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INSTITUTE OF FUNDAMENTAL MEDICINE AND BIOLOGY  
*Department of Morphology and General Pathology*

**ARTICULAR SYSTEM**  
**General and Special Arthrosyndesmology**

**Teaching manual**



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Настоящее учебное издание адресовано студентам первого курса ме-  
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дисциплины «Анатомия» по теме «Артросиндесмология» для медицинских  
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## INTRODUCTION

The manual "Articular system. General and special Arthrosyndesmology" is intended for training doctors of specialties "Medicine", "Dentistry", "Medical Biochemistry" and meets the requirements of the Federal State Educational Standard of Higher Professional Education.

The presented material is sufficient for studying the topic "Arthrosyndesmology" of the discipline "Anatomy" and "Human Anatomy" for those studying at medical specialties. Using this manual, the student will know the types of bone joints, their distinguishing features, classification, will be able to classify synovial joints, will be able to characterize any joint.

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## CHAPTER 1. GENERAL ARTHROSYNDESMOLOGY

The definition of the term “arthrosyn-desmology” is the science of articulations and ligaments (from Greek *arthros* – “articulation”, *desmos* – “ligament”, *logos* – “science”). Thus, arthrosyn-desmology (articular system) is a study of bone connections.

There is a great number of various joints (more than 230 synovial joints and about 1000 ligaments etc.) in the human body. It is important to know the phylogenesis and onthogenesis of the skeleton bones to understand the function and the causes of joints appearance.

In onthogenesis the formation of the joints reflects the phylogenetic process. It is known, that the bones pass through three stages of the development:

- ✓ connective-tissue,
- ✓ cartilaginous,
- ✓ osseous.

Hence, depending on the functional purpose, the junctions of bones can be bonded by:

- ✓ connective- tissue,
- ✓ cartilage,
- ✓ osseous tissue

or diarthrosis (synovial, cavitated, movable) joints develop.

**NB!** The bones of the neurocranium and viscerocranium are exceptions because they pass through only two stages – connective-tissue and osseous. Therefore, there can be no cartilaginous joints between these bones, here only connective-tissue or osseous joints remain.

There are numerous joints in the human skeleton, to characterize them, all the joints are divided into several groups. One of the major classifications is based on the presence of the cavity/space between connecting bones, so, the joints can be:

1. **Immovable – synarthroses** (*synarthroses*) – there is no empty space between connecting bones (space is filled by connective tissue).

2. **Movable – diarthroses** (*diarthroses*), **synovial** (*junctura articulationes synoviales*), **cavitated joints** (*articuli*) – there is empty space (gap) between connecting bones, so this joint is mobile.

*In some of the Anatomy books you can find the next classification:*

- 1) *Fibrous* (immovable)
- 2) *Cartilaginous* (*immovable synchondrosis + partially movable symphysis*)
- 3) *Synovial* (*diarthrosis*, movable)

### **1.1. Immovable joints (synarthrosis)**

In synarthroses the space between connecting bones is filled with one type of connective tissue. Type of connective tissue in synarthrosis reflects stages of the bone`s development, determines its name and properties:

- **syndesmosis** (“*syn*”– together, “*desmos*” – connective tissue) – space between bone is filled with fibrous connective tissue;
- **synchondrosis** (“*syn*”– together, “*chondros*” – cartilage) – space between bones is filled with cartilage;
- **synostosis** (“*syn*”– together, “*os*” – bone) – space between bones is filled with bone tissue.

#### **1.1.1. Syndesmosis/fibrous connections** (*syndesmosis/juncturae fibrosae*)

The space between bones is filled by dense fibrous connective tissue. Syndesmoses include:

##### **1.1.1.1. Ligaments** (*ligamenta*)

According **to the types of connective tissue**, the ligaments can be:

- ✓ **fibrous** – dense fibrous connective tissue (collagen fibers, extremely strong, but cannot stretch). For example, most of the ligaments;
- ✓ **elastic** – elastic connective tissue (fibers with protein elastin, yellow color, can stretch and come back to the primary length without deformation). For example, yellow ligament of the vertebral column.

According **to the length the ligaments** can be:

- ✓ short – connect neighboring bones (interspinous ligaments – between spinous processes of neighboring vertebrae, intertransverse ligaments, most of the limbs ligaments);

✓ long – connect several bones and bones on distance from each other (anterior and posterior longitudinal ligaments, supraspinous ligament). For example, **anterior longitudinal ligaments** (*lig. longitudinale anterius*) is attached to the pharyngeal tubercle of the occipital bone and the anterior tubercle of the atlas, then it descends along the anterior surfaces of the vertebral bodies and intervertebral discs and attached to the first sacral vertebra. This ligament is firmly linked with the discs and periosteum of vertebrae. Between the occipital bone and the atlas, the ligament is thickened and forms the anterior **atlanto-occipital membrane** (see atlanto-occipital joint).

According to **the relation to the synovial joint capsule**:

- ✓ **intraarticular** (inside the cavity of the synovial joint)
- ✓ **extraarticular**, which are divided into:
  - **extracapsular** (outside the capsule of the synovial joint),
  - **capsular** (thickening and fastening of the joint capsule).

Functions of the **extracapsular ligaments**:

- ✓ hold or fix the bones (sacrospinous, interspinous, intertransverse ligaments of the vertebral column);
- ✓ form “soft skeleton” – a place for muscles origin and insertion (for example, most ligaments of the limbs and vertebral column);
- ✓ together with bones form openings or vaults for passing vessels and nerves (for example, superior transverse scapular ligament, the ligaments of pelvis etc.).

### **1.1.1.2. Interosseus membrane** (*membrana interossea*)

It is flat, wide, dense connective tissue, placed between diaphysis of the long tubular bones (forearm and leg), and covers obturator opening. Connective-tissue fibers of membranes are mainly collagenic; they are arranged in such direction, which doesn't hinder the movements.

**Functions:**

- 1) hold the bones together,
- 2) serve for the origin and insertion of muscles,
- 3) form openings for passing nerves and vessels.

### **1.1.1.3. Fontanel** (*fonticuli cranii*)

They are flat fibrous connective tissue between bones of the fetal and newborn skull calvaria. They are structures of connective tissue containing the great amount of ground substance and sparse collagen.

### **Types of the fontanel:**

✓ **anterior (frontal) fontanel** (*fonticulus anterior, seu frontalis*) – unpaired, has a rhomboid shape, 30x25mm. It is located at the junction of the frontal and paired parietal bones, it ossifies during the 2<sup>nd</sup> year of life.

✓ **posterior (occipital) fontanel** (*fonticulus posterior, seu occipitalis*) – unpaired, triangular, 10x10mm. It is located at the junction of the occipital and both parietal bones, it completely disappears by the age of 2 months after birth.

✓ **sphenoid fontanel** (*fonticulus sphenoidalis*) – paired, at the junction of the greater wing of the sphenoid bone, frontal, temporal, and parietal bones; it closes by 2-3 months of age.

✓ **mastoid fontanel** (*fonticulus mastoideus*) – paired, at the junction of the occipital, temporal and parietal bones, it closes by 2-3 months of age.

### **Functions of the fontanel:**

- 1) the possibility of displacement of the skull bones during birth,
- 2) the possibility of bone growth of the skull after birth.

#### **1.1.1.4. Sutures** (*suturae*)

They are connection between bones of the cranium via connective tissue.

Types of sutures (according to the shape of connecting bones):

✓ **dentate suture** (*sutura serrata*) – coronoid/*sutura coronalis* (junction of frontal and both parietal bones), lambdoid/*sutura lambdoidea* (junction of occipital and both parietal bones), sagittal/*sutura sagittalis* (junction of both paired parietal bones).

✓ **squamous suture** (*sutura squamosa*) – junction of temporal and parietal bones;

✓ **plane suture** (*sutura plana*) – junction of bones of the facial skull.

### **Functions of the sutures:**

- 1) fix the bones;

2) the ability of the cranium to grow.

#### **1.1.1.5. Dentoalveolar junction or gomphosis (*gomphosis*)**

The junction between the teeth and dental alveoli via dense connective tissue (periodontium).

*This junction is very strong and it also has cushioning tissue called periodontium. The periodontium is 0,14-0,28 mm thick. It consists of collagenic and elastic fibers, oriented perpendicularly from the walls of alveolar socket to the root of the tooth. Between fibers there is loose connective tissue containing a lot of vessels and nerves. During the strong compression of jaws, the periodontium is pressed and a tooth immerses into the alveolar socket by 0,2 mm.*

*The amount of elastic fibers decreases with age, the periodontium damages at a load, its blood supply and innervation disorder, as a result teeth shatter and fall out.*

#### **Functions of the gomphosis:**

- 1) fixation of the teeth inside dental alveoli,
- 2) amortization (distribution of forces) during chewing.

#### **1.1.2. Synchondrosis (*synchondrosis*)**

It is a connection of bones via hyaline or fibrous cartilage/ junctions bonded by hyaline or fibrous cartilage.

Hyaline cartilage has good elasticity, but less strength. It covers most of the articular surfaces in synovial joints. The hyaline cartilage connects metaphyses with epiphyses in the tubular bones and also connects the parts of the pelvic bones together.

The fibrous cartilage is comprised of mainly collagenic fibers, therefore, it possesses more durability and less elasticity. Such cartilage connects the vertebral bodies.

The durability of the cartilaginous joints increases due to the periosteum of the connecting bones, which passes continuously from one bone to another. In the region of the cartilage the periosteum transforms into the perichondrium which is firmly fused with the cartilage and, moreover, reinforced by ligaments.

#### **Types of synchondrosis (according to the time of existence):**

- ✓ **permanent synchondrosis;**

- ✓ **temporary synchondrosis;**
- ✓ **symphysis.**

### 1.1.2.1. Permanent synchondrosis

It is a connection of bones via fibrous cartilage, it remains during the whole life.

**Examples:** intervertebral discs, cartilages of the ribs, sphenopetrosal and petrooccipital synchondroses.

**Intervertebral disc** (*discus intervertebralis*) – cartilaginous structure, located between bodies of the vertebrae, it has two parts:

✓ **Fibrous ring** (*annulus fibrosus*) – situated on the periphery, formed by concentric layers of the fibrous cartilage. Fibers within cartilage are important for the junction of vertebral bodies and anterior and posterior longitudinal ligaments of the vertebral column.

✓ **Nucleus pulposus** (*nucleus pulposus*) – an inner gelatinous central portion consisting of soft fibrous cartilage, a remnant of notochord.

*\*In case of herniation, the outer fibrous cartilage is damaged, nucleus pulposus is protruded. It leads to compression and irritation of the rootlets of the spinal nerve, located nearby, and is accompanied by strong pain.*

### 1.1.2.2. Temporary synchondrosis

It is a connection of bones via hyaline cartilage, it is present only during the development of the skeleton, later it becomes synostosis.

**Examples:** metaphysis (growth plate of the tubular bones), sphenoccipital synchondrosis (later becomes clivus); the junction of the pelvic bones (ileum, ischium and pubic bones); the junction between sacral vertebrae.

#### **Functions:**

- 1) amortization (distribution of pressure and weight) during high strain on the bone;
- 2) fixation of bones between each other;
- 3) provides growth of bones in length.

