GAS EXCHANGE in “Animals”

- Cells require O_2 for aerobic respiration and expel CO_2 as a waste product

Fick's Law of Diffusion

- Gas exchange involves the diffusion of gases across a membrane
- Rate of diffusion (R) is governed by Fick's Law:
- $R = \frac{DA \triangle p}{d}$

D= diffusion constant (size of molecule, membrane permeability, etc)

A= area over which diffusion occurs

$\triangle p$ = pressure difference between sides of the membrane

d = distance across which diffusion must occur

Fick's Law of Diffusion

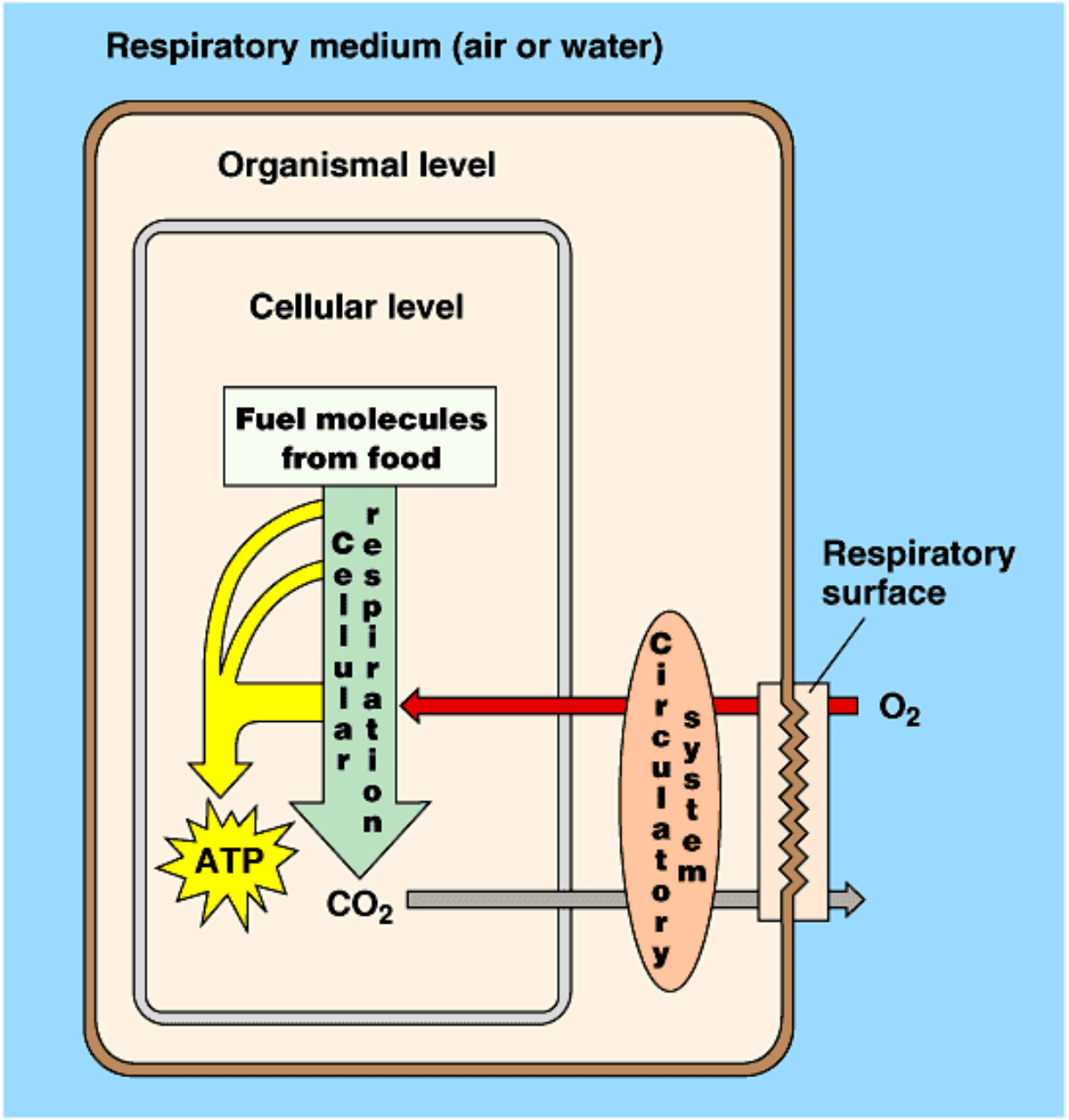
$$R = \frac{DA\triangle p}{d}$$

To maximize diffusion, R can be increased by:

- Increasing A (area over which diffusion occurs)
- Increasing $\triangle p$ (pressure difference between sides of the membrane)
- Decreasing d (distance across which diffusion must occur)

Evolutionary changes have occurred to maximize R

Figure 42.18 The role of gas exchange in bioenergetics

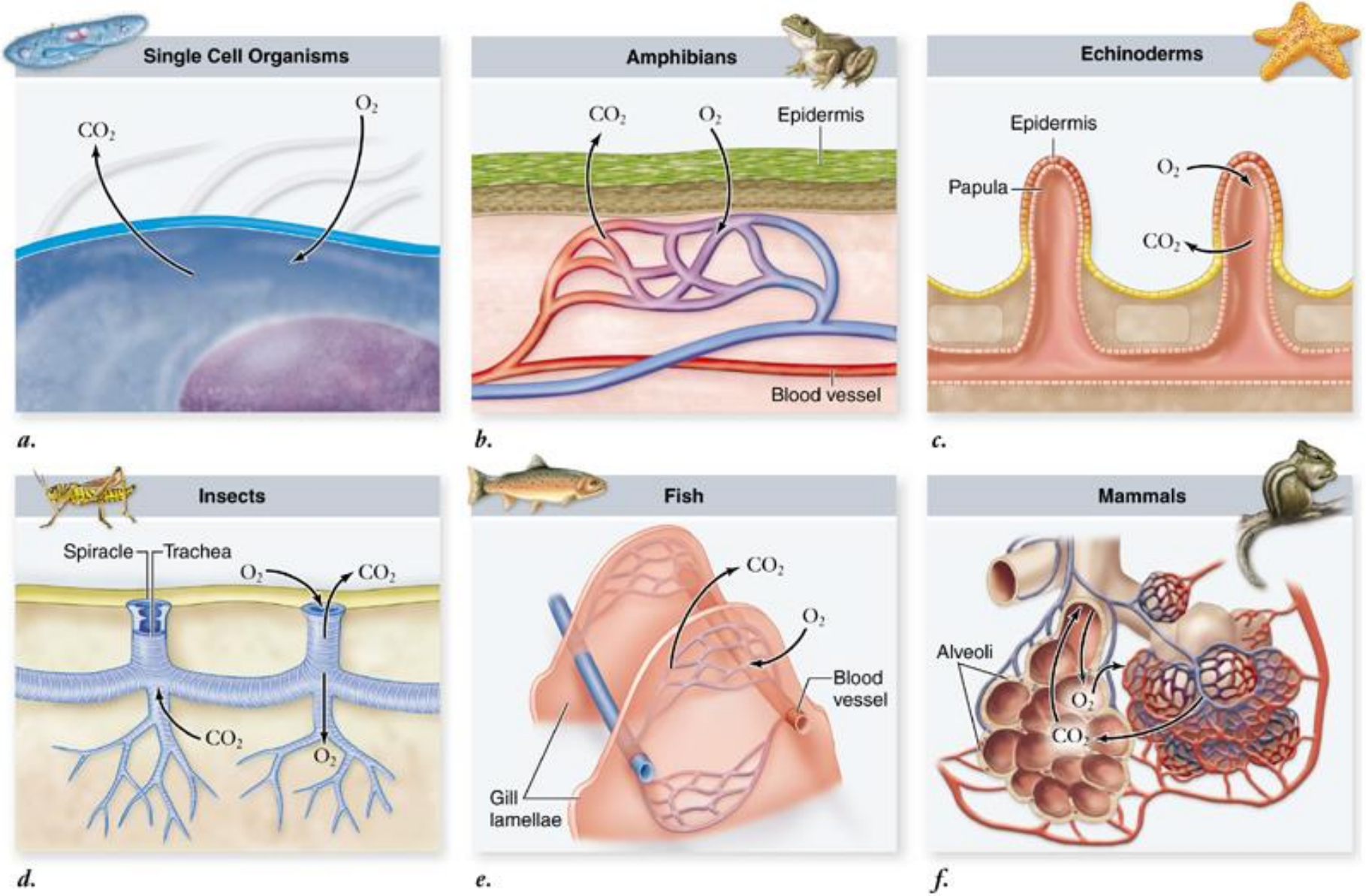


GAS EXCHANGE in “Animals”

- The part of the organism across which gases are exchanged with the environment is the **respiratory surface**

Respiratory Surfaces

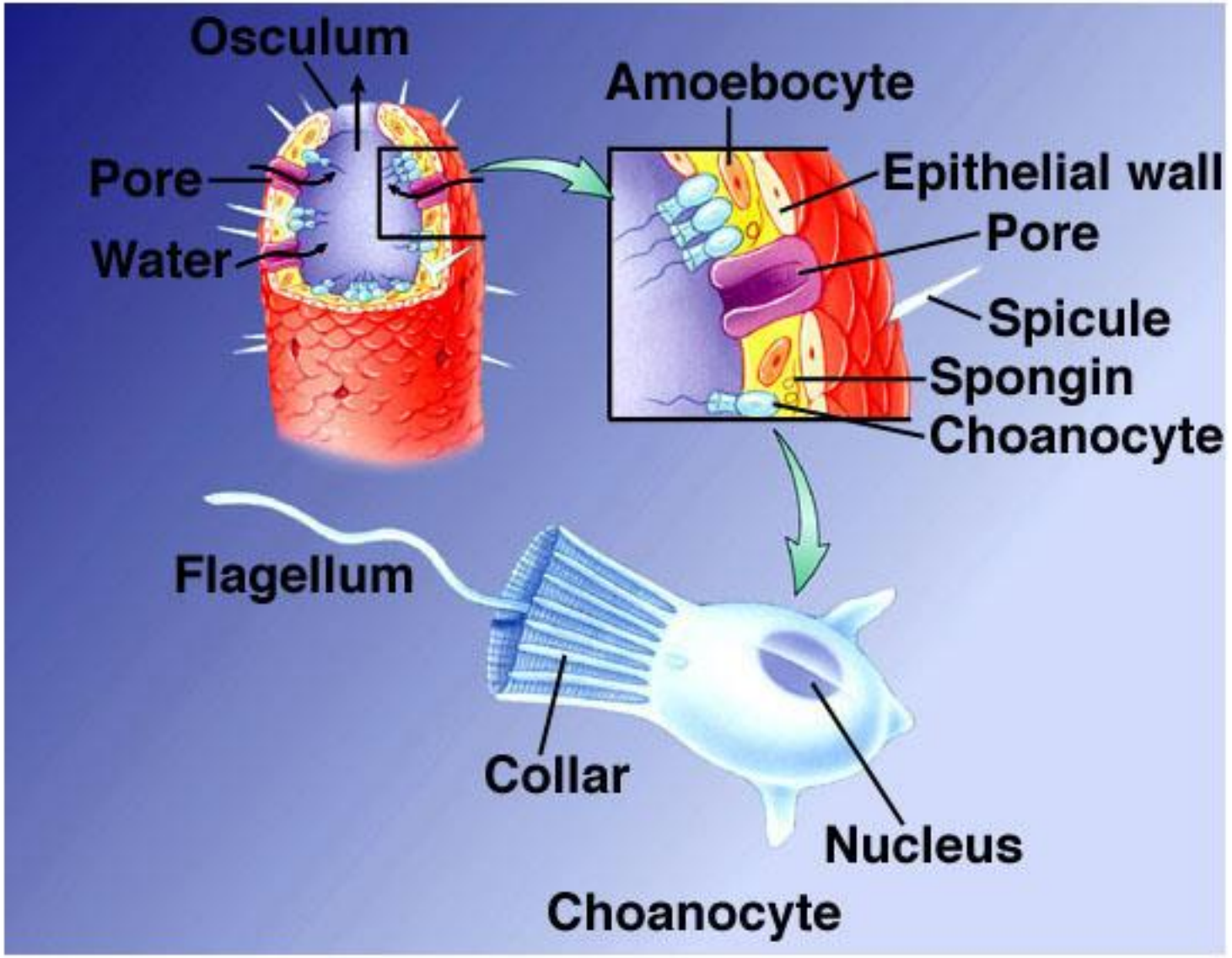
- Must be moist
  - plasma membranes must be surrounded by water to be stable
- Must be sufficiently large
  - maximize A in Fick's Law



