Exchange Surfaces & Ventilation

WALT:

- Explain why multicellular organisms need specialised exchange surfaces.
- Describe the features of an efficient exchange surface.
- Describe the structure & function of components of the mammalian gas exchange system.
- Outline the mechanism of mammalian ventilation.
- Explain the terms tidal volume & vital capacity.
- Analyse & interpret data from a spirometer.

Introduction

- All organisms must exchange things between themselves and their environment:
  - Respiratory gases.
  - Nutrients.
  - Waste products.
  - Thermal energy.

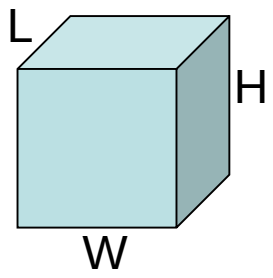
How do they do it?

- Single celled organisms:
  - Can exchange substances across the plasma membrane.
- Multicellular organisms:
  - Their outer surface is not large enough.
  - They need specialised exchange organs.

Surface Area : Volume

- Exchange takes place at the surface.
- But materials are used within the volume.
- So, surface area must be large enough compared with volume.
  - The surface area : volume ratio needs to be large.

Activity



Copy and complete the table.

Length of one side of a cube (cm)	Total surface area ($6L^2$) (cm^2)	Total volume (L^3) (cm^3)	Surface area : volume ratio
1	6	1	6.0
2	24	8	3.0
3	54	27	2.0
4	96	64	1.5
5	150	125	1.2
6	216	216	1.0
7	294	343	0.9

Features of Specialised Exchange Surfaces

- Large surface area.
- Very thin barrier/membrane.
- Permeable.
- Moist.
- Fresh supply of substances on one side.
- Movement of substances away on the other side.

Fick's Law

- Fick's law describes the rate of diffusion across a membrane.

Rate of diffusion is proportional to:

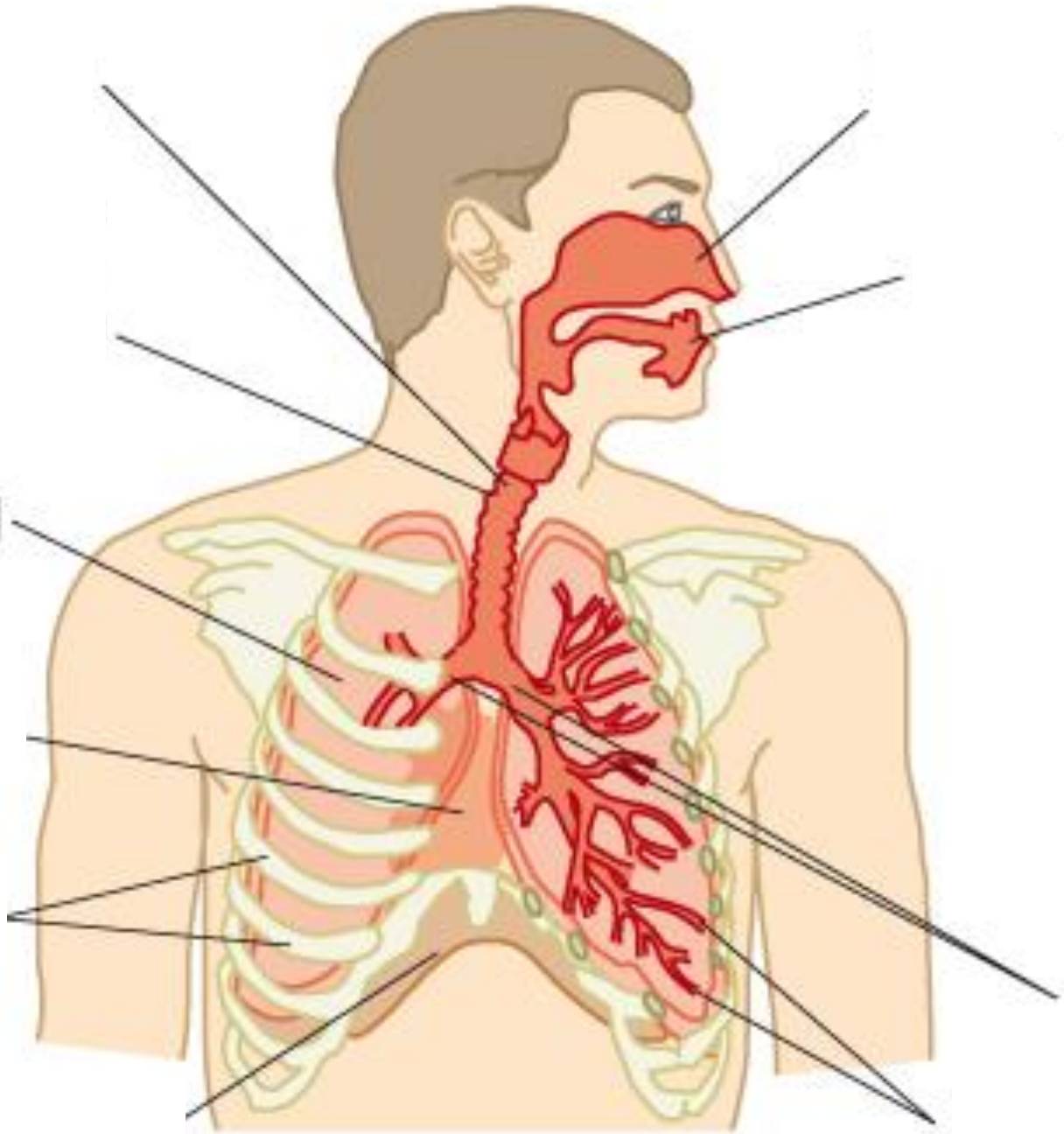
$$\frac{\text{surface area x difference in concentration}}{\text{distance over which diffusion occurs}}$$

