



# HOMEOSTASIS

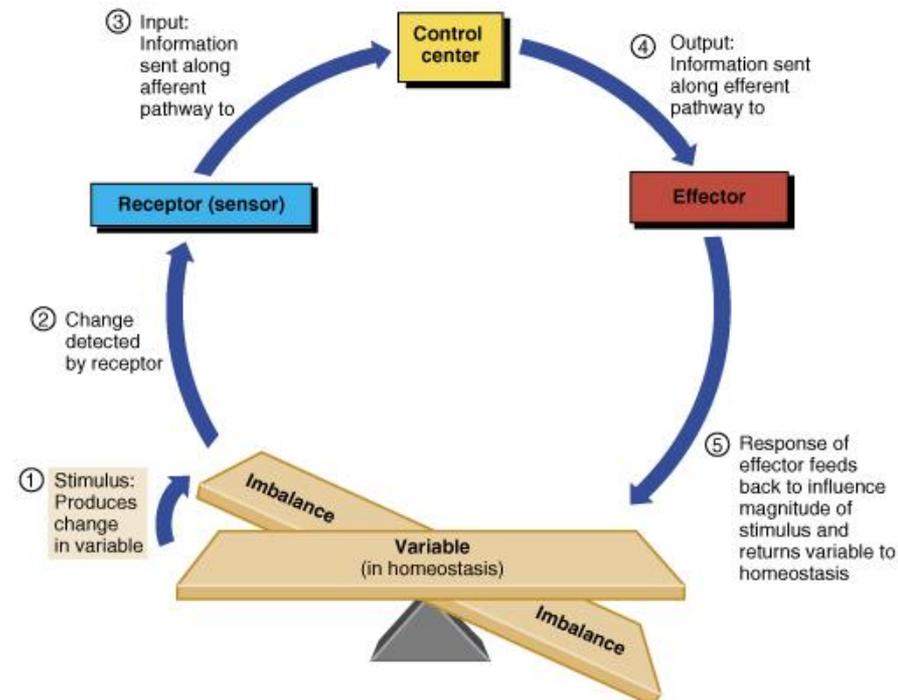
## 3 Parts!

1. Osmoregulation
2. Control of Glucose Concentration
3. *Plant Hormones*



# Homeostasis

- Homeostasis = **maintenance of constant internal environment**
- Keep **set-point** stable within narrow limits in body
- Irrespective of changes in external environment
  
- Factors such as **temperature, water potential, glucose concentration** must be maintained in the tissue fluid bcs it affects cell function
- So that internal environment can:
  - Be stable
  - Function optimally
  
- Control systems often work by using the **negative feedback mechanism**

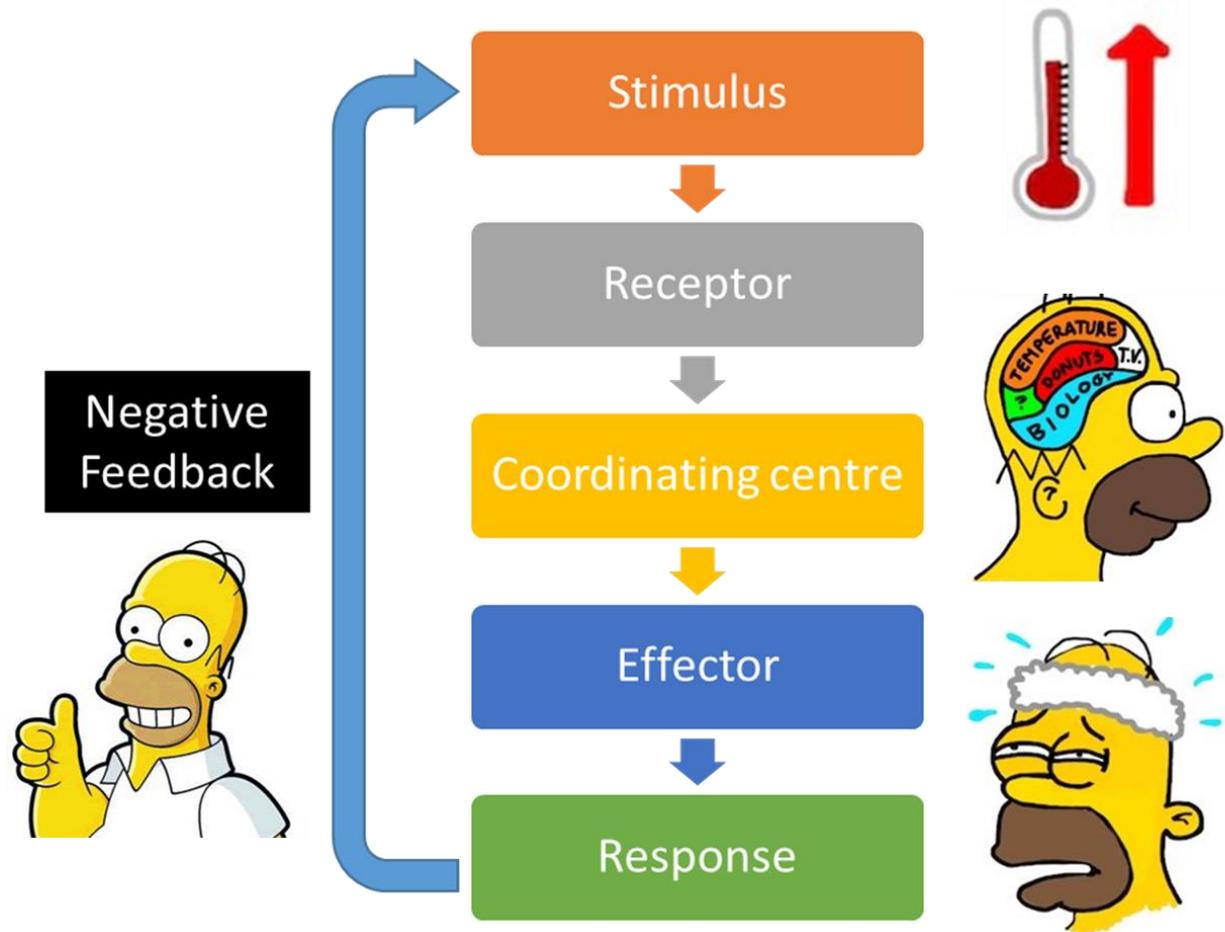


# Negative Feedback

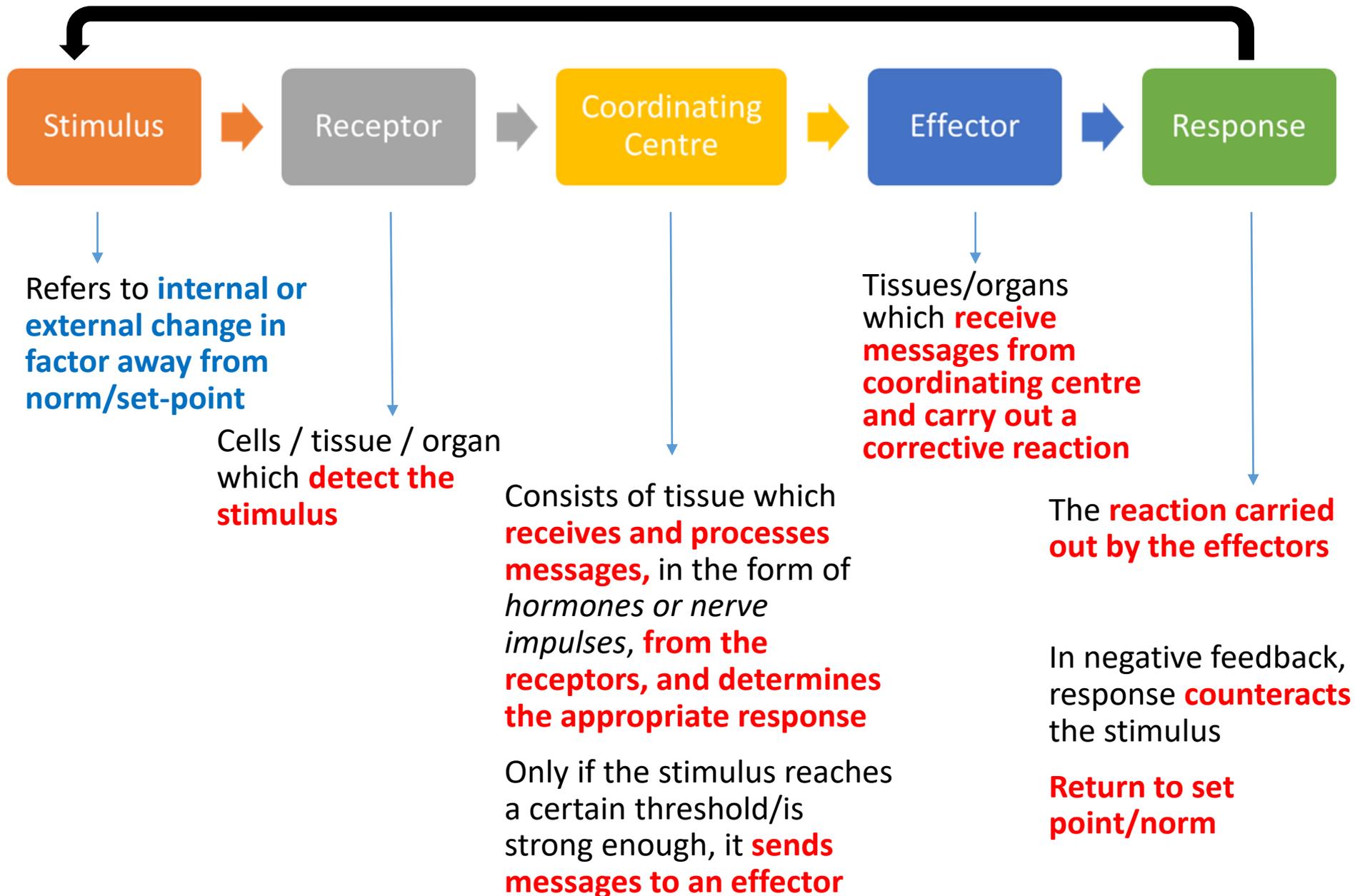
## Components needed:

- Stimulus
- Receptor
- Control center
- Effector
- Response

→ Restoration of  
norm or set point

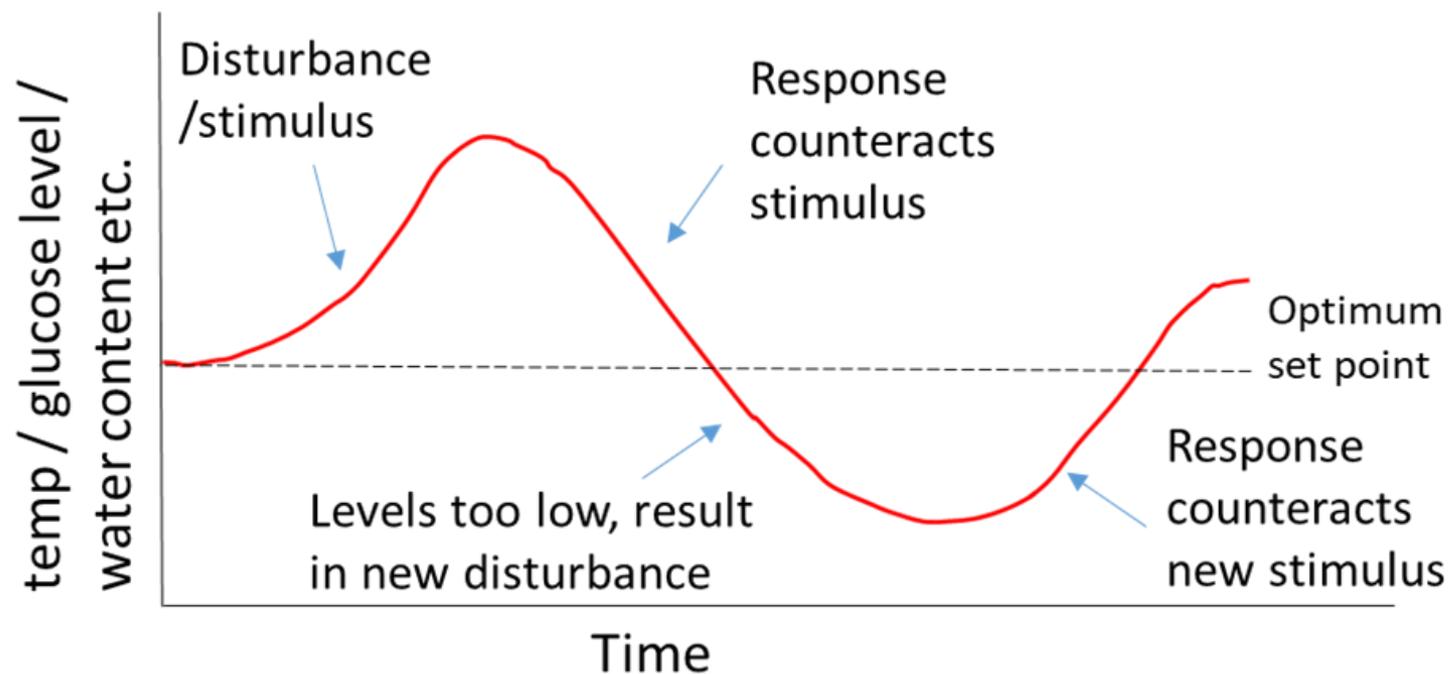


# Negative Feedback Mechanism



# Negative Feedback

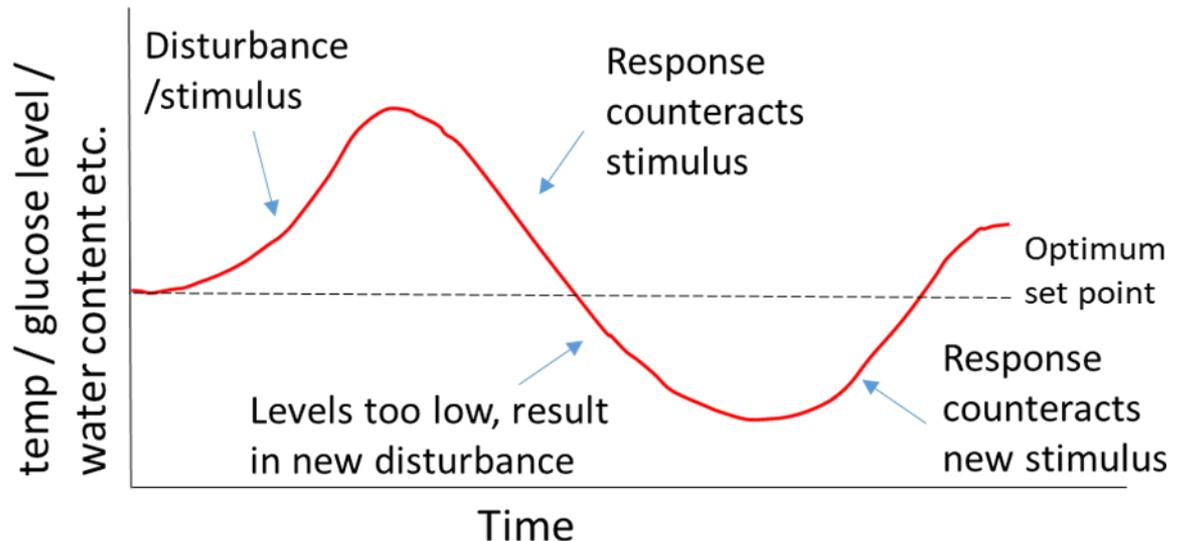
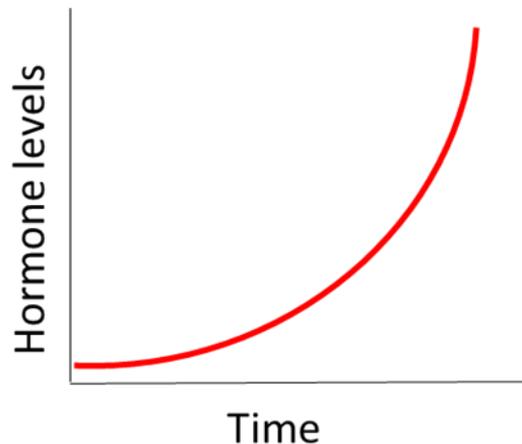
- Continuous monitoring of the factor affecting the internal environment
- Results in many “corrective actions”
- Factor thus **fluctuates around the norm/set point**



# Positive Feedback vs Negative Feedback

- Response reinforce the original stimulus
- Very uncommon
- Response worsen / intensifies the initial change
  
- E.g. labor pains, ripening of fruit, inhalation of CO<sub>2</sub>

- Response **counteracts** the original stimulus
- Common in the body
- To **maintain homeostasis** / stable internal environment
  
- E.g. maintaining blood glucose levels, temperature, oxygen levels, water content in blood etc.



# Chapter Outline

## Intro to Homeostasis

- Importance of homeostasis
- **Negative feedback**
- The role of nervous system and endocrine system in homeostasis

## Part 1: Osmoregulation

- Deamination and the urea cycle
- Structure of kidney
- Structure of nephron
- Mechanism of excretion in the kidney
  1. **Ultrafiltration**
  2. **Selective reabsorption**
- **Osmoregulation**

# Chapter Outline

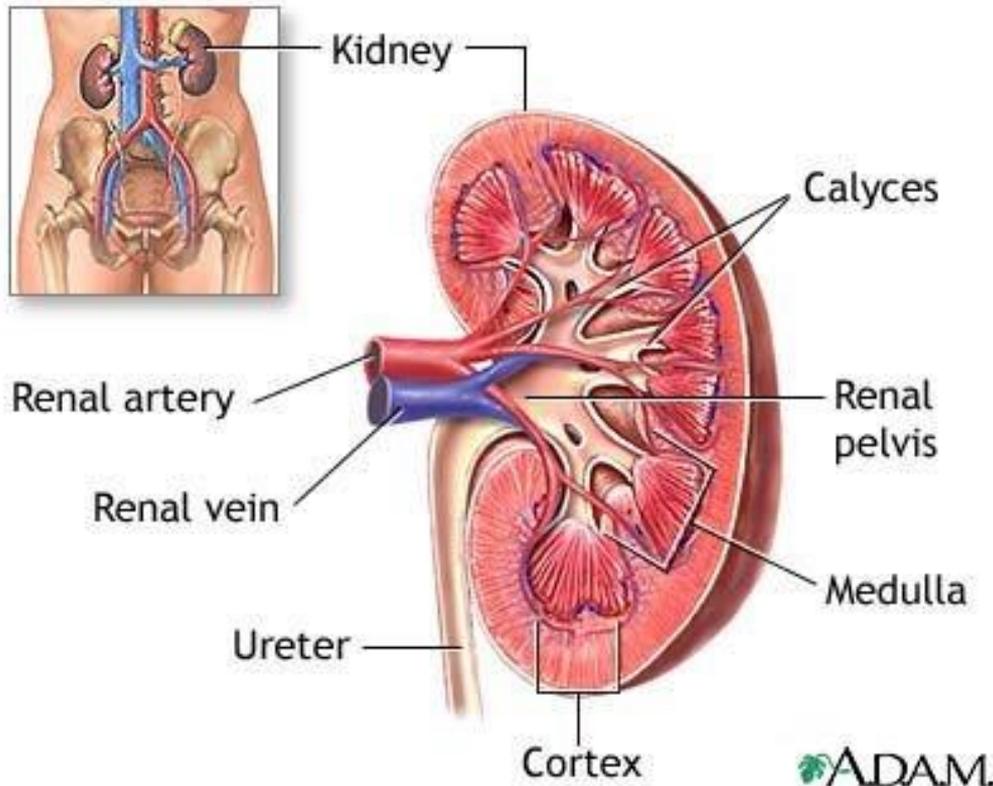
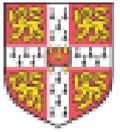
## **Part 2: Control of Blood Glucose Concentration**

