Circulatory system

Senior lecturer: Pevnev G.O.
Systema cardiovasculare

Systema sanguineum
- closed (blood never leaves the network of vessels)
- Oxygen and nutrients diffuse across the blood vessel layers into interstitial fluid

Systema lymphaticum
- the lymphatic capillaries are opened for interstitial fluid
Functions of the cardiovascular system

1. Transport:
   1) Oxygen and carbon dioxide (respiratory system)
   2) Nutrients (digestive system)
   3) Products of metabolism (uric acid)
   4) Hormones (endocrine system)
   5) Water and salts (water-salt exchange between blood and tissue)

2. Defense:
   1) Antibodies and leukocytes protect from toxins and pathogenic microorganisms
   2) Stabilize the temperature and pH
   3) Protects from water loss (blood coagulation)
   4) Maintain homeostasis
The essential components of the human cardiovascular system:

- Heart
- Blood
- Blood vessels
Hippocrates (460–377 B.C.)

- the father of medicine

- ἀρτηρία (artēria) – „windpipe“ (contain air)

- **Blood:**
  - originates in liver
  - saturated with pneuma in the heart
  - disappear in organs

- described:
  - tricuspid valve (heart)
Aristotle
(384–322 B.C.)

- “aorta” = arteria orta (direct artery)
- a.orta - aorta
Herophilus (335–280 or 255 BC)
- the first dissections of human cadavers
- together with Erasistratus they founded Anatomy as science
- differentiated arteries and veins (described differences of the walls)
- measured pulse (described its strength, frequency and rhythm)
- differentiated heart beat (systole, diastole and pause)
Erasistratus discovers the cause of the illness of Antiochus. Painting by Jacques-Louis David

Erasistratus (304–250 BC)

- performed vivisection of cadavers

- described:
  - pulse wave
  - valves of the heart and large vessels
  - lymphatic vessels

- supposed the connection between arteries and veins
Galen
(130-200 AD)

- Vessels contain blood and pneuma (“vital spirit”):
  • Arteries – more pneuma
  • Veins – more blood

- Blood (from liver) is “cleaned” in right ventricle of the heart and later conducted through veins to organs, where disappears

- Cardiac septum is permeable: the blood from right ventricle moves into left one

- In the left ventricle blood and pneuma are mixed – “vital spirit” is spread along the body

The information in these tracts became the foundation of authority for all medical writers and physicians for the next 1500 years until they were challenged by Vesalius and Harvey in the 16th century.
Leonardo da Vinci (1452-1519)

- the first who asserted disagreement with the study of Galen
- experimentally demonstrated that air can not pass into heart through the bronchus
- described 4 cardiac chambers and cardiac conducting bundle
Andreas Vesalius (1514-1564)

- found muscle prominences in the heart
- thought that blood can move between the cardiac ventricles through the pores
Miguel Servetus (1511-1553)

Pulmonary circulation

Rennaldo Colombo (1516-1559)
Ibn al-Nafis
(1210-1288)

- described pulmonary circulation and its particular properties 300 years before European researches

- wrote in comments to the book of Avicenna

2 century BC – in China – tractate “Simple questions”: “Blood circulates without continuously – without beginning and end” and “Heart runs the blood”.
William Harvey (1578-1657)

- 1616 - blood flows continuously in a circle
- center of circulation - heart
- 1628 - "On the Motion of the Heart and Blood"
- veins allow blood to flow to the heart, and the valves maintain the one way flow
- pulsation depends upon the contraction of the left ventricle
- Harvey did not predict the existence of capillaries
Marcello Malpighi (1628 – 1694)

- the "Father of microscopical anatomy, histology, physiology and embryology"

- the Malpighian corpuscles and Malpighian pyramids of the kidneys

- 1661 – the first person to see capillaries in animals – the link between arteries and veins

- “il capello” (ital.) – “hair”
The essential components of the human cardiovascular system:

- Heart
- Blood
- Blood vessels
Arteries
- blood vessels that conduct arterial blood from heart ventricle to organs and tissues

Exceptions:
1) Pulmonary arteries – conduct venous blood from right ventricle to lungs
2) Umbilical arteries – conduct venous blood from fetus to placenta
Veins

- blood vessels that conduct venous blood from organs and tissues to heart atrium

Exceptions:
1) Pulmonary veins – conduct arterial blood from lungs to left atrium
2) Umbilical veins – conduct arterial blood from placenta to fetus
Heart (Cor, Cardia)
Heart layers

- Coronary artery with branch into myocardium
- Pericardium (sac around heart)
- Heart muscle (ventricular wall)
  - Endocardium (inner lining)
  - Myocardium (heart muscle)
  - Epicardium (outer surface)

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Pericardium

Serous pericardium layers:
- Parietal
- Visceral (=epicardium)
1. **Transverse pericardial sinus** - a space posterior to the ascending aorta and pulmonary trunk and anterior to the superior vena cava and pulmonary veins. It separates the great arteries from the great veins. The transverse sinus is useful in cardiac surgery to allow isolation of the aorta and pulmonary trunk.

