III. SKELETAL SYSTEM
ANATOMY OF A LONG BONE

Bone is a living, vascular structure, composed of organic tissue (cells, fibers, extracellular matrix, vessels, nerves—about 35% of a bone's weight), and mineral (calcium hydroxyapatite—about 65% of a bone's weight). Bone functions as a support structure, a site of attachment for skeletal muscle, ligaments, tendons, and joint capsules, a source of calcium, and a significant site of blood cell development (hematopoiesis) for the entire body. Here we show a long bone, specifically the femur, the bone of the thigh.

EPIPHYYSIS

The epiphysis is the end of a long bone or any part of a bone separated from the main body of an immature bone by cartilage. It is formed from a secondary site of ossification. It is largely cancellous bone, and its articulating surface is lined with 3-5 mm of hyaline (articular) cartilage. The epiphysis is supplied by vessels from the joint capsule.

DIAPHYSIS

The diaphysis is the shaft or central part of a long bone. It has a marrow-filled cavity (medullary cavity) surrounded by compact bone which is lined externally by periosteum and internally by endosteum (not shown). The diaphysis is formed from one or more primary sites of ossification, and is supplied by one or more nutrient arteries.

ARTICULAR CARTILAGE

The only remaining evidence of an adult bone's cartilaginous past, articular cartilage is smooth, slippery, porous, malleable, insensitive, and bloodless. It is massaged by movement, permitting absorption of synovial fluid, oxygen and nutrition. Articular (hyaline) cartilage is also nourished by vessels from the subchondral bone. Bones of a synovial joint make physical contact at their cartilaginous ends. The degenerative process of arthritis involves the breakdown and fibrillation of articular cartilage.

PERIOSTEUM

Periosteum is a fibrous, cellular, vascular and highly sensitive protective sheath for bone, providing nutrient blood for bone cells and a source of osteoprogenitor cells throughout life. It does not cover articular cartilage.

CANCELLOUS (SPONGY) BONE

Cancellous (spongy) bone consists of interwoven beams (trabeculae) of bone in the epiphyses of long bones, the bodies of the vertebrae, and other bones without cavities. The spaces among the trabeculae are filled with red or yellow marrow and blood vessels. Cancellous bone forms a dynamic latticed truss capable of mechanical alteration (reorientation, construction, destruction) in response to the stresses of weight, postural change, and muscle tension.

COMPACT BONE

Compact bone is dense bone characterized in long bones by microscopic hollow cylinders of bone (haversian systems) interwoven with non-cylindrical lamellae of bone. It forms the stout walls of the diaphysis of long bones and the thinner outer surface of other bones where there is no articular cartilage, e.g., the flat bones of the skull. Blood vessels reach the bone cells by a system of integrated canals.

MEDULLARY CAVITY

The medullary cavity is the cavity of the diaphysis. It contains marrow: red in the young, turning to yellow in many long bones in maturity. It is lined by endosteal tissue (thin connective tissue with many osteoprogenitor cells).

RED MARROW

Red marrow is a red, gelatinous substance composed of red and white blood cells in a variety of developmental forms (hematopoietic tissue) and specialized capillaries (sinusoids) enmeshed in reticular tissue. In adults, red marrow is generally limited to the sternum, vertebrae, ribs, hip bones, clavicles, and cranial bones.

YELLOW MARROW

Yellow marrow is fatty connective tissue and no longer productive of blood cells. It replaces red marrow in the epiphyses and medullary cavities of long bones, and cancellous bone of other bones.