- Endocrine vs Exocrine Glands
- Hormones + Receptors
- The Pancreas
- **Insulin vs Glucagon**
- **Glucagon and Adrenaline**
  - **cAMP = second messenger**
- Diabetes mellitus
- Urine Analysis, Dip Stick Tests and Biosensors

# Chapter Outline

## **Part 3: Homeostasis in Plants** (to be continued later...)

- Stomata
- Structure and Function of Guard Cells
- Stoma Opening and Closing Mechanism
- Role of **Abscisic Acid** During Water Stress
  - calcium ions = second messenger



A2 Level Chapter 14  
**HOMEOSTASIS**  
**PART 1 of 3**  
**OSMOREGULATION**

# Chapter Outline

## Part 1: Osmoregulation

- Deamination and the urea cycle
- Structure of kidney
- Structure of nephron
- Mechanism of excretion in the kidney
  - 1. Ultrafiltration**
  - 2. Selective reabsorption**
- **Osmoregulation**

# Excretion

Removal of unwanted products of metabolism

→ Toxic, poisonous, will cause damage to tissues

Main excretory products:

a) **Carbon dioxide**

→ From **aerobic respiration**

→ Excreted via **bloodstream** (refer to Chap 8) and **lungs**

b) **Urea** (nitrogenous waste)

→ Produced in **liver**

→ From **excess amino acids**

→ Excreted via **kidneys**

c) Creatinine (N waste)

→ Small amounts produced in liver

→ From certain amino acids

→ Most used as energy storage in muscles

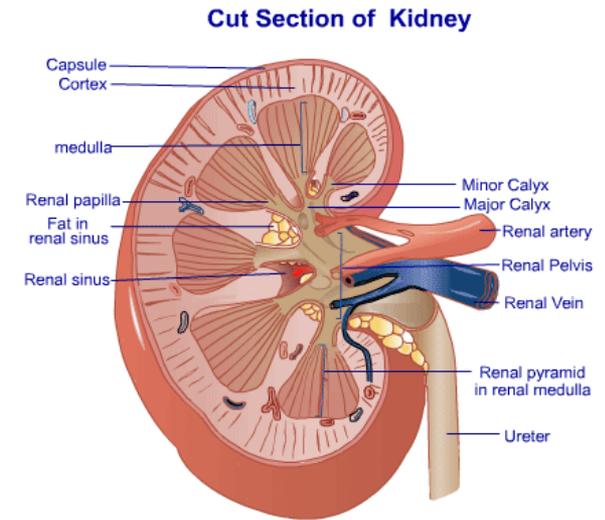
→ Excreted via kidneys

d) Uric acid (N waste)

→ Produced in liver

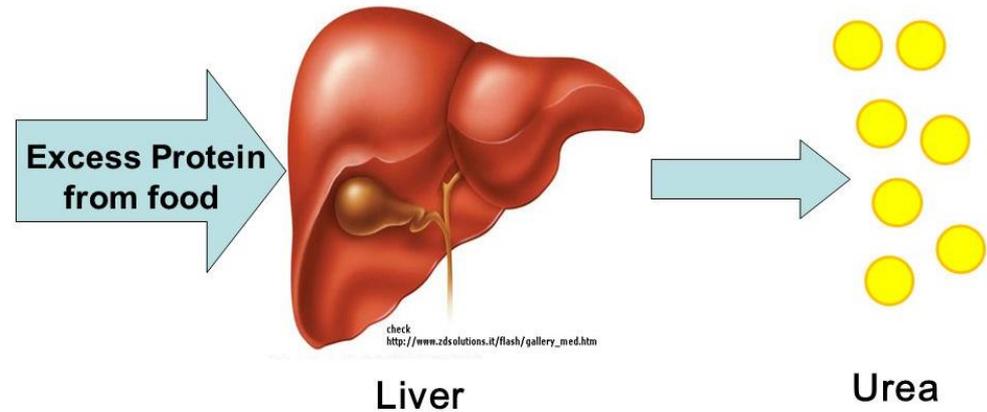
→ From excess purines of nucleotides

→ Excreted via kidneys



# Urea

- Main nitrogenous excretory product
- Formed from **excess amino acids**
- In **liver cells**



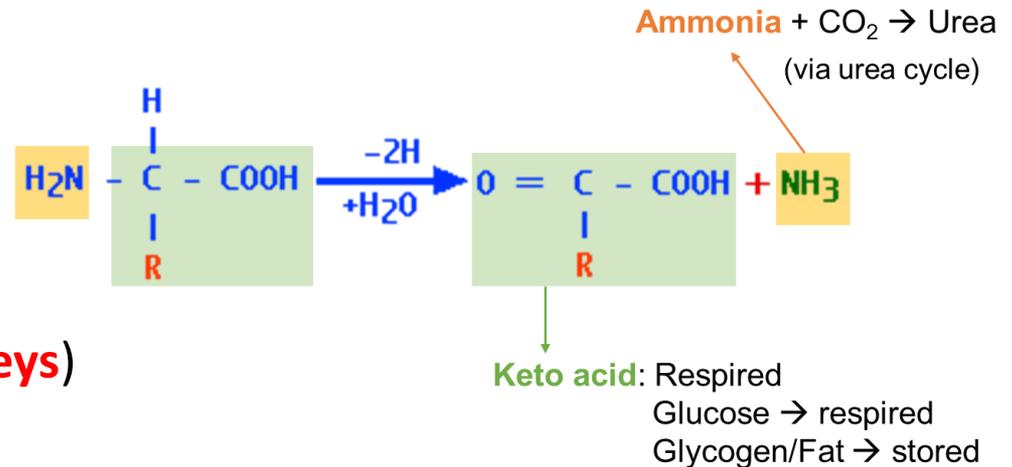
## 1. Deamination

- Remove **amine group** and a **H atom** from amino acid
- Produce **ammonia, NH<sub>3</sub>**
- Toxic if allowed to accumulate

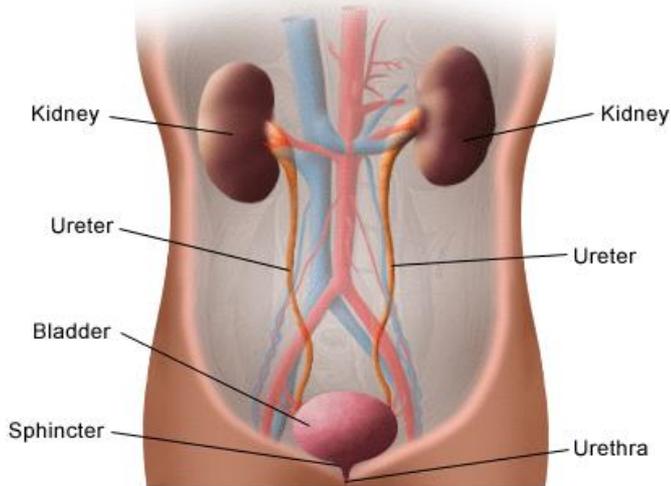
## 2. Urea cycle (aka ornithine cycle)

**NH<sub>3</sub> + CO<sub>2</sub> → urea** → excreted (**kidneys**)

- **Keto acid** remains → respired or converted to glucose/glycogen/fat



Front View of Urinary Tract



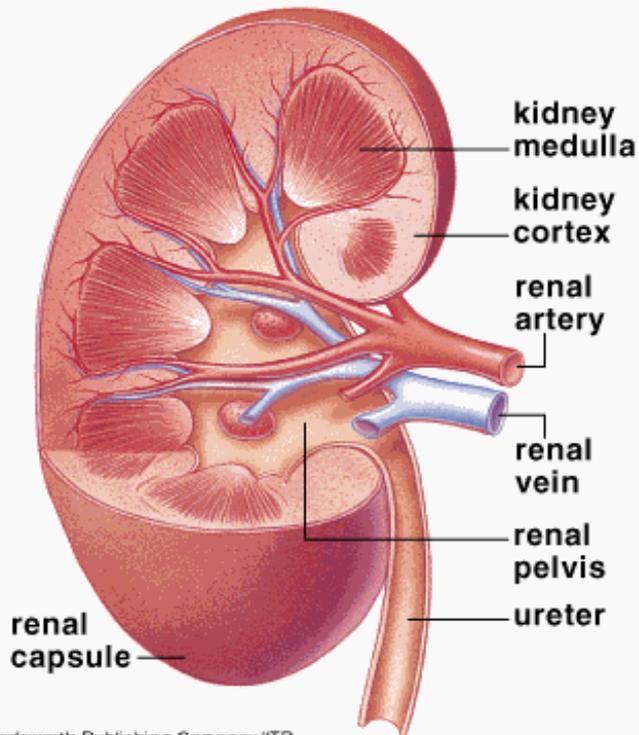
# Structure of the Kidney

## Blood vessels

- **Renal artery** (in)
- **Renal vein** (out)

## Excretory tubes

- **Ureter**
  - urine out from kidney into urinary bladder
- **Urethra**
  - urine out from urinary bladder



