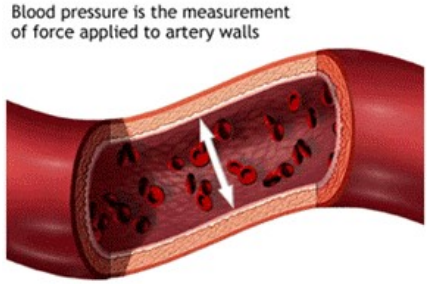
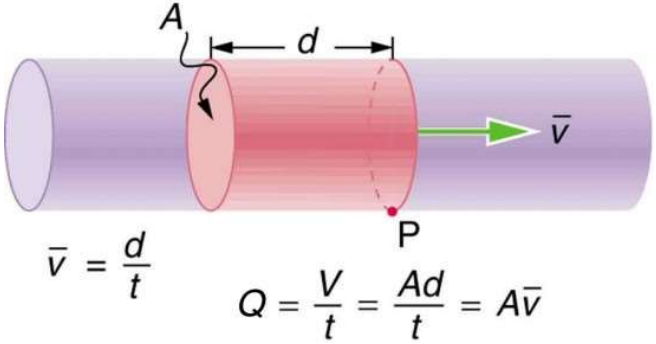
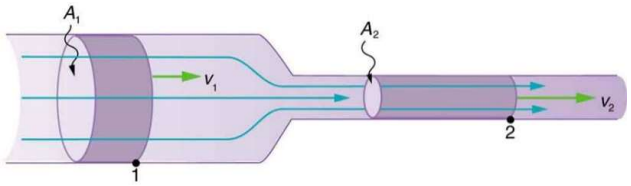
L6_Physics applicable for cardiovascular system

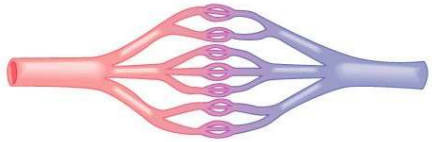


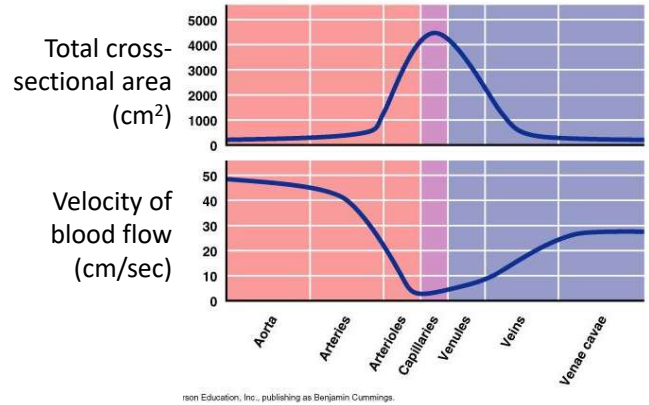
Definitions

1. **Stroke volume** (SV) = volume of blood pumped by a ventricle per beat (ml per beat)
2. **Cardiac output** (CO) = volume pumped by a ventricle per minute = SV x heart rate (HR) (L/min)
3. **Blood pressure** (BP) = force per unit area exerted on blood vessel wall by blood (mmHg)
   - proportional to CO and total peripheral resistance (TPR)
4. **Blood flow** (Q) = volume of blood flowing through a vessel/organ/the entire circulation per unit time (ml/s; L/hr)
   - proportional to pressure difference & inversely proportional to resistance
5. **Resistance** (R) to blood flow can be controlled by controlling the diameter of the blood vessel ($R \alpha 1/r^4$)
   - vasodilation (i.e. ↑ diameter → ↓ resistance → ↑ blood flow)
6. **Velocity of blood flow** (v) = distance of blood moved per unit time in a specific direction = blood flow (Q) /cross-sectional area (A)