The Effect of Surface Area:Volume Ratio on Diffusion Rate

- Practical Work.
  - Follow the instructions on the worksheet & answer the questions for homework.

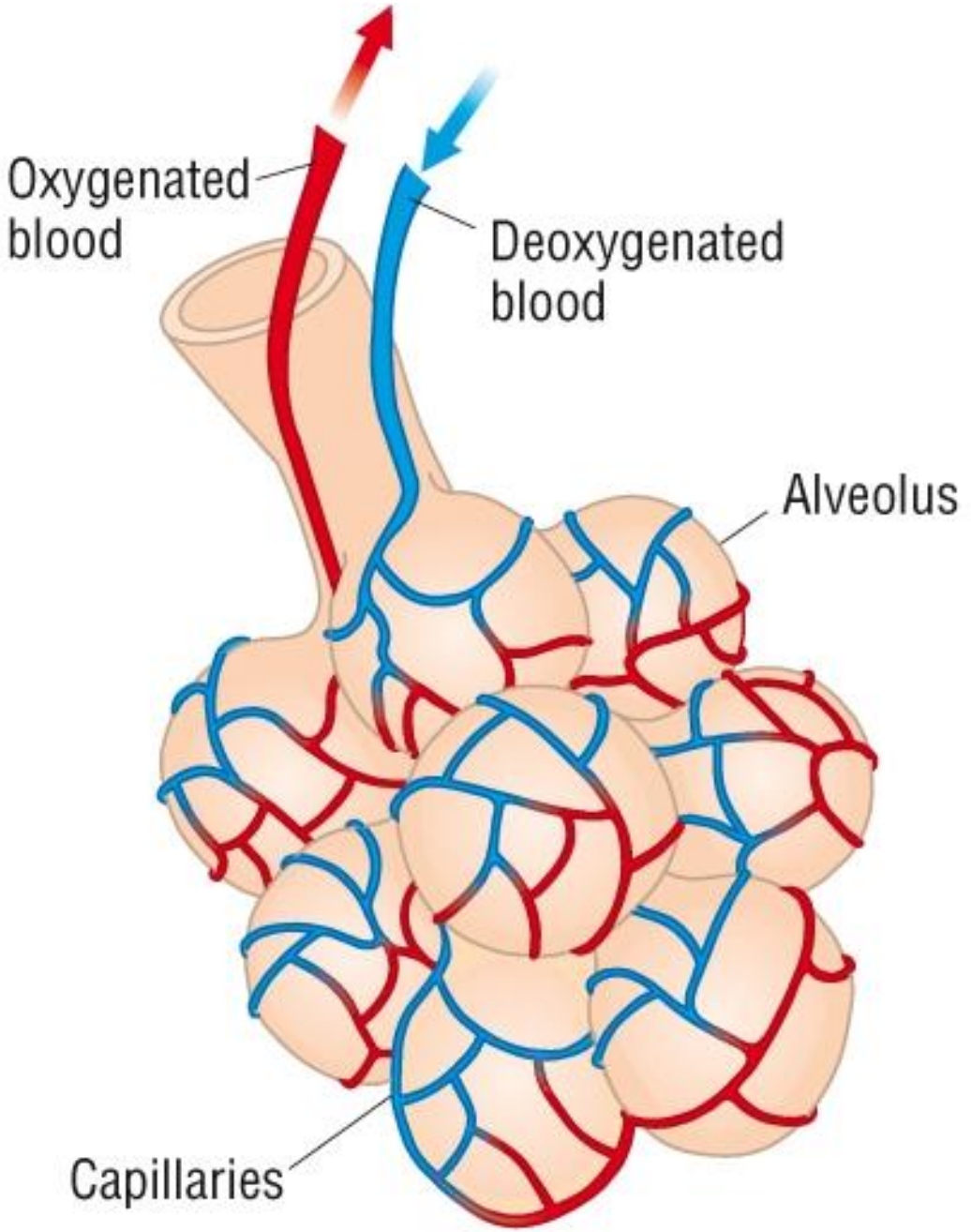
Examples of Exchange Surfaces