# Structure of the Kidney

- **Capsule**

→ Tough, protective layer

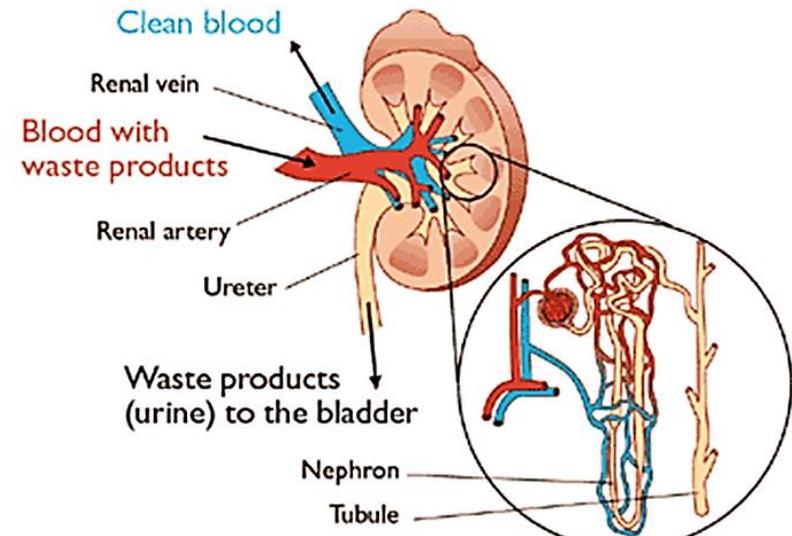
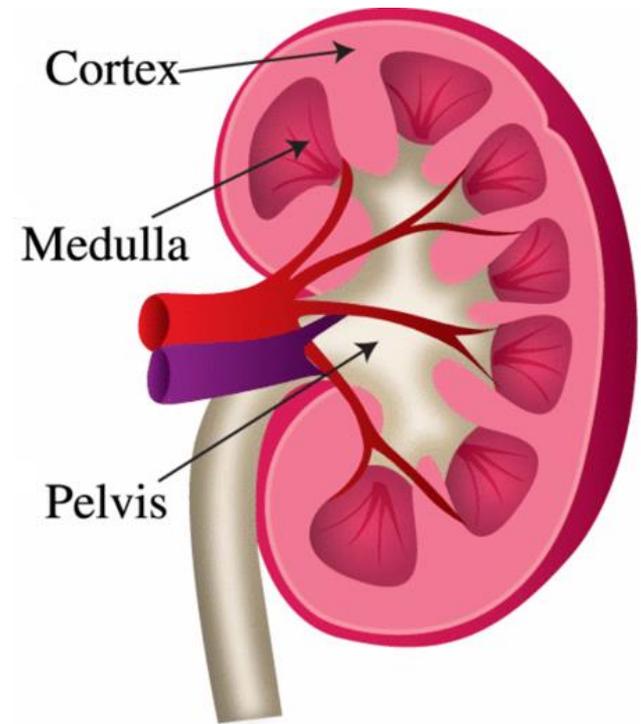
- 3 main regions:

a) **Cortex**

b) **Medulla**

c) **Pelvis**

- **Nephrons** – tiny tubes in the kidney in cortex and medulla



# Structure of a Nephron

1) **Bowman's capsule** @ cortex

aka renal capsule

2) **Proximal convoluted tubule** @ cortex

3) **Loop of Henle** @ Medulla

Subdivided to:

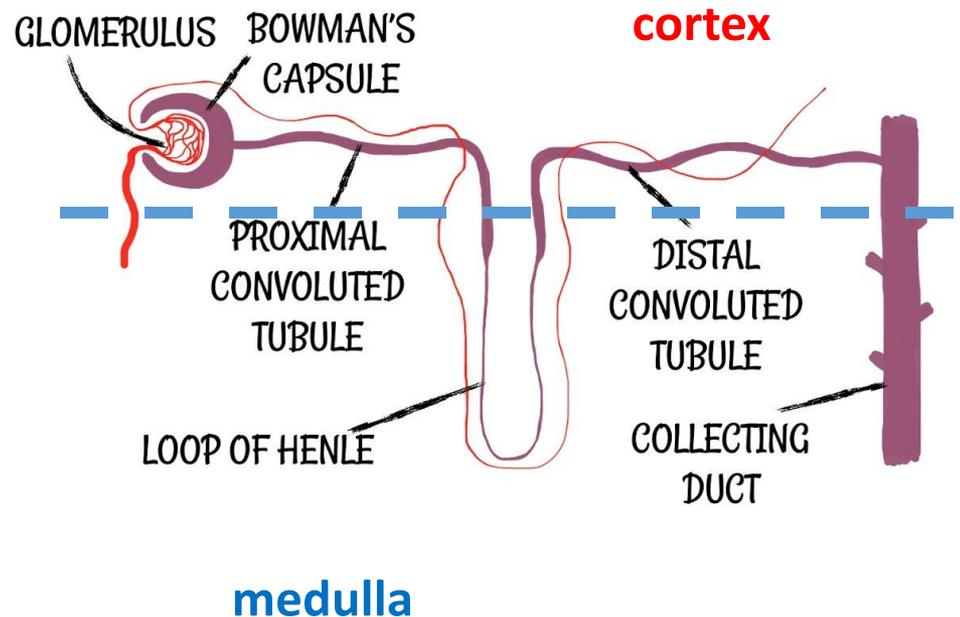
a) **Descending limb**

b) **Ascending limb**

4) **Distal convoluted tubule** @ cortex

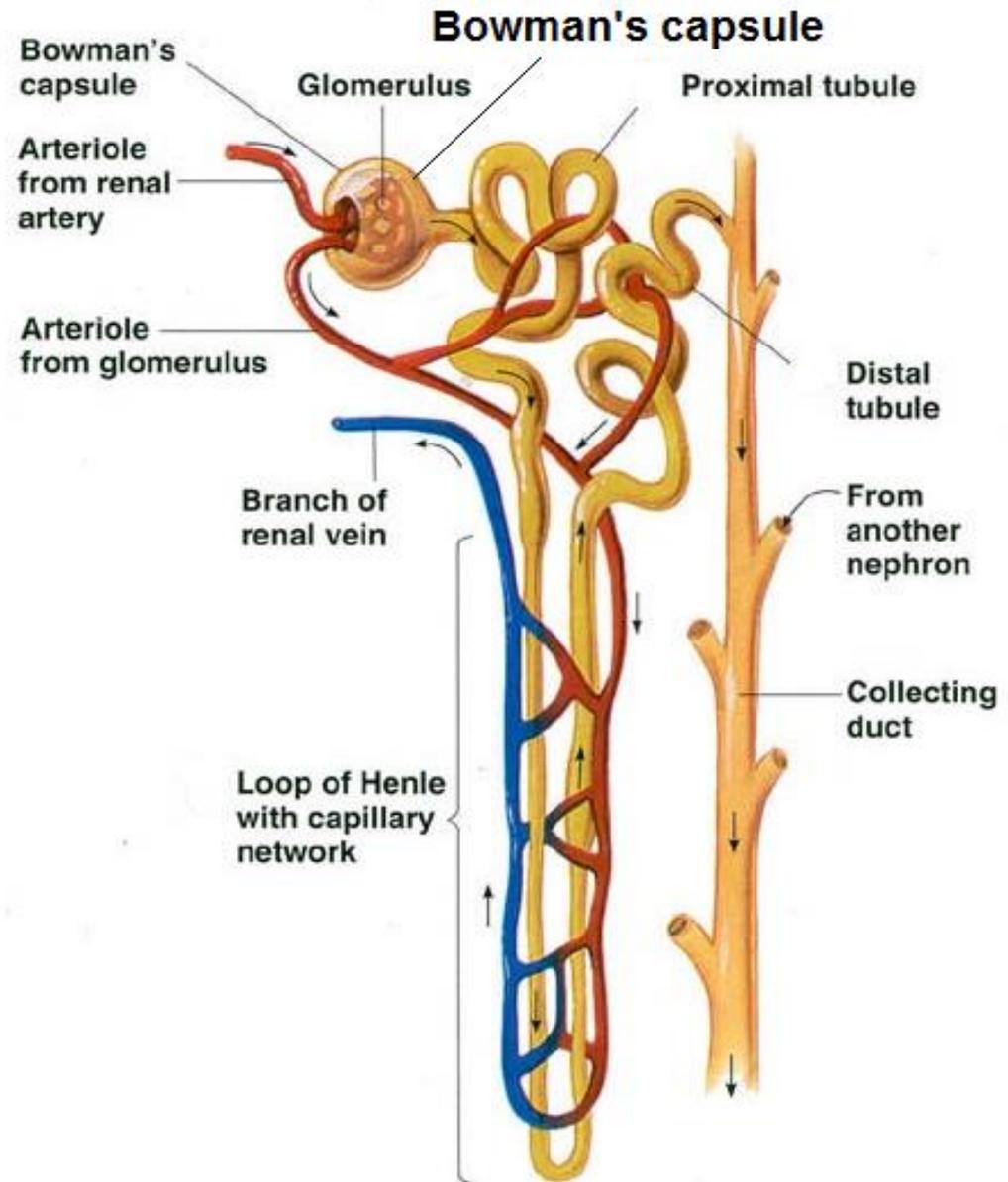
5) **Collecting duct** @ medulla

→ **Ureter** @ pelvis

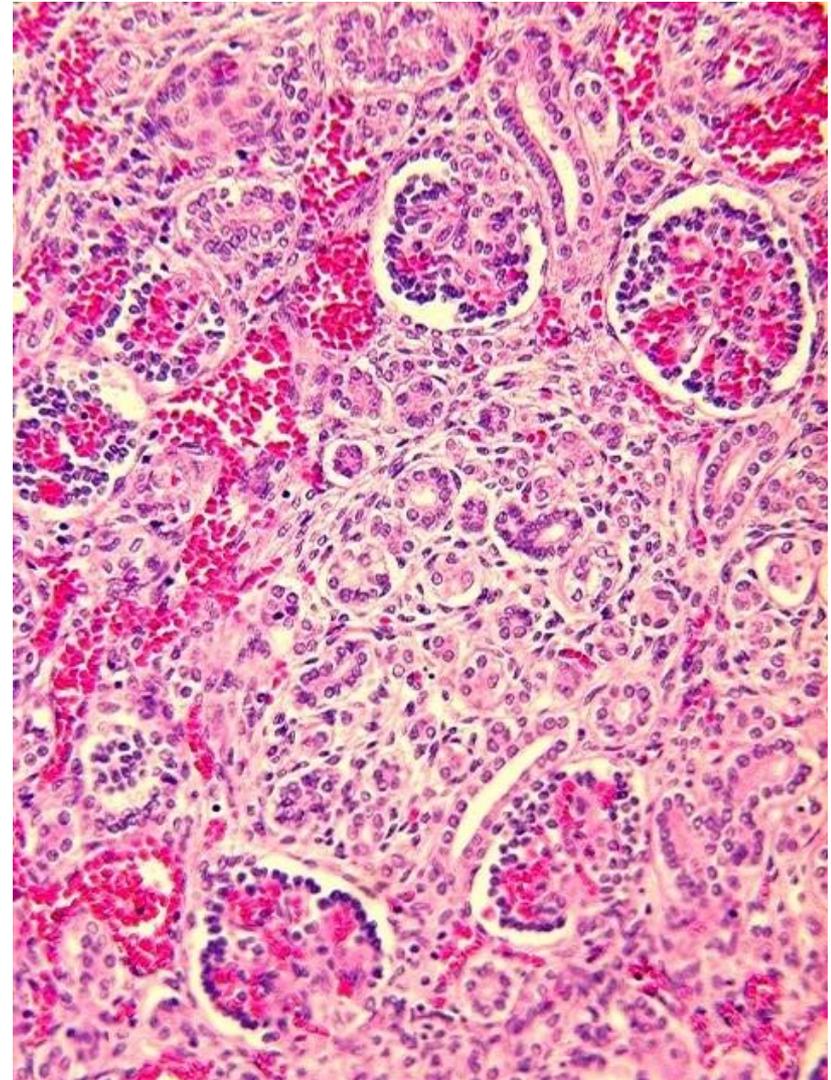
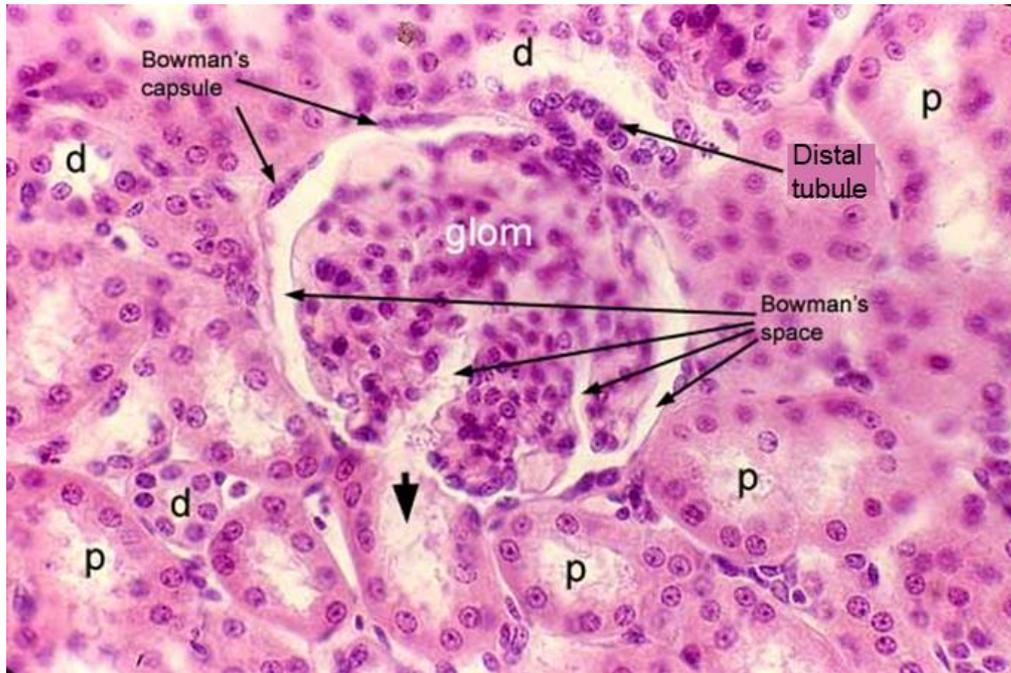


# Structure of a Nephron

- Branch of renal artery
  - **Afferent arteriole**
  - **Glomerulus**  
(tangle of capillaries in the 'cup' of the capsule)
  - **Efferent arteriole**
  - **Network of blood capillaries**  
surrounding the rest of the nephron
- Branch of renal vein



# Photomicrograph of the Cortex



# Mechanism of Excretion in the Kidneys

- 2 stages:

## **1) Ultrafiltration**

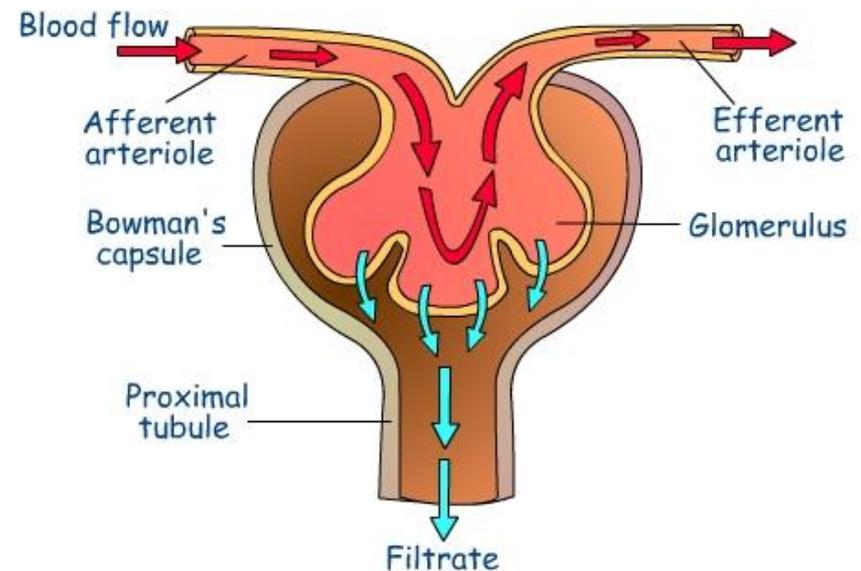
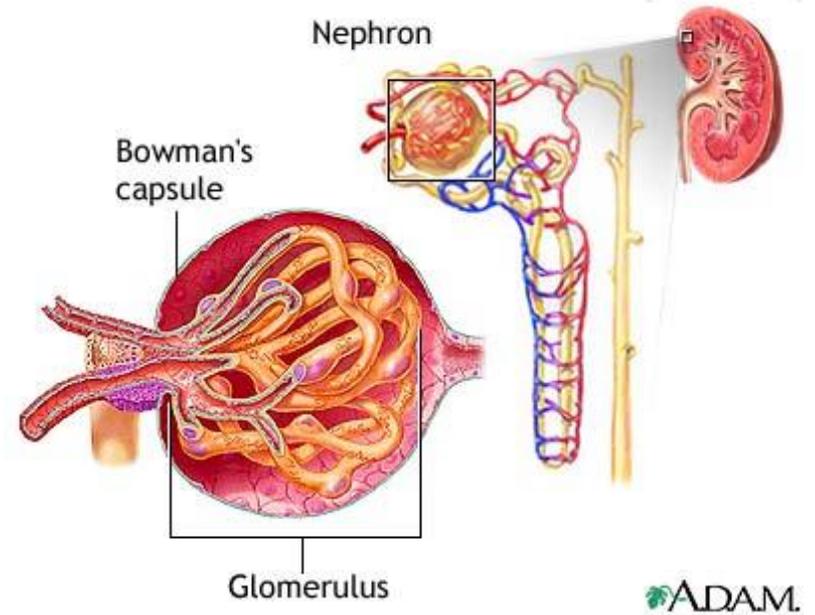
- Filtering of small molecules, incl. urea out of the blood  
@ Bowman's capsule

## **2) Selective Reabsorption**

- Absorbing any useful molecules from fluid in nephron  
@ proximal convoluted tubules, loop of Henle, distal convoluted tubule and collecting duct

# Ultrafiltration

- Filtering of small molecules, incl. urea
- Out of the **blood in glomerulus**
- Into **filtrate in Bowman's capsule space/lumen**
  
- Glomerular filtrate is produced
- Flows along the entire nephron
- Into ureter



# Ultrafiltration

## Structure of Glomerular Wall and Bowman's Capsule Wall

Blood in glomerulus is separated from lumen of Bowman's capsule by 3 layers:

### 1) **Endothelium** of blood capillaries of the glomerulus

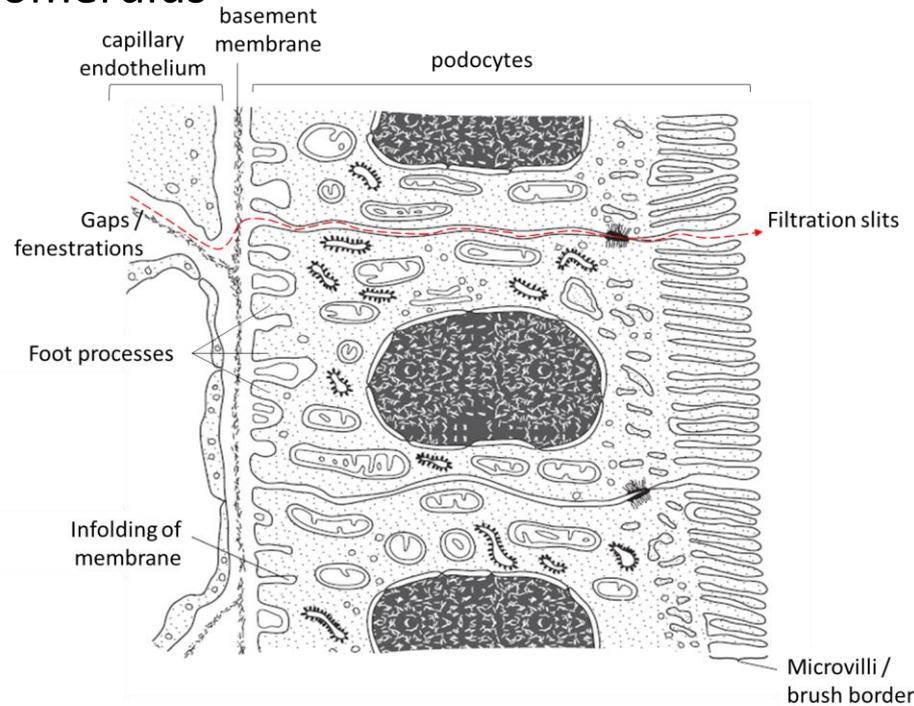
- with many more **gaps / fenestrations**