### 1.1.2.3. Symphysis (*symphysis*)

A special type of synchondrosis. In comparison to temporary

and permanent synchondrosis in this type within the fibrous cartilage a slit-like space is formed, that`s why this type of connection is called a ***semi-mobile connection***. At the same time, there is no capsule, like in synovial joints, that`s why symphysis is also called an intermediate form of connection between synchondrosis and synovial joints.

Movements in symphysis are limited and occur in specific situations (for example, mobility of the two pubic bones during delivery).

**Examples:**

- ✓ pubic symphysis
- ✓ intervertebral symphysis;
- ✓ sacrococcygeal symphysis,
- ✓ symphysis of the sternum (between manubrium and body of the sternum).

**1.1.2.4. Synostosis (*synostosis*)**

A bony junction, which is the result of the **temporary synchondrosis** (hyaline cartilage is totally replaced by bones) ossification.

**Function:** tight junction and fixation of the bones.

**Examples** – sacrum, clivus, ossified metaphysis of the bones.

In some diseases (ankylosing spondylitis, osteochondrosis etc.) ossification can occur not only in all types of synchondroses, but also in all types of syndesmoses.

**1.2. Movable joints (synovial, cavitated joints, diarthroses)**

**1.2.1. Essential elements of diarthrosis**

✓ **articular surfaces (*facies articulares*)** (minimum – 2 surfaces) – covered by hyaline cartilage (exceptions – the temporomandibular joint, sternoclavicular joint – covered by fibrous cartilage);

✓ **articular cavity (*cavitas articularis*)** – filled with synovial fluid, in the articular cavity the negative pressure exists;

✓ **articular capsule (*capsula articularis*)** – joins borders of the articular surfaces and forms a hermetically closed articular cavity.

The articular capsule has two layers:

- **fibrous membrane** (*membrana fibrosa*) – the outer layer, formed by fibrous connective tissue, locally thickens to strengthen the joint capsule in areas of greatest stress – **the capsular ligaments** (*ligamenta capsularia*).

- **synovial membrane** (*membrana synovialis*) – internal layer, producing **synovial fluid** (*synovia*).

#### **The functions of the synovial fluid:**

- reduces the friction between articular surfaces;
- nourishes the articular cartilages (cartilages has no blood vessels);
- holds the articular surfaces relatively to each other;
- distributes the tension and forces during movements in the joint;
- participates in metabolism.

### **1.2.2. Additional elements of the diarthrosis**

#### **1.2.2.1. Ligaments**

A dense fibrous connective tissue bands.

There are different types of ligaments:

- ✓ **intraarticular (intrinsic)** – fibrous ligaments inside the joint, which are covered by the synovial membrane and connect the articular surfaces (for example, *lig. capitis femoris* in the hip joint);

- ✓ **extraarticular (extrinsic)** – fibrous ligaments outside the joint, which are not connected to the capsule, they fix the bones of the joint (for example, *lig. iliofemorale* of the hip joint);

- ✓ **capsular** – thickening of the joint capsule (for example, *lig. glenohumerale superior, medius et inferior* of the shoulder joint).

#### **1.2.2.2. Intraarticular cartilage** – fibrous cartilage between articular surfaces.

- ✓ **articular disc** (*discus articularis*) – plate-like cartilage, that totally separates the cavity of the joint into two compartments;

- ✓ **meniscus** (*meniscus articularis*) – semilunar shaped cartilages, partially separates the joint cavity.

### **Functions of the intraarticular cartilages:**

- 1) increase congruence of the articular surfaces and, as a result, they increase the range of movements and their variety;
- 2) reduce and distribute the forces between articular surfaces during movements.

**Congruence** – similarity of the articular surfaces.

#### ***Rule!***

***The more the congruence, the less is the mobility in the joint.***

*For example, the sacroiliac joint with maximum congruence has a minimal volume of mobility. And opposite, the shoulder joint has small congruence and a high range of movements.*

#### **1.2.2.3. Articular labrum (*labrum articulare*)**

A round-shaped fibrous cartilage on the border of the articular surface to deepen it and to increase the congruence of surfaces.

For example, articular labrum around the glenoid cavity in the shoulder joint.

#### **1.2.2.4. Synovial fold (*plica synovialis*)**

It is a synovial membrane protrusion filling articular cavity space; if containing adipose tissue, it's called an **adipose fold** (*plica adiposa*).

For example, synovial and adipose folds of the knee joints.

#### **1.2.2.5. Synovial bursa (*bursa synovialis*)**

A cavity, formed by the protrusion of the synovial membrane. It may be connected with the articular cavity or totally separated from it. The bursae are filled with synovial fluid, which lubricates the surrounding tendons. The function of the synovial bursa – reduces friction of the tendons, passing near the joint.

#### **1.2.2.6. Sesamoid bones (*ossa sesamoidea*, “sesamos” - sesame)**

Additional bones, tightly connected with capsule and tendons, change angle of the tendons attachment, and increase range of motion in the joints. One of the surfaces is covered with hyaline cartilage and turned into the cavity.

#### **Functions:**

- ✓ change the angle of tendon attachment;

- ✓ indirectly increase the range of motion in the joint.

The hugest sesamoid bone is **the patella**. Small sesamoid bones can be also found in synovial joints of the wrist (pisiform bone) and foot (interphalangeal joints, metatarsophalangeal joint I).

***SESAMOID BONES. Why are they called so?***

*Sesamoid bones were first described by second century physician Galen and originated from the Greek word sesamoeides, meaning sesame seeds, because of the morphological resemblance. These bones are similar in size and shape to a pea or small bean; their shape can also be similar to a trihedral pyramid.*

### **1.2.3. Principles of the synovial joints classification**

The classification of joints in the human body is based on the following characteristics:

.2.3.1. Classification of Synovial Joints based on axes of movements and shape of articular surfaces

.2.3.2. Classification of Synovial Joints based on number of articular surfaces

.2.3.3. Classification of Synovial Joints based on simultaneous joint function

#### **1.2.3.1. Classification of synovial joints based on the axes of movements and shape of the articular surfaces**

The following axes and types of movement in the joints are distinguished:

- 1) **Frontal axis** – flexion (*flexio*) and extension (*extensio*);
- 2) **Sagittal axis** – abduction (*abductio*) and adduction (*adductio*);
- 3) **Vertical axis** – only rotation (*rotatio*).

**NB! Circumduction** (*circumductio*) – consequent movement along all axes.

According to the number of axes, the synovial joints can be uniaxial, biaxial and multiaxial.

**A. Uniaxial joints** – movements are possible along 1 axis only (frontal or vertical).

**Uniaxial joints by the shape of the articular surfaces can be:**

✓ **pivot (trochoid) joint** (*articulatio trochoidea*) – movements along the vertical axis (rotation).

**For example:** median atlantoaxial joint, proximal and distal radioulnar joints.

✓ **hinge joint (ginglymus)**, a kind – **cochlear joint** (*articulatio cochlearis*) – similar to a pivot joint, but the axis of movement is placed horizontally, movements occur around frontal axis (flexion and extension). On the one of the articular surfaces there is a crest, on the opposite surface – recess, this shape of surfaces prevents lateral movements. Usually, the capsule is strengthened by ligaments from lateral sides, which don't limit flexion and extension.

**For example:**

- interphalangeal joints – hinge joint;
- humeroulnar joint – cochlear joint, its crest and recess are oblique and have helical passage.

**B. Biaxial joints** – movements along 2 axes.

In comparison to uniaxial joints, biaxial joints have a greater difference in the areas of the articular surfaces, resulting in a greater volume of movements.

Biaxial joints are divided into:

✓ **bicondylar joint** (*articulatio bicondylaris*) – is a transitional form between uniaxial and biaxial joints.

**Movements:**

- 1) frontal axis – flexion and extension;
- 2) vertical axis – rotation.

**For example:** knee joint (**pay attention!** Medial and lateral rotations are possible only in the flexed knee joint).

✓ **ellipsoid (condyloid) joint and saddle joint** (*articulation ellipsoidea et articulation sellaris*)

**Movements:**

- 1) frontal axis – flexion and extension;
- 2) sagittal axis – abduction and adduction.

The 5<sup>th</sup> type of movement is also possible (*circumduction*) a combination of movements along with all common for these joints axes.

**For example:**

- ellipsoid – atlantooccipital and wrist (radiocarpal) joints,
- saddle – carpometacarpal joint I (of the pollex).

**C. Multiaxial joints** – movements are along all three axes; all 6 possible types of movements can occur at these joints.

**Movements:**

- 1) frontal axis – flexion and extension;
- 2) sagittal axis – abduction and adduction;
- 3) vertical axis – rotation;
- 4) circumduction

Multiaxial joints are divided into:

✓ **spheroidal or ball-and-socket joint** (*articulatio spheroidea*)

**For example:** the shoulder joint.

✓ **cotyloid (scyphiform) joint** (*articulatio cotylica*)

**For example:** hip joint (has strong capsule reinforced by ligaments; the acetabulum is deeper in comparison to the glenoid cavity of the shoulder joint, so the range of movements in the hip joint is less than in the shoulder joint).

✓ **plane joint** (*articulatio plana*) – plane articular surfaces, high congruence, very strong ligaments, movements are severely restricted or absent (*amphiarthrosis*).

**For example:** sacroiliac joint.

***Amphyarthrosis** – a type of bones connection with limited movements, where articular surfaces are separated from each other by cartilage with a slit-like cavity (symphysis), or hyaline cartilage (synchondrosis), and diarthrosis with tight capsule and very strong non-stretchable ligaments (for example, sacroiliac joint).*

### **1.2.3.2. Classification of Synovial Joints based on the number of articular surfaces**

***NB!** An articular disc is fused with the articular capsule and completely separates the joints into two floors. Hence, two separated cavities occur in the joint. It is necessary to count not only the articular surfaces of the main bones, but also the articular surfaces of the accessory cartilaginous elements of the joint (discs and menisci) and sesamoid bones.*

➤ **Simple joint** (*articulatio simplex*) is a joint having only two articular surfaces; each of the articular surfaces may be formed by one or several bones.

**For example:** interphalangeal joints, two articular surfaces are formed by only two bones (between proximal and middle phalanges of the fingers).

➤ **Complex joint** (*articulatio composita*) is a joint with capsule which encloses more than two articular surfaces (including articular surfaces of the additional elements like articular discs, menisci and sesamoid bones), or several simple joints that are able to function both together and separately.

**For example:**

✓ **elbow joint** has six articular surfaces between which three simple joints occur: humeroradial, humeroulnar and proximal radioulnar joints.

✓ **knee joint** is formed by articular surfaces of the femur, tibia and patella. According to international anatomical nomenclature it is made up of two simple joints: tibiofemoral and patellofemoral joints.

#### ***Is the knee joint simple or complex?***

*Some authors consider the knee joint as a complex joint, taking into account the articular surfaces on the menisci and patella. They distinguish 3 simple joints in the knee joint: femoromeniscal, meniscofemoral, and femoropatellar.*

*Other authors, including Gajvoronsky I.V., consider the knee joint as a simple one, since the menisci and patella are considered accessory elements.*

*Our opinion: in addition to the articular surfaces of the femur and tibia in the knee joint, there are also articular surfaces of the menisci, as well as the sesamoid bone of the patella.*

***The knee joint is considered a complex joint.***

### 1.2.3.3. Classification of Synovial Joints based on simultaneous joint function

✓ **combined joints** (*articulatio combinatoria*) are the joints which are anatomically separated (i.e. situated in different articular capsules), but **functioning only together**.

