SYSTEM OF SKELETAL JUNCTIONS
SYSTEMA ARTICULARE, SYNDESMOLOGIA

I. GENERAL ARTHROLOGY

The junctions between adjacent bones are described as articulationes (joints). We differentiate two elementary types of bone connections:

- **Fluent connection** using connective tissue – **synarthrosis**. According to the type of connective tissue, we differentiate articulatio fibrosa (syndesmosis) connection using ligaments (connective tissue), articulatio cartilaginea (synchondrosis) connection using cartilage, and synostosis – secondary connection using bone tissue.
- **Joint connection** with contact – **articulatio synovialis (diarthrosis).**

Synartroses – Synarthrosis

Connecting bones don't have created articulations areas; understandably the joint capsule is also missing. Movements in these synarthroses are limited, mostly minimal in its extent, or they are connections practicably immobile.

Articulatio fibrosa – syndesmosis is connection using connective tissue. The simplest type of this connection is a connection using ligaments (***ligamenta***) – e.g. connection of adjoining vertebral arches, or using fibrous membranes – e.g. membrana interossea antebrachii. Fibrous connection of the skull plane bones is indicated as suture (***sutura***). The layer of connective tissue between the edges of adjoining bones here is minimal. The sutures enable the growth of skull bones approximately up until the age of 20 years. In adulthood the sutures begin to obliterate, in senium, most skull bones connect together through synostosis. After modification, we distinguish three elementary types of sutures:

- *serrated suture (sutura serrata).* Margins of adjacent bones are indented to the joint of being serrated and bone margins interlock together (e.g. sutura sagittalis, sutura lambdoidea)
- *squamous suture (sutura squamosa).* Squama temporalis with its thinned margin overlap sideways intersected margo inferior of ossis parietalis
- *smooth suture (sutura plana seu levis).* Margins of connecting bones are straight, and mutually adjoin together (e.g. bone connection in orbita wall)

In group of syndesmoses also includes wedging (***gomphosis***), helping the tooth being inserted into alveolus dentalis of the jaw (for further details - see Teeth, chapter Digestive system).

Articulatio cartilaginea – synchondrosis is a connection using a cartilage (gristle), which is being inserted between connecting bones. For example, hyaline gristle is inserted between rib and sternum, as an example the fibrous cartilage (fibrocartilage) creates symphysis pubica between both pubic bones or it can create an intervertebral disc between the bodies of adjacent vertebrae. Synchondroses are found in those sites of skeleton, where the pressure and traction are changing. Movements in these connections are limited, alternatively these connections are practically immobile. During the development, between diaphyses and epiphyses of long bones there are growth cartilages, in which the bones are growing lengthwise. These cartilages ossify after puberty.

Synostosis is a connection, in which originally independent bones (or its parts) grow together with the help of bone tissue (e.g. sacral bone, os coxae etc). In senium the skull sutures obliterate (see above). These physiological synostose must be differentiated from pathological synostoses, when for example in consequence of inflammatory processes; the bones grow together (ankylosis) in joints that were moveable originally.

Joint – Articulatio synovialis. Diarthrosis

Joint, articulation, as a rule, is a moveable connection of two or more bones, which meet together with the help of connection (articulation) areas, covered by a joint cartilage (gristle). On each joint we differentiate contact surfaces (facies articulares), joint capsule (capsula articularis), joint cavity (cavitas articularis) and supportive joint apparatus.

Joint faces – facies articulares have various shapes, as a rule, one is convex and is called a joint head (caput articularis), the other one is concave, and it is called an articular fovea (fossa seu fovea articularis). The contact surface is created by a layer of compact bone on its surface, and it is covered by a layer of joint cartilage (cartilago articularis). The joint cartilage is mostly created by a hyalite gristle, in some cases by fibrous cartilage (e.g. in a sternoclavicular joint). The thickness of a joint cartilage runs between 0,5 to 5 mm (thickness of joint cartilage must be taken into account during an assessment of X-ray images). The gristle has a smooth surface enabling mutual shifting of contact surfaces. In mostly cases the contact surface of the head corresponds by its shape and size to the contact surface of the pit area, alternatively the shape or size imbalance is balanced out with the help of accessory joint

apparatus (see next).

Joint capsule – capsula articularis has a cuff-shape, which typically grows together to the margins of joint contact surfaces, and closes the joint (and therefore it separates the joint from its surrounding). In some cases, the attachment of joint capsule is running away from the margins of joint contact surfaces. The joint capsule is then freer, and the joint cavity is more spacious. The joint capsule is created by the two layers of connecting tissue. The external layer (membrana fibrosa) is firm, and is created by fibrous connective tissue with many colagenous fibres. This layer has the important task of firming up the joint connection. Fibrous layer transforms itself into loose porous connective tissue in the direction of joint cavity (membrana synovialis). This layer is thinner, it contains vessels and nervous fibrous, and often protrudes into the joint cavity in a form of folds (plicae synoviales) or villi (villi synoviales). Membrana synovialis produces into joint cavity a synovium (synovia), which participates both on nourishment of joint cartilages, and also has significance for joint movement. It diminishes friction and it improves adhesivity of joint cartilages by moistening them.

Joint cavity – cavitas articularis is a fissure between joint contact surfaces and a joint capsule, and is filled by synovia. It changes into a real cavity only during pathological states, when it is filled with blood, exudates or by pus. During an arthroscopical examination it can be filled with air.

Special (accessory) joint apparatus

- *Joint ligaments – ligamenta articularia*, are bands of fibrous gristle various latitude and length, which reinforce the joint capsule and influence movements within the joint (enforced ligaments, leading ligaments, obstructing ligaments). Based on their relationship to the joint, we divide them into three groups: ligamenta capsularia reinforcing the joint capsule and grow together with it, ligamenta intracapsularia (intraarticularia) run inside joint cavity. Ligamenta extracapsularia are located in the surrounding of the joint.
- *Cartilaginous labra – labra articularia* are bands of cartilaginous gristle, which enlarge and deepen joint pits at some joints (e.g. shoulder joint, and iliac joint).
- *Cartilaginous plates – disci et menisci* are plates of cartilaginous gristle, which are located intraarticularly. Discus articularis completely separates (septates) the joint cavity and divides it into two independent cavities (e.g. articulatio

temporomandibularis). Meniscus doesn't separate the entire joint cavity. It is of a falciform shape, its external circumference is higher, it is sharpened in the direction into joint (in articulatio genus). We find them in joints with incongruental joint surfaces (joint surfaces do not have the same shape and size). Both formations also help to diminish strong impact, and the discus in temporomandibular joint enables simultaneous performing of the two different movements.

- *Synovial burses – bursae synoviales* are great cavities of various sizes in close proximity of the joints, which are filled by synovia. They are bordered by a fibrous capsule, which has an analogical structure to the joint capsule (membrana fibrosa and membrana synovialis). They lie in places, where muscles or ligaments attach themselves immediately to the joint capsule, and diminish friction (facilitate movement). In some cases they can communicate directly with the joint cavity.

Division of joints

The joints are classified based on numerous criteria. The most usual classification is according to the number of contact bones, according to the shape of contact surfaces, according to the level of movement and according to the number of movement axis and basal movements.

I. Classification (types) of joints according to the number of connecting bones

- **Simple joint – Articulatio simplex**. Only two bones are connecting in the joint (e.g. shoulder joint).
- **Composed joint – Articulatio composita**. In a composed joint more than two bones meet together (e.g. elbow joint) or discus or meniscus articularis is inserted into the joint (e.g. temporomandibular joint, knee-joint).

II. Classification of joints according to the shape of contact surfaces

1. Tough joint with irregular surfaces (**amphiarthrosis**). Uneven contact surfaces disable their mutual shifting (e.g. articulatio sacroiliaca).
2. **Flat joint – articulatio plana**. Contact planes are straight, and sliding on one another during movement (e.g. tiny joints between processus articulares vertebrarum).

3. **Spherical joint – articulatio spheroidea**. Joint planes (head and pit) represent spherical segments. Spherical joints are very moveable.
    - *spherical free joint – arthrodia* has a shallow and relatively small pit, head is significantly larger. Therefore the movements have great range (e.g. shoulder joint).
    - *spherical joint restricted – enarthrosis* has a deepened pit, and head interlocks deeply into the pit. Range of its movements is therefore restricted (e.g. iliac joint).
4. **Elipsoidal joint – articulatio ellipsoidea**. Contacts surfaces have mostly ovoidal (elipsoidal) shape, which enable movement around the two axis (e.g. radiocarpal joint).
5. **Sellar joint – articulatio sellaris**. Contact planes of both articulating bones have a shape of horse saddle. Each of them is concave in one direction, and in convex in the other direction, therefore both bones perfectly interlock into each other. Movements are possible along two mutually perpendicular axis (e.g. carpometacarpal joint of thumb).
6. **Cylindrical joint – articulatio cylindroidea**. Contact surfaces form segments of the jacket of the cylinder (one plane creates a convex section of cylinder, the second plane is adequately excavated). The movement is possible along one axis, which corresponds to the axis of the cylinder. According to the positioning of cylindrical joint surfaces, we differentiate two forms:
    - *ginglymus.* Axis of movement is perpendicular to the longitudinal axis of bone (e.g. temporomandibular joint).
    - *wheel joint – articulatio trochoidea.* Axis of movement is paralel to the longitudinal axis of a long bone, bones are moving like a „door hinge“ (e.g. proximal radioulnar joint) .
7. **Trochlear joint – articulatio trochlearis.** Edge is on one of the joint surfaces and a leading groove is on the other (e.g. humeroulnar joint).