NUTRIENT ARTERY BRANCHES

The nutrient artery is the principal artery and major supplier of oxygen and nutrients to the shaft or body of a bone; its branches snake through the labyrinthine canals of the haversian systems and other tubular cavities of bones.
III. SKELETAL SYSTEM

AXIAL/APPENDICULAR SKELETON

Bones have a variety of shapes and defy classification by shape; yet such a classification generally exists. Long bones are clearly longer in one axis than another; they are characterized by a medullary cavity, a hollow diaphysis of compact bone, and at least two epiphyses; e.g., femur, phalanx. Short bones are roughly cube-shaped; they are predominantly cancellous bone with a thin cortex of compact bone; no cavity; e.g., carpals and tarsal bones. Flat bones (cranial bones, ribs) are generally more flat than round, and irregular bones (scapula, vertebrae) have two or more different shapes; e.g., the scapula, with a flat surface, and irregular-shaped spine. Bones not specifically long or short fit this latter category. Sesamoid bones are developed in tendons (e.g., patellar tendon); they are mostly bone, often mixed with fibrous tissue and cartilage. They have a cartilaginous articular surface facing an articular surface of an adjacent bone; they may be part of a synovial joint enmeshed within the fibrous joint capsule. They are generally pea-sized, and are almost always found in certain tendons/joint capsules in hands and feet, and occasionally in other articular sites of the upper and lower limbs. The largest is the patella, in the tendon of quadriceps femoris. Sesamoid bones resist friction and compression, enhance joint movement, and may assist local circulation.

CLASSIFICATION OF BONES:
LONG, SHORT, FLAT, IRREGULAR, SESAMOID

AXIAL SKELETON

The axial skeleton is the principal supportive structure of the body and is oriented along its median longitudinal axis. It includes the skull, vertebrae, sternum, ribs, and hyoid bone. Much of the mobility of the torso is due to the multiple articulations throughout the vertebral column.

APPENDICULAR SKELETON

The joints of the appendicular skeleton make possible a considerable degree of freedom for the upper and lower limbs. The appendicular skeleton includes the pectoral and pelvic girdles and the bones of the arms, forearms, wrists, hands, thighs, legs, and feet. Fractures and dislocations are more common in this part of the skeleton, but more serious in the axial skeleton.
III. SKELETAL SYSTEM

BONES OF THE SKULL (1)

CRANIAL (8):
- OCCIPITAL (1)
- PARIETAL (2)
- FRONTAL (1)
- TEMPORAL (2)
- ETHMOID (1)
- Sphenoid (1)

FACIAL (14):
- NASAL (2)
- VOMER (1)
- LACRIMAL (2)
- ZYGOMATIc (2)
- PALATINE (2)
- MAXILLA (2)
- MANDIBLE (1)
- INFERIOR NASAL CONCHA (2)

CN: Work with this plate and the next one at the same time. Save the brightest colors for the smallest bones; use light colors on bones with surface detail. Work one bone at a time, coloring it where it appears in any of the 7 views shown on this and the next plate.

1. In the anterior view, do not color the darkened areas in the orbits and nasal cavity.

The skull is composed of cranial bones (forming a vault for the brain) and facial bones (giving origin to the muscles of facial expression and providing buttresses protecting the brain). Except for the temporomandibular joint (a synovial joint), all bones are connected by generally immovable fibrous sutures.

The orbit is composed of 7 bones, has significant fissures/canals, and is home to the eye and related muscles, nerves, and vessels. The most delicate of the skull bones is at the medial orbital wall (1). The external nose is largely cartilaginous and is, therefore, not part of the bony skull.
You are looking into the interior of the right side of the skull. The vomer and perpendicular plate of the ethmoid contribute significantly to the nasal septum, and hide from view the conchae on the lateral wall of the nasal cavity.

You are looking into the cranial cavity from above. The anterior cranial fossa contains the frontal lobes of the cerebrum (brain); the olfactory tracts lie over the cribiform plate and receive the olfactory nerves. The middle cranial fossa embraces the temporal lobes of the cerebrum; note the numerous foramina/canals for cranial nerves and vessels which enter/exit the cavity. The posterior cranial fossa retains the cerebellum and the brain stem, along with related cranial nerves and vessels which enter/exit the cavity.

The occipital condyles articulate with the facets of the atlas or first cervical vertebrae. The muscular pharyngeal wall attaches around the posterior nasal apertures. The lateral pterygoid plate offers attachment for certain muscles of mastication. The foramen magnum transmits the lower brain stem/spinal cord and the vertebral arteries. Much of the occipital bone posterior to the foramen magnum is a site of attachment for large muscle bundles making up the posterior cervical (paraspinal) musculature.

