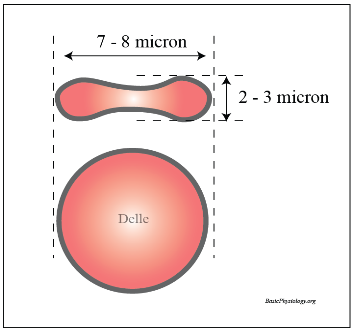
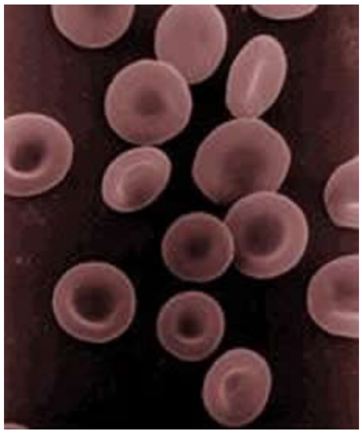
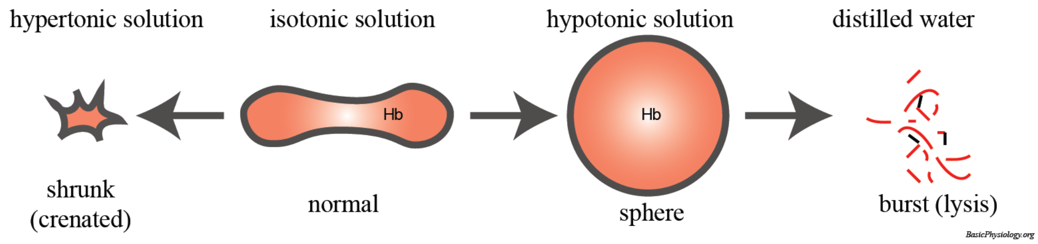
D.2.1. Erythrocytes

A. Erythrocytes (= red blood cells, also called RBC's):

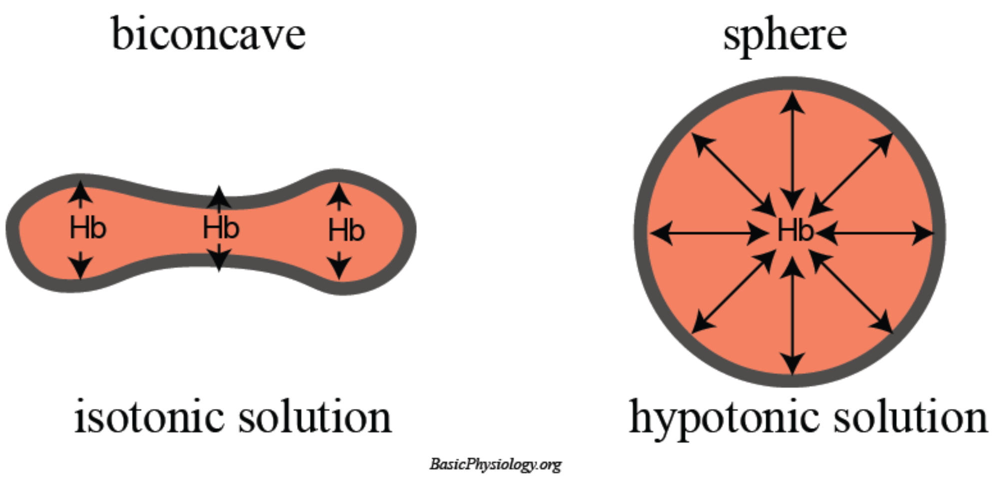
	Erythrocytes: • do **NOT** have a nucleus • do have a plasma membrane • are biconcave flat cells • the shape is caused by the cytoskeleton • the shape is very flexible so it can move through smaller capillaries • contains haemoglobin (Hb)	

B. Flexibility:



1. Erythrocytes are very flexible. Remember (*link*) that they can expand and shrink very easily with variations in salt concentrations (see diagram). Link: Osmosis in *A.2.3. Passive Transport Systems*.	2. But as they get older, flexibility is reduced (wear and tear) mainly because the cell machinery no longer replaces old pieces (no nucleus remember?). So, in due time, erythrocytes will **die**. This occurs in the spleen.
3. **Spleen**: The narrowest capillaries in the whole body are located in the spleen. Inside these narrow capillaries, the erythrocytes have to do a lot of bending while being pushed through these narrow vessels. If they rupture, then that is the end of this erythrocyte.	4. This happens on average **120 days** after they emerged from the bone marrow. The spleen is like an **exam** for the erythrocytes. If they pass the exam, then they go back to the circulation for another few cycles. If they fail -> death!

