The Respiratory System

chapter 15

page 282

The function…

- **To allow O_2 from the air to enter the blood and CO_2 from the blood to exit into the air**
- **Along with the cardiovascular system it accomplishes:**
  1. **External respiration (air <--> blood)**
  2. **Transport of gases between lungs and tissues**
  3. **Internal respiration (blood <--> tissues)**

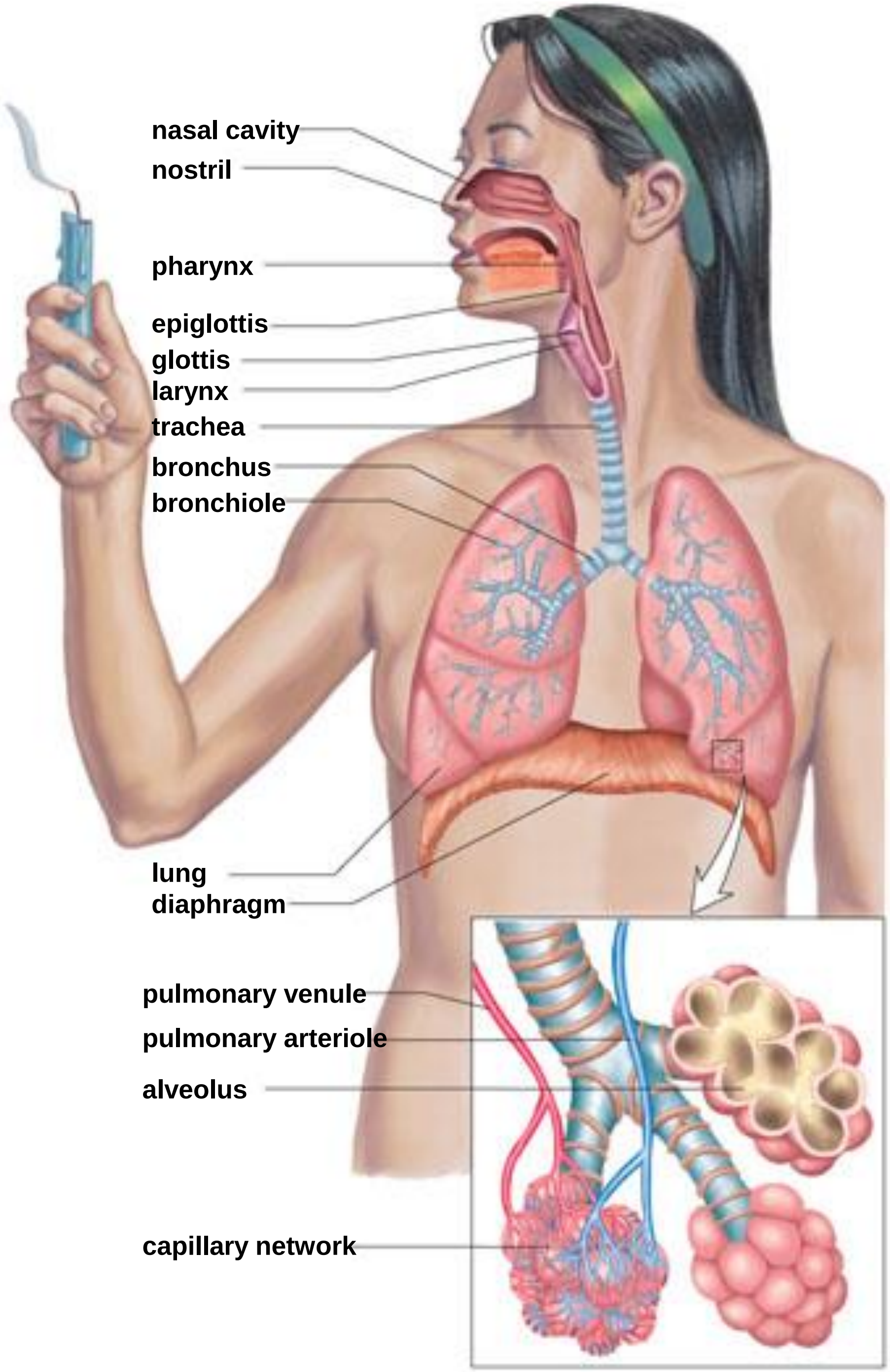
The respiratory tract…

UPPER RESPIRATORY TRACT

- Nasal Cavities
- Pharynx
- Glottis
- Larynx

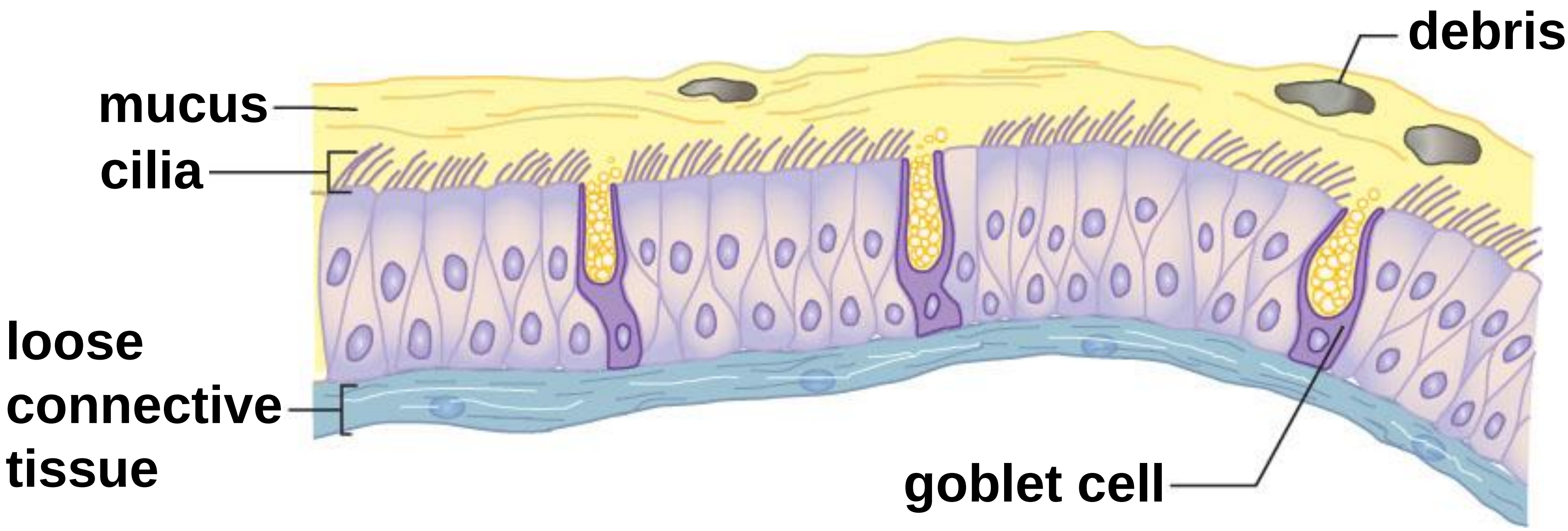
LOWER RESPIRATORY TRACT

- Trachea
- Bronchi
- Bronchioles
- Lungs
- Alveoli


nasal cavity
nostril
pharynx
epiglottis
glottis
larynx
trachea
bronchus
bronchiole
lung
diaphragm
pulmonary venule
pulmonary arteriole
alveolus
capillary network

