Muscle and Joint Anatomy

Learning Objectives

1. Differentiate between fibrous, cartilaginous, and synovial joints.
2. Classify fibrous joints as sutures, syndesmoses, or gomphoses.
3. Classify cartilaginous joints as primary or secondary.
4. Describe the basic components of a synovial joint: articular cartilage, synovial membrane, synovial fluid, and joint capsule.
5. Define ligament, skeletal muscle, tendon, aponeurosis, and enthesis.
6. Explain how skeletal muscles exert their actions at synovial joints with respect to their attachment sites.
7. Define movements at synovial joints as flexion/extension, abduction/adduction, internal/external rotation, pronation/supination, or inversion/eversion.
8. Classify synovial joints as hinge, ball-and-socket, plane, condyloid, saddle, or pivot and discuss how the shape of these joints affects the actions that can occur at them using common examples of each type.
9. Connect the affected musculoskeletal structures to the following clinical correlates: osteoarthritis, joint sprains, tendinopathy, and enthesitis.

Introduction

The skeletal system provides the framework for the entire body. Across the skeletal system, joints form between bones for strengthening bonds, providing cushion, allowing significant range of motion, or a combination thereof. The muscles that contract and relax to cause bones to articulate with one another are termed skeletal muscles. Because skeletal muscles and the skeleton are so intimately related, they are often referred to collectively as the **musculoskeletal system**.

Types of Joints

There are two main ways to classify joints. We will focus on the type of tissue, which results in three basic types of joint: fibrous, cartilaginous, and synovial. The other classification system, which you are not responsible for, focuses on the degree of motion that is permitted at the joint and also has three basic categories: synarthroses (immoveable), amphiarthroses (slightly moveable), and diarthroses (freely moveable). There is some overlap between these two categories with fibrous joints generally corresponding to synarthroses, cartilaginous joints to amphiarthroses, and synovial joints to diarthroses. Again, you are not responsible for the terms related to degree of motion at the joint.

Fibrous Joints

Fibrous joints occur between adjacent bones that are held together by fibrous connective tissue (Figure 1). This type of joint allows little to no movement between bones. Fibrous joints are further classified into three types of fibrous joints: sutures, syndesmoses, and gomphoses.

A **suture joint** occurs between bones of the skull that are tightly held together by fibrous connective tissue (Figure 1A). Eventually, suture joints ossify to fuse the bones of the skull together. A **syndesmosis**

occurs between bones that are separated spatially but held together by a dense ligament (Figure 1B). This type of joint prevents the bones from separating further and can provide strong support for muscular attachments while allowing for some degree of movement. The clearest examples of syndesmoses are between the bones of the forearm and the leg. Lastly, a **gomphosis** is a specialized joint that holds each individual tooth within its socket (Figure 1C).