**For example:** left and right temporomandibular joint, proximal and distal radioulnar joints.

### 1.2.4. Factors determining the range of movements in the joints

The range of movements at each joint depends on various factors.

1. **Congruence** – the main factor:

✓ the area of the humeral head is 6 times bigger than the area of the scapula's glenoid cavity, therefore, the shoulder joint has the maximal degree of freedom;

✓ in the sacroiliac joint the areas of the articular surfaces are approximately equal, so the movements at this joint are almost absent.

<p><i>The rule: the more the congruence, the less is mobility.</i></p>
--

2. **Presence of the additional elements.**

For example,

✓ menisci increase the congruence of articular surfaces, stabilize the diarthrosis (the knee joint);

✓ disks separate the articular surfaces and form two joints within the diarthrosis, provide additional movements (the temporomandibular joint);

✓ articular labrum enlarges the articular surface, stabilize the diarthrosis and limits the movements (the hip joint);

✓ intraarticular ligaments (within articular cavity) restrict movements only in certain direction (the cruciate ligaments of the knee joint do not restrict flexion, but prevent overextension and dislocation of the articular surfaces by extension and flexion).

3. **Combined joints.** In combined joints the range of movements is determined by the joint with a minor number of axes.

✓ according to the shape of the articular surfaces the lateral atlanto-axial joints are plane, but due to the combination with the median atlanto-axial joint they function as trochoid joints. This is also typical for the articulations of ribs, some articulations of foot etc.

✓ the joint of the head of the rib and tubercle of the rib – movements are determined by the joint of the head of the rib (biaxial saddle joint), even if the joint of the tubercle of the rib is a multiaxial plane joint.

4. ***The condition of the articular capsule*** also determines the range of movements. If the capsule is thin and elastic, the range of movements increases. In some joints the thickness of the articular capsule is not even and this fact also influences the joints functioning.

✓ the temporomandibular joint capsule is thinner anteriorly than posteriorly and laterally, thus the greatest mobility is forward.

5. ***The ligaments, strengthening the articular capsule***, provide restraining and guiding actions due to the high strength and low extensibility of collagen fibers.

✓ in the hip joint the iliofemoral ligament limits extension and pronation of the thigh, the pubofemoral ligament limits abduction and supination of the thigh.

✓ the strongest ligaments are in the sacroiliac joints, therefore, the movements at these joints are almost absent.

6. ***Muscles surrounding the joint*** have constant tone, they pull articulating bones to each other and fasten them (“active joint stabilizing apparatus”). The force of muscle tension reaches 10 kg per 1 cm<sup>3</sup> of the width of muscle. If we remove the muscles and preserve the articular capsule and ligaments (“passive joint stabilizing apparatus”), the range of movements significantly increases. Besides, the direct inhibitory effect on the movements at joints, the muscles also influence them indirectly (by means of ligaments, from which they originate). So, muscles restrict high amplitude of the movements.

7. ***Synovial fluid*** holds the articular surfaces together and lubricates them. In case of arthritis or arthrosis the production of fluid is disordered

and pain and crackling appear in such joints, the range of movements decreases.

8. *Helical deviation* is typically for the humeroulnar joint only; it limits the movements.

9. *Atmospheric pressure* contributes to the cohesion of the articular surfaces with the force 1 kg per 1 cm<sup>2</sup> and evenly pulls them together, moderately limiting the movements.

10. *Condition of skin and subcutaneous fat* effects the movements.

✓ in overweight people the range of movements is always less because of excessive subcutaneous fat. Vice versa, in slender, athletically built people the range of movements is greater.

✓ in case of skin diseases, when it loses its elasticity, the range of movements significantly decreases. After severe burn or wounds, contractures are formed which limit the movements

### **1.2.5. Joint description plan**

- name (in English and Latin);
- bones and articular surfaces forming the joint;
- attachment of the articular capsule;
- joint description/classification
  - ✓ based on number of articular surfaces (simple/complex), with indication of the articular discs/menisci if they are present;
  - ✓ based on simultaneous joint function (combined);
  - ✓ based on the number of axes of movements (uniaxial/biaxial/multiaxial);
  - ✓ based on the shape of articular surfaces (trochoid (pivot)/ellipsoid/plane etc.)
- possible movements;
- presence of additional elements (articular labrum, synovial bursa, synovial folds etc.);
- articular ligaments, their origin, insertion, function.

## CHAPTER 2. SPECIAL ARTHROSYNDESMOLOGY

### 2.1. The joints of skull (*juncturae cranii*)

The bones of the cranium articulate mostly by synarthrosis:

#### 1. syndesmosis:

- ✓ *sutures* (serrate, squamous, plane);
- ✓ *gomphosis* – dentoalveolar syndesmosis;
- ✓ *fontanelles* (frontal, occipital, sphenoid, mastoid).

#### 2. Synchondrosis:

- ✓ permanent (sphenopetrosal and petrooccipital)
- ✓ temporary sphenoccipital synchondrosis replaced by a bony union (**synostosis**) with age.

Paired **temporomandibular joint** is the only diarthrosis of the cranium.

#### 2.1.1. The temporomandibular joint (*articulatio temporomandibularis*)

##### Articular surfaces:

- ✓ the mandibular fossa and the articular tubercle of the temporal bone;
- ✓ the head of the mandible;
- ✓ the surfaces are complemented by an **articular disc** (*discus articularis*) located between them.

**Articular capsule** is attached:

- ✓ on the temporal bone – in front of the articular tubercle and behind (at the level of petrotympanic fissure);
- ✓ on the mandible – to the condylar process in the region of its neck (anteriorly 0,5 cm higher than posteriorly)

##### Description:

- ✓ complex, has **articular disc** (*discus articularis*),
- ✓ combined joint (left and right),
- ✓ biaxial (frontal, vertical),
- ✓ ellipsoid (bicondylar)

**Articular disc** (*discus articularis*) has the shape of a biconcave lens, formed by fibrous cartilage. The edges of the disc are joined to the articular capsule as a result of which the articular cavity is separated into two isolated compartments: upper and lower.

**Movements:** presence of the disc increase the range of movements and their variety.

- ✓ downwards and upwards with opening and closure of the mouth,
- ✓ forwards and backwards,
- ✓ lateral movements (rotation of the mandible to the right and to the left as it occurs in chewing),
- ✓ circumduction

*Steps of the mouth opening/ depression of the mandible (in elevation of the mandible all mentioned above phases follow each other in reverse order):*

✓ *The first phase – slight opening – movement in the lower compartment – the head of the mandible moves downward to leave the fossa for further movements, the disc remains in the mandibular fossa;*

✓ *The second phase – head of the mandible and articular disc move forward and downward to the articular tubercle (movements in both compartments at the same time);*

✓ *The third phase – significant opening – movement in the lower compartment along the frontal axis, the disc remains on the articular tubercle.*

***Lateral movements of the mandible:***

*- on the side of movement the condyle will rotate in the vertical axis (movement is only in the lower compartment, the disc remains in the mandibular fossa), while on the opposite side the condyle and disc move forward to the articular tubercle (first two phases of the mouth opening).*

**Ligaments:**

✓ **the lateral ligament** (*lig. laterale*) limits the movement of the mandible backwards; passes on the lateral side of the joint from the zygomatic process of the temporal bone to the neck of the condylar process of the mandible.

The two ligaments lie at a distance from the joint, and are parts of the fasciae, forming a loop that suspends the mandible:

✓ **the sphenomandibular ligament** (*lig. sphenomandibulare*) passes from the sphenoidal spine to the mandibular lingula.

✓ **the stylomandibular ligament** (*lig. stylomandibulare*) passes from the styloid process to the inner surface of the angle of mandible.

### ***The fetal cranium***

1. *It is large in proportion to the rest of the skeleton.*
2. *The viscerocranium is smaller than neurocranium.*
3. *There are fontanelles in the cranium.*
4. *The frontal and parietal tubers are prominent.*
5. *The two halves of the frontal bone are separate. They are united by the metopic suture. The mandible is present in two halves. The temporal and occipital bones consist of four parts each.*
6. *There are cartilaginous layers between some parts of the bones of the base which have not yet fused.*
7. *The mastoid process is absent. The external acoustic meatus is short. As a result, the stylomastoid foramen and the facial nerve are much nearer the surface than in the adult.*
8. *The air sinuses are still not developed.*

## **2.2. The vertebral joints (*juncturae vertebralis*)**

### **2.2.1. The vertebral column as a whole**

**The vertebral column** is formed by:

- ✓ all vertebrae,
- ✓ sacrum,
- ✓ coccyx,
- ✓ all vertebral joints, ligaments and cartilages.

In general, the spine is an elastic rod – the vertebral column, or spine (*columna vertebralis*). The number of vertebrae involved in the spine is from 31 to 35, sometimes reaching 37. The variability depends mainly on the number of coccygeal vertebrae.

**The length of the vertebral column:**

- ✓ in males 73 – 75 cm,
- ✓ in females 69 – 71 cm.

In the center of the spine is **the vertebral canal** (*canalis vertebralis*), which contains the spinal cord. This canal is bounded by the vertebral bodies and arches, and the yellow ligaments, and has 31 pairs of **intervertebral foramina** (*foramina intervertebralia*), through which the spinal nerves pass.

From **the openings of the transverse processes** in the cervical part, paired bone-fibrous canals are formed for the passage of the vertebral arteries and veins, supplying blood to the brain.

### **Curves of the spine:**

- ✓ **lordosis** (cervical and lumbar), these are curves facing forward,
- ✓ **kyphosis** (thoracic and sacral) – facing backward.

### **Physiological scoliosis.**

✓ the spine is typically not strictly aligned along the midline and has a deviation to the right or left, more often in the thoracic region. This curvature is called **scoliosis** (*scoliosis*). Right-sided thoracic scoliosis is present in 30% at the level of the III-V thoracic vertebrae as a result of the adherence of the descending aorta.

✓ when the spinous processes join, a spinous ridge is formed, which deviates to the right (in right-handers) and to the left (in left-handers) due to uneven muscle development, creating *scoliosis*. On this ridge, the processes of the VII cervical and III lumbar vertebrae are most prominent.

**Physiological curves**, lordosis and kyphosis act as shock absorbers, mitigating the impact of jolts and other forces on the spine, preventing these forces from reaching the skull and therefore the brain.

### **The spine curves formation:**

A newborn baby does not have lordosis or kyphosis.

✓ at 3 months, cervical lordosis occurs when the child begins to hold his head up;

✓ at 6 months, thoracic kyphosis appears when the child begins to sit up;

✓ at 9-12 months the child begins to stand and walk and lumbar lordosis forms;

✓ the final formation of curves occurs by 6-7 years.

### ***Changes in the spine in the elderly:***

*In older people, the thickness of the intervertebral discs decreases, and their ossification often occurs, which contributes to the development of the thoracic curve. At the same time, the length of the spine decreases by 3-7 cm. The appearance of a thoracic curve and lowering of the head in the elderly significantly affects the general posture. Muscle tone, which weakens with age, also plays a certain role in the formation of pathological curves of the spine. The processes of cartilage and ligament ossification are slowed down by physical exercises and measured physical load.*

The vertebrae in the vertebral column are connected to each other by synarthroses and diarthroses.

