Negative feedback

Feedback that tends to stabilize a process by reducing its rate or output when its effects are too high or too low within a narrow limit.

Mechanism of negative feedback

- There is a change in factor away from the set point.
- Change is detected by the receptor.
- In response to change, hormones are released or nerve impulses are sent.
- Hormone or impulse reaches the effector.
- Effector performs corrective action
- Factor return to its set point.

With reference to maintenance of water potential of blood, explain what is meant by negative feedback.

- Osmoreceptors in the pituitary gland releases ADH into blood.
- ADH binds with cells in collecting ducts and enzyme cascade is started which forms active phosphorylase enzyme which causes vesicles containing aquaporins to fuse with cell membranes of cells of collecting ducts and reabsorb more water which enters the blood.
- Water potential returns to set point.

Formation of urea in liver cells

- Amine group is removed from amino acid and ammonia is formed.
- Ammonia is toxic to human system.
- So, enzymes convert it to urea or uric acid by combining carbon dioxide molecules in urea cycle.

Advantage of using urea as waste product

- Non-toxic, so can be carried in blood from liver to kidney to be excreted.
- Very soluble so can easily be carried in blood.
- Very small so it can be filtered by kidney.

Kidney structure

1. The kidney is covered by a fibrous capsule.
2. There are 3 areas under the fibrous coat.
3. The dark outer region is called cortex.
   - Filtration is carried out by nephrons in here.
   - It has dense capillary network which receives blood from renal artery.
4. The lighter inner region is called medulla. Each nephron extends across the medulla to form structures called renal pyramids.
5. Renal pyramids project into central space called renal pyramids. It is where urine passes out into before it passes down the ureter.

Fig. 1.1 shows a section through a kidney.

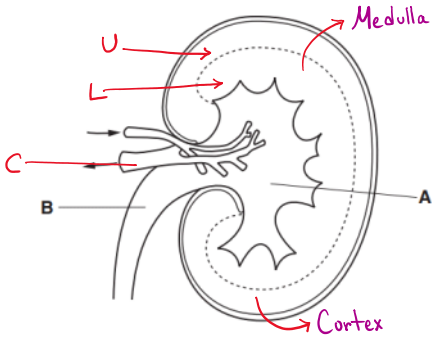


Fig. 1.1

(i) With reference to Fig. 1.1, name structures **A** and **B**.

A Pelvis

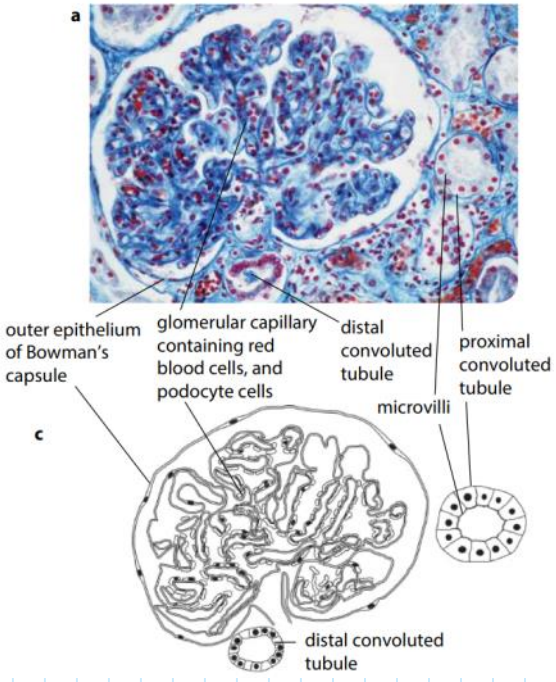
B Ureter

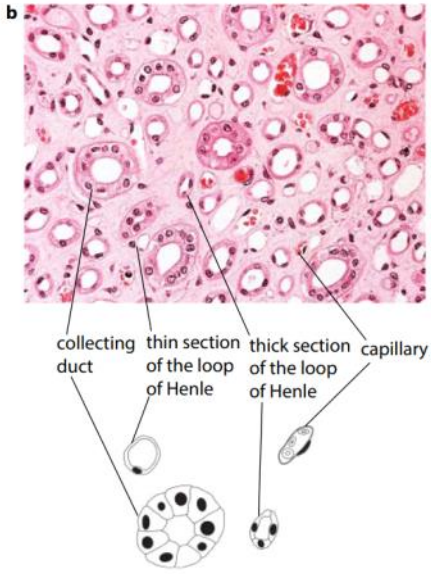
(ii) On Fig. 1.1, use label lines and letters to label where:

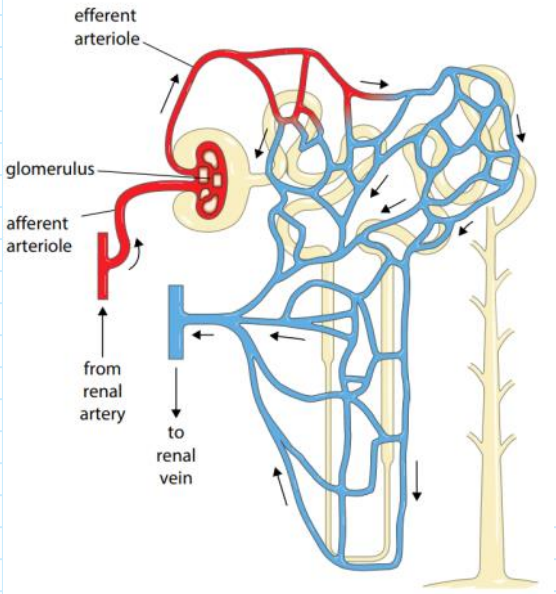
U – ultrafiltration occurs

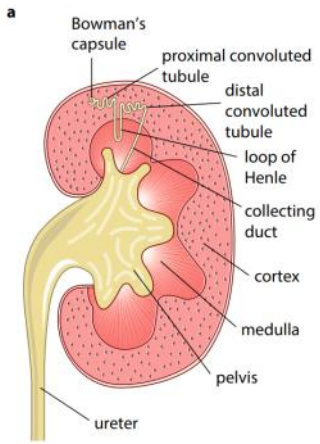
L – the loop of Henle is found

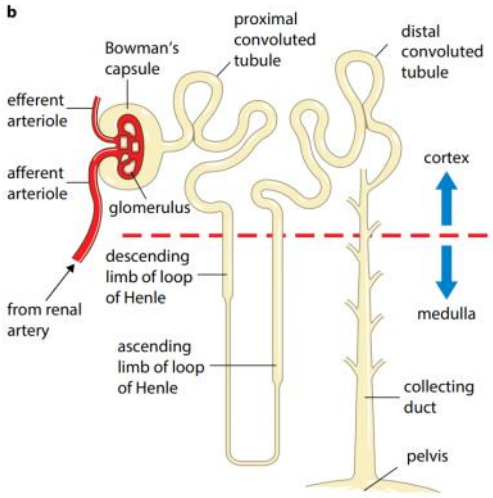
C – blood urea concentration is low.











1. Nephron is the functional unit of a kidney. At one end of the nephron in the cortex is the Bowman's capsule.
2. Below the capsule is the twisted region called proximal convoluted tubule which leads to Loop of Henle which runs deep into medulla and back out of the cortex where it forms another twisted region called distal convoluted tubule.
3. Distal convoluted tubule is connected to the collecting duct which runs through the medulla to the renal pelvis and carries urine to the renal pelvis.
4. Each nephron is supplied with blood by renal artery.
5. Renal artery branches into arterioles.
6. Afferent arteriole supplies blood to the Bowmans capsule and efferent arteriole takes away the blood from Bowmans capsule.
7. Afferent arteriole branches into knot of capillaries inside the Bowmans capsule to form the glomerulus.
8. These capillaries join up to form the afferent arteriole which leaves the Bowmans capsule to rejoin with the renal vein.

Fig. 6.1 is a diagram of a Bowman's (renal) capsule of a nephron from a mammalian kidney.

