GENERAL ANATOMY

Introduction

terminology, planes, directions;
general arrangement of the human body
The levels of structural organization are chemical, cellular, tissue, organ, system, and organismal.
Cartilago chondros

chondrocytes (isogenetic groups), tough; intercellular matrix, fibrills

perichondrium (nutrition, fibers growing from it marginate chondrons)

hyaline – glass-like, tough (collagen II, proteoglycans glykosaminoglykans, chondroitinsulphate, keratansulphate) 1.5 kg/cm²

elastic – spring-like (elastin)

fibrous – very tough, even firm (collagen I)

Hyaline cartilage covers joint surface
Haversian system

Osteon complex

Haversian, interstitial and superficial osteons (lamellar arrangement)

Alfred Wilgelm Volkmann
1800-1877, German anatomist in Halle

Clopton Havers (born in Stambourne, Essex 1657 - 1702), English physician
Osteon

Structural unit of the osseous tissue, composed from the concentric layers - lamellae (lamellae); between neighboring lamellae are positioned osteocytes.

Haversian (central) canal: narrow canal in the axial osteon part; vessels are inside.

With perforating or Volkmann canals oriented against periosteum.

Lacuna (cave) small space between neighboring lamellae.

Osteocytes osseous cells located in the lacunae.

Clopton Havers (born in Stambourne, Essex 1657 - 1702), English physician.
Osteons are arranged in a manner to resist the stresses and strains to which bone is exposed.

Osteon categories
(criterion: types of lamellae)

Superficial lamellae
Interstitial lamellae
Haversian lamellae
Lamellae making trabeculae inside spongy bone
Osteon growth
BODY SYSTEMS
GENERAL ANATOMY
OSTEOLoGY & ARTHROLOGY

BONE AS ORGAN

OS, OSSIS, OSSA GR.
All bone tissues are able to change its structure as the result of the stresses to which is subjected.

Functions of Bone Tissue
1. Supports soft tissues and provides attachment for skeletal muscles.
2. Protects internal organs.
3. Assists in movement together with skeletal muscles.
4. Stores and releases minerals.
5. Contains red bone marrow, which produces blood cells.
6. Contains yellow bone marrow, which stores triglycerides (fats).
Bones:
long
short
flat

Pneumatic
Macroscopic aspects of bone structural categories:

- dense compact bone (is formed by substantia compacta mutually compressed osteons)

- Spongy, cancellous or trabecular bone (is formed by substantia spongiosa and trabeculae)

Microscopic aspects of bone structural categories:

- primary, fibrillar (felt-like) bone (contains irregularly arranged fibers and more osteocytes; can be found in healing fractures)

- secondary, lamellar bone (arranged osteons)
Bone fractures
Opened,
Comminuted,
Impacted,
Greenstick, Pott’s and Colles’s fractures

(a) Open fracture
(b) Comminuted fracture
(c) Greenstick fracture
(d) Impacted fracture
(e) Pott’s fracture
(f) Colles’ fracture
**Substantia compacta et substantia spongiosa**

cavitas medullaris – medulla ossium – red, yellow, grey

periosteum – endosteum

Substantia compacta et substantia spongiosa
Medullary cavity

**Medulla ossium rubra**
- reticular fibers, stem blood cells
- megakaryocytes, capillaries

**Medulla ossium flava**
- a few reticular fibers, fat cells; from the 20 yr is inside all bone cavities

**Medulla ossium grisea**
- reticular fibers, a few fat cells; typical for senile age

Cavity is formed from fetal week 5
Kostní dutina - bone cavity

1 – 20 rok year

1 – 60 rok year

Stirnhöhle
(Sinus frontalis)

Siebbeinzellen
(Cellulae ethmoidales)

Keilbeinhöhle
(Sinus sphenoidalis)

Kieferhöhle
(Sinus maxillaris)

Nasenhöhle
(Cavitas nasi)