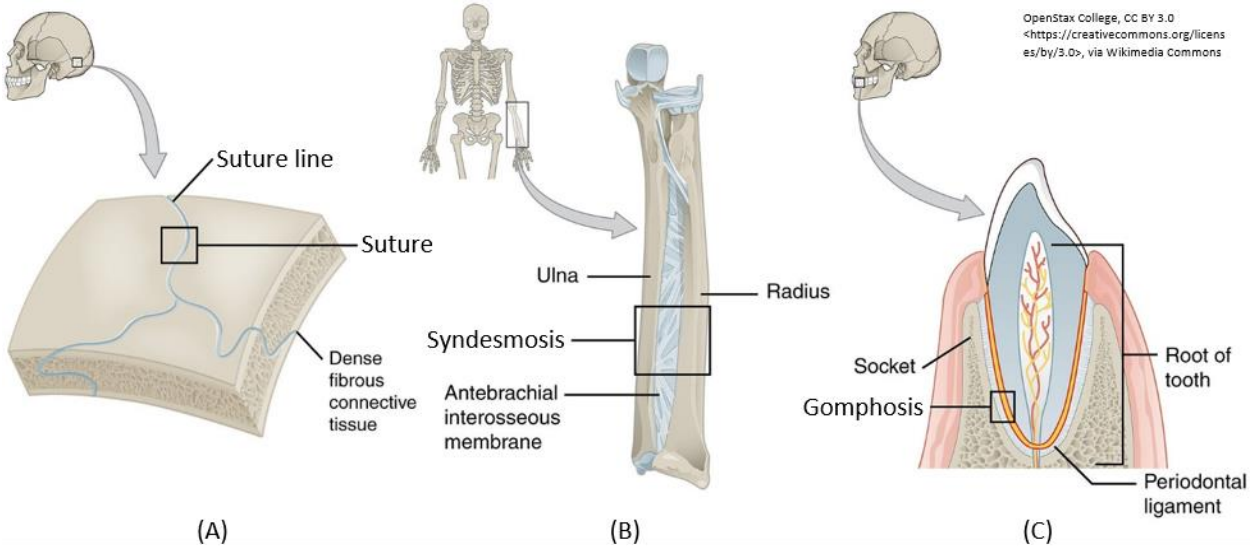


Figure 1. Types of fibrous joints. (A) Suture, (B) syndesomosis, and (C) gomphosis.

CARTILAGINOUS JOINTS

Cartilaginous joints are made of hyaline cartilage or fibrocartilage (Figure 2). As a general rule, these joints allow more movement than fibrous joints and less movement than synovial joints. Cartilaginous joints are further classified into two types of cartilaginous joints: primary and secondary.

A **primary cartilaginous joint** (also known as a synchondrosis) is a joint of hyaline cartilage that typically occurs between ossification centers such as the growth plates at the end of long bones (Figure 2A). As growth ceases after puberty, the growth plate disappears and the epiphysis at the end of the bone fuses with the rest of the bone. This type of cartilaginous joint does not permit movement.

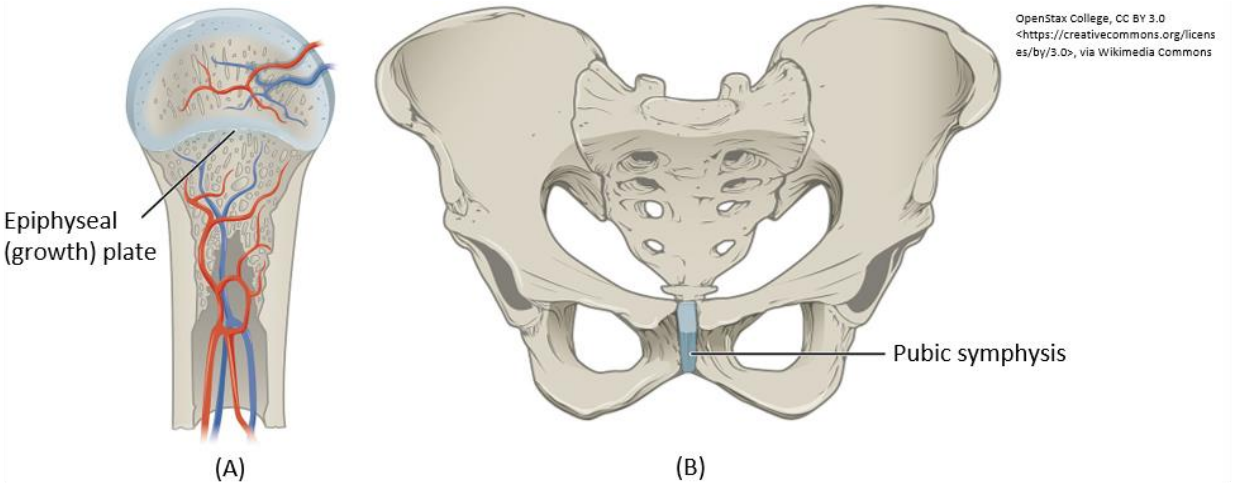


Figure 2. Types of cartilaginous joints. (A) Primary, and (B) secondary.

A **secondary cartilaginous joint** (also known as a symphysis) contains fibrocartilage and provides a cushion between two adjacent bones (Figure 2B). This type of joint allows for some movement between the bones that it connects. The two classic examples of secondary cartilaginous joints are the intervertebral discs of the spine and the pubic symphysis.