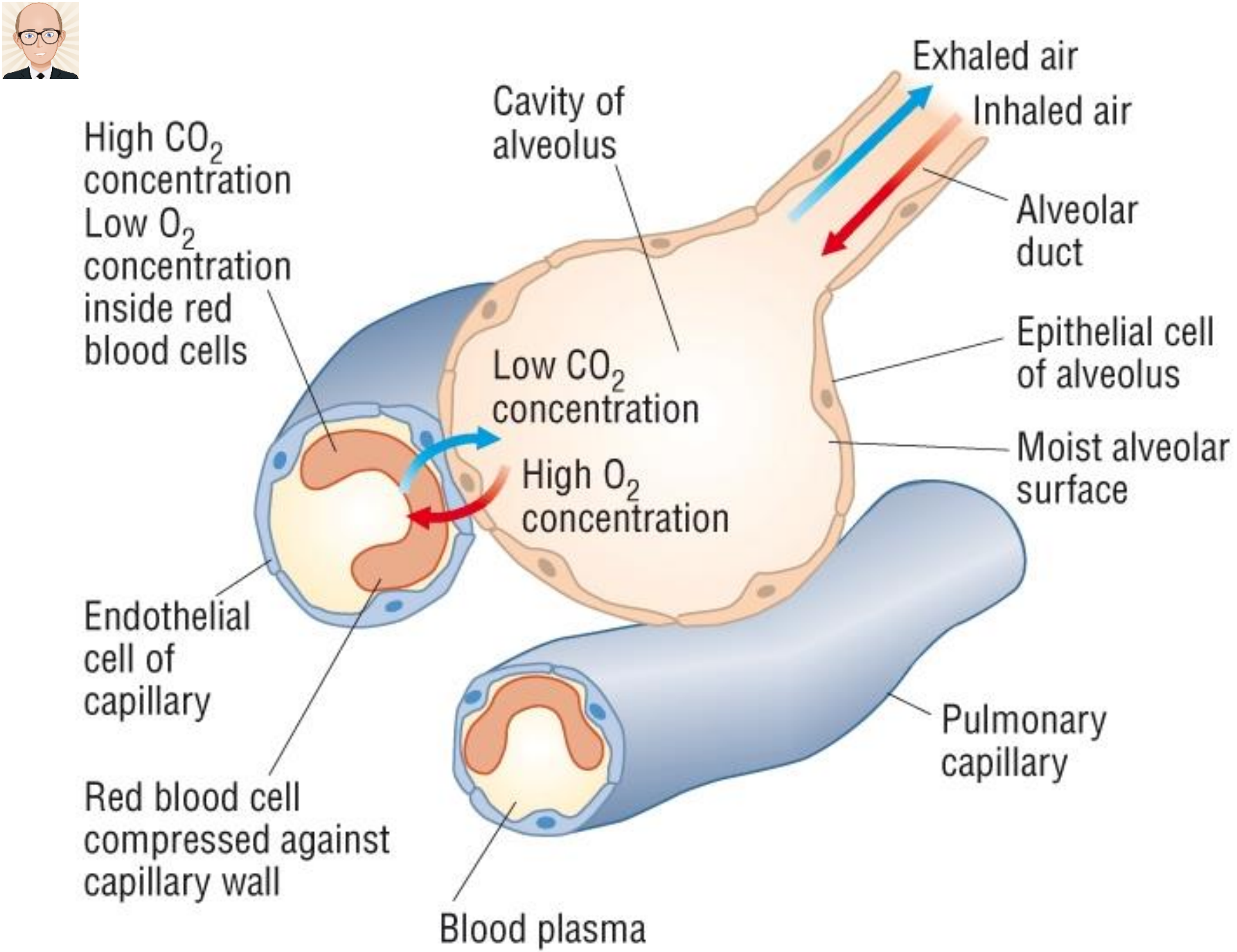
- Alveoli in lungs
- Small intestine
- Root hairs
- Fungal hyphae



Alveoli.

- Large surface area.
- Thin walled (one cell thick).
- Moist.
- Extensive blood supply.
- Movement of air in/out.

