Blood
CIRCULATORY SYSTEMS:

Cardiovascular - heart (pump) & blood
Lymphatic

Cardiovascular system includes pump (heart) and associated vessels (arteries, veins, capillaries)

Blood carried within cardiovascular system usually grouped with “connective tissue”.

Blood derived from cells in bone marrow, therefore (ultimately) from mesoderm
BLOOD – FUNCTIONS

TRANSPORT – oxygen, CO$_2$, cellular waste, nutrients, hormones, enzymes.

PROTECTION – immune response (white blood cells), blood clotting.

REGULATION – water balance, chemical levels, pH, body temperature.
BLOOD COMPONENTS

- RED BLOOD CELLS
- WHITE BLOOD CELLS
- PLASMA (about 55%)

About 90% of plasma is simple water, remaining 10% = important proteins (3 main types):
  - Albumins – promote water retention (thus maintaining normal blood volume & pressure)
  - Fibrinogen – essential for blood clotting
  - Globulins
    - Alpha and Beta globulins function to transport fat-soluble materials and lipids.
    - Gamma globulins are antibodies functioning in preventing certain diseases
Plasma (55% of whole blood volume)

Buffy coat (leukocytes and platelets; less than 1% of whole blood volume)

Erythrocytes (45% of whole blood volume)
ERYTHROCYTES (RED BLOOD CELLS)

About 50% of blood volume.
ERYTHROCYTES

~ 2 microns thick

~ 7 microns across

Disc shaped

Concave on each side

Mature RBC have no nuclei.

Almost entire volume taken up by oxygen carrying molecule HEMOGLOBIN.
RED BLOOD CELL PRODUCTION:

Before birth: yolk sac, liver, spleen.

After birth (normally): large cells of bone marrow of certain bones – vertebrae, sternum, hip, long bones.

After trauma: spleen can come back into service.

NORMAL LIFE SPAN: ~ 180 days.
HEMOGLOBIN AND OXYGEN TRANSPORT

• Transport of oxygen accomplished by iron-rich molecule, HEMOGLOBIN.
• Hemoglobin is characterized by its ability to bind Oxygen where oxygen concentration is high, and release it where it is low.
• “Heme” component is only 5% of actual molecule, but very important – the iron containing part.
• Reduced iron content in body reduces blood’s ability to carry oxygen.
CO$_2$ IN BLOOD

• RBCs also carry carbon dioxide.

• Part carried in hemoglobin, but much is dissolved directly in the plasma.

• Most carbon dioxide converted to CARBONIC ACID by reaction with water.

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-
\]
RBC LIFECYCLE:

Generated by HEMATOPOIETIC STEM CELLS in bone marrow.

Circulation in blood. (Remember, no nucleus, so it breaks down (wears out) eventually – about 80-120 days.)

Consumed by phagocytic cells, particularly in liver and spleen.

Components broken down and recycled. (See following diagram for further details.)
WHITE BLOOD CELLS (LEUKOCYTES)

• Retain nucleus
• Live for a long time
• Usually complexly shaped ("lobate")
• Outnumbered by RBC 1000 to 1 (though the number is somewhat higher in newborn infants.

2 Types: GRANULOCYTES and AGRANJULOCYTES

Granulocytes derived from bone marrow like
**NEUTROPHILS:** phagocytes that seek out, engulf, and destroy microorganisms.

**EOSINOPHILS:** lobate (“B”-shaped), mobile phagocytes, similar to neutrophils, particularly important for attacking microorganisms.

**BASOPHILS:** (elongate, lobed nuclei), regulate immunity against parasites and certain allergic responses.

**MONOCYTES:** mobile phagocytes; large (4-5x size of RBC). Line vascular network of lymphatics and associated organs. (Important! OSTEOCYTES differentiate from these.)
White Blood Cell Development
LYMPHOCYTES
(We’ll talk about these in greater detail during immunology lecture.)

• Common in lymphatic vessels.
• Originate in bone marrow, then migrate to lymphoid tissues – establish colonies.
• Then, can produce MORE lymphocytes without involving bone marrow.
• Particularly common in lymph nodes, spleen, tonsils, and lymphoid tissue of gut.
• Not phagocytes.
• Regulate cellular immune responses.
PLATELETS

• Function in: process of blood clotting & protection of vascular channels from internal damage.
• Can adhere to each other and collagen of connective tissue.
• HOWEVER, DON’T adhere to WBC or RBC.
• Good plug, but don’t adhere to blood cells themselves!
ABO BLOOD TYPES

Red blood cells have particular proteins on their surfaces. In combination with different (incompatible) kinds of blood, they induce blood cells to clump up (“agglutination”).

