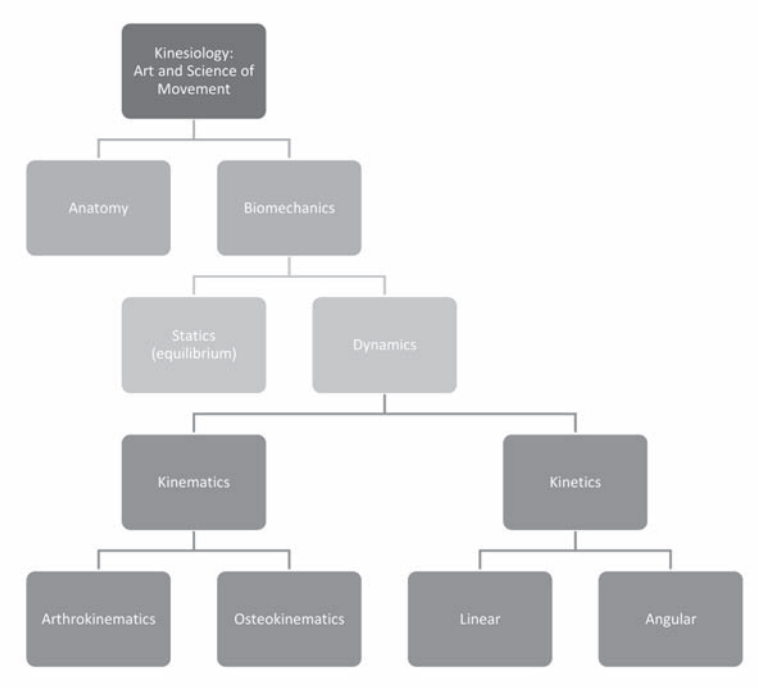

Figure 2-1. Sciences of movement.

Kinesiology and the *Occupational Therapy Practice Framework*

The *Occupational Therapy Practice Framework: Domain and Process, Third Edition* (the *Framework*) describes the concepts that define occupational therapy practice and facilitates an understanding of the basic tenets of the profession. The *Framework* guides the practice of occupational therapy, in conjunction with the knowledge of the practitioner and the existing evidence regarding efficacy of services. The *Framework* is divided into two major sections: the domain, which describes the areas of concern addressed by occupational therapists, and the process, which identifies the steps in the occupational therapy process and the actions involved in each step. The domain of occupational therapy includes several factors where an understanding of kinesiology and motion in the human body will positively affect the outcome of services. In the area of occupation, kinesiological principles can be applied to activities of daily living, work, play, leisure, and social participation to enhance client outcomes. Client factors such as body functions and body structures refer to the "physiological function of body systems … and anatomical parts of the body" (American Occupational Therapy Association, 2014), and an understanding of kinesiology can be utilized to maximize client function. Performance skills are "small units of engagement in daily life occupations" (American Occupational Therapy Association, 2014, p. S7), which can be positively affected by the application of kinesiology principles for client benefit. In the process of delivering occupational therapy services, an understanding of kinesiology will positively affect analysis of occupational performance and the planning, execution, and follow-up modification of intervention sessions.

Anatomic Position and Body Movements

Anatomic position is defined as the position in which the person is standing erect, facing forward, with the arms at their sides, palms facing forward, and the fingers and thumbs in extension (Kendall, McCreary, & Provance, 1993). It is the reference position for labeling body parts, and movements are typically described with respect to anatomical position, unless otherwise specified.

Basic trunk and/or limb movements, some of which occur in multiple joints, include flexion, extension, and hyperextension; lateral flexion to the right and left; rotation to the right and left; abduction and adduction; internal and external rotation; pronation and supination; inversion and eversion; and radial and ulnar deviation (Table 2-1).

Planes and Axes of Movement

Planes and axes provide a three-dimensional (3D) system for describing movements in space. Because space is 3D, each of these dimensions must be described by a plane in which motion occurs. The three principal (or cardinal) planes are described with respect to anatomical position, and an understanding of the planes of the body is essential to describing the space and direction in which movement occurs (Muscolino, 2006). The three basic planes in the body are the sagittal and frontal (coronal) planes, which are oriented vertically, and the transverse (horizontal) plane, which is oriented horizontally.

Table 2-1

Terminology Related to Joint Movements (From Anatomical Position)