The respiratory tract…

- Is lined with mucus and cilia
- In the nose, the hairs and cilia act as screening devices
- Mucus traps dust and other particles
- In the trachea and other airways, cilia beat upwards, carrying mucus and dust upwards
  - This is why you sneeze/cough when you inhale particles!
- Air is warmed as it enters nasal passages by the heat being given off by the blood

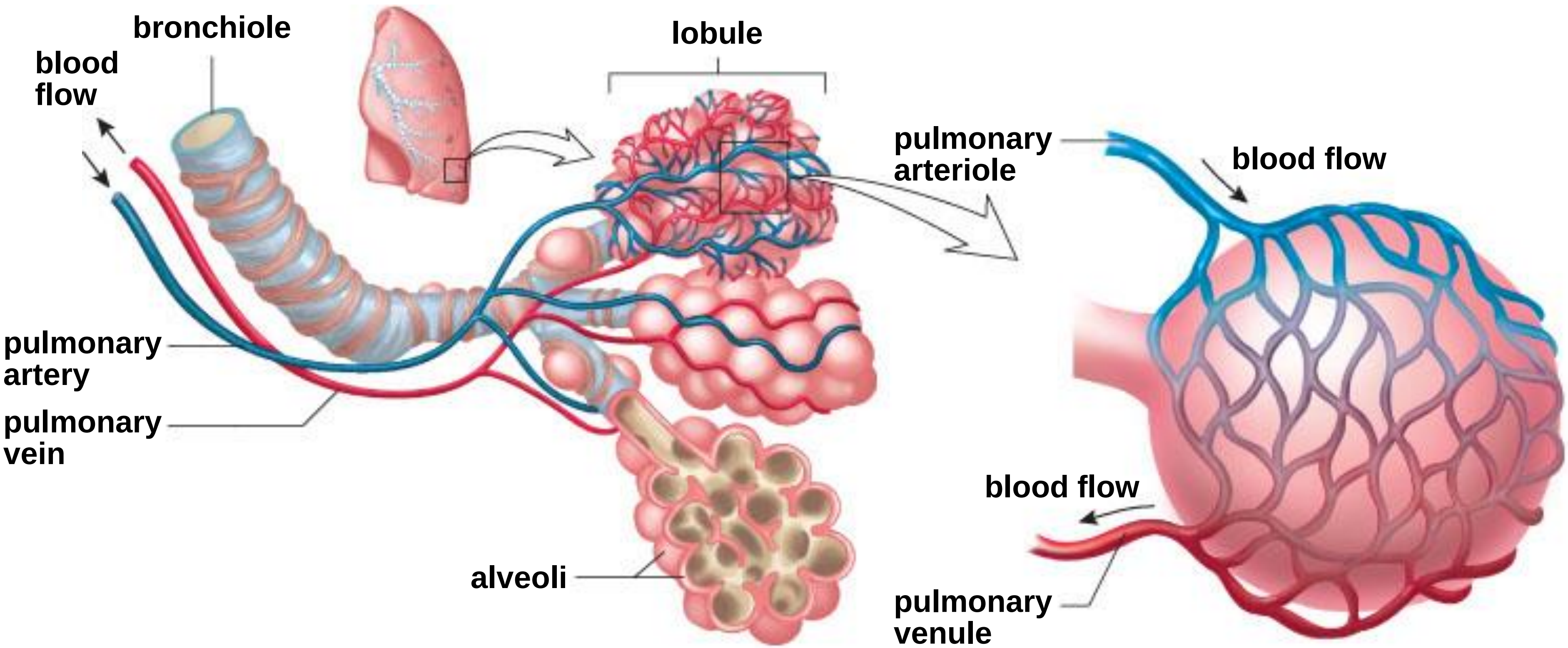

debris
mucus
cilia
loose
connective
tissue
goblet cell

The lungs

- Paired, cone-shaped organs
- Right lung has 3 lobes, left has 2 (needs room for ♡)
- Each is covered by a pleural membrane → secretes fluid that acts as a lubricant
- The bronchioles in the lungs branch into alveoli
  - Alveoli look like bunches of grapes
  - They are closely connected to a vast network of pulmonary capillaries
  - O_2 diffuses from the air in an alveoli into the blood in the capillaries
  - CO_2 diffuses from the blood in the capillaries into the alveoli

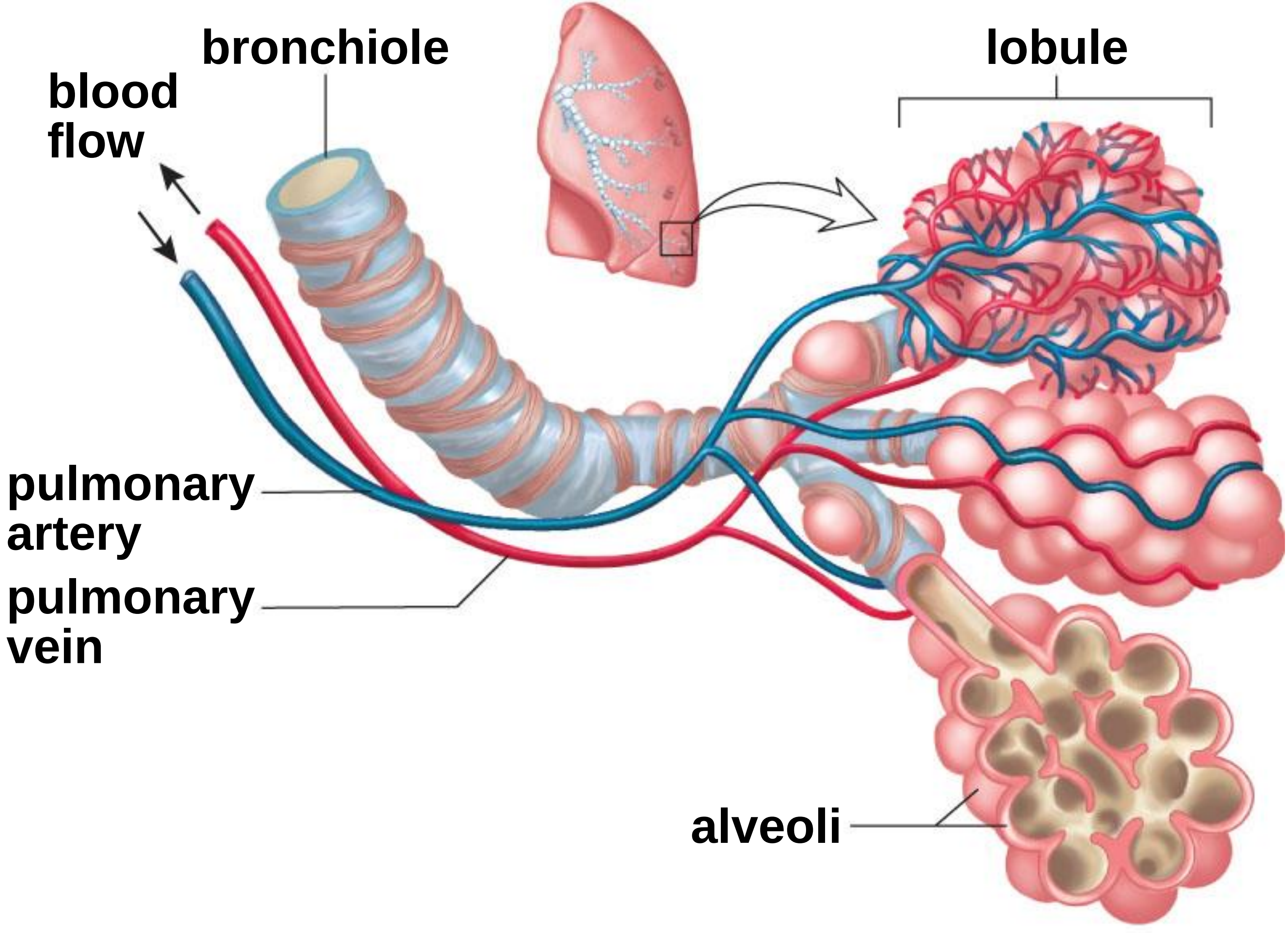
How alveolar structure relates to function