2. **Oblique pericardial sinus** - the blind, inverted, U-shaped space posterior to the heart and bounded by reflection of serous pericardium around the 4 pulmonary veins and the inferior vena cava as they enter the heart.
Heart chambers

- Brachiocephalic artery
- Superior vena cava
- Right pulmonary arteries
- Right pulmonary veins
- Right atrium
- Atrioventricular (tricuspid) valve
- Chordae tendineae
- Right ventricle
- Inferior vena cava
- Left common carotid artery
- Left subclavian artery
- Aorta
- Left pulmonary arteries
- Left pulmonary veins
- Left atrium
- Semilunar valves
- Atrioventricular (mitral) valve
- Left ventricle
- Septum

Pulmonary circulation

- Lungs
- Pulmonary vein
- Pulmonary trunk
- Vena cava
- Right atrium
- Right ventricle

Systemic circulation

- Liver
- Stomach and intestines
- Lymph node
- Portal vein
- Lymphatic vessels
- Remainder of body
Heart valves

Atrioventricular valves:
- Between left atrium and left ventricle — bicuspid (mitral) valve
- Between right atrium and right ventricle — tricuspid valve

Semilunar valves:
- Between left ventricle and aorta — aortic valve
- Between right ventricle and pulmonary arteries — pulmonary valve
Mitral valve

Normal Valve Mechanisms

Aorta
Left atrium
Closed aortic valve
Open aortic valve
Open mitral valve
Left ventricle

Closed mitral valve

PAPILLARY MUSCLE FUNCTION

Open
Closed

Chordae Tendinae

Slack
Taut

Papillary Muscles

Relaxed
Contracted

MITRAL VALVE OPEN

MITRAL VALVE CLOSED
(a) AV valves open; atrial pressure greater than ventricular pressure

1 Blood returning to the heart fills atria, putting pressure against atrioventricular valves; atrioventricular valves are forced open.
2 As ventricles fill, atrioventricular valve flaps hang limply into ventricles.
3 Atria contract, forcing additional blood into ventricles.

(b) AV valves closed; atrial pressure less than ventricular pressure

1 Ventricles contract, forcing blood against atrioventricular valve cusps.
2 Atrioventricular valves close.
3 Papillary muscles contract and chordae tendineae tighten, preventing valve flaps from evertting into atria.
Bicuspid valve (mitral) – between left atrium and left ventricle
Tricuspid valve – between right atrium and right ventricle
Semilunar cusps

**Aortic valve** – between left ventricle and aorta
**Pulmonary valve** – between right ventricle and pulmonary artery
When semilunars close, you hear 2nd heart sound, with aortic slightly before pulmonary.

As ventricles contract and intraventricular pressure rises, blood is pushed up against semilunar valves, forcing them open.

(a) Semilunar valves open

As ventricles relax and intraventricular pressure falls, blood flows back from arteries, filling the cusps of semilunar valves and forcing them to close.

(b) Semilunar valves closed
Cusp prosthetics
Coronary arteries

Left coronary artery:
- Anterior interventricular artery
- Circumflex artery

Right coronary artery:
- Posterior interventricular artery
- Marginal artery

Widow-maker artery
Venous drainage of the heart:
- **Small veins (venae cordis minimae)** – directly into cardiac cavity
- **Anterior cardiac vein** – directly into right atrium
- **Coronary veins** (accompany coronary arteries) that form coronary sinus opened into right atrium:
  1) The great, middle and small cardiac veins
  2) The oblique vein
The heart receives blood supply during diastole!

The way coronary arteries pass between cardiomyocytes
- 25% of the heart nutrition diffuse through *trabeculae carneae*

- “present of evolution”
Coronary artery bypass grafting (CABG)
Conducting system of the heart

- Superior vena cava
- Atrioventricular node (AV node)
- Left atrium
- Sinoatrial node (SA node)
- Pulmonary veins
- Right atrium
- His bundle
- Left ventricle
- Right ventricle
- Bundle branches
- Inferior vena cava
- Purkinje fibers
Artificial pacemaker (pulse generator)
Arteries
Lecture #2
The essential components of the human cardiovascular system:

- **Heart**
- **Blood**
- **Blood vessels**
Arteries

- blood vessels that conduct **arterial blood** from heart ventricle to organs and tissues

Exceptions:

1) **Pulmonary arteries** – conduct venous blood from right ventricle to lungs

2) **Umbilical arteries** – conduct venous blood from fetus to placenta
Arteries

- Arteries of pulmonary circulation
- Arteries of systemic circulation
- Arteries of the heart
Arteries

Types of arteries (wall anatomy):
- Elastic
- Muscular
- Combined (mixed)
• **Elastic arteries** - large thick walled, aorta and its branches

- has elastin in all tunics, especially tunica media
- has “pressure smoothing effect”
Muscular arteries - most of the arteries

- thickest media - more smooth muscle
- active in vasoconstriction
Arterioles

- 3mm-10µm diameter of lumen
- blood flow to capillaries is determined by diameter of arterioles
CAPILLARIES