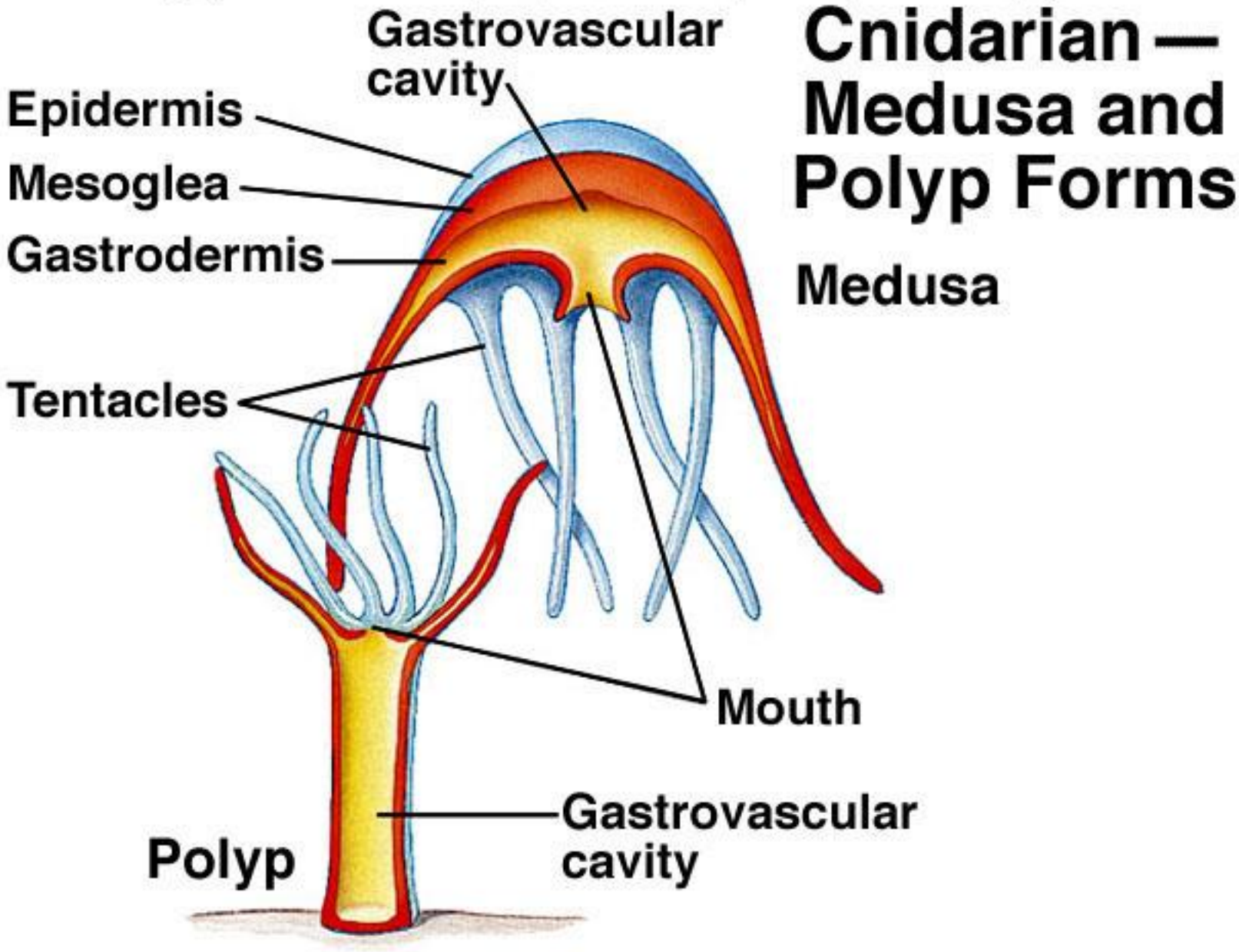
Comparative Respiratory Systems

- **Cell Membranes**
  - in unicellular organisms
  - some simpler animals (sponges, cnidarians, flatworms)

Sponge Body Plan



Cnidarian — Medusa and Polyp Forms



Comparative Respiratory Systems

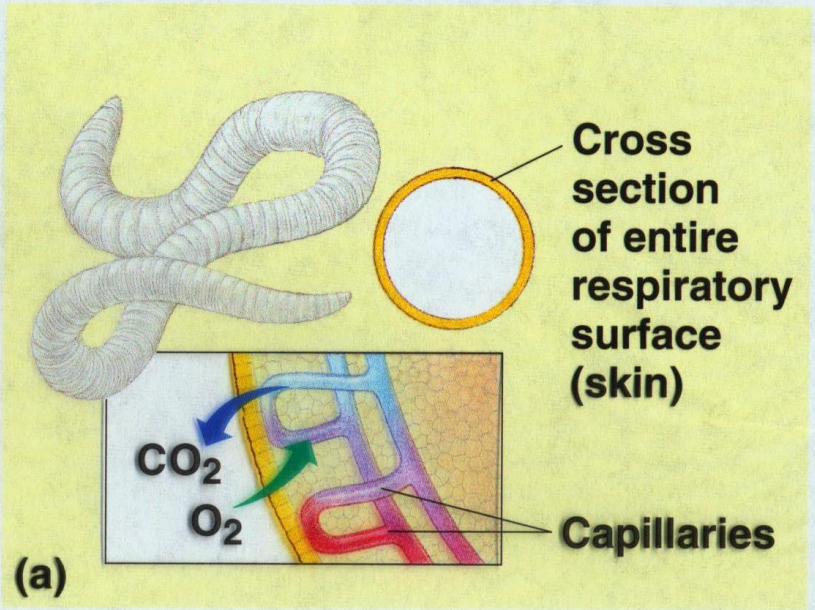
- Respiratory surface = a single layer of epithelial cells
  - separates outer **respiratory medium** (air or water) from the organism's transport system (blood)

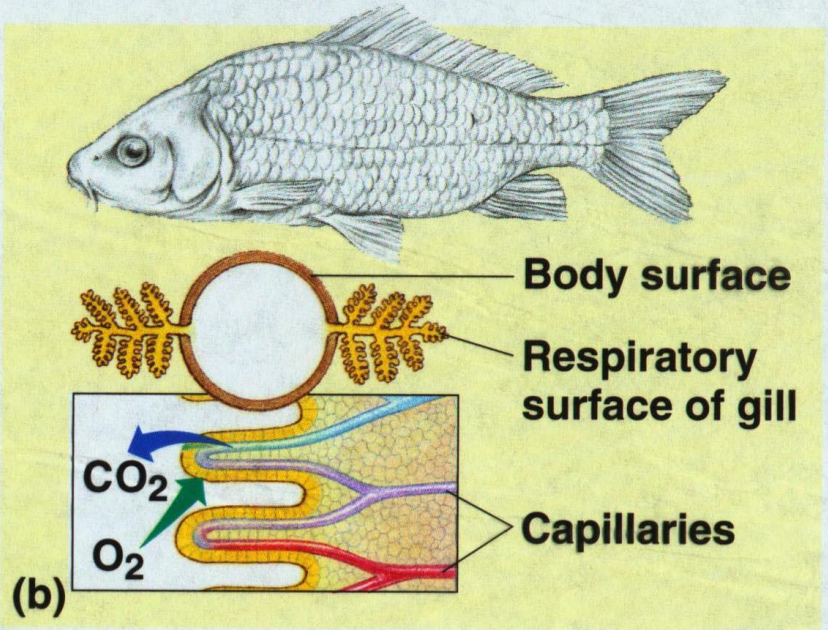
Comparative Respiratory Systems

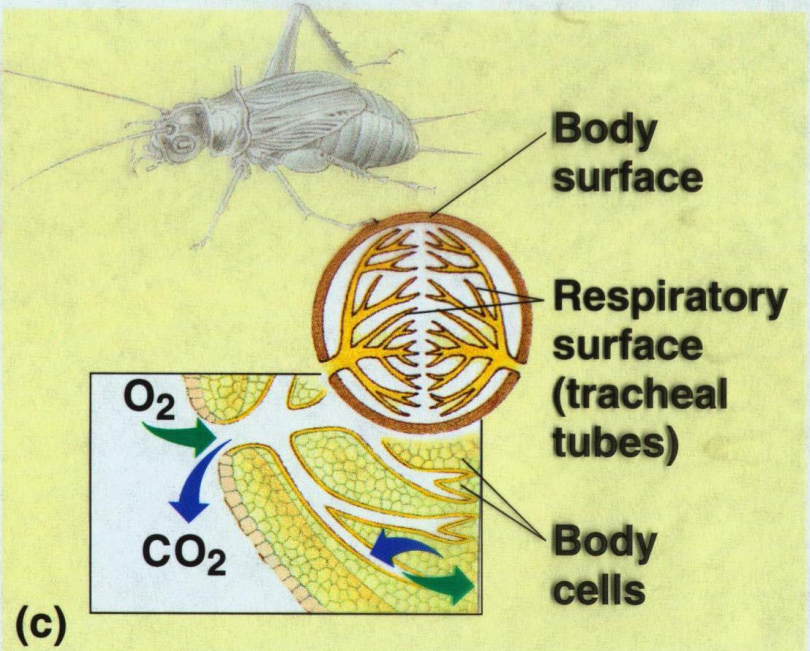
- **Skin (cutaneous respiration)**
  - Skin must be moist
  - organisms with flat or wormlike bodies so skin in sufficient surface area
  - or in frogs and some turtles to supplement respiration using lungs

Comparative Respiratory Systems

- Specialized region of body is folded and branched to provide large surface area
- This maximizes A in Fick's Law
- Also decrease d by bringing the respiratory medium close to the internal fluid
- Three such systems:
  - **Gills** (Aquatic organisms)
  - **Trachea** (insects)
  - **Lungs** (terrestrial vertebrates)


Cross section of entire respiratory surface (skin)
CO_2
O_2
Capillaries
(a)


Body surface
Respiratory surface of gill
CO_2
O_2
Capillaries
(b)


Body surface
Respiratory surface (tracheal tubes)
O_2
CO_2
Body cells
(c)

