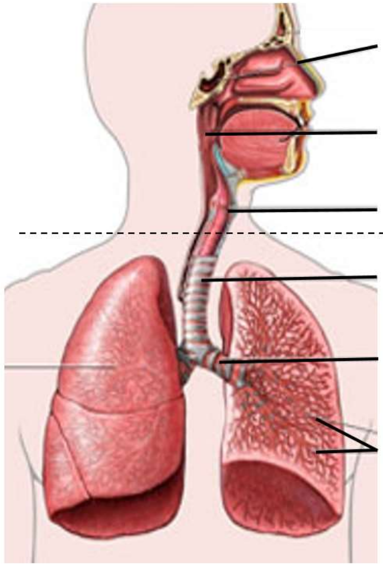
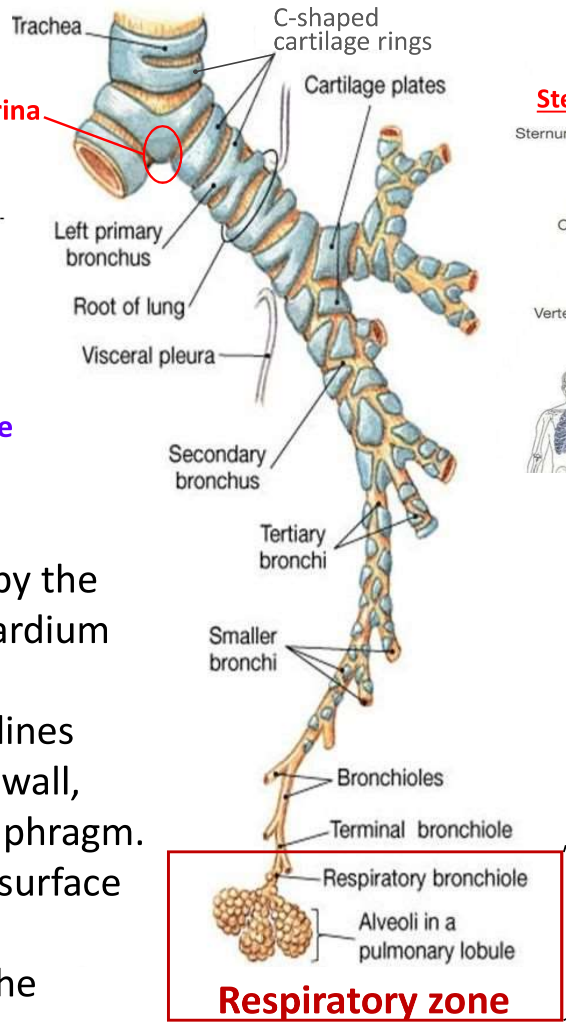
L15-17_Respiratory system

