Skeletal System

bones, cartilage and ligaments are tightly joined to form a strong, flexible framework

bone is active tissue:

→ 5-7% bone mass/week
daily Calcium requirement: 1200mg/day

Functions of Skeletal System:

1. Support
   strong and relatively light; 20% body weight

2. Movement
   framework on which muscles act act as levers and pivots

3. Protection
   brain, lungs, heart, reproductive system

4. Mineral storage (electrolyte balance
   99% of body’s calcium is in bone tissue
   (1200-1400g vs <1.5g in blood, rest in cells)
   also stores phosphate

5. Hemopoiesis
   blood cell formation

6. Detoxification
   bone tissue removes heavy metals and other foreign materials from blood
   can later release these materials more slowly for excretion
   but this can also have bad consequences

Skeletal Anatomy

each individual bone is a separate organ of the skeletal system

~270 bones (organs) of the Skeletal System at birth
with age the number decreases as bones fuse
by adulthood the number is ~206 (typical)
even this number varies due to varying numbers of minor bones:
   sessamoid bones – small rounded bones that form within tendons in response to stress
   eg. kneecap (patella), in knuckles
   wormian bones – bones that form within the sutures of skull

each skeletal organ is composed of many kinds of tissues:
   bone (=osseous tissue)
   cartilage
   fibrous connective tissues
   blood (in blood vessels)
   nervous tissue

General Shapes of Bones

bones can be categorized according to their general shape:

1. long: cylindrical, longer than wide
   rigid levers for muscle actions eg crowbars
   eg. arms, legs, fingers, toes

2. short: length nearly equal width
   limited motion, gliding if any
   eg. carpals, tarsals, patella

3. flat: thin sheets of bone tissue
   enclose and protect organs
   broad surfaces for muscle attachments
   eg. sternum, ribs, most skull bones, scapula, coxa

4. irregular: elaborate shapes different from above
   eg. vertebrae, sphenoid, ethmoid

Bone Structure

bones have outer shell of compact bone
usually encloses more loosely organized bone tissue

epiphyses
large surface area for muscle attachment and pivot
spongy bone with trabeculae;
contains red marrow (=hemopoietic tissues)
→ produces blood cells in delicate mesh of reticular tissues
in adults red marrow is limited to vertebrae, sternum, ribs, pectoral and pelvic girdles, proximal heads of humerus and femur
with age, red marrow is replaced by yellow marrow
articular cartilage
on surface of epiphyses
resilient cushion of hyaline cartilage
diaphysis
thick compact bone but light; hollow → medullary cavity
medullary cavity
yellow marrow – fat (adipose) storage
"fat at the center of a ham bone"
in event of severe anemia, yellow marrow can transform back into red marrow to make blood cells
periosteum
white fibrous connective tissue continuous with tendons penetrates bone – weds blood vessels to bone
endosteum
fibrous CT that lines medullary cavity

Microscopic Structure (Histology)

A. bone:
connective tissue; contains cells and matrix
bone cells = osteocytes
matrix predominates; ~ 1/3rd organic and 2/3rd's inorganic
matrix contains lots of collagen fibers
highly organized arrangement of matrix and cells

- lacunae w osteocyte & canaliculi
- lamellae
- haversian canal
perforating canals (Volkmann canals) interconnect the haversian canals
periostium provides life support system for bone cells
blood vessels penetrate bone and connect with those in haversian canals

B. cartilage
resembles bone:
large amount of matrix
lots of collagen fibers
differs:
firm flexible gel is not calcified (hardened)
no haversian canal system
no direct blood supply
→ nutrients and O₂ by diffusion

all bone starts out as cartilage
in bone the matrix is hardened (= ossified) by calcification (or mineralization)
microscopic structure of cartilage:
chondrocytes in lacunae
kinds of cartilage:
(all similar matrix with lots of collagen fibers; differ in other fibers)
1. hyaline
   most common
   e.g. covers articular surfaces of joints, costal cartilage of ribs, rings of trachea, nose
2. fibrous
   mostly collagen fibers
   e.g. discs between vertebrae, pubic symphysis
3. elastic
   also has elastic fibers
   e.g. external ear, eustachian tube