III. Types of joints according to the level of moveability, and according to the number of axis of movements

The direction of articular movement is given by the shape of joint surfaces. Range of the movement is determined by the ratio between the flat extent of the joint head and a pit, by osseous projections in the surrounding of a joint and by ligaments which can significantly restrict movement. Another factor is freedom of movement of joint capsule, and the amount and adaptation of muscles in the surrounding of a joint.

1. Joints with **minimum movement** (amphiarthrosis)
2. Joints with **sliding movements**. Only sliding, shifting is happening in joints (articulatio plana)
3. Joints with **rotational movements**
    - *one-axis joints*. Movement is possible only along one axis (e.g. flexion – extension) – cylindrical and trochlear joints.
    - *two-axis joints*. Movements are possible along two mutual perpendicularly axis (e.g. flexion – extension, abduction – adduction) – ovoidal and sellar joints .
    - *triaxial joints*. Movements are possible along three mutual perpendicular axis (flexion–extension, abduction–adduction, supination–pronation)

Combined joints are joints, which form a functional unit with another joint, such that in all joints adjoined this way the movements occur simultaneously (e.g. both temporomandibular joints, joints of vertebral column, some leg joints).

Elementary position of a joint means the position in a normal anatomical body position – while standing backwards with upper extremities lowered close to the body and palms inverted frontally.

Middle position of a joint is a position, in which is a joint capsule evenly relaxed, i.e. a position between possible marginal positions of a joint. The joint gets into such position in the state of health and by joint illness it is limited. Joint can also be immobilized (fixed) in middle position.

II. SPECIAL ARTHROLOGY

Columnal junctions – Juncturae columnae vertebralis

Vertebrae are connected by all elementary types of junctions. We differentiate between the junctions of adjacent vertebras and common junctions along the whole vertebral column.

1. Junctions of adjacent vertebrae

- **articulationes intervertebrales**. Joint surfaces are flat facies articulares located on against each other processus articulares of adjacent vertebrae. Orientation of joint surfaces is different in individual sections of vertebral column. In cervical column processus articulares are inclined sideways, in the thoracic column they are situated in the frontal plane, in the lumbar column they are in the sagittal plane. Each joint has its own individual joint capsule.
- **disci intervertebrales** represents synchondrotical connection between vertebral bodies. Cartilaginous plate is inserted between terminal planes of adjacent vertebrae. Its circumferential part (anulus fibrosus) is formed by a fibrous cartilage, and it slightly overlaps the margins of vertebral bodies. Central part – nucleus pulposus – is jelly–like, contains great amount of water, and it represents a spherical focus, around which adjacent structures shift during movement. There is 23 intervertebtal discs totally (the first is inserted between 2nd and 3rd cervical vertebra, the last between 5th lumbar vertebra and facies terminalis superior ossis sacri. The summary height of disci intervertebrales represents 1/5 to 1/4 of height of the vertebral column (1/14 of total body height).
- adjacent vertebrae are also connected using **syndesmotical system**. It is a system of fibrous bundles and membranes, which are being inserted between adjacent vertebral arches – ligamenta flava – (they omit the area of foramina intervertebralia). Ligamenta intertransversaria are stretched between adjoining processus transversi. Ligamenta interspinalia are connected with adjacent processus spinosi.

2. Junctions common for all vertebrae

- **ligamentum longitudinale anterius** is connecting to the frontal (anterior) side of vertebral bodies (from sacral bone to axis). It grows together with vertebral bodies, it is connected more loosely with disci intervertebrales.

- **ligamentum longitudinale posterius** runs inside the spinal canal (on its anterior side). This ligament is more firmly connected with disci intervertebrales, connection with vertebral bodies is looser.
- **ligamentum supraspinale** is stretched on the dorsal side of the vertebral column. It runs from crista sacralis mediana, it ascends cranially and it connects apex processus spinosi. In the area of cervical column it is cranially triangularly enlarged, and it attaches to crista occipitalis externa. This ligament is called ligamentum nuchae and it creates a sagittal septum between nuchal muscles. Dorsal margin of this ligament grows together with superficial fascia of nuchal region.

3. Synchondrosis sacrococcygea. Facies terminalis inferior ossis sacri and facies terminalis coccygis are connected with a layer of fibrous cartilage. This connection is reinforced using ligamenta sacrococcygea, which are laid out along the whole circumference of synchrondrosis.

Shape of vertebral column

The vertebral column originates by the junction of vertebrae, sacral bone and coccygeal bone. The individual parts of vertebrae are imposed upon each other in such way that column of vertebral bodies originates frontally, dorsally processus spinosi are imposed upon each other, alongside there are processus transversi. Foramina vertebralia being imposed upon each other results in incompletely closed **canalis vertebralis**, which cranially links to neurocranial cavity through foramen magnum, and caudally ends in hiatus canalis sacralis. Between the adjacent vertebrae, foramina intervertebralia originate by junction of incisurae vertebrales.

The vertebral column isn't straight; it is curved in the sagittal plane and in the frontal plane. Changing of lordoses – **lordosis** (curvature forwards) and kyphoses – **kyfosis** (curvature backwards) is typical for a human column. The reason for this formation is the upright body position of humans. Cervical lordosis is caused by traction of nuchal muscles. Though it is indicated as early as in the prenatal period, it is fully only developing in children in first months after birth (as soon as the child starts lifting his head). Lumbar lordosis is related to the activity of dorsal muscles, in connection with capability of child to stand and especially then to walk. Therefore it starts at the end of the 1st year. The mutually transition of lordose and kyphoses is fluent, with the exception of transition between the areas of lumbar and sacral

backbone. In this site there is a break and promontorium ossis sacralis creates accentuating, forward protruding edge (very mechanically exposed part of the spinal column) in this site.

The curvature in the frontal plane – **skoliosis** is not very prominent in physiological states. In right-handed individuals a mild physiological dextroscoliosis occurs in the area of thoracic backbone, in left-handed individuals it is called physiological sinistroscoliosis.

Movements of vertebral column

The general movements of vertebral column are directly related to the total movements of relatively little extent between single vertebrae. In vertebral column the possible movements are flexion (**lateroflexion, anteflexion, retroflexion**), **rotational** and **springy movements**. The individual segments of the soft backbone are very different when it comes to mobility. The most mobile section is the cervical column. In the area of thoracic backbone, flection movements are restricted due to adjacent ribs: predominantly rotational movements occur in here. In lumbar backbone, the sagittal position of facies articulares restricts rotational movements.

Junctions of thoracic cage. Juncturae thoracis

Articulationes costovertebrales

The rib is connected with vertebrae by two joints, which form a unit of movement:

a) Articulatio capitis costae. Contact surfaces – facies articularis capitis costae and foveae costales superior et inferior on adjacent vertebral bodies (on 10th, 11th and 12th thoracic vertebra there is always only one fovea costalis). Crista capitis costae of 2nd to 10th rib is in contact with discus intervertebralis. The joint capsule is attached to the margins of joint surfaces, it is rigid and it is reinforced from the front using ligamentum capitis costae radiatum. From crista capitis costae it runs to margin of discus intervertebralis ligamentum capitis costae intraarticulare.

b) Articulatio costotransversalis. Joint surfaces– facies articularis tuberculi costae and fovea costalis processus transversi. The joint capsule is attached to the margins of joint surfaces areas. The junction is reinforced using ligamentum costotransversarium (fills in the slit between processus transversarius vertebrae with collum costae), ligamentum costotransversarium laterale (connects the lateral end of processus transversus with

tuberculum costae) and ligamentum costotransversarium superius, which connects collum costae with transversal process of more cranially located vertebra. Processus costarius of first lumbar vertebra, is connected with the 12th rib using ligamentum lumbocostale.

Both named joints represent a functional unit, in which the movement occurs along the common axis, passing through collum costae. During the movement the frontal end of rib is rising or dropping down, and thus the shape of the chest is changing.

Juncturae sternocostales are junctions between frontal ends of the ribs and sternum:

a) articulationes sternocostales – costal cartilage (joint head) is in contact with incisura costalis sterni (at 2nd to 5th rib).The joint capsule is attached to the margins of joint surfaces. Inside of 2nd sternocostal joint there is ligamentum sternocostale intraarticulare.

b) synchondrosis sternocostalis – costal cartilage grows together with incisura costalis sterni. This type of junction is typical for the 1st rib it also often occurs at 6th and 7th rib.