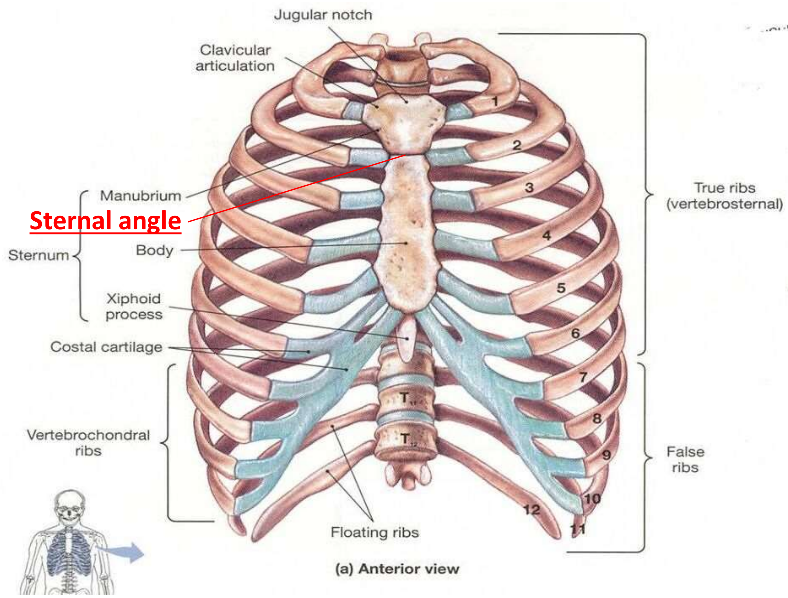


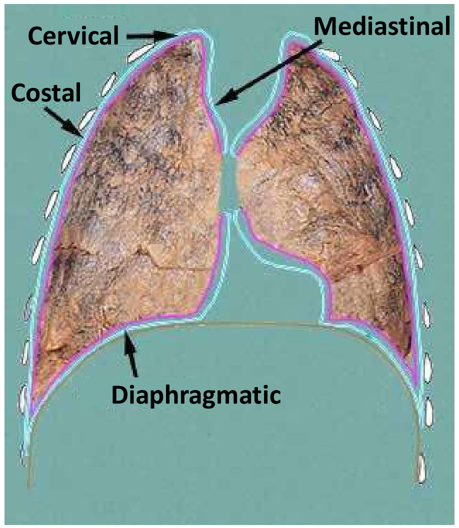
Conducting airway

Function: conducts air, no gas exchange occurs here

The Bronchial Tree

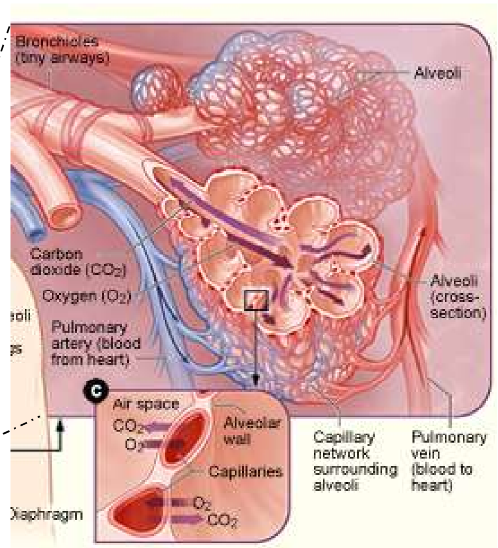


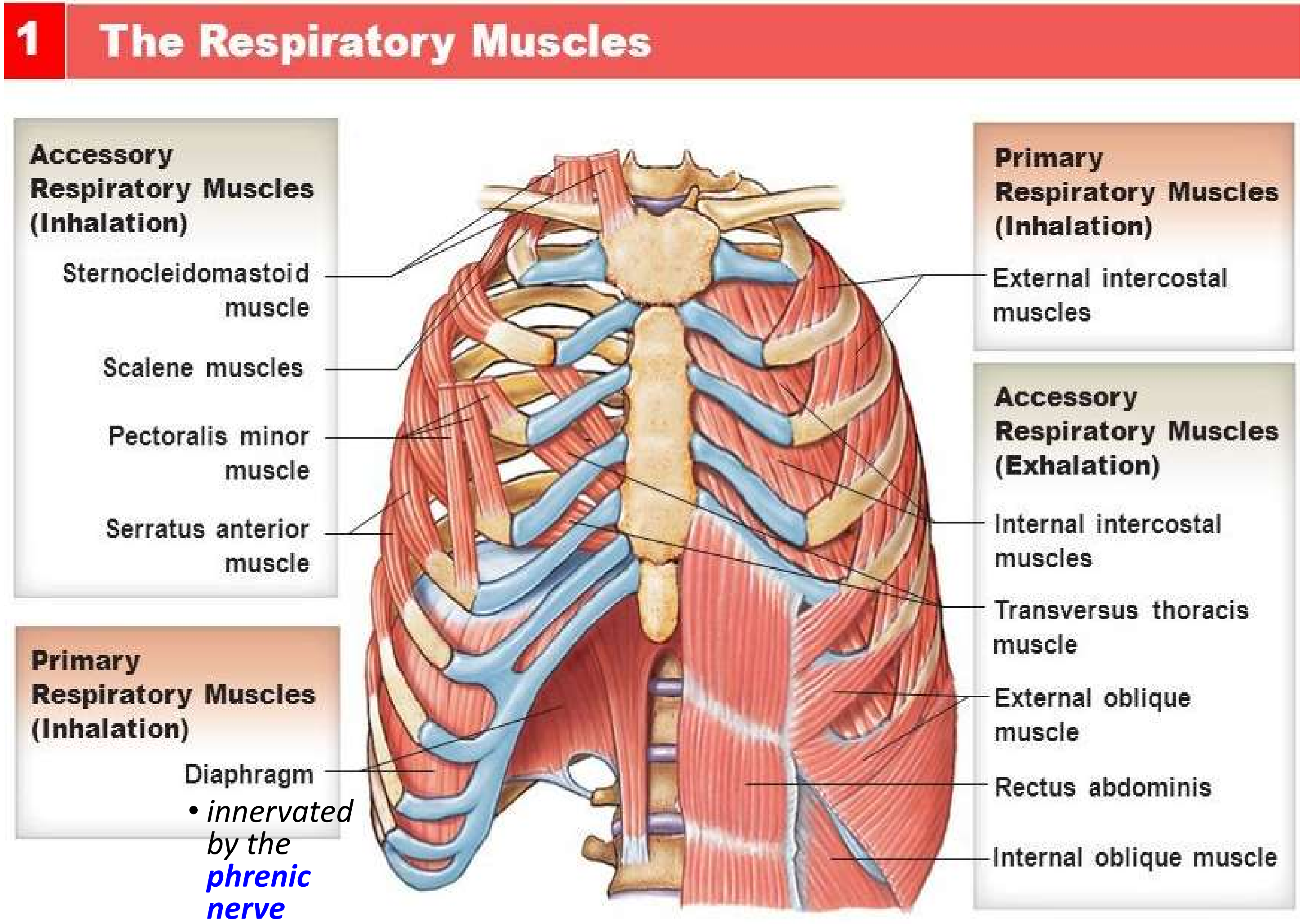




The lungs are surrounded by the pleurae (just like the pericardium surrounding the heart)

- **Parietal pleura** (**4 parts**) lines inner surface of thoracic wall, mediastinum and the diaphragm.
- **Visceral pleura** lines the surface of the lungs
- **Pleural cavity** between the pleura is filled with fluid





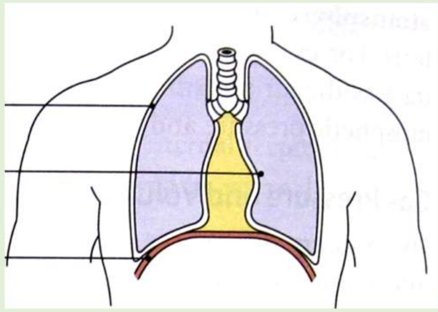
Four steps are involved in respiration (obtain O_2, remove CO_2)

1. **Pulmonary ventilation**
   - movement of air into and out of the lungs
   - depends on contraction and relaxation of *respiratory muscles*
2. **External respiration**
   - gas exchange between lungs (alveoli) and blood
   - gas diffusion driven by *partial pressure gradient* across the diffusion surface
3. **Gas transport**
   - how O_2 and CO_2 are carried in blood
4. **Internal respiration**
   - gas exchange between blood and tissue

Primary respiratory muscles contracts during every inhalation.
Accessory respiratory muscles work during forced breathing to increase rate and depth of breathing.