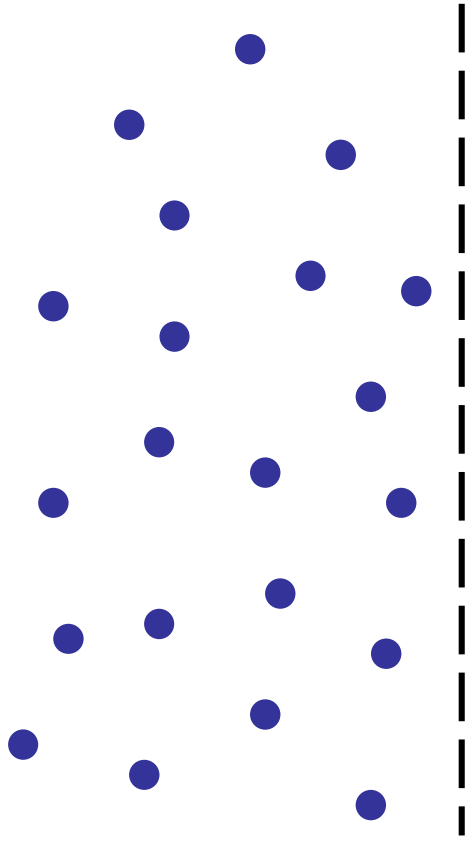



Exhaled air
Inhaled air
Cavity of alveolus
High CO_2 concentration
Low O_2 concentration inside red blood cells
Alveolar duct
Epithelial cell of alveolus
Low CO_2 concentration
High O_2 concentration
Moist alveolar surface
Endothelial cell of capillary
Pulmonary capillary
Red blood cell compressed against capillary wall
Blood plasma

Investigation

- The histology of exchange surfaces

Maintaining the Concentration Gradient

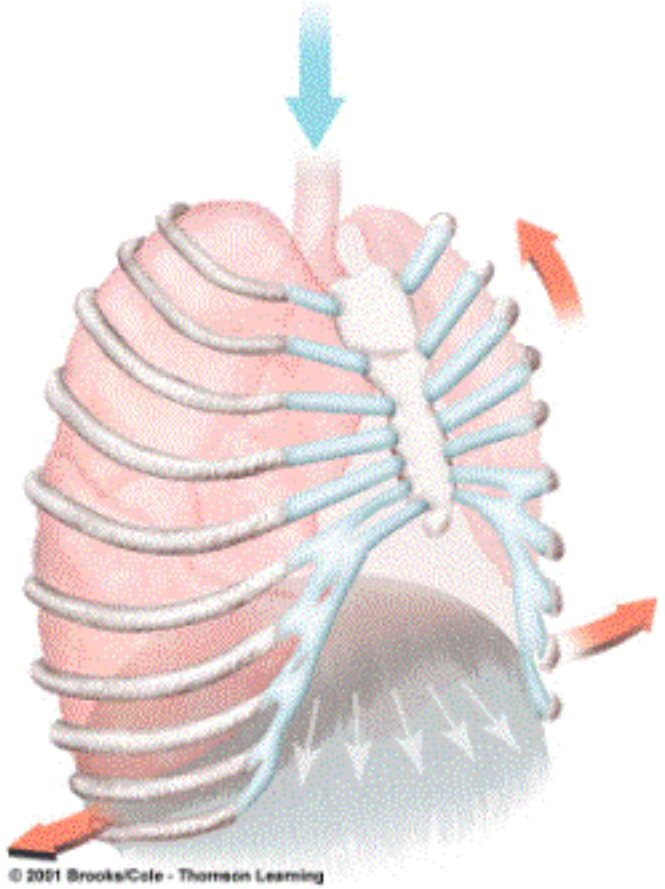


Ventilation

- Inhaling (inspiration)
  - Breathing in.
- Exhaling (expiration)
  - Breathing out