Pneumatizace VDN
Bone coverings

Periosteum (external bone surface)
- outer fibrous layer
- inner cellular layer

Endosteum (is lining bone cavity)
incomplete thin fibrocellular layer ⇒ producing matrix ⇒ purpose?
Periosteum

Endosteum

Fibrous layer

Vessels inside
Volkmann's canals

cambium

vessel

William Sharpey 1802-1880, English anatom in Edinburgh
Vascular supply of the bone

a. nutricia (nutriens)
aa. metaphysariae
aa. epiphysariae

Periostal vessels and intramuscular arteries, form anastomoses with medullary arteries
Developmental terms in relation to the bone growth

**epiphysis** *(bone end usually covered with articular cartilage)*

**metaphysis** *(end of diaphysis; there are special nutritional arteries)*

**physis** *(epiphysial cartilage, growth plate)*

**diaphysis** *(middle bone part – shaft)*

**circumferential structures:**

periosteum    endosteum
Epiphysis — supports articular cartilage, partially covered by periosteum. It is separated from metaphysis by growth plate. After birth is formed by hyaline cartilage, where ossifying centre can be seen. Ossification starts in the centre. Other ossification can be seen below periosteum (appositional growth).
Based on the macroscopic criteria epiphyses are categorised:

“proper” epiphyses – also pressure epiphyses; they have articular facets and are mostly under axial pressure.

and apophyses – also tensile epiphyses; they are located out of joint and serve as muscular insertions.
Following vascular supply there are: epiphyses type A, intraarticular – epiphyses in proximal parts of the femur and radius, they have intraarticular location, their vessels are inside articular capsule.

Epiphyses type B, extraarticular - other epiphyses; they have nutritional vessels out of articular capsule.
**Metaphysis**
is concurred with hypertrophic zone; there vessels are ingrowing to bone and calcification of the matrix starts; invaded osteoblasts make there secondary spongy-like bone.

**Diaphysis**
middle bone part (corpus or body); there stem-like vessels (aa. nutritia) are ingrowing to bone.
Ossification

Desmogenous ossification
– from the connective tissue – flat bones

Chondrogenous ossification
from the cartilaginous primordium – long bones

Perichondral
(superficial ossification from the perichondrium)

Enchondral (inside cartilaginous matrix)
<table>
<thead>
<tr>
<th>Desmogenous, Endesmal, Fibrous</th>
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<tbody>
<tr>
<td>Chondrogenous</td>
</tr>
<tr>
<td>a Perichondral</td>
</tr>
<tr>
<td>b Enchondral</td>
</tr>
</tbody>
</table>

Cells produce acid phosphatase; this enzyme hydrolyses calcium salts and support formation of the calciumphosphate, which is clotted inside bone.
Final Bone formation – ossification

intramembranous (desmogenous) and endochondral (cartilaginous)

Primary ossification center
7th – 12th week

Secondary ossification center after birth

Principle: incorporation of the calcium particles into the tissue

Primary center (for diaphysis, bone body, shaft)

Secondary centers (for epiphyses, bone ends, joint facets)

Diaphyseal-epiphyseal junction = epiphyseal cartilage plates
Rezerve zone
Synthesis and storage of the nutritional components

Proliferative zone
Proliferating chondrocytes form columns (in the base of the column there is mother chondroblast)

Hypertrophicic zone
Cells are prepared for calcification

Zone of the calcification where vessels are massively ingrowing
Ossifying groove of Ranvier 1873

Dense collar made from poorly differentiated cells around cartilaginous proliferative zone. It contains fibrocytes and serves as protection of the growth plate.

Ossifying ring of Lacroix 1950

Dense collar made from osteoid tissue. It protects growth plate against lateral pressure.
Growth plate – (physis), highly differentiated structure, contains reserve cartilage from epiphysis and diaphysis and proliferative cartilage from diaphysis; supports growth of the long bones to length; acts in growth of the flat and short bones.

Plate crosses bone transversally; it is wawed and looks like as a cone, wider to metaphysis.

About year 1 – 2 is undulating (it is wawed and bulged against metaphysis). Thicker plate is sign of accelerated growth.
Osteoclasts are developed directly from the mesenchyme cells.