1. Roughly 0.1-0.2mm in diameter → maximizes amount of surface area for gas exchange
2. Walls are one cell thick → ease of gas exchange
3. Covered with film of surfactant (lipoprotein) → lowers surface tension and prevents collapse after exhalation
4. Tons of capillaries for gas exchange
5. ~150 million alveoli in your lungs → more S.A.

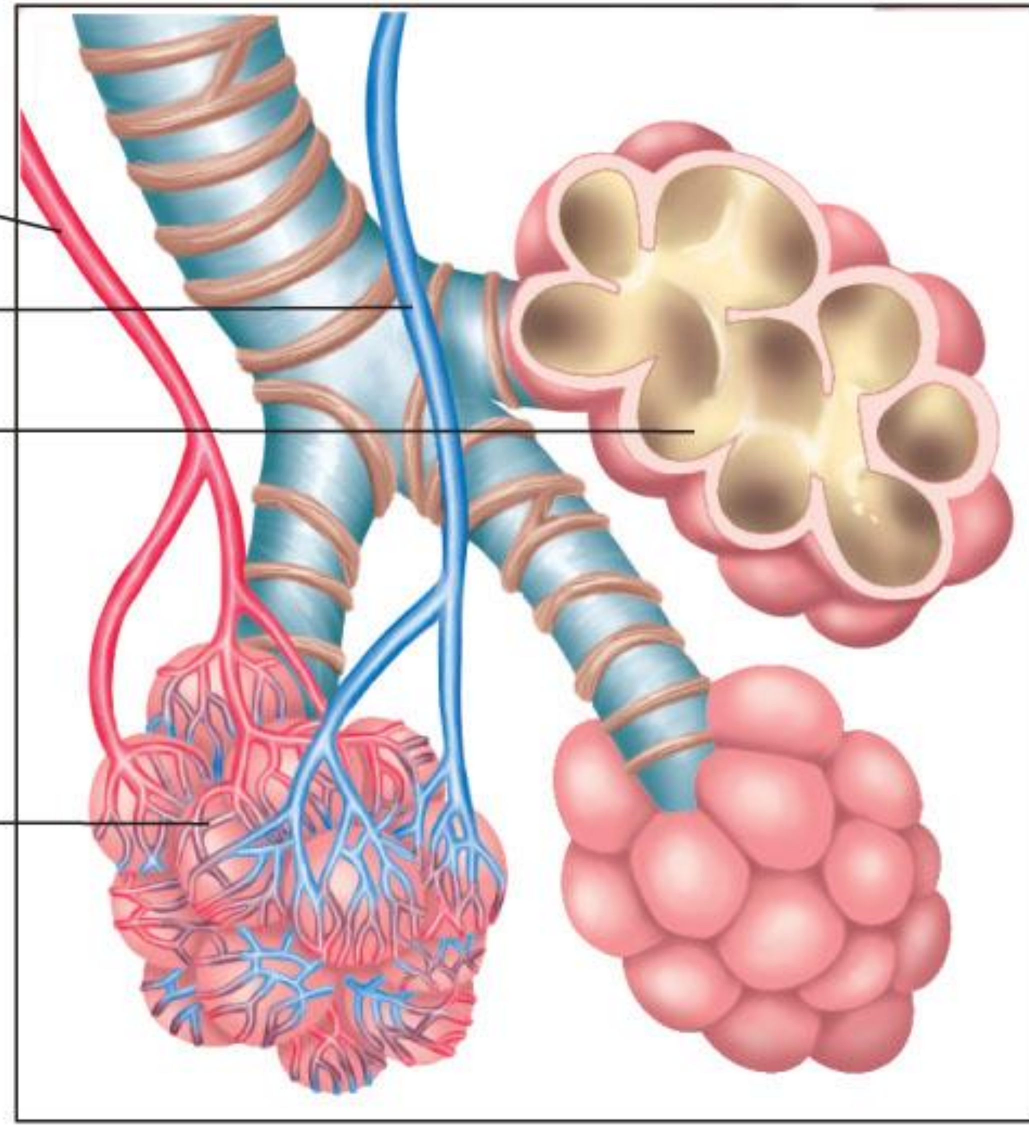


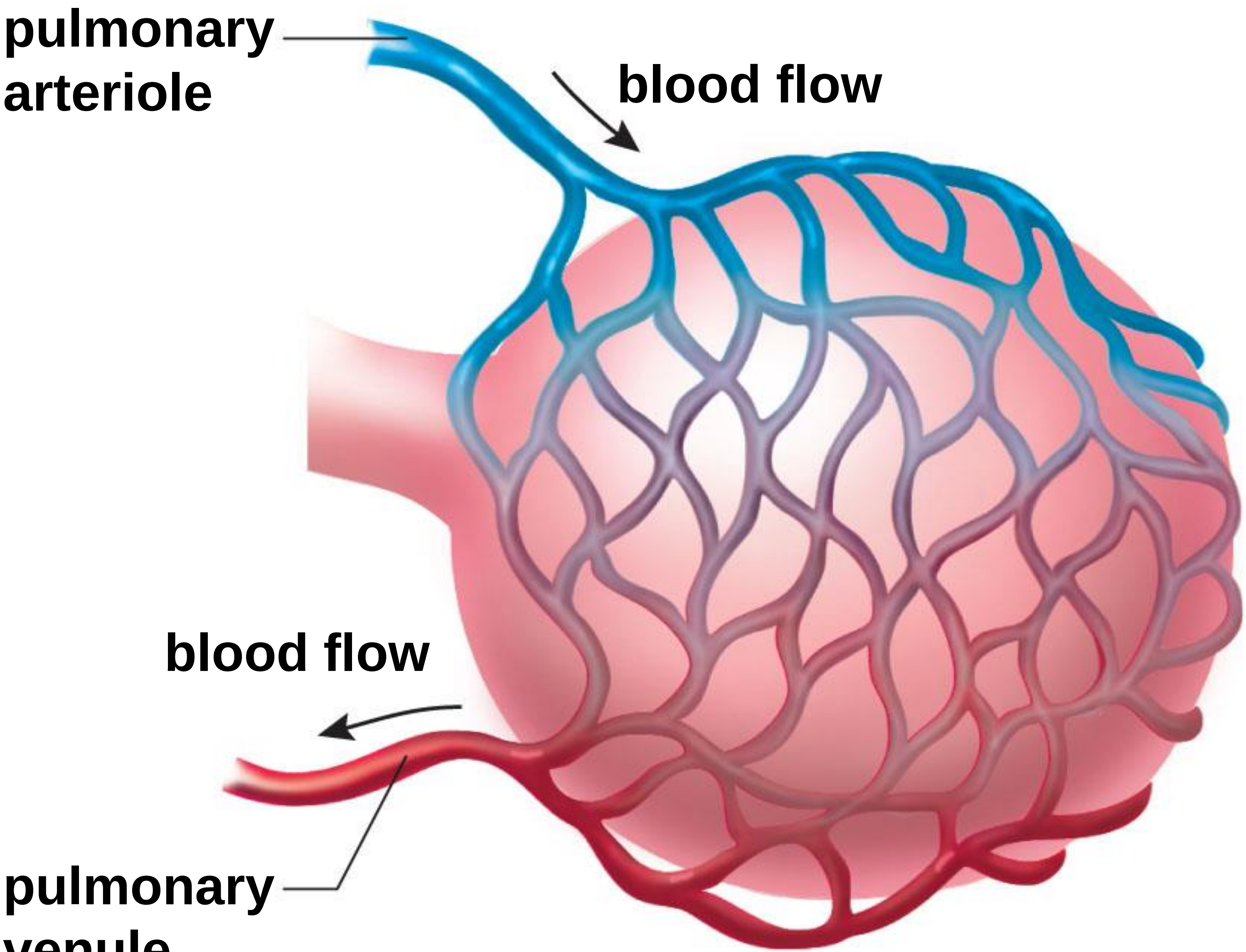
Blood supply of alveoli

Capillary network of one alveolus



Blood supply of alveoli