CN: Use the same colors as were used on Plate 19. (1) Color the three views simultaneously (2) In the lower views, pay close attention to the many foramina that are left uncolored (3) Notice but don’t color the small drawing below that identifies the large fossae of the skull interior to its left. Try to visualize those fossae in the larger view.
III. SKELETAL SYSTEM

VERTEBRAL COLUMN

REGIONS:
- CERVICAL
- THORACIC
- LUMBAR
- SACRAL
- COCCYGEAL

The vertebral column has 24 individual vertebrae arranged in cervical, thoracic, and lumbar regions; the sacral and coccygeal vertebrae are fused (sacrum/coccyx). Numbers of vertebrae in each region are remarkably constant; rarely S1 may be free or L5 may be fused to the sacrum (transitional vertebrae). The seven mobile cervical vertebrae support the neck and the 3-4 kg (6-8 lb) head. The cervical spine is normally curved (cervical lordosis) secondary to the development of postural reflexes about three months after birth. The 12 thoracic vertebrae support the thorax, head, and neck. They articulate with 12 ribs bilaterally. The thoracic spine is congenitally curved (kyphosis) as shown. The five lumbar vertebrae support the upper body, torso, and low back. The column of these vertebrae is curved (lumbar lordosis) due to the onset of walking at 1-2 years of age. The sacrum is the keystone of a weightbearing arch involving the hip bones. The sacral/coccygeal curve is congenital. The variably numbered 1-5 coccygeal vertebrae are usually fused, although the first vertebra may be movable. Vertebral curvatures may be affected (usually exaggerated) by posture, activity, obesity, pregnancy, trauma, and/or disease; these conditions are named the same as the normal curves. There may normally be a slight lateral curvature to the spine often due to dominant handedness; a significant, possibly disabling, lateral curve (scoliosis) may occur for many reasons.

MOTION SEGMENT:

VECTBEHAL COLUMN

JOINTS:
- INTERVERTEBRAL DISC
- POSTERIOR (FACET)
- LIGAMENT
- VERTEBRA

Each pair of individual, unfused vertebrae constitutes a motion segment, the basic movable unit of the back. Combined movements of motion segments underlie movement of the neck, middle and low back. Each pair of vertebrae in a motion segment, except C1-C2, is attached by three joints: a parietal movable, intervertebral disc anteriorly, and a pair of gliding synovial facet (zygapophyseal) joints posteriorly. Ligaments secure the bones together and encapulate the facet joints (joint capsules). The vertebral or neural canal, a series of vertebral foramina, transmits the spinal cord and related coverings, vessels, and nerve roots. Located bilaterally between each pair of vertebral pedicles are passageways, each called an intervertebral foramen, transmitting spinal nerves, their coverings/vessels, and some vessels to the spinal cord.

INTERVERTEBRAL DISC

ANNUUS FIBROSUS

NUCLEUS PULPOSUS

SPINAL NERVE

The intervertebral disc consists of the annulus fibrosus (concentric, interwoven collagenous fibers integrated with cartilage cells) attached to the vertebral bodies above and below, and the more central nucleus pulposus (a mass of degenerated collagen, proteoglycans, and water). The discs make possible movement between vertebral bodies. With aging, the discs dehydrate and thin, resulting in a loss of height. The cervical and lumbar discs, particularly, are subject to early degeneration from one or more of a number of causes. Weakening and/or tearing of the annulus can result in a broad-based bulge or a localized (focal) protrusion of the nucleus and adjacent annulus; such an event can compress a spinal nerve root as shown.

See 22, 23
III. SKELETAL SYSTEM.
CERVICAL AND THORACIC VERTEBRAE

CN: Use red for M and use the same colors as were used on Plate 21 for C and T. Use dark colors for N, O, and P. (1) Begin with the parts of a cervical vertebra. Color the atlas and axis and note they have been given separate colors to distinguish them from other cervical vertebrae. (2) Color the parts of a thoracic vertebra and then the thoracic portion of the vertebral column. Note the three different facet/demifacet colors.

