Skeletal System
Structural support, movement, mechanical protection
Site of hematopoiesis in adults
Fat storage
Reservoir for blood $\text{Ca}^{+2}$ and $\text{PO}_4^{-3}$

**Osteo-** bone
**Chondro-** cartilage
**Arthro-** joints
Cartilage

Cells: chondrocytes and fibroblasts

Extracellular matrix with glycosaminoglycans, chondroitin sulfate, and hyaluronic acid

Chondrocytes reside in lacunae

Interstitial and appositional growth

Types of Cartilage

Hyaline – collagen, most common type in skeletal system

Elastic – elastin, e.g., pinna of ear, epiglottis

Fibrous – fibrin, very tough joints, e.g., intervertebral discs
Four ways to classify bones

Development
- endochondral (cartilage replacement)
- intramembranous (dermal)

Location
- axial, appendicular
- cranial, postcranial

Shape
- long, short, flat, irregular

Histology
- compact, cancellous
Endochondral bone development

Begins with a **cartilage template**

Bone shape, e.g., length, governed by rate and orientation of **chondrocyte proliferation**

**Nutrient arteries** penetrate cartilage template at mid-shaft and ends of bone via **nutrient foramina**

Arteries follow longitudinal path of lacunae

**Zone of atrophy** – chondrocyte death

**Zone of hypertrophy** – chondrocyte proliferation

Centers of ossification are the **epiphyses** (articular ends) and **diaphysis** (shaft)

**Epiphyseal plate** - a persistent zone of hypertrophy where elongation continues

**Mesenchymal cells** (undifferentiated mesoderm) brought by arteries affix to walls of lacunae

Some differentiate into **fibroblasts**, deposit collagen fibers in spiral orientation

Others differentiate into **osteocytes**

**Osteoblasts** deposit calcium phosphate; crystals follow orientation of collagen

**Osteoclasts** dissolve bone
endochondral bone development (continued)

Osteocytes become trapped in lacunae as bone is deposited around them. Process repeats itself until canal is reduced to minimum for passage of artery, but spiral orientation reverses, clockwise vs counterclockwise with each layer.

In cross section, layers appear as rings termed lamellae.

Osteocytes in lacunae remain in connection to Haversian or central canal via canaliculi.

The entire cylindrical unit is termed an osteon – it is the functional unit of endochondral bone.

The osteon includes osteocytes (both osteoblasts and osteoclasts) in lacunae, canaliculi, lamellae, and the Haversian canal.

Bone is in constant state of flux: dissolution and deposition.

Hormonal control of osteocytes by endocrine glands lateral to thyroid gland:

- **Parathyroid gland**: parathyroid hormone, stimulates osteoclasts, increases blood Ca$^{+2}$.
- **Ultimobranchial bodies**: calcitonin, stimulates osteoblasts, decreases blood Ca$^{+2}$.

Circumferential lamellae – compact bone devoid of osteons due to apposition growth from periosteum or endosteum.

Sharpey’s fibers – root-like projections of periosteum into bone surface.
Intramembranous or dermal bones

Intramembranous bones are found only in parts of the skull and shoulder girdle. They are the only kind of bone that can bear teeth.

Most dermal bones are flat; but not all are and not all flat bones are dermal.

Intramembranous bone development

Forms in dermis of skin.

Thick capillary beds

Mesenchymal cells first differentiate into osteoprogenitor cells.

Osteoprogenitor cells secrete matrix of collagen termed osteoid.

Osteoblasts differentiate next to deposit woven bone—a meshwork of trabeculae.

Periosteum secretes compact outer and inner tables.

Cancellous bone between outer and inner tables is termed diploe.
Parts of typical long bone
Epiphysis
   Articular region of bone
   Cancellous – site of red marrow, hematopoiesis
Epiphyseal plate or line
Diaphysis
   Compact bone
   Medullary cavity – site of yellow marrow, fat storage

Parts of typical flat bone
Inner and outer tables - compact
Diploe - cancellous
General features of bones

Articular surface – a surface that participates in a joint, usually smooth
Condyle – an articular surface, usually convex
Epicondyle – bilateral points of ligament or muscle attachment associated with condyles
Facet – a flat articular surface
Caput or Head – a spherical or round articular surface
Neck – a narrowing that follows a head
Tuberosity – point of ligament or muscle attachment, usually rough and convex
Tubercle – a small tuberosity
Foramen (pl. foramina) – hole
Canal – a hole with a long tunnel
Meatus – a large hole or gap
Fissure – a hole or gap between bones that is elongate on the bone surface
Symphysis – any joint or articulation in the midsagittal plane
Suture – a complex immovable joint
Line – either concave or convex
Crest – elongate elevated or expanded region
Process – anything that sticks out or projects from the bone surface
Ala – wing, bilaterally exaggerated processes
Ramus – arm, an extension
Spine – a sharp or pointed process
Sulcus – a groove
Notch – a deep depression, sometimes an articular surface or for ligament attachment
Fossa – a shallow depression or concavity, sometimes an articular surface
Axial Skeleton
Skull or Cranium, including Mandible and Hyoid
Vertebrae
Costae
Sternal
Appendicular Skeleton – all elements paired right and left

Pectoral Girdle
   Clavicles
   Scapula (plural scapulae)

Pectoral Appendage
   Brachium
      Humerus (pl. humeri)
   Antebrachium
      Radius (pl. radii) – lateral
      Ulna (pl. ulnae) – medial

Carpus
   8 Carpals – one proximal row of four, one distal row of four

Manus
   5 Metacarpals
   14 Phalanges (singular phalanx)
      proximal, middle, distal or ungual
      except pollex: proximal and distal only
**appendicular skeleton** – all elements except pelvis and sacrum paired