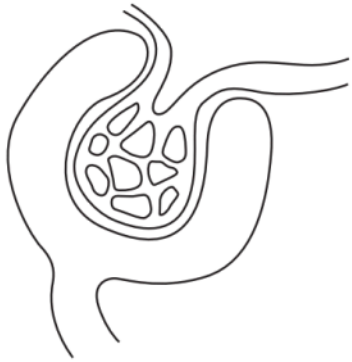


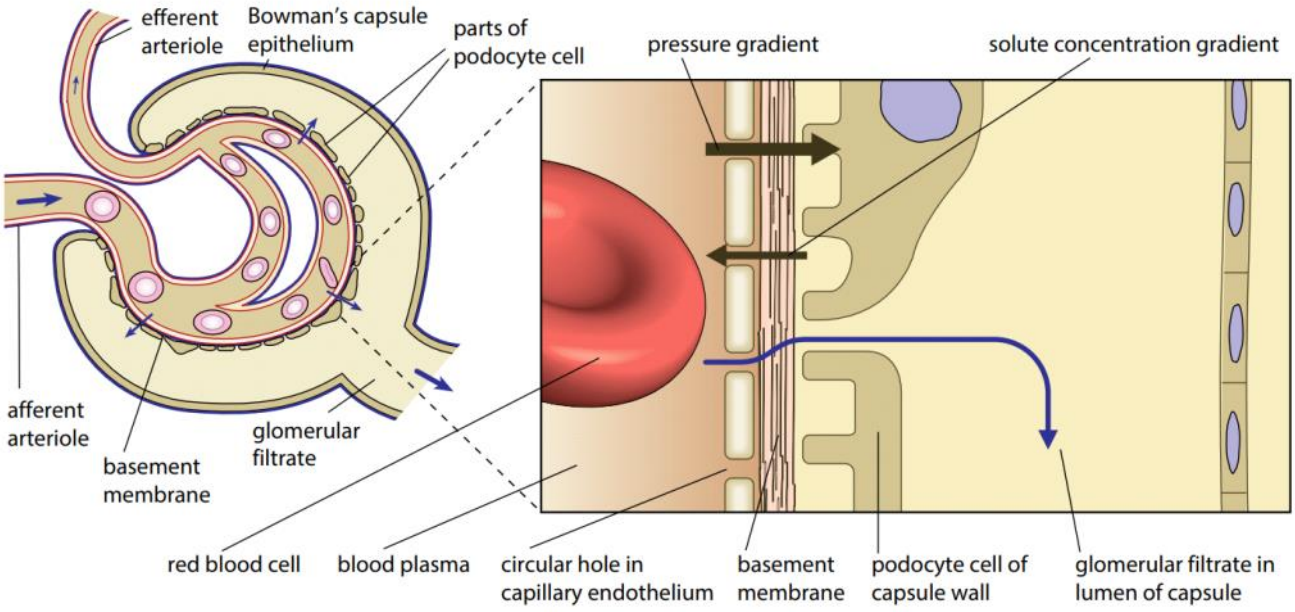
Fig. 6.1

On Fig. 6.1, use label lines and letters to label:

E – the efferent arteriole

G – the glomerulus

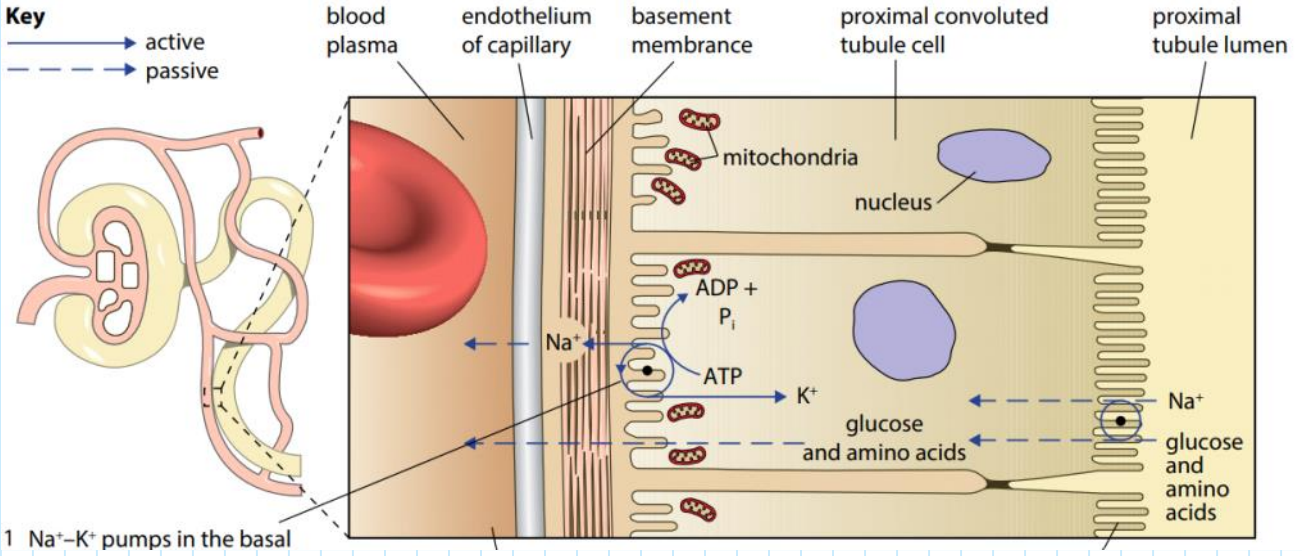
P – the region of podocyte cells.



- Diameter of lumen of afferent arteriole is wider than efferent arteriole.
- This leads to higher hydrostatic pressure of blood in capillaries of glomerulus.
- Bowmans capsule has lower hydrostatic pressure, so water potential gradient is built between glomerulus and Bowman's capsule as fluids pass from glomerulus to Bowman's capsule.
- Fluid from glomerulus pass through three layers.
- First through the first cell layer of endothelium which has tiny gap.
- Then through the second layer which is the basement membrane, made up of glycoprotein and collagen. It acts as a selective barrier and do not allow blood cells and large proteins to pass .
- Third layer is made up of epithelial cells which forms the inner lining of bowman's capsule and is made of cells known as podocytes.
- Finally the filtrate called glomerular filtrate is formed.

How the structure of epithelial cells of proximal convoluted tubule are adapted to its function.

1. Many microvilli on the surface facing the lumen of proximal convoluted tubule to increase the surface area for reabsorption of substances from filtrate in lumen.
2. Many transport proteins in the luminal membrane is present.
3. Tight junctions holds the adjacent cells together firmly to ensure that the fluid can't pass between cells and must pass through them.
4. Contains aquaporins for reabsorption of water.
5. Contains many mitochondrion which provide energy for Na^+ pump in the basal membrane of cells.
6. Selective reabsorption mostly occurs in proximal convoluted tubule.

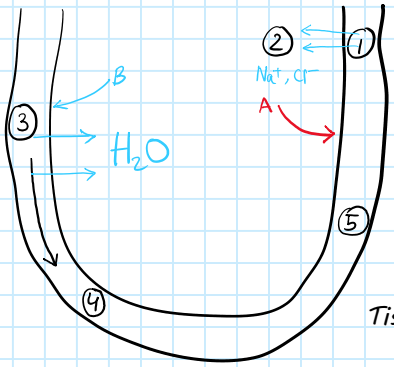


Process of selective reabsorption

1. Proximal convoluted tube contains microvilli in the lumen which increases the surface area for reabsorption.
2. Many mitochondria produce ATP which provide energy for the active transport of Na+/K+ pump in the basal membrane of PCT cell.
3. Na+ concentration in PCT cell is reduced and Na+ enters PCT cell from lumen.
4. Na+ enters PCT cell from lumen by facilitated diffusion through co-transporter proteins which bring in glucose and amino acids at the same time.
5. Vitamins and chloride ions are also reabsorbed.
6. Some water is reabsorbed by osmosis.
7. Urea is reabsorbed as it is a small molecule (URIC ACID IS NOT).
8. Creatinine is secreted into the lumen.