CERVICAL VERTEBRA
BODY
PEDICLE
TRANSVERSE PROCESS
ARTICULAR PROCESS
LAMINA
SPINOUS PROCESS

SUPERIOR VIEW

The small seven cervical vertebrae support and move the head and neck, supported by ligaments and strap-like paracervical (paraspinal) muscles. The ring-shaped atlas (C1) has no body; thus there are no weight-bearing discs between the occiput and C1, and between C1 and C2 (the axis). Head weight is transferred to C3 by the large articular processes and facets of C1 and C2. The atlantooccipital joints, in conjunction with the C3-C7 facet joints, permit a remarkable degree of flexion/extension ("yes" movements). The dens of C2 projects into the anterior part of the C1 ring, forming a pivot joint, enabling the head and C1 to rotate almost 90° ("no" movements). Such rotational capacity is permitted by the relatively horizontal orientation of the cervical facets. The C3-C6 vertebrae are similar; C7 is remarkable for its prominent spinous processes. The cervical vertebrae, enroute to the brain stem, pass through foramina of the transverse processes of the upper six cervical vertebrae. These vessels are subject to stretching injuries with extreme cervical rotation of the hyperextended neck. The cervical vertebral canal conducts the cervical spinal cord and its coverings (not shown). The C4-5 and C5-6 motion segments are the most mobile of the cervical region and are particularly prone to disc/facet degeneration.

The twelve thoracic vertebrae—characterized by long, slender spinous processes, heart-shaped bodies, and nearly vertically oriented facets—articulate with ribs bilaterally. In general, each rib forms a synovial joint with two demifacets on the bodies of adjacent vertebrae and a single facet on the transverse process of the lower vertebra. Variations of these costovertebral joints are seen with T1, T11, and T12.

THORACIC VERTEBRA
BODY
FACET
DEMFACET
TRANSVERSE FACET
RIB
LIGAMENT

See 21, 23
III. SKELETAL SYSTEM

LUMBAR, SACRAL, & COCCYGEAL VERTEBRAE

CN: Use the same colors as were used on the previous two plates for C, T, L, E, F, A, S, and Co. (1). Begin with the three large views of lumbar vertebrae. (2) Color the different planes of articular facets. (3) Color the four views of the sacrum and coccyx. Note that the central portion of the median section receives the vertebral canal color (E')

LUMBAR VERTEBRA

VERTEBRAL FORAMEN

VERTEBRAL CANAL

INTERVERTEBRAL FORAMEN

INTERVERTEBRAL DISC

PLANE OF ARTICULAR FACETS:
CERVICAL

THORACIC

LUMBAR

The five lumbar vertebrae are the most massive of all the individual vertebrae, their thick processes securing the attachments of numerous ligaments and muscles/tendons. Significant flexion and extension of the lumbar and lumbosacral motion segments, particularly at L4-L5 and L5-S1, are possible. At about L1, the spinal cord terminates and the cauda equina (bundle of lumbar, sacral, and coccygeal nerve roots; see Plate 21) begins. The lumbar intervertebral foramina are large. Transiting nerve roots/sheaths take up only about 50% of the volume of these foramina. Disc and facet degeneration is common in the L4-5 and L5-S1 segments; reduction of space for the nerve roots increases the risk of nerve root irritation/compression (radiculitis/radiculopathy). Occasionally, the L5 vertebra is partially or completely fused to the sacrum (sacralized L5). The S1 vertebra may be partially or wholly non-fused (lumbarized S1), resulting in essentially six lumbar vertebrae.

SACRUM

The sacrum consists of five fused vertebrae; the intervertebral discs are largely replaced by bone. The sacral (vertebral) canal contains the terminal sac of the dura mater (dural sac, thecal sac) to S2 and the sacral nerve roots, which transit the sacral foramina. The sacrum joins with the ilium of the hip bone at the auricular surface, forming the sacroiliac joint.