pulmonary venule
pulmonary arteriole
alveolus
capillary network

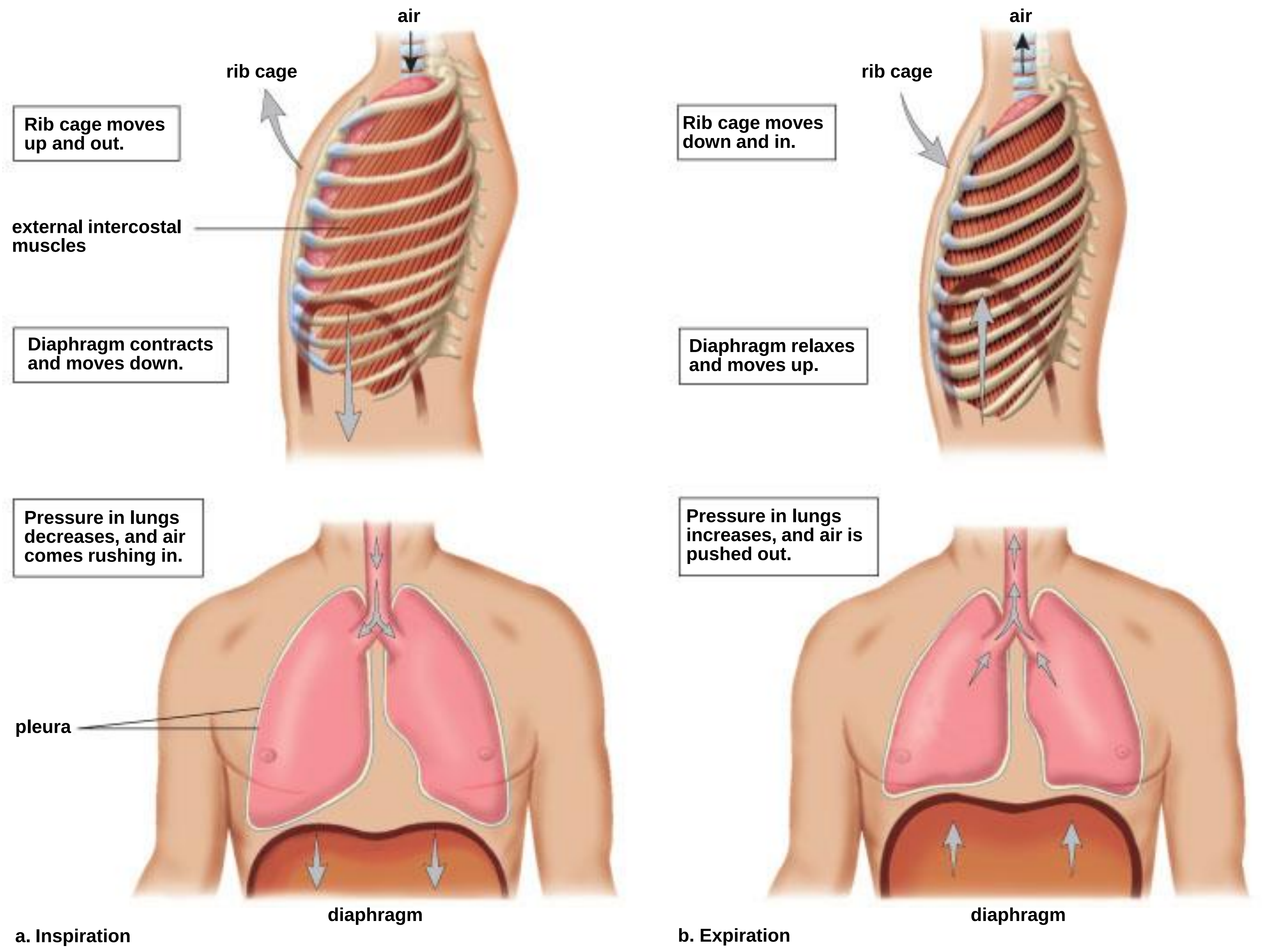


Capillary network of one alveolus

The process of breathing... pg. 291

1. <u>INSPIRATION</u>

- Diaphragm contracts and moves down
- Intercostal muscles contract and the rib cage moves upward and outward → the lungs expand
- Volume of thoracic cavity increases (↓ the pressure)
- Alveolar pressure is now < atmospheric pressure .: air rushes into the lungs!
- *"Humans inhale by negative pressure"*