Osteoblasts convert to osteocytes (prebone cells) – concentric lamellisation (haversian systems, osteons).

Intramembranous bone ossification

growth from the suture

Bone spicules

Parietal bone

Frontal bone

Occipital bone

Nasal bone

Maxilla

Cervical vertebrae

Mandible
Accretion of the osseous lamellae

Rearrangement of the Haversian system; osteoclasts are penetrating to the lacunae.
Bone remodelation
- resorbtion and apposition
through all life

Bone growth
- aposition in the
growth plate
to puberty only

Gonadal hormones reduce activity
Thyroxin stimulates
Vit. A – supports osteoblasts and osteoclasts
Vit. C – support collagen fibers
Vit. D - stimulates ossification
Parathormon – increases activity of osteoclasts; support loose Ca, Ph
Calcitonin – reduce resorption
Růst dlouhých kostí do délky
Growth of the long bones

1. year

5. year
Growth to width  Apposition

Desmogenous - Bone diameter is increased

Osteoclasts remove bone tissue in direction from the medullary cavity; osteocytes produce new bone tissue on the outer bone surface
Remodellation depends on age and weight:
Growth of the skull. The height of the cranial vault (distance between planes a and b) is drawn the same in both the infant and adult skulls. Growth of the skull occurs almost exclusively within the bones of the facial region.
Formation of the air bone cavities - sinuses

Ingrowth of the epithelial tissue - see arrows
Nerovnoměrná a zpomalená osifikace obličejových kostí vede k deformitě

Hypodifferentiation of the bone primordia results in skeleton deformities
All bone tissues are able to change its structure as the result of the stresses to which is subjected.

Bone adaptability

Skeleton is renewed/rebuilt every 5 years (= average; specifics depend on region)
Joints:

Juncturae ossium (synarthrooses, diarthrooses)

**Synarthrosis** – fibrous connections

**Diarthrosis** – joint connections (articulatio synovialis)

Characteristic:
Structures where two or more structures are connected

Definition:
Structures, where bone – bone, cartilage cartilage or bone cartilage junctions are realised
A. Functional =
   based on the degree of movement they permit
   Synarthroses  – immovable joint
   Amphiarthroses – slightly movable joint
   Diarthroses    – freely movable joint

B. Structural =
   based on presence or absence of a joint cavity
   Fibrous        – no joint cavity, bones held together by fibrous tissue
   Cartilaginous  – no joint cavity, bones held together by cartilage
   Synovial       – joint cavity, bones held together by articular capsule
## Synarthrosis /fibrous and cartilaginous connections/

<table>
<thead>
<tr>
<th>Junctura fibrosa</th>
<th>Syndesmosis</th>
<th>Ligamenta</th>
<th>all extracapsular ligaments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gomphosis</td>
<td></td>
<td>Syndesmosis dentoalveolaris</td>
</tr>
<tr>
<td></td>
<td>Membrana</td>
<td></td>
<td>Membrana interossea antebrachii et cruris, intercostalis externa et interna, obturatoria</td>
</tr>
<tr>
<td>Sutura</td>
<td>Sutura plana, squamosa, limbosa, serrata et denticulata, Schindylesis</td>
<td>33 cranial sutures</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Junctura cartilaginea</th>
<th>Synchondrosis</th>
<th>Leběční synchondrozy, epifyzární chrupavky, art. costochondrales, interchondrales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symphysis</td>
<td></td>
<td>Symphysis intervertebralis, pubis, sacrales, menti, manubriosternalis, xiphisternalis</td>
</tr>
<tr>
<td>Junctura ossea</td>
<td>Synostosis</td>
<td>Os coxae (mezi os ilium, os ischii, os pubis), os sacrum</td>
</tr>
</tbody>
</table>
Fibrous joint:

Characteristics:
Bones are joined by fibrous tissue, very little or no movement is possible.