Motion	**Description**
Flexion and extension	• Flexion and extension occur in the sagittal plane around the mediolateral (coronal, or X) axis, which extends from side to side. Flexion (often referred to as *bending*) occurs in the anterior direction in the neck, trunk, joints of the upper extremity, and the hip. Flexion of the knee, ankle, and toes occurs in the posterior direction. Extension (often referred to as *straightening*) occurs in the direction opposite of flexion. The term *hyperextension* describes movement beyond normal ROM in the direction of extension. Dorsiflexion occurs as a flexion movement of the ankle as the foot moves toward the anterior surface of the tibia. Plantarflexion is an extension movement of the foot as it moves away from the tibia at the ankle joint.
Lateral flexion	• Lateral flexion also occurs in the frontal plane around the anteroposterior axis and includes lateral (sideways) movements of the neck and trunk.
Horizontal abduction and adduction	• Horizontal abduction and adduction are shoulder movements that occur in the transverse plane around a vertical (longitudinal, or Y) axis. From a flexed position of the shoulder, horizontal abduction is movement of the shoulder away from midline in a lateral direction, and horizontal adduction involves movement toward midline in a medial direction.
Internal and external rotation	• Internal and external rotation also occur in the transverse plane around a vertical axis. In the upper and lower extremities, movement of the anterior surface of the extremity toward the midline of the body is referred to as *internal* (or *medial*) rotation, and movement away from midline is referred to as *external* (or *lateral*) rotation.
Rotation of the head, neck, trunk, and pelvis	• Rotation of the head, neck, trunk, and pelvis also occurs in the transverse plane around a vertical axis through the center of the body and may be described as rotation to the right or left, or rotation occurring in a clockwise or counterclockwise direction.
Movements of the scapula	• Scapular adduction (retraction) describes movement of the scapula toward the vertebral column and scapular abduction (protraction) describes movement of the scapula away from the vertebral column. • Elevation of the scapula refers to superior (or upward) movement of the scapula and scapular depression refers to inferior (or downward) movement of the scapula. • Upward rotation of the scapula is described by upward movement of the glenoid fossa and lateral movement of the inferior angle of the scapula, while downward rotation includes downward movement of the glenoid fossa and medial movement of the inferior angle of the scapula.
Pronation and supination of the forearm	• Pronation and supination of the forearm refers to rotation of the forearm in the transverse plane around the vertical axis of the arm. In supination, the volar surface of the hand faces anteriorly, and in pronation, the palm is oriented posteriorly.
Radial and ulnar deviation of the wrist	• Radial and ulnar deviation occurs in the frontal plane around the anteroposterior axis. Radial deviation (abduction) refers to lateral movement toward the thumb side of the hand away from the body, while ulnar deviation (adduction) refers to movement toward the little finger side of the hand toward the body.

Adapted from Houglum, P., & Bertoti, D. B. (2012). *Brunnstrom's clinical kinesiology* (6th ed.). Philadelphia, PA: F. A. Davis and Kendall, F. P., Provance, P. G., Rodgers, M., & Romani, W. (2005). *Muscles: Testing and function, with posture and pain*. Philadelphia, PA: Lippincott Williams & Wilkins.

The sagittal plane extends from front to back, divides the body into the right and left sides (Figure 2-2), and movements in the sagittal plane are anterior-posterior or posterior-anterior. Examples of movements in the sagittal plane include flexion and extension of the trunk (bending forward and backward while facing forward) and flexion and extension of the shoulder, elbow, wrist, and fingers while in anatomical position.

The frontal (coronal) plane extends from side to side and divides the body into front and back. Movements in this plane go from right to left or left to right (Muscolino, 2006). Movements include bending the trunk in a side-to-side fashion and abduction (moving away from the body to the side) and adduction (moving toward the body) of the shoulders and hips.

The transverse (horizontal) plane divides the body into upper and lower sections. This plane has a horizontal orientation as opposed to the sagittal and frontal planes, which are oriented vertically. Movements that occur in the transverse plane are typically rotational, including turning the head from

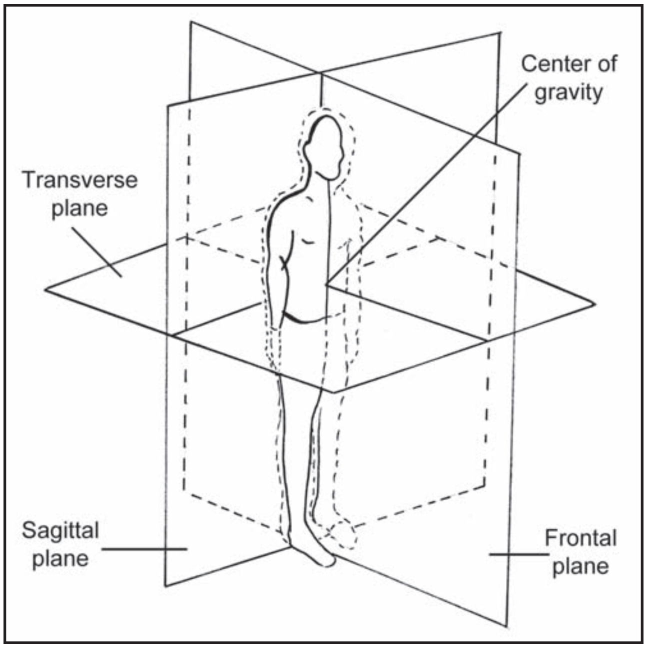

Figure 2-2. Planes and axes.

Table 2-2

MOTIONS IN EACH PLANE AND AXIS

PLANE AND AXIS	MOVEMENTS
Sagittal plane around the mediolateral (frontal, coronal, X) axis	Flexion, extension, and hyperextension
Frontal (coronal) plane around the anteroposterior (sagittal, Z) axis	Abduction, adduction, lateral flexion, radial and ulnar deviation
Transverse (horizontal) plane around the vertical (longitudinal, Y) axis	Supination, pronation, internal and external rotation, neck and trunk rotation, horizontal abduction and adduction

side to side, twisting at the waist, and internal and external rotation of the upper and lower extremities with the body in anatomical position.