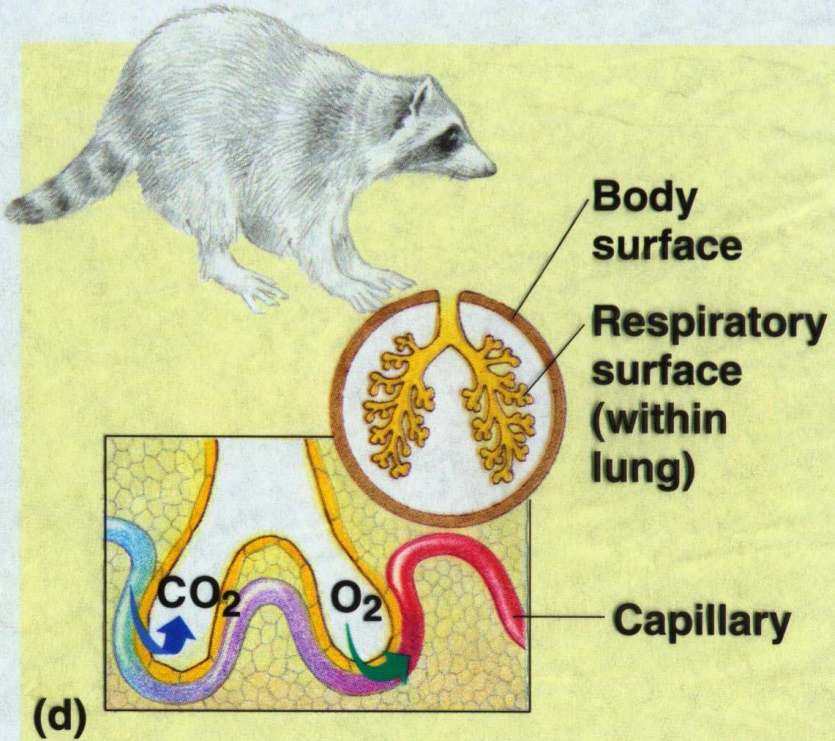
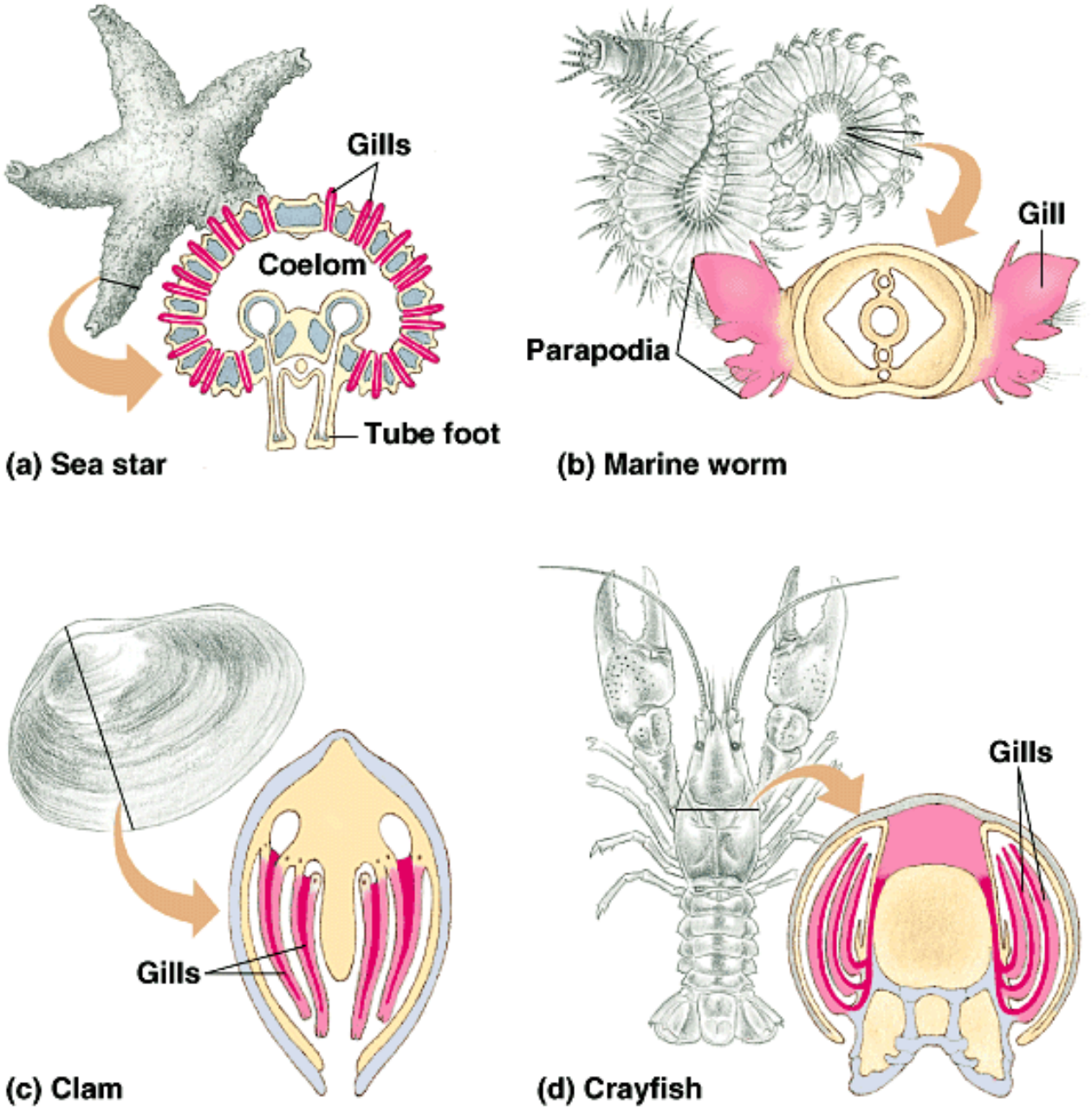

Body surface
Respiratory surface (within lung)
CO_2
O_2
Capillary
(d)

Figure 42.19 Diversity in the structure of gills, external body surfaces functioning in



Gills

- most aquatic organisms
- outfoldings of the body surface specialized for gas exchange
- Water is the respiratory medium

Water as Respiratory Medium

- Respiratory surface always moist
- Oxygen content of water is much less than that of air
- denser medium so harder to ventilate

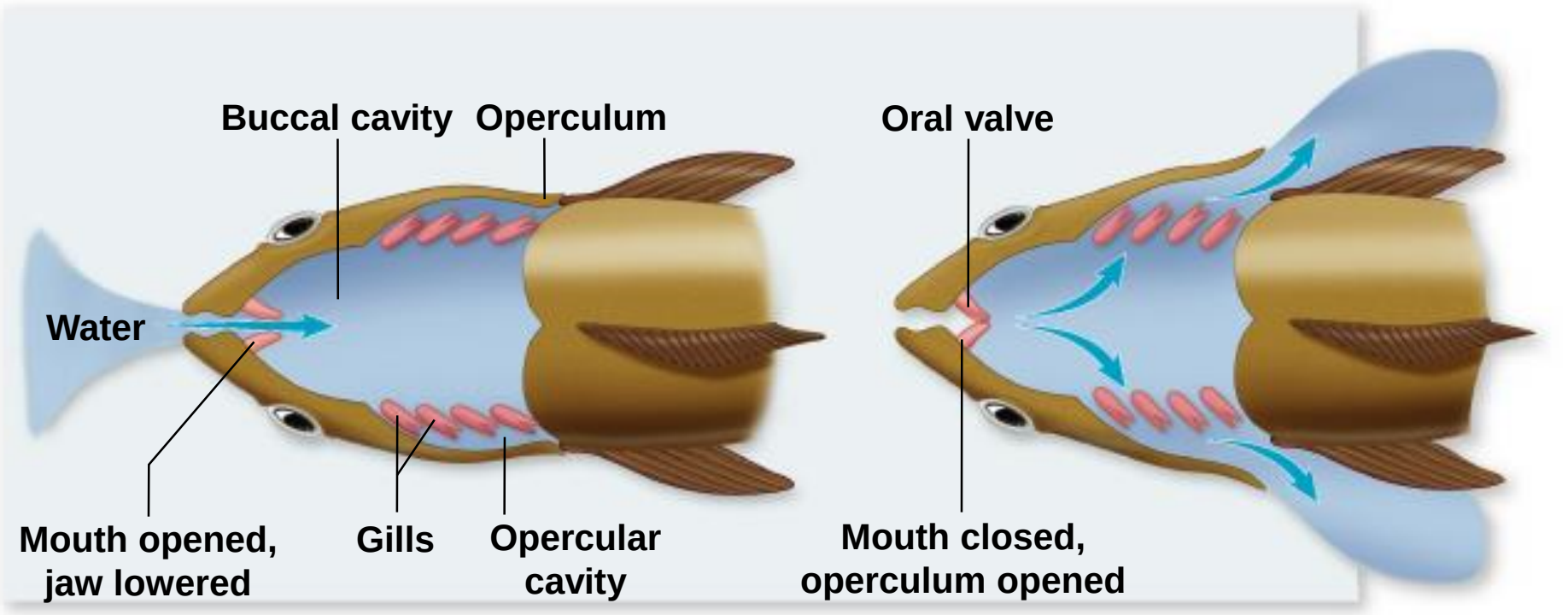
Ventilation

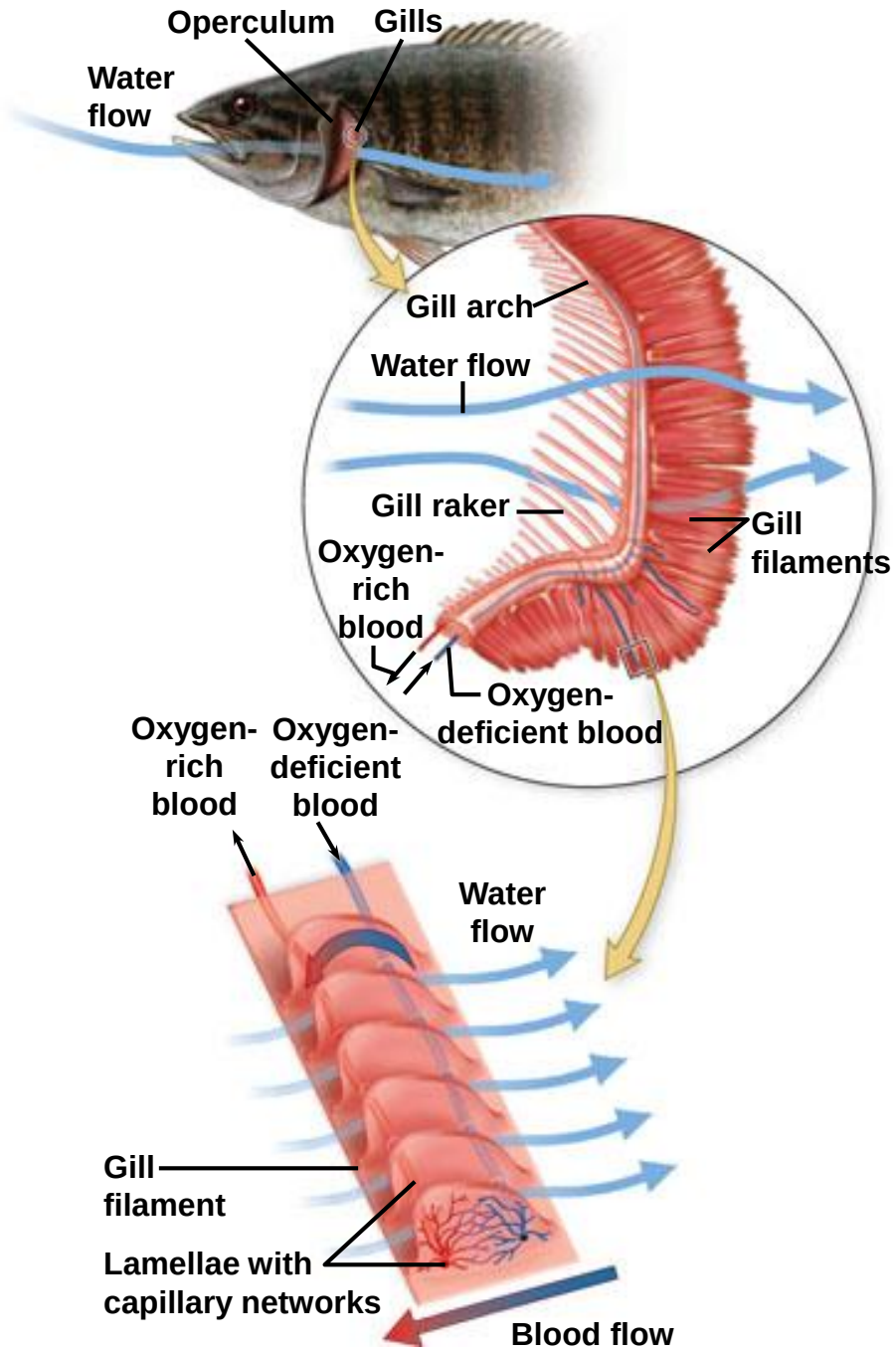
- Any method that increases the flow of the respiratory medium across the respiratory surface
- This maximizesΔp in Fick's Law
  - By constantly have new air or new water with more oxygen

Ventilation

- requires a lot of energy to ventilate gills b/c water is denser than air
- pumping operculum, ram ventilation

