types of Bones

Type	Appendicular Skeleton		Axial Skeleton
	Upper Extremity	Lower Extremity	
Long bones	Clavicle Humerus Radius Ulna Metacarpals Phalanges	Femur Fibula Tibia Metatarsals Phalanges	None
Short bones	Carpals	Tarsals	None
Flat bones	Scapula	None	Cranial bones (frontal, parietal, occipital, temporal) Ribs Sternum
Irregular bones	None	Innominate	Vertebrae Sacrum Coccyx Mandible, facial bones
Sesamoid		Patella	

Table 2-3 Bone Markings

Depressions and Openings

Marking	Description	Examples
1. Foramen	Hole through which blood vessels, nerves, and ligaments pass	Vertebral foramen of cervical vertebra
2. Fossa	Hollow or depression	Glenoid fossa of scapula
3. Groove	Ditchlike groove containing a tendon or blood vessel	Bicipital (intercondylar) groove of humerus
4. Meatus	Canal or tubelike opening in a bone	External auditory meatus
5. Sinus	Air-filled cavity within a bone	Frontal sinus in frontal bone

Projections or Processes That Fit Into Joints

Marking	Description	Examples
1. Condyle	Rounded knucklelike projection	Medial condyle of femur
2. Eminence	Projecting, prominent part of bone	Intercondylar eminence of tibia
3. Facet	Flat or shallow articular surface	Articular facet of rib
4. Head	Rounded articular projection beyond a narrow, necklike portion of bone	Femoral head

Projections/Processes That Attach Tendons, Ligaments, and Other Connective Tissue

Marking	Description	Examples
1. Crest	Sharp ridge or border	Iliac crest
2. Epicondyle	Prominence above or on a condyle	Medial epicondyle of humerus
3. Line	Less prominent ridge	Linea aspera of femur
4. Spine	Long, thin projection (spinous process)	Scapular spine
5. Tubercle	Small, rounded projection	Greater tubercle of humerus
6. Tuberosity	Large, rounded projection	Ischial tuberosity
7. Trochanter	Very large prominence for muscle attachment	Greater trochanter of femur

Osteoporosis is a condition characterized by loss of normal bone density, or bone mass (Fig. 2-7). The bone density in this figure can be compared with that in Figure 2-2. This condition can weaken a bone to the point where it will fracture. The vertebrae of an elderly person are common sites for osteoporosis. Osteopenia is also a condition of reduced bone mass, though not as severe as osteoporosis. **Osteomyelitis** is an infection of the bone usually caused by bacteria. A fracture that breaks through the skin (open fracture) poses a greater risk of developing osteomyelitis than a fracture that does not break the skin (closed fracture).

Because the epiphysis of a growing bone is not firmly attached to the diaphysis, it can slip or become misshapen. The proximal head of the femur is a common site for problems such as **Legg-Calvé-Perthes disease,** which happens when blood supply is interrupted to the femoral head, causing necrosis of the bone, at the pressure epiphysis in growing children. A **slipped capital femoral epiphysis** occurs when the head of the femur becomes displaced due to a separation at the growth plate.

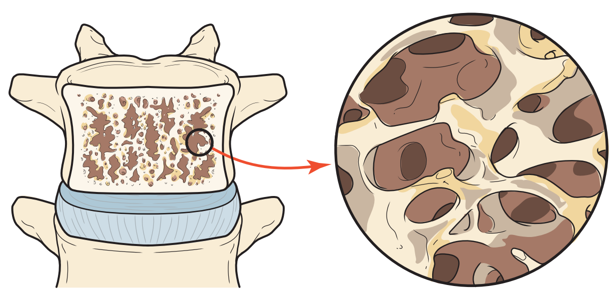

Figure 2-7. Osteoporotic bone.

Overuse can cause irritation and inflammation of any traction epiphysis where tendons attach to bone. A common condition called Osgood-Schlatter disease occurs at the traction epiphysis of the tibial tuberosity in children whose bones are still growing. Problems at these pressure and traction epiphyses usually exist only during the bone-growing years and not after the epiphyses have fused and bone growth stops.

Review Questions

1. What are the differences between the axial and appendicular skeletons?
2. Give one example of compact bone and one of cancellous bone.
3. Which is heavier: compact bone or cancellous bone? Why?
4. What type of bone is mainly involved in an individual's growth in height? In what portion of the bone does this growth occur?
5. What is the purpose of sesamoid bones?
6. Name the bone markings that can be classified as
   a. depressions and openings
   b. projections or processes that fit into joints
   c. projections or processes that attach connective tissue such as tendons, ligaments, and fascia

In Questions 7 to 9, classify the bone markings.

7. Bicipital groove
8. Humeral head
9. Acetabulum
10. What is the name of the membrane that lines the medullary canal?
11. The main shaft of bone is called what?
12. In children, does long bone growth occur at a traction epiphysis or at a pressure epiphysis?
13. Is the humerus part of the axial or appendicular skeleton?
14. Is the clavicle part of the axial or appendicular skeleton?
15. Is the sternum part of the axial or appendicular skeleton?

CHAPTER 3
Articular System

Types of Joints
Joint Structure
Planes and Axes
Degrees of Freedom
Common Pathological Terms
Review Questions

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A joint is a connection between two bones. Although joints have several functions, perhaps the most important is to allow motion. Joints also help to bear the body's weight and to provide stability. This stability may be mostly due to the shape of the bones making up the joint, as with the hip joint, or may be due to soft tissue features, as seen in the shoulder and knee. Joints also contain synovial fluid, which lubricates the joint and nourishes the cartilage.

Types of Joints

A joint may allow a great deal of motion, as in the shoulder, or very little motion, as in the sternoclavicular joint. As with all differences, there are trade-offs. A joint that allows a great deal of motion will provide very little stability. Conversely, a joint that is quite stable tends to have little motion. There is often more than one term that can be used to describe the same joint. These terms tend to describe either the structure or the amount of motion allowed.

A **fibrous joint** has a thin layer of fibrous periosteum between the two bones, as in the sutures of the skull. There are three types of fibrous joints: synarthrosis, syndesmosis, and gomphosis. A **synarthrosis,** or suture joint, has a thin layer of fibrous periosteum between the two bones, as in the sutures of the skull. The ends of the bones are shaped to allow them to interlock (Fig. 3-1A). With this type of joint, there is essentially no motion between the bones; its purpose is to provide shape and strength. Another type of fibrous joint is a **syndesmosis,** or ligamentous joint. There is a great deal of fibrous tissue, such as ligaments and interosseous membranes, holding the joint together (Fig. 3-1B). A small amount of twisting or stretching movement can occur in this type of joint. The distal tibiofibular joint at the ankle and the distal radioulnar joint are examples. The third type of fibrous joint is called a **gomphosis,** which is Greek for "bolting together." This joint occurs between a tooth and the wall of its dental socket in the mandible and maxilla (Fig. 3-1C). Its structure is referred to as *peg-in-socket*.

A **cartilaginous joint** (Fig. 3-2) has either hyaline cartilage or fibrocartilage between the two bones. The vertebral joints are examples of joints in which fibrocartilage disks are directly connecting the bones. The first sternocostal joint is an example of the direct connection made by hyaline cartilage. Cartilaginous joints are also called **amphiarthrodial joints** because they allow a small amount of motion, such as bending or twisting, and some compression. At the same time, these joints provide a great deal of stability.