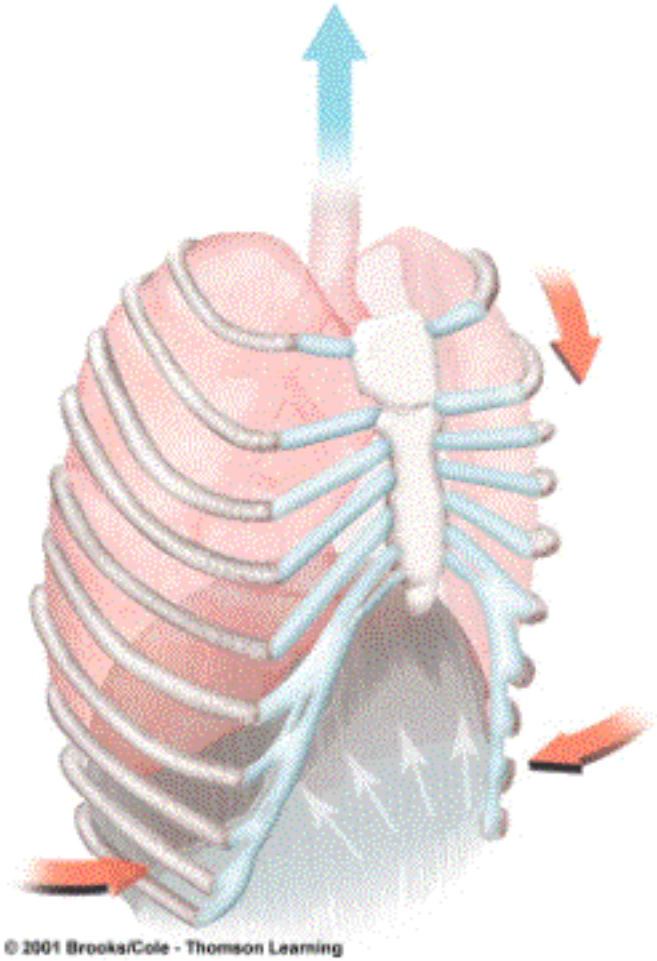
Inhalation

- Diaphragm flattens
- External intercostal muscles contract
- Volume of thoracic cavity increases
- Lungs expand
- Air flows down pressure gradient into lungs



Normal (Passive) Exhalation

- Muscles of inhalation relax
- Thoracic cavity recoils
- Lung volume decreases
- Air flows down pressure gradient and out of lungs

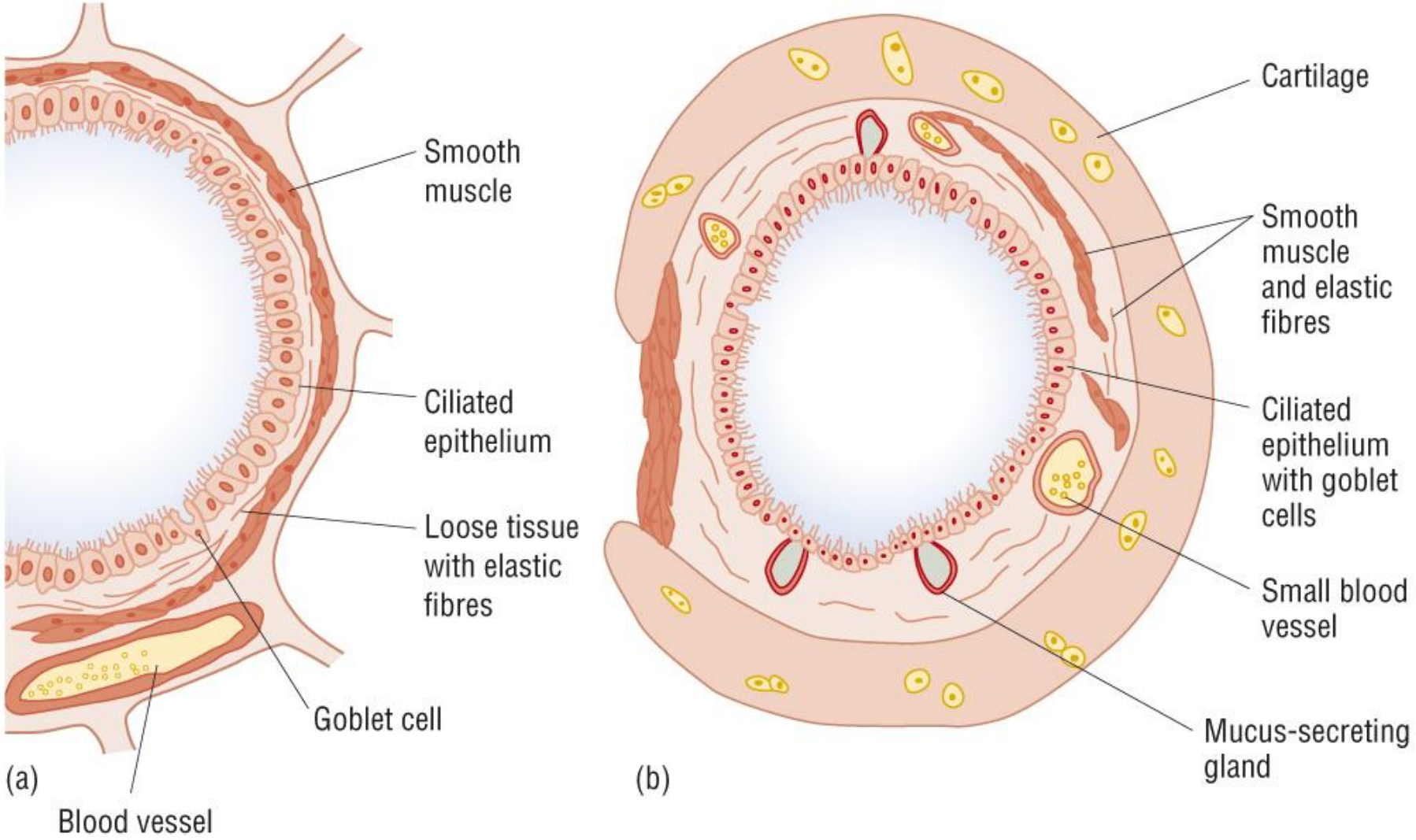


Trachea, Bronchi & Bronchioles

Complete the following table by dissecting the lung specimens:

Structure	Diameter (mm)	Wall Thickness (mm)	Number of cartilage rings per 10cm length	Cut a 2cm length out. How easy is it to squash flat? (1 = does it on its own, 10 = like a copper water pipe)
Trachea				
Main bronchus				
Bronchiole				

A bronchiole (a) and Trachea (b)



Homework

- What is the role and location of each of the following lung tissues:
  - Cartilage
  - Smooth muscle
  - Elastic fibres
  - Goblet cells
  - Ciliated epithelial cells

- You could present the information in a table to show role of each tissue in the lung, trachea, bronchi, bronchioles & alveoli.

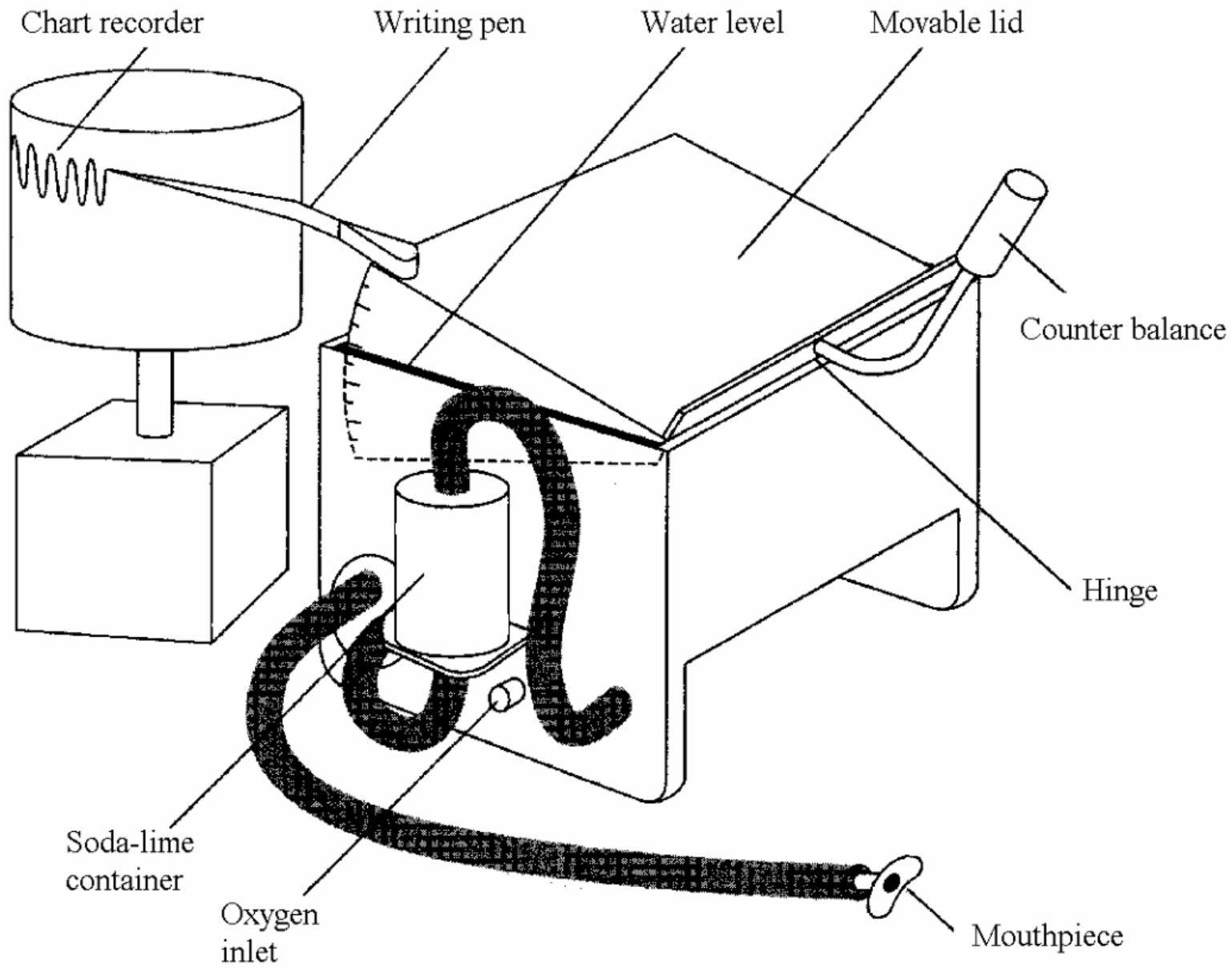
Homework table

Tissue Type	Role	Location
Cartilage		
Smooth Muscle		
Elastic Fibres		
Goblet Cells		
Ciliated Epithelial Cells		

