


## Mammalian Transport System

(G)

AICE Biology  
Ch. 8 Jones; Ch 50 Raven



Heart Anatomy and Physiology features the "Start Walk-Through Heart," originally built in 1954 as a temporary exhibit entitled "The Engine of Life."

## Learning Outcomes

Candidates should be able to:

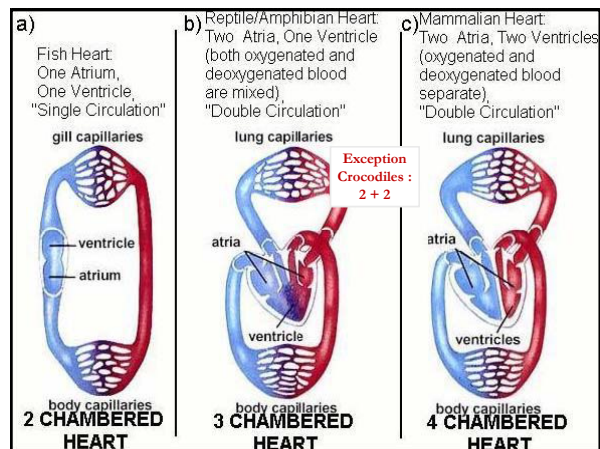
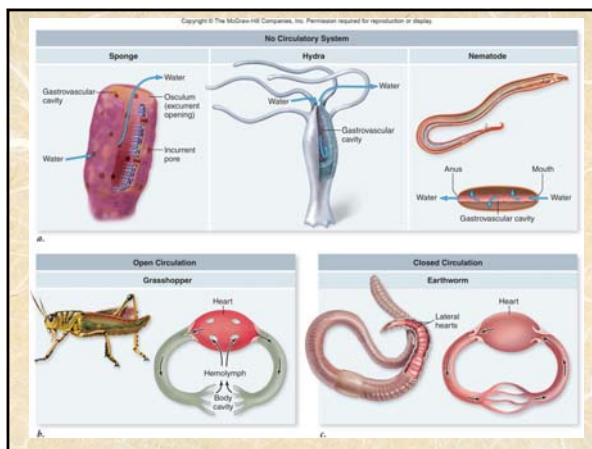
- (m) [PA] describe the structures of arteries, veins and capillaries and be able to recognise these vessels using the light microscope;
- (n) explain the relationship between the structure and function of arteries, veins and capillaries;
- (o) [PA] describe the structure of red blood cells, phagocytes and lymphocytes; \*
- (p) state and explain the differences between blood, tissue fluid and lymph; \*
- (q) describe the role of haemoglobin in carrying oxygen and carbon dioxide;
- (r) describe and explain the significance of the dissociation curves of adult oxyhaemoglobin at different carbon dioxide levels (the Bohr effect);

## Continued

- (s) describe and explain the significance of the increase in the red blood cell count of humans at high altitude;
- (t) describe the external and internal structure of the mammalian heart;
- (u) explain the differences in the thickness of the walls of the different chambers in terms of their functions;
- (v) describe the mammalian circulatory system as a closed double circulation;
- (w) describe the cardiac cycle;
- (x) explain how heart action is initiated and controlled (reference should be made to the sinoatrial node, the atrioventricular node and the Purkyne tissue);
- (y) use the knowledge gained in this section in new situations or to solve related problems.

## Transport Systems

|   |  |
|---|--|
| <p><b>Not very active</b></p> <ul style="list-style-type: none"> <li>• <b>Paramecium</b> <ul style="list-style-type: none"> <li>- Diffusion</li> <li>- Large surface area to volume ratio</li> </ul> </li> <li>• <b>Cnidarians</b> <ul style="list-style-type: none"> <li>- Diffusion</li> <li>- Large surface area to volume ratio</li> </ul> </li> <li>• <b>Green Plants</b> <ul style="list-style-type: none"> <li>- Xylem &amp; phloem</li> </ul> </li> </ul> | <p><b>Active</b></p> <ul style="list-style-type: none"> <li>• <b>Insects</b> <i>open</i></li> <li>• <b>Fish</b> <i>single</i></li> <li>• <b>Mammals</b> <i>double</i> <ul style="list-style-type: none"> <li>- All have large oxygen requirements and large amounts of waste products</li> <li>- Well-organized transport systems</li> </ul> </li> </ul> |
|---|--|



### Cardiovascular System


- Main transport system in mammals
  - Pump (heart)
  - Interconnecting tubes (vessels)
- Closed system
  - Blood always remains within the vessels
- Double loop
  - systemic and pulmonary circulation