The intersection of the center of all three of these planes is the center of gravity (COG; Kendall et al., 1993). Planes that do not lie in line with any one of these planes in one of the three basic planes are described as oblique planes (Neumann, 2010).

An axis is an imaginary straight line around which rotary or angular movement occurs. The axis around which movement occurs is always perpendicular to the plane in which the movement is occurring. For each of the principal planes, there is a corresponding axis and, therefore, movement can be described as occurring within a plane and around the associated (perpendicular) axis. The axis that is perpendicular to the sagittal plane is called the *mediolateral axis*, named by its directional orientation, although it is also referred to as the *frontal, coronal, or X axis* in various publications (Muscolino, 2006; Neumann, 2010). It runs in a left-to-right or right-to-left direction. Movements around the mediolateral axis include flexion and extension of the trunk, shoulders, elbows, wrists, fingers, hips, and knees, as well as dorsi- and plantarflexion of the ankle.

The axis that is located perpendicular to the frontal plane is referred to as the *anteroposterior axis* as it is oriented from the front to the back or back to the front of the body. It is also called the *sagittal* or *Z axis* by some authors. The abduction and adduction that occurs at the shoulders and hips when doing a jumping jack is an example of movement in the frontal plane around the anteroposterior axis. Other motions occurring in the frontal plane around the anteroposterior axis are lateral flexion of the trunk, radial and ulnar deviation at the wrist, and inversion and eversion of the foot.

The axis located perpendicular to the transverse plane runs in a superior-inferior direction and is called the *vertical axis*, but may also be labeled the *longitudinal* or *Y axis*. Shaking one's head "no" is an example of movement in the transverse plane around the Y axis. Motions occurring around this axis include internal and external rotation, horizontal abduction and adduction, and pronation and supination of the forearm.

The importance of understanding planes and axes lies in the ability of this 3D system to describe movements clearly and consistently (Table 2-2). Movement in the sagittal plane and around the corresponding mediolateral axis is best visualized from the side of the body. Movements taking place in the frontal plane and around the anteroposterior axis are best observed from the front of the body. Motion in the transverse plane and around the longitudinal axis are most easily visualized from a superior or inferior perspective. Using an index card that is pierced by a rod (such as a pencil) to represent a plane and its corresponding axis can be a valuable and portable tool to help practitioners and students alike to visualize these concepts.

It is critical for the learner to be able to visualize both the orientation of and the relationship between the planes and axes to fully understand a description of movement, as well as to properly conduct assessments such as manual muscle testing and passive range of motion (PROM).

JOINT CLASSIFICATIONS

Neumann (2010) describes a joint as the junction or pivot point between two or more bones. Joints can be classified either by how much motion is available at the joint or by the type of tissue that comprises the junction between the components of the joint (Resnick & Kransdorf, 2005). Classification of joints based on available motion includes three basic categories: synarthroses, amphiarthroses, and diarthroses. Synarthroses are joints that essentially allow no motion. Amphiarthroses are joints that are slightly moveable, and diarthroses are joints that move freely in the absence of pathology (Table 2-3; Resnick & Kransdorf, 2005). The classification of joints based on the type of connecting tissue overlaps with the classification based on available movement and includes fibrous, cartilaginous, and synovial joints.

Table 2-3

JOINT CLASSIFICATIONS

JOINT TYPE	CHARACTERISTICS	TYPES	EXAMPLES
Synarthrosis (fibrous)	• Immovable joints • Connective tissue or hyaline cartilage	• Suture	• Skull
		• Syndesmosis	• Distal radioulnar joint • Distal tibiofibular joint • Sacroiliac ligament
		• Gomphosis	• Teeth insertion into mandible and maxilla
Amphiarthrosis (cartilaginous)	• Slight movement	• Symphysis	• Symphysis pubis • Manubrioalsternal joint • Intervertebral disc
		• Synchondrosis	• Physeal plate (growth plate) • Sphenooccipital joint
Diarthrosis (synovial)	• Most numerous in body • Freely moveable	• Hinge (ginglymus)	• Elbow; knee
		• Pivot	• Atlantoaxial joint in the spine; humeroradial joint
		• Condyloid	• MCP joints of the hand
		• Saddle	• Carpometacarpal joint of the thumb
		• Ball and socket	• Shoulder • Hip

Fibrous Joints (Synarthroses)

There are three types of fibrous joints. The bones of a synarthrodial joint are joined by dense fibrous connective tissue that directly unites bone to bone. An example of this is a suture joint in the skull. A syndesmosis is a fibrous joint (Lippert, 2017) that is held together by an interosseous ligament or membrane, and motion is limited to the stretching or extensibility of the connecting ligament or membrane (Resnick & Kransdorf, 2005). The distal radioulnar joint is an example of syndesmosis. A gomphosis is a fibrous joint characterized by a peg in socket alignment, such as the articulation between a tooth and the mandible.