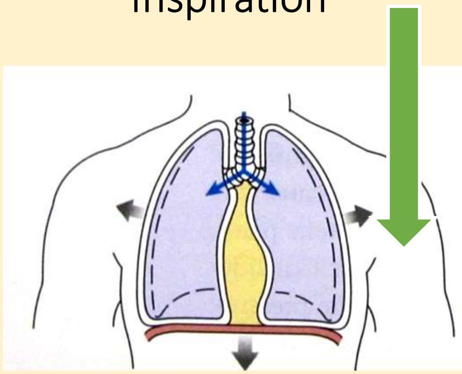
Pulmonary ventilation is accomplished by contraction and relaxation of **respiratory muscles** to change the size of the thoracic cavity and the lungs (as the lungs adhere to the chest wall through the pleura). According to **Boyle's law**, gas pressure is inversely proportional to gas volume ($P_1V_1 = P_2V_2$) . Changes in the size of the lungs therefore changes the pressure in the lungs (P_{alv}). Air flow occurs when P_{alv} is different from the atmospheric pressure. (P_{atm})

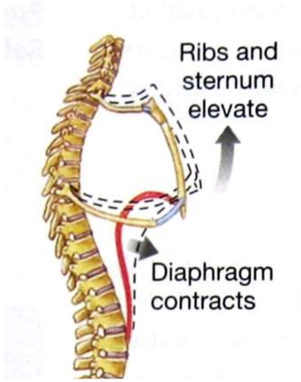
At rest



$P_{atm} = P_{alv}$

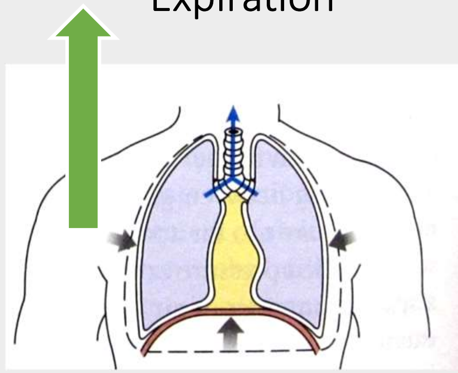
Inspiration





$P_{atm} > P_{alv}$

Expiration



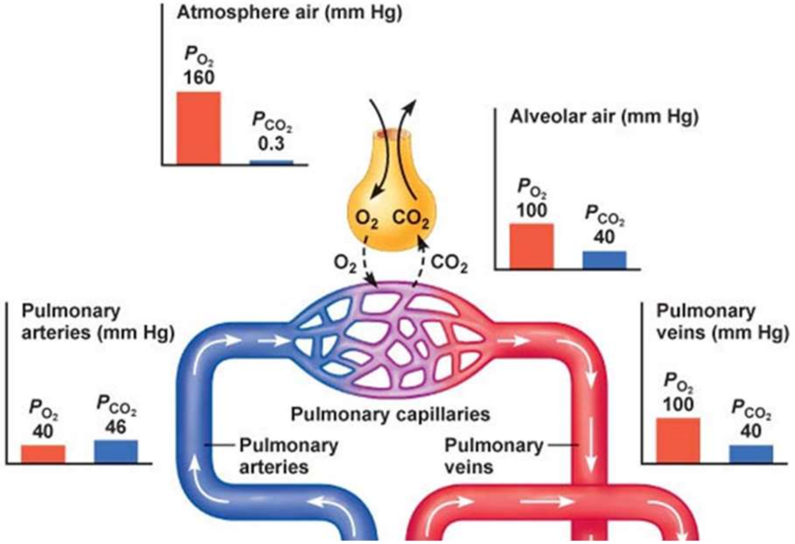
$P_{atm} < P_{alv}$

No air flow:
F = 0
$\mathbf{P_{alv} - P_{atm} = 0}$
$\mathbf{P_{atm} = 0, P_{alv} = 0}$

During inspiration, diaphragm flattens and the rib cage is elevated when the **diaphragm** and the **external intercostal muscles** contract respectively. It causes the thoracic cavity and the lungs to expand, leading to a drop in $P_{alv.}$ Air flows into the lungs as the P_{atm} is higher than P_{alv}.

During expiration, diaphragm moves up and the rib cage descends when the diaphragm and the external intercostal muscles relax. The **lungs recoils** and volume decreases, leading to an increase in P_{alv}. Air flows out the lungs as the P_{atm} is lower than P_{alv}.