<http://www.innerbody.com/anim/card.html>

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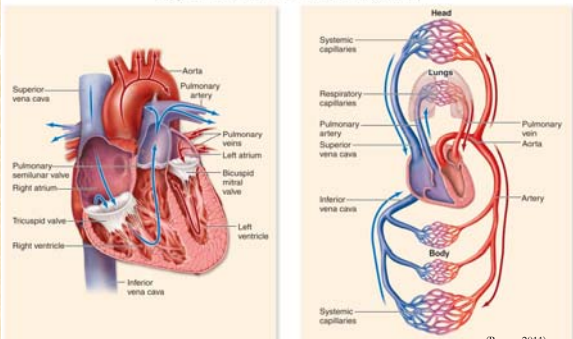
### Cardiovascular System

- Heart
- Blood
- Blood vessels
  - Arteries
  - Capillaries
  - Veins



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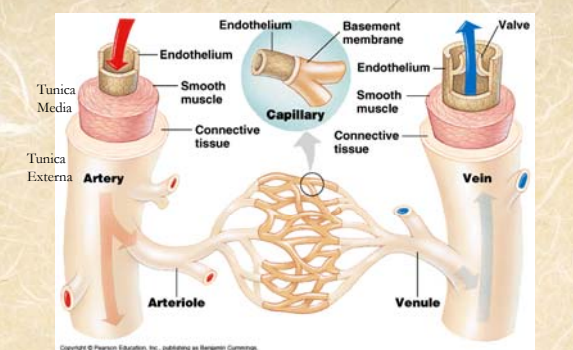
### 4 chambered heart



(Raven, 2011)

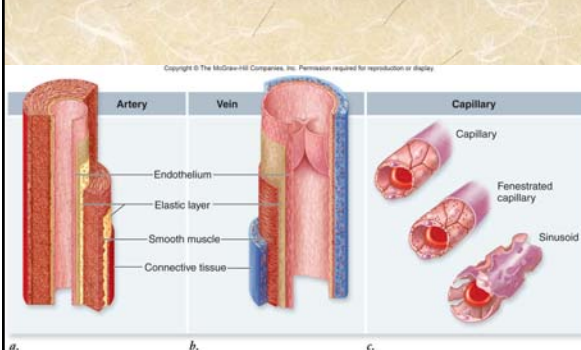
### Arteries, Veins, and Capillaries

- Arteries
  - Transports blood **away from the heart**
  - Thickest walls of any blood vessel
  - diameter able to be regulated
- Veins
  - Transports blood **back to the heart**
  - little elasticity
  - contain valves
- Capillaries
  - functional unit of the circulatory system
  - all exchanges occur within the capillaries
  - 7  $\mu\text{m}$  thick
  - arterioles
  - venules



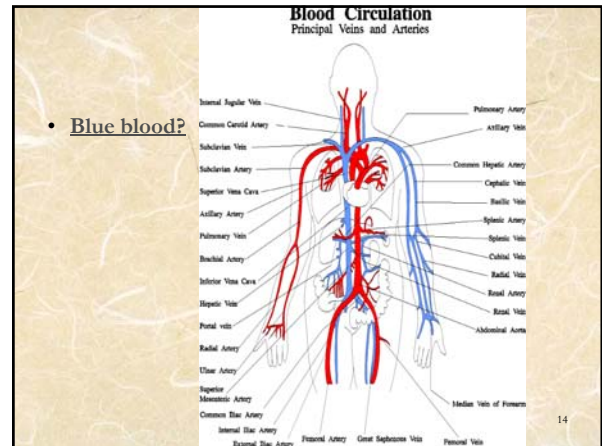
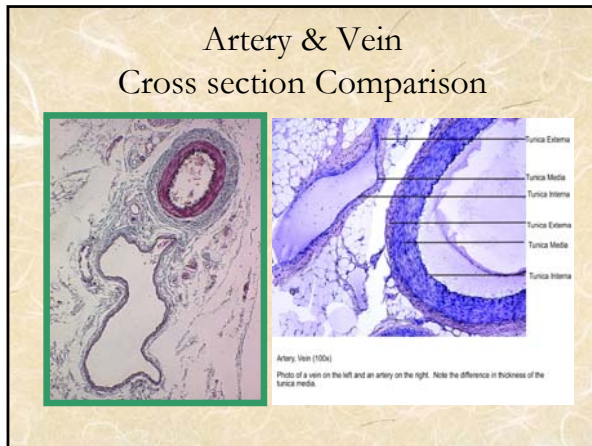
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Tunica Media: smooth muscle, collagen and elastic fibres  
 Tunica Externa: elastic fibres and collagen fibres  
 Artery wall known for strength... blood leaving heart is at very high pressure



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(Raven, 2011)



### Vascular Systems

- Most mammalian tissues are supplied by **two** distinct vascular systems
  - one carrying blood
    - pump
  - the other lymph
    - No pump