Cartilaginous Joints (Amphiarthroses)

There are two types of cartilaginous joints: symphyses and synchondroses. The junction of a symphysis joint is formed by fibrocartilage or hyaline cartilage, and they are typically characterized by relatively restrained movement. Examples of symphysis joints include the interbody joints of the spine, the symphysis pubis, and the manubriosternal joint. Synchondroses are temporary joints that are present as the skeleton grows but become thinner and are ultimately replaced by bony union as skeletal maturity is reached (Resnick & Kransdorf, 2005).

Synovial Joints (Diarthroses)

Synovial joints allow much greater freedom of motion, and the adjacent bones are separated by a distinct space referred to as the *joint cavity*. The entire joint is encased in a fibrous joint capsule (Rybski, 2012), and connective tissue does not directly connect adjacent bony surfaces. The articulating surfaces of the bones comprising the joint are covered by a layer of connective tissue, usually hyaline cartilage. This tissue, which varies in thickness depending on the size, functional demand, external forces, and joint, serves as a shock absorber and decreases friction within the joint. The fibrous joint capsule is composed of a tough outer layer and a thin, more fragile inner layer called the *synovial membrane*. The synovial membrane secretes synovial fluid into the joint space, nourishing the articular cartilage and lubricating the joint surfaces, decreasing friction within the joint. Outside of the capsule, ligaments, fasciae, aponeuroses, and tendons provide support to the joint, and synovial sheaths surrounding the tendons promote gliding. In addition, fluid filled sacs called *bursae* increase lubrication and thus gliding between adjacent layers of tissue (Figure 2-3).

Classification of Synovial Joints

Synovial joints can be classified by degrees of freedom or the directions in which they move. A uniaxial joint is constructed in such a way that only one degree of freedom exists in the joint, meaning that rotary movement occurs around one axis and takes place within the corresponding plane of the body. A hinge joint (ginglymus joint) is a type of uniaxial joint that typically

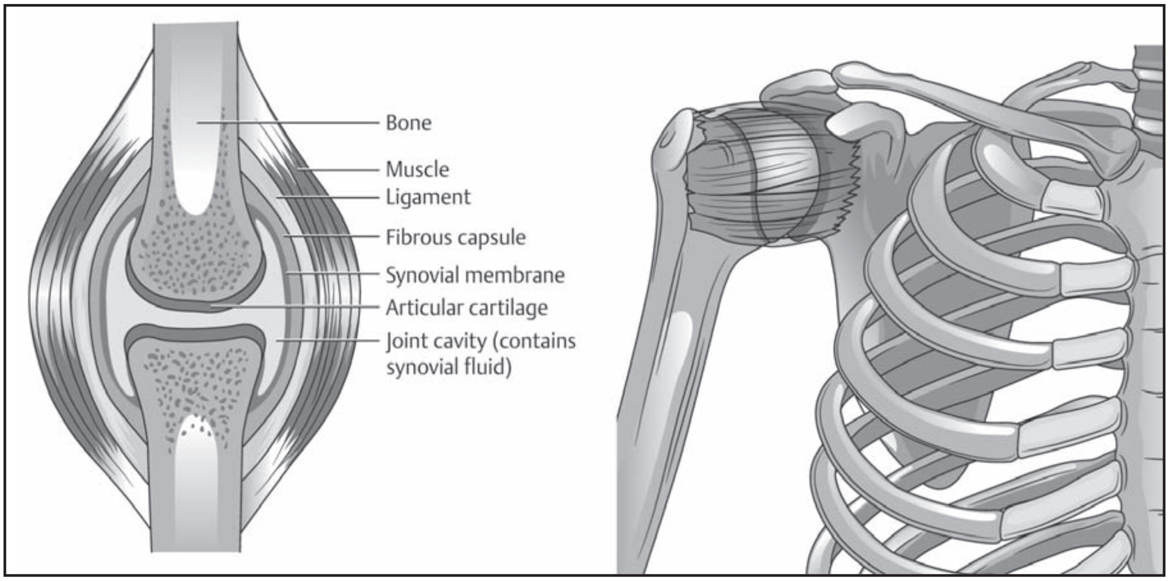

Figure 2-3. Structure of a synovial joint.

connects a concave surface with a convex surface and moves in flexion and extension (Figure 2-4). From the anatomic position, movement occurs in the sagittal plane around the mediolateral axis. Examples of hinge joints include the elbow and knee. Another type of uniaxial joint is a pivot joint (trochoid joint), in which one component of the joint is shaped like a ring and the other component rotates within it (Figure 2-5). From an anatomic position, the only movement that occurs is rotation in the transverse plane around the longitudinal axis. Examples of this type of joint include the atlantoaxial joint in the cervical spine, in which the second cervical vertebra has an upward bony projection providing an axis around which the first cervical vertebra rotates, and the humeroradial joint of the elbow.