The Axial Skeleton
A. Skull
most complex part of the skeleton
consists of facial and cranial bones
most bones are paired, not all

Anatomy of Skeletal System

each individual bone has numerous holes, bumps, depressions and ridges

= Bone Markings

- Foramen: opening in bone – passageway for nerves and blood vessels
- Fossa: shallow depression – e.g. a socket into which another bone articulates
- Sinus: internal cavity in a bone
- Condyle: rounded bump that articulates with another bone
- Tuberosity: small rough projection – point of attachment for muscle
- Spine: sharp slender process
two main subdivisions of skeletal system:
axial: skull, vertebral column, rib cage
appendicular: arms and legs and girdles
skull bones joined by **sutures**

**Fontanels**

ossification of skull begins in about 3rd month of fetal development

not completed at birth → bones have not yet fused

gaps = **fontanels**

- frontal (anterior)
- occipital (posterior)
- 2 sphenoid
- 2 mastoid

at this stage skull is covered by tough membrane for protection

bones eventually grow together and fuse to form solid case around brain

**Sinuses** (Paranasal Sinuses)

in 4 of the bones making up the face

in life sinuses are lined with mucous membrane

sinuses lighten bone, warm and moisten air

6 sinuses:

- frontal - 2
- maxillary - 2
- ethmoid - 1
- sphenoid - 1

**Maxilla Bone**

resembles bat or butterfly in shape

keystone in floor of cranium: anchors many of the bones of cranium

contains **sinuses**

- sella turcica – depression for the pituitary gland

**Ethmoid Bone** – irregular, unpaired bone

honeycombed with **sinuses**

- cribiform plate – perforated with openings which allow olfactory nerves to pass
- nasal conchae – passageways for air; filtering, warming, moistening
- crista galli – attachment of meninges

very delicate and easily damaged by sharp upward blow to the nose

can drive bone fragments through the cribiform plate into the meninges or brain itself

can also shear off olfactory nerves → loss of smell

**Hyoid bone** – single "U" shaped bone in neck just below mandible and above larynx (voice box)

suspended from **styloid process** of temporal bone

only major bone in body that doesn’t directly articulate with other bones

serves as point of attachment for tongue and several other muscles

**cheek bones, upper teeth cemented to these bones**

**hard palate**: palatine process and palatine bones

**cleft palate** → when bones of **palatine process** of **maxilla bones** do not fuse properly

not only cosmetic effect can lead to serious respiratory and feeding problems in babies and small children today, fairly easily corrected

**Temporal Bone**

- **external auditory meatus** - opening to ear canal leads to middle ear chamber

only bone that contains other bones:

- **malleus** = hammer
- **incus** = anvil
- **stapes** = stirrup

**Mandible** = lower jaw

largest, strongest bone of face articulates at temporal bone

**Occipital Bone**

- **foramen magnum** - large opening in base through which spinal cord passes
- **occipital condyles** – articulation of vertebral column

**Sphenoid Bone** – irregular, unpaired bone

B. **Vertebral Column**

main axis of body

vertebrae are separated by pads of fibrous cartilage

= **intervertebral discs**

make vertebral column flexible rather than rigid

permits forward, backward, and some sideways movement

in the newborn the spinal column forms a "C" shaped curve

after ~ age 3 has a double "S" shape with 4 bends; cervical, thoracic, lumbar, pelvic

divided into 5 regions:

- **cervical**
- **thoracic**
- **lumbar**
- **sacral**
- **coccygeal**

all but last two are similar in structure:

- **body**
- **spinal process**
- **vertebral foramen**
- **transverse process**
- **superior and inferior articular process**
- **intervertebral foramen** between each pair separated by **intervertebral discs**
Cervical (7):
have transverse foramena
1st and 2nd cervical vertebrae are highly modified for movement of the head:
   atlas – holds head up
   no body or spinous process
   "yes" movement of head
   axis -- dens (odontoid process) – forms pivot
   "no" movement