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### Lymph

- Fluid inside lymphatics
- Virtually identical to tissue fluid
- Absorb lipids from digested foods
- Lymph nodes are involved in protection against disease as white blood cells in nodes secrete antibodies (more in ch 14)
- Lymph drains into subclavian vein

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### Lymph

- About 10% of the fluid leaked from the capillaries is collected and returned to the blood system by the lymphatic system
  - Tiny vessels
  - Found in most tissues in the body
  - Drain into subclavian veins
  - Movement by contacting of muscles providing the push (no pump [heart]).
- Nodes involved in protection against disease
  - White blood cells w/in nodes secrete antibodies

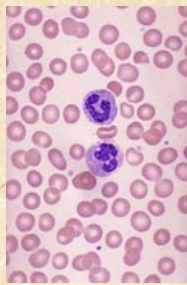
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| Blood Plasma  | Red Blood Cells                               | Platelets                                 |
|---|---|---|
| <b>Plasma proteins (7%)</b><br>Albumin (54%)<br>Globulins (39%)<br>Fibrinogen (7%)<br>All others (1%) | 4 million-6 million/<br>mm <sup>3</sup> blood | 150,000-300,000/<br>mm <sup>3</sup> blood |
| <b>Water (91.5%)</b><br>Electrolytes<br>Nutrients<br>Gases<br>Regulatory substances<br>Waste products | <b>Neutrophils</b><br>60-70%                  | <b>Eosinophils</b><br>2-4%                |
| <b>Monocytes</b><br>3-8%  | <b>Basophils</b><br>0.5-1%                    | <b>Lymphocytes</b><br>20-25%              |

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(Raven, 2011)

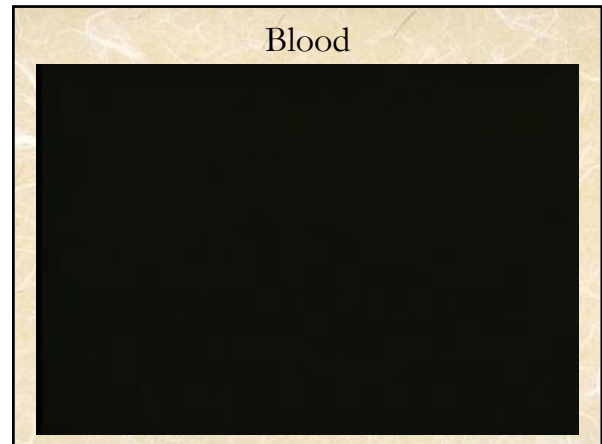
### Blood

- **Red Blood Cells**
  - **Erythrocytes**  
Transport oxygen and CO<sub>2</sub>
- **White Blood Cells**
  - **Leukocytes** : Play a major role in our immune and defense system
  - **Phagocytes**
  - **Lymphocytes**
    - Antibodies



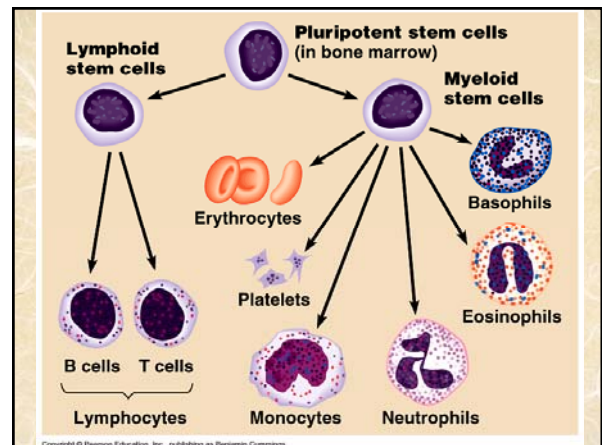
The Bloodmobile - 16.6M

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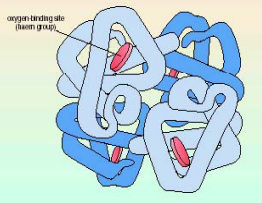
- Blood is a connective tissue
  - the ground substance is plasma
  - blood cells are called formed elements
- Plasma makes up 55% and cellular/formed elements make up remaining 45%
  - The three **formed elements**
    - Erythrocytes
    - Leukocytes
    - Platelets
  - Develop from a single population of pluripotent (embryonic) stem cells in the red marrow of bones
  - This marrow is found in the ribs, vertebrae, breastbone, and pelvis of the fetus
  - Potential to develop into any type of blood cell or cells that produce platelets

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### Globular Protein/ Haemoglobin

- You should be able to clearly indicate (using arrows) where the iron is located in the haemoglobin molecule
  - Hint, 4 per molecule
- Haem group = oxygen binding site



(Open University, 2009)