Gas exchange occurs when there is partial pressure difference of a gas between 2 compartments separated by membrane. Gas diffuses from area of high partial pressure to area of low partial pressure by simple diffusion.



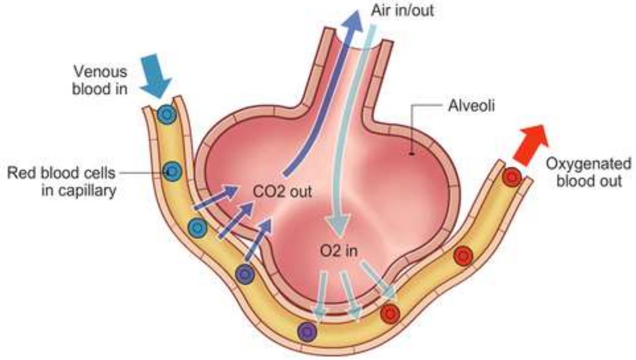
In the lungs (external respiration)

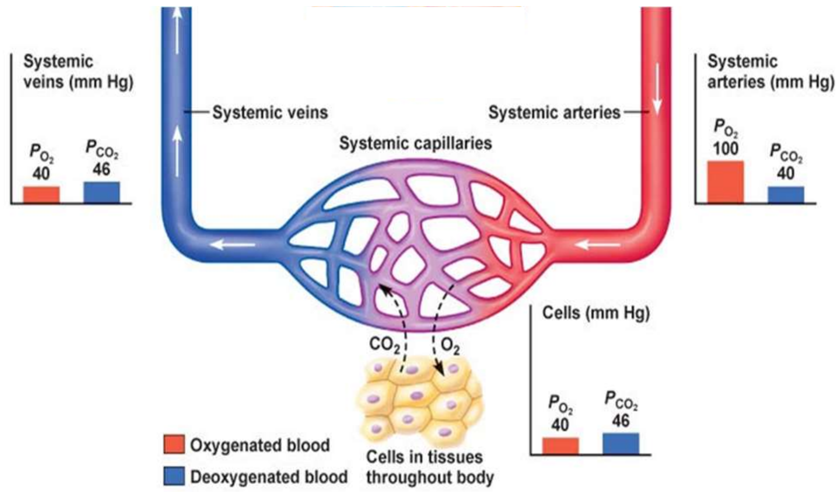
PO_2 is higher in alveolar air (100 mmHg) than in the blood entering lungs (40 mmHg), therefore O_2 diffuses from alveolar air into the blood

PCO_2 is lower in alveolar air (40 mmHg) than in the blood entering lungs (46 mmHg), therefore CO_2 diffuses from the blood into alveolar air

Respiratory membrane in lungs

: alveolar wall, endothelium & their basement membranes





In the tissue (internal respiration)