COCCYX

The sacrum and the ilia of the hip bones form an arch for the transmission and distribution of weightbearing forces to the heads of the femora. It is a strong arch, and the sacrum is its keystone. The coccyx consists of 2–4 tiny individual or partly fused, rudimentary vertebrae. The first coccygeal vertebra is the most completely developed.
III. SKELETAL SYSTEM

BONY THORAX

CN: Use the same colors as were used on Plate 22 for true ribs, thoracic vertebrae, demifacets, and transverse process facets. Use bright colors for A-C. (1) Color the anterior view of the bony thorax. Color each rib completely before going on to the next. (2) Color the posterior view in the same manner. (3) Color the lateral view of the bony thorax. (4) When coloring the drawings of a rib and the sites of articulation, note that the rib facets (drawn with dotted lines) are to be colored even though they are on the underside of the rib.

12 RIBS:
- 7 TRUE
- 5 FALSE
- 2 FLOATING

COSTAL CARTILAGE (10):

THORACIC VERTEBRA (12):

The bony thorax is the skeleton of the chest, representing a fairly mobile set of structures important to respiration and harboring the heart, lungs, and other significant organs. The superior thoracic aperture (thoracic inlet; often incorrectly termed thoracic outlet in a clinical context) transmits the esophagus, trachea, nerves, and important ducts and vessels. The inferior thoracic aperture is virtually sealed by the thoracic diaphragm. The space between ribs is the intercostal space, and contains three layers of muscle and fasciae, and intercostal vessels and nerves. Collective rib movement is responsible for about 25% of the respiratory effort.

The fibrocartilaginous joint between the manubrium and the body of the sternum (sternal angle, sternomanubrial joint) makes subtle hinges-like movements during respiration. The xiphoid makes a fibrocartilaginous (xiphisternal) joint with the body of the sternum. The sternum is largely cancellous bone containing red marrow. The costal cartilages, representing unsuited cartilage models of the anterior ribs, articulate with the sternum by gliding-type synovial joints (sternocostal joints; except for the first joint, which is not synovial). All ribs form synovial joints with the thoracic vertebrae (costovertebral joints). Within each of these joints, the rib (2 through 9) forms a synovial joint with a demifacet of the upper vertebral body and with a demifacet of the lower body (costocorpostral joints). In addition, the tubercle of the rib articulates with a cartilaginous facet at the tip of the transverse process of the lower vertebra (costotransverse joint). Ribs 1, 10, 11, and 12 each join with one vertebra instead of two; ribs 11 and 12 have no costotransverse joints. True ribs (1–7) articulate directly with the sternum; false ribs (8–12) articulate indirectly with the sternum (via cartilages connecting to the 7th costal cartilage); floating ribs (11, 12) end in the muscular abdominal wall.
The mobility of the upper limb is largely dependent upon the pectoral girdle whose only bony attachment to the axial skeleton is via the sternoclavicular joint (saddle type synovial joint with disc). Distally, the clavicle articulates with the acromion of the scapula (acromioclavicular joint, a gliding type synovial joint). The clavicle forces the scapula backward and outward, creating the shoulder; in its role as a strut, it is subject to fracture. The scapula is moored to the axial skeleton by muscles, giving it considerable mobility on the upper back (scapulo-thoracic motion). Largely packaged in muscle, the scapula fractures infrequently. The supraspinatus muscle/tendon passing under the acromion and coracohumeral ligament is subject to irritation (impingement syndrome). The glenoid fossa of the scapula is shallow, and the glenohumeral joint (shoulder, ball and socket, synovial) is relatively insecure. The glenohumeral ligaments/joint capsule are lax, and are reinforced by a musculotendinous cuff. Given these “rotator cuff” muscles, the humerus has excellent mobility at the shoulder joint. The humerus is vulnerable to fracture at the surgical neck, mid-shaft, and medial epicondyle.