### **2.2.2. Synarthroses of the vertebral column**

#### **Syndesmoses:**

✓ *ligaments* (**yellow ligaments** which fill the spaces between the vertebral arches, **interspinous ligaments** – between the spinous processes, **intertransverse ligaments** – between the transverse processes of two adjacent vertebrae; **anterior and posterior longitudinal ligaments** connect the vertebral bodies; anterior and deep posterior ligaments between the sacrum and the coccyx;

The part of **the interspinous ligaments** stretched over the apices of the spinous processes is **the supraspinous ligament** (*lig. supraspinale*). In the cervical region, this ligament is called **the nuchal ligament** (*lig. nuchae*). It is attached to the spinous processes of cervical vertebrae, external occipital protuberance.

#### **Synchondroses:**

✓ permanent (connection of the bodies of adjacent vertebrae by means of an intervertebral disc);

✓ temporary (between the bodies of the sacral vertebrae), with age, it is replaced by a bony connection (**synostosis**).

#### **Symphysis:**

✓ between the vertebral bodies, more often in the lumbar region;

✓ between the sacral and coccygeal bodies.

### 2.2.3. Diarthroses of the typical vertebrae

#### 2.2.3.1. Zygapophysial joints (*articulationes zygapophysiales*) or intervertebral joints (*articulationes intervertebrales*)

**Articular surfaces:** the superior articular facet of one vertebra (on vertebral superior articular processes) – the inferior articular facet of the vertebra above it (on its inferior articular processes).

**Articular capsule** is attached to the borders of articular surfaces.

#### **Description:**

- ✓ simple,
- ✓ plane,
- ✓ multiaxial,
- ✓ combined joint (left and right).

#### **Movements:**

- ✓ flexion and extension of the spine,
- ✓ lateral bending of the spine (right and left),
- ✓ rotation along vertical axis.

### 2.2.4. Diarthroses of the atypical vertebrae

#### 2.2.4.1. The atlanto-occipital joint (*articulatio atlantooccipitalis*)

#### **Articular surfaces:**

- ✓ articular surfaces of the occipital condyles,
- ✓ the superior articular surfaces of the atlas.

**Articular capsule** is attached to the borders of articular surfaces; it is thin, fibroelastic.

#### **Description:**

- ✓ simple,
- ✓ biaxial (frontal, sagittal),
- ✓ ellipsoid (bicondylar),
- ✓ combined joint (left and right).

#### **Movements:**

- ✓ flexion and extension (bending the head backwards and forwards),
- ✓ lateral bending the head to the right and to the left,
- ✓ circumduction.

**The wide spaces between the atlas and occipital bone are closed by:**

✓ **the anterior atlanto-occipital membrane** (*membrana atlantooccipitalis anterior*) passes from the anterior arch of the atlas to the anterior border of the foramen magnum.

✓ **the posterior atlanto-occipital membrane** (*membrana atlantooccipitalis posterior*) passes from the posterior arch of the atlas to the posterior border of the foramen magnum.

#### **2.2.4.2. The lateral atlantoaxial joint**

(*articulatio atlantoaxialis lateralis*)

**Articular surfaces:**

- ✓ the inferior articular facets of the atlas,
- ✓ the superior articular surfaces of the axis

**Articular capsule** is attached to the borders of articular surfaces.

**Description:**

- ✓ simple,
- ✓ plane (pivot in function),
- ✓ uniaxial,
- ✓ combined joint (left and right + median atlantoaxial joint).

**Movements:** rotation (movements are determined by the median atlanto-axial joint). Head turns right and left, sliding with a slight displacement of joint surfaces relative to each other.

**Ligaments:**

✓ **the cruciate ligament of the atlas** (*lig. cruciforme atlantis*) has two parts:

- **the transverse ligament of atlas** (*lig. transversum atlantis*) lies between the inner surfaces of the lateral masses of the atlas;

- **the longitudinal fibrous bands** (*fasciculi longitudinales superior et inferior*) arise from the central, slightly widened part of the transverse atlantal ligament upward and downward. **Superior fascicle** ascends to the anterior semicircle of the *foramen magnum*, **inferior fascicle** descends to the posterior surface of the body of axis.

### 2.2.4.3. The median atlanto-axial joint

*(articulatio atlantoaxialis mediana)*

Consists of two parts:

**Anterior part** is formed by:

- ✓ the anterior articular facet of the axial dens;
- ✓ the facet for dens of the atlantal anterior arch;

**Posterior part** is formed by:

- ✓ the posterior articular facet of the axial dens;
- ✓ the anterior surface of the **atlantal transverse ligament** (*lig. transversum atlantis*).

**Articular capsule:**

✓ is attached to the borders of the dens facet on the anterior arch of the atlas;

- ✓ encircles the dens of the axis;
- ✓ is strengthened by *the cruciform ligament of the atlas*.

**Description:**

- ✓ complex (has two parts),
- ✓ pivot (trochoid),
- ✓ uniaxial,
- ✓ combined joint (with lateral atlanto-axial joints).

**Movements:** along vertical axis (rotations of the atlas around the dens).

**Ligaments:**

✓ **the transverse ligament of atlas** (*lig. transversum atlantis*) lies between the inner surfaces of the lateral masses of the atlas. It doesn't permit the dens to displace backwards;

✓ **the apical ligament of dens** (*lig. apicis dentis*) passes from the apex of the dens to the anterior border of the *foramen magnum*;

✓ two **alar ligaments** (*ligg. alaria*) pass from the lateral surfaces of the dens to the medial surfaces of the occipital condyles. These ligaments limit the rotation at the atlantoaxial joints.

✓ **the cruciate ligament of the atlas** (*lig. cruciforme atlantis*) serves as an articular surface for the axial dens and guides its movements; it prevents the dens dislocation (see lateral atlantoaxial joint);

✓ **the tectorial membrane** (*membrana tectoria*) is the upper part of the **posterior longitudinal ligament**. It passes from the inner surface of the basilar part of the occipital bone (clivus) and anterior edge of the foramen magnum to the body of the axis.

#### 2.2.4.4. The sacrococcygeal joint (*articulatio sacrococcygea*)

##### **Articular surfaces:**

✓ articular surfaces of the sacral apex and the I coccygeal vertebrae.

**Movements:** allows the coccyx to lean back during childbirth.

##### **Ligaments:**

✓ **the lateral sacrococcygeal ligament** (*lig. sacrococcygeum laterale*) is an analogue of intertransverse ligaments, it passes from the inferior border of the lateral sacral crest to the rudiment of the transverse process of the I coccygeal vertebra;

✓ **the superficial posterior (dorsal) sacrococcygeal ligament** (*lig. sacrococcygeum posterius (dorsale) superficiale*) corresponds to the yellow and supraspinous ligaments; passes from the margin of sacral hiatus to the posterior surface of the coccyx;

✓ **the anterior (ventral) sacrococcygeal ligament** (*lig. sacrococcygeum anterius (ventrale)*) is the continuation of the **anterior longitudinal ligament** of the spine;

✓ **the deep posterior (dorsal) sacrococcygeal ligament** (*lig. sacrococcygeum posterius (dorsale) profundum*) is the continuation of the **posterior longitudinal ligament** of the spine.

### 2.3. The thoracic joints (*juncturae thoracis*)

#### 2.3.1. The thorax as a whole

**Thorax or thoracic cage** (*compages thoracis*) is formed by:

- ✓ thoracic vertebrae,
- ✓ ribs,
- ✓ sternum.

The thoracic cage forms the walls of **the thoracic cavity** (*cavitas thoracis*).

The thoracic cage has two apertures:

**Superior thoracic aperture** (*apertura thoracis superior*) is formed by:

- ✓ I thoracic vertebra,
- ✓ pair of I ribs,
- ✓ manubrium of the sternum.

The vessels, nerves, trachea, esophagus pass through the superior thoracic aperture.

**Inferior thoracic aperture** (*apertura thoracis inferior*), is formed by:

- ✓ XII thoracic vertebra,
- ✓ lower ribs,
- ✓ costal cartilages,
- ✓ xiphoid process of the sternum.

The inferior thoracic aperture is closed by the diaphragm.

The spaces between neighboring ribs are called **the intercostal spaces** (*spatium intercostale*).

The cartilages of the false ribs on each side form the costal arches, which together laterally delimit the **infrasternal angle** (*angulus infrasternalis*) which is open below.

When forming the chest, the angles of all ribs, when forming the chest, form **pulmonary grooves** (*sulci pulmones*).

**Three forms of the thorax are distinguished:**

✓ **flat**, narrow and long, strongly flattened in anteroposterior diameter, so that its anterior wall is almost vertical, the ribs are strongly inclined, the angulus infrasternalis is sharp. The chest is in a state of expiration, which is why it is called expiratory. This is seen in individuals with poorly developed muscles and lungs;

✓ **conical**, wide, but short, i.e. its lower part is wider than the upper, the ribs are slightly inclined, the angulus infrasternalis is large. Such a chest is in a state of inspiration, which is why it is called inspiratory. This is seen in individuals with well-developed muscles and lungs;

✓ **cylindrical**, occupies an intermediate position between the two described before.

### **Sex differences:**

In female, the thorax is shorter and narrower in the lower section than in male, and more rounded.

### **Factors impacting the formation of the thorax:**

✓ children living in dark houses, with a lack of nutrition and sunlight, **rickets** develops (“English disease”), in which the thorax takes the shape of a “chicken breast”: the anteroposterior size predominates, and the sternum protrudes abnormally forward, like in chickens.

✓ in children, due to poor muscle development, a long and flat thorax is formed; when sitting incorrectly at a desk, the thorax appears to be in a collapsed state, which affects the activity of the heart and lungs. To avoid diseases, children need physical activity.

### **Movements of the thorax**

Respiratory movements consist of alternately raising and lowering the ribs, along with which the sternum moves. When inhaling, the posterior ends of the ribs rotate around the axis mentioned in the description of the joints of the ribs, and their anterior ends are raised so that the thorax expands in anteroposterior size. Due to the oblique direction of the axis of rotation, the ribs simultaneously move apart to the sides, as a result of which the transverse size of the thorax also increases. At the end of the inhalation caused by the muscular act, the ribs lower, and then exhalation occurs.

## **2.3.2. The sternocostal joints**

### **2.3.2.1. The sternocostal joints (II-VII ribs)**

*(articulationes sternocostales)*

#### **Articular surfaces:**

- ✓ the anterior ends of the costal cartilages (II-VII ribs),
- ✓ costal notches of the sternum.

**Articular capsule** is a continuation of the perichondrium of the costal cartilage and sternal periosteum.

**Description:**

- ✓ simple,
- ✓ spheroidal (II – saddle),
- ✓ multiaxial,
- ✓ combined (with joints of costal head and costotransverse joints).

**NB!**

*The cartilage of the first rib fuses directly with the sternum, forming a **permanent hyaline synchondrosis** (*synchondroses costae primae*).*

**Movements:** Rising and lowering the ribs

**Ligaments:**

- ✓ **the radiate sternocostal ligaments** (*ligg. sternocostalia radiata*) strengthen the articular capsule from the anterior and posterior sides and form the sternal membrane (*membrana sterni*).