SYNOVIAL JOINTS

Synovial joints contain synovial fluid within a joint capsule. These joints generally allow for a significant range of motion. Because of the prominent actions that occur at this type of joint, we typically think of a synovial joint when we hear the generic term "joint." Joints like the shoulder, elbow, wrist, hip, knee, ankle, and smaller joints of the hands and feet are all synovial joints.

Before we further classify synovial joints, we need to define the components that are common to all synovial joints (Figure 3). **Articular cartilage** is hyaline cartilage that covers the surfaces of bones that articulate with one another at synovial joints. Articular cartilage provides a smooth surface for bones to slide across one another and cushions the impact points between bones.

Clinical correlate: **Osteoarthritis** occurs when the articular cartilage that cushions bones at synovial joints breaks down. This is the most common form of arthritis as it occurs with age and use. The most common joints affected are the hands, knees, hips, and the joints of the spine. The radiographs on the right show the same patient's knee at baseline and 3 years later with joint space narrowing (arrow) due to osteoarthritis.

Cecil Essentials of Medicine. Cunha, Joanne S.; Arzomand, Zuhal; Tsoukas, Philip.
Published January 1, 2022. Pages 813-817. © 2022

A **joint capsule** consists of two layers that surround every synovial joint. The outer fibrous layer of the joint capsule provides strength to the joint. The inner layer of the joint capsule is the synovial membrane. The **synovial membrane** is a thin layer of connective tissue that produces synovial fluid. **Synovial fluid** fills the joint space in order to lubricate the joint and provide some nutrients to the articular cartilage, which contains no blood vessels.

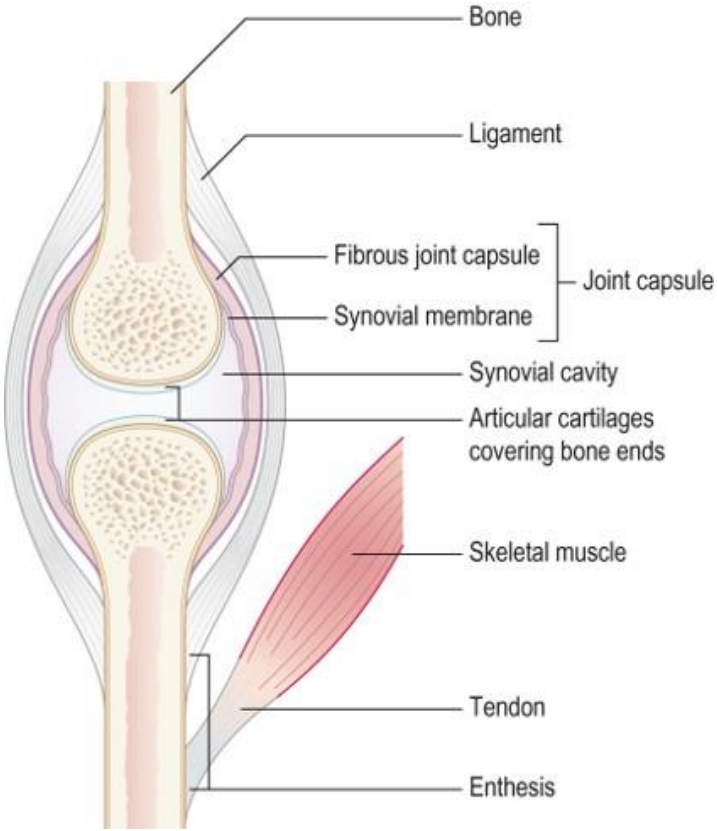
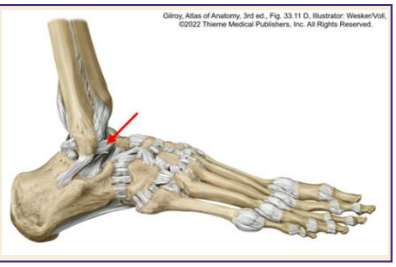


Figure 3. Components of a synovial joint. The synovial cavity, or joint cavity, is filled with synovial fluid produced by the synovial membrane.

Medical Sciences. Robson, Lesley; Court, Denise
Syndercombe. Published December 31, 2018. Pages 393-439. © 2019.