Thoracic (12):
distinguished by facets smooth areas for articulation of ribs
each rib articulates at two places:
on one body of vertebrae
one on transverse process

Lumbar (5):
short and thick spinous processes
modified for attachment of powerful back muscles

Sacrum (5 fused):
triangular bone formed from fused vertebrae
sacroiliac joint – lots of stress

Coccyx (4-5, some fused):
tailbone

Appendicular Skeleton
arms and legs plus the bones that attach each to the axial skeleton (=girdles)
both have similar structure but:
arms sacrifice strength for dexterity and freedom of motion
legs sacrifice freedom of motion for strong support of the body

A. Upper Extremeties
shoulder (=pectoral girdle)
upper and lower arm
wrist and hand

Pectoral Girdle:
scapula & clavicle
only attached to trunk by 1 joint (between sternum and clavicle)
scapula is very moveable – acts as almost a 4th segment of limb
scapula rides freely and is attached by muscles and tendons to ribs but not by bone to bone joint
extensive flat areas of scapula are used as origins for arm muscles and trunk muscles

C. Ribcage

sternum { manubrium
   body (=gladiolus)
   xiphoid process

ribs: most joined to sternum by costal cartilages
   true ribs (7prs)
   false ribs (5prs)
   include floating ribs (2prs)

very shallow joint cavity (= glenoid cavity) for articulation of upper arm
clavicle is the most frequently broken bone in the body,
sometimes even during birth

Upper Arm:
humerus: longest and largest bone of arm
loosely articulates with scapula by head – glenoid cavity
   "ball and socket joint": allows movement in all directions
large processes of scapula, acromium and coracoid
   ⇒ have muscles which help to hold humerus in place

Forearm:
consists of two bones: radius & ulna
very mobile; adds to flexibility of hand
they are attached along their length by interosseous membrane
ulna:
   main bone of forearm
   firmly joined to humerus at elbow
   "hinge joint": allows only flexion and extension
large process = olecranon process, extends behind elbow joint
   acts as lever for muscles that extends forearm
**radius:**
main attachment of lower arm to hand
more moveable of two
can revolve around ulna to twist lower arm and hand

**Hand:**
attached by muscles mainly to radius provides great flexibility
made of three kinds of bones:

- **carpals**
  large # of rounded bones allows movement of fingers in all directions
  provide flexibility and ability to grasp things

- **metacarpals**
  form the “palm” of the hand
  rounded at proximal ends for flexibility
  attached to fingers as hinge joint

- **phalanges**
  simple hinge joints for grasping

**B. Lower Extremeties**
number and arrangement of bones in the lower limb are similar to those of the upper limb
lower limb they are adapted for weight bearing and locomotion, not dexterity

**Pelvic Girdle**
- **coxa** (os coxa, innominate bones)
  pelvis consists of a pair of coxa that articulate with sacrum
  rigid connection to axial skeleton; strength, not flexibility
  the two coxal bones forms large basin of bone
  \(\rightarrow\) receptacle for many internal organs
  as bipedal animals the pelvis must support most of the body weight
  \(\rightarrow\) viscera bear down on pelvic floor (common site of hernias)
  pelvis is funnel shaped; yet must remain large enough for the birth canal
  large flaring portion of pelvis = false pelvis
  smaller actual opening = true pelvis
  \(\rightarrow\) in women it is the actual space child must fit through
  pelvis is easiest part of skeleton to distinguish between sexes

pelvic bones are also the origin of thigh muscles and trunk muscles
each coxa is produced by fusion of three bones:

- **ilium** – upper, fan shaped
- **ischium** – bottom, the actual bone you sit on
- **pubis** – front
  the 2 pubic bones are joined by a pad of fibrous cartilage = pubic symphysis
  in women before birth it softens to allow expansion of birth canal

**Upper Leg = Thigh**
- **femur** the largest bone in body
  like the upper arm, the articulation between the pelvis and upper leg is a “ball and socket” joint
  head of femur fits in large deep socket = acetabulum of pelvis
  great strength, much less flexibility than humerous