**Pelvic Girdle or Pelvis**
- Sacrum and coccyx (really parts of axial skeleton)
- 2 coxal or innominate bones
  - ilium (pl. ilia)
  - ischium (pl. ischia)
  - pubis (pl. pubes)

**Pelvic Appendage**
- **Femur**
  - Femur (pl. femora)
- **Genu**
  - Patella (pl. patellae)
- **Crus**
  - Tibia (pl. tibiae) – medial
  - Fibula (pl. fibulae) – lateral
- **Pes**
  - 7 tarsals: calcaneus, talus, navicular, cuboid, 3 cuneiforms
  - 5 metatarsals
  - 14 Phalanges (s. phalanx)
    - proximal, middle, distal or ungual
    - except hallux: proximal and distal only
Axial skeleton
Skull or cranium (including mandible and hyoid)

**Neurocranium** – braincase
1-2 frontals, 1 ethmoid, 1 sphenoid, 2 parietals, 2 temporals, 1 occipital

**Viscerocranium** or **Splanchnocranium** – face and jaws
2 nasals, 2 lacrimals, 2 maxillae (including 2 fused premaxillae), 2 zygomatics, 2 palatines, 1 vomer, 1 mandible, 1 hyoid, 3 paired middle ear ossicles

**Endocranium** or **Chondrocranium** – endochondral
ethmoid, sphenoid, part of temporal, occipital, middle ear ossicles, hyoid

**Dermatocranium** – intramembranous
nasal, frontal, parietal, part of temporal, maxillae, palatine, vomer, mandible
Major features of the skull
orbits
nasal cavity
external nares
internal nares or choanae
paranasal sinuses
floor of cranial cavity
  anterior cranial fossa – houses frontal lobes of cerebrum
  middle cranial fossa – houses temporal lobes of cerebrum, separated from anterior cranial fossa by lesser wing of sphenoid
  posterior cranial fossa - houses cerebellum, separated from middle cranial fossa by petrous portion of temporal bone
zygomatic arch
temporal fossa
infratemporal fossa
foramen magnum
occipital condyles
Anterior

- Supraorbital foramen
- Superior orbital fissure
- Lamina papyracea of ethmoid
- Lacrimal
- Inferior orbital fissure
- Zygomaticofacial foramen
- Infraorbital foramen
- Nasal cavity
- Inferior nasal concha
- Mental foramen
- Maxilla
- Mandible
- Frontal
Inferior
Midsagittal

Floor of cranial cavity
**Orbit**
Frontal
Lacrimal
Lacrimal fossa
Ethmoid
Sphenoid
  - Superior orbital fissure
  - Optic foramen
  - Inferior orbital fissure
Maxilla
Palatine
Zygomatic
Features of anterior skull

**Bones** (excluding orbit) – frontal, nasal, zygomatic, maxilla, vomer, mandible

**Orbit** (features only)
- **Lacrimal Fossa** – lacrimal bone, includes opening of nasolacrimal duct
- **Superior Orbital Fissure** – between lesser and greater wings of sphenoid, from middle cranial fossa, cranial nerves nIII (oculomotor), nIV (trochlear), nV₁ (ophthalmic branch of trigeminal), nVI (abducens)
- **Optic Foramen** of sphenoid bone, from middle cranial fossa, cranial nerve nII (optic), ophthalmic artery
- **Inferior Orbital Fissure** – between greater wing of sphenoid and maxilla, communicates to infratemporal fossa

**External Nares** – nasal and maxillary bones, bony opening of nasal cavity

**Supraorbital Foramen** – frontal bone, supraorbital nerve (terminal branch of nV₁ ophthalmic nerve)

**Infraorbital Foramen** – maxilla, infraorbital nerve (terminal branch of nV₂ maxillary branch of trigeminal nerve)

**Mental Foramen** – mandible, mental nerve (terminal branch of nV₃ mandibular branch of trigeminal nerve)
Features of lateral skull

**Bones** - frontal, parietal, occipital, temporal, sphenoid, zygomatic, maxilla, nasal, mandible

**Temporal Fossa** – lateral to orbit, primarily sphenoid bone, muscle origin

**Temporal Line** - frontal, parietal bones, muscle origin

**Zygomatic Arch** – zygomatic and temporal bones, muscle origin

**Infratemporal Fossa** – inferior to temporal fossa, medial to zygomatic arch

**Pterygomaxillary Fissure** – between maxilla and lateral pterygoid plate of sphenoid

**Sphenopalatine or Pterygopalatine Foramen** – to nasal cavity, for sphenopalatine or pterygopalatine ganglion and artery

**Inferior Orbital Fissure** - between greater wing of sphenoid and maxilla, to orbit

**Temporal bone**

**Squamous Portion**

**Petrous Portion**

**Mandibular Fossa** – articulation of mandible

**External Auditory Meatus** – opening to tympanic cavity

**Styloid Process** – temporal bone, muscle and ligament attachment

**Mastoid Process** – temporal bone, sternocleidomastoid muscle insertion
Detailed features of the floor of cranial cavity

**Frontal bone** (anterior cranial fossa)

**Ethmoid bone** (anterior cranial fossa)
- **Cribiform Plate** – nl, olfactory nerve
- **Crista Galli**
Detailed features of the floor of cranial cavity (continued)

Sphenoid bone

**Lesser Wing** – separates anterior and middle cranial fossae

**Body**

- **Anterior Clinoid Processes**
- **Posterior Clinoid Processes**
- **Sella Turcica** – hypophyseal fossa, for hypophysis or pituitary
- **Dorsum Sellae**

**Greater wing** (middle cranial fossa)

semicircle of five foramina:

- **Superior Orbital Fissure** – nIII oculomotor nerve, nIV trochlear nerve, nV₁ ophthalmic branch of trigeminal nerve, nVI abducens nerve
- **Optic Foramen** or **Canal** – nII optic nerve
- **Foramen Rotundum** – nV₂ maxillary branch of trigeminal nerve
- **Foramen Ovale** – nV₃ mandibular branch of trigeminal nerve
- **Foramen Spinosum** – middle meningeal artery
Detailed features of the floor of cranial cavity (continued)

Between Sphenoid, Occipital, and Temporal bones

Foramen Lacerum – continuous with carotid canal (Internal Carotid Artery)

Occipital and Sphenoid bones

Clivus – midsagittal ridge separating right and left sides of middle cranial fossa

Temporal bone (mostly posterior cranial fossa)

Petrous Portion – houses middle and inner ear

Internal Auditory (or Acoustic) Meatus – nVII facial and nVIII vestibulocochlear (posterior cranial fossa)

Between Temporal and Occipital bones (posterior cranial fossa)

Jugular Foramen – internal jugular vein, nIX glossopharyngeal, nX vagus, nXI spinal accessory
Detailed features of the floor of cranial cavity (continued)

**Occipital bone** (posterior cranial fossa)
- **Foramen Magnum** – spinal cord, vertebral arteries, nXI spinal accessory (nXI entering cranium)
- **Hypoglossal Canal** – nXII hypoglossal
- **Sulcus of Transverse Sinus** – transverse dural sinus, continuous with…
- **Sulcus of Sigmoid Sinus** – sigmoid dural sinus, ends in jugular foramen
- **Internal Occipital Protuberance** - midsagittal separation of cerebellar hemispheres and occipital lobes of cerebrum
Detailed features of the base of skull (excluding mandible and hyoid)

Bones - maxilla (including premaxilla), palatine, vomer, zygomatic, sphenoid, temporal, occipital

Hard palate – maxilla (including premaxilla), palatine
  Incisive Foramen – terminal nerve and vomeronasal organ
  Dental Arcade – bilaterally 2 incisors, 1 canine, 2 premolars, 3 molars
  Greater and Lesser Palatine Foramina

Internal Nares or Choanae – palatine and sphenoid bones

Sphenoid bone
  Pterygoid Processes
    Medial Pterygoid Plate and Hamulus – muscle origin
    Lateral Pterygoid Plate – muscle origin
  Foramen Ovale – for nV₃ mandibular branch of trigeminal
  Spine of Sphenoid – ligament attachment
  Foramen Spinosum – for middle meningeal artery
Detailed features of the base of skull (continued)

Temporal bone

- **Zygomatic Process** – posterior part of zygomatic arch
- **Mandibular Fossa** – articulation with mandible
- **Styloid Process** – origin of muscles and ligaments
- **Stylomastoid Foramen** – exit of nVII facial nerve
- **Mastoid Process** – attachment of muscles
- **Petrous Portion** – ‘rock’-like, encloses tympanic cavity
- **Carotid Canal** – entrance of internal carotid artery

Occipital bone

- **Foramen Magnum** – the ‘big hole’, for spinal cord, vertebral arteries, and spinal accessory nerves
- **Occipital Condyles** – articulate with first cervical vertebra
- **Superior Nuchal Line** – insertion of trapezius muscle, division of cranial and cervical regions

Between bones

- **Foramen Lacerum** – distal pathway of internal carotid artery to cranial cavity, between sphenoid, occipital and temporal bones
- **Jugular Foramen** – venous drainage of the cranial cavity by the internal jugular vein, between the occipital and temporal bones
Nasal Cavity - external nares to internal nares

Bones of the nasal cavity
- Nasal – superior
- Frontal – superior
- Lacrimal – lateral
- Ethmoid – superior, lateral, midsagittal (septal)
- Sphenoid – superior
- Maxilla – lateral, inferior
- Palatine – lateral, inferior
- Inferior Concha - lateral
- Vomer – midsagittal (septal)

Nasal cartilages
- Septal – midsagittal
- Lateral – paired
- Alar (several) – paired
Bones of Nasal Cavity

Lateral View

Superior concha
Middle concha
Inferior concha

Superior, middle and inferior meati.
Nasal Cavity - external nares to internal nares

Nasal Septum
Perpendicular Plate of Ethmoid
Vomer
Septal Cartilage

Features of lateral walls
Sphenopalatine Foramen - Sphenopalatine ganglion and artery
(branch of maxillary artery)
Sphenoethmoid Recess – opening of sphenoid sinus
Superior Nasal Concha – superior meatus, opening of ethmoid air cells
Middle Nasal Concha – middle meatus and semilunar hiatus, opening of ethmoid air cells, maxillary sinus, frontal sinus via maxillary sinus
Inferior Nasal Concha (a separate bone) – inferior meatus, opening of nasolacrimal duct
Paranasal sinuses

**Frontal** – supraorbital, variable, joins maxillary sinus

**Maxillary** – largest

**Ethmoid air cells** – anterior, middle, posterior, between orbit and nasal cavity

**Sphenoid** – midsagittal
Cavities of temporal bone

Tympanic cavity

1) Outer ear – air-filled

A) auricular cartilage – supports auricle (or pinna) tragus, antitragus, helix, antihelix

B) external ear canal and external auditory (acoustic) meatus
Cavities of temporal bone

Tymanpanic cavity

1) Outer ear – air-filled
   A) auricular cartilage
      tragus, antitragus, helix, antihelix
   B) external ear canal and external auditory meatus

2) Middle ear cavity – air-filled
   separated from external ear canal by tympanic membrane
   Skeletal contents - 3 middle ear ossicles articulated end to end
   A) Malleus – attached to tympanic membrane
   B) Incus - intermediate
   C) Stapes – attached to fenestra ovale
Cavities of temporal bone

Tymppanic cavity

1) Outer ear – air-filled
   A) auricular cartilage
      tragus, antitragus, helix, antihelix
   B) external ear canal and external auditory meatus