Juncturae sternocostales are reinforced using ligamenta sternocostalia radiata, which in a ray-shaped way is running from costal cartilage to sternum on both the anterior side and the posterior side. A continuous membrana sterni anterior et posterior are created in this way.

Juncturae intercostales (junctions of adjacent ribs)

The ribs are connected together using:

a) Artt. interchondrales are joints, in which connects using joint surfaces, processus of costal cartilages of the 5th to 9th rib. The tight joint capsule is affixed on margins of joint surfaces.

b) Membranae intercostales are connecting adjacent ribs.

Membrana intercostalis externa is stretched between the cartillagines parts of adjoining ribs, its fibres have the same course as the fibres of mm. intercostales externi, i.e. they are descending mediocaudally from the caudal margin of cranial ribs to cranial margin of caudal ribs.

Membrana intercostalis interna connects adjacent ribs in the surrounding of vertebral column; the course of its fibres is mediocranial (same as mm. intercostales interni).

Chest cage shape

The thoracic (chest) cage has shape of truncated cone (conus), which is lightly flattened anterio-posterior way. On its surface there are three walls, a basis and an apex. Inside it, there is a cavity, cavum thoracis.

1. Frontal wall (paries ventralis) – is flattened, sternum is located in the middle, to which costal cartilages attach on the sides, laterally there are frontal sections of sternal parts of the ribs. Between the single ribs there are intercostal splits – spatia intercostalia. In live humans it is possible to palpate sternum and partially also the ribs and intercostal splits. The only exception is the first rib and the first intercostal slit (the collar bone overlaps them both). The last (11th) intercostal slit lies between the 11th and 12th rib.

2. Dorsal wall (paries dorsalis) – is light flattened similarly to the frontal wall. It is formed by thoracic part of vertebral column in the middle part. Ribs (costae) laterally attach (laterally from processus transversi situated anguli costarum) to the vertebral column. On dorsal thoracic wall we can palpate vertebral processus spinosi (the first palpable processus spinosus belongs to the 7th cervical vertebra – vertebra prominens).

3. Lateral walls (paries laterales) form rounded transitions between the frontal and the dorsal wall. Its basis consists of strong curved ribs parts.

4. Cranial end (apex thoracis) – there is a big apertura (apertura thoracis superior) here, which is bordered by cranial margin manubrium sterni (with incisura jugularis) from the front, alongside it is bordered by the 1st rib, dorsally by the 1st thoracic vertebra. Plane apertura thoracis superior is inclined slightly (frontally) caudally; the body of the second thoracic vertebra is projecting on the cranial margin of manubrium sterni.

5. Lower end (basis) – is created by apertura thoracis inferior. Circumference of this apertura is demarcated dorsally by the 12th thoracic vertebra and by both 12th ribs. This part is inclining upwards and frontally. From the anterior margin of the 12th rib, the anterior part of circumference protrudes frontal and cranially, and then proceeds over the frontal margin of 11th rib to the gristles of 10th to 8th rib (arcus costalis) and to the lower end of sternum. Both arcus costales border an angle – angulus infrasternalis below processus xiphoideus. In this angle processus xiphoideus is easily palpable. The bordering of apertura thoracis inferior is easily palpable in its entire extent.

Cavum thoracis represents an imperfectly closed cavity, which communicates with its surroundings either through apertura thoracis superior and apertura thoracis inferior, or

through intercostal slits. In the cross-section, the thoracic cavity is of approximately ovoid shape (transversal axis is longer than longitudinal axis). Dorsally, vertebral bodies are arching into cavum thoracis in middle plane, longitudinal grooves (fissures) originate alongside of vertebral column.

Movements of the chest cage

The movements of the chest cage are linked to the possibilities of movement of individual ribs. These are connected with thoracic vertebrae and with each other ether directly or by sternum, therefore they cannot move on their own. If one rib rises, then the whole thorax is moving as a whole. The movements occur predominantly in costovertebral junctions, the axis of movement runs parallel to collum costae. The upward rotation lifts the ribs, and at the same time lifts sternum upwards and frontally. Transversal and sagittal diameter of chest is thus increasing, as well as the volume of chest cavity. On the other hand as the ribs decline, the diameters and the volume of thorax decrease. The changes in chest volume are the basis for inspiration (inspirace) and exspiration (exspirace).

Junctions of skull. Juncturae ossium cranii

Skull junctions consist of craniovertebral junctions, temporomandibular joint, syndesmoses and skull synchondroses and junctions of hyoid bone. (hyoidal junctions).

Craniovertebral junctions

comprise connections between the skull basis and the atlas, and connections between the first and the second cervical vertebra.

a) articulatio atlantooccipitalis – paired joint, in which condyli occipitales are connected with foveae articulares superiores atlantis. Joint capsules are individual for each of the two joints. According to the shape of joint surfaces, we talk about an ovoidal joint, i.e. a joint with two axes. Because there are two joints, the movement is possible only along their common axis (transversal axis) in a way frontal bend (flexion) and dorsal bend (extension) of the head. Movements into the sides (head lateroflexion) are only minimal.

b) articulatio atlantoaxialis is a composite joint, in which there are several parts:

articulatio atlantoaxialis mediana is an unpaired joint, joint surfaces are facies articularis ant. et post. on dens axis. Fovea dentis of atlas communicates with anterior plane, ligamentum transversum atlantis attaches itself on dorsal plane (strong band, which is stretched transversally between massae laterales atlantis, this band also secures a position of dens axis, and prevents spinal cord lesions (the spinal cord adjoins from behind on dens axis).

Second part of this connection is a paired joint articulatio atlantoaxialis lateralis. The joint surfaces are parts of processus articulares superiores axis and facies articulares inferiores of atlas.

The joint capsules are independent for each of the named joints, and they attach themselves to the margins of contact surfaces. Above mentioned parts of articulatio atlantoaxialis represent a functional unit.

The atlas is rotating along the longitudinal axis passing through dens axis, and joint surfaces of lateral joints simultaneously slide on each other. Whole head is rotating simultaneously with the movements of both vertebrae, total range of movement is about 60^{o}. The movements of the head occur not only in craniovertebral joints, but also movements of cervical vertebral column as a whole participate significantly on these movements.

The system of craniovertebral joints is reinforced by a system of many fibrous membranes and ligaments. Between the margins of foramen magnum and arches of the atlas membrana atlantooccipitalis anterior and membrana atlantooccipitalis posterior are inserted. A thin ligament – ligamentum apicis dentis runs from margo superior of apex dentis to margo anterior of foramen magnum. More significant fibrous ligaments are ligamenta alaria running from apex dentis to partes laterales of foramen magnum. These ligaments are stretching during rotational movements, and are restrict the rotation. Another ligament is ligamentum cruciforme atlantis. Its transversal ramus is ligamentum transversum atlantis, a vertical ramus forms lengthwise fibrous fasciculi, which run from margo anterior of foramen magnum to dorsal part of axis body (fasciculi longitudinales).

Area of dens axis is overlapped from behind by membrana tectoria, which is an extension of ligamentum longitudinale posterius. It proceeds all the way to clivus in cranial direction.

Skull synchondroses can be found on the skull basis in adult individuals in the form of synchondrosis sphenopetrosa and synchondrosis petrooccipitalis (bands of fibrous cartilage fill equally named slits). Both synchondroses link to fibrocartilago basialis, which are closed by foramen lacerum.

Skull syndesmoses occur either as sutures, or as individual ligaments. Sutures connect the margins of adjacent flat skull bones (types of sutures are shown in chapter Synarthroses).In sutura sagittalis medial margins of both parietal bones are connected. Anterior margins of parietal bones are connecting with squama ossis frontalis in sutura coronalis. In some cases a suture or sutural remainder is maintained between both bases of squama temporalis (sutura metopica). In the dorsal part of the skull, squama ossis occipitalis is connecting with dorsal margins of parietal bones in sutura lambdoidea. Sutura squamosa is between squama ossis temporalis and margo lateralis ossis parietalis. Independent fibrous ligaments on the skull comprise for example ligamentum pterygospinosum, which connects spina ossis sphenoidalis with lamina lateralis processus pterygoidei ossis sphenoidalis.