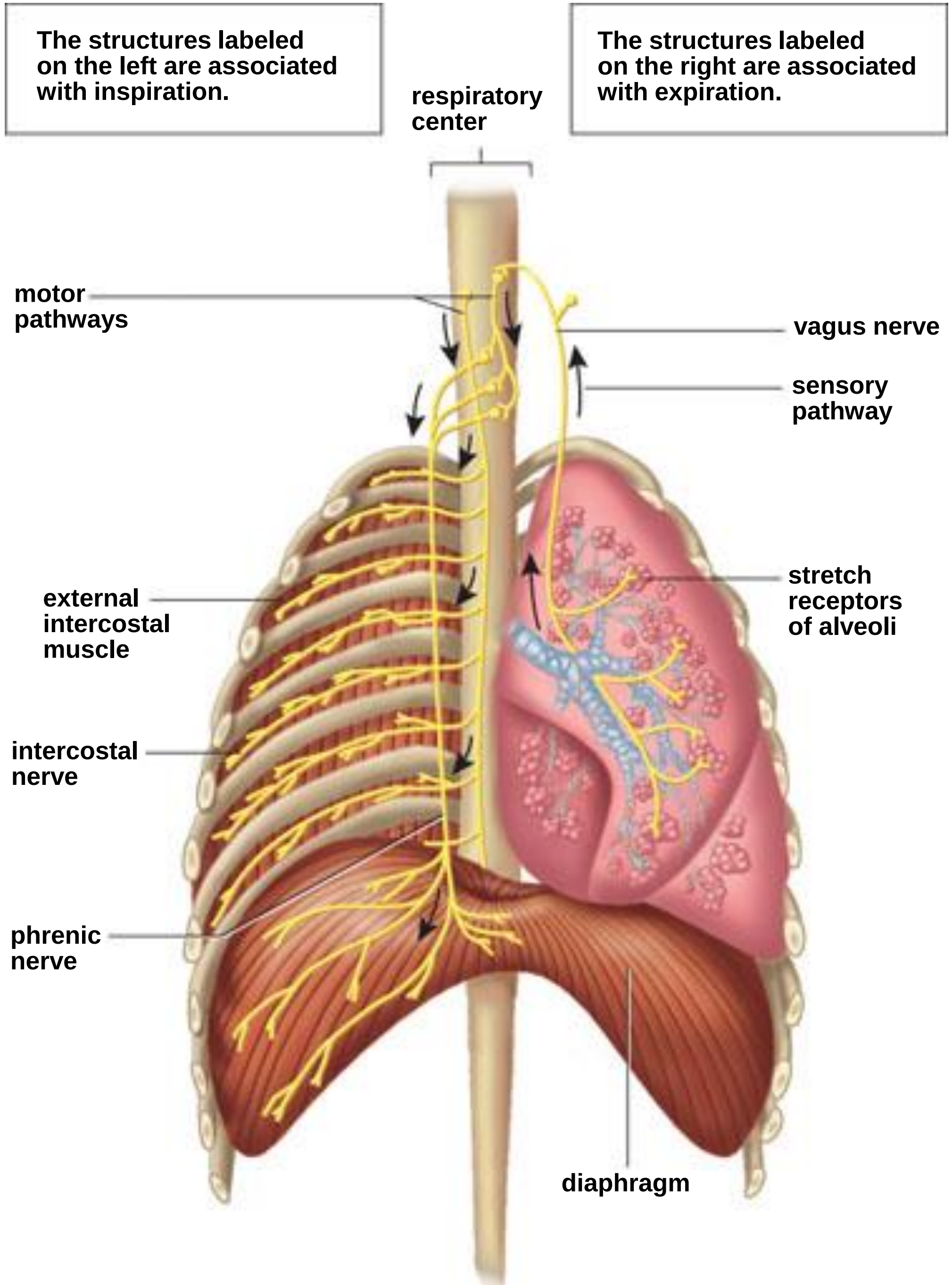

air
rib cage
Rib cage moves up and out.
external intercostal muscles
Diaphragm contracts and moves down.
Pressure in lungs decreases, and air comes rushing in.
pleura
diaphragm
a. Inspiration
air
rib cage
Rib cage moves down and in.
Diaphragm relaxes and moves up.
Pressure in lungs increases, and air is pushed out.
diaphragm
b. Expiration

2. Expiration

- Passive phase of breathing – no effort required
  - *It is the* ABSENCE *of nerve impulses that result in expiration*
- The elastic qualities of the thoracic cavity and lungs cause them to recoil
- Diaphragm relaxes and moves up
- The rib cage moves down and inward
- Lung volume decreases (↑the pressure)
- Thoracic pressure is > atmospheric pressure .: air is pushed out
- Can be active… you can use your abdominal muscles to push the diaphragm up and force air out
  - Try it!

Control of breathing…

- You have a breathing/respiratory centre in your brain
- Located in the <u>medulla oblongata</u>
- Stimulates the diaphragm and intercostal muscles to contract via nerve impulses
- Can be influenced by nervous input via stretch receptors in alveoli or chemical input via chemoreceptors in carotid artery and aorta


The structures labeled on the left are associated with inspiration.
respiratory center
The structures labeled on the right are associated with expiration.
motor pathways
vagus nerve
sensory pathway
stretch receptors of alveoli
external intercostal muscle
intercostal nerve
phrenic nerve
diaphragm

Nervous input…

- **Stretch receptors in alveoli inhibit the breathing centre**

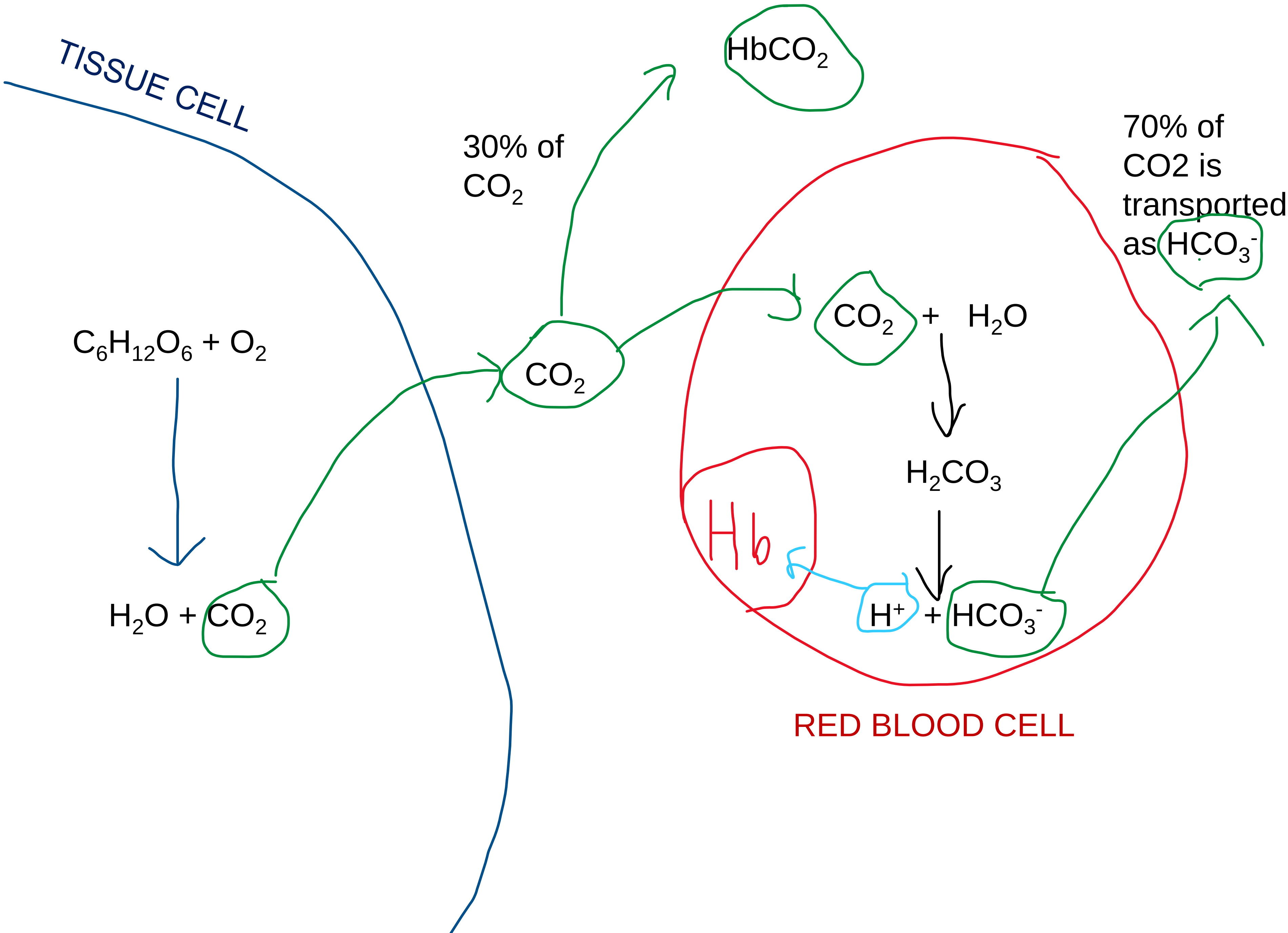
- **Tells the breathing centre to stop sending out nerve impulses to diaphragm and intercostal muscles**
  - *Thus, those muscles relax and you exhale*