- **patella** (=kneecap)
  a sesamoid bone (= bones found where tension or pressure exists; also in thumb and large toe)
  in tendons at knee joint; does not articulate directly with any other bone
  acts as kind of a bearing
  \(\rightarrow\) allows tendon to slide smoothly across knee joint

if patella is lost through accident or injury get ~30% loss of mobility and strength due to > friction

**Lower Leg**
- **tibia** (=shinbone)
  main bone, articulates with both femur and foot
  \(\rightarrow\) more strength, much less mobility than lower arm bones

- **fibula**
  thin & narrow, offers extra support for lower leg and foot

**Foot**
like hand, made of three types of bones:

- **tarsals**
  thick angular bones; must support all the weight of the locked together and immoveable
greatly limits the movement of the rest of the foot
  almost no dexterity compared to the hand

- **metatarsals**
  support most of the structure of the foot
  much less movement than metacarpals

- **phalanges**
simple hinge joints

**arches:** the tarsals and metatarsals are strung with ligaments to provide double arches

act as shock absorbers

arches also furnish more supporting strength than any other type of construction ≫ more stability

If ligaments and muscles weaken, arches are lost = flatfootedness = fallen arches,

→ more difficult walking, foot pain, back pain

high heels redistribute the weight of foot

→ throw it forward; ends of metatarsals bear most weight of the body instead of the arches

→ sore feet

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**Articulations (joints)**

**Articulations** = any place where 2 or more bones meet

joints hold bones together

some allow for some degree of movement

joints can be categorized into three general kinds by the **degree of movement** & their **structure**:

A. **Immoveable Joints** (= Synarthroses; “joined together”)

bones are joined by **fibrous connective tissue**

eg. sutures – only in skull

eg. gomphoses = teeth in socket

B. **Slightly Moveable Joints** (= Amphiarthroses; “on both sides”)

bones are joined by some kind of **cartilage**

eg. symphysis pubis

eg. intervertebral discs

eg. costal cartilage between ribs & sternum

C. **Freely Moveable Joints** (= Diarthroses; “through a joining”)

most complex joint structure; are actually **organs**, consisting of several tissues:

→ entire joint is connected by a **joint capsule** that continuous with the periosteum of each bone

→ end of each bone is padded with **articular cartilage**

→ the ends of both bones are enclosed by **synovial membrane**

→ joint cavity is filled with **synovial fluid**

→ often supported by **ligaments**

= cords of fibrous connective tissue that join bone to bone

ligaments bind bones together across joints but limit their range of motion

more elastic than tendons

→ sometimes includes fluid filled **bursae**

= synovial sacs spaced around joints between tendons or ligaments to cushion, reduce tension & friction

eg. hinge joint (fingers, toes, elbow)

eg. ball and socket joints (shoulder, hip)

**Exercise and Synovial Joints**

synovial fluid is warmed by exercise and becomes thinner

→ this is more easily absorbed by articular cartilage

→ provides more effective cushion against compression

this warmup and compression also helps to distribute nutrients to cartilage cells (nonvascular tissue) and squeeze out metabolic wastes

→ warm up is good for you
Skeletal Physiology

Composition of Bone

bone is active tissue:

→ 5–7% bone mass/week

- mature haversian canal systems are replaced up to 10x’s during a lifetime

→ equiv. of skeletal mass is replaced every 7 years

bone is the densest tissue in the body

→ only 20% water

bone has a grain just like wood:

- grain runs longitudinally for greatest strength

as bone is remodeled old bone is eroded to accommodate new bone but grain is preserved

matrix of bone consists of:

2/3rd mineral salts; mainly calcium & phosphorus

(CaPO₄, CaOH, CaCO₃; also Mg, Na, K)