Articulatio temporomandibularis

Paired joint, in which mandibula connects with the skull basis. The joint surfaces are caput mandibulae, fossa mandibularis and tuberculum articulare ossis temporalis. Dorsal part of the joint pit is represented by pars tympanica ossis temporalis (temporomandibular joint therefore has a very narrow connection to the tympanic cavity and to meatus acusticus externus). Discus articularis is inserted between head and joint pit. This plate of fibrous cartilage full separates the joint cavity (capsule is connected to its joint margin) and divides it into two joints. The cranial part represents discotemporal joint, the caudal part represents discomandibular joint. On the temporal bone the joint capsule is attached to the margins of joint surfaces, on mandibula reach to cervical region. It’s relatively free, and from lateral side it is reinforced using ligamentum laterale, which descends from radix processus zygomaticus ossis temporalis to collum mandibulae. Also medial part of the joint capsule is strong. In the vicinity of temporomandibular joint, there are two ligaments, which belong more to the skull syndesmoses – ligamentum stylomandibulare (between processus styloideus ossis temporalis and angulus mandibulae) and ligamentum sphenomandibulare (between spina ossis

sphenoidalis and lingula mandibulae). These ligaments have no influence on the mechanics of temporomandibular joint.

Articulatio temporomandibularis is composed and paired joint, and therefore it has a relatively complicated mechanism of movement. Functionally translation movements occur in the region of temporomandibular joint, (discus articularis is shifting forwards and backwards), and in discomandibular part rotational movements occur (caput mandibulae is rotating along the transversal axis). Both mentioned type of soft movement run in both part soft joint simultaneously, furthermore they occur bilaterally. The result of these movements is opening of the mouth – mandibular depression, closing of the mouth – mandibular elevation, shifting of the entire jaw (chin) forwards – mandibular protraction, shifting of jaw (chin) backwards – mandibular retraction.

Note

During and extraordinarily large opening of the mouth, discus articularis with caput mandibulae could slide in front of tuberculum articulare into fossa infratemporalis (mandibula luxation). In this case Caput mandibulae cannot spontaneously return into its physiological position.

Hyoidal joints. Juncturae ossis hyoidei

Hyoid bone is hung below the skull in musculature (suprahyoidal, infrahyoidal, muscles, and lingual muscles). From processus styloideus, ligamentum stylohyoideum descends to it, which attaches on cornu minus ossis hyoidei. The ligament can ossify in various extents – processus styloideus elongatus (see hyoid bone).

Junction of bones upper extremity. Juncturae ossium membri superioris

Junction of girdle of the upper extremity and junctions of free upper extremity belong to bone junctions of upper extremity.

Junctions of girdle of upper extremity. Juncturae ossium cinguli extremitatis superioris

a) articulatio sternoclavicularis. The joint surfaces are incisura clavicularis on manubrium sterni and facies articularis sternalis claviculae. Joint fissure is full separated by the inserted discus articularis (fibrous cartilage). Sternal ends of clavicula bones protrude cranially and a distinctive fossa (fossa jugularis) is between the ends is above the sternum. Joint capsule is solid and it attaches to the margins of joint surfaces. Junction is reinforced by several ligaments. Ligamentum interclaviculare links sternal parts of both collar bones above incisura jugularis sterni. Ligamentum sternoclaviculare is represented by fibrous fibres linking sternal end of clavicle with manubrium sterni (on both frontal and dorsal side). Ligamentum costoclaviculare links sternal end of the collar bone with the first rib. From mechanical point of view this joint is a spherical joint, with restricted movements in all directions. The movement in the joint is linked to the movements of the shoulder-blade and the shoulder joint. Clavicula in its lateral part is inclining frontally dorsally, upwards and backwards during these movements.

b) articulatio acromioclavicularis. Lateral end of the collar bone (facies articularis acromialis) is connected with facies articularis acromii of the shoulder-blade. Discus articularis from fibrous cartilage is usually inserted between joint surfaces. The joint capsule is being attached to the margins of joint surfaces and it is reinforced on its upper side using ligamentum acromioclaviculare. A very strong ligament – ligamentum coracoclaviculare – links the collar bone with processus coracoideus of scapula.

Movements inside the joint are possible into all directions in a very small extent. Similar as with the sternoclavicular joint, these are connected with overall movements of shoulder blade and shoulder joint.

c) Shoulder-blade syndesmoses (syndesmoses)

Ligamentum transversum scapulae superius separates incisura scapulae and changes it into an opening, through which n. suprascapularis passes into fossa supraspinata scapulae.

Ligamentum transversum scapulae inferius connects the basis of spina scapulae with the border of cavitas glenoidales. Throuh this opening n.suprascapularis and vasa suprascapularia pass ito fossa infrascapularis.

Ligamentum coracoacromiale links processus coracoideus and acromion scapulae. Together with both projections these form fornix humeri, which significantly restricts abduction in the shoulder joint. (into the level of a horizontal plane).

Movements of shoulder blade

The shoulder-blade is linked using clavicula with sternum, and in the shoulder joint it is linked with humerus; its position is secured by muscles on the dorsal side of chest. It lies on the chest in the extent of 2nd-7th (8th) rib. Shoulder-blade moves through muscle activity by shifting and rotational movements. The shoulder-blade is shifted either medially or laterally, and either cranially or caudally. Movements of the collar bone occur at the same time. During rotational movement articulatio acromioclavicularis is a point around which the shoulder-blade is rotating, Its caudal angle is shifting dorsomedially or ventrolaterally. During these movements cavitas glenoidalis scapulae changes its position and thus the movement of the entire upper extremity is enabled. Practically each limb movement is accompanied by the movement of the shoulder-blade.

Junctions of free upper extremity. Juncturae ossium extremitatis superioris liberae

Shoulder joint. Articulatio humeri

In the shoulder joint the shoulder-blade is connected to humerus. Joint pit is formed by cavitas glenoidalis scapulae, which is deepened by joining of labrum glenoidale to its margin. Caput humeri is the head. The joint capsule is strong and spacious, and it is attached to the margin of cavitas glenoidalis, on humerus on collum anatomicum (on the medial side it descends somewhat distally). The joint capsule is reinforced by several ligaments. Ligamenta glenohumeralia are being pulled from labrum glenoidale along the cavital side of the frontal wall of the joint capsule towards the humerus. Ligamentum coracohumerale descends from processus coracoideus scapulae on the anterior side of the joint capsule. The joint capsule is then reinforced by muscle tendons, which grows together with it. The muscle coverage is missing on the lower side, therefore the caput humeri is most often luxated in this direction. Tendon of long head biceps has a significant relation to the joint cavity and to the joint capsule. From its origin on tuberculum supraglenoidale scapulae runs through the joint cavity (it lays onto caput humeri), enters into sulcus intertubercularis humeri and abandons the joint. In the site of penetration through the joint capsule a synovial capsule is attached to it, which accompanied it as vagina synovialis intertubercularis into sulcus intertubercularis. In the surrounding of the joint there are many synovial burses (bursa subdeltoidea, bursa

subcoracoidea, bursa subacromialis, bursa m. subscapularis subtendinea), which may connect with the joint cavity.

The shoulder joint is typical free spherical joint, with three axis of movement: ventral flexion (anteflexion) – dorsal flexion (dorsiflexion extension). Abduction (abduction) is possible only into the horizontal plane, further movement is restricted by fornix humeri, which tuberculum majus humeri leans onto (continuation of movement- raising arms upwards by abduction is possible only with simultaneous rotation of the shoulder-blade) – adduction (adduction). Humeral pronation (rotation inwards) – humeral supination (outwardly rotation). Mentioned elementary pairs of movement can be combined.

The middle position of a joint – mild ventral flexion and abduction of about 45°.

Note:

Mm. humeri encircle the shoulder joint. They run from the shoulder-blade and clavicula, and attach themselves onto the proximal end of humerus. The attachment parts of soft muscles, which run from the shoulder-blade, and directly are linked to the fibrous components of joint capsule from its dorsal side (m. supraspinatus, m. infraspinatus and m. teres minor) and from the frontal side (m. subscapularis) are denoted as rotator-scuff in clinical practice.

Elbow joint. Articulatio cubiti

In the elbow joint humerus, radius and ulna meet together. Individual bones meet together in such way that three independent parts are created – articulatio humeroradialis, articulatio humeroulnaris, articulatio radioulnaris proximalis. In articulatio humeroradialis, capitulum humeri is linked with fovea capitis radii, in articulatio humeroulnaris trochlea humeri is linked with incisura trochlearis ulnae, in articulatio radioulnaris proximalis circumferentia articularis radii is inserted in incisura radialis ulnae. Incisura radialis ulnae is completed with a circular ligament (ligamentum anulare radii), which both secures the position of capitulum radii, as well as its inner plane becomes an integral part of the joint pit. Joint capsule is attaching onto humerus proximally from fossa radialis, fossa coronoidea and fossa olecrani (these are located intraarticularly, at flexion and extension capitulum radii, processus coronoideus ulnae and olecranon ulnae are running into them). Along the sides, the attachment of the capsule is shifted somewhat distally; both epicondyles humeri are located extraarticularly. On ulna, the

joint capsule is attached to the margins of incisura trochlearis, on radius it descends distally into the region of collum radii (here they create recessus sacciformis). The joint capsule is reinforced along the sides by collateral ligaments, which are fan-like running from both humeral epicondylus (ligamentum collaterale ulnare, ligamentum collaterale radiale).