Chemical input

- The breathing centre is sensitive to levels of CO_2 and H^+ in the blood
  - *If either go up, breathing rate and depth of breathing increases*
- Chemoreceptors in the carotid artery and aorta monitor O_2 levels in the blood = ***carotid and aortic bodies***
  - When levels of O_2 are low they send signals to breathing centre in medulla oblongata telling it to stimulate breathing
  - *Breathing rate and depth of breathing will increase*

CO_2 production and transport from the tissues

- CO_2 and water are produced in the tissues due to cellular respiration
- They combine to form bicarbonate (HCO_3^-) and hydrogen ions (H^+) (happens in RBCs)
  - The enzyme carbonic anhydrase catalyzes the above reaction
- The bicarbonate diffuses into the blood and makes it way to the lungs – this is how 70% of CO_2 is transported
- The rest of the CO_2 binds to Hb → *carbaminohemoglobin*
  - This binding is favored by a higher temperature and lower pH
- The H^+ also binds to Hb to produce “reduced” hemoglobin (HHb)



TISSUE CELL
$C_6H_{12}O_6 + O_2$
$H_2O + CO_2$
CO_2
30% of CO_2
$HbCO_2$
CO_2 + H_2O
H_2CO_3
H^+ + HCO_3^-
Hb
70% of CO2 is transported as HCO_3^-
RED BLOOD CELL

Internal respiration:

$$CO_2 + H_2O \xrightarrow{\text{carbonic anhydrase}} H_2CO_3 \longrightarrow H^+ + HCO_3^-$$

carbon dioxide + water → carbonic acid → hydrogen ion + bicarbonate ion

Internal Respiration

1. $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow HCO_3$- + H^+

2. $CO_2 + Hb \rightarrow HbCO_2$

3. $H^+ + Hb \rightarrow HHb$ *("reduced Hemoglobin")*

4. $HbO_2 \rightarrow Hb + O_2$

Internal respiration

The exchange of gases between the tissues and the blood capillaries

1. O_2 is released from Hb and diffuses into the tissue cells
2. CO_2 is released from the tissue cells and diffuses into the RBCs
3. CO_2 is either transported in $HbCO_2$ or as bicarbonate
4. Hb picks up H^+ ions to become HHb → "reduced" Hb

The release of CO_2 at the lungs…

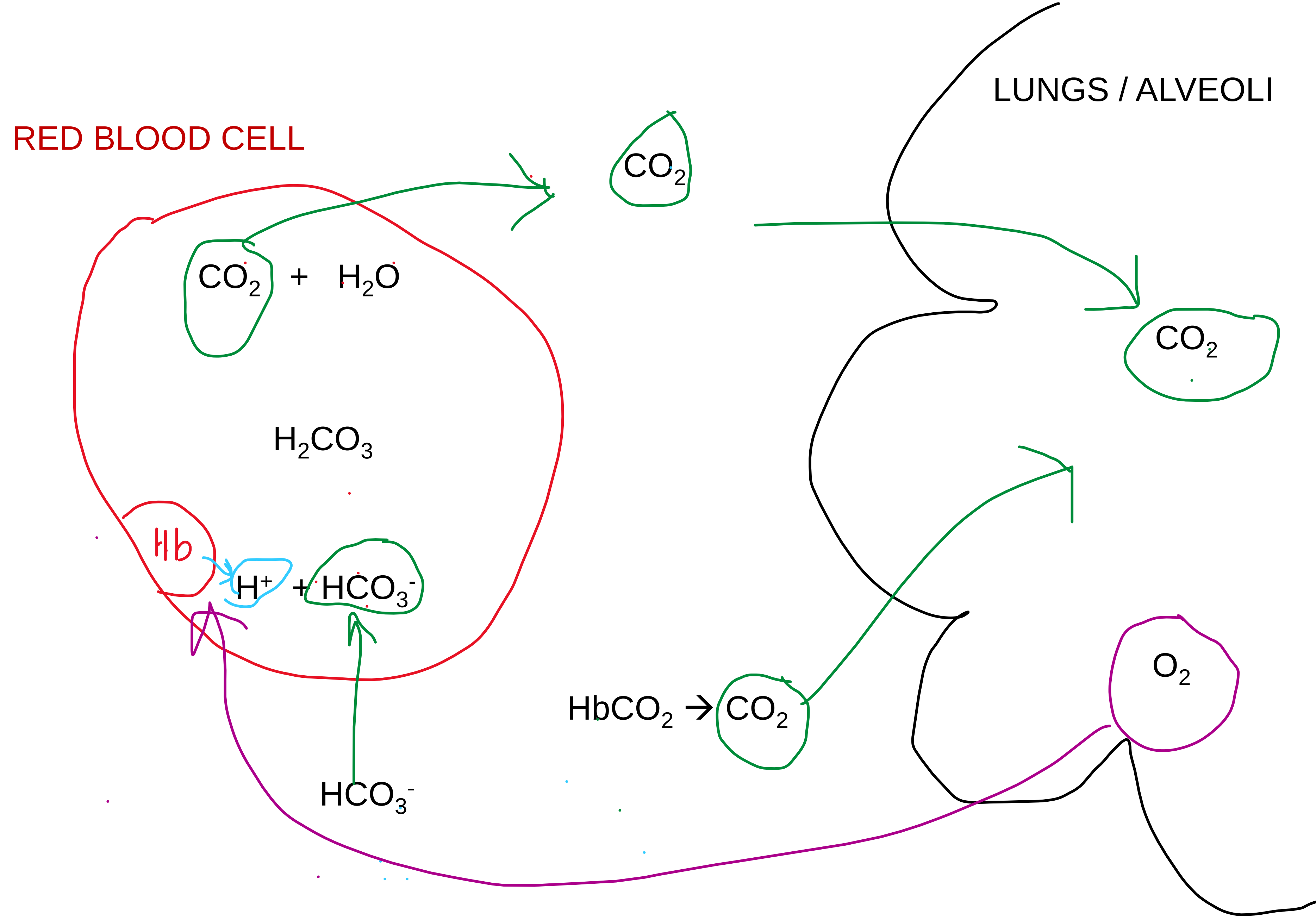
- Bicarbonate reacts with H^+ in RBCs and produces H_2CO_3 which is then broken down to produce CO_2
  - The enzyme carbonic anhydrase catalyzes the above reaction too!