**2.3.3. The costovertebral joints****2.3.3.1. The joint of head of rib** (*articulatio capitis costae*)**Articular surfaces:**

- ✓ the articular facet of the head of rib;
- ✓ the costal demi-facets of two adjacent thoracic vertebrae (II-X), the costal facets of the I, XI, XII thoracic vertebrae.

**Articular capsule:** is attached to the borders of articular surfaces.

**Description:**

- ✓ simple (I, XI, XII ribs), complex (II-X ribs),
- ✓ spheroidal (I, XI, XII ribs), saddle (II-X ribs),
- ✓ combined (with costotransverse and sternocostal joints),
- ✓ uniaxial

**Movement:** raising and lowering the ribs.

**Ligaments:**

- ✓ in each joint (ribs II-X) between the crest of the costal head and the intervertebral disc, there is an **intra-articular ligament of the head of the rib** (*lig. capitis costae intraarticulare*).

### 2.3.3.2. The costovertebral joint (*articulatio costovertebralis*)

#### Articular surfaces:

- ✓ articular surface of the ribs' tubercle (I – X);
- ✓ the costal facets of the transverse process of a thoracic vertebra.

**Articular capsule:** is attached to the borders of articular surfaces.

#### Description:

- ✓ simple,
- ✓ trochoid (pivot, around its own axis passing through the neck of the rib),
- ✓ uniaxial (along the axis of the rib),
- ✓ combined joint (with sternocostal joint and joint of head of rib)

**Movements:** raising and lowering the ribs.

#### Ligaments:

- ✓ **the costovertebral ligament** (*lig. costovertebralis*) strengthens a thin articular capsule, consists of three bundles:
  - ✓ **the anterior costovertebral ligament** (*lig. costovertebralis anterior*), which connects the costal neck with the corresponding transverse process;
  - ✓ **the superior costovertebral ligament** (*lig. costovertebralis superior*), which connects the costal neck with the superior transverse process.
  - ✓ **the lateral costovertebral ligament** (*lig. costovertebralis lateralis*), which connects the transverse process with the costal tubercle.

## 2.4. Diarthrosis of the upper limb

### 2.4.1. The sternoclavicular joint (*articulatio sternoclavicularis*)

#### Articular surfaces:

- ✓ the sternal facet of the clavicle,
- ✓ the clavicular notch of the sternum;
- ✓ an articular disc is present.

**Articular capsule** is attached to the borders of articular surfaces.

#### Description:

- ✓ complex, has an articular disc (*discus articularis*), its edges are joined to the articular capsule, as a result of which the articular cavity is separated into two isolated compartments.

- ✓ saddle (95%)/ spheroidal (5%),
- ✓ biaxial (95%)/multiaxial (5%),
- ✓ combined (with acromioclavicular joint).

**Movements:**

- ✓ along sagittal axis: raising and lowering the clavicle;
- ✓ along vertical axis: movement of the clavicle forward and backward;
- ✓ rotation;
- ✓ if it is ball-and-socket, rotation around the frontal axis is also possible.

**Ligaments:**

✓ **the anterior and posterior sternoclavicular ligaments** (*lig. sternoclavicularis anterior, posterior*) intertwine with the periosteum of the sternum, limits forward and backward movements of the clavicle.

✓ **the interclavicular ligament** (*lig. interclavicularis*) connects two sternal ends of the clavicles, stretches over the jugular notch of the sternum and limits downward movements of the clavicle.

✓ **the costoclavicular ligament** (*lig. costoclavicularis*) extends from the cartilage of the first rib to the inferior surface of the sternal end of the clavicle, limits upward movements of the clavicle.

**2.4.2. The acromioclavicular joint** (*articulatio acromioclavicularis*)

**Articular surfaces:**

- ✓ the acromial facet of the clavicle,
- ✓ clavicular facet of the acromion.

**Articular capsule** is attached to the borders of articular surfaces.

**Description:**

- ✓ simple; however, in 1/3 of cases, there may be an intraarticular disc between the articular surfaces, then the joint will be considered complex,
- ✓ combined (with the sternoclavicular joint),
- ✓ plane,
- ✓ multiaxial.

**Movements** are restricted:

- ✓ along sagittal axis: raising and lowering the clavicle;
- ✓ along vertical axis: movement of the clavicle forward and backward;
- ✓ rotation.

### **Ligaments:**

✓ **the acromioclavicular ligament** (*lig. acromioclaviculare*) between the acromion and the acromion end of the clavicle, strengthens the articular capsule.

✓ **the coracoclavicular ligament** (*lig. coracoclaviculare*) has two part:

- **the trapezoid ligament** (*lig. trapezoideum*) passes from the coracoid process of the scapula to the trapezoid line on the inferior surface of the acromial end of the clavicle.

- **the conoid ligament** (*lig. conoideum*) passes from the coracoid process of the scapula to the conoid tubercle on the inferior surface of the acromial end of the clavicle.

### **2.4.3. Shoulder joint** (*articulatio humeri*)

#### **Articular surfaces:**

- ✓ the glenoid cavity of the scapula,
- ✓ the head of the humerus.

**Articular capsule** is thin, loose, attached along the edge of the articular labrum on the scapula and along the anatomical neck of the humerus, the tubercles remain free.

#### **Description:**

- ✓ simple,
- ✓ spheroidal,
- ✓ multiaxial (frontal, sagittal, vertical).

#### **Movements:**

- ✓ frontal axis: flexion (to horizontal level) and extension;
- ✓ sagittal axis: abduction up to 90° and adduction to the body;
- ✓ vertical axis: rotation of the shoulder outward (supination, *supinatio*) and inward (pronation, *pronatio*),
- ✓ circular movement (conical): transition from frontal to sagittal axis.

#### **Ligaments:**

✓ **the coracohumeral ligament** (*lig. coracohumerale*): from the outer edge and base of the coracoid process of the scapula to the upper part of the anatomical neck of the humerus;

✓ **the glenohumeral ligaments (superior, medialis and posterior)** (*ligg. glenohumeralia superius, mediale et inferius*), capsular, from the glenoid labrum of the scapula to the anatomical neck of the humerus.

**Additional elements:**

✓ **articular labrum** (*labrum glenoidale*), is located along the edge of the glenoid cavity of the scapula, deepens it.

✓ **intertubercular synovial sheath** (*vagina synovialis intertubercularis*), formed by the synovial membrane of the joint capsule, surrounds the tendon of the **long head of the biceps brachii muscle**.

✓ **subtendinous bursa of the subscapularis muscle** (*bursa subtendinea m. subscapularis*), formed by eversion of the synovial membrane, located at the base of the coracoid process of the scapula under the tendon of the **subscapularis muscle**.

#### **2.4.4. The elbow joint** (*articulatio cubiti*)

Three articulating bones form three joints invested in a common capsule:

- ✓ the humeroulnar joint,
- ✓ the humeroradial joint,
- ✓ the proximal radio-ulnar joint.

**Articular capsule** common to three joints:

- ✓ loose, loosely stretched, thicker on the sides;
- ✓ at the level of the olecranon fossa it is especially thin;
- ✓ is attached to the humerus above the coronoid and ulnar fossae of the humerus, leaving them in the joint cavity.

**Ligaments (common to the elbow joint):**

✓ **the ulnar collateral ligament** (*lig. collaterale ulnare*) inhibits lateral movements in the elbow joint, passes from the medial epicondyle of the humerus to the medial border of the trochlear notch of the ulna;

✓ **the radial collateral ligament** (*lig. collaterale radiale*) inhibits lateral movements in the elbow joint, passes from the lateral epicondyle of the humerus then divided into two bundles:

- the anterior bundle is attached at the anterolateral edge for the trochlear notch of the ulna.

- the posterior bundle passes behind the neck of the radius, covers it in the form of a loop and is attached to the annular ligament of the radius.

- ✓ **the annular ligament of radius** (*lig. anulare radii*) - encircles the neck of the radius and holds the radius to the ulna, attaches along the edge of the radial notch of the ulna.

- ✓ **the quadrate ligament** (*lig. quadratum*) passes from the distal edge of the radial notch of the ulna to the neck of the radius.

#### **2.4.4.1. The humeroulnar joint** (*articulatio humeroulnaris*)

##### **Articular surfaces:**

- ✓ the trochlea of the humerus,
- ✓ the trochlear notch of the ulna.

##### **Description:**

- ✓ simple,
- ✓ cochlear (ginglymus), hinge,
- ✓ uniaxial (frontal axis),
- ✓ combined (with humeroradial joint).

##### **Movements:**

- ✓ frontal axis: flexion and extension of the forearm.

#### **2.4.4.2. The humeroradial joint** (*articulatio humeroradialis*)

##### **Articular surfaces:**

- ✓ the capitulum of the humerus,
- ✓ the articular facet of the head of the radius.

##### **Description:**

- ✓ simple,
- ✓ spheroidal,
- ✓ biaxial,
- ✓ combined (with the humeroulnar, the proximal and distal radio-ulnar joints).

##### **Movements:**

- ✓ frontal axis: flexion and extension of the forearm,
- ✓ vertical axis: rotation (pronation, supination).

### 2.4.4.3. The proximal radio-ulnar joint

(*articulatio radioulnaris proximalis*)

#### Articular surfaces:

- ✓ the articular circumference of the radius,
- ✓ the radial notch of the ulna.

#### Description:

- ✓ simple,
- ✓ pivot (throchoid),
- ✓ uniaxial,
- ✓ combined (with the distal radio-ulnar and humeroradial joints).

#### Movements:

- ✓ vertical axis: rotation (pronation, supination).

**Pronation** (*pronatio*) – inward rotation.

**Supination** (*supinatio*) – outward rotation.

### 2.4.4.5. The distal radio-ulnar joint (*articulatio radioulnaris distalis*)

#### Articular surfaces:

- ✓ the articular circumference of the ulna,
- ✓ the ulnar notch of the radius,
- ✓ **the articular disc**, a triangular-shaped cartilaginous plate that separates the cavity of the wrist joint (see below).

**Articular capsule** is attached to the borders of articular surfaces.

The upper part is weak and is evaginated by the synovial membrane from *the sacciform recess* in front of the interosseus membrane.

#### Description:

- ✓ complex, has a disc,
- ✓ pivot,
- ✓ uniaxial (vertical axis of rotation),
- ✓ combined (with the proximal radio-ulnar joint).

#### Movements:

- ✓ rotation (supination and pronation) of the radius on the longitudinal axis in humeroradial and proximal and distal radio-ulnar joints.

The bones of the forearm are also connected to each other by **syndesmosis**: a fibrous membrane is stretched between the interosseous edges of the ulna and radius bones – the interosseous membrane of the forearm (*membrana interossea antebrachii*).

#### **2.4.6. The wrist joint (*articulatio radiocarpalis*)**

##### **Articular surfaces:**

- ✓ the carpal articular surface of the radius and the articular disc (see the distal radio-ulnar joint),
- ✓ the proximal articular surfaces of the first row of carpal bones (scaphoid, lunate and triquetral),
- ✓ the articular disc, a triangular-shaped cartilaginous plate that separates the cavity of the distal radio-ulnar joint.

**Articular capsule** is attached to the borders of articular surfaces.

##### **Description:**

- ✓ complex, has an articular disc,
- ✓ ellipsoid,
- ✓ biaxial (frontal, sagittal axes),
- ✓ combined (with midcarpal joint).

