1 General Anatomy

Three general principles are recognizable in the architecture of the human organism:

1. **The principle of polarity**: Polarity is reflected mainly in the formal and functional contrast between the head (predominantly spherical form) and the extremities (radially arranged skeletal elements). In the phylogenetic development of the upright position of the human body, polarity developed also among the extremities: The lower extremities provide the basis for locomotion whereas the upper extremities are not needed anymore for locomotion, so they can be used for gesture, manual and artistic activities.

2. **The principle of segmentation**: This principle dominates in the trunk. The anatomical structures (vertebrae, pairs of ribs, muscles, and nerves) are arranged segmentally and replicate rhythmically in a similar way.

3. **The principle of bilateral symmetry**: Both sides of the body are separated by a midsagittal plane and resemble each other like image and mirror-image.

There are also different principles in the architecture and function of the inner organs:

- The **skull** contains the brain and the sensory organs. They are arranged like mirror and mirror-image and are the basis of our consciousness.

- The **thorax** contains the organs of the rhythmic system (heart, lung), which are only to some extent bilaterally organized. The consciousness (feeling, etc.) is located in-between.

- In the **abdominal cavity**, the most important abdominal organs (intestinal tract, liver, pancreas) are arranged unpaired. Their functions remain subconscious.
The bones of the skeletal system are palpable through the skin at different points. This enables physicians to localize the inner organs. On the ventral side, the clavicle, sternum, ribs, and intercostal spaces are palpable. Furthermore, the anterior iliac spine and the symphysis can be localized. For better orientation, several lines of orientation are used, e.g., the parasternal line, the midclavicular line, the anterior axillary line, the umbilical-axillary line, and the umbilical-pelvic line. By means of these lines, the heart and the position of the vermiform process can be localized.
Position of the inner organs of the human body (posterior aspect).

Regional lines and palpable points at the dorsal side of the human body.

Regional lines
E = paravertebral line
F = scapular line
G = posterior axillary line
H = iliac crest

1. Brain
2. Lung
3. Diaphragm
4. Heart
5. Liver
6. Stomach
7. Colon
8. Small intestine
9. Testis
10. Kidney
11. Ureter
12. Anal canal
13. Clavicle
14. Manubrium sterni
15. Costal arch
16. Umbilicus
17. Anterior superior iliac spine
18. Inguinal ligament
19. Scapular spine
20. Spinous processes
21. Iliac crest
22. Coccyx and sacrum

At the dorsal side of the body, the posterior spines of the vertebral column, the ribs, the scapula, the sacrum, and the iliac crest are palpable. Lines of orientation are the paravertebral line, the scapular line, the posterior axillary line, and the iliac crest.
Planes and Directions of the Body

Planes of the body:
A = horizontal or axial or transverse plane
B = sagittal plane (at the level of the knee joint)

Directions:
1 = cranial  3 = anterior (ventral)
2 = caudal   4 = posterior (dorsal)

MRI scan through the pelvic cavity and the hip joints (horizontal or axial or transverse plane).

Sagittal section through the knee joint.

MRI scan through the knee joint (sagittal plane).

Horizontal section through the pelvic cavity and the hip joints.
Planes and Directions of the Body

Planes of the body:
A = midsagittal or median plane
B = frontal or coronal plane (through the pelvic cavity)

Directions:
1 = posterior (dorsal) 4 = medial
2 = anterior (ventral) 5 = cranial
3 = lateral 6 = caudal

MRI scan through the pelvic cavity and the hip joints (frontal or coronal plane).
Median section through the trunk of a female.
Osteology: Skeleton of the Human Body

Skeleton of a female adult (anterior aspect).

Skeleton of a female adult (posterior aspect).
Axial skeleton
Head
1 Frontal bone
2 Occipital bone
3 Parietal bone
4 Orbit
5 Nasal cavity
6 Maxilla
7 Zygomatic bone
8 Mandible

Trunk and thorax
Vertebral column
9 Cervical vertebrae
10 Thoracic vertebrae
11 Lumbar vertebrae
12 Sacrum
13 Coccyx
14 Intervertebral discs
Thorax
15 Sternum
16 Ribs
17 Costal cartilage
18 Infrasternal angle

Appendicular skeleton
Upper limb and shoulder girdle
19 Clavicle
20 Scapula
21 Humerus
22 Radius
23 Ulna
24 Carpal bones
25 Metacarpal bones
26 Phalanges of the hand

Lower limb and pelvis
27 Ilium
28 Pubis
29 Ischium
30 Symphysis pubis
31 Femur
32 Tibia
33 Fibula
34 Patella
35 Tarsal bones
36 Metatarsal bones
37 Phalanges of the foot
38 Calcaneus

Skeleton of a 5-year-old child (anterior aspect). The zones of the cartilaginous growth plates are seen (arrows). In contrast to the adult, the ribs show a predominantly horizontal position.
Femur of the adult. Coronal section of the proximal and distal epiphyses displaying the spongy bone and the medullary cavity.

MRI scan of the right femur and the hip joint (coronal section) (from Heuck et al., MRT-Atlas, 2009).

X-ray of the right femur and the hip joint (a.-p. direction).

1 Head of the femur
2 Spongy bone
3 Diaphysis of the femur
4 Compact bone
5 Articular cartilage

Three-dimensional representation on the trajectorial lines of the femoral head (according to B. Kummer).

Coronal section through the proximal end of the adult femur showing the characteristic structure of the spongy bone.
The **ossification of the bones** of the limbs starts within the ossification centers of the primary cartilagenous bones. Here, the medullary cavity develops. The ossification process of limb bones is not finished at birth.

Ossification of the femur (left: coronal section, right: posterior view of the femur). Arrows: distal epiphysis.