- smallest 1mm long x 8-10µm diameter
- tunica intima only - endothelium
- exchange of gases, nutrients with interstitial fluid
Types of Capillaries

- **Continuous** - one endothelial cell wraps all around ends joined by tight junctions (brain)
- **Fenestrated** have windows very permeable to fluids and solutes
- **Sinusoidal** - modified, very leaky
Tissues without vessels

- transparent tissues of the eye (cornea, corpus vitreum, lens)
- cartilage
- epithelium
- endothelium
- dentin and enamel

They are tolerant and can be transplanted without risk of rejection
Arteries

- trunk – parietal and visceral branches of aorta

- paired and unpaired branches

- arteries reaches organ along the shortest ways, usually together with nerves

- every region has its own original main artery (head and neck – carotid artery, abdomen – abdominal part of aorta, etc.)

- with or without anastomoses (connections)
Arterial blood supply of the limbs

- mostly on the **flexor side** of the limbs
- around joints form **arterial network**
- on the palm and foot form **arterial arches**
The main arteries

Diameter of aortal bulb – 25-30mm
Diameter of descending aorta – 21-22mm
Branches of external carotid artery:
1) Superior thyroid artery
2) Lingual artery
3) Facial artery
4) Maxillary artery
5) Ascending pharyngeal artery
6) Occipital artery
7) Posterior auricular artery
8) Superficial temporal artery
Anastomoses

1) Between different systems of arteries:
   - external and internal carotid arteries
   - external and internal iliac arteries
   - vessels of the right and left parts of the body

2) Inside system of one artery
Anastomoses on the head

a. angularis
(branch of facial artery – external carotid artery)

a. dorsalis nasi
(branch of ophthalmic artery – internal carotid artery)
Arterial blood supply of the brain – circle of Willis
Arterial anastomoses of the neck

- between left and right external carotid arteries (arterial network of the organ)
Arterial anastomoses of the anterior abdominal wall

- Internal thoracic a.
- Superior epigastric a.
- Musculophrenic a.
- Inferior epigastric a.
- Deep circumflex iliac a.
Corona mortis – “crown of death”

- 15-30% of people
- wound of this anastomosis (during hernial sac operation) leads to strong bleeding, which is very hard to stop
Arteries clamping points

a. temporalis
a. occipitalis
a. maxillaris
a. carotis communis
a. subclavia
   a. axillaris
   a. brachialis
   a. radialis
   a. ulnaris

a. femoralis
a. poplitea

a. dorsalis pedis
a. tibialis posterior

Radial Artery
Blood pressure

120/80?

120 – cardiac (force of the heart)
80 – tension of the vessels ("kidney")
Lecture #3 Cardiovascular system

Venous and lymphatic systems
Veins

- blood vessels that conduct **venous blood** from organs and tissues to heart atrium

Exceptions:
1) **Pulmonary veins** – conduct arterial blood from lungs to left atrium
2) **Umbilical veins** – conduct arterial blood from placenta to fetus
Functions of the veins

1) drain carbon dioxide and products of metabolism from periphery tissues
2) absorbed substances pass into venous vessels
3) performance of humoral regulation (hormones are produced into venous vessels)
4) venous circulation influence on arterial circulation
Veins

- In compare to arteries, veins have large and somewhat irregular lumen and thin walls.
- Veins are relatively compressible by external forces.
- Muscle in venous walls tend to be arranged in a loop near the point of drainage of tributary – “sluice gate.”
Veins

- Large veins are usually single (v. cava superior, v. cava inferior, v. porta)

- In several regions arterial and venous patterns are separate and distinct (brain, liver, lungs and penis)

- “counter-current” pattern of parallel arteries and veins is often related to transfer of water (kidney) and heat (limbs)
- **Superficial veins** form subcutaneous network
- **Deep veins** are frequently doubled, accompany (**venae comitantes**) arteries of the same names
- **Perforating veins (perforators)** pass through (perforate) fasciae and connect systems of the superficial and deep veins
Venous hemodynamics

1. Pressure gradients between the periphery and the right side of the heart:
   - An arterial pressure (approx. 10mm Hg) transmitted through the capillary bed to the venous side
   - The sucking bulb-syringe action of the heart during right ventricular diastole
Venous hemodynamics

2. The sucking bulb-syringe action of the veins of the neck
- Negative consequence - risk of gaseous embolism
Venous hemodynamics

3. Negative pressure (relative to atmospheric pressure), produced by the thoracic cage during inspiration
   - Yawning and stretching (high concentration of carbon dioxide in venous blood)
4. Pulse wave of the arteries (veins are near to arteries, venae comitantes = accompany)
Venous hemodynamics

5. Rigidity of the walls of the sinuses of dura mater
Venous hemodynamics

6. Fusion of vein walls with periosteum:
- V. subclavia and periosteum of clavicle bone

- **Advantage** – never deflate, cannulated in emergency cases
- **Disadvantage** – trauma of clavicle – gaseous embolism and it is hard to stop the bleeding
Venous hemodynamics