Biaxial joints present with movement of the bony components in two planes and around two axes; therefore, they have two degrees of freedom. The condyloid (or ellipsoid or ovoid) joint has an oval or egg-shaped convex surface that fits into a reciprocally shaped concave surface, allowing the concave surface to slide over the convex surface in two directions (Figure 2-6). The movements include flexion/extension and abduction/adduction. Circumduction is also present in these joints but is actually a sequential combination of the already mentioned movements. The metacarpophalangeal (MCP) joints of the hand are condyloid joints. The saddle joint is also biaxial, so named because the joint components fit together like a rider on a saddle, with two degrees of freedom (Figure 2-7). In a saddle joint, each bony component is convex in one plane and concave in the other, with flexion and extension in one plane and abduction/adduction in another. The carpometacarpal joint of the thumb is an example of a saddle joint.

Triaxial or multiaxial joints have multiple degrees of freedom with distinctly different movements occurring in the three cardinal planes of motion and around the three cardinal axes. Ball and socket joints are one type of multiaxial joint, in which a spherical head at the end of one bone fits into and moves within a cup or saucer like concavity in the bone with which it articulates. This type of articulation is found in the glenohumeral joint of the shoulder, where the head of the humerus (ball) sits in the glenoid fossa (socket; Figure 2-8). In the hip, the head of the femur (ball) sits in the acetabulum (socket) of the pelvis. The structure of these joints allows for movement in flexion and extension (sagittal plane, X axis), abduction and adduction (frontal plane, Z axis), and internal and external rotation (transverse plane, Y axis). The plane joint is another type of multiaxial joint. Plane joints are typically composed of flat or slightly curved, irregularly shaped bones. This joint structure allows for multidirectional gliding between two or more bones. An example of plane joints is the intercarpal articulations in the wrist, at which slight gliding motions occur between the carpal bones during wrist motions.

Types of Motion

Movement can occur as linear (translatory) or angular (rotational) motion, but during every day activities, a combination of the two is necessary. According to Lippert (2017), the majority of the movement within the human body is angular and movement outside of the body is more linear in nature; however, it is not uncommon to see both types of movements occurring simultaneously. For example, a person walking down the street is traveling in a linear fashion from point A to point B. However, each of the joints of the lower extremities (hips, knees, and ankles) are moving in an angular fashion to advance the legs forward. Movement in the body is rarely only one type of motion.

Linear motion is defined as motion that occurs when all parts of the object move at the same time, in the same direction, and travel the same distance. Linear motion can be further described as either rectilinear or curvilinear (Lippert, 2017). Rectilinear movement occurs in a more or less straight line from one location to another, such as a person being pushed in a wheelchair down a hallway. When a person shrugs the shoulders up and down into elevation and depression, this would be considered linear motion.

When the trajectory is curved, the motion would be curvilinear, such as when a person throws a ball and the path of

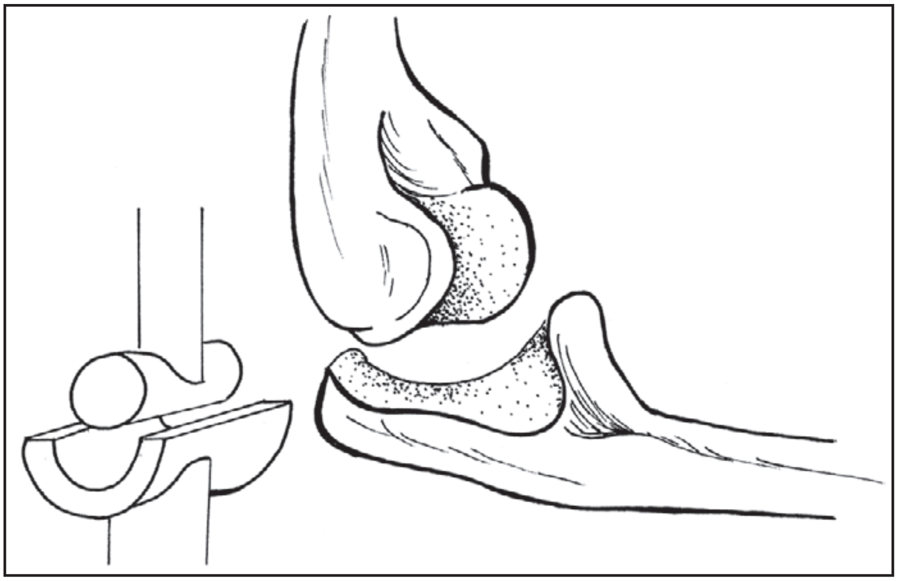

Figure 2-4. Uniaxial or ginglymus joint.

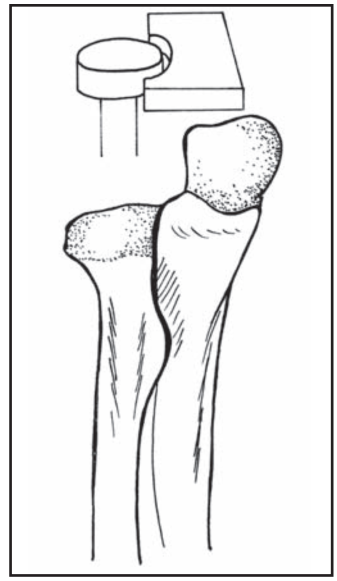

Figure 2-5. Pivot or trochoid joint.