Reabsorption in the loop of Henle

Descending limb



Ascending limb

A is impermeable to water

B is permeable to water

Tissue fluid

Function of the loop of Henle: It creates very high concentration of sodium and chloride ions in the tissue fluid of medulla.

- Concentrated tissue fluid allows water to be reabsorbed from the fluid in the collecting duct as water flows through it.
- This produces very concentrated urine and allows the body to retain water.

HOW IT FUNCTIONS

- Sodium and chloride ions are pumped out of the ascending limb.
- This raises the concentration of sodium and chloride ion in the tissue fluid.
- This in turn cause water to move into the tissue fluid from the loop of Henle.
- Loss of water concentrates sodium and chloride in the descending limb.
- Sodium and chloride then diffuse out of the lower part of ascending limb.

Osmoregulation

The role of hypothalamus, posterior pituitary gland and ADH in osmoregulation.

1. Water potential of blood is constantly monitored by osmoreceptors in the hypothalamus.
2. If water potential is below the set point , nerve impulses are sent along the neurons to posterior pituitary gland and ADH is secreted into the blood.
3. ADH reaches the cells of collecting duct and bind to specific receptor on the cell surface membrane.
4. Binding of ADH activates a series of enzyme controlled reaction ending with formation of active phosphorylase enzyme.
5. Active phosphorylase causes vesicles containing aquaporins to fuse with the membrane of cells in the collecting duct and making it mire permeable to water.
6. More water moves out of the collecting duct by osmosis and into the tissue fluid and blood.
7. Urine is more concentrated, water concentration of blood is returned to normal.
8. ADH release is stopped and is broken down slowly.

Blood glucose regulation

Effect of insulin on muscle cells

- Causes glucose uptake
- Adds transport protein to cell surface membrane of muscle cells.
- Causes more glucose respiration.
- Causes more glucose conversion to glycogen.

When blood glucose level increases above normal

1. Increase in blood glucose concentration is detected by alpha and beta cells in the pancreas when blood flows through it.
2. Alpha cell responds by stopping secretion of glucagon.
3. Beta cell responds by starting secretion of insulin into the blood plasma.
4. Blood carries insulin to all parts of the body and insulin binds to specific receptors on the liver and muscle cells.
5. Receptor then signals the cells to move vesicle bound GLUT4 proteins to fuse with cell membrane, GLUT 4 facilitates the movement of glucose into cells.
6. Insulin stimulates activation of enzyme glucokinase which phosphorylates glucose, this traps the glucose as phosphorylate glucose can't pass through glucose transporters.
7. Insulin stimulates activation of phosphofructokinase and glycogen synthase which together catalyze the addition of glucose to glycogen- glycogenesis.

When blood glucose level decreases below normal

1. Alpha cells detect decrease in blood glucose concentration and secrets glucagon and beta cells respond by stopping secretion of insulin.
2. Glucagon binds to membrane receptor on cell surface membrane of liver cells and cause conformational change in the receptor which activates g-protein which in turn active adenylyl cyclase enzyme.
3. Activated adenylyl enzyme converts ATP to cAMP which is a second messenger molecule.
4. cAMP activates protein kinase A which initiates an enzyme cascade.
5. Enzyme cascade activates more by phosphorylation and leads to formation of activates glycogen kinase enzyme which breaks down glycogen to glucose.
6. This increases glucose concentration inside liver cells and glucose leaves the cells through GLUT 2 protein by facilitated diffusion.
7. Glucagon also stimulates formation of glucose from amino acids, glycerol, pyruvate and lactate.

Decrease in blood glucose concentration

When there is a decrease in blood glucose concentration, alpha and beta cells detect the change. Alpha cells respond by secreting glucagon and beta cells respond by stopping secretion of insulin.

Rate of glucose uptake decreases but uptake of glucose continues

Glucagon binds to different specific receptors as cell surface membrane of liver cells.

There are no glucagon receptors on muscle cells.

Describe how glucagon or adrenaline can stimulate liver cells to convert glycogen to glucose.