Not necessarily considered part of the synovial joint, **ligaments** are tough, elastic bands of connective tissue that connect bone to bone. Joint capsules may be directly reinforced with discrete thickenings of the fibrous layer known as capsular ligaments. The length and strength of the ligaments around a synovial joint has an impact on the types and range of actions that may occur at a joint.

Clinical correlate: A **joint sprain** involves damage to one or more of the ligaments that support a joint. The severity of the sprain depends on whether the ligament is stretch, partially torn, or completely torn or ruptured. The most commonly sprained joint is the ankle (specifically the anterior talofibular ligament, red arrow).



SKELETAL MUSCLE GROSS ANATOMY

Skeletal muscles are the striated muscles that attach to our skeleton for the primary purpose of producing movement across synovial joints. These skeletal muscles are innervated by somatic motor/efferent neurons, which we have voluntary control over for executing conscious movement. Skeletal muscles are also innervated by somatic sensory/afferent neurons that monitor the degree of stretch and contraction/relaxation within the muscle, an important process for spinal reflexes and modulation of movements.

Some terms are needed for us to describe how muscles exert their actions at synovial joints (Figure 3). A **tendon** is a dense band of connective tissue that transfers the contractile force of a muscle to a bone. We tend to think of tendons as thick cords of tissue, like your patellar tendon at the knee or Achilles/calcaneal tendon at the heel. However, tendons may also be flat or sheet-like. A broad, flat tendon is referred to as an **aponeurosis** and they are associated with broad, flat muscles like the ones found in the abdomen and across the back. An **enthesis** is the point at which a tendon or ligament attaches to bone through a continuous gradient of cells that gives the connection its strength.

Clinical correlate: **Tendinopathy** is the term used to describe any damage that occurs within the tendon, which includes tendinosis (degeneration of a tendon) and tendinitis (inflammation of a tendon). Golfer's elbow and tennis elbow are two common forms of tendinopathy (specifically, tendinitis).
Enthesitis is inflammation at the enthesis, the insertion site of the tendon. This may be the result of overuse or an underlying inflammatory condition such as psoriatic arthritis.

DEFINING MOVEMENTS ACROSS SYNOVIAL JOINTS

Now that we have defined how a muscle attaches to a bone, we are ready to introduce a simple but important musculoskeletal concept: *If a muscle or its tendon crosses a joint, it will act on that joint*. The type(s) of action that a muscle exerts on a joint is related to the side that the muscle crosses on, the site of the enthesis, and the direction of the muscle fibers. When we define these actions, it is helpful to reference anatomical position—standing with arms near the sides and palms facing forward—and the other directional terms defined in your Basic Body Plan reading.

In the lists and figures below (Figures 4 & 5), joint actions are defined in pairs of antagonistic actions, actions that move the joint in opposite directions.

- **Flexion**: Generally, a decrease in the angle between two articulating bones. In lay terms, this is considered to be bending a joint, like the knee. From anatomical position, flexion has a greater range of motion than extension.
- **Extension**: Generally, an increase in the angle between two articulating bones, bringing the associated regions of the body back towards anatomical position. In lay terms, this is straightening a joint. From anatomical position, extension has a smaller range of motion than flexion. For example, the knee is already maximally extended in anatomical position.

- **Abduction**: Movement of a body part away from the midline. For example, abduction of the arm at the shoulder brings the upper limbs out away from the axial skeleton. From anatomical position, abduction has a greater range of motion than adduction.
- **Adduction**: Movement of a body part towards the midline which, generally, brings the body back towards anatomical position.

- **Internal rotation**: Also called medial rotation. Rotation of a bone along its long axis that points the anterior aspect of that bone towards the midline. For example, internal rotation of the thigh at the hip points all aspects of the lower limb (femur, patella, toes, etc) towards the midline.
- **External rotation**: Also called lateral rotation. Rotation of a bone along its long axis that points the anterior aspect of that bone away from the midline.