7. Contractile activity of the muscles of the extremities – ‘muscle pump’
- the muscles of the extremities, between which the deep lie, are surrounded by relatively inelastic fascial septa
- upon shortening, muscles become wider, thereby increasing the pressure on the deep veins and moving blood in a direction guided by internal valves
Venous hemodynamics

8. Many veins contain valves that permit proximal flow only
- valves occur primarily in veins of limbs and movable viscera, but not in the cerebral veins
- Valves are especially prevalent at junctions between tributaries and large veins

No valves:
- Vv. cava superior et inferior
- Pulmonary veins
- Portal vein
- Veins with diameter less than 2mm
- Near valves the veins wall becomes thinner and orifice narrower (arteries have constant diameter, veins – changeable)
Superficial veins

- provide convenient sites for venipuncture
Varicose nodules:
- Low limbs
- Testis and spermatic cord
- Hemorroidal zone

- The function of the valves is destroyed + gravity (price for upright posture)
Large veins systems

• V. cava superior
• V. cava inferior
• V. porta
Portal system (from unpaired abdominal organs, except liver)

- Drains most of the venous blood from the capillary beds of the gastrointestinal tract to the sinusoids of the liver

- **Tributaries:**
  1) the superior mesenteric vein (small intestine + large intestine till splenic flexure)
  2) the splenic vein (spleen + portion of stomach and pancreas)
  3)* the inferior mesenteric vein (descending + sigmoid colon)
  4)* celiac veins

*3) and 4) – tributaries of splenic vein!
System of v. cava superior

- receives venous return from the upper half of the body, above the diaphragm

- **Tributaries:**
  - 1) Right and left brachiocephalic veins
  - 2) The azygos vein
System of v. cava inferior

- Venous drainage of abdominal organs, not drained by hepatic portal vein + drainage of abdominal walls

- **Parietal tributaries:**
  - Common iliac veins
  - Lumbar veins
  - Right inferior phrenic vein

- **Visceral tributaries:**
  - right gonadal vein
  - renal veins
  - right adrenal vein
  - hepatic veins
Porto-caval anastomoses

1. v. porta and v. cava superior

Anastomosing veins:
- Esophageal veins (influent of v. azygos – v. cava superior)
- Left gastric vein (system of v. porta)

The location of anastomosis:
- Lower third of esophagus and cardial part of the stomach
Porto-caval anastomoses

2. v. porta and v. cava inferior

Anastomosing veins:
- **Superior rectal vein** (influent of v. mesenterica inferior - v. porta)
- **Middle rectal vein** (influent of v. iliaca interna – v. cava inferior)
- **Inferior rectal vein** (influent of v. pudenda interna – v. cava inferior)

The location of anastomosis:
- In the wall of rectum
Superior to that line the intestine derives from the embryonic hindgut and the epithelium derives from endoderm - a. et v. mesenterica inferior

Inferior to that line the epithelium derives from ectoderm - a. et v. iliaca interna
Cava-caval anastomoses

4. v. cava superior and v. cava inferior

Anastomosing veins:
- Superior epigastric veins (influent of v. thoracica interna – v. cava superior) - #28
- Thoracicoepigastric vein (influent of v. axillaris – v. cava superior) - #29
- Inferior epigastric vein (influent of v. iliaca externa – v. cava inferior) - #23
- Superficial veins (influent of v. femoralis – v. cava inferior) - #22

The location of anastomosis:
- In the depth of anterior abdominal wall
Cava-caval anastomoses

5. v. cava superior and v. cava inferior

Anastomosing veins:
- Azygos and hemiazygos veins (right and left ascending lumbar veins - v. cava superior)
- Right and left lumbar veins (v. cava inferior)

The location of anastomosis:
- On the posterior wall of abdomen
Cava-caval anastomoses

6. v. cava superior and v. cava inferior

Anastomosing veins:
- **Spinal veins** (influent of posterior intercostal veins - v. cava superior)
- **Spinal veins** (influent of lumbar veins - v. cava inferior)

The location of anastomosis:
- Inside the vertebral canal and around the vertebral column
Porto-cava-caval anastomoses

7. v. cava superior, v. cava inferior and v. porta

Anastomosing veins:
- Superior epigastric vein (influent of v. thoracica interna - v. cava superior)
- Inferior epigastric vein (influent of v. iliaca externa - v. cava inferior)
- Paraumbilical veins (system of v. porta)

The location of anastomosis:
- In the depth of anterior abdominal wall
Liver cirrhosis – narrowing of v.porta – varices formation
Liver cirrhosis – narrowing of v.porta – caput medusae
Anastomose between facial vein and cavernous sinus

Angular vein (facial vein) – dorsal nasal vein – superior ophthalmic vein – cavernous sinus

Facial vein has no valves!!!
Development of the veins

Main veins of the embryo (derivate from mesoderm):
1) Cardinal vein
2) Umbilical vein
3) Vitelline vein
Development of the veins