- this matrix tends to accumulate toxic metals: lead & radium

→ bone cancer, leukemia

1/3rd collagen and proteins

this mixture of organic and inorganic components allow bone to be strong without being brittle

osteocytes = the cells of bone tissue

cells that secrete the matrix

2 kinds of bone cells:

osteoblasts = bone building cells

osteoclasts = bone destroying cells

Skeleton in Infancy & Childhood

parts of skeleton begin to form in 1st few weeks of development

- begins in fetus as cartilage template

once the cartilage is laid down, it begins to turn into bone by ossification

Ossification = conversion of cartilage or other connective tissue into bone by depositing calcium and other minerals

in longbones ossification begins 3rd month of development

centers of ossification in longbones:

legs proportionately longer vertebral column develops two additional curves (already had thoracic and pelvic curves)

cervical curve ~3mo; lifts head

lumber ~1 yr; standing, walking

Puberty

at puberty the sex hormones (estrogen & testosterone) begin to affect the process of ossification

leads to masculinizing and feminizing features of skeleton

facial features develop especially rapidly also:

- male deep and funnel shaped pelvis; whole skeleton larger and heavier

- female shallow, broader and flaring pelvis

limbs grow more slowly

estrogen and testosterone continue to help maintain skeletal health throughout adulthood

in teen years your skeleton gains about 50% of total bone accrual
smoking, especially in girl, dramatically slows that rate making them more susceptible to hip and vertebral fracture (~5% middle schoolers smoke)

**Adulthood: Bone Maintenance and Remodeling**

by early adulthood the skeleton has reached its maximum height
the skeletal system is strongest in early adulthood
bones continue to grow and remodel themselves throughout life
even after bone growth has stopped, osteoblasts and osteoclasts continue working
→ bones constantly adapting to stresses reaction to mechanical stresses
→ weak areas are strengthened
→ old bone is removed to reduce bulk
in adult these opposing processes balance each other out so bone neither grows nor shrinks

**The Skeleton as a Calcium Reservoir**
most calcium in body is contained in teeth and skeleton
acts as a mineral reservoir, esp for calcium, and phosphate
calcium is used in body for:
- muscle contractions
- nerve impulses
- synapses
- heart beat
- secretions
- blood clotting
- cofactors for enzymes
a supply of calcium must be constantly available for all these activities

**blood calcium homeostasis** is maintained by depositing or dissolving bone tissue via osteoblast & osteoclasts

Ca++ deficiency:
- severe neuromuscular problems
- hyperexcitability
- loss of function
Ca++ excess:
- Calcium deposits in blood vessels, kidneys and soft organs

**vitamin D**
needed for absorption of calcium by small intestine
deficiency: poor calcification deformed bones

**The Skeleton in Old Age**
as we age sex hormones gradually decline
sex hormones stim bone deposition, and decrease osteoclast activity
reabsorption outpaces growth
→ bone become brittle
shaggy margins, spurs, joint problems
too much bone loss may lead to **Osteoporosis**
= a group of diseases in which bone reabsorption outpaces bone deposition
bones lose mass and become more brittle
affects entire skeleton but esp spongy bone of vertebrae and neck of femur
most serious consequence is pathologic fractures esp in hip, wrist and vertebral column
also, as bones become less dense they compress like marshmallows
→ results in **kyphosis**
→ exaggerated thoracic curve
(widow’s hump, dowager’s hump)
bone loss is especially severe in post menopausal women (esp caucasian women)
menopause causes sharp reduction in **estrogen**
smoking also reduces estrogen levels
by 70 yrs the average white woman has lost 30% of her bone mass (some up to 50%)
not as drastic in men
→ bone loss begins ~60 yrs and seldom exceeds 25% loss
suggestions:
need good bone mass by 35 or 40
plenty of weight bearing exercise, esp before menopause
good calcium uptake (850-1000 mg/d) early in life, esp 25-40 fluoro
dated water helps harden bones
don't smoke
hormone replacement therapy only slows loss, doesn't replace
lost bon -No longer recommended, too dangerous

Disorders of Skeletal System

1. Fractures
   repairs more slowly than skin; up to 6 months
   a. clot (hematoma) formation
      hours
      broken blood vessels, damaged tissues, bone cells die
   b. soft callus (fibrocartilage)
      days
      growth of new capillaries
disposal of dead tissue
   c. bony callus
      weeks
      spongy bone tissue grows around area and replaces
fibrocartilage
      join two pieces firmly together
   d. remodeling
      months
      dead portions of original area reabsorbed
      compact bone replaces spongy bone
      ends are remodeled to blend in
      usually thickened area remains
      misset bones may heal crooked
      but weight bearing bones usually reassume proper shape
      elec current speeds calcification and repair
      new synthetic materials may soon be useful in replacing missing
      bone