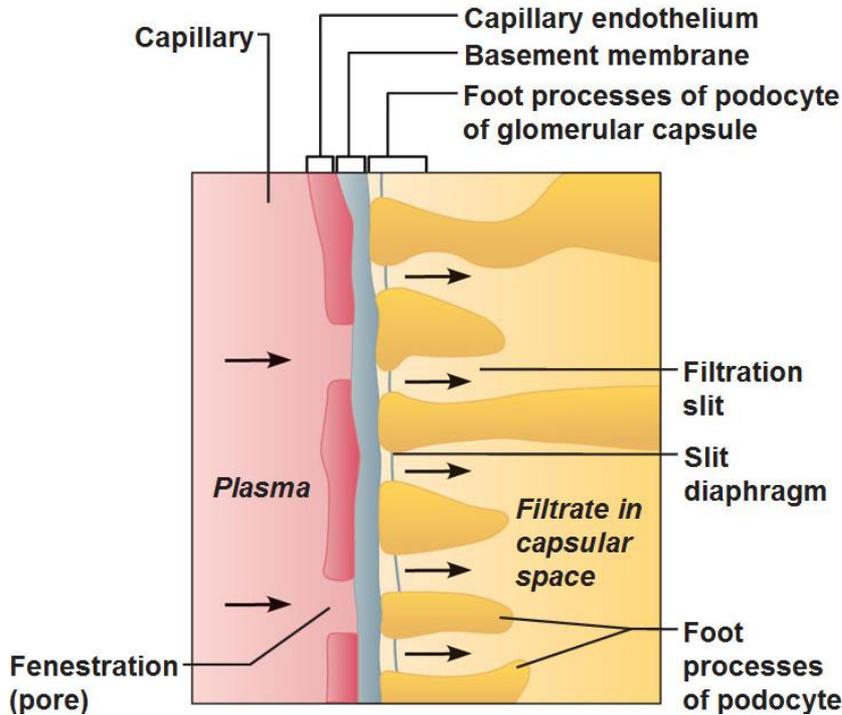
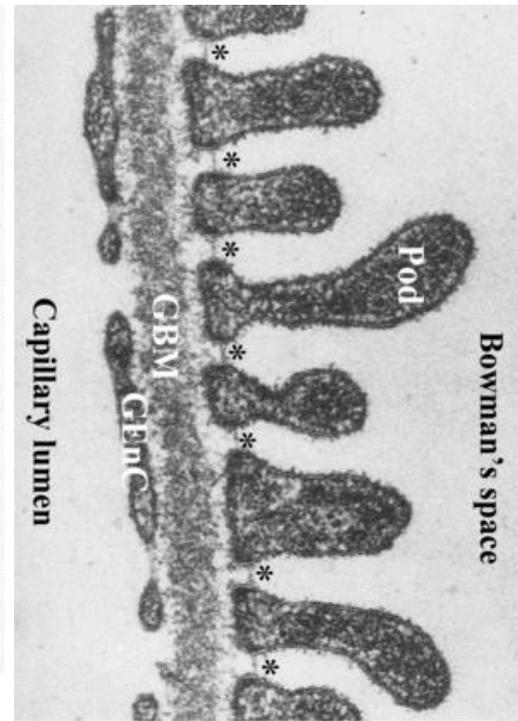
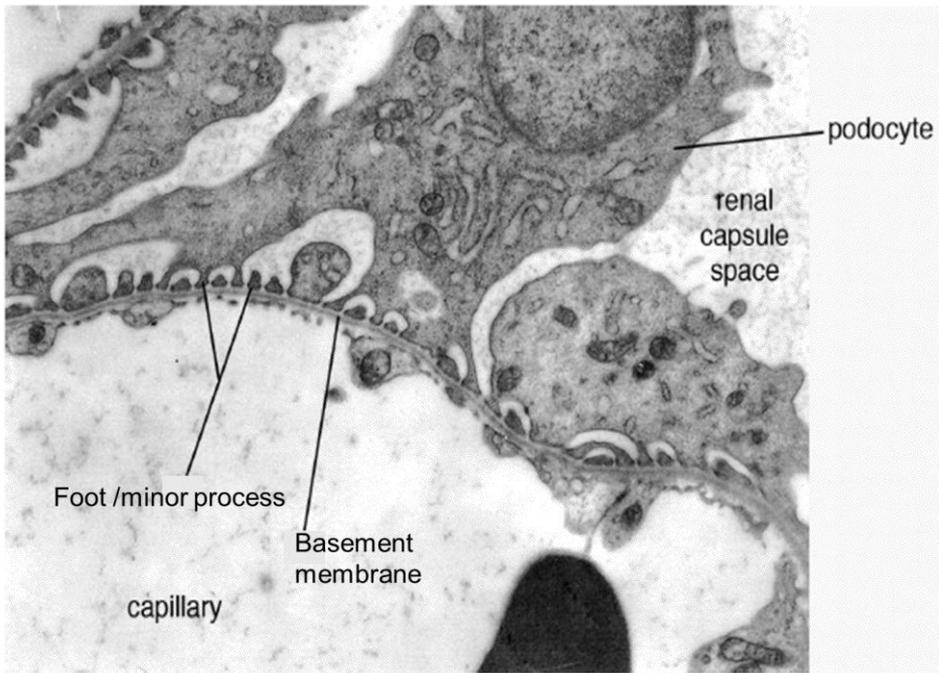
### 2) **Basement membrane**

- Mesh of collagen and glycoprotein fibres
- Acts as main selective barrier/ filter

### 3) **Epithelial cells of Bowman's capsule (podocytes)**

- Inner lining of Bowman's capsule
- Wrap around capillaries of the glomerulus
- **Podocytes** have many **finger-like projections** that forms **gaps / filtration slits**





# Ultrafiltration

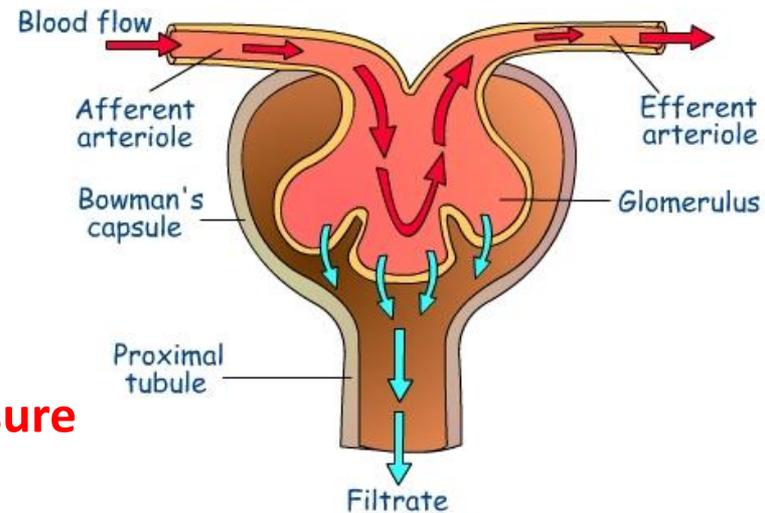
How is the structure is adapted for ultrafiltration?

1) **Many large gaps in capillary endothelium + filtration slits between foot processes of podocytes**

- Allow movement of substances from blood plasma easily into Bowman's capsule lumen

2) Diameter of the lumen of **afferent arteriole is wider than efferent arterioles**

- Leads to **high blood pressure / hydrostatic pressure** in the glomerulus than the Bowman's capsule
- Fluid forced out of glomerulus into Bowman's capsule



# Ultrafiltration

How is the structure is adapted for ultrafiltration?

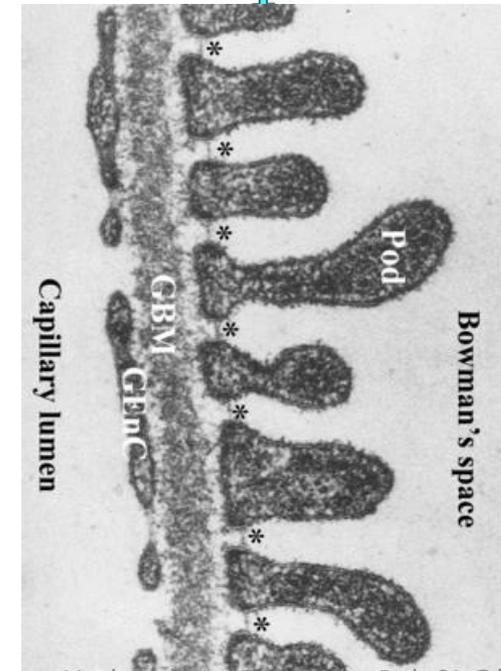
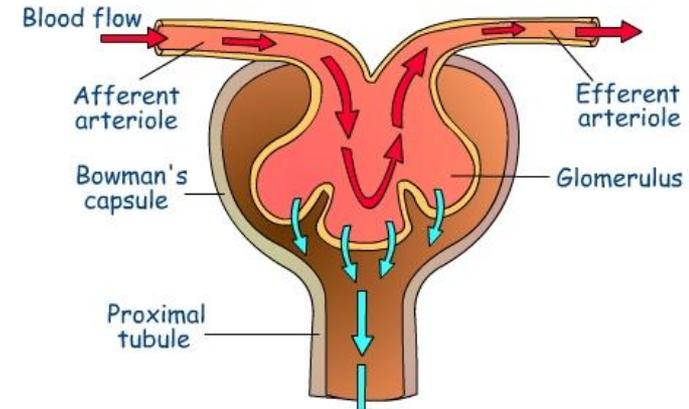
### 3) Basement membrane acts as a filter

→ Prevents RBCs, WBCs & large plasma proteins (RMM > 68 000Da) from passing through

Resulting **glomerular filtrate** contains:

- **No cells and large proteins**
- Soluble molecules: **Water, amino acids, glucose, urea, inorganic ions ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$ )**, uric acid, creatinine, vitamins

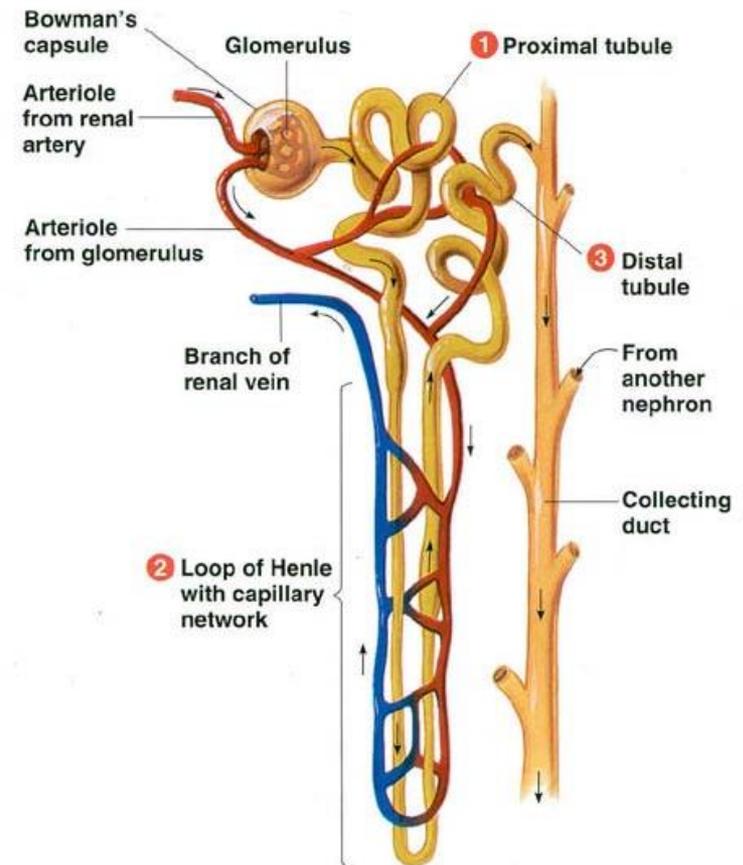
→ **Glomerular filtrate** passes through gaps between **podocytes** and into **renal capsule**



## 2) Selective Reabsorption

- Necessary
- **To reabsorb essential substances from filtrate / renal fluid**
- **Back into blood**
- Selective reabsorption so only certain substances are reabsorbed
- E.g. Glucose, amino acids, vitamins,  $\text{Cl}^-$ ,  $\text{Na}^+$ ,  $\text{H}_2\text{O}$

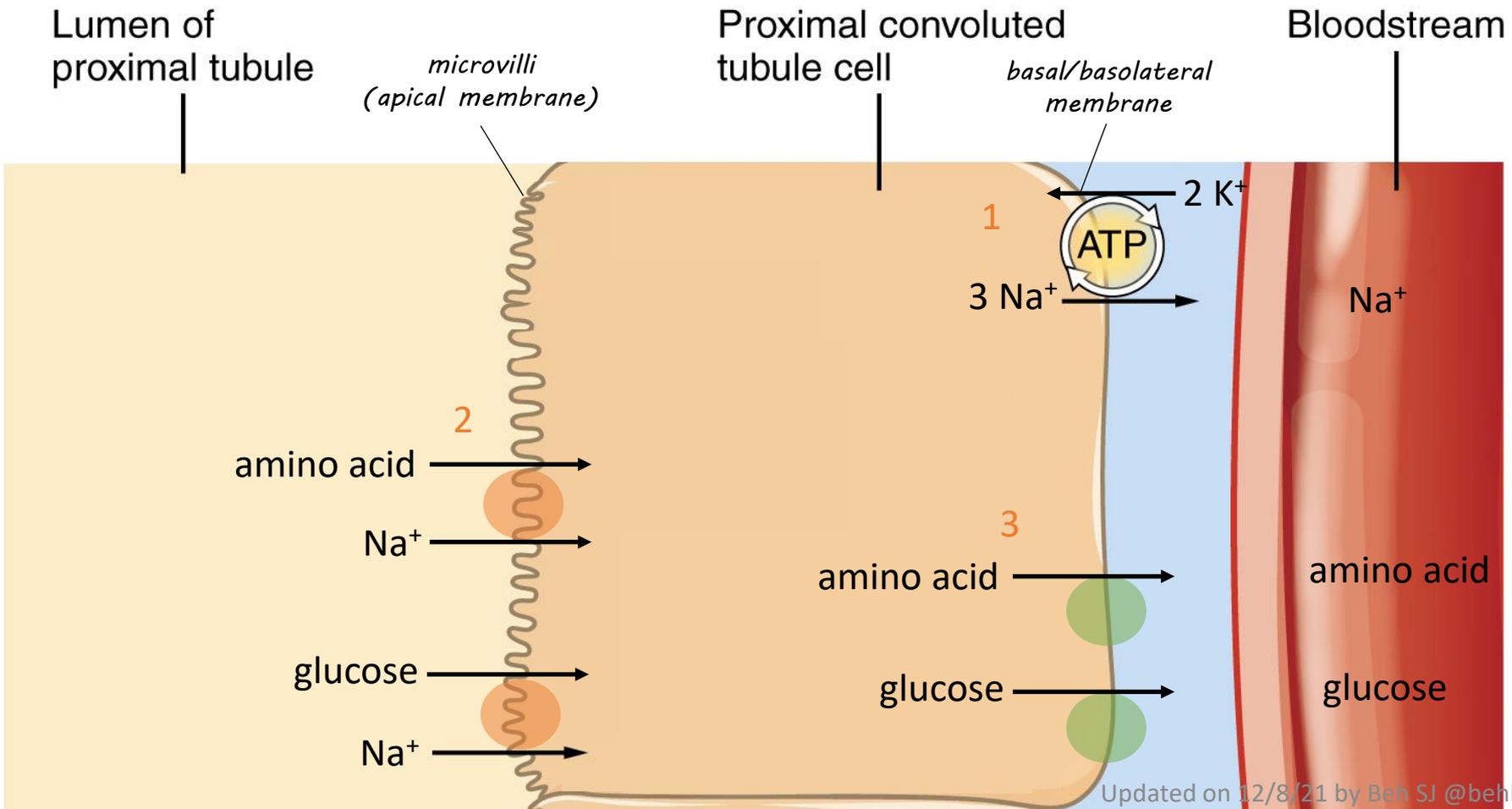
@ proximal convoluted tubules, loop of Henle, distal convoluted tubule and collecting duct



# Selective Reabsorption

## @Proximal Convoluted Tubule (PCT)

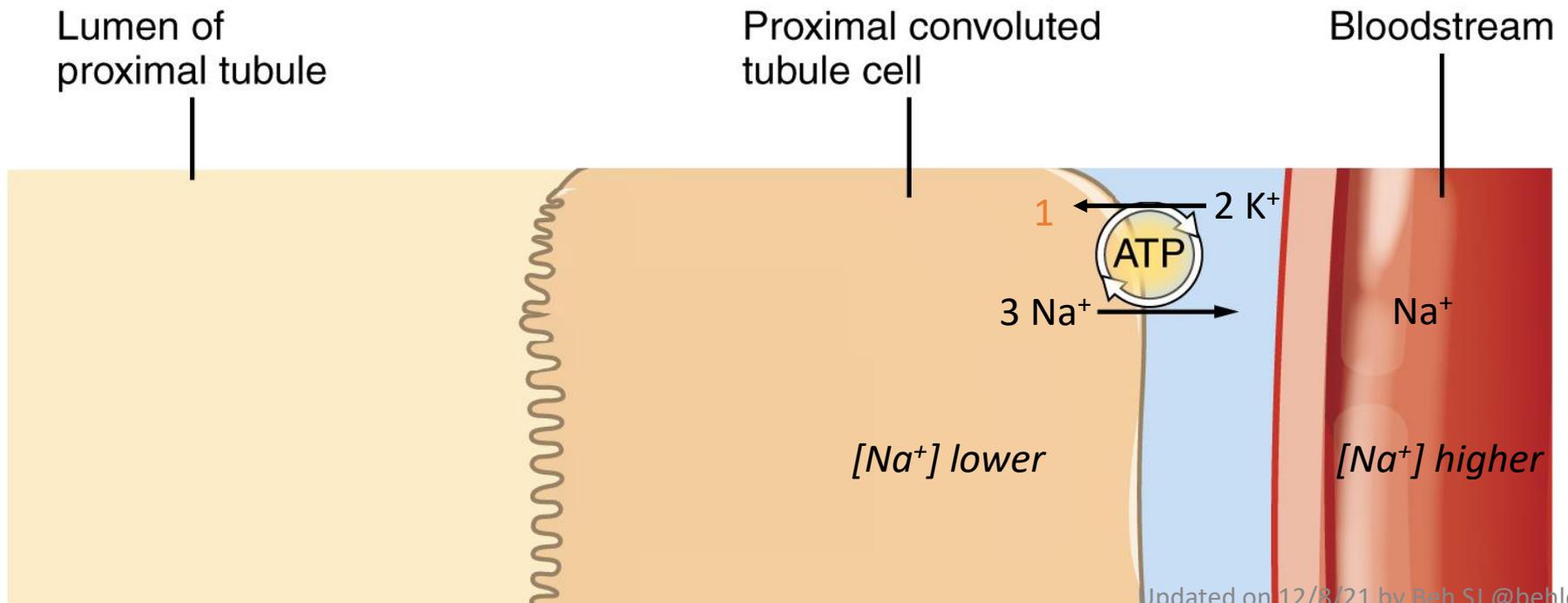
- Main site for **glucose / amino acid / vitamin / Cl<sup>-</sup> active reabsorption**
- **Most water passively reabsorbed here (65%)**
- Walls made of single layer of cuboidal epithelial cells