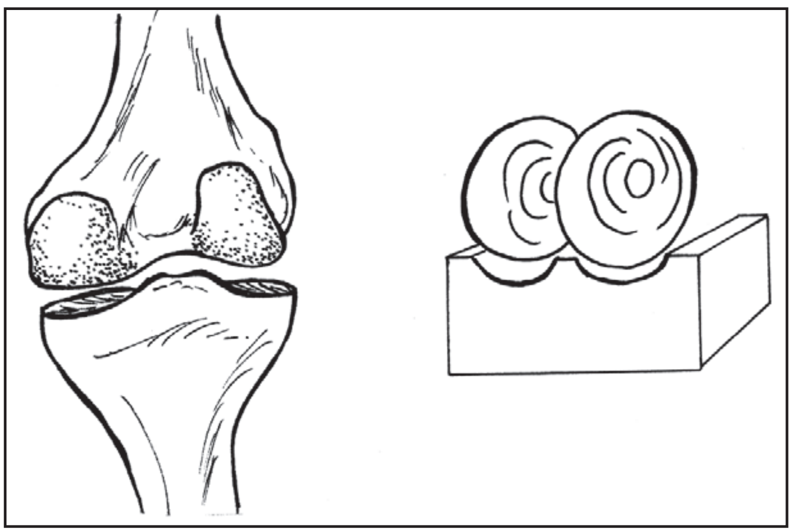

Figure 2-6. Condyloid or ellipsoid joint.

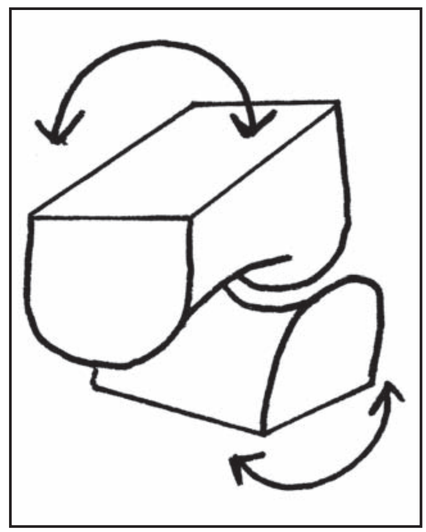

Figure 2-7. Saddle joint.

the object represents a parabola. Angular motion is defined as motion that occurs when all parts of the object move at the same time, in the same direction, but at different distances from the axis of motion. Angular motion occurs when a person swings his or her leg, or flexes his or her knee, the foot travels farther through space than does the ankle or leg. The ankle and the middle of the leg itself are closer to the knee joint, or joint axis than the foot (Lippert, 2017).

Arthrokinematics

Following the discussion of osteokinematics, which deals with the movement of bones around a joint axis, we will now consider the relationship of joint surface movement, which is referred to as *arthrokinematic motion* (Lippert, 2017). The terms typically utilized to describe this motion are *roll*, *slide* (or *glide)*, and *spin*. Roll occurs when multiple points on one

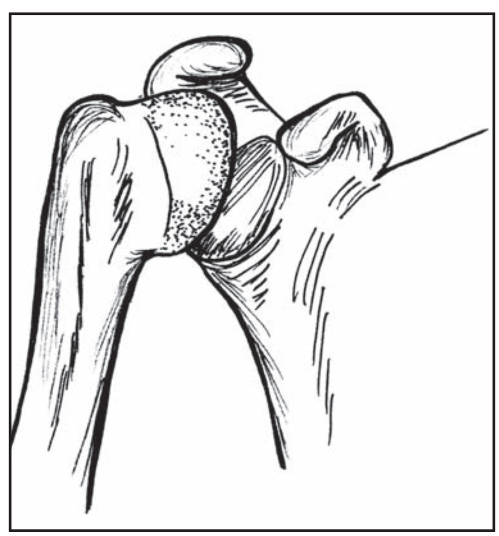

Figure 2-8. Ball and socket joint.

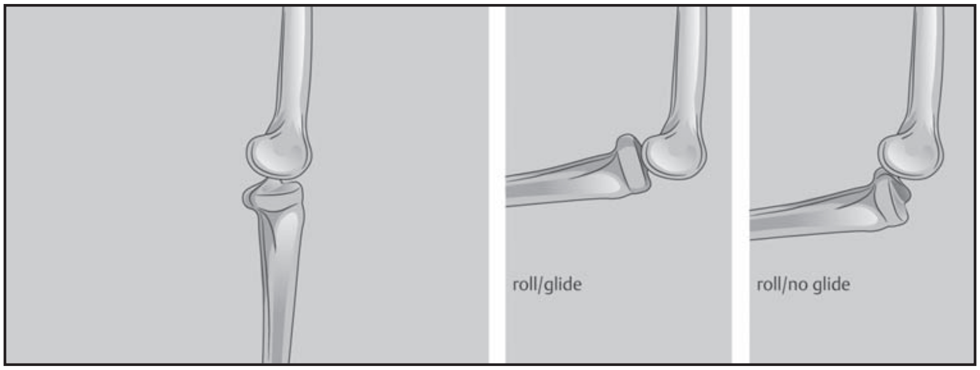

Figure 2-9. Knee arthrokinematics.