A **synovial joint** (Fig. 3-3) has no direct union between the bone ends. Instead, there is a cavity filled with synovial fluid contained within a sleevelike capsule. The outer layer of the capsule is made up of a strong fibrous tissue that holds the joint together. The inner layer is lined with a synovial membrane that secretes the synovial fluid. The articular surface is very smooth and covered with cartilage called *hyaline* or *articular cartilage.* The synovial joint is also called a **diarthrodial joint** because it allows free motion. It is not as stable as the other types of joints but does allow a great deal more motion. Table 3-1 provides a summary of the joint types. The number of axes, the shape of the joint, and the type of motion allowed by the joint could further classify synovial, or diarthrodial, joints (Table 3-2).

In a **nonaxial joint,** movement tends to be linear instead of angular (Fig. 3-4). The joint surfaces are relatively flat and glide over one another instead of one

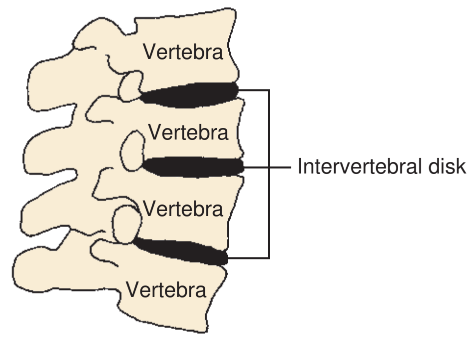

Figure 3-2. Cartilaginous joint.

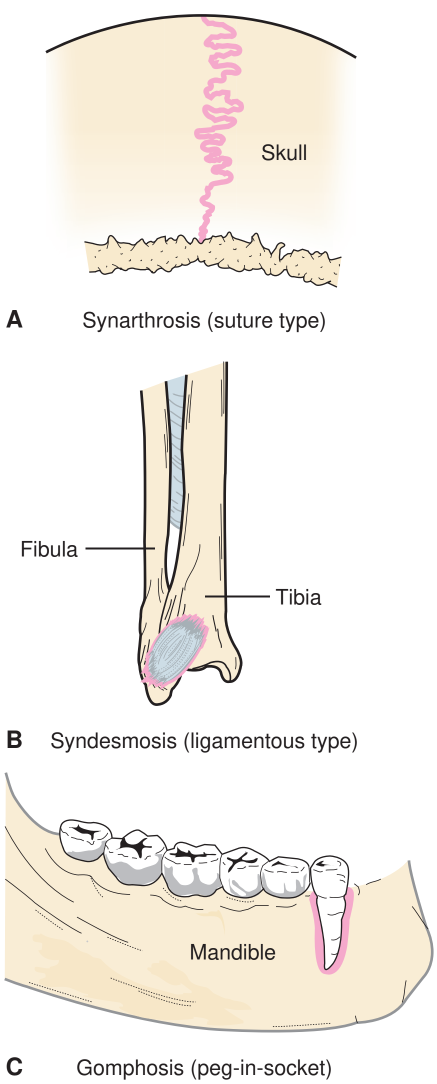

Figure 3-1. Fibrous joints.

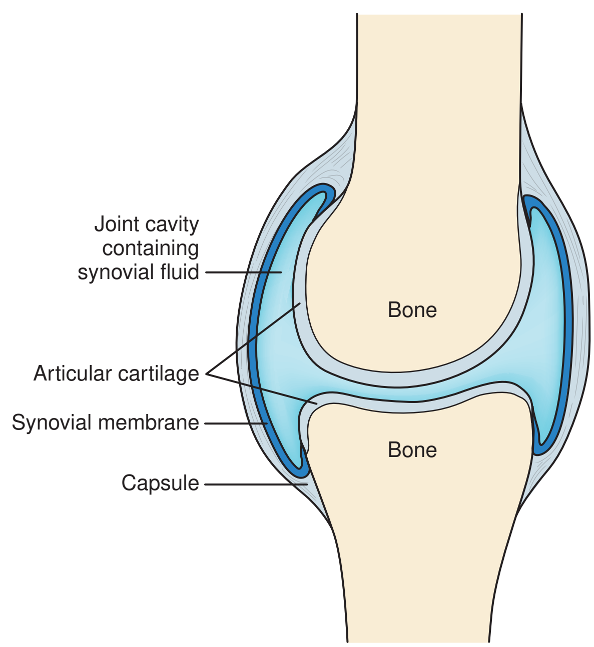

Figure 3-3. Synovial joint.

Table 3-1 Joint Classification

Type	Motion	Structure	Example
Synarthrosis	None	Fibrous—suture	Bones in the skull, except mandible
Syndesmosis	Slight	Fibrous—ligamentous	Distal tibiofibular
Gomphosis	None	Fibrous—peg-in-socket	Teeth in mandible and maxilla
Amphiarthrosis	Little	Cartilaginous	Symphysis pubis, vertebrae
Diarthrosis	Free	Synovial	Hip, elbow, knee

Table 3-2 Classification of Diarthrodial Joints

Number of Axes	Shape of Joint	Joint Motion	Example
Nonaxial	Plane (Irregular)	Gliding	Intercarpals
Uniaxial	Hinge	Flexion/extension	Elbow and knee
	Pivot	Rotation	Atlas/axis, radius/ulna
Biaxial	Condyloid (Ellipsoidal)	Flexion/extension, abduction/adduction	Wrist, MPs
	Saddle	Flexion/extension, abduction/adduction, rotation (accessory)	Thumb CMC
Triaxial (multiaxial)	Ball and socket	Flexion/extension, abduction/adduction, rotation	Shoulder, hip

moving around the other and can be described as a **plane joint.** The motion that occurs between the carpal bones is an example of this type of motion. Unlike most other types of diarthrodial joint motion, nonaxial motion occurs secondarily to other motion. For example, you can flex and extend your elbow without moving other joints; however, you cannot move your carpal bones by themselves. Motion of the carpals occurs when the wrist joint moves in either flexion and extension or abduction and adduction.

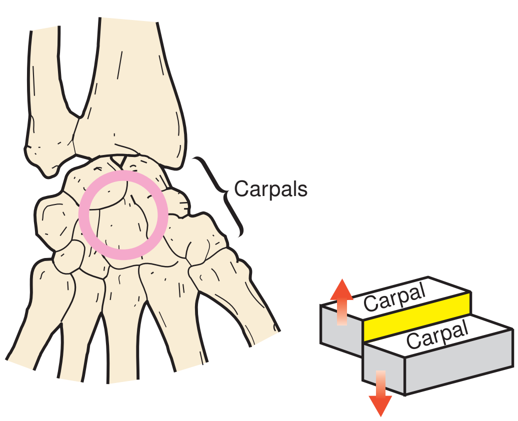

Figure 3-4. Plane joint demonstrates gliding motion between bones.

A **uniaxial joint** has angular motion occurring in one plane around one axis, much like a hinge. The elbow, or humeroulnar joint, is a good example of a **hinge joint** with the convex shape of the humerus fitting into the concave-shaped ulna (Fig. 3-5). The only motions possible are flexion and extension, which occur in the sagittal plane around the frontal axis. Planes and axes will be described later in this chapter. No other motions are possible at this joint. The interphalangeal joints of the hand and foot also have this hinge motion. The knee is a hinge joint, but this example must be clarified. During the last few degrees of extension, the femur rotates medially on the tibia. This rotation is not an active motion but rather

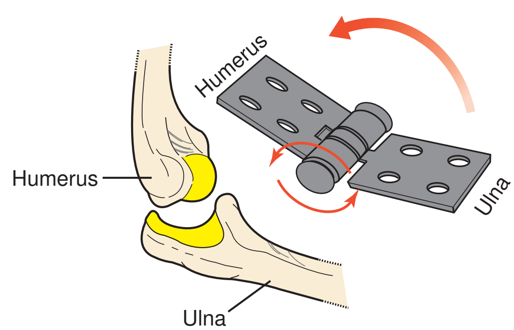

Figure 3-5. Hinge joint has anterior-posterior motion allowing flexion and extension.

the result of certain mechanical features present. Therefore, the knee is best classified as a uniaxial joint, because it has *active* motion around only one axis.