- The CO_2 is then free to diffuse into the alveoli and be exhaled
- The pH of the lungs is higher (more alkaline) and the temp. is lower than that of the blood
  - This favors the release of CO_2 from hemoglobin
  - It also favors the attachment of O_2 to Hb

External respiration:

$$H^+ + HCO_3^- \longrightarrow H_2CO_3 \xrightarrow{\text{carbonic anhydrase}} H_2O + CO_2$$

hydrogen ion + bicarbonate ion → carbonic acid → (carbonic anhydrase) → water + carbon dioxide


RED BLOOD CELL
LUNGS / ALVEOLI
CO_2 + H_2O
H_2CO_3
Hb
H^+ + HCO_3^-
HCO_3^-
CO_2
CO_2
$HbCO_2 \rightarrow CO_2$
O_2

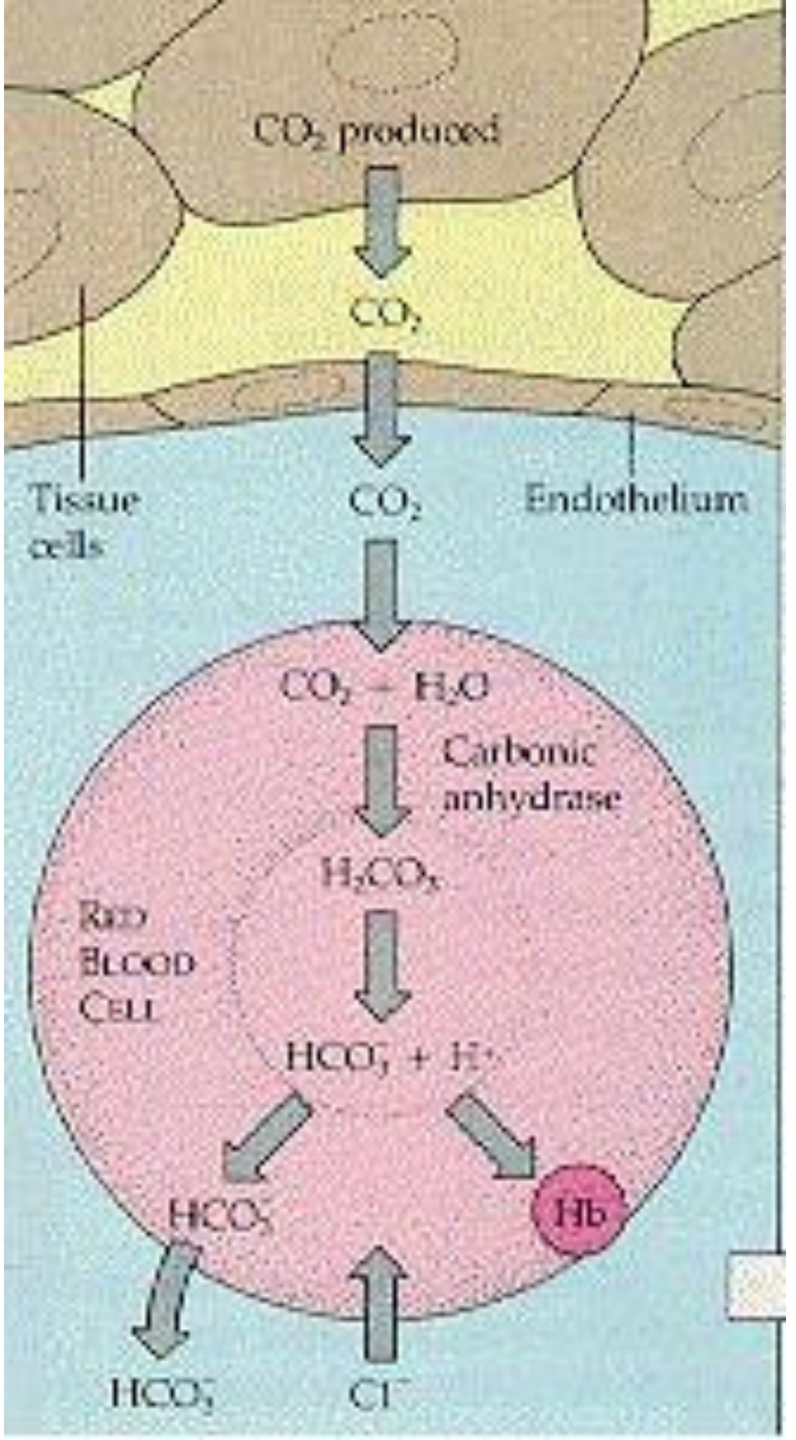
External Respiration

1. $HCO_3^- + H^+ \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$

2. $HbCO_2 \rightarrow CO_2 + Hb$

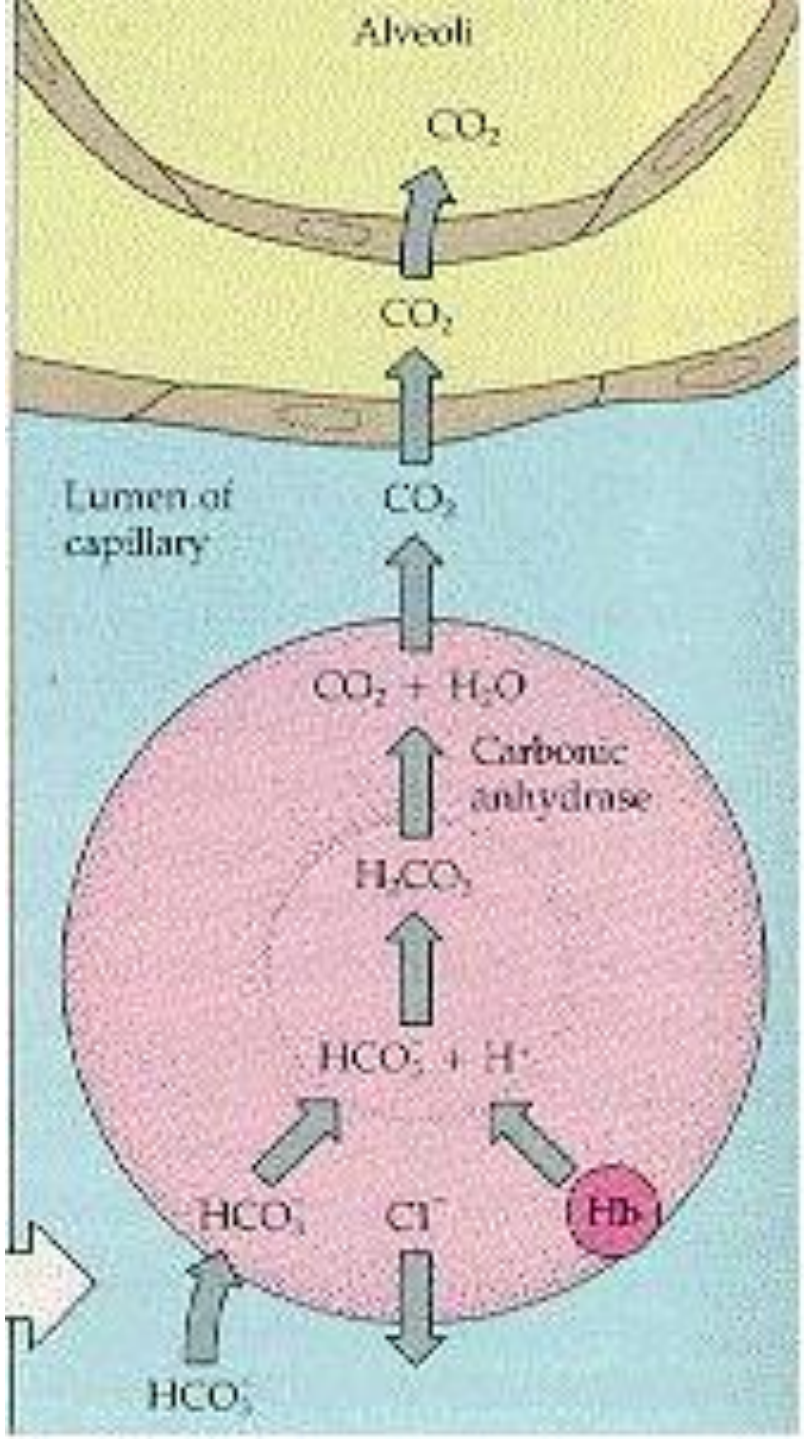
3. $HHb \rightarrow H^+ + Hb$

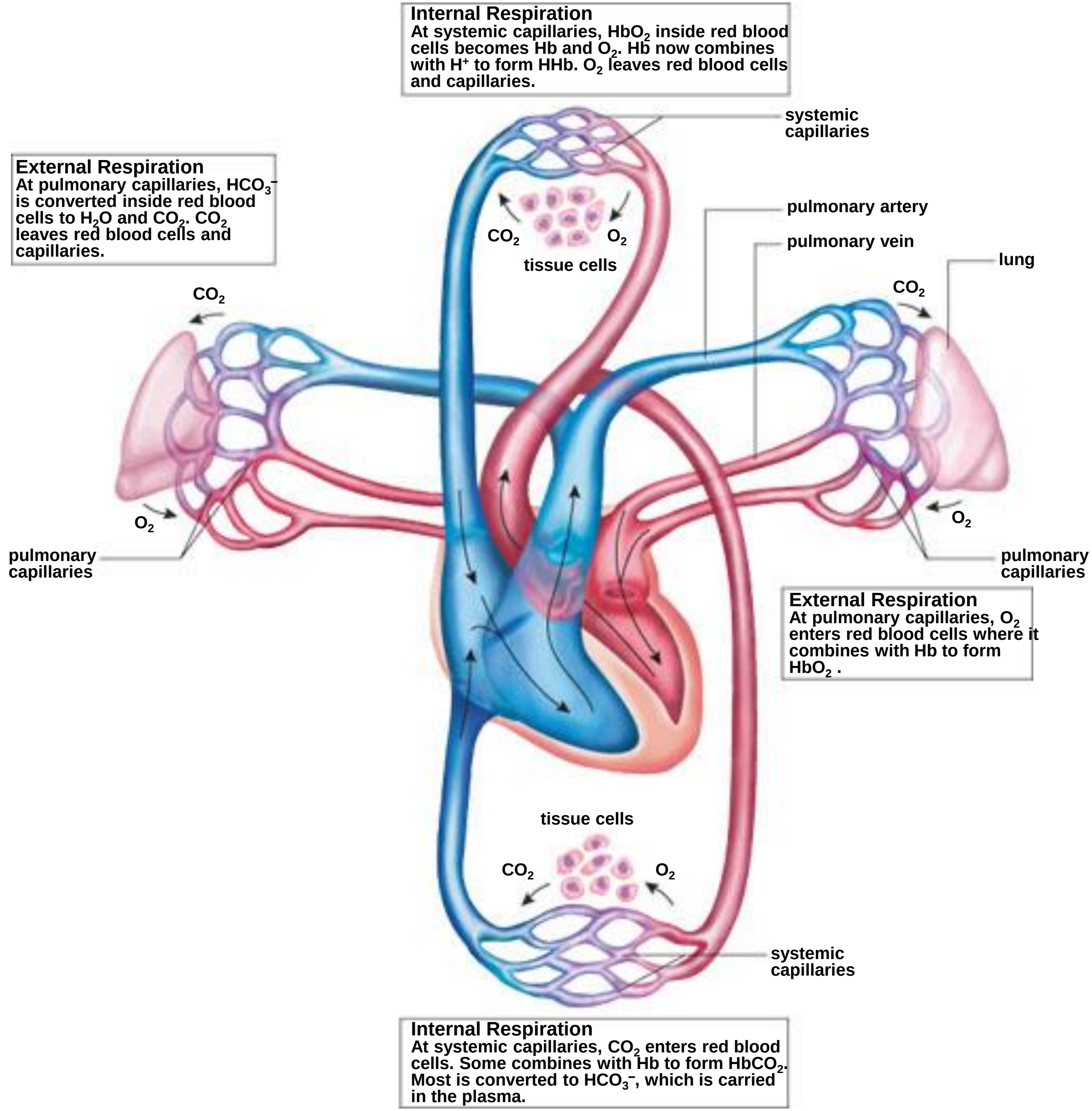
4. $Hb + O_2 \rightarrow HbO_2$


CO_2 produced
CO_2
Tissue cells
CO_2
Endothelium
$CO_2 + H_2O$
Carbonic anhydrase
H_2CO_3
RED BLOOD CELL
$HCO_3^- + H^+$
HCO_3^-
Hb
HCO_3^-
Cl^-

External Respiration:

1. Reduced hemoglobin, AKA: HHb, releases H^+ at the lungs.
2. CO_2 diffuses out of blood into lungs
   - Most CO_2 is in the form of bicarbonate: HCO_3^-