2) Middle ear cavity – air-filled
   separated from external ear canal by tympanic membrane
   Skeletal contents - 3 middle ear ossicles articulated end to end
      A) Malleus – attached to tympanic membrane
      B) Incus - intermediate
      C) Stapes – attached to fenestra ovale

Several openings
   A) mastoid air cells – connected to superior of middle ear cavity
   B) pharyngotympanic or tympanic tube or Eustachian canal
   C) fenestra ovale – unites inner ear cavity, covered by stapes
   D) fenestra rotundum – unites inner ear cavity, membrane covered
Cavities of temporal bone

Tymppanic cavity

3) Inner ear cavity – the bony labyrinth
   connected to middle tympanic cavity via:
   A) fenestra ovale (covered by stapes)
   B) fenestra rotundum (covered by membrane)

Features

Vestibule
3 Semicircular canals
Perilymphatic (cochlear) duct
Endolymphatic duct
Cochlea and Modiolus
Cavities of temporal bone

Tympanic cavity

3) Inner ear cavity – the bony labyrinth connected to middle tympanic cavity via:
   A) fenestra ovale (covered by stapes)
   B) fenestra rotundum (covered by membrane)

Features

Vestibule
3 Semicircular canals
Perilymphatic (cochlear) duct
Endolymphatic duct
Cochlea and Modiolus

4) Other features of petrous (or mastoid) temporal

Mastoid air cells – connected to superior of middle ear cavity
Facial canal – path of facial nerve and location of geniculate ganglion uniting internal auditory meatus and stylomastoid foramen alongside the middle ear cavity
4 smaller autonomic branches of nVII emerge elsewhere
Carotid canal – path of internal carotid artery, joining foramen lacerum
Internal auditory meatus

Vestibular nerve

Facial nerve

Cochlear nerve

Pharyngotympanic canal

Membranous labyrinth

Tympanic membrane

Facial nerve at stylomastoid foramen

Chorda tympani (SS gustation)
Mandible

Body – thick, dense

Alveolar margin – bears alveoli, sockets for teeth

Symphysis – genu

Ramus – flat, thin
  
     Angle – insertion of masseter muscle
  
     Coronoid process – insertion of temporalis muscle
  
     Mandibular condyle – articulation with temporal bone

Lateral

     Mental foramen – for mental nerve, terminal branch of nV₃ mandibular nerve

Medial

     Mandibular foramen – for nV₃ mandibular nerve

     Mylohyoid line – muscle origin


Hyoid

    – suspended from styloid process
    anchors tongue, suspends larynx

    Body

    Lesser cornu (pl. cornua)

    Greater cornu (pl. cornua)
Major blood vessels related to the skull

Arterial blood supply to the cranial cavity

**Internal carotid arteries** – carotid canal of temporal bone → foramen lacerum between temporal, sphenoid, and occipital bones → middle cranial fossa

**Vertebral arteries** – foramen magnum of occipital bone

**Middle meningeal arteries** – foramen spinosum of sphenoid bone

Venous drainage of cranial cavity

**Internal jugular veins** – jugular foramen between occipital and temporal bones

(Major) Blood supply to nasal cavity

**Sphenopalatine artery** (branch of **Maxillary artery**) – sphenopalatine foramen between sphenoid and palatine bones

Blood supply to orbit

**Ophthalmic artery** and vein – optic foramen of sphenoid bone
Cranial Nerves – any nerve that emanates from the skull
Motor = efferent
  somatomotor – to skeletal muscles
  autonomic (ANS) – to smooth muscles and glands via ganglia

Sensory = afferent
  somatosensory modalities – touch, pain, temperature, vibration, proprioception
  special sensory (SS) modalities – olfaction, vision, gustation, hearing, equilibrium
Cranial nerves - functions
nI – olfactory, SS olfaction
nII – optic, SS vision
nIII – oculomotor, somatomotor to extrinsic ocular muscles, ANS to intrinsic ocular muscles
nIV – trochlear, somatomotor to one extrinsic ocular muscle
nV – trigeminal, somatomotor to muscles of mastication, somatosensory to head
nVI – abducens, somatomotor to one extrinsic ocular muscle
nVII – facial, somatomotor to muscles of facial expression, ANS to nasal and paranasal glands via sphenopalatine ganglion, SS gustation, somatosensory to auricular region
nVIII – vestibulocochlear, SS equilibrium, orientation, angular acceleration, hearing
nIX – glossopharyngeal, somatomotor to posterior tongue and pharynx, ANS to salivary glands, SS gustation, somatosensory
nX – vagus, somatomotor to larynx, ANS parasympathetic throughout body
nXI – spinal accessory, somatomotor to superior trapezius and sternocleidomastoid muscles of neck
nXII – hypoglossal, somatomotor to anterior tongue
Cranial nerves – pathways from anterior cranial fossa

nI – olfactory

from anterior cranial fossa →
via cribriform plate of ethmoid →
to nasal cavity

Cranial nerves – pathways from middle cranial fossa to orbit

from middle cranial fossa via optic foramen or canal of sphenoid

nII – optic

from middle cranial fossa via superior orbital fissure of sphenoid

nIII – oculomotor
nIV – trochlear
nVI – abducens

nV₁ – ophthalmic branch of trigeminal nerve

and via supraorbital foramen or notch of frontal →
supraorbital nerve
Cranial nerves – pathways from middle cranial fossa (cont’d)

nV – trigeminal

  nV₁ – ophthalmic (previous slide)
  nV₂ – maxillary
    from middle cranial fossa →
    via foramen rotundum of sphenoid →
    via inferior orbital fissure between sphenoid and maxilla → (many branches, e.g., superior alveolar nerves)
    via infraorbital groove of maxilla→
    via infraorbital foramen of maxilla→ infraorbital nerve