Cardinal veins (left and right) conduct the blood towards the heart:
- **Anterior cardinal veins** (#1) – from head
- **Posterior cardinal veins** (#6) – from the rest of the body

Further anterior and posterior cardinal veins fuse and form **common cardinal vein (ducts of Cuvier)** (#2), that opens into **venous sinus**
- #3 – vitelline vein
- #4 – omphalomesenteric vein
- #5 – subcardial vein
- #7 – developing subcardial plexus in mesonephros
- #8 – liver

4th week, McClur and Batler
Development of the veins

- Anterior cardinal veins - jugular, brachiocephalic veins, v. cava superior and venous sinus
- Posterior cardinal veins - iliac veins, v. cava inferior, azygos and hemiazygos veins
- Vitelline vein – v. porta
Capillaries

- Exchange sites of the circulatory system
- The diameter of a capillary is about 5mcm, large enough to enable a red blood cell to squeeze through
- The velocity of circulation changes from 0.5m/sec in the aorta to 0.5 mm/sec in the capillaries
Capillaries

- Diffusion barrier
- Capillary walls are formed by a single layer of endothelial cells – this endothelium and a thin layer of connective tissue fibers (the basal lamina) constitute the diffusion barrier.
Capillaries function

- Exchange of gas – gaseous diffusion occurs according to partial pressure gradients
- Exchange of fluid – according to differentials between blood pressure and osmotic pressure
Arteriovenous anastomoses (shunts)

- **Function** – permit direct transfer of blood from arterial to venous channels, bypassing the capillary bed

- In organs with intermittent function:
  - **In the gut** - anastomoses are opened except during periods of digestion

- In the skin – apical parts (fingers, nose, lips, ears) – temperature regulation

- Rise as a side branch of a terminal arteriole and join a venule

- Has a thick muscular wall, forming a sphincter
Sinusoids substitute for capillaries in some organs (liver, spleen, red bone marrow), where blood flow is slow. They often contain phagocytic cells.
Hematoencephalic barrier

Every capillary of the brain is covered by the processes of astrocytes - protection of the brain from bacteria and toxins
**Edema** – the collection of excess fluid in the tissue space (associated with trauma or inflammation) – increased permeability of the walls of the capillary deb whereby red blood cells are contained.

**Hematoma** (black-and-blue mark associated with edema) – results from a major loss of integrity of capillary walls or the walls of other blood vessels; red blood cells, in addition to plasma, leak into the tissue and cause discoloration.
Fetal circulation

Table III-2-2. Adult Vestiges Derived from the Fetal Circulatory System

<table>
<thead>
<tr>
<th>Changes After Birth</th>
<th>Remnant in Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closure of right and left umbilical arteries</td>
<td>Medial umbilical ligaments</td>
</tr>
<tr>
<td>Closure of the umbilical vein</td>
<td>Ligamentum teres of liver</td>
</tr>
<tr>
<td>Closure of ductus venosus</td>
<td>Ligamentum venosum</td>
</tr>
<tr>
<td>Closure of foramen ovale</td>
<td>Fossa ovalis</td>
</tr>
<tr>
<td>Closure of ductus arteriosus</td>
<td>Ligamentum arteriosum</td>
</tr>
</tbody>
</table>
Ductus venosus – ligamentum venosum hepatis
Umbilical vein – ligamentum teres hepatis
Remnant of oval foramen – fossa ovalis
Ductus arteriosus

Deflated lung (before birth)

Foramen ovale

Inferior vena cava

Aorta

Ductus arteriosus

Ligamentum arteriosum

Ascending aorta

Superior vena cava

Auricle of right atrium

Right atrium

Left pulmonary artery

Pulmonary trunk

Auricle of left atrium

Right ventricle

Fat in anterior interventricular sulcus

LEFT VENTRICLE

RIGHT VENTRICLE

Ductus arteriosus → Ligamentum arteriosum
1 – plica umbilicalis mediana (obliterated urachus)
2 – plica umbilicalis medialis
3 – plica umbilicalis lateralis
4 – fossa supravesicalis
5 – fossa inguinalis medialis
6 – fossa inguinalis lateralis

Left and right umbilical arteries – **medial umbilical plicae** (paired, #2)
Lymphatic system

- an extensive network of extremely variable lymphatic vessels and lymph nodes, which serve as filters and a source of lymphocytes and plasma cells
Lymphatic system

Function:
1. a specialized mechanism to return to the bloodstream interstitial fluids that were not taken up by the blood capillaries
2. absorption and transport of fatty acids and fats as chyle from the digestive system
3. transport of white blood cells to and from the lymph nodes into the bones
4. transport of antigen-presenting cells (APCs) to the lymph nodes where an immune response is stimulated.
Structure of Lymphatic system

Lymphatic tissue:
- a) Spleen
- b) Lymphatic nodes
- c) Thymus
- d) Tonsils
- e) Peyer’s patches
- f) Appendix vermiformis

Lymphatic vessels:
- a) Capillaries
- b) Postcapillaries
- c) Vessels
- d) Ducts
- e) Trunks
Lymph