- Glucagon / adrenaline binds to the specific receptor on the cell surface membrane of liver cells and cause a conformational change in the receptor protein that activates a G-protein. This g-protein in turn activates the enzyme adenylyl cyclase, which (like the receptor) is also a part of the cell surface membrane.
- Adenylyl cyclase catalyzes the conversion of ATP to cyclic AMP which is a second messenger molecule.
- Molecules of cAMP binds to a protein Kinase A enzymes in the cytoplasm and activates them.
- Active protein kinase A enzymes activates phosphorylase kinase enzymes by adding phosphate groups to them.
- Activated phosphorylase kinase enzyme activates glycogen kinase enzymes by adding phosphate groups to them. This is an enzyme cascade that amplifies the original signal from glucagon.
- Activated glycogen kinase enzymes catalyzes the breakdown of glycogen to glucose - a process known as glycogenesis. This is done by removing glucose units from numerous ends of glycogen molecule.
- Concentration of glucose increases inside the cell and molecules of glucose leave the liver cells through the GLUT -2 transport proteins by facilitated diffusion.
- Glucagon also stimulates formation of glucose from amino acids, fatty acids, glycerol, pyruvate and lactate in a process called gluconeogenesis.

Blood glucose control

Blood glucose control is carried out by two hormones that are secreted by endocrine tissue in the pancreas. This tissue contains groups of cells called Islets of Langerhans.

The islets contain two types of cells:

1. α cells - glucagon
2. β cells - insulin

- α and β cells act as receptors, they detect rise in blood glucose as blood flows through the pancreas. When blood glucose concentration rises, α cells respond by stopping secretion of glucose and β cells respond by secreting insulin.
- Insulin is a protein and cannot pass through the cell surface membrane, insulin binds to specific receptors on many cell. For example liver cells, muscle cells, adipose (fat) tissue.
- Insulin also stimulates increase rate at which they absorb glucose from blood and convert it to glycogen.
- Insulin also increases use of glucose in respiration.
- Glucose can only enter cells by facilitated diffusion through transporter proteins called GLUT proteins. There are several types of GLUT proteins.
  - Brain cells have GLUT 1
  - Liver cells have GLUT 2
  - Muscle cells have GLUT 4

GLUT 1, GLUT 2 are always in the cell membrane and their distribution is not altered by insulin.

- GLUT proteins are kept in the cytoplasm in the same way as aquaporins. In collecting duct cells they bind to cell membrane when receptor signals the cell.
- Insulin stimulates the activation of enzyme glucokinase which phosphorylates glucose. This traps glucose inside the cell as phosphorylated glucose cannot leave the cell through GLUT proteins.
- Insulin stimulates two enzymes- phosphofructokinase and glycogen synthase-which together catalyzes the addition of glucose molecules to glycogen, process known as glycogenesis.

How urine dipsticks work

Test strips contain glucose oxidase and peroxidase enzymes for detecting glucose concentration.

The enzymes are immobilized on a small pad at one end of the stick, covering the pad is a cellulose membrane that only allows small molecules from urine to reach the enzymes.

The pad is immersed in urine for a brief period of time.

If urine contains glucose, glucose oxidase catalyzes a chemical reaction in which glucose is oxidized to gluconic acid, hydrogen peroxide is also produced.

$$\text{Glucose} + \text{oxygen} \xrightarrow{\text{Glucose oxidase}} \text{Gluconic acid} + \text{hydrogen peroxide}$$

Peroxidase catalyzes the reaction between hydrogen peroxide and colorless chemical in the pad to form a colored compound.

$$\text{Hydrogen peroxide} + \underset{\text{(colorless)}}{\text{Chromogen}} \longrightarrow \underset{\text{(Colorful)}}{\text{Oxidized Chromogen}} + \text{water}$$

Resulting color of pad is matched with color chart that shows colors that indicate different concentration of glucose, more the glucose the darker the color.

How biosensors work

Biosensor is a device that uses biological material such as an enzyme to measure the concentration of a chemical compound.