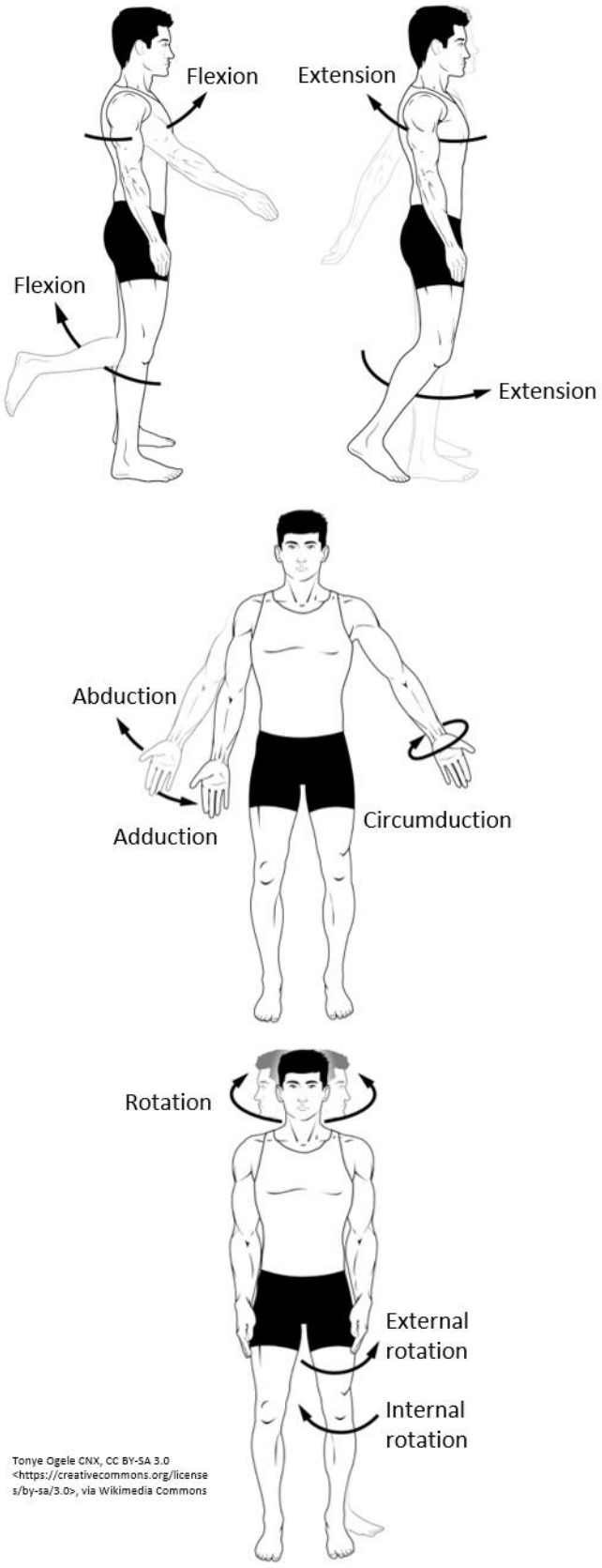


Figure 4. Common joint actions

- **Pronation**: An action specific to the forearm where the radius rotates over the ulna to point the palm posteriorly (from anatomical position) or down (when the forearms are held in front of an individual).
- **Supination**: An action specific to the forearm where the radius rotates over the ulna to point the palm anteriorly (as in anatomical position) or up (when the forearms are held in front of an individual).
- **Inversion**: An action specific to the foot where the plantar surface or sole of the foot is pointed towards the midline.
- **Eversion**: An action specific to the foot where the plantar surface is pointed away from the midline.
- Circumduction: A coordinated combination of flexion/extension and abduction/adduction that produces a cone-shaped action (Figure 4). For example, holding your elbow and wrist straight while making large circular motions with your upper limb is achieved through circumduction at the shoulder.