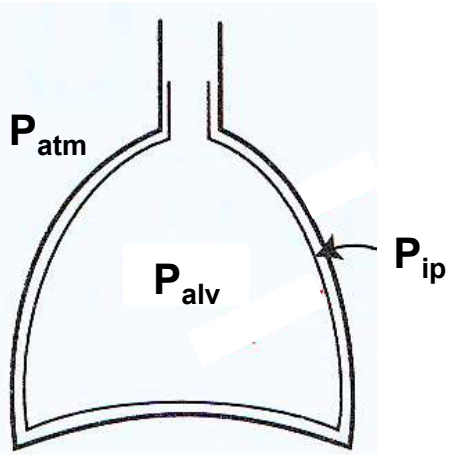




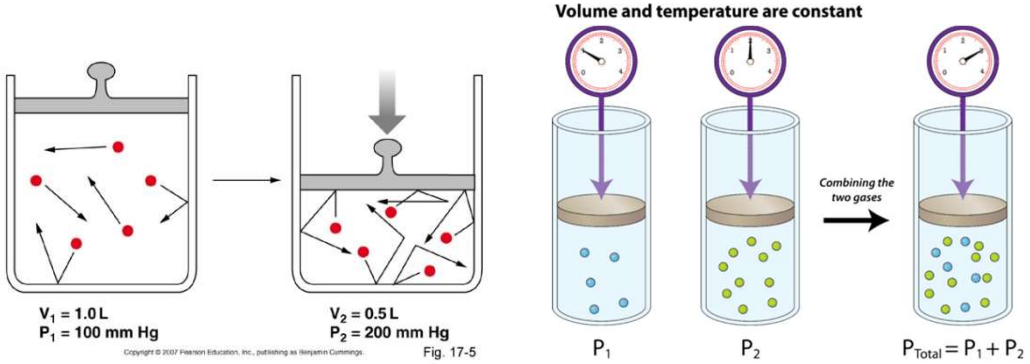




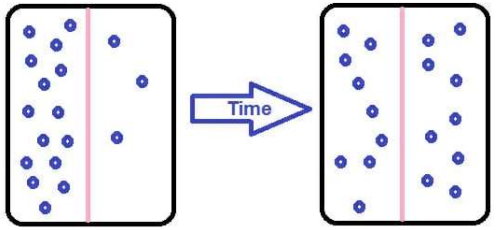
L7_Physics applicable for respiratory system



1. Fluid (liquid – blood & gas - air) flows from area of high pressure to low pressure
2. All pressures related to respiratory system are relative to atmospheric pressure (P_{atm} = 760 mmHg)
3. Intrapulmonary pressure = **alveolar pressure (P_{alv})** = pressure in the lungs
4. **Intrapleural pressure (P_{ip})** = pressure in the pleural cavity, which is always smaller than P_{alv} (given the pleura are intact)
5. **Transpulmonary pressure = alveolar pressure – intrapleural pressure** = force that determine the size of the lung
6. **Bolye's law**: $P_1V_1 = P_2V_2$ (i.e. gas pressure and gas volume are inversely related at a given temperature)
7. **Dalton's law of partial pressure**: total gas pressure = sum of partial pressure of all gases in a gas mixture
   - e.g. $P_{atm} = P_{N2} + P_{O2} + P_{CO2} + \ldots$
   - partial pressure of individual gas can be calculated if the total pressure and composition of the gas mixture is known



8. **Fick's first law of diffusion** defines factors affecting the rate of diffusion of a substances from high to low concentration
   - concentration gradient (partial pressure difference of the diffusing gas)
   - diffusion distance
   - total surface area
   - solubility & temperature



L8_Concept of homeostasis

Homeostasis is the maintenance of a relatively constant **internal environment** (i.e. the extracellular fluid) in the body (e.g. temp., [Na^+], [glucose]…)

In order to do this, the body develops mechanisms for

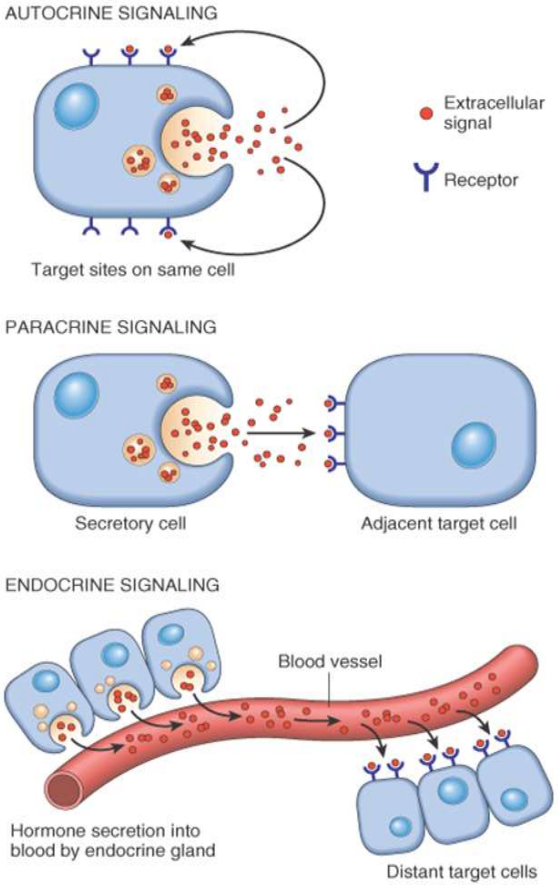
1. Detection ***(sensor/receptor)*** – detect changes (stimuli)
2. Integration of information and coordination of adjustment process ***(the control centre)***
   - *though control by nervous system (electrical signal and neurotransmitters)*
   - *through control by chemicals (autocrine, paracrine, endocrine)*
3. Adjustment ***(effector)*** – response by the body to revert the changes