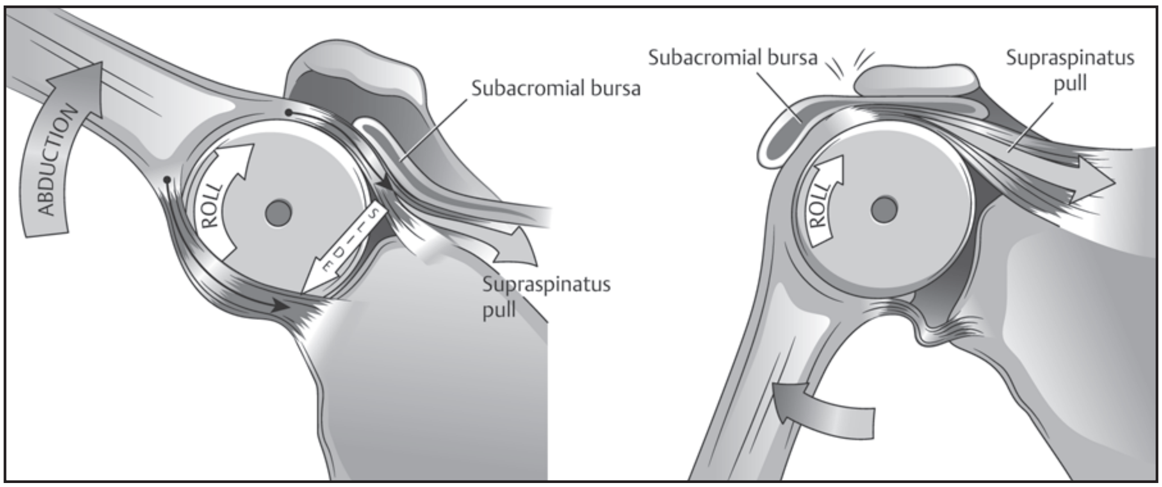

Figure 2-10. Convex-on-concave motion.

rotating articular surface contact multiple points on the other articulating surface, such as a tire rotating along a paved road. Slide (or glide) occurs in a joint when a point or set of points on one articular surface contacts multiple points on another articular surface, such as when a box is being pushed up a ramp or incline. Lastly, spin occurs when one single point on one articular surface rotates on a single point on another articular surface, like a top spinning on one point on the floor. "Essentially, the same point on each surface remains in contact with each other" (Lippert, 2017, p. 35).

Understanding arthrokinematics is essential for occupational therapy practitioners because this type of movement can be generated passively by a clinician to a client during intervention techniques utilized to increase range of motion (ROM). In general, rolling and sliding occur simultaneously to achieve optimal joint motion and maintain proper joint congruency. If a joint does not demonstrate simultaneous sliding and rolling, one joint surface is at risk for rolling off of the other joint surface before the full ROM is achieved. An example provided by Lippert (2017) describes the knee joint requiring roll and glide to keep the joint surfaces aligned. If rolling and sliding do not occur simultaneously, unhealthy relationships between the bones of a joint can occur, as depicted in Figure 2-9.

The relationship between the articulating joint surfaces is essential for optimal, safe motion, as described in the convex-concave patterns of movement, in which osteokinematics and arthrokinematics are analyzed together. When a convex joint surface moves on a fixed concave joint surface, the roll and slide occur in the opposite direction (convex-on-concave; Figure 2-10). When a concave surface moves on a stationary convex surface, the roll and slide occur in the same direction (concave-on-convex). During abduction of the shoulder, the convex head of the humerus rolls in a superior direction and slides in an inferior direction. Another example of convex-on-concave can be seen when a person is sitting down on a chair with a fixed distal lower extremity. When the person rises to standing, the convex head of the distal femur rolls anteriorly as it slides posteriorly.

Conversely, an example of concave-on-convex is when a person is sitting on a swing and kicking the lower leg forward and back. The concave end of the proximal tibia rolls and slides in the same direction on the stable, convex end of the femur (Figure 2-11). For a visual of these patterns of movement, please see https://www.youtube.com/watch?v=RHY0LCkayg&feature=youtu.be. According to Samuels (2018), there has been evidence of joint arthrokinematics that appear to be inconsistent with these rules as described. However, the fundamentals of these patterns that occur during human movement can be appreciated by acknowledging that rolling and sliding happen synchronously to produce efficient and safe movement.

Kinematic Chains

In the examples listed previously, open- vs. closed-chain movement is also highlighted. Open-chain movement occurs when the distal segment of a joint moves on a relatively fixed proximal segment, such as the person sitting on a swing and kicking the lower leg back and forth. In contrast, closed-chain movement occurs when the proximal segment of the joint moves on a fixed distal segment, such as when a person rises from a sitting to standing position with the feet planted. In other words, the feet are fixed to the floor during a closed-chain movement, as compared to the person swinging the legs on a swing, where the legs (or distal segment) are free to move back and forth.