Also at the elbow is the radioulnar joint, which as a **pivot joint** demonstrates another type of uniaxial motion. The head of the radius pivots on the stationary ulna during pronation and supination of the forearm (Fig. 3-6). This pivot motion is in the transverse plane around the longitudinal axis. The motion of the atlantoaxial joint of C1 and C2 is also pivotal. The first cervical vertebra *(atlas),* on which the head rests, rotates around the odontoid process of the second cervical vertebra *(axis).* This allows the head to rotate.

Biaxial joint motion, such as that found at the wrist, occurs in two different directions (Fig. 3-7). Flexion and extension occur around the frontal axis, and radial and ulnar deviation occur around the sagittal axis. This bidirectional motion also occurs at the metacarpophalangeal (MCP) joints. The wrist and MCP joints are referred to as **condyloid joints,** or sometimes *ellipsoid joints* because of their shape.

The carpometacarpal (CMC) joint of the thumb is biaxial but differs somewhat from the condyloid joint. In this joint, the articular surface of each bone is concave in one direction and convex in the other. The bones fit together like a horseback rider in a saddle, which is why this joint is also descriptively called a **saddle joint** (Fig. 3-8).

Unlike the condyloid joint, the CMC joint allows a slight amount of rotation. Like the motion within the carpal bones, this rotation cannot occur by itself. If you try to rotate your thumb without also flexing and abducting, you find that you cannot do it. Yet, rotation does occur. Look at the direction to which the pad of your thumb is pointing when it is adducted. Abduct and flex your thumb and notice that the direction to which the pad is pointing has changed by approximately 90 degrees. This rotation has not occurred actively; rotation has occurred because of the joint's shape. Therefore, although the CMC joint of the thumb is not a true biaxial joint due to the rotation allowed, it fits best into this category because the *active* motion allowed is around two axes.

With a **triaxial joint,** sometimes referred to as a *multiaxial joint,* motion occurs actively around all three axes (Fig. 3-9). This joint allows more motion than any other type of joint. The hip and shoulder allow motion around the frontal axis (flexion and extension), around the sagittal axis (abduction and adduction), and around the vertical axis (rotation). The triaxial joint is also referred to as a **ball-and-socket joint** because in the hip, for example, the ball-shaped femoral head fits into the concave socket of the acetabulum.

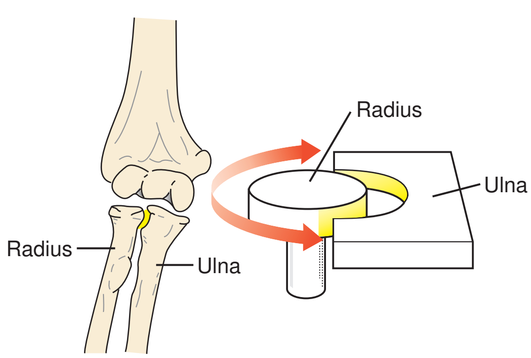

Figure 3-6. Pivot joint has rotation of one bone around another. At the elbow, this allows for pronation and supination of the forearm.

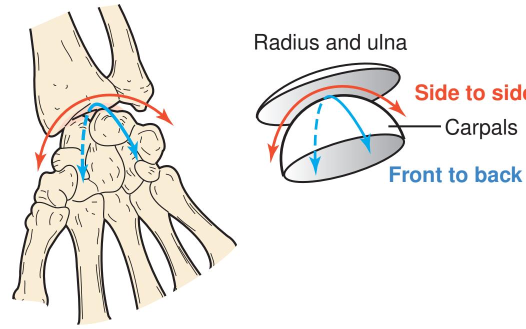

Figure 3-7. Condyloid joint has motion in two planes: posterior/anterior (allowing flexion/extension) and lateral/medial (allowing abduction/adduction).

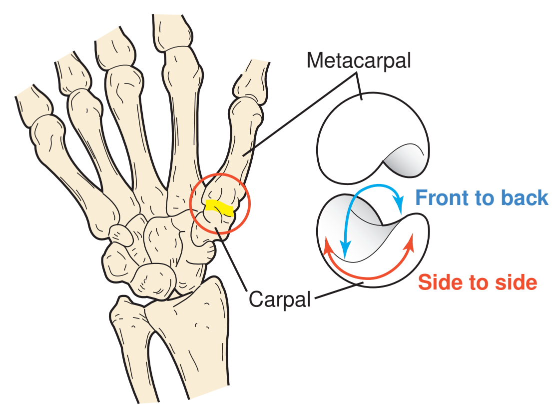

Figure 3-8. Saddle joint, while although to the condyloid joint, is uniquely different. Its two planes of motion: anterior-posterior allows carpometacarpal (CMC) joint abduction and adduction; medial-lateral motion allows CMC flexion/extension. The planes of this joint are the exception to the rule. Anterior-posterior motion usually occurs in the sagittal plane, whereas medial-lateral motion occurs in the frontal plane.

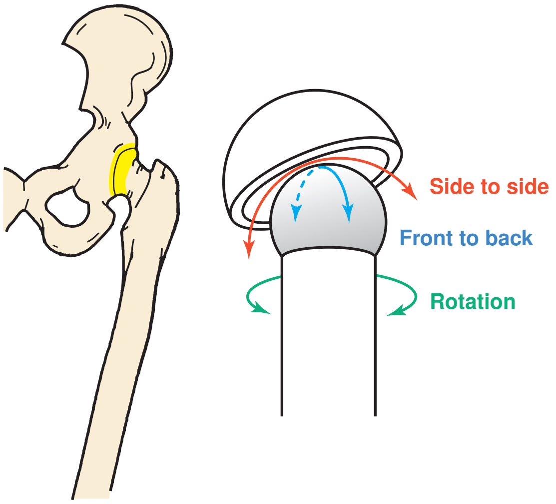

Figure 3-9. Ball-and-socket joint allows for motion in three directions: anterior-posterior (allowing flexion/extension), medial-lateral (allowing adduction/abduction), and rotation (allowing medial rotation/lateral rotation).

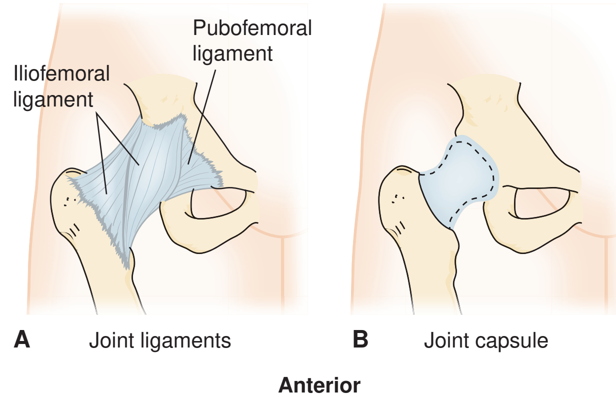

Figure 3-10. Support structures of a synovial joint: ligaments **(A)** and capsule **(B)**, which lies immediately deep to the surrounding ligaments.

Joint Structure

There are many components of a synovial joint (see Fig. 3-3). First, there are **bones,** usually two, that articulate with each other. The amount and direction of motion allowed at each joint are dictated by the shape of the bone ends and by the articular surface of each bone.