Homeostasis is achieved through **negative feedback mechanism**.

- i.e. when there is a disturbance to the internal environment, our body will respond to **restore the balance**. (e.g. when blood pressure is too high → mechanisms [e.g. slows the heart rate] to return blood pressure to normal)

Positive feedback mechanism is not for maintaining homeostasis but for our body to accomplish certain goals. With positive feedback, a deviation will lead to a response that triggers an even larger deviation. It are only limited examples for positive feedback, e.g.

- blood clotting – activation of clotting factors
- childbirth (labour) – oxytocin induces uterine contraction
- generation of nerve impulses



L9_Introduction to cells and tissues

	Prokaryotes (bacteria)	Eukaryotes
	Unicellular	Unicellular/multicellular
Cell size	1 – 10 μm	10– 100 μm
Structural complexity	Simpler	More complex
Presence of cell wall?	Yes	Plant cells only
Presence of cell membrane?	Yes	Yes
Presence of membrane - bounded organelles?	No	Yes
Presence of nucleus	No	Yes
Chromosomal DNA - number - shape - location	one circular nucleoid	> one (46 in a human cell) linear nucleus
Reproduction	Asexual, binary fission	Asexual or sexual

Basic structure of eukaryotic cells

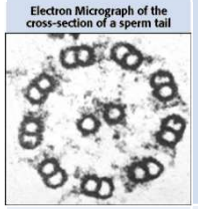
- **Cell membrane**
  - Phospholipid bilayer with proteins
  - Function
    - separate cell interior (intracellular) from environment
    - control entry and exit of substances (semipermeable)
    - various membrane protein for different functions
      - **receptors** for recognition of signals and regulation of cellular function (e.g. receptor for insulin)
      - **glycoprotein** for cell recognition
      - **channels and transporters** for movement of molecules like ions, glucose…
      - **enzymes** to catalyse chemical reactions
- **Cytoplasm – cytosol + organelles**
  - cytosol – water + various solutes (ions, enzymes…) – medium for chemical reactions
  - organelles (except ribosomes) are membrane-bounded, each with specific function
- **Nucleus**
  - houses chromosomal DNA, site of transcription
  - double layered nuclear envelop continuous with the endoplasmic reticulum, nuclear pores for entry and exit

SUMMARY TABLE 7.2 **Eukaryotic Cell Components**

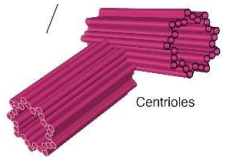
Icons not to scale		Structure: Membrane	Structure: Components	Function
	**Nucleus**	Double ("envelope"); openings called nuclear pores	Chromosomes Nucleolus Nuclear lamina	Genetic information Assembly of ribosome subunits Structural support
	**Ribosomes**	None	Complex of RNA and proteins	Protein synthesis
	**Endomembrane system**			
	Rough ER	Single; contains receptors for entry of selected proteins	Network of branching sacs Ribosomes associated	Protein synthesis and processing
	***Golgi apparatus***	Single; contains receptors for products of rough ER	Stack of flattened cisternae	Protein processing (e.g., glycosylation)
	***Smooth ER***	Single; contains enzymes for synthesizing phospholipids	Network of branching sacs Enzymes for synthesizing lipids	Lipid synthesis
	***Lysosomes***	Single; contains proton pumps	Acid hydrolases (catalyze hydrolysis reactions)	Digestion and recycling
	**Peroxisomes**	Single; contains transporters for selected macromolecules	Enzymes that catalyze oxidation reactions Catalase (processes peroxide)	Oxidation of fatty acids, ethanol, or other compounds (detoxification)
	**Mitochondria**	Double; inner contains enzymes for ATP production	Enzymes that catalyze oxidation-reduction reactions, ATP synthesis Mitochondrial DNA	ATP production
	**Cytoskeleton**	None	Actin filaments Intermediate filaments Microtubules	Structural support; movement of materials; in some species, movement of whole cell