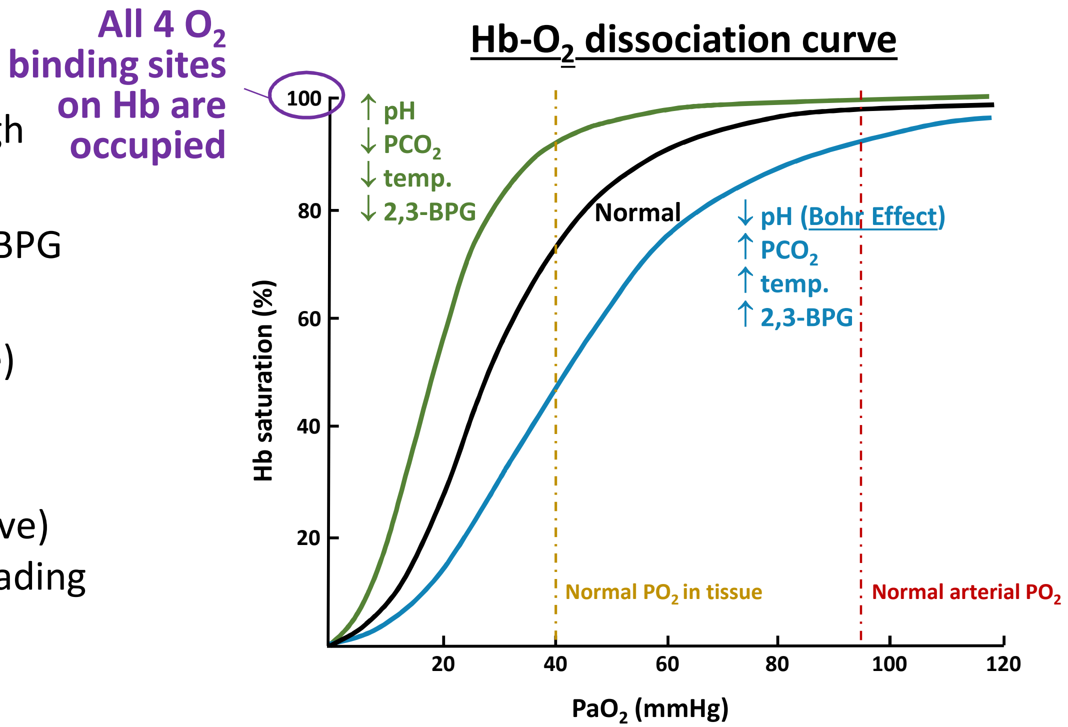
PO_2 is higher in the blood entering tissue (100 mmHg) than in the tissue (40 mmHg), therefore O_2 diffuses from blood into the tissue

PCO_2 is higher in the tissue (46 mmHg) than in the blood entering the tissue (40 mmHg), therefore CO_2 diffuses from the tissue into the blood

Gas transport

How is oxygen being carried in the blood?

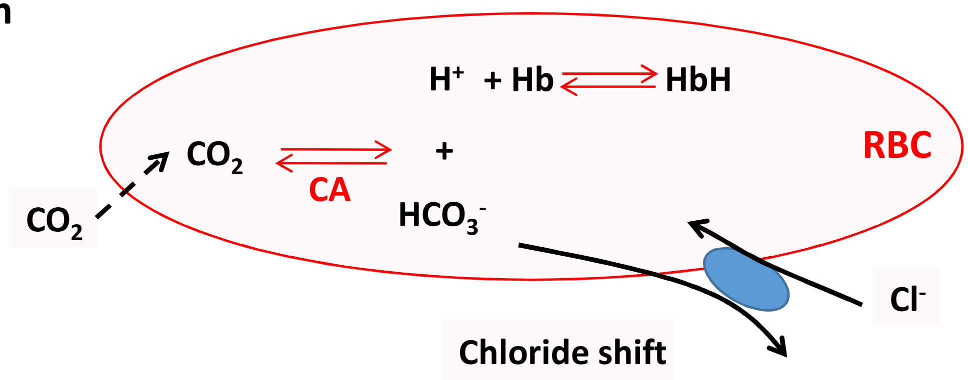
- majority (98%) of O_2 is carried by red blood cell (RBC) through binding to hemoglobin (oxyhaemoglobin – HbO_2)
  - Hb affinity for O_2 affected by PCO_2, pH, temperature and BPG for control of O_2 unloading
    - affinity increases (left-shift of Hb-O_2 dissociation curve) with ↑ in pH and ↓ in PCO_2, temp. & BPG → ↓ O_2 unloading
    - affinity decreases (right-shift of Hb-O_2 dissociation curve) with ↓ in pH and ↓ in PCO_2, temp. & BPG → ↑ O_2 unloading
- small amount dissolves in plasma



How about CO_2?