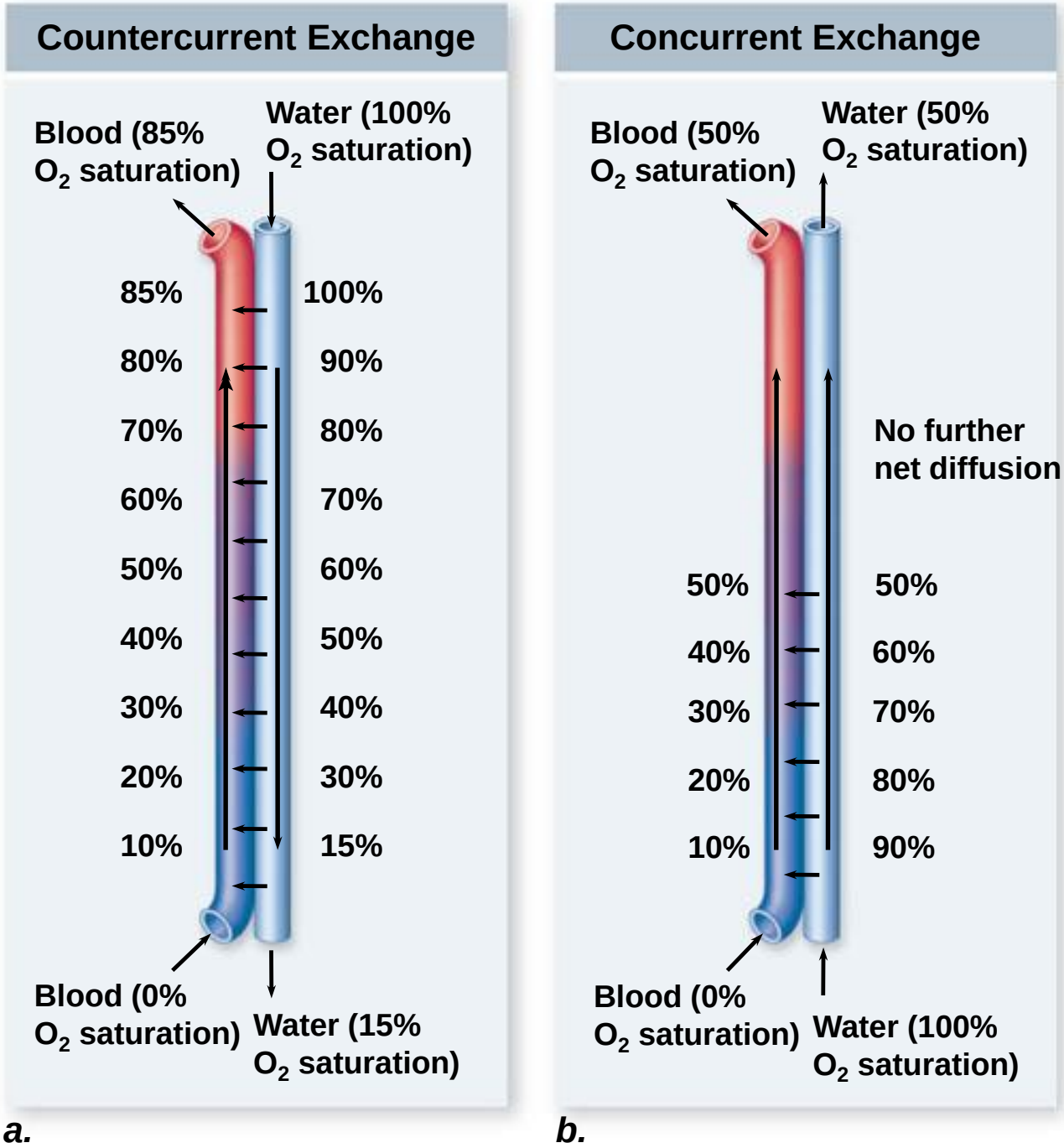
Gills





Countercurrent Exchange

- Enhances gas exchange in the gills of fish
- blood is continually loaded with O_2 b/c it meets water with increasing O_2 concentration
  - Increases Δp in Fick's Law



Air as respiratory medium

- Higher oxygen concentration
- ventilation is easier b/c air is less dense
- respiratory surface loses water to air by evaporation

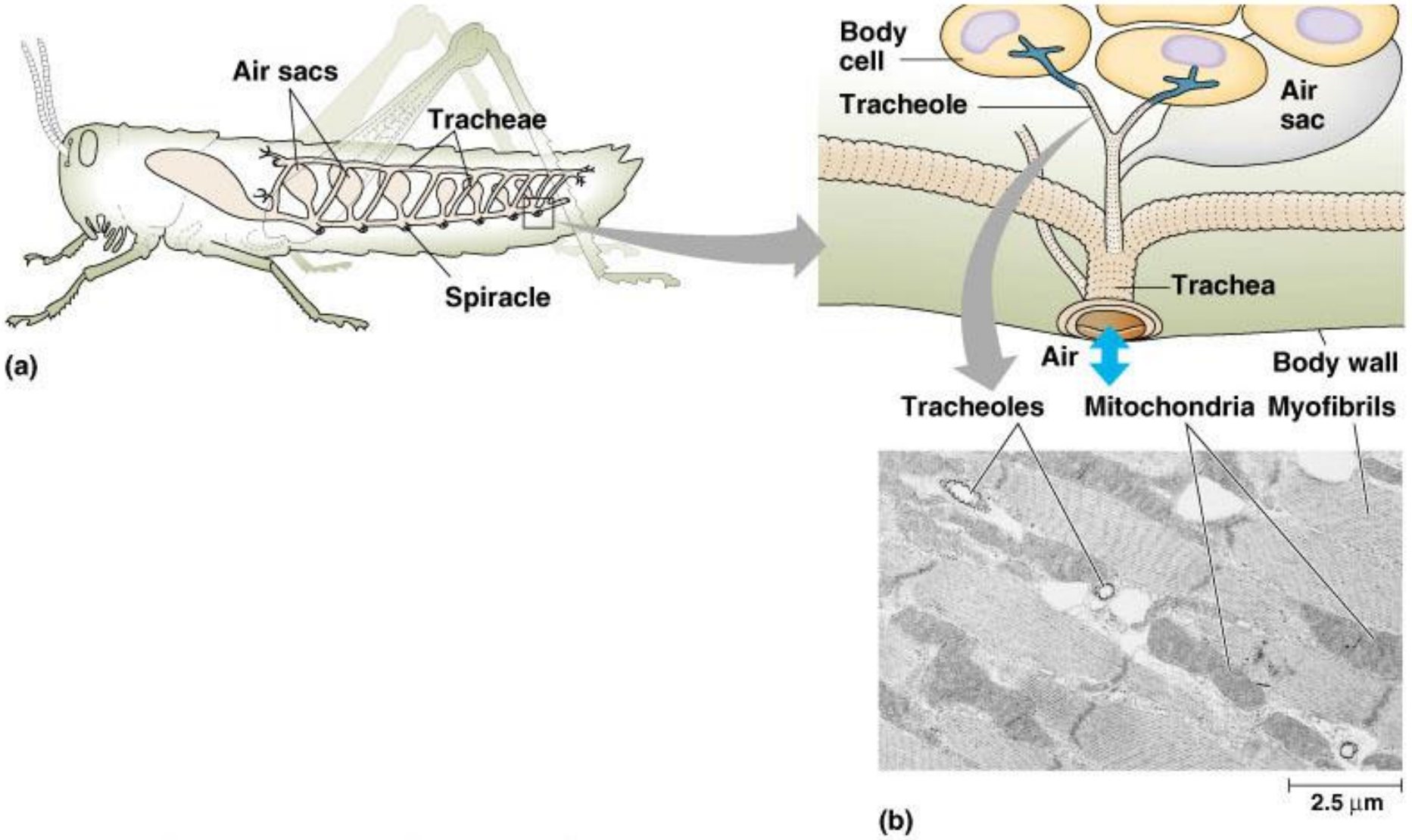
Air as respiratory medium

- Solution…
  - fold respiratory surface inside the body

Trachea

- Air tubes that branch throughout the body
- finest tubes (tracheoles) extend to nearly every cell in the body
- gas diffuses across moist epithelium that lines the terminal ends

Figure 42.22 Tracheal systems



Trachea

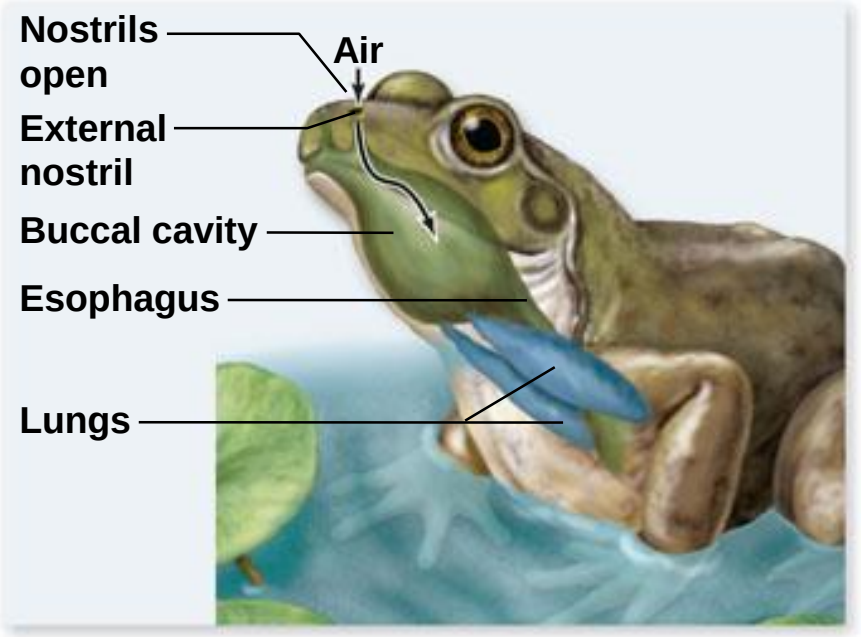
- Found in insects
- Open Circulatory system of insects is NOT involved in transporting gases
- Ventilation
  - diffusion
  - body movements

Lungs

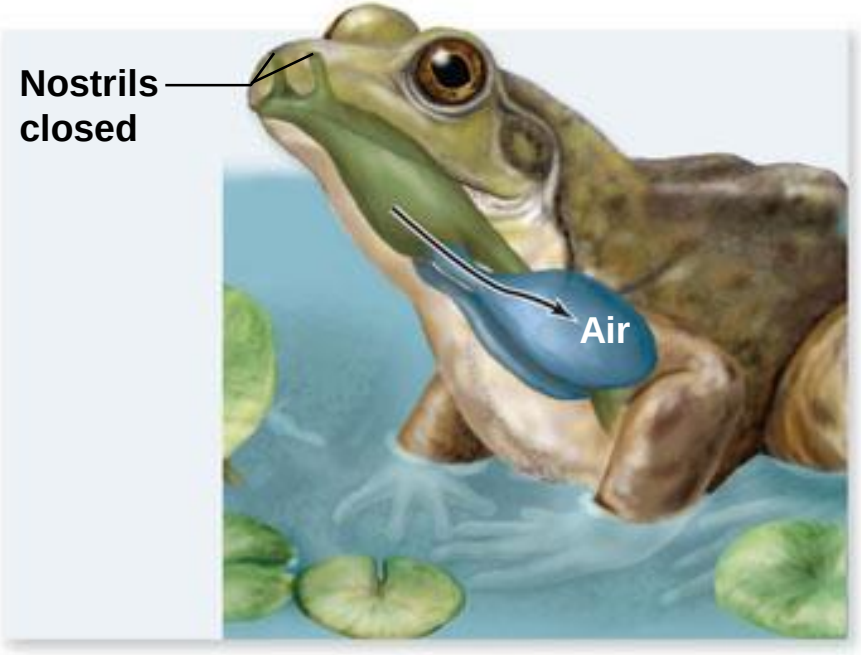
- Localized in one area of body
  - circulatory system must transport gases

Lungs

- Ventilation
  - Positive pressure breathing - frogs



a.