Measuring a Person's Breathing

- How many breaths per minute do you take?
- What volume of air do you breathe in/out each time?
  - This is your tidal volume.
- Ventilation rate = tidal volume x breaths per minute.
  (dm^3) (min^{-1})

There is an easier way…



A Spirogram

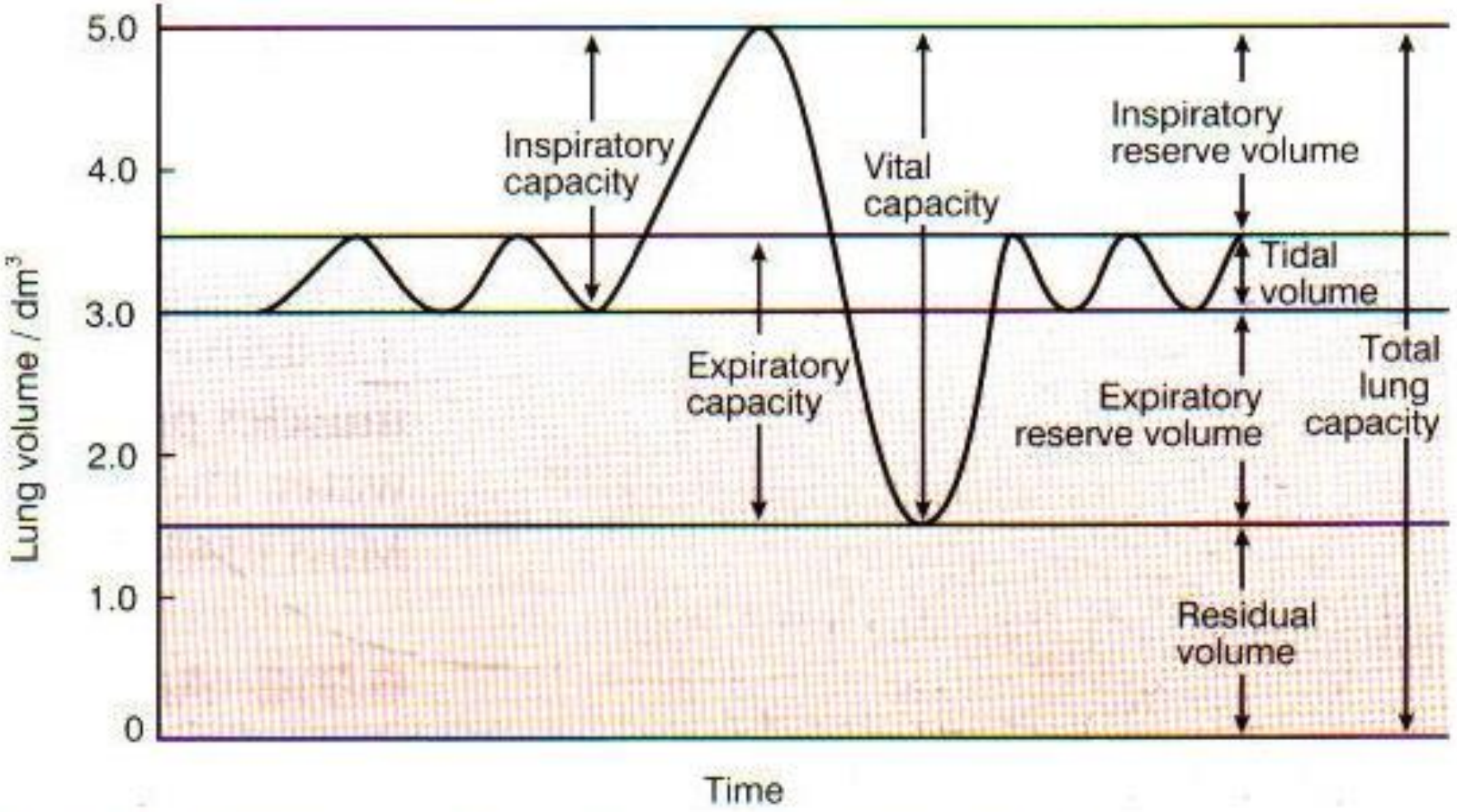


Fig 6.13 *Graph to illustrate lung volume and capacities*

Typical values for an average human adult lung

	Description	Volume
Tidal Volume	Volume of air exchanged at each breath at rest.	0.5 dm^3
Inspiratory Reserve Volume	Maximum additional volume that can be inspired.	1.5 dm^3
Expiratory Reserve Volume	Maximum additional volume that can be expired.	1.5 dm^3
Residual Volume	Volume that cannot be removed from the lungs. Prevents moist alveolar walls sticking together, making re-inflation impossible.	1.5 dm^3
Vital Capacity	Maximum volume that can be exchanged.	3.5 dm^3