  nV₃ – mandibular
    from middle cranial fossa →
    via foramen ovale of sphenoid → (many branches)
    via mandibular foramen of mandible →
    via alveoli → inferior alveolar nerves
    via mental foramen → mental nerve
Cranial nerves – pathways from posterior cranial fossa
nVII – facial
  via internal auditory or acoustic meatus of petrous temporal →
  facial canal of petrous temporal →
  via stylomastoid foramen
nVIII – vestibulocochlear
  via internal auditory or acoustic meatus of petrous temporal →
  ends in inner tympanic cavity of petrous temporal bone
nIX – glossopharyngeal
  via jugular foramen
nX – vagus
  via jugular foramen
nXI – spinal accessory
  enters cranial cavity via foramen magnum
  exits cranial cavity via jugular foramen
nXII – hypoglossal
  exits cranial cavity via hypoglossal canal (in margins of foramen magnum)
General parts of vertebrae

Body or centrum – anterior, load bearing
Vertebral or neural arch
Vertebral foramen – for spinal cord and spinal nerves
Transverse processes - bilateral
Spinous process dorsal
Pedicle – lateral vertebral arch, thick, round in transverse section
Lamina – dorsal vertebral arch, thin, flat in transverse section
Superior articular processes - facets face medially
Inferior articular processes - facets face laterally
Pars interarticularis – part of lamina between superior and inferior articular processes
Superior vertebral notch – formed above pedicle between body and superior articular process
Inferior vertebral notch – formed below pedicle between body and inferior articular process
Intervertebral foramen – formed between superior and inferior vertebral notches of articulated adjacent vertebrae
Axial skeleton - **Vertebra** (pl. vertebrae) – numbered superior to inferior

7 **cervical vertebrae** – characterized by small body, transverse foramen for vertebral artery formed by fused costal process, long spinous process

**Atlas vertebra** – C1, superior articular processes flattened to articulate with occipital condyles, no vertebral body, pivots on axis vertebra

**Axis vertebra** – C2, **odontoid process** (*dens*) formed from atlas body

12 **thoracic vertebrae** – facets on transverse process and demifacets on body for articulation with costae, kyphosis – ventral curvature

5 **lumbar vertebrae** – large body, long ‘transverse process’ created by fusion of costal process, lordosis – dorsal curvature

1 **sacrum** (5 fused sacral vertebrae)

  - **Ala**
  - **Auricular region** - sacroiliac articulation

**Body**

**Promontory** – superior margin of body, most anterior part of sacrum

**Median sacral crest** – fused spinous processes on dorsal side

**Sacral foramen** – superior vertebral foramen

**Sacral canal** – fused vertebral canal

Anterior or ventral sacral foramina (4) – ventral rami of spinal nerves

Posterior or dorsal sacral foramina (4) – dorsal rami of spinal nerves

**Sacral hiatus** – inferior vertebral foramen

1 **coccyx** (3-4 fused coccygeal or caudal vertebrae)
Axial skeleton

Costa (pl. costae)
   1-7 true ribs, costal cartilages articulate directly with sternum
   8-12 false ribs, do not articulate directly with sternum, costal cartilages if present articulate with next-superior costa
   11 & 12 floating ribs, no costal cartilages
Parts: head, neck, tubercle, angle, body

Sternum
   manubrium – articulates with clavicles, costae 1 and 2
   sternal body (4 fused sternebrae) – articulates with costae 2-7
   xiphoid process
Pectoral Girdle
Clavicle
Sternal extremity
Acromial extremity

Scapula
posterior view
  Lateral margin, Vertebral or medial margin, Superior margin
  Superior angle, Inferior angle
  Suprascapular notch
  Spine
  Acromion
  Supraspinous fossa
  Infraspinous fossa
Anterior view
  Subscapular fossa
  Coracoid process
Lateral view
  Glenoid fossa or surface
  Supraglenoid tubercle
**Humerus**

**Caput** or **head** - articulates with glenoid fossa  
**Anatomical neck**  
**Surgical neck**  
**Greater tubercle** – lateral, insertion of rotator cuff muscles  
**Lesser tubercle** - medial, insertion of rotator cuff muscle  
**Intertubercular sulcus** – sulcus of biceps brachii  
**Deltoid tuberosity** – insertion of deltoid muscle  
**Spiral or radial sulcus** – groove for radial nerve  
**Medial epicondyle** – origin of ligaments and flexor muscles  
**Lateral epicondyle** – origin of ligaments and extensor muscles  
**(lateral) supracondylar crest** – origin of extensor muscles  
**Coronoid fossa** - accommodates flexed ulna  
**Radial fossa** - accommodates flexed radius  
**Olecranon fossa** - accommodates extended ulna  
**Capitulum** or **capitellum** – lateral, articulation for radial head  
**Trochlea** – medial, articulation for ulnar trochlear notch
Antebrachium

Radius
Head proximal, shorter proximally, longer distally, narrow proximal, broad distal, articulates with carpal bones
Head – round in proximal view, articulates with capitulum of humerus
Neck
Radial tuberosity – insertion of tendon of biceps brachii muscle
Anterior oblique line – attachment of interosseous membrane and muscles
Posterior oblique line
Styloid process

Ulna
Head distal, longer proximally, shorter distally, broad proximal, narrow distal, does not articulate with carpal bones
Olecranon process – insertion of triceps muscle
Trochlear notch – articulates with trochlea of humerus
Coronoid process – insertion of brachialis muscle
Radial notch – articulates with radial head
Head - articulates with distal radius
Styloid process
Carpal bones
Proximal row, lateral to medial
Scaphoid – articulates with radius
Lunate – articulates with radius
Triquetral or triquetrum – articulates with other carpals only
Pisiform – anterior to triquetral to which it articulates, bony landmark