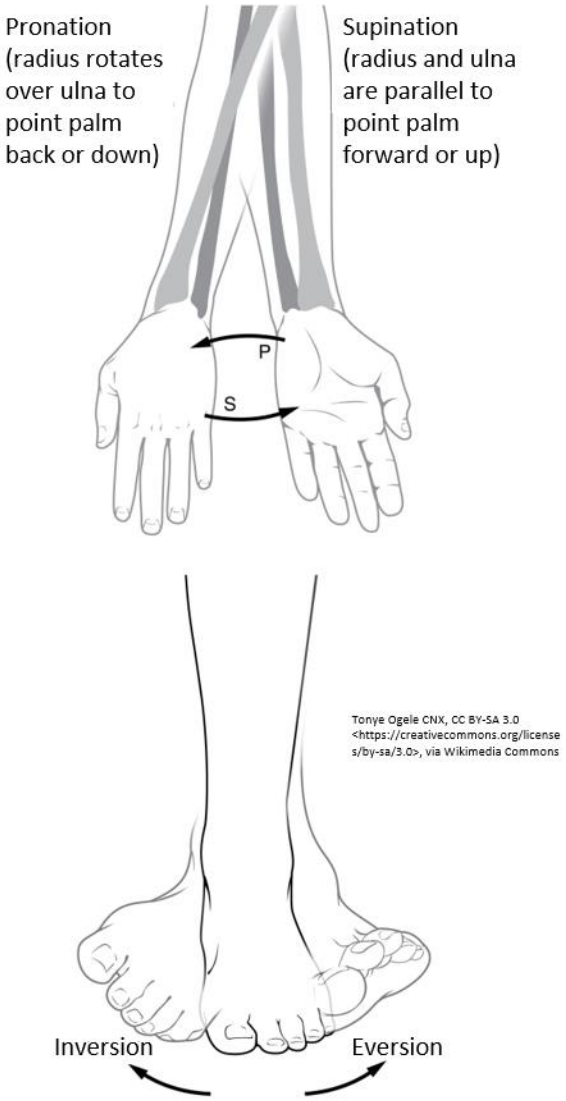


Figure 5. Specialized joint actions

Written definitions and static images are not as helpful as videos when defining movements. Watch the video in the following link beginning at 5:23 to cover these movements (or watch the entire video from the beginning to include a review of anatomical position and planes):
https://www.youtube.com/watch?v=n70udDiVtz0&t=324s&ab_channel=SamWebster

CLASSIFICATION OF SYNOVIAL JOINTS BY MORPHOLOGY

In addition to the muscles that act on joints, the shape of a joint affects the actions that are possible at that joint. Synovial joints are classified as six types of joints based on their shape (Figure 6):

- **Hinge**: A joint shaped to only allow movement in one plane, like the hinges of a door. Flexion and extension are the only actions that are possible at hinge joints. Examples of hinge joints include the elbow (specifically the humeroulnar joint), the knee, and the ankle.

- **Ball-and-socket**: A joint where the "ball" formed by one bone fits in a "socket" formed by another bone. This relationship allows for a large degree of movement in all planes for flexion/extension, abduction/adduction, internal/external rotation, and circumduction. Examples of ball-and-socket joints include the shoulder and hip.
- **Plane**: A joint where relatively flat surfaces of adjacent bones articulate with one another. The flat surfaces of these bones are able to glide across one another. There are multiple plane joints between the carpal bones of the hand and tarsal bones of the foot.
- **Condyloid**: A joint where an ovoid or egg-shaped end of a bone fits into a matching socket formed by another bone. This type of joint allows for flexion/extension, abduction/adduction, and circumduction, however, the ovoid shape of this joint prevents internal/external rotation. Examples of condyloid joints include the wrist and metacarpophalangeal joints.
- **Saddle**: A joint formed between two adjacent bones each having a convex and a concave curvature. The convex curve of one bone fits over the concave curve of the other, creating the look of a rider sitting in a saddle. Like the condyloid joint, the saddle joint allows for flexion/extension, abduction/adduction, and circumduction while preventing rotation. The classic example of a saddle joint is the carpometacarpal joint of the thumb formed by the trapezium and the base of the first metacarpal.
- **Pivot**: A joint where a cylinder-shaped portion of a bone fits within a ring formed by an adjacent bone and a supporting ligament. This arrangement only allows for axial rotation at the joint. This type of synovial joint is only found in three locations within the body: the atlanto-axial joint, the proximal radioulnar joint near the elbow, and the distal radioulnar joint near the wrist.