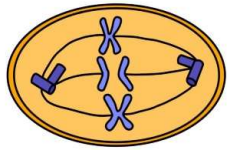
Cilium vs Flagellum

	Cilium	Flagellum
Similarity	• Both are hair-like structures on cell surface • Both formed by **microtubules** arranged in 9+2 arrangement (9 pairs surrounding a central pair of microtubule) • Both can **move**	
Length	Short	Long
Number	Numerous along the entire membrane surface	Only 1 or a few on a cell
Function	Move substances along cell surface	Propel entire cell
Example	Ciliated epithelium lining the respiratory tract	Sperm



Parts of the Cell: Centrioles

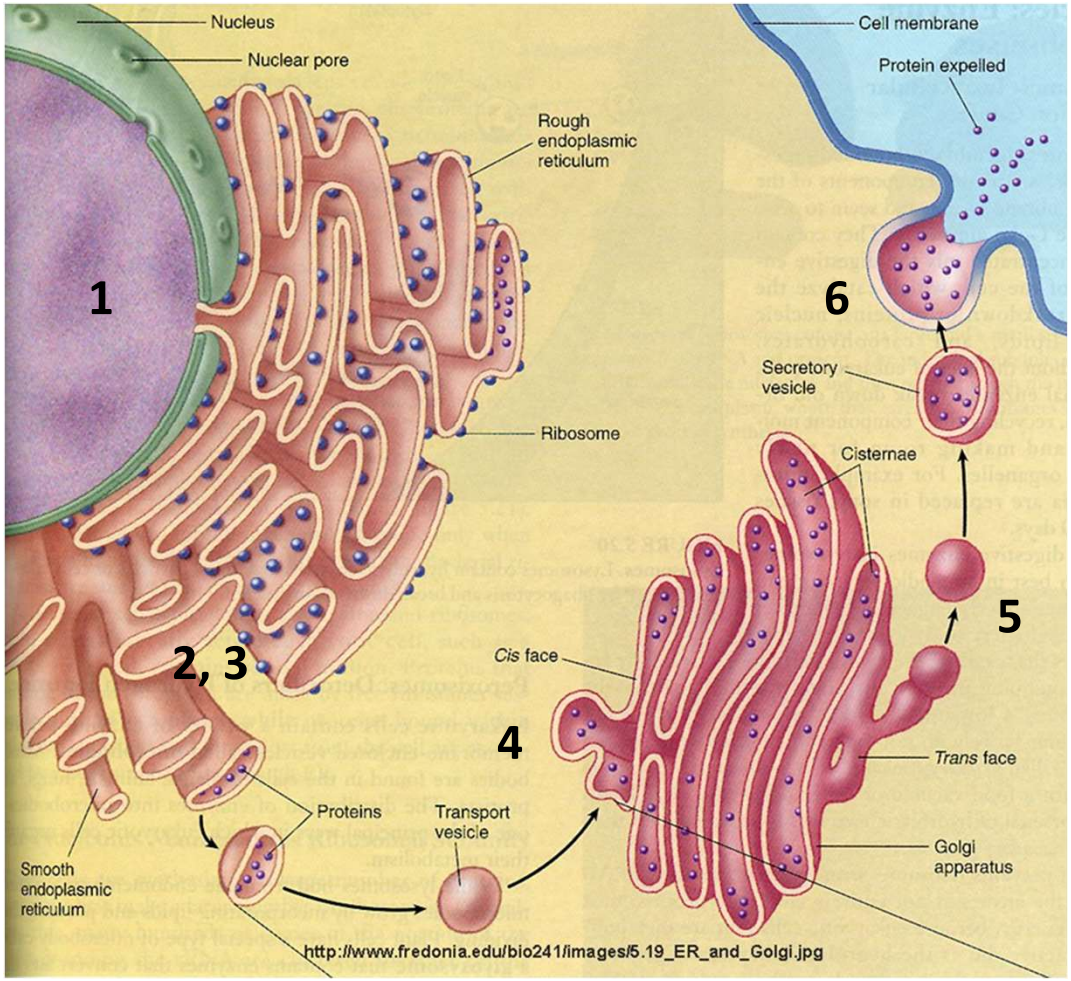




Centrioles are organelles which are only active during cell division.