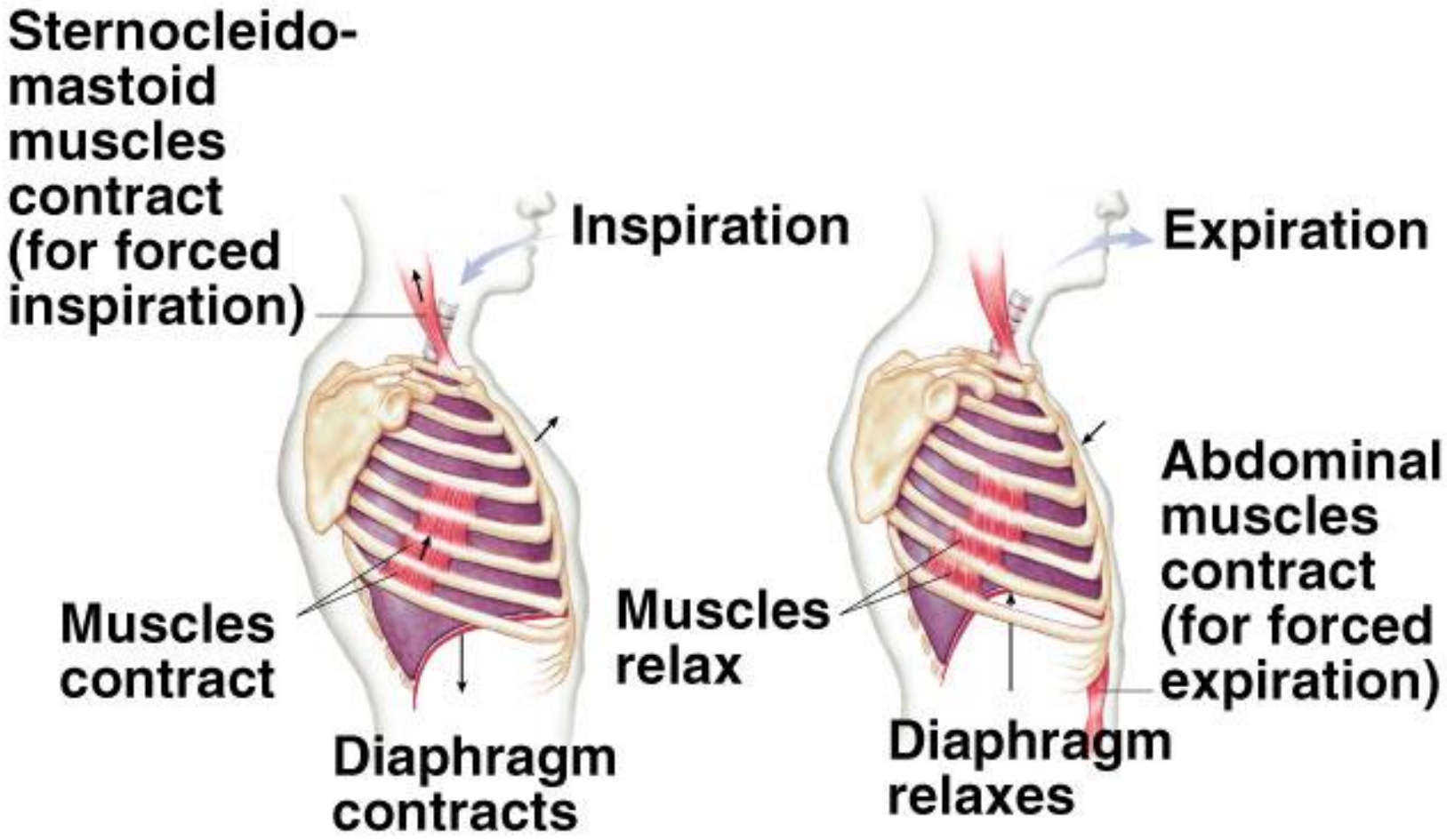


b.