Distal row, lateral to medial
Trapezium – articulates with pollical metacarpal
Trapezoid – articulates with metacarpal II
Capitate – articulates with metacarpal III
Hamate – articulates with metacarpals IV and V, hamulus distal to pisiform
Pelvis
Sacrum, coccyx, plus two coxal or innominate bones
Acetabulum – socket for head of femur, formed by ilium, ischium, and pubis
Obturator foramen – supports obturator membrane, formed pubis and ischium
Pelvic inlet or brim – separates abdominal and pelvic cavities, false and true pelves
  sacral promontory, sacral ala, arcuate line, pectineal crest, pubic tubercle
Pelvic outlet – supports pelvic and urogenital diaphragms, floor of pelvic cavity
  pubic symphysis, inferior rami of pubis and ischium, ischial tuberosity, coccyx
Coxal or innominate bone

**Ilium** – superior
- **Ala** – false pelvis, flat and thin
- **Auricular region** – sacroiliac joint
- **Iliac fossa** – anteromedial ala
- **Iliac crest** – insertion of muscles

**Anterior superior iliac spine** – bony landmark, muscle and ligament origin
**Anterior inferior iliac spine** – muscle origin

**Posteror superior iliac spine** – insertion of sacroiliac ligaments
**Posteror inferior iliac spine** – insertion of sacroiliac ligaments

**Greater sciatic notch** – for sciatic nerve (and one muscle)

**Arcuate line**

**Ischium**
- **Ischial spine** – insertion of ligament
- **Lesser sciatic notch** – for muscles

**Ischial tuberosity** – origin of muscles, supports body weight while sitting

**Pubis**
- **Pectineal crest** – insertion of muscles
- **Pubic tubercle** – insertion of ligaments
- **Acetabular notch** – origin of ligament

**Pubic symphysis**
Femur
Anterior view
  Caput or head
  Fovea capitis – ligament insertion
  Neck
  Greater trochanter – (some) gluteal muscle insertions
  Lesser trochanter – femoral flexor muscle insertions
  Intertrochanteric line – muscle insertions
  Adductor tubercle – muscle insertion
  Patellar surface – articular surface for patella
  Medial condyle – articulates with medial condyle of tibia
  Lateral condyle – articulates with lateral condyle of tibia
  Medial epicondyle – origin of ligaments and muscles
  Lateral epicondyle – origin of ligaments and muscles

Posterior view
  Intertrochanteric crest – muscle insertions
  Trochanteric fossa – muscle insertion
  Gluteal tuberosity – insertion of gluteus maximus muscle
  Linea aspera – muscle origin and insertions
  Intercondylar notch – origin of cruciate ligaments of knee
Crus

Tibia
extends further proximally than fibula, alone articulates with femur
Medial condyle
Lateral condyle
Tibial tuberosity – insertion of patellar ligament
Intercondylar eminence – insertion of cruciate ligaments
Anterior tibial crest – subcutaneous
Posterior tibial crest – deep attachment of interosseous membrane
Medial malleolus – articulates with talus, bony landmark
Plafond – articulates with talus, load-bearing

Fibula
Head – proximal
Neck
Fibular crest – attachment of interosseous membrane
Lateral malleolus – articulates with talus, bony landmark
**Tarsal bones**

**Medial column, proximal to distal**

**Talus** – proximal, alone articulates with tibia and fibula, rests on top of calcaneus

- **Trochlea**
- **Head and neck**
- **Sulcus of flexor hallucis longus tendon** – posterior and inferior to trochlea

**Navicular** – middle

**Cuneiform I** – distal medial, articulates with hallucal metatarsal

**Cuneiform II** – distal middle, articulates with metatarsal II

**Cuneiform III** – distal lateral, articulates with metatarsal III

**Lateral column, proximal to distal**

**Calcaneus or calcaneum**

- **Sustentaculum tali** – medial protrusion to support talus
- **Sulcus of flexor hallucis longus tendon** – posterior and inferior to sustentaculum tali

**Cuboid** – articulates with metatarsals IV and V

- **Groove for tendon of peroneus longus tendon** formed with tuberosity of metatarsal V
Arthrology

Types of joints

**Diarthrosis** (pl. diarthroses) or arthrodial joints – defined by the presence of a synovial cleft

**Synarthrosis** (pl. synarthroses) – lack a synovial cleft
  - **Sutures** – complex, immovable
  - **Synchondroses** – bone to hyaline cartilage
  - **Syndesmoses** – bone to fibrocartilage

Others

“Amphiarthrosis” – a poor term, subjective
**Symphysis** – any midsagittal joint
**Gomphosis** – peg-in-socket
Parts of a typical diarthrotic joint
Articular surfaces of bone covered with hyaline cartilage
Joint capsule
  Synovial membrane
    contains synovial cleft, secretes synovial fluid or synovium
  Fibrous capsule or capsular ligament
Intracapsular or Intra-articular ligaments or cartilages
Articular (or Interarticular) ligaments (maybe thickenings of joint capsule or separate and outside capsule)

Miscellaneous
  Bursa (pl. bursae) – synovial membrane and fluid, often cushioning muscle traversing a joint but sometimes not associated with a joint
  Synovial tendon sheaths – extensions of synovial capsule to surround tendon and provide freedom of movement
Joint movements (most paired as antagonists)

Flexion – reducing angle of joint, generally in anterior direction
Extension – opposite of flexion

Adduction – movement “towards or together”, generally towards midsagittal
Abduction – opposite of adduction

Circumduction – combination of flexion, extension, adduction, and abduction

Rotation – turning on longitudinal axis

Supination – radius and ulna parallel, as in anatomical position
Pronation – rotation of radius so it crosses ulna distally, palm faces posteriorly