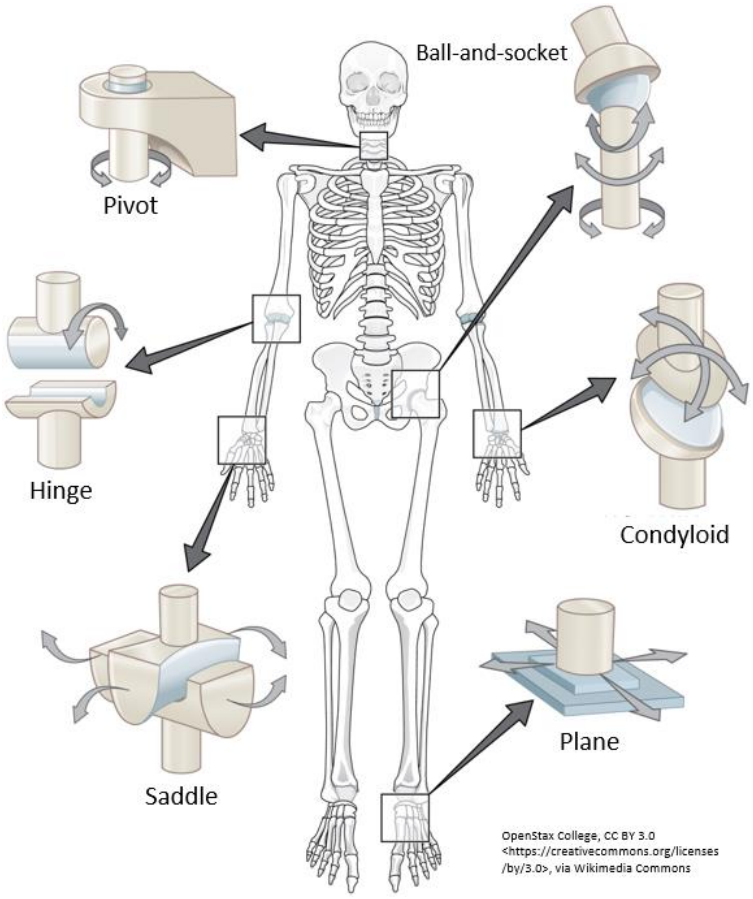


Figure 6. Types of synovial joints. Figure points to an example of each type of synovial joint and attempts to demonstrate planes of actions with gray arrows.

Pivot: e.g. atlanto-axial joint; rotation.

Hinge: e.g. elbow [humeroulnar] joint; single plane of action for flexion/extension.

Saddle: e.g. 1st metacarpophalangeal joint; two planes of action for flexion/extension and abduction/adduction which may be combined for circumduction.

Ball-and-socket: e.g. hip; multiple planes of action for flexion/extension, abduction/adduction, and rotation.

Condyloid: e.g. wrist; two planes of action.

Plane: e.g. between tarsal bones; gliding actions.

The following video is useful for visualizing the movements that are permitted at each type of synovial joint. The video was made from an artist's perspective, so there are some minor inaccuracies in the introduction. Just focus on the illustrations of the six prototypical joints: https://www.youtube.com/watch?v=0cYal_hitz4&ab_channel=Proko

SUMMARY

Joints between bones are classified as fibrous, cartilaginous, or synovial based on the type of tissue that makes up the joint. Fibrous joints are generally immoveable and are further classified as sutures, syndesmoses, or gomphoses. Cartilaginous joints are slightly moveable and are further classified as primary or secondary. Synovial joints are freely moveable thanks to the general makeup of each synovial joint: two adjacent bones covered in articular cartilage surrounded by a joint capsule that has an outer fibrous layer for strength and an inner synovial layer that produces synovial fluid for lubrication. Movement at these joints is controlled by skeletal muscles, which form a tendon that attaches to a bone at an enthesis.

If a muscle crosses a joint, it acts on that joint; the orientation and attachment site of the skeletal muscle determines the effect that contraction of that muscle will have on the joint. In addition, the shape of the synovial joint itself—hinge, ball-and-socket, plane, condyloid, saddle, or pivot—affects what actions are permitted at the joint.

These concepts along with concepts from the Basic Body Plan reading are summarized in this video: https://www.youtube.com/watch?v=DLxYDoN634c&list=PL8dPuuaLjXtOAKed_MxxWBNaPno5h3Zs8&index=21&ab_channel=CrashCourse