- tissue fluid
- water + proteins + sugar + fat
- clear and colorless

**Chyle** – lymph, that contains fat droplets (these fatty droplets are absorbed by the lymphatics from the gastrointestinal tract).
Lymphatic tissue: **Spleen**

The largest mass of lymphatic tissue in body

**Size:** 5 inches x 3 inches x 2 inches (like heart)

**Location** – upper left quadrant between fundus of stomach and diaphragm

**Function:**
1) Filter blood
2) Destroys old RBC
3) Produce Lymphocytes
Spleen: How is it built to carry its functions?

- Connective tissue capsule (collagenous and elastic fibers)
- Covered by peritoneum (intraperitoneal)
- Internal support – trabeculae of collagenous fibers
- Reticulum – network of reticular fibers – filtrate blood through
- On reticulum – macrophages – destroy pathogens
**Spleen:** How is it built to carry its functions?

- On reticulum – white pulp and red pulp
- **White pulp** – central artery + mass of Lymphocytes around (only in spleen!)
- **Red pulp** (majority of spleen) – blood sinuses + Lymphocytes
Lymphatic tissue: Thymus
Lymphatic tissue: **tonsils**

**Pirogow-Waldeyer`s ring** (lymphoepithelial)

1. Tonsilla pharyngealis (adenoidea) (1)
2. Tonsilla tubaria (2)
3. Tonsilla palatina (2)
4. Tonsilla lingualis (1)
Lymphatic tissue: Peyer`s patches
Lymphatic tissue: Appendix vermiformis
Lymphatic tissue: **Lymph nodes**

- small oval bodies
- 1mm (tip of the pen) to several centimeters (lima beans)
- Lymph may filter through several nodes before reaching the major trunk

**Function:**
1) Filter lymph
2) Produce lymphocytes
3) Produce plasma cells (source of Ig)
Lymphatic tissue: Lymph nodes

**Structure:**
- Oval shaped
- Connective tissue capsule + trabeculae
- Different arrangement of vessels:
  - large curvature – afferent lymph vessels
  - lesser curvature – efferent lymph vessels

**Reticulum**
- for filtration + places of lymphocytes development (!w/o central artery!)
Lymphatic nodes are usually grouped in specific regions and named accordingly.
1) **Lymphatic capillaries** (opened for interstitial fluid and endothelium without valves)
2) **Postcapillaries** (endothelium with valves)
3) **Vessels** (endothelium with valves, smooth muscle layer, adventitia)
4) **Lymphatic ducts**
5) **Lymphatic truncs**
6) **Lymphatic ducts** (thoracic and right lymphatic ducts)
Lymphatic vessels

**Functions:**

1) convey lymph

2) convey proteins
   (Blood capillaries bring proteins to tissues, but protein cannot come back into blood vessels. When there is excess of proteins, patient dies)

   - To get proteins back into bloodstream lymph vessels are **permeable**

3) fat is absorbed in small intestine in lymph capillaries (=**lacteals**) – lymph vessels – **cysterna** (reservoir) **chyle** (white fat) – thoracic duct along thoracic aorta – junction of internal jugular and subclavian vein
Lymphatic capillaries

- begin as cul-de-sacs that drain the tissue spaces
- are wider than blood capillaries and are irregular in diameter

**Numerous** lymphatic capillaries in:
- the mucous membranes,
- serous surfaces,
- dermis of the skin

**Lack of lymphatic capillaries:**
- Brain
- Spinal cord
- Eyeball

**Absence of lymphatic capillaries:**
- Bone marrow
- Parenchyma of the spleen
- Superficial fascia
Lymphatic vessels

- Are formed by convergence of lymph capillaries
- Have valves
- Are plentiful and accompany veins
- Larger lymphatics acquire small amount of smooth muscle and elastic tissue
- Intercalated along the lymphatic vessels are the lymph nodes

**Figure:** Canulation of mesenteric lymphatic vessels. The lymphatic vessels and the lymph nodes were colored by injection of Evans blue and dwelling catheters were inserted into the efferent lymphatics.
Lymphatic nodes – clinical consideration

- Bacteria or antigens filtered by the phagocytes of the lymph nodes may induce inflammation or a cell-mediated immune reaction, either of which can produce swelling of the node (swollen glands)

- When nodes are swollen by inflammation or blocked by metastatic cells, edema or drainage along alternative lymphatic pathway may occur
Clinical considerations:

- Lymph return from the trunk and extremities is to axillary and inguinal nodes.