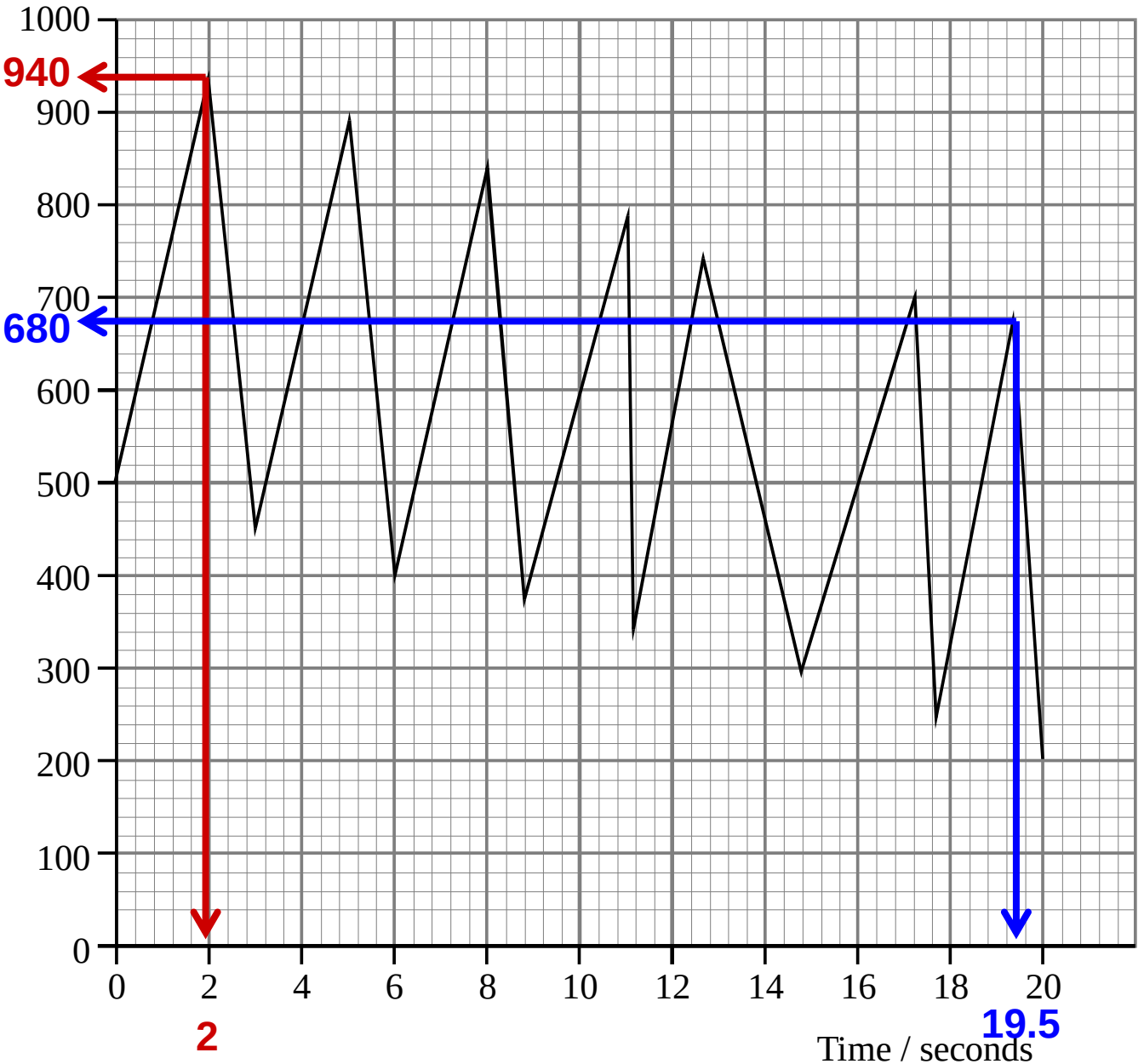
Measuring Oxygen Uptake

Volume used = 940 – 680 = 260cm³

Time taken = 19.5 - 2 = 17.5 sec

Oxygen uptake = 14.9 $cm^3\ sec^{-1}$

Oxygen uptake = 891 $cm^3\ min^{-1}$



The mechanisms of ventilation and gas exchange in bony fish and insects

- To include:
  - Bony fish
    - Changes in volume of the buccal cavity and the functions of the operculum, gill filaments and gill lamellae (gill plates); countercurrent flow.
  - Insects
    - spiracles, trachea, thoracic and abdominal movement to change body volume, exchange with tracheal fluid.