- majority (70%) of CO_2 is carried in the form of **bicarbonate ion** (HCO_3^-) due to the action of an enzyme – **carbonic anhydrase**

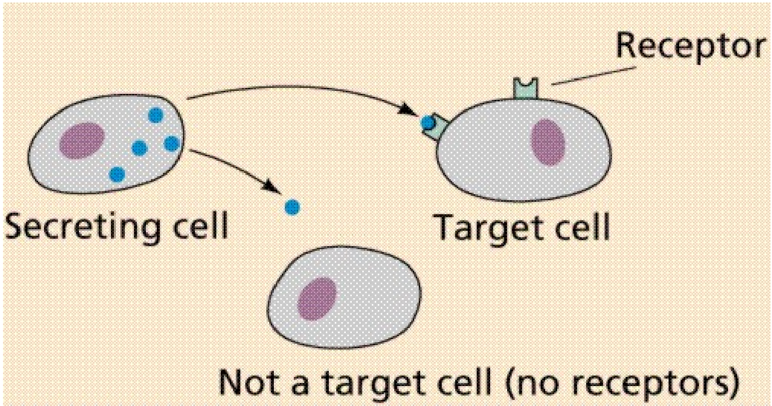
  $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
- some (20%) are bound to haemoglobin (as carbaminohaemoglobin – $HbCO_2$)
- small amount (10%) dissolves in plasma



L18_Introduction to endocrine system

Classification of hormone
- Amino acid derivatives (e.g. thyroid hormones from tyrosine)
- Peptide/protein hormones (e.g. insulin, glucagon)
- Steroid hormones (e.g. aldosterone, cortisol, oestrogen, testosterone)
  - All derived from cholesterol
  - insoluble in plasma – protein carriers → longer half-life (time for concentration of a substance to reduce by half) as protein binding protects the hormone from degradation/excretion

Not all cells are affected by a hormone as the actions of hormones are mediated by specific receptor binding
- Water-soluble hormones – receptors on plasma membrane
- Lipid-soluble hormones – intracellular receptors

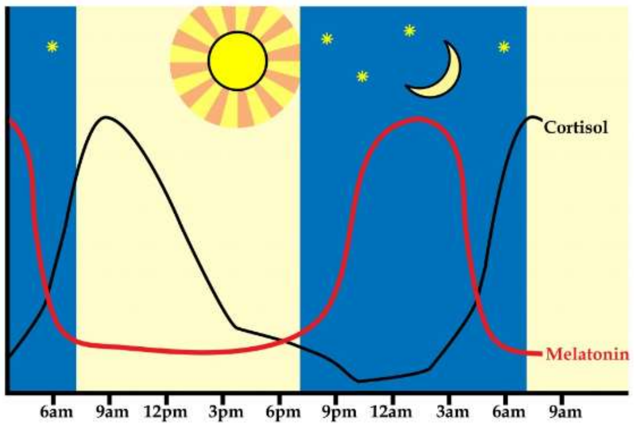


<u>Hormone interaction</u>

1. **Redundant effect** (i.e. having same effects) which produces **synergistic** outcome (i.e. combined effect is larger than the sum of the effect when each hormone works separately), e.g.
   - glucose-elevating effect is greater when glucagon, epinephrine & cortisol work together
2. **Reinforcement effect** (i.e. the same hormone acts on different tissues to produce different responses that reinforce each other) e.g.
   - cortisol (皮質醇) acts differently in different tissues but the overall result is to ↑ glucose
3. **Antagonistic** (i.e. opposing) **effect**, e.g.
   - insulin lowers blood glucose level and glucagon increases glucose level
4. **Permissive effect** (i.e. a hormone is needed for another hormone to work properly), e.g.
   - oestrogen induces expression of progesterone receptors in the endometrium (子宮內膜) so that progesterone can act

Rhythms (pattern) of hormone secretion

1. **Pulsatile secretion** in response to stimuli (e.g. insulin, glucagon)
2. **Diurnal secretion** (daily rhythm), e.g.
    - cortisol peaks shortly after awaken then level drops
    - melatonin peaks at night
3. **Cyclic secretion**
    - e.g monthly fluctuation of FSH, LH, oestrogen and progesterone secretion in regulation of menstrual cycle