Elbow joint is a composed joint. Its individual parts are differentiated from one another by their movement possibilities. Articulatio humeroradialis is a spherical joint with three axis of movement. However its mobility is limited by humeroulnar joint, which represents a one-axis joint (trochlear joint). Radioulnar proximal joint is a wheel-joint, with longitudinal axis of movement. By a combination of all three parts of the elbow joint, movements are possible alongside two axes. It is a flexion and an extension (in humeroradial and humeroulnar part) and rotational movements (supination and pronation) in humeroradial and proximal radioulnar part.

The middle position of a joint is in pronation and light flexion.

Radioulnar junctures. Juncturae radioulnares

Connection of radius with ulna are, apart from parts of elbow joint (articulatio radioulnaris proximalis), secured also by membrana interossea antebrachii and articulatio radioulnaris distalis.

Membrana interossea antebrachii is strengthened between the bodies of radius and ulna (margines interossei). In the proximal part there is a stronger fibrous band (chorda obliqua), which runs from tuberositas radii to processus coronoideus ulnae. Membrana interossea antebrachii links both antebrachial bones, restricts supination, and at the same time it also serves as a plane for adjoining of numerous antebrachial muscles.

Articulatio radioulnaris distalis. In this joint caput ulnae is connecting with incisura ulnaris radii (joint pit). The joint pit is completed by a plate of a fibrous cartilage (discus articularis), which attaches itself to the margin of incisura ulnaris radii and to processus styloideus ulnae. The joint capsule is attached to the margins of joint surfaces. It is peg joint (monoaxial), which enable rotational movements such as pronation and supination. Ulna is fixed during movement; distal end of radius is rotating around it. The movement in the joint is accompanied by concomitant movement in the elbow joint.

Hand joints. Articulationes manus

Hand joints consists articulatio radiocarpalis, articulatio mediocarpalis, articulatio ossis pisiformis, articulatio carpometacarpalis pollicis, articulationes carpometacarpales II.-V., articulationes metacarpophalangeales, articulationes interphalangeales manus.

Radiocarpal joint. Articulatio radiocarpalis

The joint pit is represented by facies articularis carpalis radii, extended ulnarly using discus articularis (from the distal radioulnar joint). Distal ulnar joint is therefore excluded from the contact with distal capal bones. Joint head is formed by os scaphoideum, os lunatum and os triquetrum. All three bones are joined together using ligamentua intercarpalia interossea. The joint capsule attaches itself on the margins of joint surfaces.

The joint creates a functional unit with joint that follows.

Mediocarpal joint. Articulatio mediocarpalis

In this joint proximal row of carpal bones (with exception of os pisiforme) are joined with distal row of bones. On radial side the head is created by os scaphoideum, joint pit is created by little planes on os trapezium, os trapezoideum and on ulnar side by os capitatum. On ulnar side is head formed by os capitatum and os hamatum, joint pit is formed by little planes on os scaphoideum, os lunatum and os triquetrum. Joint split therefore has a shape of a transversally positioned letter S.

Carpal bones are connected together using ligamenta intercarpea dorsalia, palmaria et interossea. An interosseal ligament is missing between os trapezium and os trapezoideum; joint split (cavity) of mediocarpal joint communicates through here with joint split (cavity) of articulationes metacarpophalangeales II. - V. Joint capsule is attached to the margins of joint surfaces, and it is reinforced by a row of ligaments. Ligamentum radiocarpeum palmare et dorsale runs from processus styloideus radii onto palmar and dorsal side of capal bones. Similar ligaments also run from processus styloideus ulnae (ligamentum ulnocarpeum palmare et dorsale). Os capitatum runs from palmar side into all directions to the adjoining carpal bones of ligamentum carpi radiatum. Ligamentum arcuatum carpi dorsale runs from the dorsal side of os scaphoideum onto the dorsal side os triquetrum. Similar variably occurring ligament is also on the palmar side (ligamentum arcuatum carpi palmare).

Both joints, articulatio radiocarpalis and articulatio mediocarpalis form a functional unit, which can be considered to be a joint of ellipsoidal type. For this reason movements along two axes are possible here. Palmar and dorsal hand flexion, and ulnar and radial hand duction (movement in way of ulnar fiction is more prominent). Combination of both types of movements results in circular movements (circumduction).

Articulatio ossis pisiformis

Os pisiforme with its joint surface is coming onto the joint surface of central side of os triquetrum. Joint capsule is attached onto the margins of joint surfaces. Ligamentum pisohamatum goes from os pisiforme to hamulus ossis hamati and to the basis of the 4th a 5th metacarpus ligamentum pisometacarpeum (mentioned ligaments represent basically the attachment tendon m. flexor carpi ulnaris, and os pisiforme is a sesamoideal ossicle in this tendon).

Sulcus et canalis carpi

Both rows of carpal bones, their processus and tuberosities, forms arch-shaped structure, which is dorsally inverted with its convexity. Tuberculum ossis scaphoidei and tuberculum ossis trapezii (eminentia carpi radialis) protrude into the palm on the radial side; another projection is on the ulnar side eminentia carpi ulnaris, which is formed by hamulus ossis hamati and os pisiforme. Concave sulcus on the palmar side (sulcus carpi) is bridged by a strong fibrous retinaculum – retinaculum flexorum, which connects both eminentiae carpi. That's how canalis carpi is created, flexor tendons of hand and fingers and n. medianus pass through it into the palm.

Articulatio carpometacarpalis pollicis

In the joint the joint surfaces are joining on the basis of first metacarpus and on the basis of os trapezium, joint capsule is attached onto the margins of joint surfaces. This is a sellar-type of joint, and it enables movements along two axis. One of the pair of movement is abduction and adduction of a thumb (abduction and adduction of a thumb in relation to the 2nd finger), another pair of movement is the opposition and reposition of a thumb (during opposition the

thumb is positioned against the remaining fingers). The capability of thumb opposition on a human hand enables grasping of tools.

Articulationes carpometacarpales II.-V.

In this composited joint the bases of 2nd to 5th metacarpus are meeting with distal row of carpal bones, contacts between joint surfaces on adverted metacarpal bases also belong here. The joint capsule is firm and it attaches to the margins of joint surfaces. The joint cavity communicates with mediocarpal joint, (through slit between os trapezium and os trapezoideum). The joint capsule is reinforced by an entire row of ligaments (ligamenta carpometacarpalia palmaria, dorsalia et interossea, ligamenta metacarpalia palmaria, dorsalia et interossea). The joint slit has irregular course, its mobility is minimal (amphiarthrosis).

Articulationes metacarpophalangeales

Metacarpal heads meet with the joint surfaces on the basis of proximal phalanges. On the palmar side there are joint pits deepened using fibrous plates – laminae fibrocartilagineae palmares. Joint capsules are attached on the margins of joint surfaces, and on the margin of lamina fibrocartilaginea. Frontal and dorsal part of the joint capsule is thinner and looser, along the sides the joint capsule is strong, and is furthermore reinforced using ligamentum collaterale ulnare et radiale.

The thumb joint is independent, heads of 2nd to 5th metacarpus are connected on the palmar side using the transversally oriented strong ligament, which grows together with lamina fibrocartilaginea (ligamentum metacarpeum transversum profundum). In lamina fibrocartilaginea palmaris of the thumb joint two sesamoideal bones are being constantly inserted (these bones are not an exception in other metacarpophalangeal joints).

According to the shape of joint surfaces, metacarpophalangeal joints belong to ellipsoidal joints, and possible movements inside them are flexion and extension, and abduction and adduction.

Articulationes interphalangeales manus

Adjoining phalanges are meeting using trochlear joints. Head is formed by trochlea phalangis, pit is formed by the basis of distally situated phalanx. Analogically, as with previous joints, the joint pits are on the palmar side arched using fibrous lamina fibrocartilaginea palmaris. The joint capsule is reinforced along the sides using ligamentum collaterale radiale et ulnare. Dorsal side of the joint capsule is reinforced by aponeurosis of the finger extensors.

The movements are trochlear-shaped, movements occurs as flexion and extension.

Bone junctions of lower extremity. Juncturae ossium extremitatis inferioris

To junctions of lower extremity include girdle junctions and bone junctions of free lower extremity.

Girdle junctions of lower extremity . Juncturae ossium cinguli extremitatis inferioris

Using junctions of girdle bones of lower extremities, a greater complex – pelvis (pelvis) is created. Pelvis is formed by both pelvis bones and caudal part of vertebral column (os sacrum and os coccygis).