1. Biosensor uses immobilized glucose oxidase on a recognition layer.
2. Small sample of blood is tested.
3. Small molecules in blood plasma pass through the membrane.
4. Glucose molecules enter the active site of glucose oxidase enzyme. This catalyzes the reaction to produce gluconic acid and hydrogen peroxide.
5. Hydrogen peroxide is oxidized at an electrode that detects electron transfer.
6. Electron floe is proportional to glucose molecules in blood.
7. Biosensors amplifies the current which is read by a meter which produces a digital reading within seconds.

Advantages and disadvantages of test strip and biosensors·

Advantage of dipstick	Advantages of biosensor
1· It is non-invasive	1· Gives rapid reading
2· Painless	2· More accurate reading than dipstick or gives quantitative data·
3· Less risk of infection	3· Shows current blood glucose level
4· Easy to use	4· Can be used many times
5· Cheap	

Disadvantage of dipstick	Disadvantages of biosensor
1· Less precise	1· Expensive
2· Difficult to determine the result if color produced lies between two color in the color chart·	2· Painful
	3· Invasive

Homeostasis in plants

The structure of guard cell

- Thich cell wall that faces the stomatal pore·
- Thin cell wall that faces adjacent epidermal cells·
- Cell walls have no plasmodesmata·
- Folded cell surface membrane and contain many channel and carrier proteins·
- Many chloroplast and mitochondria·
- Chloroplasts have thylakoids but very few grana·
- Mitochondria have many cristae·
- Nucleus occupies large space as guard cell is small·
- Several vacuoles than one large one·
- Have bands of cellulose microfibrils around the cell·

Stomata closes due the following factors:

- Darkness
- Low humidity
- High temperature
- High rates of transportation
- Water stress/ less supply of water from roots

Advantage of stomata closing

- Water is retained inside

Disadvantage of stomata closing

- Supply of carbon dioxide decreases, so rate of photosynthesis decreases·

- Stomata responds to changes in environmental conditions by opening and closing itself.
- Opening and closing of stomata balances the need for carbon dioxide uptake by diffusion with the need to minimize water loss by transpiration.
- Stomata have daily rhythms of opening and closing.

Stomata opens when:

- Light intensity increases.
- Low carbon dioxide concentration in airspaces within the leaf.
- Guard cell open when they gain water by osmosis and become turgid.
- Guard cell closes when they lose water by osmosis and become flaccid.

Stomata opening

- Decrease in water potential inside the guard cell before water can enter by osmosis.
- In response to light, ATP -powered proton pumps in the membrane of guard cells pumps H^+ out of the guard cells.
- Low H^+ concentration and negative charge inside the cell causes potassium ion channels to open and K^+ diffuses into the cell down the electrochemical gradient.
- High concentration of K^+ inside the guard cells lowers water potential inside the cell.
- Water moves into the guard cell by osmosis down the water potential gradient.
- Entry of water increases the volume of guard cells so they expand.
- Thin outer wall expands more so cells curve apart.
- Starch stored in chloroplasts is broken down to form negatively charged malate ion which help maintain electrical balance and also decreases the water potential inside the guard cell.

Stomata closing

- Stomata close when guard cells become flaccid by losing water.
- H^+ protein pumps are stopped.
- K^+ leaves the guard cells.
- Malate ions return to chloroplasts to convert to starch.
- These events cause water potential to rise within guard cells and water leaves the guard cells down the water potential gradient by osmosis.
- This causes guard cells to become flaccid and close the stomata.

Role of abscisic acid (ABA) min the closure of stomata during drought.

- ABA is a stress hormone and is produced during drought.
- ABA binds to the receptor in the cell surface membrane of the guard cells which leads to inhibition of proton pumps.
- H+ ions are not pumped out of the cytoplasm of the guard cell.
- ABA also stimulates the movement of Ca^{2+} into the cytoplasm and tonoplast through the cell surface membrane of the guard cell.
- Ca^{2+} ats as secondary messenger molecule to activate channel proteins to open.
- This allows Cl^- ions to leave the guard cell.
- This in turn stimulates more channel proteins to open and K^+ ions to leave the guard cell. At the same time channel proteins that allow K^+ to enter are closed.
- The loss of ions increases the water potential of the cell and water leaves the cell by osmosis.
- The volume of cell decreases, the cell becomes flaccid closing the stoma.