- Lymph follows two sets of channels:
  a) The superficial lymphatics accompany the superficial veins to the axillary and inguinal nodes. Infection may spread along superficial lymphatics, causing fine striae.
  b) Lymphedema is the accumulation of tissue fluid as a result of lymphatic obstruction (e.g., elephantiasis caused by *Filaria bancrofti*).
Elephantiasis caused by Filaria bancrofti
Lymphatic ducts

- Are formed by convergence of lymph vessels
- Lymphatics from the lower extremities converge on lymph nodes located anteriorly and superficially in the uppermost part of the thigh
- From inguinal lymph nodes, the main duct from each lower extremity enters the abdomen
- After passing through the lumbar lymph nodes, the main duct becomes known as the lumbar duct, which enters the cisterna chyli
The cisterna chyli

- Is a dilated sac located between the diaphragmatic crura, opposite the 1st lumbar vertebra and behind the right side of the aorta
- It contains some smooth muscle and is somewhat pulsatile
- In addition to the lumbar lymphatics, the cisterna chyli also receives the large common duct, which conveys lymph from most of the intestinal tract.
The thoracic duct

- Originates from the upper end of the cisterna chyli
- Ascends upward on the anterior aspect of the vertebral column, slightly inclines to the left
- Ends at the base of the neck, usually entering the left brachiocephalic vein
- Normally, the large volume of lymph flowing through the thoracic duct (1-2ml/kh/hr) is derived mainly from the liver and alimentary tract
- Volume of lymph – thoracic duct – 1000ml per 24h
- Receives the lymph from both legs, the pelvis, the abdomen and the left side of the thorax, the left side of the head and neck (left subclavian lymph duct join the thoracic duct in the base of the neck):

- A) the left jugular lymph duct – accompany the left internal jugular vein
- B) the left subclavian lymph duct drains the left axillary and subclavian nodes of the left upper extremity and accompany left subclavian vein
- C) the left bronchomediastinal lymph duct - drains the thoracic viscera on the left
The right lymph duct

- Receives lymph from:
  - A) right jugular lymph duct – right side of the head and neck
  - B) right subclavian lymph duct – right axillary and subclavian nodes
  - C) right bronchomediastinal lymph duct – right thoracic viscera

- Returns lymph to the great veins at the base of the neck on the right side
Lymph capillaries converge to become collecting vessels and end up as either Thoracic duct or right lymphatic duct.
Areas of lymphatic drainage
Lymph flow
Clinical considerations

1. Lymphatics are the major route by which carcinoma metastasizes
   a) Malignant cells may be trapped in lymph nodes where they proliferate
   b) Malignant cells may be delivered to the venous system
   c) Surgical removal of malignant tumors involves dissection of the major lymphatic vessels and nodes draining the involved region
   d) Wound healing requires the regeneration of the lymphatics as well as the growth of the blood capillaries
Tumor Nodule Metastasis (TNM)
Complications after lymphectomy

NO!
Get cold
Massage and sauna
Sport activities

SENTINEL LYMPH NODES
the lymph nodes closest to the tumor

Sentinel Lymph Nodes
Vascular Endothelial Growth Factor (VEGF)
Vascular Endothelial Growth Factor (VEGF)

Blood Vessel Overgrowth on Cell

1. Tumor secretes VEGF
2. VEGF increases blood vessel expression and movement to tumor
3. Tumor has increased blood supply
ANGIOGENESIS INHIBITORS FOR CANCER

[Diagram showing various inhibitors and their effects on VEGF and VEGFR signaling]

- Bevacizumab
- Cabozantinib
- Pazopanib
- Regorafenib
- Sorafenib
- Sunitinib
- Vandetanib
- Ziv-Aflibercept

Endothelial cell membrane

VEGF signaling

Pericyte

Endothelial cells
Thank you for your attention!
Lymph flow

Unidirectional toward the large veins at the base of the neck

1. Hydrostatic pressure from the volume of the tissue fluids taken up by the lymphatic capillaries
2. Mechanical forces
   a) The pressure resulting from the voluntary muscular activity (immobile limb – no lymph flow)
   b) Respiratory movements – the alternation of pressures within the thorax during ventilation propels lymph in the valved lymphatics of the mediastinum
   c) The contractions of the muscles of the abdominal wall on expiration, coughing, and straining: these procedure a positive abdominal pressure on the cisterna chyli that propels the lymph
   d) The pulsation of adjacent blood vessels: these have a massaging effect on lymph vessels to aid the flow of the lymph
   e) In some parts of the body, rhythmic flow may be aided by the contraction of the smooth muscles in the walls of the lymphatic vessels and the cisterna chyli
3. Valves in the thoracic duct and right lymph duct, which prevent backflow
Lymphaticovenous communications

- Function when lymphatic pressure is increased by blockage of the usual channels.

- **Sample:**
  - Between the thoracic duct and the hemiazygous vein
  - The abdominal lymphatic ducts and inferior vena cava

- These connections are the result of enlargements of preexisting channels that normally convey little or no lymph
Figure 1: Lymphaticovenous anastomosis (LVA) for leg lymphoedema is usually done at a minimum of three sites. b A collecting lymphatic vessel (Ly) is sutured to a cutaneous vein (V) under microscopy. The arrow indicates the direction of lymphatic flow.

https://www.researchgate.net/figure/264710531_fig2_Figure-1-Lymphaticovenous-anastomosis-LVA-for-leg-lymphoedema-is-usually-done-at-a
Venous blood is typically colder than arterial blood,[1] and has a lower oxygen content and pH. It also has lower concentrations of glucose and other nutrients, and has higher concentrations of urea and other waste products. The difference in the oxygen content of arterial blood and venous blood is known as the arteriovenous oxygen difference.[2]

Most medical laboratory tests are conducted on venous blood, with the exception of arterial blood gas tests. Venous blood is obtained for lab work by venipuncture (also called phlebotomy), or by finger prick for small quantities.