Sacro-iliac joint. Articulatio sacroiliaca

Os coxae is attached to axial skeleton using this joint. Joint surfaces represent facies auricularis osiss coxae, and equally named joint surface on the sacral bone. Joint surfaces have an uneven surface, joint capsule is attached to the margins of joint areas, it is solid and short. Junction of both bones is secured by a row of very strong ligaments. Ligamenta sacroiliaca ventralia reinforce the joint capsule from the frontal side. Ligamenta sacroiliaca interossea are very strong, and they attach themselves onto tuberositas sacralis and tuberositas iliaca. Ligamenta sacroiliaca dorsalia run between spinae iliacae posteriores and tuberosities on the dorsal side of sacral bone. The joint is practical immobile (amphiarthrosis), due to uneven surface of its planes.

Other ligaments, which also partially participate on reinforcing of the pelvis are typically classified together with the above mentioned joint. Ligamentum iliolumbale links the dorsal

part of crista iliaca with processus costarii L4 and L5. Ligamentum sacrospinale runs from spina ischiadica and attaches itself on the lateral margin of sacral bone and coccygis.

Ligamentum sacrotuberale runs in a similar way. It links tuber ischiadicum with lateral margin of os sacrum and os coccygis. From tuber ischiadicum, processus falciformis runs from this ligament frontally (it attaches itself to the lower margin of os coxae).

Ligamentum sacrospinale closes incisura ischiadica major by its positioning and course and changes it into foramen ischiadicum majus. This foramen is separated by the course of m. piriformis into two parts. The superior part (foramen suprapiriforme) serves for passing of n. et vasa glutea superiora, inferior part (foramen infrapiriforme) serves for passing of n. et vasa glutea inferiora, n. ischiadicus, n. cutaneus femoris posterior, vasa pudenda interna a n. pudendus.

Both ligaments transform incisura ischiadica minor into foramen ischiadicum minus, through which a tendon of m. obturatorius internus passes, and into fossa ischiorectalis n. pudendus and vasa pudenda interna.

Pubic symphysis. Symphysis pubica

In this unpaired synchrondrosis the frontal margins of pelvic bones are connected. Between facies symphysiales of both pubic bones, there is discus interpubicus (layer of fibrous cartilage, high at women about 45 mm, in men about 50 mm) inserted, inside which there is a sagitally oriented slit. Dorsal margin of discus overlaps the dorsal bone margins (eminentia retropubica), in women this formation is easily palpable per vaginam. The junction is reinforced by two strong ligaments.

Ligamentum pubicum superius is found on the cranial (upper) side of symphysis, stronger ligamentum arcuatum pubis fills the angle between lower margins of symphyses.

The junction is practically immobile. Towards the end of pregnancy, the symphysis somewhat softens due to the influence of hormones, and in labour enables slight enlargement of the birth canal.

Membrana obturatoria

Foramen obturatum is incompletely closed by a strong fibrous membrane (membrana obturatoria). Sulcus obturatorius is transformed into canalis obturatorius (for n. et vasa obturatoria) by the attachment of membrana obturatoria. Both planes (faces) of membrana obturatoria are sites of origin of mm. obturatorii.

Pelvis as a whole

Pelvis, which is created by joining of both pelvis bones and their adjoining to the vertebral column, forms an osseous cylinder (ring). Along both sides the pelvis leans on thigh bones through the deep excavations (acetabula) and this way the body weight is transmitted to lower extremities.

Pelvis participates in locomotion, the movement of the lower extremities are transmitted onto the trunk region.

Inside of pelvis there is a pelvic cavity (cavum pelvis). Linea terminalis (margins, which runs from promontorium over the sacral bone, linea arcuata on the iliac bone, and eminentia iliopubica on the upper margin of symphysis) divides the pelvis into pelvis major (big pelvis) and pelvis minor (little pelvis). Pelvis major lies above linea terminalis, topographically it is an integral part of paries inferior (lower wall) of abdominal cavity (cavitas abdominalis), and pelvis minor is cylinder-shaped and encircles the actual pelvic cavity. Apertura pelvis superior (aditus pelvis) opens cranially using pelvic entry (through this apertura the little pelvis is connected with the big pelvis – abdominal cavity), inferior parts opens using apertura pelvis inferior (exitus pelvis).

Little pelvis forms a firm case, inside which significant organs (rectum, part of urogenital organs) are located. In women it also represents the birth canal, during labour the foetus leaves the mother body through this birth canal. Female pelvis, by its design, is obviously different from male pelvis. On a female skeleton the pelvis represents significant secondary gender characteristic, and it gives the woman figure its typical shape and appearance. From the point of obstetrics practice, a demand for assessment of pelvis shape and its parts comes into forefront for the purpose of adaptation (passageway) of the birth canal. The measurements of internal and external dimensions serve this purpose mentioned above (using pelvimeter).

On bone woman pelvis, there are four significant planes:

l. Plane of apertura pelvis (apertura pelvis superior seu aditus pelvis). It is bordered by linea terminalis and is of a roughly ovoid shape (longitudinal axis is oriented transversally). In this plane several dimensions are determined.

Diameter recta aditus pelvis (conjugata anatomica) is linking the promontorium and upper margin of symphysis. It measures about 11 cm.

Diameter transversa represents the biggest transversal distance between lineae terminales. It measure about l3 cm.

Diameter obliqua. A connection between articulatio sacroiliaca and eminentia iliopubica. The right dimension – diameter obliqua dextra (prima) emerges from articulatio sacroiliaca dextra, diameter obliqua sinistra (secunda) from articulatio sacroiliaca sinistra. It measures about l2 cm.

Diameter obstetricia is the shortest distance between the dorsal side of symphysis (eminentia retropubica) and the anterior margin of promontorium. It measures about l0,5 cm.

Conjugata diagonalis is the only dimension in this area that can be measured in a living woman per vaginam (fingers inserted into the vagina). It is a distance between margo inferior symphysis, and margo anterior promontories. It's about 2 cm longer than conjugata obstetricia, i.e. it's about 12,5 to 13 cm long. At normal pelvis fingers of obstetrician cannot reach as far as to the margo anterior promontories. In case that promontorium is palpable, it always is a narrowed pelvis.

2. Plane of pelvis amplitude (amplitudo pelvis) is demarcated by a line linking the interface between

S2 and S3, the centre of acetabular basis, and the centre of symphysis. It is of an approximately circular shape. Elementary dimensions can be defined also in this plane.

Diameter recta amplitudinis pelvis is a connecting line between the centre of dorsal side symphysis, and the interface between S2 and S3 (about 12,5 cm).

Diameter transversa amplitudinis pelvis is a connecting line between the bases of centres of both hips fossas (about 12,5 cm).

3. Plane of angustia pelvis (angustia pelvis) is bordered by a line, linking margo inferior symphysis, spina ischiadica, and apex ossis sacri. It has an ovoid shape, the longer axis is oriented sagitally – diameter recta, i.e. connecting line between margo inferior symphysis and apex ossis sacri (about 11,5 cm).

4. Exitus pelvis plane (apertura pelvis inferior seu exitus pelvis) is rhomboidal-shaped. It is demarcated by a line, linking margo inferior symphysis, tuber ischiadicum and apex coccygis. This plane consists of two triangles with one common basis (connecting line of both tubera ischiadica) and they create an obtuse angle inverted cranially. Also in this plane it is possible to define two elementary dimensions.

Diameter transversa – connecting line of tubera ischiadica (about 11 cm).

Diameter recta – is a connecting line of margo inferior symphysis and apex coccygis (about 9 cm). During labour, the foetus passing through birth canal shifts the coccyx away dorsally. This results in an increase of distance between margo inferior symphysis and apex coccygis up to 11 - 11,5 cm.

During labour the foetus head passes through the pelvis canal, in a way, so that its longitudinal sagital axis (about 11 cm) is being inserting into bigger dimensions of individual pelvis planes. In the course of foetus passing through aditus pelvis, the anteroposterior axis of foetus is being inserting in diameter transversa. In amplitudo pelvis plane, head of the foetus hits against the muscular fundus of the pelvis, and by this mechanism, foetus head is forced to rotation, that means, that the longitudinal axis of foetus head rotates sagitally, and enters into the biggest dimensions of angustia pelvis, in diameter recta (internal rotation of head). In this position, the foetus head can pass in exitus of the pelvis plane.

The measurements of internal pelvis dimensions can be mostly performed only on the body skeleton (with the exception of conjugata diagonalis). Because of this, only external pelvis dimensions are used in obstetrics, which are measured on a living femal body. Based on measured values, we can make an indirect judgement regarding the construction of a bone skeleton in the little pelvis, and predict the actual course of labour. These dimensions can be measured using pelvimeter, and these measurements are performed as an integral part of standard prenatal examination, in prenatal clinics before labour.

1. Distantia bispinalis – distance between both spinae iliacae anteriores superiores, the average value is 26 cm.

2. Distantia bicristalis – is the distance between most lateral points of cristae iliacae, the average value is about 29 cm.

3. Distantia bitrochanterica – is the distance between trochanter majors of both femoris, it measures about 31 cm.

4. Distantia bituberalis – is a distance between apex of both ischiadical tubers. It gives us information about spaciousness of exitus pelvis. Its average value is 12 cm.