The two bones of a joint are held together and supported by **ligaments,** which are bands of fibrous connective tissue. Ligaments also provide attachment for cartilage, fascia, or, in some cases, muscle. Ligaments are flexible but not elastic. This flexibility is needed to allow joint motion, but the nonelasticity is needed to keep the bones in close approximation to each other and to provide some protection to the joint. In other words, ligaments prevent excessive joint movement. When ligaments surround a synovial joint, they are called *capsular ligaments* (Fig. 3-10A).

Every synovial joint has a **capsule** that surrounds and encases the joint and protects the articular surfaces of the bones. Figure 3-10B shows the capsule of the hip joint. It lies deep to, and is encased and supported by, the ligaments. In the shoulder joint, the capsule completely encases the joint, forming a partial vacuum that helps hold the head of the humerus against the glenoid fossa. In other joints, the capsule may not be as complete.

As was described earlier, there are several components within a synovial joint (see Fig. 3-3). The joint capsule has two layers: an outer layer and an inner layer. The outer layer consists of fibrous tissue and supports and protects the joint. This layer is usually reinforced by ligaments (see Fig. 3-10A). The inner layer is lined with a **synovial membrane,** a thick, vascular connective tissue that secretes synovial fluid. **Synovial fluid** is a thick, clear fluid (resembling an egg white) that lubricates the articular cartilage; this reduces friction and helps the joint move freely. This fluid provides some shock absorption and is the major source of nutrition for articular cartilage.

Cartilage is a dense, fibrous connective tissue that can withstand great amounts of pressure and tension. The body has three basic types of cartilage: hyaline, fibrocartilage, and elastic. **Hyaline cartilage,** also called **articular cartilage,** covers the ends of opposing bones within a synovial joint. With the help of synovial fluid, it provides a smooth articulating surface in all synovial joints. Because hyaline cartilage lacks its own blood or nerve supply and must get its nutrition from the synovial fluid, it cannot repair itself if it is damaged.

Fibrocartilage acts as a shock absorber and is present in both synovial and cartilaginous joints. Shock absorption is especially important in weight-bearing joints such as the knee and vertebrae. At the knee, the semilunar-shaped cartilage called the **meniscus** builds up the sides of the relatively flat articular surface of the tibia. Intervertebral **disks** (see Fig. 3-2) lie between the vertebral bones. Because of their very dense structure, these disks are capable of absorbing an amazing amount of shock that is transmitted upward from weight-bearing forces.

In the upper extremity, a fibrocartilaginous disk located between the clavicle and sternum is important for absorbing the shock transmitted along the clavicle to the sternum should you fall on your outstretched hand. This disk helps prevent dislocation of the sternoclavicular joint and is also important in allowing motion. The disk, which is attached to the sternum at one end and the clavicle at the other, is much like a swinging door hinge that allows motion in both directions. This double-hung hinge allows the clavicle to move on the sternum as the acromial end is elevated and depressed or protracted and retracted. In effect, the fibrocartilage divides the joint into two cavities, allowing two sets of motion.

There are other functions of fibrocartilage in joints. The shoulder fibrocartilage, called the **labrum,** deepens the shallow glenoid fossa, making it more of a socket to hold the humeral head (Fig. 3-11). Fibrocartilage also fills the gap between two bones. If you examine the wrist, you will notice that the ulna does not extend all the way to the carpal bones, as does the radius. A small triangular disk located in this gap acts as a space filler and allows force to be exerted on the ulna and carpals without causing damage.

The third type of cartilage, **elastic cartilage,** is designed to help maintain a structure's shape. Elastic cartilage is found in the external ear and eustachian (auditory) tube, and is also found in the larynx, where its motion is important to speech.

Muscles provide the contractile force that causes joints to move. Therefore, they must span the joint to have an effect on that joint. Muscles are soft and cannot attach directly to the bone. A **tendon** must connect them to bone. The tendon may be a cylindrical cord, like the long head of the biceps tendon, or a flattened band, like the rotator cuff. In certain locations, tendons are encased in **tendon sheaths.** These fibrous sleeves surround the tendon when it is subject to pressure or friction, such as when it passes between muscles and bones or through a tunnel between bones. The tendons passing over the wrist all have tendon sheaths. These sheaths are lubricated by fluid secreted from their lining.

An **aponeurosis** is a broad, flat tendinous sheet. Aponeuroses are found in several places where muscles attach to bones. The large, powerful latissimus dorsi muscle is attached at one end over a large area to several bones by means of an aponeurosis. In the anterior abdominal wall, aponeuroses provide a base of muscular attachment where no bone is present but where great strength is needed. As the abdominal muscles approach the midline from both sides, they attach to an aponeurosis called the **linea alba.**

Bursae are small, padlike sacs found around most joints. They are located in areas of excessive friction, such as between tendons and bony prominences (Fig. 3-12). Lined with synovial membrane and filled with a clear fluid, bursae reduce friction between moving parts. For example, in the shoulder, the deltoid muscle passes directly over the acromion process. Repeated motion would cause excessive wearing of the muscle tissue. However, the subdeltoid bursa that is located between the muscle and acromion process prevents excessive friction and reduces the likelihood of damage. The same arrangement occurs in the elbow, where the triceps tendon attaches to the olecranon process. Some joints, such as the knee, have many bursae. There are two types of bursae: natural bursae (which have just been described) and acquired bursae. In an area that normally does not have excessive friction, a bursa can appear in the event that abnormal friction does occur. These *acquired bursae* tend to occur in places other than joints. For example, a person may develop a bursa on the lateral side of the third finger of the writing hand. This is often called the "student's bursa," because students often do a lot of writing and note-taking. These bursae disappear when the activity or friction is stopped or greatly reduced.

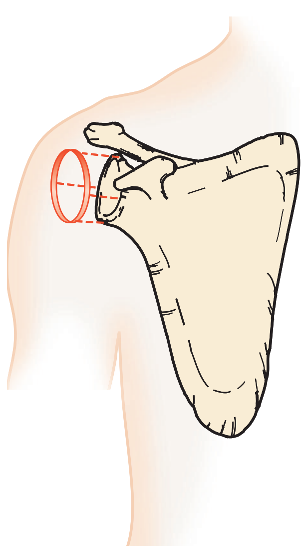

Figure 3-11. Labrum.

Planes and Axes

Planes of action are fixed lines of reference along which the body is divided. There are three planes, and each plane is at right angles, or perpendicular, to the other two planes (Fig. 3-13).

The **sagittal plane** passes through the body from front to back and divides the body into right and left parts. Think of it as a vertical wall that the extremity moves along. Motions occurring in this plane are flexion

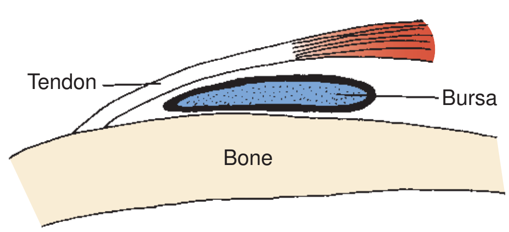

Figure 3-12. Bursa.