Regulation of hormone activity

1. **Regulation of hormones receptor**
    - ✓ sensitivity (& response) of a cell to a hormone increases with the number of receptor present
        - ↑ no. of receptor → ↑ chance of hormone binding → ↑ no. of hormone-receptor complex → ↑ response
    - ✓ number of receptor can be increased by increasing the level of gene expression of the receptor → ↑ sensitivity
    - ✓ number of receptor can be decreased by internalization of the hormone-receptor complex → ↓ sensitivity
2. **Regulation of hormone production**
    - ✓ **Negative feedback control**
        - e.g. high glucose → insulin secretion → glucose level returns to normal → no more stimulus → no more insulin
    - ✓ **Positive feedback control**
        - e.g. oxytocin secretion during child birth
          – oxytocin causes uterine contraction → pressure on cervix → more oxytocin…

L19_Thermoregulation

<u>Learning outcome 1</u>: Define thermal balance & explain its importance

- Thermal balance when heat gain (determined mainly by metabolic rate) = heat loss (via skin surface by conduction, convection, radiation and evaporation)
- Importance: to provide optimal temperature for biochemical reactions and to maintain stable biochemical reaction rates

<u>Learning outcome 2</u>: Explain the homeostatic regulation of core body temperature

- Thermoregulation is a **negative feedback** mechanism
- Sensory (input) – warmth and cold receptors located in the skin (*peripheral thermoreceptors*), and in hypothalamus and deep tissues (*central thermoreceptors*)
- Control centre = **hypothalamus**
  - **determines thermal-set point** and compare it with the actual body temp.
- Motor (output)
  - **Heat conversation + heat production** when core body temp < normal
    - sympathetic noradrenergic neurons → noradrenaline → smooth muscles contraction → **cutaneous vasoconstriction**
    - **shivering thermogenesis** (not in infants) – ↑ muscle contraction → ↑ metabolic rate and heat production
    - ***Infants: non-shivering thermogenesis***
      - sympathetic noradrenergic neurons → noradrenaline → ↑ **breakdown of brown fat** → heat (not ATP)
  - **Heat loss** when body temp. > normal
    - inhibits sympathetic noradrenergic neurons → ↓ noradrenaline → smooth muscle relax → **cutaneous vasodilation**
    - stimulation of sympathetic cholinergic neurons → ↑ acetylcholine → **sweating**

- *also behavioural responses to hot and cold*

L19_Thermoregulation

Learning outcome 3: Describe the body changes in pyrexia, hyperthermia, acclimatisation to heat and hypothermia

a. Fever (pyrexia)

- increase in core body temp. as a resulted of **elevated thermal set-point**
- caused by ↑ hypothalamic prostaglandin E_2 production triggered by inflammatory response (cytokines released by inflammatory cells) and/or microbial toxins (e.g. LPS)
- can be treated by antipyretic drugs that inhibit production of PGE_2 (e.g. aspirin/ibuprofen)
- initial response of the body: heat gain responses to elevate core body temp. to the set point

b. Hyperthermia

- core body temp. > thermal set-point and the set point is not changed
- occurs when heat gain > heat loss (e.g. strenuous ex., high ambient temp. and/or humidity)
- profuse sweating → dehydration, hypotension & electrolyte imbalance
- heat exhaustion – core body temp. < 41^oC
- heat stroke – core body temp. ≥ 41^oC --> complete failure of thermoregulatory systems --> temp. keeps rising --> depression of CNS function (fainting, confusion, loss of consciousness..)

c. Acclimatisation with prolonged (1-6 wks) exposure to heat

- profuse sweating --> reduce body temp more effectively
- lower salt content in sweat --> less salt is loss due to sweating

d. Hypothermia

- heat loss > heat gain (e.g. prolonged exposure to cold - immersion in cold water; vasodilation in alcohol intoxication)
- core body temperature fall below 35^oC
- frequently lethal if core body temp. > 32^oC