Two different versions of these types of proteins (called “agglutinogens”: A and B.

Based on possible combinations of A & B types of agglutinogens, there are four possible blood types in this system: A, B, AB, neither (called O).
ANTIGEN – any substance that, as a result of coming into contact with appropriate tissues, induces a state of sensitivity and which reacts in a demonstrable way with tissues of the sensitized subject.

ANTIBODY – an immune or protective protein (usually associated with a particular type of cell) that is characterized by reacting with a specific antigen.
<table>
<thead>
<tr>
<th>Cell Surface Protein</th>
<th>Blood Type Antibodies</th>
<th>Compatible with(!)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>Anti-B</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>Anti-A</td>
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<tr>
<td>AB</td>
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<td>None</td>
</tr>
<tr>
<td>O</td>
<td>O</td>
<td>Anti-A Anti-B</td>
</tr>
</tbody>
</table>
INTRODUCTION TO BLOOD VESSELS
Blood vessels – tubular structures, with particular named layers from innermost to outermost:

INNERMOST

*Tunica Intima* (has three subcomponents):
- Inner lining of simple epithelial cells attached to a basement membrane.
- Middle layer of fine connective tissue made up of collagen.
- Internal elastic lamina – outer elastic layer

*Tunica Media* – smooth muscle, elastic fibers, other connective tissue components.

*Tunica Adventitia* (or *Tunica Externa*) – mostly elastic and collagenous fibers. (In large vessels this layer has dedicated nerves, tiny blood vessels and lymphatics.)

OUTERMOST
**Tunica intima**

**Tunica media**

**Tunica externa** (adventicia)
Tunica intima

Tunica media

Tunica adventicia
The TUNICA MEDIA is relatively much thinner in veins.

Veins usually have little or not smooth muscle, except in the largest of veins.

Veins have periodic valves to prevent backflow.
Extremely thin tunica media in a vein.
ARTERIES to ARTERIOLES

• Smallest definable arteries are arterioles.
• They have relatively more smooth muscular tissue, less elastic tissue.
• Thus, they are more easily regulated by (autonomic) nervous control.
• Very smallest arterioles (terminal arterioles):
  • Have no internal elastic layer.
  • Tunica media densely supplied with sympathetic nerve fibers.
Rest, arteriolar tone

Contraction of smooth muscle causes vasoconstriction

Relaxation of smooth muscle causes vasodilation
VEINS TO VENULES

• Some veins to have smooth muscle in them (the very largest).
• Have same layers as arteries, but *tunica media* is much thinner.
• Have relatively less elastic tissue.
• Operate at low pressure.
• Have periodic bicuspid-shaped valves to prevent backflow.
• Smallest (venules) receive capillary blood – have no *tunica media*. 
Capillaries:

• Blood to capillaries from arterioles.

• Smallest and thinnest of vessels.

• Usually constructed of only a single layer of tunica intima.

• Greatest loss of blood pressure is at capillaries.

• Gas transfer takes place across wall.

• Nutrient transfer takes place across walls.

• Blood from capillaries to venules.
The first blood vessels of the embryo form inside the embryonic disc even before somites appear. They form near the edge of the yolk sac (a primitive condition inherited from macroolecithal organisms that stored yolk for food).
Angiogenetic cell clusters extend in an arc around the head end of the ventral opening of the yolk sac. Initially, this means that the angiogenetic cell clusters (and the blood vessel that forms from them) have the pattern of a "horseshoe" if viewed from a dorsal or ventral perspective.
An important point to understand is that the coelom runs up and down either side of the body.

At the head end, right underneath the developing pharynx, the coelom on the left communicates with the coelom on the right.

Thus, the coelom **cuts across the midline here.**
The brain grows at an incredible rate. It grows so fast that it makes the head bend around under the embryo's body.

(For the same reason that the gut is subdivided into three parts), this is why the heart winds up on the VENTRAL SIDE of the body.
The part of the heart ventral to the gut tube is a single tube itself.

The tube exiting the heart at its cranial end is the ventral aorta.

However, the heart cannot remain a simple tube (like a fish), so it must be subdivided into a right and left side.

A septum subdivides the heart into a left and right side.
The tube exiting the heart at its cranial end is the ventral aorta.

It also subdivides:

The right side connects with the lungs.

The left side supplies the body.

(More later…)