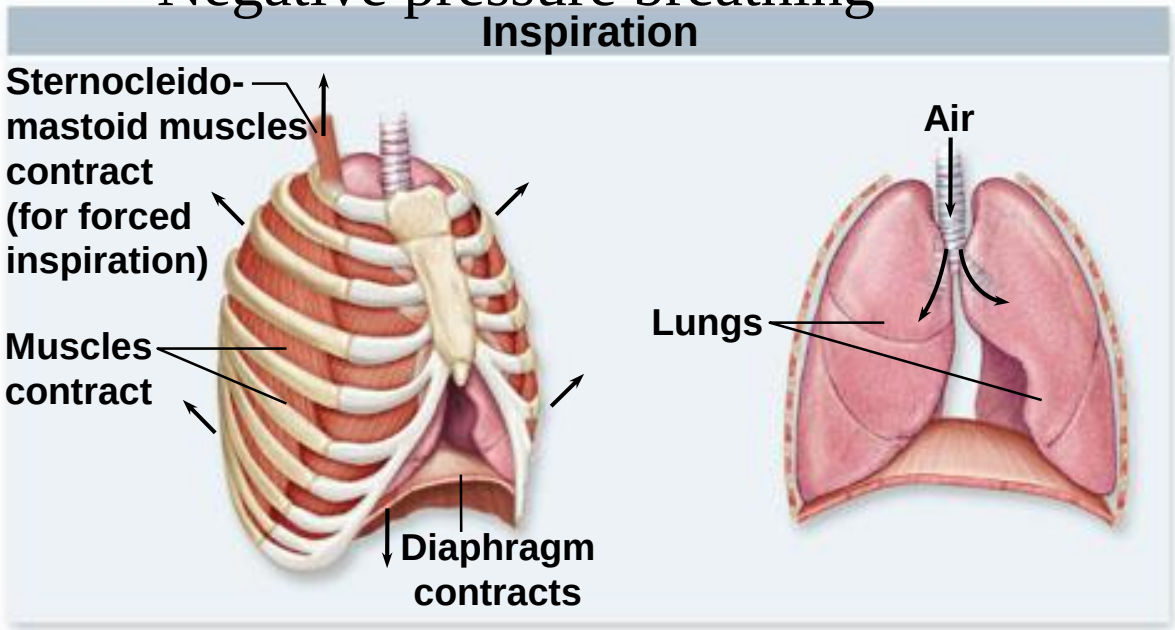
Lungs

- Ventilation
  - Negative pressure breathing- mammals

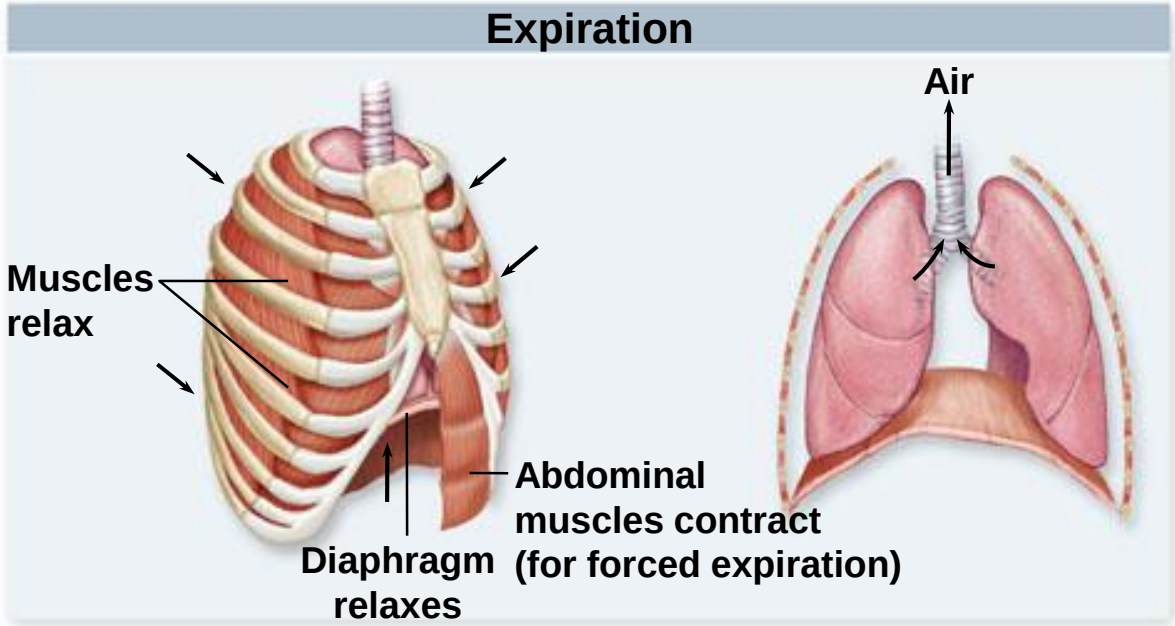
Negative pressure breathing



Negative pressure breathing

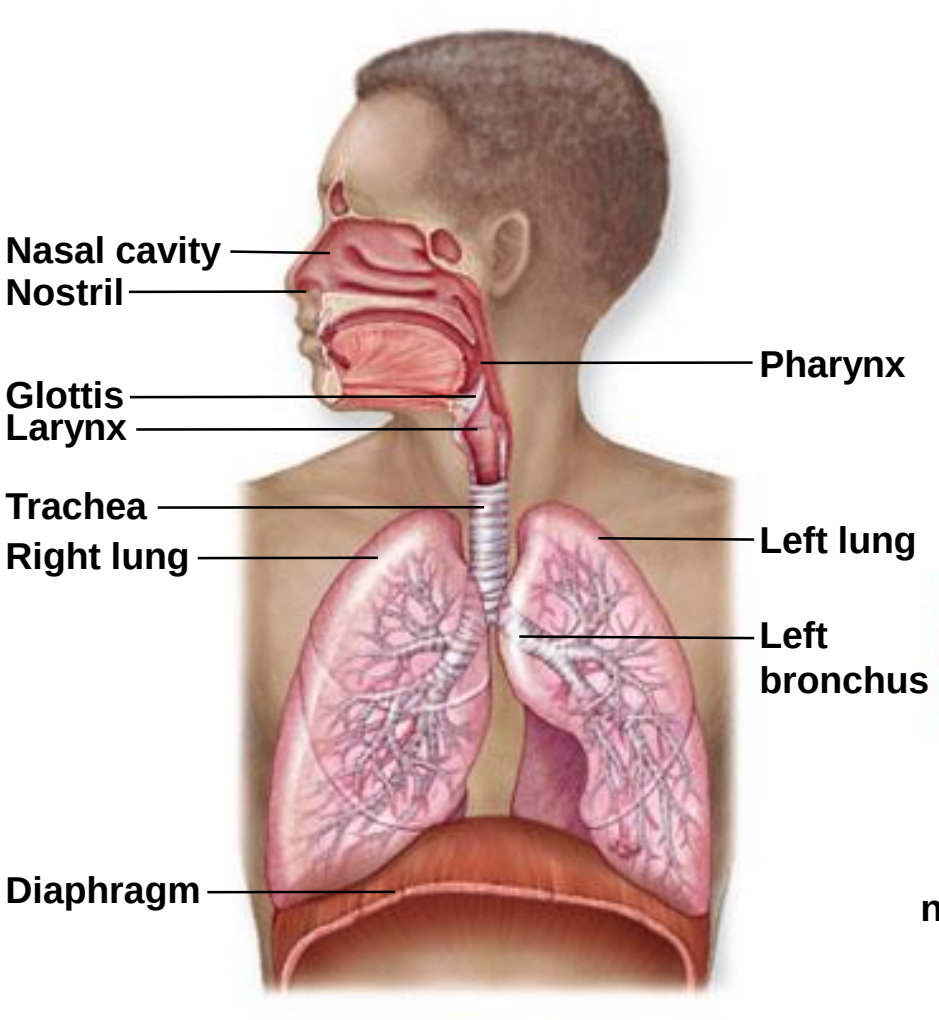


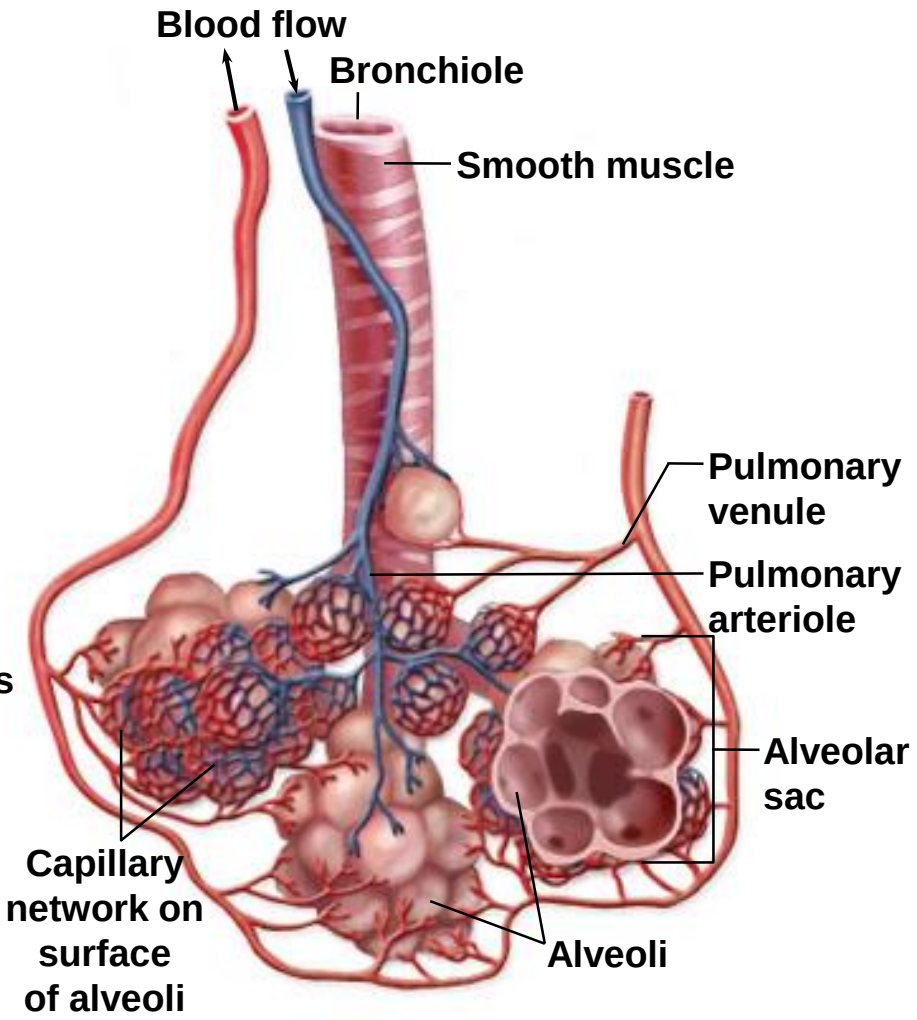
a.



b.

Lungs

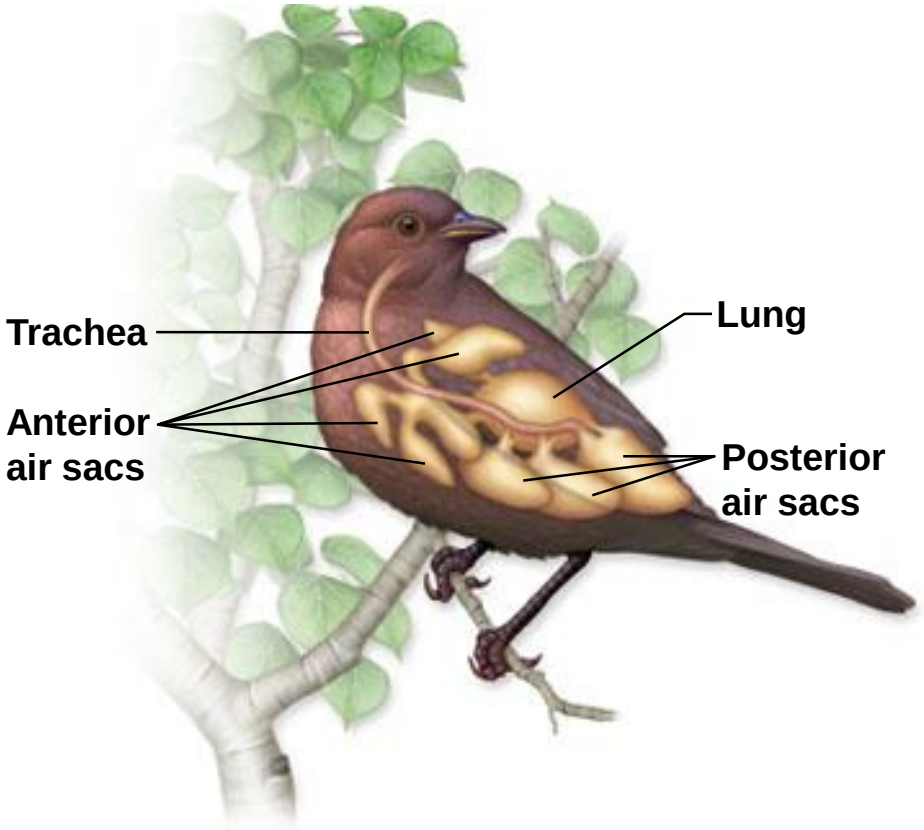

Nasal cavity
Nostril
Pharynx
Glottis
Larynx
Trachea
Right lung
Left lung
Left bronchus
Diaphragm


Blood flow
Bronchiole
Smooth muscle
Pulmonary venule
Pulmonary arteriole
Alveolar sac
Capillary network on surface of alveoli
Alveoli

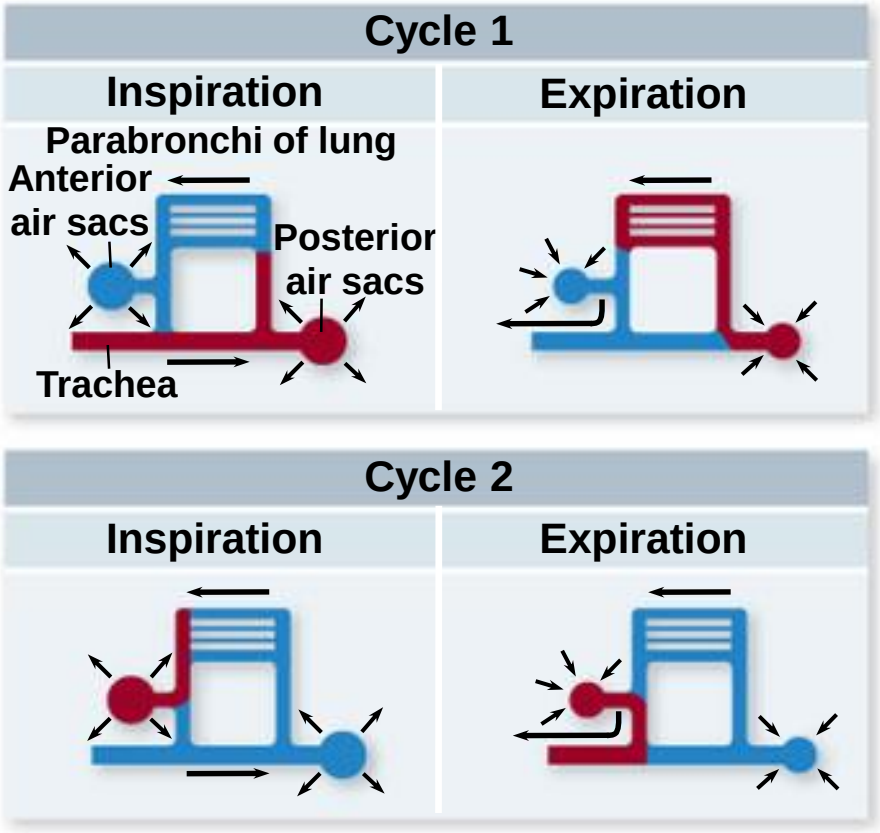
Lungs

- Ventilation
  - air sacs act as bellows in birds
    - air flows in one direction during both inhalation & exhalation

Lungs of Birds



a.



b.