##### **Movements:**

- ✓ frontal axis: flexion and extension of the hand,
- ✓ sagittal axis: adduction and abduction of the hand,
- ✓ transition from the frontal to the sagittal axis: circumduction.

##### **Ligaments:**

✓ **the radial collateral ligament of the wrist joint** (*lig. collaterale carpi radiale*) inhibits adduction of the hand, passes from the styloid process of the radius to the scaphoid bone;

✓ **the ulnar collateral ligament of the wrist joint** (*lig. collaterale carpi ulnare*) inhibits abduction of the hand, passes from the styloid process of the ulna to the triquetral and pisiform bones;

✓ **the palmar radiocarpal ligament** (*lig. radiocarpale palmare*) inhibits extension of the hand, passes from the anterior surface of the articular surface of the radius to the bones of the first carpal row and the capitate bone;

✓ **the dorsal radiocarpal ligament** (*lig. radiocarpale dorsale*) inhibits flexion of the hand, passes from the posterior surface of the articular surface of the radius to the bones of the first carpal row.

#### **2.4.7. The carpometacarpal joints of the II-V fingers**

(*articulationes carpometacarpales II-V*)

##### **Articular surfaces:**

- ✓ the distal articular surfaces of second row of the carpal bones,
- ✓ the articular surfaces of bases of the II-V metacarpal bones.

**Articular capsule** is attached to the borders of articular surfaces.

##### **Description:**

- ✓ complex,
- ✓ plane, limited mobility (solid base of the wrist).
- ✓ multiaxial.

**Movements:** are restricted, slight slips are possible.

##### **Ligaments:**

✓ **the dorsal and palmar carpometacarpal ligaments** (*lig. carpometacarpalia palmaria et dorsalia*), strengthen the capsule, passes from the bones of the second row of the wrist to the bases of the II – V metacarpal bones, strong.

#### **2.4.8. The carpometacarpal joints of the I finger**

(*articulatio carpometacarpalis pollicis*)

##### **Articular surfaces:**

- ✓ articular surface of the trapezium bone,
- ✓ base of the first metacarpal bone.

**Articular capsule** is attached to the borders of articular surfaces.

##### **Description:**

- ✓ simple,
- ✓ saddle,
- ✓ biaxial.

### **Movements:**

- ✓ frontal axis: flexion and extension, opposition of the thumb to the rest of the fingers of the hand (*oppositio*);
- ✓ sagittal axis: adduction and abduction, in this case, the thumb is adduction (approached) to the index (II) finger and abduction from it.
- ✓ transition from the frontal to the sagittal axis: circular movement (*circumductio*).

### **2.4.9. The metacarpophalangeal joints**

(*articulationes metacarpophalangeae*)

#### **Articular surfaces:**

- ✓ rounded articular surfaces of the heads of the metacarpal bones,
- ✓ ellipsoidal bases of the proximal phalanges.

**Articular capsule** is attached to the borders of articular surfaces.

#### **Description:**

- ✓ simple,
- ✓ ellipsoid/spheroidal,
- ✓ biaxial.

#### **Movements:**

- ✓ frontal axis: flexion and extension of the hand,
- ✓ sagittal axis: adduction and abduction of the hand,
- ✓ transition from the frontal to the sagittal axis: circular movement (*circumductio*).

*The I (first) metacarpophalangeal joint is trochlear.*

*Movements are possible only along the frontal axis: flexion and extension.*

#### **Ligaments (capsular):**

- ✓ **the collateral ligaments** (*ligg. collateralia*), passes from the radial and ulnar surfaces of the heads of the metacarpal bones to the lateral surfaces of the bases of the proximal phalanges;
- ✓ **the palmar ligaments** (*ligg. palmaria*), passes from the radial and ulnar surfaces of the heads of the metacarpal bones to the palmar surfaces of the bases of the proximal phalanges;

✓ **the deep transverse metacarpal ligament** (*ligg. metacarpalia transversa profunda*), there are three of them, connecting the heads of the II-V metacarpal bones, preventing their divergence to the sides and forming a solid base of the palm.

#### **2.4.10. The interphalangeal joints of hand**

(*articulationes interphalangeae manus*)

**Articular surfaces:** the head and the base of the adjoining phalanges.

**Description:**

- ✓ simple,
- ✓ hinge,
- ✓ uniaxial.

**Movements:**

- ✓ frontal axis: flexion and extension.

**Ligaments (capsular):**

✓ **the collateral ligaments** (*ligg. collateralia*) – eliminate the possibility of lateral movements, located between the lateral surfaces of the heads of the phalanges and the lateral surfaces of the bases of the phalanges;

✓ **the palmar ligaments** (*ligg. palmaria*), located between the lateral surfaces of the heads of the phalanges and the palmar surfaces of the bases of the phalanges.

### **2.5. Diarthrosis of the lower limb**

#### **2.5.1. The pelvis as a whole**

**Pelvis** (*pelvis*) is formed by:

- ✓ hip bones,
- ✓ sacrum.

**The sacrotuberous** (*lig. sacrotuberale*) and **sacrospinous** (*lig. sacrospinale*) ligaments close the sciatic notches, forming:

- ✓ **greater sciatic foramen** (for. ischiadicum majus),
- ✓ **lesser sciatic foramen** (for. ischiadicum minus).

**Obturator foramen** (*for. obturatorum*), located on the lateral wall of the pelvis, is closed by a fibrous **obturator membrane** (*membrana obturatoria*), which, spreading across the obturator groove of the pubic bone, together with the upper edge of the obturator internus muscle, forms the **obturator canal** (*canalis obturatorius*).

**The terminal line** (*linea terminalis*) is formed by:

- ✓ behind – the promontory of the sacrum,
- ✓ arcuate line of the ilium,
- ✓ the pectin of the pubic bone,
- ✓ in front – superior border of the pubic symphysis.

The terminal line separates the pelvis for two divisions:

**Greater pelvis** (*pelvis major*) is formed by:

- ✓ wings of the ilium,
- ✓ body of V lumbar vertebra.

**Lesser pelvis** (*pelvis minor*) is bounded by:

- ✓ the pubic symphysis and the ramus of the pubic bones (in front),
- ✓ internal surface of the hip bones below the terminal line,
- ✓ the sacrotuberous and the sacrospinous ligaments (on the sides),
- ✓ pelvic surface of the sacrum,
- ✓ anterior surface of the coccyx (behind).

**Pelvic inlet / superior pelvic aperture** (*apertura pelvis superior*) – is the entrance to lesser pelvis and bounded by *linea terminalis*.

**Pelvic outlet / inferior pelvic aperture** (*apertura pelvis inferior*) – the exit from lesser pelvis – **is formed by:**

- ✓ behind – coccyx,
- ✓ on the sides – the sacrotuberous ligaments, sciatic tubers, ramus of the ischium, lower ramus of the pubic bones,
- ✓ in front – pubic symphysis.

Sex differences are associated with the function of the female pelvis, which is the container for the developing fetus, as well as the formation of the narrowest and toughest part of the birth canal (table 1).

Table 1

## Sex differences of the pelvis

Feature	Male pelvis	Female pelvis
Transverse size	narrow	wide
Thickness of the bones	thick	thin
Shape of the sacrum	narrow and concave	wide and flattened
Subpubic angle between lower ramus of the pubic bones	sharp	right or obtuse
The pubic symphysis	high, the cartilage is thin	short, the cartilage is thick
Movements in the pubic symphysis	absent	possible during childbirth
Distance between sciatic tubers	less	more
Distance between the wings of the ilium	less	more
Superior aperture	oval	round
Inferior aperture	narrow, longitudinal oval	wide, transverse oval
Pelvic volume	less	more
Joint between the sacrum and the coccyx	movements are absent	movements are possible during childbirth

**2.5.2. Synarthroses of the pelvic bones****Syndesmoses:**

- ✓ *ligaments* (iliopsoas, sacrotuberous, sacrospinous),
- ✓ *interosseous membrane* (obturator membrane)

**Synchondrosis:**

- ✓ temporary (between parts of the pelvic bone in the acetabulum area (in children), replaced by a bony union (**synostosis**) with age.

**Symphyses:**

- ✓ semi-mobile connection of the symphyseal surfaces of the right and left pubic bones, covered with hyaline cartilage (**pubic symphysis**).

The interpubic fibrous disc has a slit-like cavity. Small movements are possible in women during childbirth. There are two ligaments: the superior pubic ligament (*lig. pubicum superior*) and the inferior pubic ligament (*lig. pubicum inferior*).

### **2.5.3. The sacro-iliac joint (*articulatio sacroiliaca*)**

#### **Articular surfaces:**

- ✓ the auricular surfaces of the sacrum (covered by fibrocartilage),
- ✓ the auricular surfaces of the ilium (covered by hyaline cartilage).

**Articular capsule** is attached to the borders of articular surfaces.

#### **Description:**

- ✓ simple,
- ✓ plane,
- ✓ multiaxial,
- ✓ combined (left and right, with zygapophysial joints of the lumbar and thoracic vertebrae).

#### **Movements:**

- ✓ are restricted, slight rotation forward and backward along the transverse axis of the joint when tilting the body forward and backward.

#### **Ligaments:**

- ✓ **the anterior sacroiliac ligament** (*lig. sacroiliacum anterior*), strengthens the articular capsule in front;
- ✓ **the posterior sacroiliac ligament** (*lig. sacroiliacum posterior*), strengthens the articular capsule at the back;
- ✓ **the interosseous sacroiliac ligament** (*lig. sacroiliacum interosseum*), the strongest ligament of this joint, is located under the anterior and posterior sacroiliac ligaments. The ligament fuses with the posterior surface of the articular capsule and fills the depression between the rough surfaces of the sacrum and ilium;

**Additional ligaments** stabilize the pelvis as a whole:

- ✓ **the iliolumbar ligament** (*lig. iliolumbale*), passes from the transverse processes of the IV and V lumbar vertebrae to the crest and tuberosity of the ilium, strengthens the joint;

✓ **the sacrospinous ligament** (*lig. sacrospinale*), passes from the lateral edge of the sacrum and coccyx to the ischial spine.

✓ **the sacrotuberous ligament** (*lig. sacrotuberale*), passes from the lateral edge of the sacrum and coccyx to the ischial tuberosity.

#### **2.5.4. The hip joint** (*articulatio coxae*)

##### **Articular surfaces:**

- ✓ the lunate surface of the acetabulum of the hip bone,
- ✓ the articular surface of head of the femur.

##### **Articular capsule:**

- ✓ on the pelvic bone it is attached around the circumference of the acetabulum, leaving the acetabulum inside the joint cavity.
- ✓ it is attached to the femur along the intertrochanteric line anteriorly and just above the intertrochanteric crest posteriorly.

##### **Description:**

- ✓ simple,
- ✓ cotyloid (a kind of spheroidal),
- ✓ multiaxial.

##### **Movements:**

- ✓ frontal axis: flexion and extension,
- ✓ sagittal axis: abduction and adduction,
- ✓ vertical axis: rotation (pronation, supination).

##### **Additional elements:**

- ✓ fibrocartilaginous acetabular labrum (*labrum acetabulare*), fuses with the edge of the acetabulum, deepens it.

##### **Ligaments:**

##### **intraarticular:**

✓ **the ligament of the head of the femur** (*lig. capitis femoris*), located between the pelvic bone in the area of the notch of the acetabulum and the fossa of the head of the femur:

- prevents excessive adduction and external rotation of the hip,
- vessels pass through it to the head of the femur,

- during the formation of the joint, holds the head of the femur at the acetabulum.