Examples:
Sutures among the skull flat bones, inferior tibiofibular joint, fusions among vertebrae in a sacral bone.
Types of fibrous joints:
- Sutures
- Syndesmosis
- Interosseous membranes
- Gomphosis

Sagittal, squamous, plana.
Cartilaginous joint:

Characteristics:
Primary: plate or bar of hyaline cartilage between epiphysis and diaphysis
Secondary: bones are joined by fibrocartilaginous tissue, a little movement is possible

Examples: vertebral column, Symphysis pubis
Body of sternum

Sternochondral synovial joints with fibrocartilagenous articular surfaces (sometimes synarthroses with fibrocartilage bond)

Interchondral synovial joints

Xiphoid process

Interchondral ligaments (interchondral syndesmoses)

Costochondral synarthroses with adherent fibrocartilagenous plate; periosteum and perichondrium continuous
Synovial joint:

Characteristics:

They have **synovial cavity** = space between two bones

Articulating bone ends are joined by **fibrous capsule** occupied with **synovial fluid**; articular surfaces of the bones covered by a thin hyaline cartilage

Always **synovial joints** = mono, di-, and triaxial

Derivatives: ligaments (cruciate ligaments), fat pads, articular discs (menisci), bursae, capsular articular muscles
Simple joint

Compound joint

Synovial joint
Joint cartilage

Superficial flat layer – a few cells and fibers are parallel with surface
Arcadial layer – fibers are arcuate and are ingrowing to the bone
Third layer – ball –like chondrocytes and plexiform fibers  
(1% of all cartilage)
Deep layer – big chondrocytes and hypertrofied matter
Various in thickness; nutrition from the synovial fluid; is disintegrated without pressure;
Small pores about 6 nm; resists 6-8 kg/cm²
Hygroscopic - about 60% of fluid can be released back to joint cavity during pressure
Synovial fluid = plasma
dialysate = hyaluronic acid = cells

2-4 ml; some thousands cells in 1 mm³

60 cells/1 cmm; 15-25 gr/l; glucose 66 mg/100 ml; HA 2.7 g/l; pH 7.4 - 7.7
Synovial membrane
membrana synovialis:

- Fibrous – a few cells, intercellular matrix
- Areolar – 2-3 layers of cells, able to shift
- Adipous – 1 layer, cover adipous folds

Villi synoviales:

- Poorly differentiated mesenchymal origin, good regeneration

Intraarticular folds (plicae)

Drobné krystaloidy procházejí rychle;
Plyny rychle dovnitř dutiny kloubu;
velké proteiny do mízních cév
Capsula articularis
Joint capsule

Membrana fibrosa, stratum fibrosum

Membrana synovialis, stratum synoviale

Membrana synovialis is not covering joint cartilage and discs
Special structures inside synovial joint

- **Labrum articulare /joint brim/**
- **Fibrocartilago /fibrocartilages/— increases joint fossa and supports capsule**
- **Disci et menisci articulares /articular discs and menisci/ — are balancing different forms of the articular facets; they are elastic**
- **Ligamenta /ligaments/ - capsular, intracapsular (intraarticular), extracapsular (extraarticular)**
- **Bursae synoviales /synovial fluid sacs/**
- **Musculi articulares /articular muscles/ - protect compression of the capsule**
Ligamenta * Bursae * Disci
mm. articulares
Discus articularis
Articular disc
meniscus

Vyrovnávají zakřivení ploch - they compensate congruency of the joint surfaces
Podporují rozsah pohybu - they support extent of the motions
Zabraňují turbulenci - they decrease turbulence
Úhlový pohyb
Slewing angle motion

Translační pohyb
Translation motion
Closely packed synovial joint
Loosely packed synovial joint
Vascular & nerve supply

Hilton’s law

Sensory nerves supplying the joint also supplies the muscles moving the joint and skin overlying the insertion of these muscles.