CN: Use very light colors. 
(1) Color each view completely before going on to the next. 
(2) Color the ligaments of the shoulder region (inset) in gray. Note the ligaments at the top of the plate which should also be colored.
The presence of two bones in the forearm make possible the diverse movements seen at the elbow and reflected in hand motion. The ulna, the major, stabilizing forearm bone at the elbow, narrows distally to form an inconsequential joint with the radius (distal radioulnar joint; synovial, pivot-type). The radius, smaller above, widens and thickens distally to form the major joint at the wrist (radiocarpal joint; synovial, biaxial, ellipsoidal-type). At the elbow, the ulna forms a hinge type synovial humeroulnar joint with the trochlea of the humerus, and the radius forms a pivot-type synovial radioulnar joint with the capitulum of the humerus. These joints share the same joint capsule with the proximal radioulnar joint (synovial, pivot type) between the radial notch of the ulna and the radial head. The three joints constitute the elbow (cubital) joint.

Rotation of the radius at the elbow (involving two of the three joints at the elbow) rotates the forearm, wrist, and hand without moving the ulna. Rotation of the hand to a palm-forward (up) position is supination: movement of the hand to a palm-back (down) position is pronation.

After coloring and studying the supination/pronation and elbow movement diagrams, try this: place the fingers of your left hand on your right olecranon (bump at posterior elbow), elbow flexed so that the palm of your right hand is up (supine). Now rotate (pronate) your right hand so your palm turns away from you, facing down. Move your right hand back and forth in this manner, feeling that the olecranon does not move during these motions. Further, stare at the styloid process of the radius at the base of the right thumb and note that it rotates back and forth with the thumb. You have just demonstrated that the radius moves around the ulna during pronation/supination, and that joint movement occurs at the radioulnar and proximal radioulnar joints.
The hand is a most remarkable device. It is perhaps the most highly evolved mechanical structure of our bodies. Movement of the hand and wrist is made possible by the architecture of the joints among the bones. The wrist joint is formed by the distal articular surface of the radius and the distal surface of the articular disc (just distal to the ulna) with the proximal articular surfaces of the scaphoid, lunate, and triquetrum bones. Forces transmitted from a fall on the hand to the wrist pass largely through the scaphoid, lunate, and radius; thus, fractures of the scaphoid and distal radius are common. The intercarpal (IC) joints work in linkage with the wrist joint. Note that the carpal bones are arranged in two rows: distal and proximal. A strong handgrip is dependent upon a neutrally positioned or extended wrist, as shown in the small illustration showing finger flexion. With the wrist in flexion, the hand or finger grip is weak.

Using your own hand, in conjunction with coloring, note that each hand normally has 5 digits (there can be fewer or more). Note that each digit has 3 phalanges except the thumb which has two. Note that the interphalangeal (IP) joints are limited to movements of flexion/extension. The metacarpals support the hand proximal to the fingers, and the MP joints permit the added movements of abduction/adduction. Of the CM joints, the thumb has exceptional movement (1st CM joint: saddle type, synovial); when moving the thumb toward the little finger in an arcing motion, note that the thumb rotates 90°, reflecting medial rotation of the first metacarpal on the trapezium. The 5th CM joint works during cupping of the hands when the 1st and 5th metacarpals are brought together.
III. SKELETAL SYSTEM / UPPER LIMB

BONES IN REVIEW

CN: For all of these bones, except the carpals (F), use the same colors you used for them on Plates 25, 26, 27. Select a new, light color for F. (1) Color the arrows pointing to places where these bones can be seen or palpated on the surface of the body. (2) You may wish to test your knowledge of joints by writing their names in the spaces provided below. The answers are listed in the Appendix.

CLAVICLE
SCAPULA
HUMERUS
ULNA
RADIUS
CARPALS
METACARPALS
PHALANX

The upper limb is remarkable for its mobility. The mechanism for this begins with the scapula which is dynamically tethered by muscle to the posterior thoracic wall. On yourself, reach over your shoulder to palpate the scapular spine and acromion (recall Plate 25). Looking into a mirror over your shoulder, move your shoulders up and down, wrap your arms around yourself and stretch them out, reach upward then downward to see the scapula move.

The humerus can be palpated easily just distal to the shoulder on down to the elbow. There the medial and lateral epicondyles, as well as the olecranon, can be felt. Can you feel the ulnar nerve under the medial epicondyle? Feel hard enough and it might "speak" to you, all the way down to your little finger! Starting with that little finger and working to the thumb and up, move each joint of the upper limb that you can, identify it, and test its range of motion.