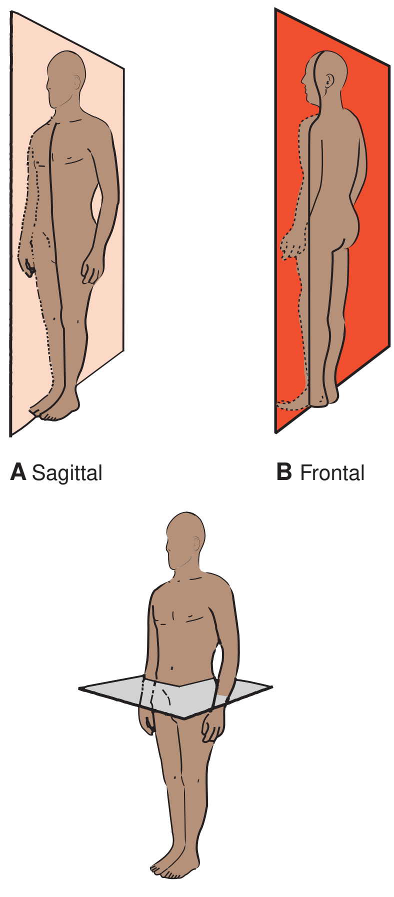

Figure 3-13. Planes of the body. **(A)** Sagittal plane. **(B)** Frontal plane. **(C)** Transverse plane.

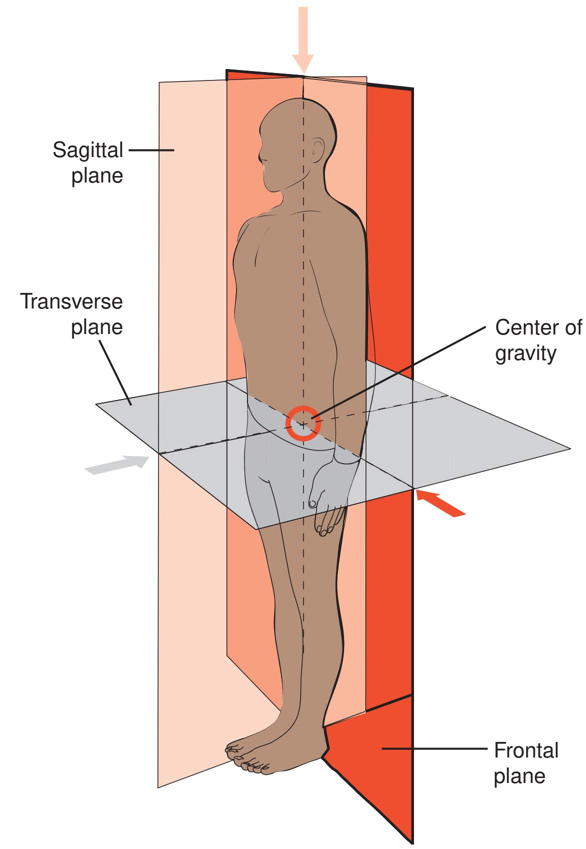

Figure 3-14. The center of gravity is the point at which the three cardinal planes intersect.

and extension. A mid-sagittal plane would divide the body in the middle into equal right and left parts. For example, a mid-sagittal section of the brain (see Fig. 6-5) would view the brain that has been cut in half from front to back (i.e., in the sagittal plane).

The **frontal plane** passes through the body from side to side and divides the body into front and back parts. It is also called the *coronal plane.* Motions occurring in this plane are abduction and adduction.

The **transverse plane** passes through the body horizontally and divides the body into top and bottom parts. It is also called the *horizontal plane.* Rotation occurs in this plane.

Whenever a plane passes through the midline of a part, whether it is the sagittal, frontal, or transverse plane, it is referred to as a *cardinal plane* because it divides the body into equal parts. The point where the three cardinal planes intersect each other is the **center of gravity.** In the human body, that point is in the midline at about the level of, though slightly anterior to, the second sacral vertebra (Fig. 3-14).

Axes are points that run through the center of a joint around which a part rotates (Fig. 3-15). The **sagittal axis** is a point that runs through a joint from front to back. The **frontal axis** runs through a joint from side to side. The **vertical axis,** also called the *longitudinal axis,* runs through a joint from top to bottom.

Joint movement occurs around an axis that is always perpendicular to its plane. Another way of stating this is that joint movement occurs *in a plane* and *around an axis.* A particular motion will always occur in the same plane and around the same axis. For example, flexion/extension will always occur in the sagittal plane around the frontal axis. Abduction/adduction will always occur in the frontal plane around the sagittal axis. Similar motions, such as radial and ulnar deviation of the wrist, will also occur in the frontal plane around the sagittal axis. The thumb is the exception, because flexion/extension and abduction/adduction do not occur in these traditional planes. (These thumb motions, and their planes and axes, will be described in Chapter 13.) Table 3-3 summarizes joint motion in relation to planes and axes.

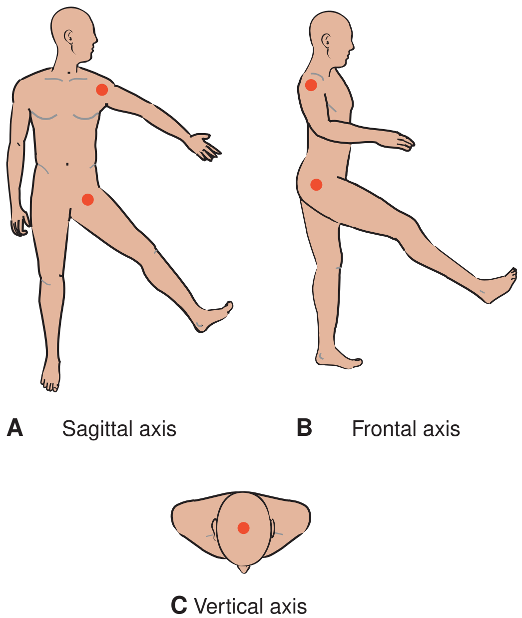

Figure 3-15. Axes of the body. **(A)** Sagittal axis. **(B)** Frontal axis. **(C)** Vertical axis.

Table 3-3 Joint Motions

Plane	Axis	Joint Motion
Sagittal	Frontal	Flexion/extension
Frontal	Sagittal	Abduction/adduction Radial/ulnar deviation Eversion/inversion
Transverse	Vertical	Medial-lateral rotation Supination/pronation Right/left rotation Horizontal abduction/adduction

Degrees of Freedom

Joints can also be described by the degrees of freedom, or number of planes, in which they can move. For example, a uniaxial joint has motion around one axis and in one plane. Therefore, it has one degree of freedom. A biaxial joint would have two degrees of freedom, and a triaxial joint would have three, the maximum number of degrees of freedom that an individual joint can have.

This concept becomes significant when dealing with one or more distal joints. For example, the shoulder has three degrees of freedom, the elbow and radioulnar joints each have one, and together they have five degrees of freedom. The entire limb from the finger to the shoulder would have 11 degrees of freedom.

Common Pathological Terms

Dislocation refers to the complete separation of the two articular surfaces of a joint. A portion of the joint capsule surrounding the joint will be torn. **Subluxation,** a partial dislocation of a joint, usually occurs over a period of time. A common example is a shoulder subluxation that develops after a person has had a stroke. Muscle paralysis and the weight of the arm slowly subluxes the shoulder joint.

Osteoarthritis is a type of arthritis that is caused by the breakdown and eventual loss of the cartilage of one or more joints. Also known as *degenerative arthritis,* it occurs more frequently as we age and commonly affects the hands, feet, spine, and large weight-bearing joints, such as the hips and knees.

Sprains are a partial or complete tearing of ligament fibers. A *mild* sprain involves the tearing of a few fibers with no loss of function. With a *moderate* sprain, there is partial tearing of the ligament with some loss of function. In a *severe* sprain, the ligament is completely torn (ruptured) and no longer functions. In contrast to a sprain, which affects a ligament, a **strain** refers to the overstretching of muscle fibers. As with sprains, strains are graded depending on severity.