2. Vertebral curvature
   normally spine has two "S" shaped curves
   provides flexibility and resilient support
   several types including:
   scoliosis – abnormal lateral curvature
   may appear spontaneously
   or be result of polio, rickets or TB

3. Osteoporosis
   bones lose mass and become more brittle
   group of diseases in which bone reabsorption
   outpaces bone deposition
   affects entire skeleton but esp
   spongy bone of vertebrae and neck of femur
   esp in post menopausal women
   sex hormones
   stim bone deposition,
decrease osteoclast activity
   menopause – sharp reduction in sex hormones
   esp post menopausal women (esp caucasian women)
   by 70 yrs the average white woman has lost 30% of her bone
   mass (some up to 50%)
   not as drastic in men
   bone loss begins ~60 yrs and seldom exceeds 25% loss
   smoking also reduces estrogen levels
   low body fat reduces estrogen production by ovaries in young
   female runners and dancers
   most serious consequence is pathologic fractures
   esp in hip, wrist and vertebral column
   also, as bones become less dense they compress like
   marshmallows
   results in kyphosis ➔ exaggerated thoracic curve
   (widow's hump, dowager's hump)
   suggestions:
   need good bone mass by 35 or 40
   plenty of weight bearing exercise, esp before menopause
   good calcium uptake (850-1000 mg/d) early in life, esp 25-40
   fluoro
dated water helps harden bones
don't smoke
   hormone replacement therapy only slows loss, doesn't replace
   lost bone
   -No longer recommended, too dangerous

4. Rickets
   childhood disease: bowed legs, deformed pelvis,
due to Vit D (or Ca++) deficiency during growing years
   body unable to absorb calcium from intestine
   reduces calcification – bones stay soft

5. Osteoarthritis
   most common age change is degeneration of joints
   ➔ wear and tear arthritis
   rarely occurs before age 40; affects 85% of those over 70
   as joints age get gradual softening and loss of articular cartilage
   bone formation at margin of articular cartilage
   as cartilage becomes roughened by wear, joint movements may
   be accompanied by crunching or cracking sounds (=crepitus)
affects especially fingers, intervertebral joints, hips and knees
bony spurs may form as cartilage wears away → deform joint
interfere with movement, pain

6. Rheumatoid Disease
far more severe than OA
is an autoimmune attack against synovial membrane
inflammation of synovial membranes and degeneration of
cartilage
synovial membranes fill with abnormal tissue growth =
granulation tissue
may erode articular cartilage, bones and ligaments
mainly small joints of body; wrists, ankles
tends to flare up and subside periodically
affects women far more than men
typically begins between age 30 – 40
no cure, but can be slowed with steroids, cortisone, etc

7. Osteomyelitis
any infection of bone, cartilage or periosteum
localized or general
usually bacterial

8. Ruptured (herneated) disc
intervertebral discs pad vertebrae
with age outer layer thins and cracks; inner layers less firm
extra pressure can cause rupture
= herneated disc: pain, numbness, partial paralysis

9. Gout
group of diseases characterized by elevated uric acid in blood
forms sodium urate crystals in synovial fluid causing severe pain
exacerbated by alcoholism

10. Bursitis
inflammation of bursal sacs around joints
fills with fluid
usually caused by blow or friction
="housemaid's knee"
="water on the knee"

11. Tendonitis
inflammation, usually due to overuse

12. Achondroplastic Dwarfism
spontaneous mutation of genes, not necessarily from parents
long bones of limbs stop growing in childhood while growth of
other bones is not affected
→ results in short stature but normal sized head and trunk
not same as pituitary dwarfism, only certain cartilage cells are
affected

13. Polydactyly & Syndactyly
too many or too few fingers and toes

14. Hip Fractures
329,000/yr in US (2007)