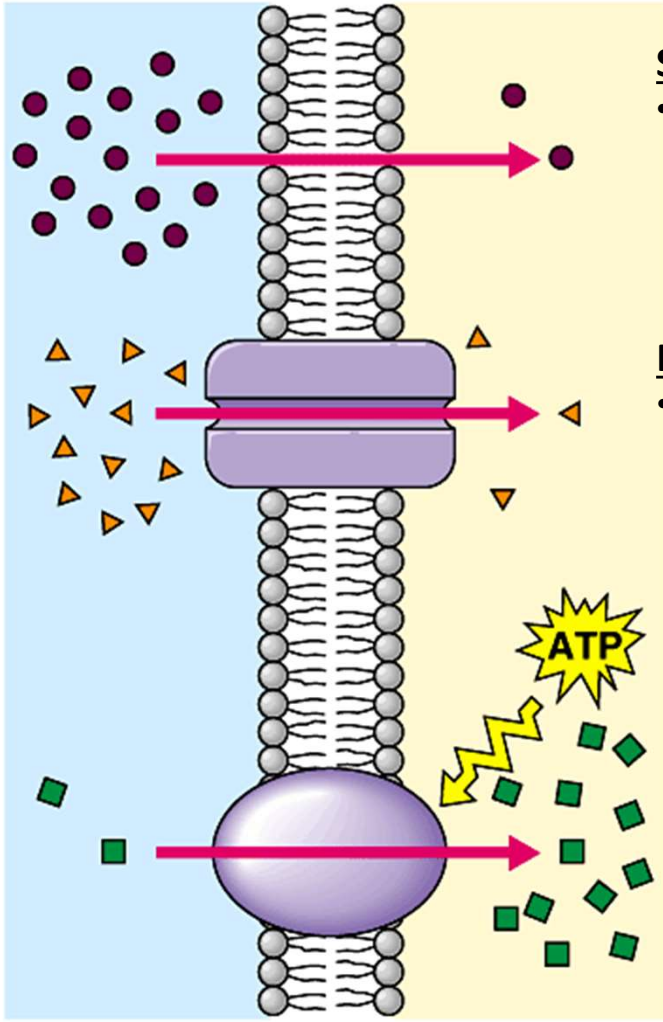
They produce spindle fibers which attach to chromosomes. The fibers pull a copy of each chromosome to opposite sides of the cell so that when it splits, each new daughter cell has all the DNA it needs.

Protein synthesis and export



1. Transcription occur in ***nucleus*** to make mRNA (contain codes for protein synthesis)
2. mRNA transported from nucleus to ***cytosol*** (through the nuclear pore)
3. ***Ribosome on rough endoplasmic reticulum*** binds to mRNA and carries out translation
4. The synthesized protein is transferred to ***Golgi apparatus*** for modification
5. Modified protein is sorted and packaged into vesicles
6. Some vesicles contain substances (e.g. hormone, neurotransmitters) for export by exocytosis (***secretory vesicles***)
7. Some vesicles remains in the cells (e.g. ***lysosome***) – not shown in picture

L10_Transport across membrane



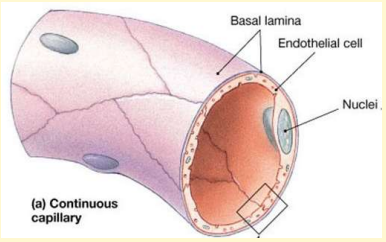
Simple Diffusion
- **Small, non-polar /uncharged molecules pass through lipid bilayer (e.g. O_2, CO_2, fatty acids)**

Facilitated diffusion
- **Large, polar or charged molecules pass through with aids of channels or transporter (e.g. glucose, amino acids)**

Passive transport
- **no ATP needed**
- **driven by chemical gradient/pressure gradient**

Water can freely move across the semipermeable plasma membrane from region of high water potential (low solute concentration/osmolality) to region of low water potential (high solute concentration/osmolality) and the process is called **osmosis**.

Filtration is a kind of bulk movement of fluid and its solute across membrane due to hydrostatic pressure



Active transport
- **transport against chemical gradient with expense of ATP**
- **e.g. Na^+ /K^+ ATPase on all cells (primary)**
- **e.g. Na^+ -dependent absorption of glucose in GI tract (secondary active transport)**

Endocytosis and **exocytosis** also require ATP – active transport