Tendonitis is an inflammation of a tendon. **Synovitis** is an inflammation of the synovial membrane. **Tenosynovitis** is an inflammation of the tendon sheath and is often caused by repetitive use. The tendon of the long head of the biceps and the flexor tendons of the hand are common sites. **Bursitis** is an inflammation of the bursa. **Capsulitis** is an inflammation of the joint capsule. When a joint capsule is inflamed for an extended time, it begins to lose its extensibility, and loss of joint motion results. Each joint has a characteristic pattern of lost motion that presents when capsular tightness is present. This is referred to as the **capsular pattern** of motion restriction. There are many reasons why loss of motion may occur. When the capsular pattern is present, it aids the clinician in identifying the capsule as the *source* of the motion restriction and in directing appropriate treatment toward that structure. Some common capsular patterns are presented in Table 3-4.

Table 3-4 Common Capsular Patterns

Joint	Capsular Pattern
Shoulder	Severe loss of lateral rotation Moderate loss of abduction Slight loss of medial rotation
Wrist	Equal loss of flexion and extension
Knee	More loss of flexion than extension

Review Questions

1. What are the three types of joints that allow little or no motion?
2. What are the two terms for a joint that allows a great deal of motion?
3. What are the three features that describe diarthrodial joints?
4. What type of joint structure connects bone to muscle?
5. What type of joint structure pads and protects areas of great friction?
6. How does hyaline cartilage differ from fibrocartilage? Give an example of each type of cartilage.
7. When the anterior surface of the forearm moves toward the anterior surface of the humerus, what joint motion is involved? In what plane is the motion occurring? Around what axis?
8. What joint motions are involved in turning the palm of the hand down and up? In what plane and around what axis do these joint motions occur?
9. What joint motion is involved in returning the fingers to anatomical position from the fully spread position? In what plane and around what axis does the joint motion occur?
10. Identify the 11 degrees of freedom of the upper extremity.
11. Give an example of a synarthrodial joint in the axial skeleton.
12. *Diarthrodial, synovial, triaxial,* and *ball-and-socket* are all terms that could be used to describe which joint of the upper extremity? Could these same terms apply to a joint in the lower extremity? If so, what joint is it?
13. *Diarthrodial, synovial, biaxial,* and *saddle* are all terms that could be used to describe which joint?
14. What are two joint terms that could be used to describe the symphysis pubis?
15. What joint structure surrounds and encases the joint and protects the articular surfaces?

CHAPTER 4

Arthrokinematics

Osteokinematic Motion
- *End Feel*

Arthrokinematic Motion
- *Accessory Motion Terminology*
- *Joint Mobilization*

Accessory Motion Forces
- *Joint Surface Shape*
- *Types of Arthrokinematic Motion*
- *Convex-Concave Rule*
- *Joint Surface Positions (Joint Congruency)*

Points to Remember

Review Questions

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Osteokinematic Motion

Joint movement is commonly thought of as one bone moving on another, causing such motions as flexion, extension, abduction, adduction, or rotation. These movements, which are done under voluntary control, are often referred to as **classical, physiological,** or **osteokinematic motion** and were described in Chapter 1. Osteokinematic motion can occur actively or passively. Active range of motion (AROM) occurs when muscles contract to move joints through their ranges of motion (ROM). As we move our joints throughout the day, we are actively performing osteokinematic movements. Passive range of motion (PROM) occurs when a person's joint is moved passively through its range of motion. When a clinician moves a patient's joint passively through its range of motion, it is usually done to maintain or restore range of motion (e.g., stretching technique) or to determine the nature of the resistance the clinician feels at the end of the range. The latter is called the *end feel* of a joint.

End Feel

End feel is the type of the resistance that a clinician feels when bringing a patient's joint to the end of its passive range of motion, then applying a slight overpressure. It was first described by James Cyriax, who used this principle to identify what tissue was responsible for limiting further motion at the end range of a joint.

An end feel may be either normal or abnormal. A normal end feel exists when there is full PROM at a joint, and the motion is limited by the expected anatomical structure(s) for that particular joint (e.g., bone, capsule, muscle, and ligament). Abnormal end feel may be present when pain, muscle guarding, swelling, or abnormal anatomy stops the joint movement. When an abnormal end feel is noted, it can help to identify the "tissue at fault," or the tissue creating the dysfunction. This knowledge, in turn, helps clinicians to direct treatment toward the true anatomical source of the problem.

The three types of normal end feel are soft, firm, and hard. A **soft end feel** occurs when muscle bulk is compressed, and it is sometimes called *soft tissue approximation*. For example, elbow flexion is stopped by the approximation of the forearm and arm. This is particularly evident on a person with well-developed muscles or who is extremely obese. A **firm end feel** results from tension in the surrounding ligaments, capsule, and/or muscles and is perceived as a firm stop to the motion with only a "slight give" on overpressure. This is the most common end feel and is usually qualified by labeling the tissue type that limits the motion (e.g., firm muscular end feel, firm capsular end feel, firm ligamentous end feel). Examples would be shoulder medial and lateral rotation, hip and knee extension, and ankle dorsiflexion. A **hard end feel** is characterized by a hard and abrupt limit to passive joint motion with no give on overpressure. This occurs when bone contacts bone at the end of the ROM, and sometimes it is called a *bony end feel*. An example would be end range elbow extension as the bony olecranon process contacts the bony olecranon fossa.

Any of the normal end feels can be considered abnormal if they occur at the wrong joint or if they occur at the wrong point in the range. A firm capsular end feel is normal for shoulder lateral rotation. Soft tissue approximation is the normal end feel for elbow flexion. Therefore, a firm capsular end feel for elbow flexion is considered abnormal. A firm capsular end feel for elbow flexion may be due to capsular shortening after wearing a long arm cast. A hard end feel can result from abnormal bony structures (e.g., osteophyte) limiting joint motion.

Some end feels are always considered abnormal and may be present when pain, muscle guarding, swelling, or abnormal anatomy stops the joint movement. Abnormal end feels can be described as boggy, muscle spasm, empty, and springy block. These terms can be used to explain the source of the limitation of joint motion. **Boggy end feel** is often found in acute conditions in which soft tissue edema is present, such as immediately after a severely sprained ankle or with synovitis. It has a soft, "wet sponge" feel. **Muscle spasm** is a reflexive muscle guarding during motion. It is a protective response seen with acute injury. Palpation of the muscle will reveal the muscle in spasm. The clinician's ability to palpate normal end feel and to distinguish changes from normal end feel is important in protecting joints during ROM exercises. **Empty end feel** occurs when movement produces considerable pain and the patient stops the clinician from moving the joint beyond the painful point. Because the clinician does not bring the joint to the end of its physiologic range of motion, there is no way to tell if a limitation may exist past the point of pain, or to determine the tissue type that would have been the cause of any potential limitation. With **springy block,** a rebound movement is felt at the end of the ROM. It usually occurs with internal derangement of a joint, such as torn cartilage.