ANTERIOR VIEW
(Right upper limb)

POSTERIOR VIEW
(Right upper limb)

REVIEW OF JOINTS*

1
2
3
4
5
6
7
8
9
10
11
12
13

(See appendix for answers)
The coxal bone (hip bone, innominate bone, os coxa) consists of three fused bones in the adult: the ilium, the ischium, and pubis. The paired coxal bones constitute the pelvic girdle. The two somewhat-twisted coxal bones form a weight-bearing arch with the sacrum and the femoral (thigh) bones, accommodating the body weight and forces imposed vertically up from the feet. The two hip bones and the sacrum constitute the pelvis.

The sacroiliac joint is a movable, partly synovial, partly fibrocartilaginous joint. The articular surfaces are flat but roughened. Note the larger posterior sacroiliac ligaments (compared to the anterior ligaments): they resist downward displacement of the sacrum. The sacrospinous and sacrotuberous ligaments secure the apex of the sacrum to the pelvic girdle, resisting the effects of weightbearing and gravity on the sacroiliac joint. Still, sacroiliac dysfunction is common. The iliolumbar ligaments are often involved in postural low back pain. The symphysis pubis (pubic symphysis, interpubic joint) is a partly movable, cartilaginous joint composed of a fibrocartilaginous disc interposed between cartilaginous articular surfaces. The inguinal ligament represents the inferior border of the external oblique muscle of the anterior abdominal wall.

The hip joint, characterized by a deep socket and secured by tight, strong ligaments between the coxal bone and the neck of the femur, has a somewhat limited range of motion compared to the shoulder joint.
The hip (coxal) joint (multiaxial, ball and socket synovial joint) is concerned with the transmission of considerable weightbearing forces; the neck of the femur is particularly subject to pathologic changes with any significant alteration of blood supply (avascular necrosis). The greater trochanter is the site of attachment for several important muscles crossing the hip joint.

The knee (genual) joint consists of two condylar-type, synovial (tibiofibular) joints between the condyles of the femur and the flat, plateau-like articular surfaces above the condyles of the tibia. The principal movements at these joints are flexion and extension. The knee joint includes the saddle-type synovial (patellofemoral) joint between the patella and femur. The deep surface of the patella is cartilaginous and exhibits medial and lateral facets (note patellar surface of the femur). Premature wear of the patellar cartilage is common (chondromalacia patellae). The patella is a sesamoid bone which develops in the tendon of the quadriceps femoris muscle; as such, it resists the stress imposed on that tendon during knee movements.

The stability of the knee joint comes from ligaments and the muscles crossing the joint. The collateral ligaments resist sideward displacement and rotation. The cruciate (crossing) ligaments resist hyperextension (anterior cruciate) and hyperflexion (posterior cruciate) of the joint. The C-shaped menisci (the medial larger than the lateral) deepen the articulating surfaces of the tibial condyles. Often torn by misuse of the knee joints (rotation and adduction/abduction with weightbearing), the menisci can often be repaired by arthroscopy.
III. SKELETAL SYSTEM / LOWER LIMB
ANKLE & FOOT BONES

TARSALS: (7)*
TALUS: CALCANEUS,
CUBOID: NAVICULAR,
CUNEIFORMS (3)*

METATARSALS (5)*
PHALANGES (14)*

LIGAMENTS*

DORSAL (TOP) VIEW
(Right foot)

Tuberosity
Head
Neck
Facet for tibia
Facet for fibula

PLANTAR (BOTTOM) VIEW
(Right foot)

Head
Base
Sesamoid bones
Transverse tarsal joint
Sustentaculum tali

INVERSION
EVERSION

Calcaneal (Achilles) tendon
Calcaneal (Achilles) ligament

LATERAL VIEW
Calcaneus (Achilles) tendon
Tarsal sinus
Tuberosity
Calcaneus
Interosseous membrane
Calcaneocuboid lig.
Ant. talofibular lig.
Post. & Ant. inferior tibiofibular lig.