- ✓ **the transverse acetabular ligament** (*lig. transversum acetabuli*), stretched over the acetabular notch.

**extraarticular:**

- ✓ **the zona orbicularis** (*zona orbicularis*), consists of circular fibers. These fibers embrace the femoral neck like a loop and attach to the bone under the anterior inferior iliac spine;

- ✓ **the iliofemoral ligament** (*lig. iliofemorale*), limits extension in the joint and is involved in keeping the body in an upright position, located between the lower anterior iliac spine and the intertrochanteric line of the femur;

- ✓ **the pubofemoral ligament** (*lig. pubofemorale*), strengthens the joint capsule from the upper ramus of the pubic bone and the body of the ilium at the site of its fusion with the pubic bone to the medial edge of the intertrochanteric line of the femur, delays medial rotation of the femur, together with the lateral part of the lig. iliofemorale inhibits adduction,

- ✓ **the pubofemoral ligament** (*lig. ischiofemorale*) – strengthens the joint capsule from the body of the ischium to the vertical fossa of the greater trochanter of the femur, delays inward rotation of the femur, together with the lateral part of the lig. iliofemorale inhibits adduction.

### **2.5.5. The knee joint** (*articulatio genus*)

**Articular surfaces:**

- ✓ The medial and lateral condyles, patellar surface of the femur,
- ✓ The superior articular surface of the tibia,
- ✓ The articular surface of the patella.

**Articular capsule:**

- ✓ is attached 1 cm above to the borders of the articular surface of the femur;
- ✓ it is attached to the borders of articular surfaces of the tibia and the patella,
- ✓ fuses with the outer edges of the menisci.

### **Description:**

- ✓ complex, has the menisci,
- ✓ biaxial,
- ✓ bicondylar.

### **Movements:**

- ✓ frontal axis: flexion and extension,
- ✓ vertical axis: rotation becomes possible when the knee is flexed (relaxed collateral ligaments).

### **Additional elements:**

- ✓ **two menisci** of semilunar shape, triangular in section –
  - o **medial meniscus** (*meniscus medialis*),
  - o **lateral meniscus** (*meniscus lateralis*).
- ✓ **folds** of the synovial membrane that contain fatty tissue:
  - o **paired alar folds** (*plicae alares*), is located below and lateral to the patella, passing into the joint cavity between the articulating bones;
  - o **infrapatellar synovial fold** (*plica synovialis infrapatellaris*) passes from the patella down to the anterior intercondylar field, dividing the joint cavity into left and right parts;
  - o **synovial villi** (*villi synoviales*).

### **Synovial bursa:**

- **synovial bursae that communicate with the joint cavity:**
  - **suprapatellar bursa** (*bursa suprapatellaris*) is located between the distal epiphysis of the femur and the tendon of the quadriceps femoris muscle;
  - **deep infrapatellar bursa** (*bursa infrapatellaris profunda*) lies between the patellar ligament and the proximal epiphysis of the tibia;
  - **bursa of the popliteus muscle** (*bursa m. poplitei*) lies between the popliteus tendon and the posterior part of the joint capsule at the edge of the lateral meniscus;

- **lateral and medial subtendinous bursae of the gastrocnemius muscle** (*bursa subtendinea m. gastrocnemii lateralis et bursa subtendinea m. gastrocnemii medialis*) is located under each head of the gastrocnemius muscle and joint capsule (at the level of the posterior surface of the corresponding femoral condyle);

- **bursa of the semimembranosus muscle** (*bursa m. semimembranosi*) is located between the tendon of the semimembranosus muscle and the medial head of the gastrocnemius muscle;

- **bursa of the semimembranosus muscle propria** (*bursa m. semimembranosi propria*) is located at the muscle insertion.

➤ **synovial bursae that do not communicate with the joint cavity:**

- **subfascial (subcutaneous) prepatellar bursa** (*bursa prepatellaris subfascialis (subcutanea)*) is located on the anterior surface of the joint;

- **subtendinous prepatellar bursa** (*bursa prepatellaris subtendinea*) is located between the patella and the tendon of the quadriceps femoris muscle;

- **inferior subtendinous bursa of the biceps femoris muscle** (*bursa subtendinea m. bicipitis femoris inferior*) is located between the biceps tendon and the peroneal collateral ligament.

### **Ligaments:**

➤ **intraarticular ligaments:**

- ✓ **the transverse ligament of the knee** (*lig. transversum genus*) – connects the anterior ends of the menisci, stretched between the anterior ends of the menisci;

- ✓ **the anterior cruciate ligament** (*lig. cruciatum anterius*) connects the medial surface of the lateral condyle of the femur with the anterior intercondylar area of the tibiae.

**Function:** limits inward rotation of the shin, keeps the tibia from slipping forward. Main stabilizing element of the knee joint.

- ✓ **the posterior cruciate ligament** (*lig. cruciatum posterius*) con-

nects the lateral surface of the medial condyle of the femur with the posterior intercondylar area of the tibiae.

**Function:** limits inward rotation of the shin, keeps the tibia from slipping backward. Main stabilizing element of the knee joint.

➤ **extraarticular ligaments:**

✓ **the fibular collateral ligament** (*lig. collaterale fibulare*) – limits extension and inward rotation of the shin, stretches on the lateral side from the lateral epicondyle of the femur to the head of the fibula;

✓ **the tibial collateral ligament** (*lig. collaterale tibiale*) – limits extension and outward rotation of the shin, stretches on the medial side from the medial epicondyle of the femur to the edge of the tibia;

✓ **the oblique popliteal ligament** (*lig. popliteum obliquum*), passes on the posterior surface of the joint from the medial condyle of the tibia upwards and laterally and fuses with the capsule;

✓ **the arcuate popliteal ligament** (*lig. popliteum arcuatum*), stretches from the posterior surface of the head of the fibula and the lateral epicondyle of the femur to the posterior surface of the tibia, partially attached to the middle part of the oblique popliteal ligament.

✓ **the patellar ligament** (*lig. patellae*) is a part of the quadriceps tendon, passes from the apex of the patella to the tuberosity of the tibia;

✓ **the lateral and medial patellar retinaculum ligaments** (*ligg. retinaculum patellae mediale et laterale*) – are the internal and external bundles of the quadriceps tendon, pass on the sides of the patella and attach to the lateral and medial condyles of the tibia.

*Two Belgian orthopedic surgeons, Steven Claes and Johan Bellemans, in 2013 discovered a ligament that French surgeon Paul Segond wrote about in 1879, officially called **the anterolateral ligament of the knee joint**. This ligament is located between the lateral epicondyle of the femur and the tibia (Figure 1). The authors believe that the biomechanical function of this ligament is associated with the control of the medial rotational movement of the tibia.*

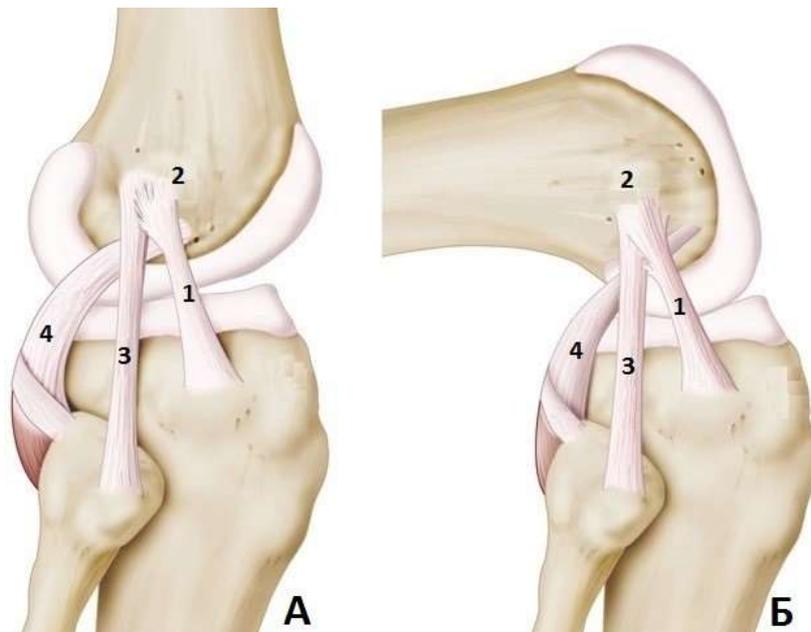


Fig. 1. Lateral view of the knee joint during extension (A) and flexion (B): 1 – anterolateral ligament of the knee joint; 2 – lateral epicondyle of the femur; 3 – fibular collateral ligament; 4 – tendon of the popliteus muscle

### 2.5.6. The tibiofibular joint (*articulatio tibiofibularis*)

#### Articular surfaces:

- ✓ the fibular articular facet of the tibia;
- ✓ the articular facet of the head of the fibula.

**Articular capsule** is attached to the borders of articular surfaces.

#### Description:

- ✓ simple,
- ✓ plane,
- ✓ multiaxial.

**Movements:** are restricted.

**Ligaments (capsular):** are located in front and behind the joint from the lateral epicondyle of the tibia to the head of the fibula:

- ✓ **the anterior ligament of fibular head** (*lig. capitis fibulae anterioris*)
- ✓ **the posterior ligament of fibular head** (*lig. capitis fibulae posterioris*)

The distal ends of the leg bones are connected by **the tibiofibular syndesmosis** (*sydesmosis tibiofibularis*). **The interosseous membrane** of the shin (*membrana interossea cruris*) connects the interosseous edges of both bones.

### **2.5.7. The ankle joint** (*articulatio talocruralis*), or **supratalar joint**

#### **Articular surfaces:**

- ✓ the articular facet of the lateral malleolus of the fibula.
- ✓ the inferior articular surface and articular facet of the medial malleolus of the tibia.
- ✓ the articular surfaces of talus trochlea.

#### **Articular capsule** is attached:

- ✓ anteriorly: for 5-8 mm in front of articular cartilages (covers part of the neck of the talus).
- ✓ posteriorly and from the sides: to the borders of articular surfaces.

#### **Description:**

- ✓ complex,
- ✓ hinge,
- ✓ uniaxial,
- ✓ combined joint (with talotarsal joint).

#### **Movements:**

- ✓ flexion (plantar flexion) and extension (dorsiflexion);
- ✓ restricted side movements may occur during plantar flexion.

#### **Ligaments:**

✓ **the medial collateral (deltoid) ligament** (*lig. collaterale mediale, s. deltoideum*) consists of four parts:

- **the tibio-navicular ligament** (*lig. tibionaviculare*), between medial malleolus and dorsal surface of the navicular bone;
- **the tibio-calcaneal ligament** (*lig. tibiocalcanea*), between anterior margin of the medial malleolus and sustentaculum of the talus;
- **the anterior tibio-talar ligament** (*lig. tibiotalaris anterior*), between anterior margin of the medial malleolus and posteromedial surface of the talus;
- **the posterior tibio-talar ligament** (*lig. tibiotalaris posterior*) between posterior margin of the medial malleolus and posteromedial surface of the talus;

✓ **the lateral collateral ligament** (*lig. collaterale laterale*) consists of three parts:

- **the anterior talo-fibular ligament** (*lig. talofibulare anterius*) from external surface of the lateral malleolus to the neck of the talus;
- **the posterior talo-fibular ligament** (*lig. talofibulare posterius*) from the lateral malleolus to the lateral tubercle of the posterior process of the talus;
- **the calcaneo-fibular ligament** (*lig. calcaneofibulare*) from the lateral malleolus to the external surface of the calcaneus.