Arthrokinematic Motion

Another way of viewing joint movement is to look at what is taking place within the joint at the joint surfaces. Called **arthrokinematic motion,** it is defined as the manner in which adjoining joint surfaces move on each other during osteokinematic joint movement. Therefore, osteokinematic motion is referred to as *joint motion,* and arthrokinematic motion is referred to as *joint surface motion.*

Accessory Motion Terminology

Terminology can be somewhat confusing because various experts use words somewhat differently. That said, there are two types of accessory arthrokinematic motions that must be described: those that occur during active motion and those that occur during passive motion. Neither is under voluntary control, but both are necessary for normal functional motion to occur. **Component movements** are the small arthrokinematic joint motions that accompany active osteokinematic motion. For example, the head of the humerus must glide inferiorly in order for the shoulder to perform full flexion. The medial tibial condyle glides anteriorly on the medial femoral condyle during the last few degrees of knee extension. The joint surface of the first metacarpal glides posteriorly on the trapezium during thumb abduction. None of these component motions can be done independently; they must accompany osteokinematic motions for normal joint motion to occur. **Joint play** is the arthrokinematic movement that happens between joint surfaces when an external force creates passive motion at the joint. Regardless of whether the accessory motion occurs actively (component motion) or passively (joint play), the arthrokinematic motions that result can be described using the terms *roll, glide,* and *spin,* which will be defined later.

Joint Mobilization

If an accessory motion is limited, reduced joint motion usually results. **Joint mobilization** is a technique that applies an external force to a patient's joint to generate a passive oscillatory motion or sustained stretch between the joint surfaces. Joint mobilization can be used to restore joint mobility or decrease pain originating from joint structures. When used to restore ROM, the force is most commonly applied by generating passive arthrokinematic movement into the direction of restriction. A joint that presents with a capsular pattern of motion restriction (see Chapter 3) is one that will commonly present with reduced joint play and will be treated with joint mobilization to stretch the joint capsule. Another technique for restoring joint mobility is a high-velocity, low-amplitude (HVLA) thrust **manipulation.** This technique involves moving the joint with high speed through a very slight and calculated range that is just past where the joint play ends. Both techniques are beyond the scope of this book.

Accessory Motion Forces

When performing joint mobilization, three main types of force are used to create movement between the joint surfaces: traction, compression, and shearing. **Traction forces** cause *joint distraction* in which the joint surfaces pull apart from one another (Fig. 4-1). Carrying a heavy suitcase or hanging from an overhead bar causes distraction at the shoulder, elbow, and wrist joints. You can demonstrate this on another person by grasping their index finger at the proximal end of the middle phalanx with one thumb and index finger. Next, grasp the distal end of the proximal phalanx with your other thumb and index finger. Move the proximal interphalangeal (PIP) joint into a slightly flexed position (loose-packed position), and pull gently in opposite directions. This description, and others to follow, is meant to illustrate the various forces and is not a description of therapeutic technique. *Care must be exercised when performing these motions.*

Compression forces cause *joint approximation* in which the joint surfaces are pushed closer together (Fig. 4-2). Doing a chair or floor push-up causes the joint surfaces of the shoulder, elbow, and wrist joints to be approximated.

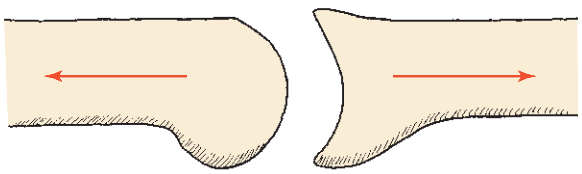

Figure 4-1. Traction force causes joint distraction in which joint surfaces move apart from each other.

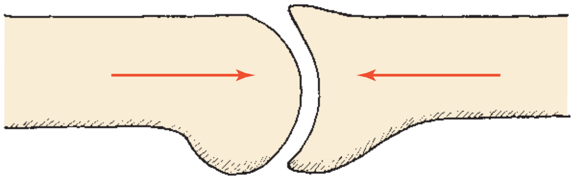

Figure 4-2. Compression force causes joint approximation in which joint surfaces move toward each other.

Shearing forces cause a *gliding motion* in which the joint surfaces move parallel to one another (Fig. 4-3). Using the positions described with distraction, grasp another person's index finger at the proximal end of the middle phalanx with one thumb and index finger. Next, grasp the distal end of the proximal phalanx with your other thumb and index finger. With the PIP joint slightly flexed, gently move your two hands in an opposite up-and-down motion. This motion describes anterior-posterior glide of the PIP joint (a shearing force).

Bending and torsional forces are actually a combination of forces. **Bending** occurs when an other-than-vertical force is applied, resulting in compression on the concave side and distraction on the convex side (Fig. 4-4). Rotary or torsional forces involve a twisting motion. One force is

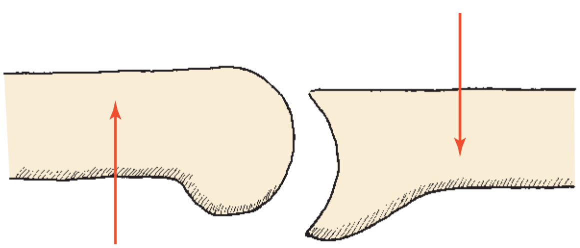

Figure 4-3. Shear force causes a glide between the joint surfaces in which bone ends move parallel to, and in opposite directions from, each other.

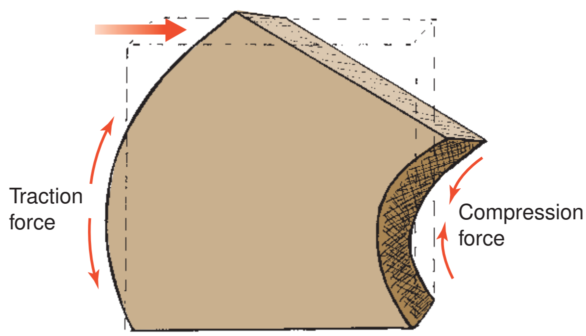

Figure 4-4. Bending force causes compression on one side and traction on the other side.

trying to turn one end or part about a longitudinal axis while the other force is fixed or turning in the opposite direction (Fig. 4-5).

Clinically, why are these accessory motion forces relevant? Distraction, gliding, bending, and torsional forces are often used to assist in restoring a joint's mobility, whereas approximation can assist in promoting joint stability.

Joint Surface Shape

To understand arthrokinematics, one must recognize that the type of motion occurring at a joint depends on the shape of the articulating surfaces of the bones. Most joints have one concave bone end and one convex bone end (Fig. 4-6). A convex surface is rounded outward, much like a mound. A concave surface is "caved" in, much like a cave.

All joint surfaces are either ovoid or sellar. An **ovoid joint** has two bones forming a convex-concave relationship. For example, in the metacarpophalangeal joint, one surface is concave (proximal phalanx) and the other is convex (see Fig. 4-6). Most synovial joints are ovoid. In an ovoid joint, one bone end is usually larger than its adjacent bone end. This permits a greater ROM on a lesser articular surface, which reduces the size of the joint.

In a **sellar,** or **saddle-shaped, joint,** each joint surface is concave in one direction and convex in another. The carpometacarpal (CMC) joint of the thumb is perhaps the best example of a sellar joint (Fig. 4-7). If you look at the carpal bone (trapezium), it is concave in an anterior-posterior direction and convex in a medial-lateral direction. The first metacarpal bone that articulates with this carpal bone has just the opposite shape. It is convex in an anterior-posterior direction and concave in a medial-lateral direction. Figure 13-2 compares the shape of this joint with the shape of two Pringles® potato chips stacked one atop the other.

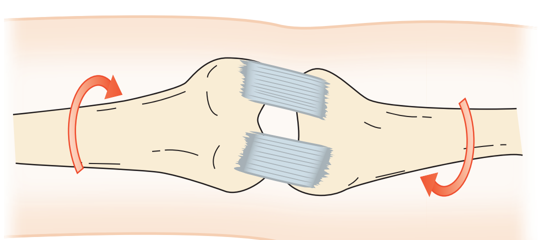

Figure 4-5. Rotary or torsional force is a twisting motion.