5. Conjugata externa is the distance between thorn L5 and margo superior symphysis; it measures approximately 20 cm (18 cm minimum). The measurements are performed in woman laying her side.

Gender differences of pelvis

The main function of female pelvis during labour, is the function of a birth canal (in course of labour, the foetus leaving its mothers body through the canal). For this function it is necessary, that woman pelvis is adapted to the labour requirement, that means- it shows some shape-differences, in comparison with the male pelvis. This is a reason why some parts of woman pelvis, have significantly different modification than parts of male pelvis.

l. Ala ossis ilii of male pelvis is located more sagitally, in femal the pelvis is located more frontally, the distance between both female alae is bigger (because of this, women have more accentuated hips, cristae iliacae protrude more significantly to the body surface).

2. Tubera ischiadica (distantia bituberalis) on a femal pelvis are much further apart than on a male pelvis. Because of this the distance between trochanters majors (distantia bitrochanterica) is much bigger. Trochanter majors of female pelvis protrude more prominently to the body surface, and they participate on the entire configuration of hips and the iliac region.

3. Symphysis of men is high, pubic bones below the symphysis create an angle (angulus pubis). In female the symphysis is much lower, pubic bones below symphysis (as a result of more spacious aditus pelvis) widely diverge caudally and laterally (arcus pubis).

4. Aditus pelvis plane in men is heart-shaped, it significantly protrudes in posteroanterior direction into promontorium. The promontorium in women is less apparent, therefore aditus pelvis is more of an ovoid shape.

5. Os sacrum in women is lower and wider than in men.

6. Incisura ischiadica major in a woman is more spacious and wider. At men it is narrow and deep.

7. Ramus superior ossis pubis in women is absolutely longer than in a man of the same size. Because of this, in women the area mons pubis protrudes much more onto body surface.

8. Foramen obturatum in women is of a triangular shape, in men it is of an ovoid shape.

Junctions of free lower extremity. Juncturae ossium extremitatis inferioris liberae

Coxal. Hip joint. Articulatio coxae

In the hip joint femur is joined with the pelvis bone. Joint surfaces are facies lunata acetabuli (remaining part of acetabulum is filled by adipose pillar– pulvinar acetabuli) and caput femoris. Joint pit is excavated using labrum acetabulare, which complements the joint pit, along the entire acetabular circumference. Incisura acetabuli is separated by the transversal ligament (ligamentum transversum acetabuli). Strong joint capsule is attached to the acetabular margin, which on femur reaches forward to linea intertrochanterica, dorsally it reaches approximately to the centre of collum femoris (fossa trochanterica lies extraarticularly). Spacious joint capsule is reinforced by several strong ligaments.

Ligamentum iliofemorale arises from spina iliaca anterior inferior, descends on the anterior plane of the joint capsule, and attaches itself onto linea intertrochanterica.

Ligamentum pubofemorale descends from cranial margin of ramus ossis pubis to the frontal and lower side of the joint capsule, and blends with it.

Ligamentum ischiofemorale begins on the dorsal acetabular margin, grows together with the dorsal part of the joint capsule, and then it diminishes on its cranial side.

All mentioned ligaments have the same course, and ligamentum pubofemorale together with ligamentum ischiofemorale participate on the origin of the fibrous band (zona orbicularis), which encircles collum femoris.

Ligamentum capitis femoris runs from fovea capitis femoris, it leaves the joint cavity below ligamentum transversum acetabuli, and attaches itself in the surrounding of acetabulum.

Below m. iliopsoas constant bursa iliopectinea is located on the anterior side of joint capsule.

(Coxal) hip joint based on the shape of its joint surfaces is a typical spherical joint with restricted movement (enarthrosis). Movements around the three elementary axis - flexion (leg forward) and extension (leg backwards) are possible here. Extension is restricted by the

course of above mentioned ligaments and by zona orbicularis. The ligaments are relaxed during flexion, and stretched during extension. The second pair of movements is (leg sideways) abduction and (leg towards the body) adduction. Abduction is during simultaneous extension restricted by stretched ligaments. Abduction during simultaneous joint flexion is much more accentuated. The third pair of movements is femoral pronation (internal rotation) and femoral supination (external rotation).

The middle position of the coxal point is in flexion, light abduction and in external rotation.

Knee-joint. Articulatio genus

Knee joint is the most complicated joint of a human body. Three bones - femur, tibia and patella meet here. Three joint divisions are created by their mutual contact.

a) Condylus medialis femoris adjoins onto facies articularis medialis on the proximal tibial end. Joint surfaces of femur and tibia have very different curvature, this disproportion (incongruence) is balanced by the semilunar fibrocartilagineous plate – meniscus medialis (has shape of a letter „C“). Frontal and dorsal ends of meniscus is attached to area intercondylaris anterior et posterior.

b) Condylus lateralis femoris adjoins onto facies articularis lateralis of proximal tibial end. The disproportion between the size and the curvature of joint surfaces is balanced here using meniscus lateralis, which has a circular shape. Its free ends attach to tuberculum intercondylare laterale.

c) Facies articularis patellae adjoin onto facies patellaris femoris.

The joint capsule is strong and spacious, and attaches onto margo tibialis of joint surfaces. On femur it reaches about l cm proximally from the margins of joint surfaces. Synovial layer of joint capsule is inserted from the medial and lateral side of ligamenta cruciata genus, in front of them it protrudes forwards to patella as plica synovialis patellae. Below patella an adipose pillar (corpus adiposum genus) is inserted between the synovial and fibrous layer of the joint capsule. Plica synovialis patellae laterally continues into two plicae padded with an adipose layer (plicae alares), which form an integral part of corpus adiposum genus. Using synovial layer the knee-joint cavity is in the infrapatellar area only incompletely sagitally separated into medial and lateral part.

Articular junctions are secured using several strong bands and ligaments.

Tendo) of m. quadriceps femoris blends with the anterior margin of joint capsule, this tendo is attached on patella. From apex patellae a strong ligament (ligamentum patellae) descends to tuberositas tibiae. The system of chain tendons of quadriceps femoris also includes two longitudinal bands, which run from the tendons m. vastus medialis and m. vastus lateralis to the corresponding margin of patellae (retinaculum patellae mediale et laterale). The patella (knee-cap) represents a big sesamoideal bone, which is inserted into the tendon of m. quadriceps femoris.

Ligamentum collaterale tibiale originates from epicondylus medialis femoris, grows together with joint capsule, and attach on proximal part of margo medialis tibiae.

Ligamentum collaterale fibulare represents an independently (extraarticularly) occurring ligament, which connects epicondylus lateralis femoris with caput fibulae.

Ligamentum popliteum obliquum is an integral part of insertion tendon of m. semimembranosus. It runs from condylus medialis tibiae to condylus lateralis femoris.

Ligamenta cruciata (anterius et posterius) are two strong ligaments, connecting areae intercondylares tibiae with fossa intercondylaris femoris.

Ligamentum cruciatum anterius runs from area intercondylaris anterior tibiae, ascending proximally, dorsally and laterally, and is attached onto the medial plane of condylus lateralis femoris.

Ligamentum cruciatum posterius runs from area intercondylaris posterior proximally, and attach on fibular plane of condylus medialis femoris. As mentioned above, ligamenta cruciata are laterally covered by synovial layer of joint capsule. This layer directed frontally to patella as plica synovialis patellae represents the remainder of former septum, separating joint cavity into an internal and external part. Ligamenta cruciata, therefore are located intraarticularly in relation to the fibrous layer of the joint capsule and they are located extraarticularly in relation to synovial layer.

A whole range of synovial burses (with various extent) (bursa suprapatellaris, bursa praepatellaris, bursa praepatellaris subcutanea) is often created in the area of knee-joint which could sometimes directly communicate with the joint cavity.

The knee joint represents a composed (and complicated) type of a joint. From mechanical viewpoint it is a monoaxial trochlear joint. The elementary movements of this joint are flexion (bend) and extension (stretch). Ligamenta cruciata, in the course of extension, spiral-

shaped turn around each other, and by this they are stretching, and restricting extension. In the course of flexion, ligamenta cruciata are released, therefore only mild rotation movements along longitudinal axis are possible while the knee-joint is flexed. Patella (knee-cap) in the course of flexion and extension, slides proximally and distally onto the frontal side of femur.

Longitudinal axis of femur and tibia create an obtuse angle in the frontal plane, the angle is open laterally (physiological abduction of the knee-joint). This state is mainly caused by femoral position in the coxal joint. Abductional position of female knee-joint, due to wider pelvis, is more apparent. The middle position of a knee-joint is here in light flexion.