C. Why are erythrocytes biconcave?



1. Why is it useful that erythrocytes have a **biconcave shape** (= more or less flat) and not spherical?	2. This diagram shows what happens when an erythrocyte is placed in a **hypotonic** solution -> the erythrocyte swells and becomes a sphere. The surface area of the membrane, of course, has not increased but the **volume** has increased.
3. But in a sphere, the diffusion **distance** from the surface of the membrane to the haemoglobin in the middle of the sphere is much **longer** than in the biconcave situation. And a longer diffusion distance means a longer **diffusion time**.	4. In other words, the biconcave shape has a very favourable **surface:volume ratio** whereas a sphere has a much more unfavourable surface:volume ratio.
5. Diffusion of oxygen is therefore much promoted with shorter distances between the plasma membrane and the Hb molecules.	6. In addition, a sphere cell is much less **flexible** than a biconcave cell. This is very important when the erythrocytes have to flow through very narrow **capillaries**.

D. Diffusion of oxygen in the lungs:

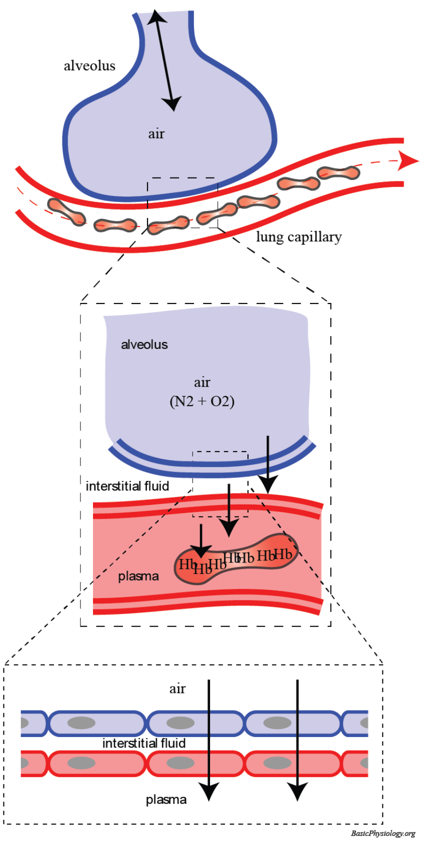
1.
This diagram shows the pathway of oxygen molecules from the lungs to the blood. In the lungs, air from outside is transported to small airspaces at the end of the bronchial system called the **alveoli**.

2.
One alveolus is depicted in the diagram (blue). The space inside is filled with air, which is a mixture of **nitrogen** (N_2; 80%), **oxygen** (O_2; 19%) and a few more gases.

3.
In the blood vessel, which runs as close as possible to the wall of the alveolus, blood is pumped from the heart. This blood contains erythrocytes that have little oxygen as they have been used by the metabolism in the rest of the body.

4.
Therefore the **concentration** of oxygen in the erythrocytes is **low** while the concentration of oxygen in the alveolus is **high**. Therefore, there will be oxygen diffusion:

a. from the **alveoli**, through the alveolar membrane, to the interstitial fluid
b. from the **interstial** fluid, through the endothelium, into the blood plasma
c. from the **plasma**, through the plasma membrane, into the erythrocytes.



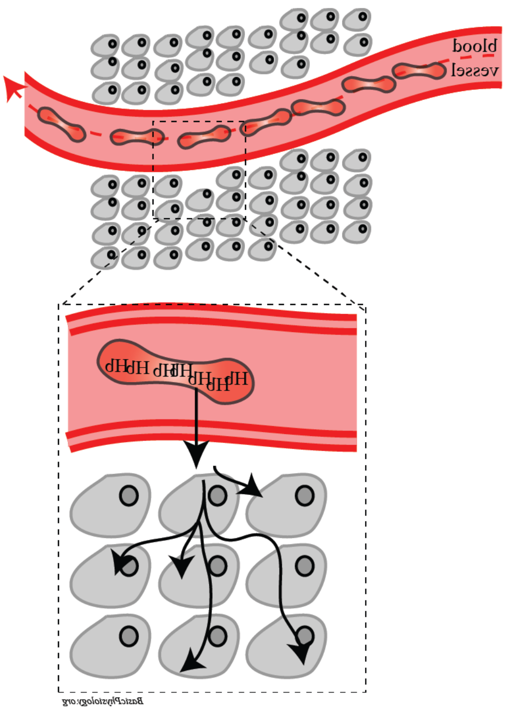
5.
Note that both the alveolar membrane and the capillary membrane consist of cells. Therefore the oxygen molecules have to pass through the plasma membranes of both cells. Thus, the oxygen molecules passes, in total, **five** plasma membranes (2 membranes in the alveolar cells + 2 in the endothelial cells + 1 erythrocyte membrane).