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### Haemoglobin Hb

- Transports oxygen from gas exchange to tissues all over the body.
  - Pg. 35 Haemoglobin image 4 polypeptides, each one containing a haem group
  - Each haem group can combine with one oxygen molecule (O<sub>2</sub>)

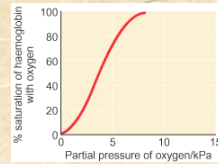
$$\text{Hb} + 4\text{O}_2 \rightleftharpoons \text{HbO}_8$$

haemoglobin                      oxygen                      oxyhaemoglobin

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## The S shaped curve

- The shape of the haemoglobin dissociation curve can be explained by the behaviour of a haemoglobin molecule as it combines with or loses oxygen molecules



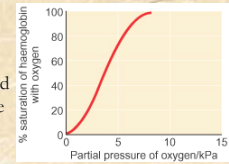
(RCS, 2009)

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## Haemoglobin Hb

### Oxygen dissociation curve

- The curve shows
  - at relatively low oxygen concentrations there is uncombined haemoglobin in the blood and little or no oxyhaemoglobin
    - e.g. in body tissue
  - at relatively high oxygen concentrations there is little or no uncombined haemoglobin in the blood; it is in the form of oxyhaemoglobin
    - e.g. in the lungs



(RCS, 2009)

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## Bohr Shift & Bohr Effect

- Bohr Shift
  - Helps maintain the pH level in the blood
- Bohr Effect
  - <http://www.youtube.com/watch?v=hJscP4e23xc>
  - Good Review <http://www.youtube.com/watch?v=wLPgxfBqtOM>

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## Carbon dioxide transport

- 85% of the carbon dioxide transported in blood is in the form of hydrogencarbonate ions,  $\text{HCO}_3^-$
- 5% of carbon dioxide is transported in the blood as is
- 10% combine with a terminal amine group ( $-\text{NH}_2$ ) and forms carbamino-hemoglobin

## Fetal hemoglobin

- A developing fetus obtains its oxygen from mother via the placenta, wastes also leave via placenta
  - Mother's blood is brought very close to fetus, allowing diffusion of substances
  - Placenta oxygen partial pressure is lower allowing for simple diffusion
- Fetal Hb has a higher affinity for oxygen than adult, fetal dissociation curve lies above the adult

## Myoglobin

- Pigment found inside cells of some tissues, especially in muscle cells
- Dissociation curve is even higher than fetal (see pg. 112, Jones)
- Myoglobin is made from one polypeptide rather than four
  - Just one haem group and can combine with one oxygen molecule
- Once combined, it becomes very stable and hard to release, known as oxymyoglobin
- Myoglobin is an **oxygen store**, the last to release its oxygen unless partial pressure of oxygen around it is very low
- Used for great oxygen demand

## Problems with oxygen transport

- Carbon monoxide:
  - Hb combines irreversibly and easily with CO, 250x
  - Combines with Hb forming caroxyhemoglobin
- High altitude:
  - Sea level partial pressure is 20 kPa, lungs 13 kPa
  - High altitude is 10 kPa. Hemoglobin may only become 70% saturated with oxygen
  - Altitude sickness: dizzy, weak, nose bleeds, head aches
  - Worse: arterioles in brain dilate, tissue leaks out, disoriented. Fluid may also leak into lungs, can be fatal
  - People can **adapt** to higher altitudes after living, training. ie: Train in high alt. and perform in low alt gives an advantage



- Three vampires walk into a bar. The bartender looks up and says "What'll you have?"
- The first vampire says "I'll have a pint of O positive"
- The second vampire says "I'm tasting a pint of B negative"
- The third vampire says "How about a pint of plasma tonight"
- The bartender turns and says "OK, so I need two Bloods and a Blood light."

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## Resources

- Campbell, N., Reece, J. (2005). *AP Edition Biology, 7<sup>th</sup> ed.* San Francisco, CA: Benjamin Cummings Publishing Company.
- Gray, H. (2009). *Anatomy of the Human Body*. Philadelphia: Lea & Febiger, 1918; Retrieved January 19, 2010 from Bartleby website [www.bartleby.com/107/](http://www.bartleby.com/107/)
- Jones, M., Fosbery, R., Taylor, D., & Gregory, J. (2007). *AS Level and A Level Biology, 2<sup>nd</sup> ed.* Cambridge, UK: Cambridge University Press.
- Jones, M. (2010). *Biology revision guide*. London, UK: Hodder Education.
- Open University. (2009). Nutrition: vitamins and minerals. Retrieved January 26, 2010 from the Learning Space website <http://openlearn.open.ac.uk/mod/resource/view.php?id=192850>
- Raven, et al. (2011). *Biology, 9<sup>th</sup> ed.* New York, NY: McGraw-Hill Companies, Inc.

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