Tibiofibular junctions.Juncturae tibiofibulares

a) Articulatio tibiofibularis. Joint surfaces (facies articularis capitis fibulae and facies articularis fibularis tibiae) are flat and straight. Short joint capsule is attached to the margins of joint surfaces, and it is reinforced by ligamentum capitis fibulae (anterius et posterius). Shifting movements are of negligible extent.

b) Membrana interossea cruris is stretched between margo interosseus tibiae and fibulae. It serves as a division site of some crus muscles.

c) Syndesmosis tibiofibularis. Distal end of fibula is being inserted into incisura fibularis tibiae. It is not an articular junction (joint surfaces are not created here !), but is a syndesmosis. Junction of both bones is secured by strong ligaments, running from tibia to margo anterior and posterior of maleolus lateralis (ligamentum tibiofibulare anterius et posterius).

All three above mentioned junctions firmly connect fibula with tibia. The position of both bones is practical unchanged, both bones form a mechanical unit. Fibular movements are only possible in the sense of a slight spring-shaped elastic movement.

Leg joints. Articulationes pedis

a) Articulatio talocruralis. In this joint bifurcation (fork) of crus bones (facies articularis inferior tibiae, facies articularis malleoli tibiae, facies articularis malleoli fibulae) is adjoining onto trochlea tali. Joint capsule is attached onto the margins of joint surfaces. Its anterior and posterior side is free, laterally it is reinforced by strong ligaments.

Ligamentum collaterale mediale (ligamentum deltoideum) is compact, it runs from maleolus medialis, and in a fan-shaped way diverges to os naviculare (pars tibionavicularis), to talus (pars tibiotalaris anterior), sustentaculum tali (pars tibiocalcanea) and to dorsal part of the talus (pars tibiotalaris posterior).

Ligamentum collaterale laterale represents three individually running ligaments: ligamentum talofibulare anterius runs from maleolus lateralis to collum tali, ligamentum calcaneofibulare situated in the middle is stretched between maleolus lateralis and lateral plane of calcaneus (close to trochlea peronealis). Dorsally there is another ligament (ligamentum talofibulare posterius) connecting fossa malleoli lateralis and processus posterior tali.

Art. talocruralis is a trochlear joint, enabling plantar and dorsal flexion of the leg. Trochlea tali is narrower proximally rather than distally, for this reason the leg is fixed while in a normal position on planta pedis. During plantar flexion the narrow part of trochlea tali gets in bifurcation crus bones, and the joint is relaxed. For this reason (standing on tip toe) only wobbly movements are possible in this position

b) Articulationes intertarsales

1. Articulatio subtalaris. In this joint, talus connects with calcaneus. Joint surfaces are facies articularis calcanea posterior tali and facies articularis talaris posterior calcanei. Short joint capsule is attached to the margins of joint surfaces, and it is laterally reinforced by fibrous ligaments (ligamentum talocalcaneum laterale et mediale).

2. Articulatio talocalcaneonavicularis is a complicated joint, in which joint surfaces are adjoining each other on talus (facies articularis calcanea media et anterior) and on calcaneus (facies talaris media et anterior), and on caput tali and the proximal joint surface is adjoining onto os naviculare. Joint capsule is very thin, and it is common for all mentioned parts. On the plantar side the junction is reinforced by strong ligamentum calcaneonaviculare plantare (runs from sustentaculum tali, then runs below caput tali and attaches itself onto tuberositas ossis navicularis. Attaching tendon m. tibialis posterior grown onto plantar side of this ligament. A part of a ligament, which caput tali adjoins onto is transformed into a fibrous cartilage, which is an integral part of the joint surface (fibrocartilago navicularis).

Joint capsule is reinforced by further ligaments: ligamentum calcaneonaviculare plantare, ligamentum talonaviculare is situated on the dorsal side, sinus tarsi fills in strong ligamentum talocalcaneum interosseum. Ligamentum calcaneonaviculare (an integral part of ligamentum

bifurcatum) runs from dorsal horn of calcaneus (cornu internum calcanei) in direction to planum dorsale ossis navicularis.

Both mentioned joints represent a mechanical unit (lower tarsal joint seu astraglar joint), in which the movements occur along the axis, passing through sinus tarsi. Resulting movements are internal rotation (pronation) and external rotation (supination) of the foot.

3. Articulatio calcaneocuboidea is a junction between facies articularis cuboidea calcanei and a proximal joint surface on os cuboideum. Thin and short joint capsule is reinforced by a deep and shorter ligamentum calcaneocuboideum plantare, and by more superficially lying and longer ligamentum plantare longum (ligament running from tuber calcanei to bases of metatarsal bones). On dorsal side ligamentum calcaneocuboideum runs from dorsal horn of calcaneus, attaching itself onto the dorsal side of os cuboideum (second part of ligamentum bifurcatum).

Joint slits between caput tali and os naviculare, and between calcaneus and os cuboideum represent so called Chopart joint (articulatio tarsi transversa). Exarticulations are performed in this slit. During a surgical intervention, it is possible to open the slit by (setting) cutting both parts of ligamentum bifurcatum (ligamentum calcaneocuboideum, ligamentum calcaneonaviculare).

4. Articulatio cuneonavicularis. In this joint the distal joint surface is adjoined onto os naviculare, with the proximal joint surfaces of all three ossa cuneiformia. Joint capsule is reinforced by ligamenta cuneonavicularia plantaria et dorsalia. Joint slit is tightly connected with slits between adjacent ossa cuneiformia, and by means of this also with the joint slit of intermetatarsal joints. The common joint capsule is reinforced using ligamenta intercuneiformia dorsalia, plantaria et interossea.

5. Articulatio cuneocuboidea. Joint surface on media side of os cuboideum is in contact with the lateral joint surface on os cuneiforme laterale. Joint capsule is reinforced by ligamenta cuneocuboidea (dorsale, plantare, interosseum).

c) Articulationes tarsometatarsales

This composite joint is sometimes called a Lisfranck joint. It has three parts: junction between os cuneiforme mediale and basis ossis metatarsi I., junction between os cuneiforme intermedium et laterale and os metatarsi II. et III, and junction between os cuboideum and os metatarsi IV. et V. Joint capsules of these joints often blend with joint capsules of previous

joints. The junctions are reinforced by ligamenta tarsometatarsea dorsalia, plantaria et interossea.

Articulationes intermetatarsales between the bases of adjoining metatarsal bones are related to the joints. Also these junctions are reinforced by ligamenta metatarsea dorsalia, plantaria et interossea.

Note:

In Lisfranck joint exarticulations also occur. From this viewpoint it is important to know, that the basis of II. metatarsus interlocks into bifurcation between ossa cuneiformia.

From mechanical viewpoint articulationes tarsometatarsales, articulatio cuneonavicularis, articulatio cuneocuboidea and articulatio calcaneocuboidea are joints with irregular joint surfaces (amphiarthroses). In these named joints only shifting movements of small extent are possible, such as during loading of foot vaulting and during movements in the lower tarsal joint.

d) Articulationes metatarsophalangeales

These joints have analogical design to the corresponding joints of hand. Joint pits on the metatarsal bones are completed by cartilaginous fibrocartilagines plantares on plantar side. In the plate of a big toe joint there are two constant sesamoideal bones (medial and lateral). Joint capsules are independent in each finger , and they are reinforced by ligamenta collateralia. On plantar side the heads of metatarsus are connected by strong ligamentum metatarsale transversum profundum. Flexion and extension, and abduction and adduction are possible in the joints (foot axis runs through the second finger).

e) Articulationes interphalangeales pedis

Structure of these joints is analogical to the finger joints (knuckles) on a hand. Joint pits are excavated helping fibrocartilagines plantares on the plantar side, joint capsules are reinforced by ligamenta collateralia. Flexion and extension is possible in these trochlear joints.

Foot vault (arcus pedis)

All foot bones are organised into two lengthwise rows. Talus is proximally located In the tibial row,, followed by os naviculare, more distally ossa cuneiformia, 1st - 3rd metatarsal bones and their respective phalanges. Fibular row is created by calcaneus, os cuboideum, by 4th and 5th metatarsal bones, and their respective phalanges. In the distal part, both rows of bones are located along each other, proximally the tibial row is inserted onto the fibular row (talus attaches itself onto dorsal side of calcaneus). An arch is created this way and by its convexity is directed cranial, which forms a basis for longitudinal foot vaulting. The longitudinal foot vaulting is accentuated also by the fact, that both rows of bones (without phalanges) are arches dorsally.

In area of ossa cuneiformia and metatarsal bones, the foot skeleton is transversally bended, that means it is concave on the plantar side (transversal foot vaulting).

The longitudinal and transversal foot vaultings are secured by both the ligaments, as well as by muscle traction (predominantly m. tibialis anterior et posterior, m. peroneus longus and long flexors of the thumb and fingers). Due to the longitudinal and transversal foot vaultings, the foot bones lean against a support in three points – proximally tuber calcanei, distally heads of the first and the fifth metatarsus.

Foot vaultings protect soft parts (predominantly vessels and nerves) in planta pedis against lesions by pressure during standing, it participates also during threading fully on a foot.