Dorsiflexion – elevation of dorsum of pes, as if standing on heel
Plantarflexion – depression of distal pes, as if wearing high heels

Inversion – intertarsal rotation, turning planter pes medially towards midsagittal
Eversion – turning planter pes laterally

Elevation – movement superiorly
Depression – movement inferiorly

Protraction – movement anteriad
Retraction – movement posteriad

Constriction – narrowing (not a movement of a joint)
Dilation – widening (not a movement of a joint)
Miscellaneous cartilages and connective tissues of cranium

Nasal (or Narial) cartilages of Agger Nasi – hyaline cartilage
Septal cartilage
Lateral cartilages
Alar cartilages
Miscellaneous cartilages and connective tissues of cranium

Orbital septum or palpebral ligament
Palpebral or “medial palpebral” ligament
Lateral raphe or “lateral palpebral” ligament
Superior and inferior tarsus or tarsal plates – hyaline cartilage
Miscellaneous cartilages and connective tissues of cranium

Auricular cartilage of Auricle (or Pinna) – elastic cartilage
  Tragus
  Antitragus
  Helix
  Antihelix

Auricular Cartilage

Auricle

Arthrology of the neurocranium

Sutures

**Coronal** – frontoparietal
**Sagittal** – parietal symphysis
**Lambdoid** – parieto-occipital
**Squamosus** – sphenotemporal, temporoparietal, temporo-occipital
**Sphenoparietal**

Suture Intersections

**Bregma** – intersection of coronal and sagittal sutures
**Lambda** – intersection of sagittal and lambdoid sutures
**Pterion** – intersection of sphenoparietal and squamous sutures, superficial to middle meningeal artery
**Asterion** – intersection of squamous and lambdoid sutures
**Nasion** – intersection of nasal symphysis and nasofrontal sutures
Arthrology of the viscerocranium

Styloid process
  **Stylohyoid ligament** – styloid process of temporal to lesser cornu of hyoid

Temporomandibular joint (‘TMJ’) – mandibular fossa and mandibular condyle
  adduction/abduction (elevation/depression), protraction/retraction,
  lateral mandibular movement
  **Capsular ligament** – double synovial cleft
  **Temporomandibular ligament** – lateral thickening
  **Stylomandibular ligament** – styloid process of temporal to mandibular
  angle
  **Sphenomandibular ligament** – spine of sphenoid to mandibular foramen
Arthrology of vertebrae (not including costal articulations)

Intervertebral disc – between vertebral bodies

  Annulus fibrosus – fibers vertical and oblique around circumference
  Nucleus pulposus and its theca – gelatinous vestige of embryonic notochord, provides cushioning and spacing

Ligaments of vertebral arch and processes

  Ligamentum flavum or subflavum – between laminae
  Intertransverse ligament – between transverse processes
  Interspinous ligament – between spinous processes
  Supraspinous ligament – between dorsal tips of spinous processes
  Nuchal ligament – occipital bone to supraspinous ligament to spine of C7
  Anterior longitudinal ligament – anterior to vertebral bodies
  Posterior longitudinal ligament – posterior to vertebral bodies, ventral surface of vertebral canal

Vertebral Curvature

  Kyphosis – flexion-like curvature of thoracic vertebrae
  Lordosis – extension-like curvature of lumbar and cervical vertebrae
  Scoliosis – pathological bilateral asymmetry
Arthrology of vertebrae - pathologies

Herniated or **slipped disc** – rupture of annulus fibrosus and theca, protrusion of nucleus pulposus
nervous tissue irritated by pH of nucleus pulposus
entrainment of spinal nerve at intervertebral foramen

**Spondylolysis** or “Pars defect” – separation of inferior articular process

**Spondylolisthesis** – anterior shift of vertebral body
Arthrology of thoracic cage

**Costovertebral joints** - costal head to demifacet of vertebral body (diarthroses)

**Costotransverse joints** - costal tubercle to facet of transverse process (diarthroses)

**Costochondral joint** – costal body to costal cartilage (synchondroses)

**Sternocostal joints** – costal cartilages to sternum
  - Costa 1 – synchondrosis to manubrium
  - Costa 2 – separate diarthroses to manubrium and sternal body
  - Costae 3 thru 7 – diarthroses to sternal body
  - Sternocostal diarthroses may degenerate to synchondroses with age

**Interchondral joints** – diarthroses between adjacent costal cartilages
  - costal cartilages 6-10

**Sternal joints** (syndesmoses)
  - **Sternal angle** – manubrium to sternal body, level of 4th thoracic disc
  - **Xiphisternal joint** – sternal body to xiphoid process, level of 8th thoracic disc
Arthrology of pectoral girdle

**Sternoclavicular joint** – diarthrosis with double synovial cleft protraction/retraction, elevation/depression

**Superior and inferior sternoclavicular ligaments**

**Interclavicular ligament**

**Costoclavicular ligament**
Arthrology of pectoral girdle
Shoulder

Acromioclavicular joint – diarthrosis, limited movement
  Superior and inferior acromioclavicular ligaments
Coracoclavicular ligaments
  Trapezoid ligament – lateral
  Conoid ligament - medial

Glenohumeral joint – diarthrosis, circumduction, rotation
  Glenoid labrum
Capsular ligament
  Superior, middle, inferior glenohumeral ligaments – from
    supraglenoid tubercle roughly to greater tubercle and below,
    highly oblique orientation

Coracohumeral ligament
Coracoacromial ligament

Transverse ligament – between humeral tubercles, restrains
  long head of biceps brachii muscle in intertubercular sulcus
Bursae – subacromial, supraacromial, of deltoid, of subscapularis,
  of supraspinatus, synovial sheath of tendon of biceps brachii, etc.
Bursae of shoulder

subacromial, supraacromial, of deltoid, of subscapularis, of supraspinatus, synovial sheath of tendon of biceps brachii, etc.
Bursae of shoulder

subacromial, supraacromial, of deltoid, of subscapularis, of supraspinatus, synovial sheath of tendon of biceps brachii, etc.
Pathologies of shoulder joints