POSTERIOR VIEW
Tibial tuberosity
Fibular head
Interosseous membrane
Post. calcaneofibular lig.
Lateral collateral lig.
Calcaneo-fibular lig.
Calcaneo-tal if.
Calcaneo-tal lig.
Calcaneo-cuboid joint
Tibialis posterior
Tibialis anterior

MEDIAL VIEW
Calcaneus (Achilles) tendon
Tuberosity
Calcaneus
Long plantar lig
Tarsal sinus

CN: Use different colors from those used for the ilium on Plate 29 and for the femur, tibia, fibula, and patella on Plate 30. (1) Begin with the talus (A); color that bone wherever it appears on the plate. Follow that procedure with each of the other bones. (2) Color gray all of the ligaments.

The foot is a mobile, weightbearing structure. The ankle joint (hinge-type synovial joint) between tibia, fibula, and the talus forms a mortise, permitting only flexion (plantar flexion) and extension (dorsiflexion) here. With excessive rotation of this joint, characteristic fractures and torn ligaments occur. The foot can adjust to walking/running on tilted surfaces by virtue of the subtalar (talocalcaneal) and transverse tarsal (talo-calcaneonevicular and calcaneocuboid) joints. Here inversion and eversion movements occur. The ankle has strong medial ligamentous (deltoid ligaments) and weaker lateral ligamentous support. The relatively high frequency of inversion sprains (taring the lateral ligaments) over eversion sprains seems to reflect this fact.

The bony architecture of the foot includes a number of arches that are reinforced and maintained by ligaments and influenced by muscles. The medial longitudinal arch transmits the force of body weight to the ground when standing and to the great toe in locomotion, creating a giant lever that gives spring to the gait. Both longitudinal arches function in absorbing shock loads and balancing the body.

LATERAL LONGITUDINAL ARCH*
TRANSVERSE ARCH*
MEDIAL LONGITUDINAL ARCH*
III. SKELETAL SYSTEM/LOWER LIMB
BONES IN REVIEW

CN: Use the same colors for these bones that you used for them on Plates 29-31.
In the case of the coxal bone (A), use the color given to the ilium on Plate 29; for
the tarsal bones (F), use any one of the tarsal colors. (1) Color the bones of the
lower limb, their surface markings, and the corresponding bones on the hind
limb of the dog. (2) Color the names and bones of the upper limb and the forelimb
of the dog. The clavicle of the dog is not shown in this view.

LOWER LIMB:

COXAL
FEMUR
PATELLA
TIBIA
FIBULA
TARSAL
METATARSAL
PHALANX

The structure of a part reflects an adaptation for function.
The truth of this statement is borne out in comparing the
bones of the upper and lower limbs in a biped (human) with
those of a quadruped. The pectoral girdle provides a basis
for mobility, the more sturdy pelvic girdle provides stability in
both locomotion and weight bearing. The limb bones of the
lower limb are large and solid, consistent with weight-bearing;
the related joints are structurally secure, except the
knee, which gives up stability for flexibility. In the upper limb,
the bones are lighter, and the joints are more flexible and
able of greater ranges of motion (compare shoulder with
hip, elbow with knee, wrist with ankle). Although forearm
and leg each have two bones, there is little functional correlation
between those pairs of bones. The foot is clearly adapted for
locomotion and weight bearing, the hand (especially the
thumb) for mobility and dexterity.

The quadruped (in this case, the domestic dog) uses both
forelimbs and hindlimbs for supporting body weight and
locomotion. The girdle (coxal/scapular) bones are adapted
for locomotion, and are not as differentiated structurally or
functionally as they are in humans. The canine scapula has
much less scapulohumeral motion than the human scapula;
the canine coxal bones do not carry a disproportionate
weight, as does the human pelvic girdle. The animal bears
weight on the heads of the metacarpals and metatarsals, a
condition that is particularly suitable for acceleration.

UPPER LIMB:

CLAVICLE
SCAPULA
HUMERUS
ULNA
RADIUS
CARPAL
METACARPAL
PHALANX

QUADRUPED
(Dog)

Most mammals walk on their "fingers" and "toes."