   - The HCO_3^- combines with H^+ to form CO_2 and H_2O, and the CO_2 diffuses out
3. O_2 diffuses into the blood from lungs
   - The higher pH and lower temp. favors the binding of Hb to O_2 → oxyhemoglobin


Alveoli
CO₂
CO₂
Lumen of capillary
CO₂
CO₂ + H₂O
Carbonic anhydrase
H₂CO₃
HCO₃⁻ + H⁺
HCO₃⁻
Cl⁻
Hb
HCO₃⁻


Internal Respiration
At systemic capillaries, HbO_2 inside red blood cells becomes Hb and O_2. Hb now combines with H^+ to form HHb. O_2 leaves red blood cells and capillaries.
systemic capillaries
External Respiration
At pulmonary capillaries, HCO_3^- is converted inside red blood cells to H_2O and CO_2. CO_2 leaves red blood cells and capillaries.
CO_2
O_2
tissue cells
pulmonary artery
pulmonary vein
lung
CO_2
CO_2
O_2
O_2
pulmonary capillaries
pulmonary capillaries
External Respiration
At pulmonary capillaries, O_2 enters red blood cells where it combines with Hb to form HbO_2 .
tissue cells
CO_2
O_2
systemic capillaries
Internal Respiration
At systemic capillaries, CO_2 enters red blood cells. Some combines with Hb to form $HbCO_2$. Most is converted to HCO_3^-, which is carried in the plasma.

Your assignment:

- Complete the PLOs for this UNIT
- Complete the Ch.15 PKG.
- Study for your quiz on Tuesday
- Provincial review questions!!!