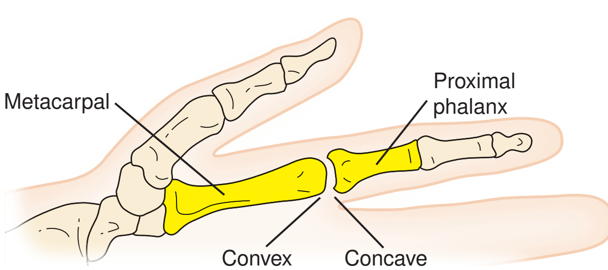

Figure 4-6. Shape of bone surfaces of an ovoid joint—MCP joint of finger.

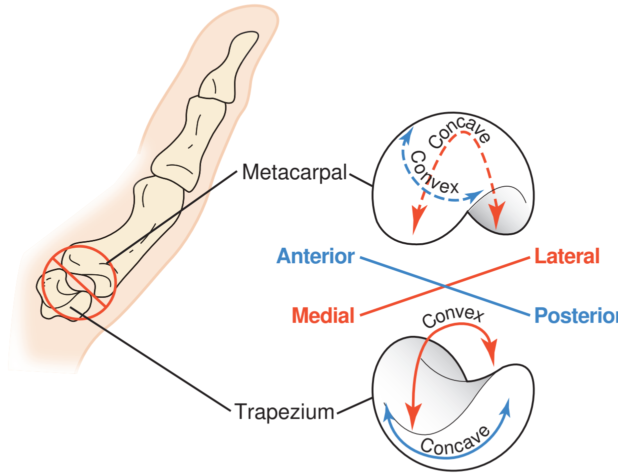

Figure 4-7. Shape of bone surfaces of a sellar joint—CMP joint of thumb.

Types of Arthrokinematic Motion

The types of arthrokinematic motion are roll, glide, and spin. Most joint movement involves a combination of all three of these motions. **Roll** is the rolling of one joint surface on another. New points on each surface come into contact throughout the motion (Fig. 4-8). Examples include the surface of your shoe on the floor during walking, or a ball rolling across the ground. **Glide,** or slide, is linear movement of a joint surface parallel to the plane of the adjoining joint surface (Fig. 4-9). In other words, one point on a joint surface contacts

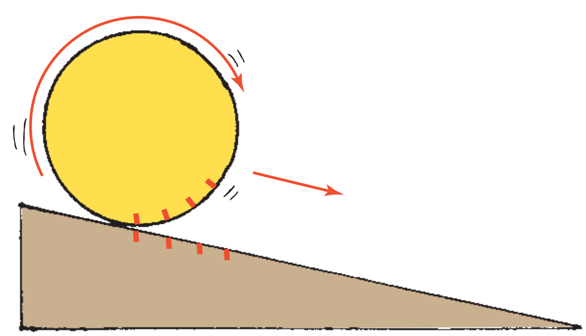

Figure 4-8. Roll—movement of one joint surface on another. New points on each surface make contact.

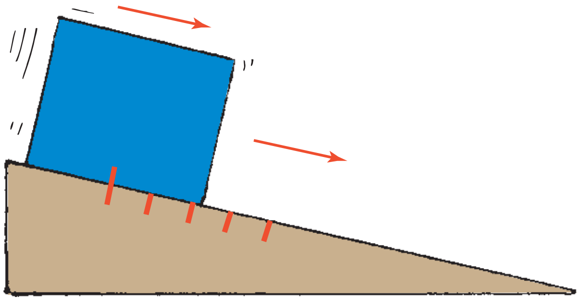

Figure 4-9. Glide—linear movement of one joint surface parallel to the other joint surface. One point on one surface contacts new points on other surface.

new points on the adjacent surface. An ice-skater's blade (one point) gliding across the ice surface (many points) demonstrates the glide motion. **Spin** is the rotation of the movable joint surface on the fixed adjacent surface (Fig. 4-10). Essentially the same point on each surface remains in contact with each other. An example of this type of movement would be a top spinning on a table. If the top remains perfectly upright, it spins in one place. Examples in the body would be any pure (relatively speaking) rotational movement, such as the humerus rotating in the glenoid fossa during shoulder medial and lateral rotation, or the head of the radius spinning on the capitulum of the humerus during forearm pronation and supination.

Analyzing the direction in which a joint surface glides during functional movement of the body is important because a glide is often the arthrokinematic motion that is passively introduced by the clinician during a joint mobilization technique. Be aware, however, that during normal joint motion, gliding is usually accompanied by rolling. Although rolling is needed to utilize all available articular surfaces, and thus to produce full range of motion at a given joint, it is the concurrent gliding that prevents one joint surface from rolling off the edge of the other before the joint motion was complete. The knee joint is a good example of how roll and glide work together to keep the joint surfaces aligned (Fig. 4-11). When an individual stands up from a chair, the convex femoral condyles begin to roll anteriorly on the concave tibial condyles. However, the tibial condyles possess far less articular surface than the femoral condyles, and because of the large range of flexion and extension permitted at the knee, the femur would roll off the tibia if the femoral condyles did not also glide posteriorly on the tibia. There is also an important spin component that is necessary during the last portion of knee extension. The nature and direction of this spin will be discussed further in Chapter 19.

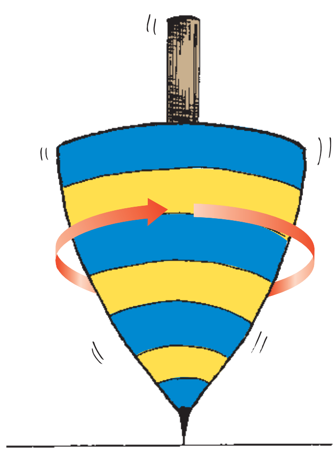

Figure 4-10. Spin—rotation of one joint surface on another. Same point on each surface remains in contact.

Convex-Concave Rule

Knowing whether the shape of a joint surface is concave or convex is important because shape determines motion. The **concave-convex rule** describes how the differences in shapes of bone ends require joint surfaces to move in a specific way during joint movement. The rule expresses the relationship between the osteokinematics and arthrokinematics for a given movement. To properly analyze the link between these two types of movement, one must observe the motion occurring at two locations: the joint surface of the moving bone (arthrokinematics) and the distal/opposite end of the moving bone (osteokinematics).

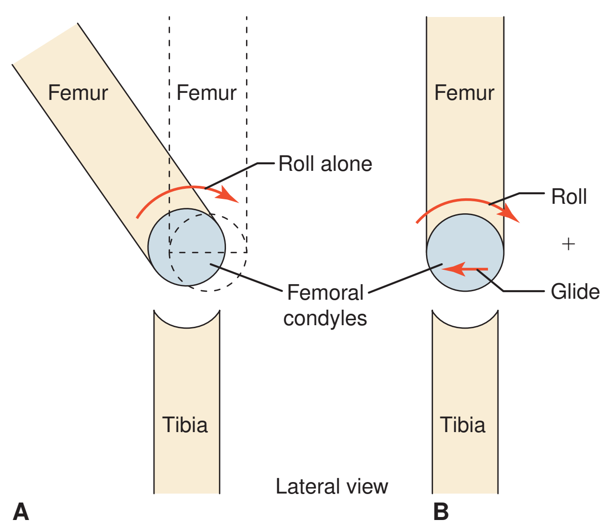

Figure 4-11. Roll and glide of femoral condyles on tibial condyles at knee joint.