**Color**

Human blood is red in color, ranging from bright red when oxygenated to a very dark, almost blackish-red when deoxygenated.[3] It owes its color to hemoglobin, to which oxygen binds. Deoxygenated blood is darker due to the difference in color between deoxyhaemoglobin and oxyhaemoglobin.

The blue appearance of surface veins is caused mostly by the scattering of blue light away from the outside of venous tissue if the vein is at 0.5 mm deep or more. Veins and arteries appear similar when skin is removed and are seen directly
Thank you for attention
Development of the heart

3\textsuperscript{rd} week
- from splanchnic mesoderm within the cardiogenic area of the cranial end of the embryo
- the cardiogenic cells condense to form a pair of primordial heart tubes
Development of the heart

1 - epimyocardial plates (epicard and myocard)
2 – endocardial bulbs
3 – endocardial tubes
4 – tubular heart
Development of the heart

Dorsal aorta

Endocardial tubes
These structures can be distinguished in the tube:

- Arterial conus
- Ventriculus
- Venous sinus
Development of the heart

- Venous sinus moves up and back
- Ventriculus goes front and to the left
- Arterial conus moves front and down
The heart tube undergoes dextral looping (bends to the right) and rotation.

- The upper truncus arteriosus (ventricular) end of the tube grows more rapidly and folds downward and ventrally and to the right.
- The atria and sinus venosus lower part of the tube fold upward and dorsally and to the left.

The 4th week – first contraction of the myocardium!
Development of the heart

- Cells of the endocardial tube
- Visceral mesoderm surrounding the primitive heart tube
- Endocardium
- Myocardium
Development of the pericardium

Intraembryonic body cavity (coelom) → Pericardial cavity
Somatic mesoderm → Parietal pericardium
Splanchnic mesoderm → Visceral pericardium (epicardium)
Atrioventricular partition – formation of the AV valves (5\textsuperscript{th} week)
Partition of the heart – formation of the left (arterial) and right (venous) parts

1. Development of atrial septum
2. Development of ventricular septum
3. Development of arterial truncus septum
Partition of the left and right atrium
Foramen ovale

Degenerated part of the primary septum

Oval foramen is closed by its valve

Oval foramen is opened

Valve of the oval foramen
Circulatory changes at birth

Antenatal circulation

Postnatal circulation
Remnant of oval foramen – fossa ovalis
Patent foramen ovale (PFO)
Partition of the left and right ventricles
Ventricular septum defect (VSD)

perimembranous

muscular
VSD Closure device
Partition of truncus arteriosus

Longitudinal partition – partition of aorta and pulmonary arteries
Transverse partition – formation of semilunar valves
Ductus arteriosus

Ductus arteriosus

Ligamentum arteriosum
Patent ductus arteriosus
Development of the arteries

Blood of the embryo flows from heart into:
- aortic sac
- ventral aorta (paired)
- aortic arches (6 pairs)
- dorsal aorta
Dorsal end of ventral aorta – external carotid artery
Aortic arches – pharyngeal arches
Aortic arches – pharyngeal arches

Aortic arches 1 completely regress except to form maxillary artery.
Aortic arches 2 completely regress except to form stapedial and hyoid arteries.
Aortic arches 3 forms common, external (partially) and internal carotid arteries.
Development of the arteries

Aortic arch 4 left forms arch of aorta. Aortic arch 4 right forms right subclavian artery.
Development of the arteries

Aortic arches 5 completely regress.
Development of the arteries

Aortic arches 6 form pulmonary arteries.
Development of the arteries

dorsal end of ventral aorta – external carotid artery
I and II aortic arches – reduce
III aortic arch – common, external and internal carotid arteries
right IV aortic arch – right subclavian artery
left IV aortic arch – arch of aorta
V aortic arch – reduce
VI aortic arch - pulmonary arteries
The right and left dorsal aorta fuse caudal to heart to form the definitive dorsal **descending aorta**
Branches of **dorsal aorta** – **descending aorta** (thoracic and abdominal parts of aorta):

#1 - ventral – **vitelline arteries** (yolk sac, celiac, superior and inferior mesenteric arteries) and **umbilical arteries** (fetus-placenta)
Branches of *dorsal aorta* – *descending aorta* (thoracic and abdominal parts of aorta):

#2 - lateral – *visceral arteries* (kidneys, suprarenal glands, gonads)
Branches of **dorsal aorta** – **descending aorta** (thoracic and abdominal parts of aorta):

#3 - **intersegmental** arteries – supply neural tube, deep muscles of the back and skin
Coarctation of aorta

- Congenital pathology of aorta development
- Disproportional development of parts of the body