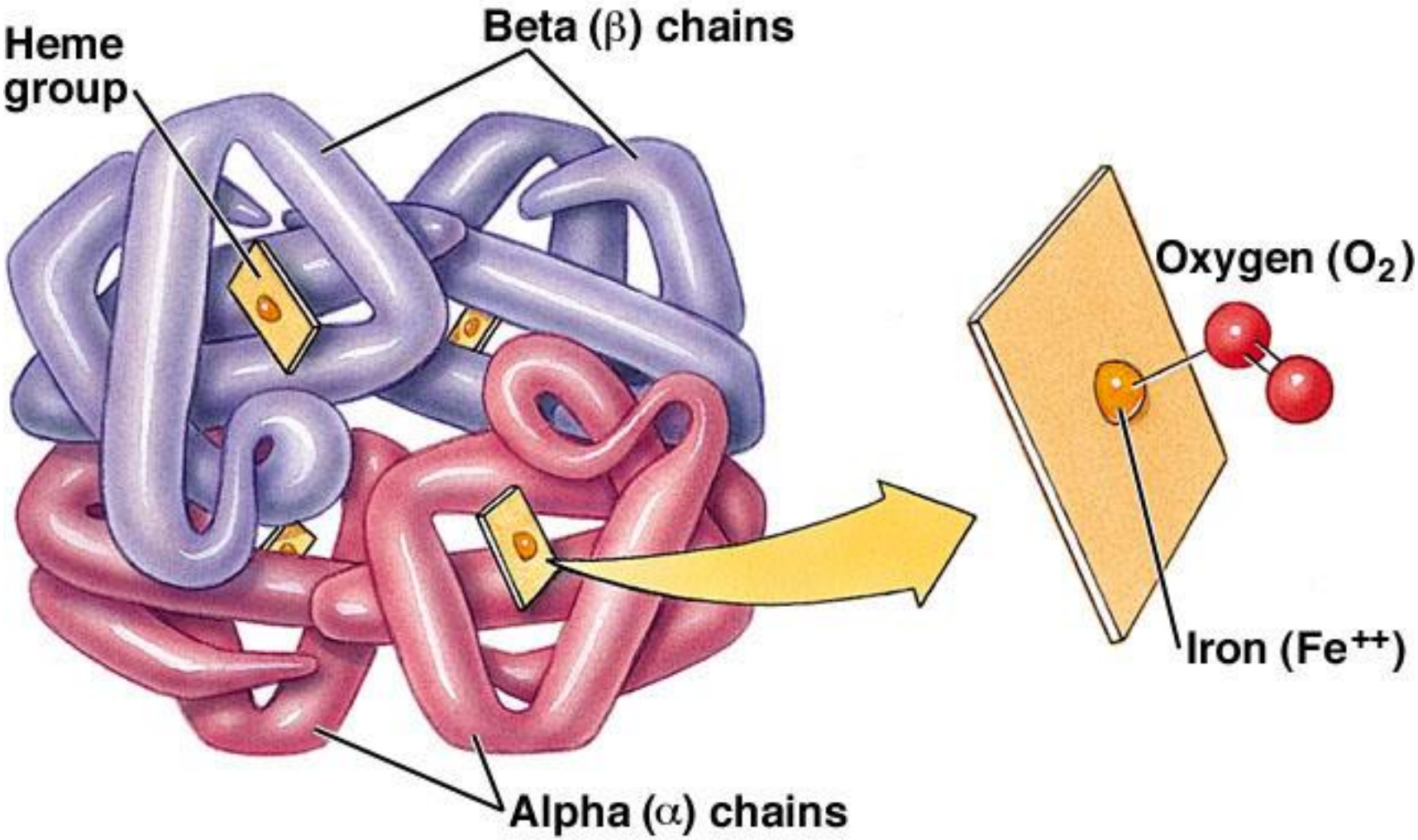
Transport of Gases

- Occurs in the circulatory system when needed

Transport of Gases

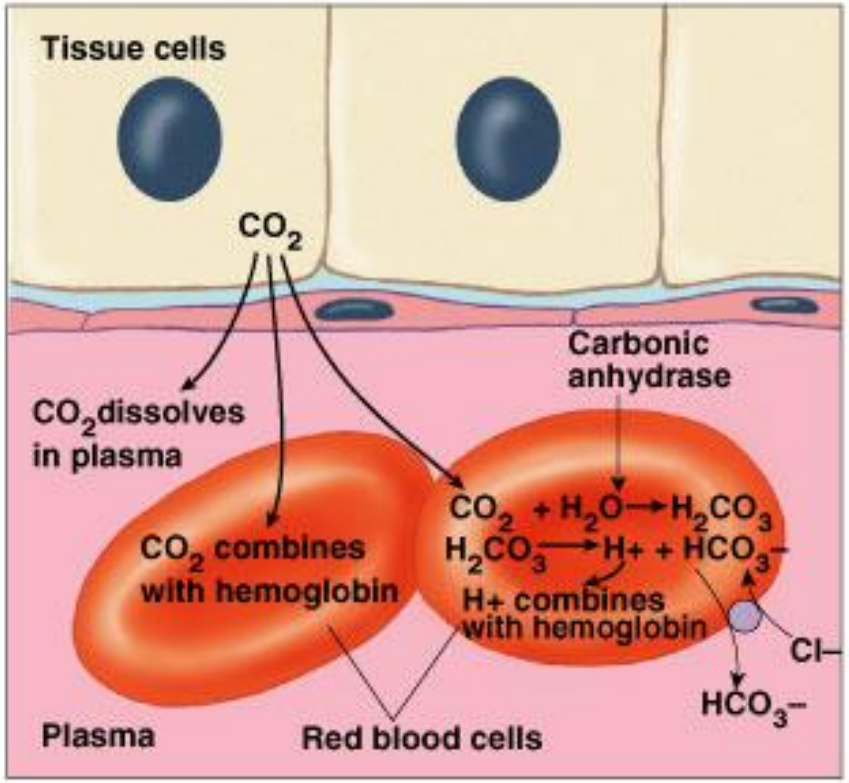
- O_2 is transported by respiratory pigments
  - **hemoglobin** on red blood cells or hemocyanin in the plasma

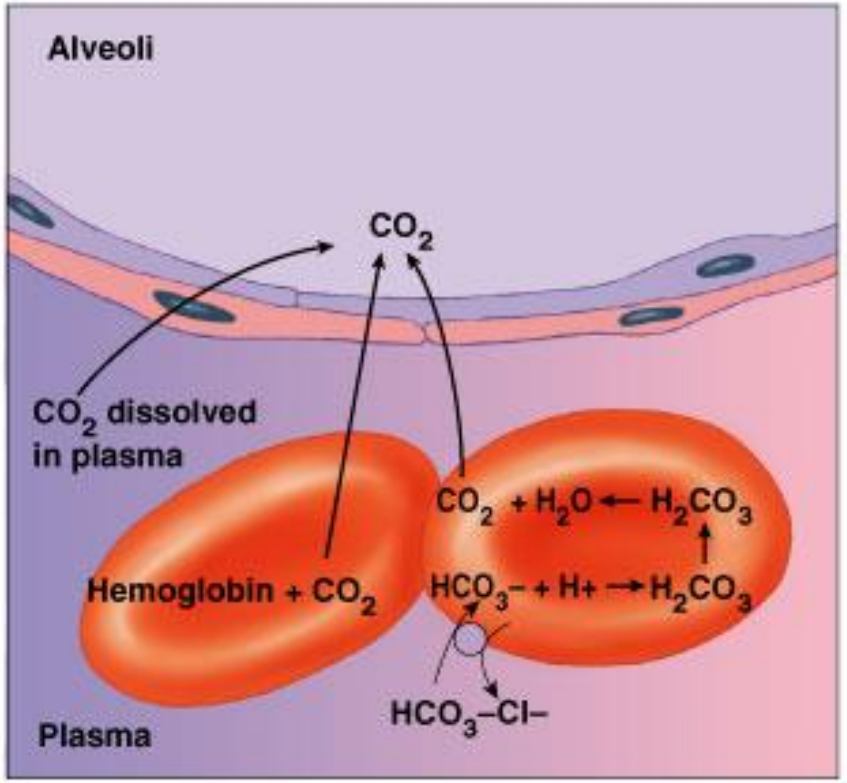
Hemoglobin Structure



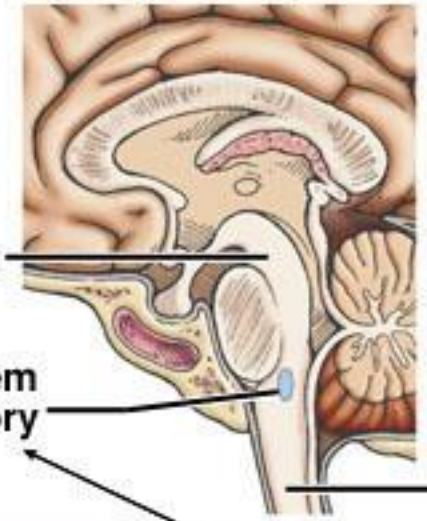
Transport of Gases

- CO_2 is transported by respiratory pigments and dissolved in the plasma and in red blood cells as bicarbonate ion (HCO_3^-)





Regulation of Breathing by Chemo-receptors



Increased breathing

Peripheral chemoreceptors (aortic and carotid bodies)

Central chemoreceptors

Decreased blood pH

Decreased cerebrospinal fluid pH

Increased blood CO_2 concentration (P_{CO_2})

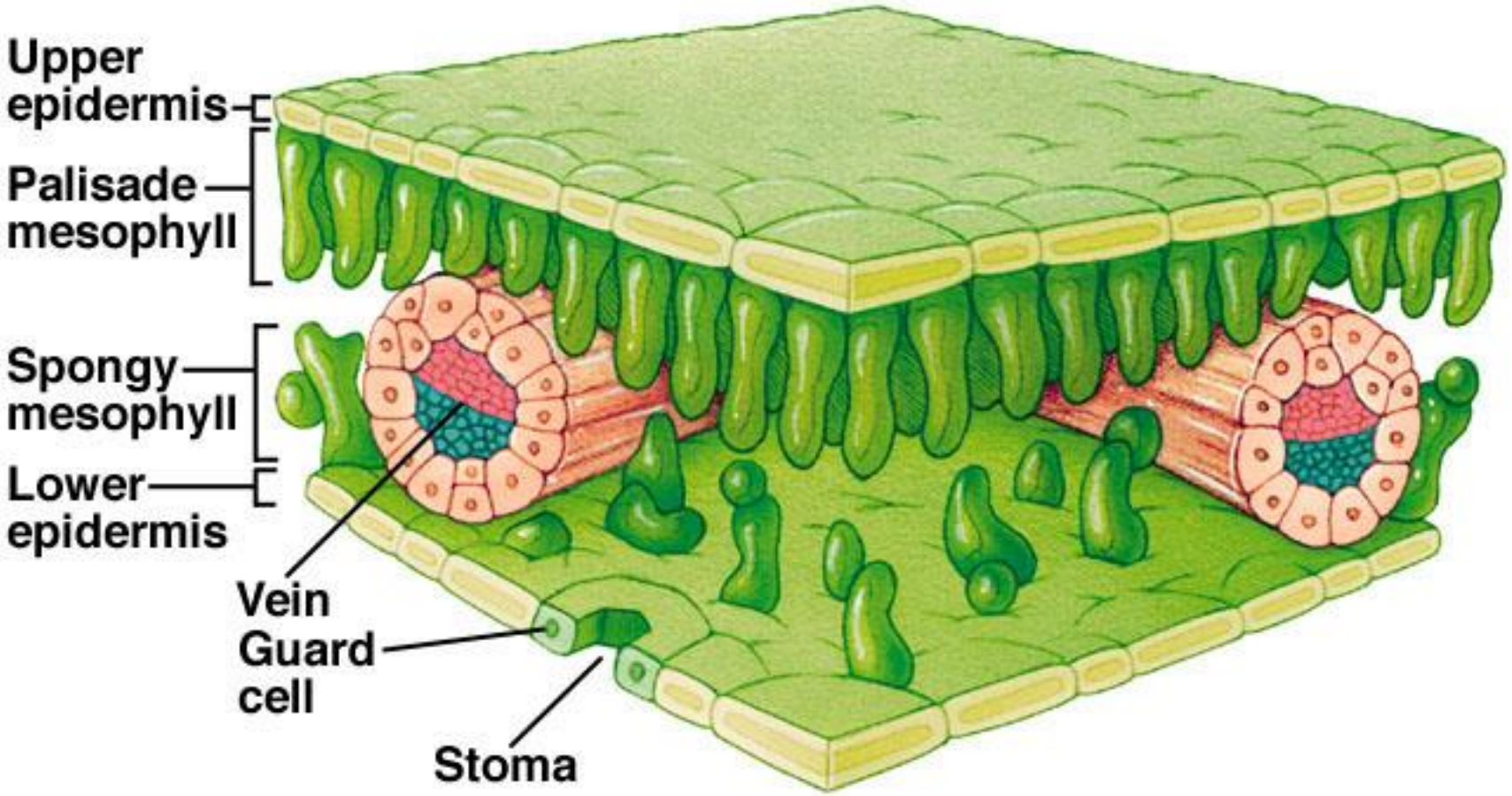
Negative feedback ⊖ correction

Inadequate breathing

Gas Exchange in Plants

- Stomata
  - tiny pores on the underside of leaves
  - lead to air spaces in the mesophyll

Leaf—Cross Section



Gas Exchange in Plants

- Guard cells
  - regulate the opening & closing of stomata
  - turgid - stomata open, flaccid - stomata close

Figure 36.12x Stomata on the underside of a leaf

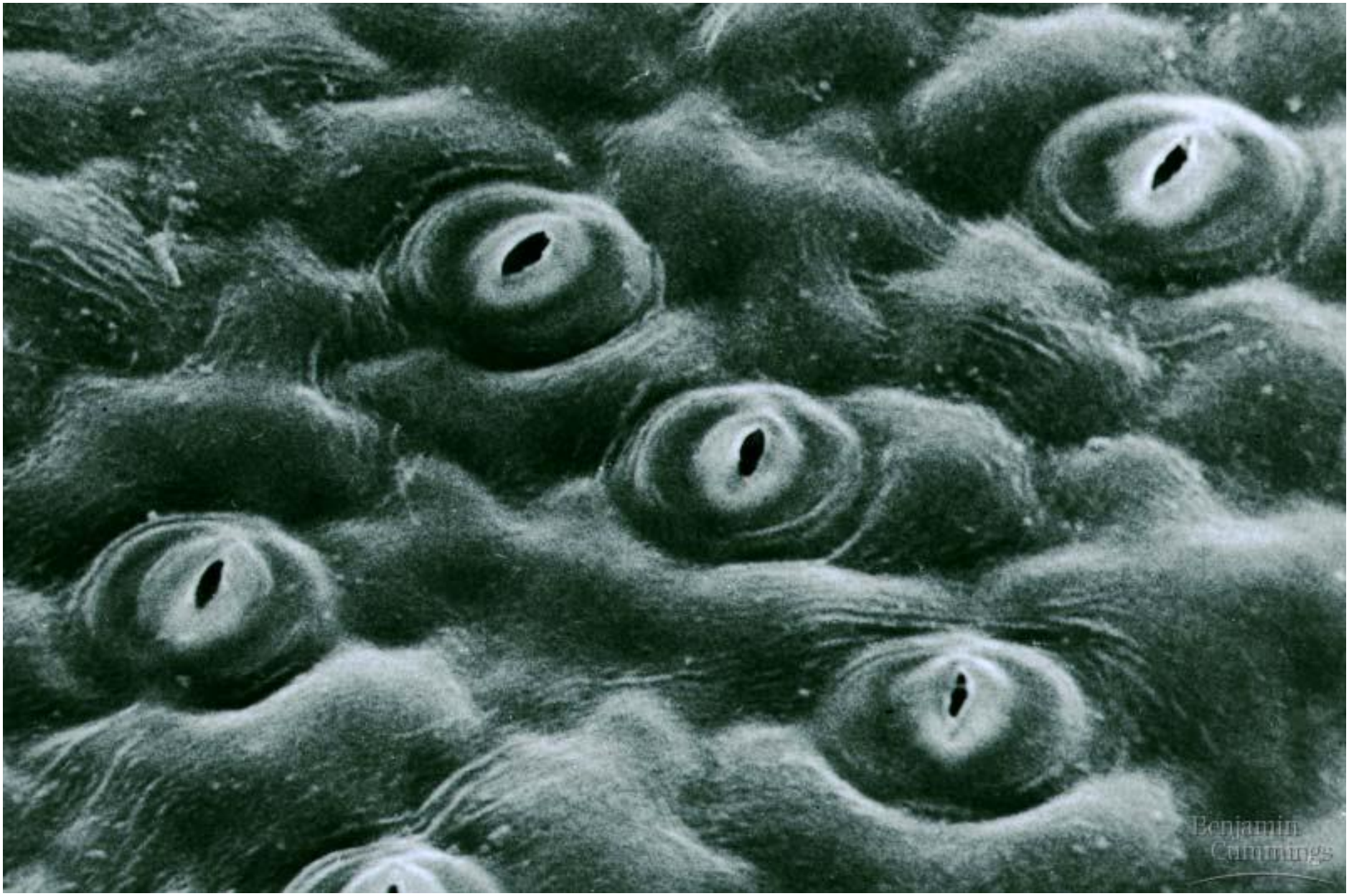


Figure 36.12 An open (left) and closed (right) stoma of a spider plant *(Chlorophytum colosum)* leaf