This concept of open- and closed-chain movements must be considered when clinicians prescribe exercise. Sometimes referred to as *kinematic chains*, these movements enable the body to transform stereotypical angular motion of joints into efficient curvilinear motion (Smith, Weiss, & Lehmkuhl, 1996). Kinematic chains are several joints that unite successive segments, creating a series of connected links that allow motion (Lippert, 2017). Imagine an orchestra conductor: the wave of his baton represents an open kinematic chain, while the sway of his body in time to the music represents a closed kinematic chain.

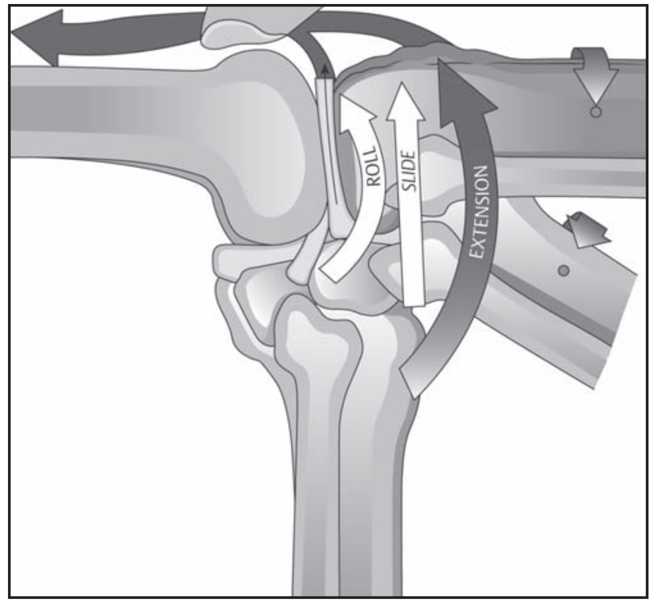

Figure 2-11. Concave-on-convex motion.

Joint Congruency

According to Lippert (2017), "How well joint surfaces match or fit is called joint congruency" (p. 36). When a joint is congruent, there is maximum contact between the articulating surfaces and the two parts are tightly compressed, making it challenging to distract or separate them. In this position, the joint capsule and ligaments holding the bones together are taut, or tight. This position would be considered close packed, and further passive movement of the joint is not possible. An example of a close-packed position at one extreme of ROM is full flexion of the patellofemoral joint of the knee.

When the knee is flexed, the lateral and medial patellar movements, which can be accomplished manually while the knee is extended, are unavailable. Another example of a close-packed position is MCP flexion (Lippert, 2017). When the MCP joint is extended, there is significant abduction and adduction of the fingers, but when flexed, these motions are unavailable. The tibiofemoral joint at the knee is also in a close-packed position in full extension. Clinical relevance of the close-packed position includes assessment for stability and joint integrity. A joint in a close-packed position is more likely to be injured than if it were in an open-packed position. If edema is present, it is more difficult for a client to move into a close-packed position (Lippert, 2017).

All other positions of the joint are called *open-* or *loose-packed*, where the joint surfaces do not fit perfectly. Clinically, this is also referred to as a *resting position*. Parts of the joint capsule and supporting ligaments are lax, and there is very little congruency between the articular surfaces. Open-packed positions permit additional or accessory motions (Lippert, 2017) since the ligaments and capsular structures are lax. Accessory motion is defined as movement in surrounding joints that accompanies active motion in the primary joint. Accessory motion is necessary for normal ROM but cannot be isolated voluntarily (Thomas, 1997). This can be seen in the scapula and clavicle as the humerus is flexed or abducted. As the humerus is raised, the scapula rotates upwardly and may protract, while the clavicle moves forward and elevates. This movement of the scapula and clavicle occurs without conscious control and is essential for full humeral elevation.

Another example of accessory motion is the downward movement of the humeral head in the glenoid fossa during shoulder elevation accomplished by rotator cuff muscles. Although the deltoid muscles are primarily responsible for elevating the humerus, if downward movement of the head of the humerus in the glenoid fossa did not occur, the greater tuberosity would hit the acromion process. The rotator cuff muscles allow the accessory motion necessary for the deltoid muscles to complete humeral elevation without pain or impingement (Smith et al., 1996).

Joint play "is the arthrokinematic movement that happens between joint surfaces when an external force creates passive motion at the joint" (Lippert, 2017, p. 32). It can also be defined as the accessory movement present in a joint, which is not under volitional control but is critical to achieve full function or ROM at a joint. Joint play is the extensibility of the joint capsule or the "give" that occurs when joints are passively distracted. Specific joint mobilization techniques are used to restore or maintain joint play and should only be implemented by a trained clinician.

Kinetics

Kinetics is an analysis of the forces that create motion or maintain equilibrium and begins with a review of Newton's laws. Understanding these theories will help clarify movement of the human body, which is of interest to the occupational therapy practitioner.