“Separated” shoulder
subluxation of acromioclavicular joint

“Dislocated” shoulder
subluxation of glenohumeral joint
integrity of joint maintained by 4 rotator cuff muscles, all originate from scapula, all insert on humeral tubercles

Hill-Sachs lesion – defect of humeral head due to impact with rim of glenoid
Glenoid fracture
Cubitus
Humeroradial joint – flexion/extension, rotation
Humeroulnar joint – flexion/extension
Proximal Radioulnar joint – pronation/supination
Cubital Tunnel – between olecranon process and humeral medial epicondyle

Annular Ligament - forms ring around neck of radius
origin ulna, approximately at coronoid process
insertion ulna, approximately at coronoid process

Lateral (or Radial) Collateral Ligament
origin humeral lateral epicondyle
insertion annular ligament

Medial (or Ulnar) Collateral Ligament
origin humeral medial epicondyle
insertion proximal ulna

Anterior Capsular Ligament
Posterior Capsular Ligament

Nursemaid’s elbow - subluxation of radial head – until age 4 or 5
Antebrachium

**Interosseous membrane** – anterior oblique line of radius to ulnar diaphysis, muscular origin

**Carpal region** – all joints diarthroses
**Distal radioulnar joint** – pronation/supination
**Radiocarpal joint** – diarthrosis of radius, scaphoid, and lunate, circumduction
**Intercarpal joints** – little movement
**Carpal tunnel** – path of **median nerve** and tendons of flexor muscles, restrained by...
  **Flexor Retinaculum**
**Guyon’s canal** – path of **ulnar nerve** between pisiform and hamulus of hamate, restrained by...
  **Pisohamate ligament**

**Extensor retinaculum**
**Palmar or Anterior Radiocarpal Ligament**
**Dorsal or Posterior Radiocarpal Ligament**
**Radial Collateral Ligament**
**Ulnar Collateral Ligament**
Manus – all joints diarthroses

Carpometacarpal joints
  Trapezium-pollical metacarpal – circumduction
  all other carpometacarpal joints little movement

Metacarpophalangeal joint (MCP)
  Pollex – flexion/extension
  Digits II thru V – circumduction

Proximal interpalangeal joint (PIP) – flexion/extension
Distal interphalangeal joint (DIP) – flexion/extension
  collateral ligaments of MCP, PIP, DIP
Joints and ligaments of the pelvis

Sacrocoxal

**Sacroiliac joint** – both diarthrosis and syndesmosis, virtually no movement

*Anterior sacroiliac ligament*

*Posterior sacroiliac ligament*
  - **Short** – superior, relatively horizontal
  - **Long** – inferolateral, relatively vertical

**Sacrospinous ligament** – origin sacrum, insertion, ischial spine, creates greater sciatic foramen

**Sacrotuberous ligament** – origin sacrum, insertion ischial tuberosity, creates lesser sciatic foramen

**Pubic symphysis** – both synchondrosis and syndesmosis, relaxes during parturition

**Inguinal ligament** – anterior superior iliac spine to pubic tubercle, creates femoral canal between abdominal cavity and femoral triangle

**Obturator membrane** – covers obturator foramen and serves as muscle origin

**Coxofemoral joint** diarthrosis, circumduction and rotation

**Capsular ligament**
  - Iliofemoral ligament
  - Ischiofemoral ligament
  - Pubofemoral ligament

**Ligamentum teres** – origin acetabular notch, insertion fovea capitis
Genu

Patellar joint and ligaments

Patella – a sesamoid bone of the tendon of the quadriiceps muscle
Diarthrosis with femur
Patellar ligament – origin patella, insertion tibial tuberosity
Patellar retinacula
  Medial patellar retinaculum
  Lateral patellar retinaculum
Genu Femorotibial joint (simplified) - diarthrosis, flexion/extension, rotation
3 paired ligaments – cruciate, menisci, and collateral ligaments

**Anterior cruciate ligament (ACL)**
- origin posterior intercondylar notch of femur
- insertion anterior intercondylar eminence of tibia
- stretched during crural extension

**Posterior cruciate ligament (PCL)**
- origin anterior intercondylar notch of femur
- insertion posterior intercondylar eminence
- stretched during crural flexion

**Medial meniscus**
- origin posterior intercondylar eminence
- insertion anterior intercondylar eminence – shared with ACL

**Lateral meniscus**
- Origin anterior intercondylar eminence
- Insertion posterior intercondylar eminence

**Tibial collateral ligament**
- Origin medial epicondyle of femur
- Insertion medial meniscus and medial condyle of tibia

**Fibular collateral ligament**
- Origin lateral epicondyle of femur
- Insertion fibular head
Crus

Proximal Tibiofibular Joint – diarthrosis, virtually no movement
Distal Tibiofibular Joint – syndesmosis, virtually no movement
Interosseous membrane – unites posterior tibial crest and fibular crest, muscular origin

Tarsal region and Pes

Extensor Retinaculum
  Superior
  Inferior

Flexor Retinaculum

Tibiotalar Joint – diarthrosis, dorsiflexion/plantarflexion
  Plafond to Trochlea
  Medial Malleolus to medial trochlear facet of talus

Deltoid Ligament

Tibiotalar Ligaments

Tibiocalcaneal Ligament

Fibulotalar Joint – diarthrosis, dorsiflexion/plantarflexion
  Lateral Malleolus and lateral trochlear facet of talus

  Fibulotalar and Fibulocalcaneal ligaments

Intertarsal and tarsometatarsal ligaments

Long and Short Plantar Ligaments