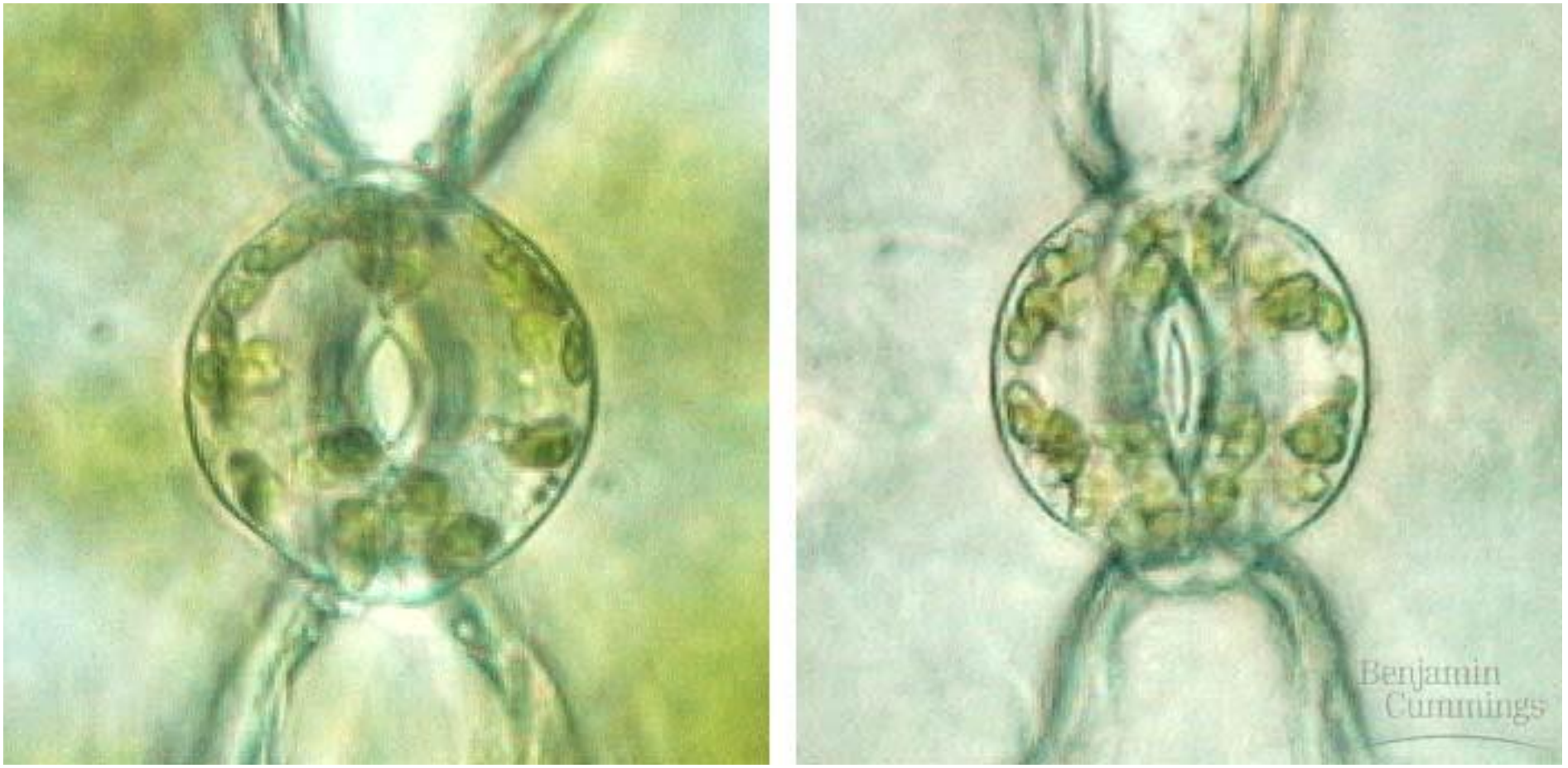
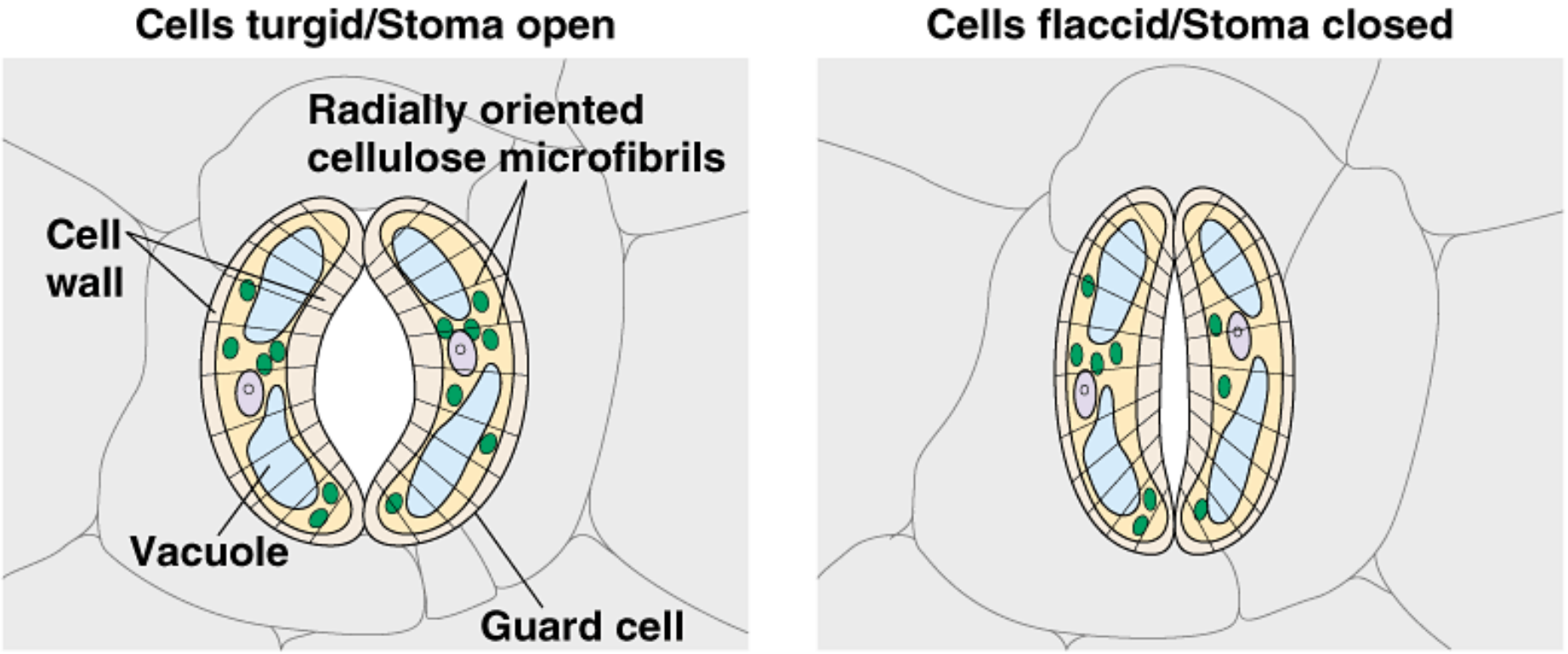
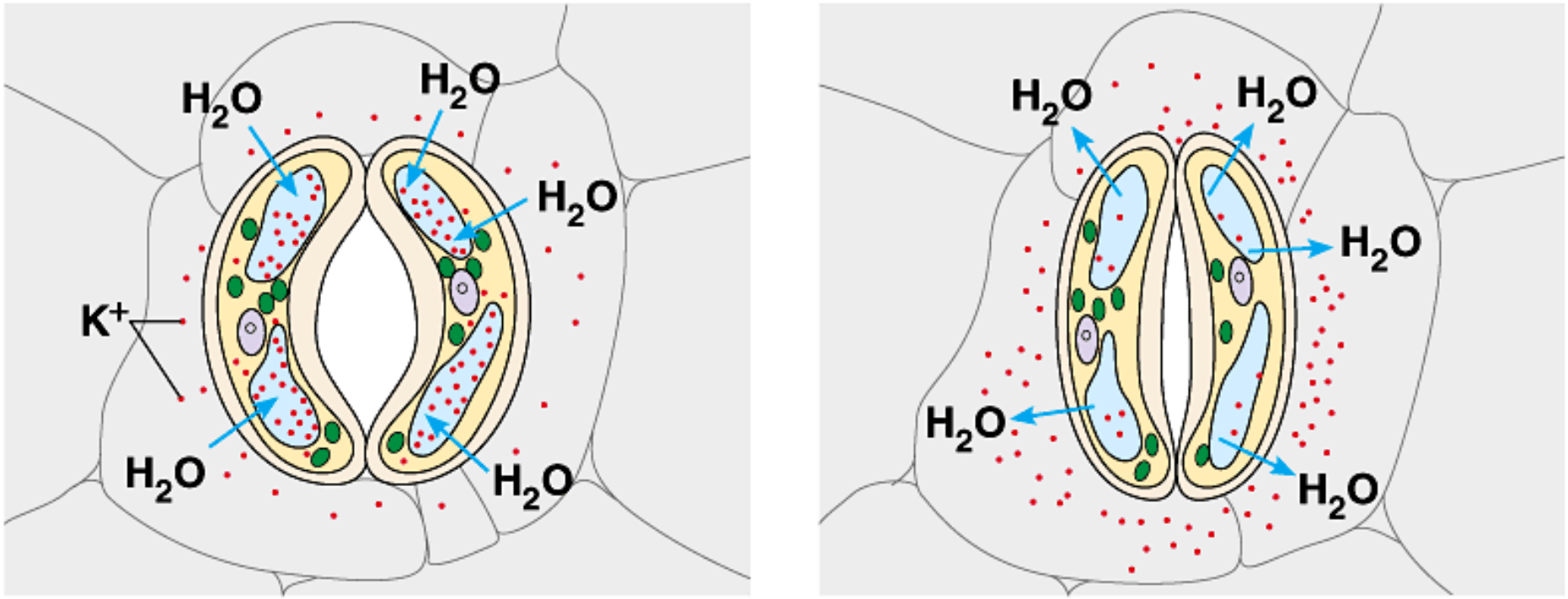


Figure 36.13a The mechanism of stomatal opening and closing



(a) Changes in guard cell shape and stomatal opening and closing (surface view)

Figure 36.13b The mechanism of stomatal opening and closing



(b) Role of potassium in stomatal opening and closing

Guard cells' turgor pressure

- K+ into guard cells -- water follows due to osmosis, cells become turgid
- K+ out of guard cells -- water moves out and cells become flaccid

Stomata

- Generally open during the day & closed at night
- Cues:
  - Light
  - depletion of CO_2
  - Circadian rhythms – biological clock