### **2.5.8. The subtalar joint** (*articulatio subtalaris*) or **talocalcaneal joint** (*articulatio talocalcanea*)

#### **Articular surfaces:**

- ✓ posterior calcaneal articular surface of the talus
- ✓ posterior talar articular surface of the calcaneus

#### **Description:**

- ✓ simple,
- ✓ pivot,
- ✓ uniaxial, own axis of the foot,
- ✓ combined joint (with talocalcaneonavicular joint).

**Articular capsule** is attached to the borders of articular surfaces, forming one articular cavity for subtalar and talocalcaneonavicular joints.

#### **Movements:**

- ✓ abduction and adduction.

### **2.5.9. The talocalcaneonavicular joint** (*articulatio talocalcaneonavicularis*)

#### **Articular surfaces:**

**The head** is formed by three articular surfaces of the talus:

- ✓ navicular articular surface,
- ✓ anterior and middle calcaneal articular surfaces of the talus.

**The glenoid cavity (socket)** is formed by **two articular surfaces** of two bones:

- ✓ posterior articular surface of the navicular bone,
- ✓ anterior talar articular surface of the calcaneus.

**Description:**

- ✓ complex,
- ✓ spheroidal (ball-and-socket),
- ✓ uniaxial, own axis of the foot,
- ✓ combined joint (with subtalar joint).

**Articular capsule** is attached to the borders of articular surfaces, forming one articular cavity for subtalar and talocalcaneonavicular joints.

**Movements:**

- ✓ supination and pronation.

**Ligaments:**

✓ **the plantar calcaneo-navicular ligament** (*lig. calcaneonaviculare plantare*), strengthens the capsule from below, some of the fibers fuses with the fibrous cartilage of the articular cavity and through it can impact the position of the talus: when the ligament is stretched, it pulls the head of the talus down and flattens the foot;

✓ **the medial talo-calcaneal ligament** (*lig. talocalcaneum mediale*) runs along the calcaneus from the posterior tubercle to the posterior edge;

✓ **the lateral talo-calcaneal ligament** (*lig. talocalcaneum laterale*), runs obliquely from the lower surface of the neck of the talus to the upper surface of the calcaneus, and is located in a wide band at the entrance to **the sinus of the tarsus** (*sinus tarsi*);

✓ The interosseus talo-calcaneal ligament (*lig. talocalcaneum interosseum*) filling the sinus of the tarsus (*sinus tarsi*).

*The subtalar joint + the talocalcaneonavicular joint have  
one axis – the own axis of the foot*

*Both joints functions as a single  
talotarsal joint (articulatio talotarsalis)*

*ATTENTION!*

*By adding the ankle (subtalar) joint,  
we get the FOOT JOINT (articulatio pedis)*

*In newborns the joints can work independently.*

### **Features of the foot joint (articulatio pedis)**

- ✓ the talus remains stationary and plays the role of a bony disc,
- ✓ together with the calcaneus and navicular bone, in an adult the entire foot moves,
- ✓ **the movements are performed in combination:**
  - dorsal flexion + pronation + abduction,
  - plantar flexion + supination + adduction.

### **2.5.10. The calcaneocuboid joint (articulatio calcaneocuboidea)**

#### **Articular surfaces:**

- ✓ cuboid articular surface of the calcaneus,
- ✓ posterior articular surface of the cuboid bone.

**Articular capsule** is attached to the borders of articular surfaces, the lateral part is thin and loose, the medial part is strong and stretched.

#### **Description:**

- ✓ simple,
- ✓ saddle (by the function: simple rotational joint),
- ✓ combined joint (with **talocalcaneonavicular** and **subtalar** joints).

#### **Ligaments:**

- ✓ **the long plantar ligament (lig. plantare longum)**, is capsular, has several layers, divided into bundles, and is attached from the lower tuberosity of the calcaneus to:
  - deep bundles – to the cuboid bone,
  - superficial – to the bases of the II – V metatarsal bones.

Superficial bundles spread across the groove of **the peroneus longus tendon (and the tendon itself)**, transforming the groove into a canal.

✓ **the bifurcated ligament** (*lig. bifurcatum*) begins on the upper edge of the calcaneus and consists of two:

- **the calcaneo-cuboid ligament** (*lig. calcaneocuboideum*) is short, connects the calcaneus and cuboid bones, lies on the dorsum of the cuboid bone,
- **the calcaneo-navicular ligament** (*lig. calcaneonaviculare*) connects the calcaneus and the posterolateral edge of the navicular bone.

***Surgeon's opinion!***

***The calcaneocuboid joint and the talonavicular joint (part of the talocalcaneonavicular joint) are considered as one joint –***

***THE TRANSVERSE TARSAL JOINT (articulatio tarsi transversa) –***

***CHOPART'S joint.***

*It is used to dissect the foot in case of severe trauma or injury. To do this, it is necessary to cut the **bifurcated ligament** (*lig. bifurcatum*), it is the “key” to the **Chopart's joint**.*

### **2.5.11. The cuneonavicular joint (*articulatio cuneonavicularis*)**

#### **Articular surfaces:**

- ✓ anterior articular surfaces of the navicular bone,
- ✓ posterior articular surfaces of the cuneiform bones,
- ✓ the articular surfaces of the cuneiform, cuboid and navicular bones facing each other.

**Articular capsule** is attached to the borders of articular surfaces.

#### **Description:**

- ✓ complex,
- ✓ plane.

**Movements:** are restricted.

#### **Ligaments:**

- ✓ **the dorsal and plantar cuneonavicular ligaments** (*ligg. cuneonavicularia dorsalia et plantaria*);

✓ **the dorsal and plantar intercuneiform ligaments** (*ligg. intercuneiformia interossea dorsalia et plantaria*);

✓ **the intercuneiform interosseous ligament** (*ligg. intercuneiformia interossea*), it can only be seen on a horizontal cut.

### **2.5.12. The tarsometatarsal joints** (*articulationes tarsometatarsae*), *Lisfranc's joint*

#### **Articular surfaces:**

- ✓ articular facets of the distal surfaces of the three cuneiform bones,
- ✓ articular surfaces of the cuboid bone,
- ✓ the bases of five metatarsal bones.

In this case, **three isolated joints** are formed between:

- 1) I metatarsal bone and the medial cuneiform bone,
- 2) II and III metatarsal bones and the intermediate and lateral cuneiform bones;
- 3) IV and V metatarsal bones and the cuboid bone.

**Articular capsule** is attached to the borders of articular surfaces.

#### **Description:**

- 1) simple,
- 2) and 3) – complex, plane, multiaxial.

#### **Ligaments:**

✓ **the dorsal and plantar tarsometatarsal ligaments** (*ligg. tarsometatarsae dorsalia et plantaria*) run between:

- the medial cuneiform bone and the base of I metatarsal bone,
- the intermediate and lateral cuneiform bones and the bases of II and III metatarsal bones,
- the cuboid bone and the bases of IV and V metatarsal bones.

✓ **the cuneo-metatarsal interosseous ligaments** (*ligg. cuneometatarsae interossea*) run between the cuneiform bones and metatarsal bones.

**Movements:** are restricted.

***Surgeon's opinion!***

*From a surgical point of view, all three tarsometatarsal joints are combined into one **Lisfranc's joint** and the ligament between the medial cuneiform and the II metatarsal bone is called **the "key" of the Lisfranc's joint.***

### **2.5.13. The metatarsophalangeal joints**

*(articulationes metatarsophalangeae)*

#### **Articular surfaces:**

- ✓ articular surfaces of the heads of the metatarsal bones,
- ✓ the bases of proximal phalanges.

**Articular capsule** is attached to the borders of articular surfaces.

#### **Description:**

- ✓ simple,
- ✓ ellipsoid or spheroidal,
- ✓ biaxial

#### **Movements:**

- ✓ flexion and extension,
- ✓ abduction and adduction (for II-V joints),
- ✓ circumduction (for II-V joints).

#### **Ligaments:**

- ✓ **the lateral and medial collateral ligaments** (*ligg. collateralia lateralis et medialis*) are located on the sides of the joints;
- ✓ **the plantar ligaments** (*ligg. plantaria*) are located on the plantar side of the joints;
- ✓ **the deep transverse metatarsal ligament** (*lig. metatarsale transversum profundum*) plays an important role in the formation of the transverse metatarsal arch of the foot, **running transversely** from the head of the I metatarsal to the head of the V metatarsal bone, fused with the capsules of the metatarsophalangeal joints and connecting the heads of all metatarsal bones.

### 2.5.14. The interphalangeal joints of the foot

*(articulationes interphalangeae pedis)*

#### **Articular surfaces:**

- ✓ the heads and the bases of neighboring phalanges

**Articular capsule** is attached to the borders of articular surfaces.

#### **Description:**

- ✓ simple,
- ✓ hinge,
- ✓ uniaxial

#### **Movements:**

- ✓ flexion and extension.

#### **Ligaments:**

- ✓ **the collateral ligaments** (*ligg. collateralia*) are located on the sides of the joints;
- ✓ **the plantar ligaments** (*ligg. plantaria*) are located on the plantar side of the joints.

### 2.5.15. The foot as a whole

The human foot has an arched structure, which is a characteristic feature associated with upright walking. This structure arose in connection with new functional requirements placed on the human foot: an increase in the load on the foot when the body is in an upright position and a decrease in the bearing area. The arches of the feet provide amortization during walking, running, and jumping.

The foot as a whole has 3 footholds:

- ✓ tuber of the calcaneus,
- ✓ the heads of I and V metatarsal bones.

**The complex of bones** of the foot, connected almost motionlessly with the help of tight joints, forms the so-called **hard base of the foot**, which includes 10 bones: *os naviculare; ossa cuneiformia mediale, intermedium, laterale; os cuboideum; ossa metatarsalia I, II, III, IV, V.*

### The arch of the foot is provided by:

- ✓ **passive “tightening”** – are the ligaments of the foot:
  - **the long plantar ligament** (*lig. plantare longum*), strengthens the longitudinal arch of the foot and is especially important; it is attached between the lower surface of the heel bone and the tuberosity of the cuboid bone and the bases of the metatarsal bones.
  - **the deep transverse metatarsal ligament** (*lig. metatarsale transversum profundum*), strengthens **transverse arches** of the foot.
- ✓ **active “tightening”**:
  - **muscle tone**: longitudinally located muscles and their tendons, attached to the phalanges of the fingers, strengthen **the longitudinal arches**, and transversely located muscles and their tendons strengthen **the transverse arch** of the foot.

Active and passive “tightenings” ensures the formation of the arches of the foot:

- ✓ **five longitudinal arches**: from the tuber of the calcaneus bone to the heads of I – V metatarsal bones (the longest and highest – second arch),
- ✓ **transverse arch** (metatarsal): the navicular, cuneiform and cuboid bones of the foot (the connection of the highest points of the longitudinal arches) take part in its formation.

When active and passive “tightenings” are relaxed, the arches of the foot drop, the foot flattens, and **flatfoot** develop.

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**Teaching manual**

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