John Hilton 1805-1878, English surgeon

**vessels:** rete articular from surrounding arteries; capillaries closely to surface

**lymph vessels:** blind beginnings; deeply in capsule

**nerves:**
- Centripetal sensory fibers
  - Informations about position, direction, motion range and tension (= proprioception)
  - Information about pain and pressure
- Centrifugal autonomous fibers (diameters of vessels are regulated)
Vascular and nervous supply in the joint

- **vessels**: rete articulare from surrounding vessels, capillaries are closely following joint capsule

- **lymph vessels**: blindly begin in the deeper layers of the capsule

- **nerves**:
  - centripetal sensory fibers
    - Information about position, direction of movements, angular speed of movement, tension
    - Information about pain and pressure
  - centrifugal autonomous fibers (regulation of the vascular diameters)
Dehiscence - spacing of cells in tissue and cummulation of fluid in intercellular cavities
Degeneration – loose of intercellular fluid; fibrills become nude – fibrilation of cartilage
and proliferation – growth, cleavage and ossification of cells in transitional zone of synovial membrane; osteofytes are created
Factors that keep the articular surface of synovial joint held together closely:

Fit of the articular bones:
e.g. interlocking at hip joint

Strength of surrounding ligaments:
e.g. especially important in the hip joint

Tension of muscles around the joint:
e.g. musculotendinous rotator cuff of shoulder joint
Movements Stabilizing and limited factors

Apposition of soft parts
Tension of ligaments
Configuration of the articulating bones
Three Types of Motion at Synovial Joints

- **Linear motion** = gliding

- **Angular motion**:  
  - flexion, extension, hyperextension  
  - ab-, adduction  
  - circumduction

- **Rotation**:  
  - left - right, internal or medial, external or lateral  
  - supination, pronation
Types of simple diarthroses
(following form of the articular surfaces)

1. Sphaeroidea (ball and socket: arthrodia, enarthrosis)
2. Ellipsoidea (ellipsoidal)
3. Sellaris (saddle)
4. cylindroidea - (ginglymus: condyloid hinge-like)
5. cylindroidea - trochoidea (pivot)
6. cylindroidea – trochlearis (hinge, pulley-like)
7. cylindroidea - plana (gliding)
8. cylindroidea - amphiarthrosis (tough, firm)
Six types of Diarthroses

1 Ball & Socket joint
1 Ellipsoidal joint
1 Gliding (plane) Joint
2 Hinge Joint
3 Pivot Joint
5 Saddle joint
Ball and Socket Joint

Ball-and-socket joint: shoulder joint, hip joint

Ball like surface of bone 1 fits into cuplike depression of bone 2

Biaxial, multiaxial
Ellipsoid joint

Ellipsoid (condyloid) articular faces

Oval shaped condyle of bone 1 fits into elliptical cavity of bone 2

- Angular motion in two planes – flexion/extension and duction

biaxial

Example:

- Radiokarpal joint (wrist)
- Atlantoaxial joint
Saddle joint

Articular surfaces shaped like saddle and rider
Modified condyloid joint
Extensive angular motion without rotation
Also between malleus and incus

Biaxial

Saddle joint: carpometacarpal joint of the thumb
Condyloid joint - *ginglymus*

Permit flexion, extension, very poor adduction, abduction, circumduction; stabilised by collateral ligaments.

**monoaxial**

Example. Interphalangeal joint
Pivot Joint

rotation

Projection of bone 1 articulates within ring of bone 2

Also found in proximal ends of ulna and radius

⇒ pronation and supination

monoaxial

Pivot joint: atlantoaxial joint
**Hinge (trochlear) Joint**

Convex surface of bone 1 fits into concave surface of bone 2

- monoaxial

Examples: humeroulnar joint, interphalangeal joints
Gliding (plane) Joint

Flat articulating facets
also found between carpals and tarsals
• only slight movement - rotation prevented by tight capsule

Monoaxial

Plane joints: sternoclavicular joint
acromioclavicular joint
Articulatio cylindroidea - amphiarthrosis

firm

Between proximal end of the ulna and radius ⇒ pronation and supination

monoaxial ??

example: sacroiliac joint
position of rest

flexion of thumb

abduction of thumb

extension of thumb

adduction of thumb

position of function

opposition of thumb
END