6.
Note that the oxygen molecule is **dissolved** in the interstitial fluid and in the plasma but, in the erythrocytes, it is **bound** to the hemoglobin molecule.

E. Diffusion of oxygen in the tissues:

1.
This diagram shows the pathway of oxygen molecules from the blood to the individual cells in tissues.

2.
In contrast to the situation in the lungs, in the tissues, the concentration of oxygen is highest in the erythrocytes and lower in the cells. It is lower in the cells because of the metabolism in the cells that consumes oxygen.



3.
Therefore, there will be oxygen diffusion:
a. from the **erythrocytes**, through its membrane, to the plasma
b. from the **plasma**, through the endothelium, into the interstitial fluid
c. from the **interstitial fluid**, through the plasma membrane of the tissue cells, into those cells.

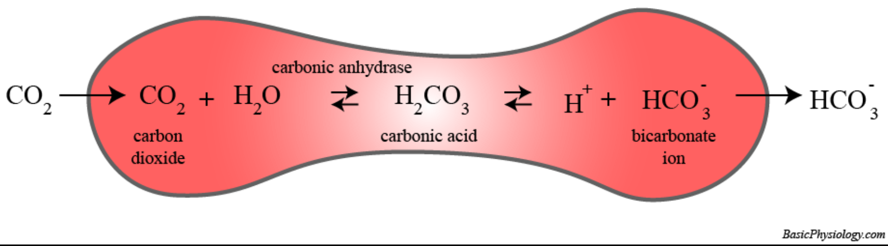
4.
In contrast to the diffusion in the lungs, the distance that the oxygen molecules have to travel is often much **longer**. That is because it is impossible to provide every cell with its own capillary! This therefore limits the metabolism of the tissue. In some cases, such as in skeletal muscles, the problem is solved by opening additional capillaries. (*Link B.5.6. Special Circulations*)

5.
For example, this happens when the muscle exercises. In a normal resting muscle, about 80-90% of the capillaries are closed. But when the muscle exercises, **more capillaries open**, thereby **shortening** the diffusion time from the capillaries to the individual cells.

6.
Another, long term solution, is to create **new capillaries**, especially when you exercise a lot. This will create new blood vessels (= **angiogenesis**; from angio = blood vessel and genesis = creation).

7.
The amount of oxygen that can be **dissolved** in plasma is very small and not sufficient for keeping us alive. That is the reason why we have erythrocytes; they are like **batteries** that can pack (=store) a lot more oxygen for **transportation** to the tissues where they are needed. Without (sufficient) erythrocytes, our tissues will literally **suffocate** and **die** because of lack of oxygen.

F. Other functions of erythrocytes:



1.
Other **transport functions**:

Erythrocytes are also used to transport **other compounds** in blood. One of these is **carbon dioxide** (=CO_2). This CO_2 is formed by the metabolism in active cells in the body. And this CO_2 has to go back from the tissues to the lungs, where our lungs **exhale** it.

Some of the CO2 is bound to haemoglobin while another portion is converted to bicarbonate as shown in the diagram:

2.
This conversion of CO_2 to bicarbonate ion occurs in the erythrocytes.

1. An enzyme (**carbonic anhydrase**) helps in this conversion.
2. This enzyme is located in the erythrocytes, **not** in the plasma.
3. The CO_2 diffuses into the erythrocytes.
4. With the help of carbonic anhydrase, it **binds CO_2 to water** to form carbonic acid.
5. Carbonic acid is **not stable** and splits immediately into 1 hydrogen ion and 1 **bicarbonate ion**.
6. The bicarbonate ion (and the hydrogen ion) **diffuses back into the plasma.**

3.
In summary; the erythrocytes transports CO_2 bound to Hb and also converts CO_2 into bicarbonate ion that is transported in the plasma.