X-ray of hand and foot of a newborn.
Arthrology: Types of Joints

Shoulder joint as an example of a multiaxial ball-and-socket joint (coronal section).

Elbow joint with ligaments as an example of a hinge joint (monaxial humero-ulnar joint) in combination with a pivot joint (monaxial radio-ulnar joint), which allows rotation.

Ball-and-socket joint with its different axes (schematic drawing). Arrows: axes of movement.

1 Humerus
2 Radius
3 Ulna
4 Articular cavity (shoulder joint)
5 Metacarpophalangeal joint
6 Joints of fingers

Coronal section of the elbow joint (MRI scan, courtesy of Prof. Heuck, Munich). The possibilities of movement are shown in the schematic drawings on p. 11.

Skeleton of the right arm and shoulder girdle (anterior aspect).
Joints exhibit a variety of functions. In general, mobility becomes reduced in the direction from proximal to distal. The hip joint, e.g., is multiaxial; the knee joint is biaxial, and the joints of toes and fingers are monaxial.

Coronal section of the shoulder joint (MRI scan, from Heuck et al., MRT-Atlas, 2009).

Skeleton of right wrist and hand (medial aspect). The metacarpophalangeal joints are biaxial, as is the carpometacarpal joint of the thumb (* in the figure). The joints of the fingers, however, are monaxial.

Hinge joint
(e.g. humero-ulnar joint). Left: extension, right: flexion. Arrows: axes of movement.

Pivot joint
(e.g. radio-ulnar joint).

Saddle joint
(e.g. carpometacarpal joint of the thumb).
Joints are places of articulation allowing movements between bones. Synovial joints are characterized by a joint cavity enclosed by a joint capsule containing synovial fluid, which is produced by the articular capsule. The kind of movements depends not only on form and structure of the articulating bones but also on ligaments incorporated into the articular capsule. In some synovial joints, fibrocartilagenous articular discs develop, when the articulating surfaces of the bones are incongruous.
The human body possesses a great variety of muscles. The architecture of the muscles depends on the functional systems in which they are involved, i.e., the kind of movements, the form of the joints with their specific ligaments, etc. The movements themselves vary to a great extent individually.
Joints are moved by muscles. The highly differentiated movements are coordinated by special groups of muscles (synergists). Their counterparts are called antagonists. Movements can only be carried out harmoniously if the contraction of the synergists are supported by a corresponding dilatation of the antagonists. This interaction is controlled by the nervous system. In order to carry out certain directions of movements, often the tendons of muscles have to be directed by ligaments. At those places, the tendons often develop synovial sheaths, e.g., at the wrist joint or at the fingers.
Comparative Imaging of Skeletal and Muscular Structures in MRI and X-Ray

Shoulder joint (MRI scan, coronal section) (from Heuck et al., MRT-Atlas, 2009).

1 Trapezius muscle  6 Deltoid muscle
2 Supraspinatus muscle  7 Cavity of shoulder joint
3 Scapula  8 Articular cartilage
4 Acromion  9 Articular cavity
5 Head of humerus  10 Humerus

Shoulder joint (X-ray, a.-p. direction) (courtesy of Dr. Holik, Spardorf).

Shoulder joint (schematic drawing of the MRI scan above) (from Heuck et al., MRT-Atlas, 2009).

Frontal section of the shoulder joint (compare with the two pictures above).
The center of the circulatory system is the heart, which is situated in the thoracic cavity and in contact with the diaphragm. In the right ventricle, the venous blood is collected and pumped through the pulmonary artery and into the lung where the blood is oxygenated. The veins of the lung transport the blood to the left ventricle, where it is pumped through the aorta and its branches (arteries) in the human body. Arteries and veins mostly run parallel. The venous blood from the intestine reaches the liver via the portal vein.
Organization of the lymphatic system. Course of the main lymphatic vessels and lymph nodes in the body. Dotted red line = border between lymphatic vessels draining toward the right and the left venous angles.

Lymphatic vessels originate in the tissue spaces (lymph capillaries) and unite to form larger vessels (lymphatics). These resemble veins but have a much thinner wall, more valves, and are interrupted by lymph nodes at various intervals. Large groups of lymph nodes are located in the inguinal and axillary regions, deep to the mandible and sternocleidomastoid muscle, and within the root of the mesentery of the intestine. The lymphatic vessels of the right half of the head and neck, the right thorax, and the right upper limb drain toward the right venous angle; those of the rest of the body, toward the left venous angle.
Organization of the Nervous System

The nervous system can be divided into three functionally distinct parts:
1. The cranial part, which comprises the great sensory organs and the brain.
2. The spinal cord, which shows a segmental structure and serves predominantly as a reflex organ.
3. The autonomic nervous system, which controls the involuntary functions (subconscious control) of organs and tissues. The autonomic part of the nervous system forms many delicate plexuses near or within the organs.

At certain places these plexuses contain aggregations of nerve cells (prevertebral and intramural ganglia).

The spinal nerves leave the spinal cord at regular intervals. The ventral rami of the spinal nerves form the cervical and brachial plexus, which innervates the upper extremity, and the ventral rami of the lumbar and sacral spinal nerves form the lumbosacral plexus, which innervates the pelvis and genital organs and the lower extremity.

Diagram illustrating the localization of the three functional portions of the nervous system (brain, spinal cord and autonomic nervous system). Yellow = sympathetic system; red = parasympathetic system.

Posterior part of the trunk. The solar plexus with its connection to the vagus nerve and the sympathetic trunk has been dissected.

Legend:
1. Cerebrum
2. Cranial nerves
3. Spinal nerves
4. Sympathetic trunk
5. Solar plexus
6. Nervous plexus of the autonomic system
7. Aorta
8. Vagus nerve and esophagus
9. Bifurcation of trachea