# Selective Reabsorption @Proximal Convoluted Tubule (PCT)

## 1. Active transport of $\text{Na}^+$ ions

- From PCT cells into blood in capillary
- via  $\text{Na}^+/\text{K}^+$  pumps
- Concentration of  $\text{Na}^+$  ions in the PCT cell decreases
- Concentration gradient formed



# Selective Reabsorption

## @Proximal Convoluted Tubule (PCT)

2. **Na<sup>+</sup> ions in PCT lumen diffuse** down its gradient into cells lining the PCT

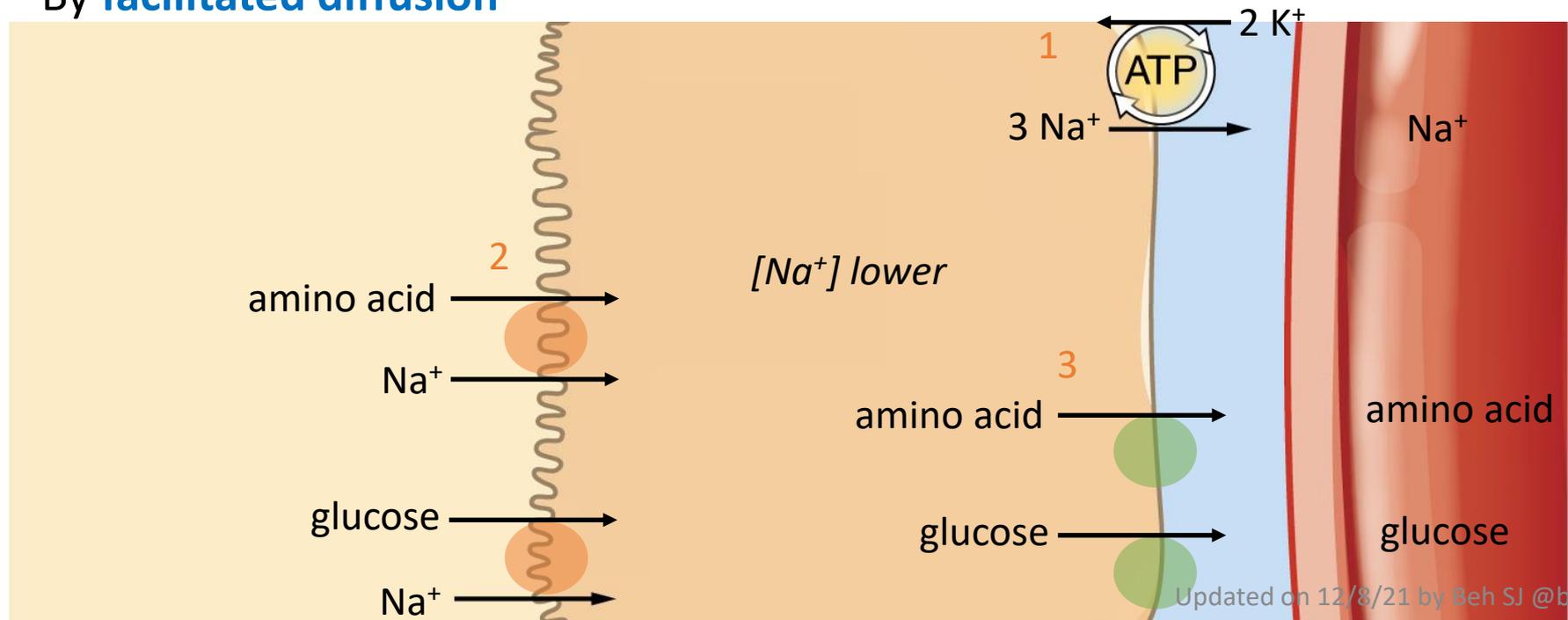
- By **facilitated diffusion**

- Via co-transporter carrier proteins

- **Na<sup>+</sup> co-transported with glucose/amino acids** / vitamins / Cl<sup>-</sup> ions into cell

3. **Glucose/amino acid** / vitamins / Cl<sup>-</sup> ions **diffuse into blood** via transport protein

- By **facilitated diffusion**

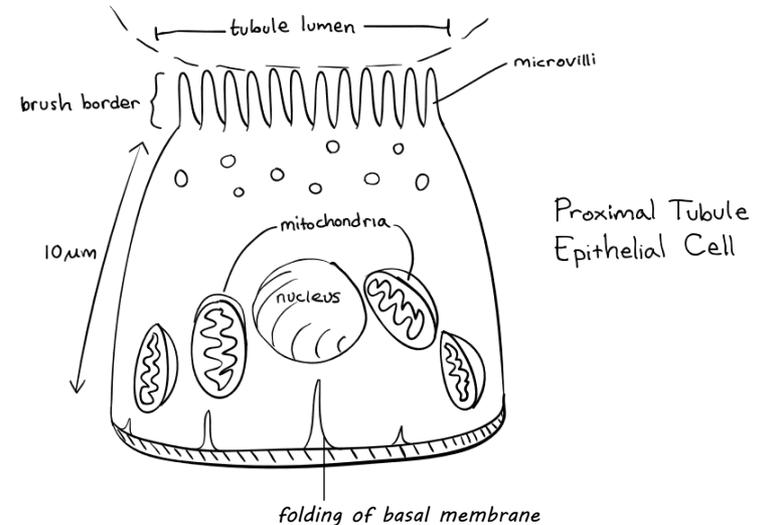


# Selective Reabsorption @Proximal Convoluted Tubule (PCT)

- Glucose is
  - **ALL actively reabsorbed** into blood
  - No glucose in urine
- Amino acids, vitamins &  $\text{Cl}^-$  ions
  - **Actively reabsorbed**
- Water
  - **65% reabsorbed!**
  - Passively reabsorbed
- Urea → passively reabsorbed
- Uric acid & creatinine → **NOT reabsorbed**
- Creatinine → actively secreted/transported into lumen of PCT



# Selective Reabsorption @Proximal Convoluted Tubule (PCT)



## Adaptations of PCT cells:

- Numerous **microvilli** (facing lumen)
  - large surface area for absorption
- Presence of different **transport proteins** in membranes (facing lumen)
  - i.e. cotransporters, pumps, aquaporins
- High **infolding of basal membranes** (facing blood capillaries)
- High density of **mitochondria**
  - provide energy in the form of ATP for active transport
- Tight junctions** holding adjacent cells together
  - separate proteins of front and basal membrane
  - so fluid cannot pass between cells, substance must pass through cells

# Selective Reabsorption @ Loop of Henle (LOH)

- LOH is located at the **medulla**
- Mainly for active **water reabsorption**

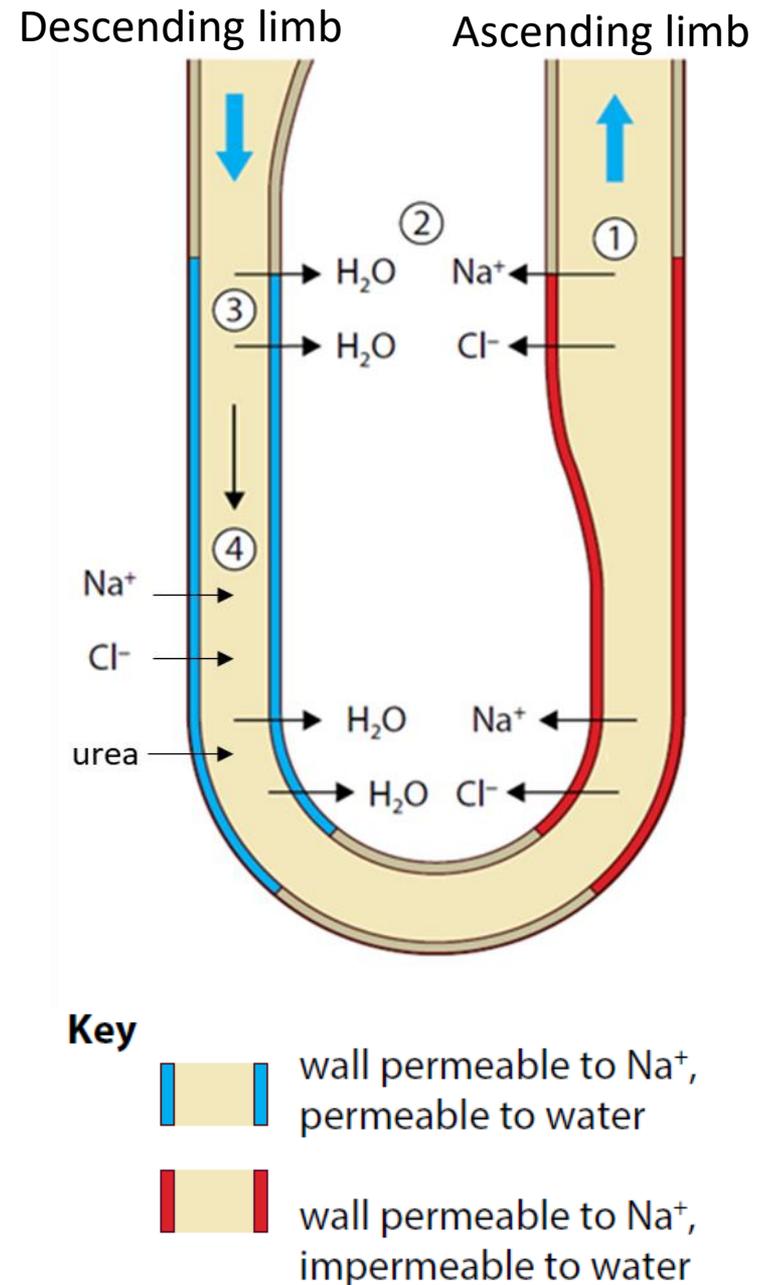
2 parts:

## 1) Descending limb

- **Permeable to both water & Na<sup>+</sup> & Cl<sup>-</sup> ions**

## 2) Ascending limb

- **Impermeable to water**
- **Permeable to Na<sup>+</sup> & Cl<sup>-</sup> ions**



# Selective Reabsorption @Loop of Henle(LOH)

@ Ascending limb

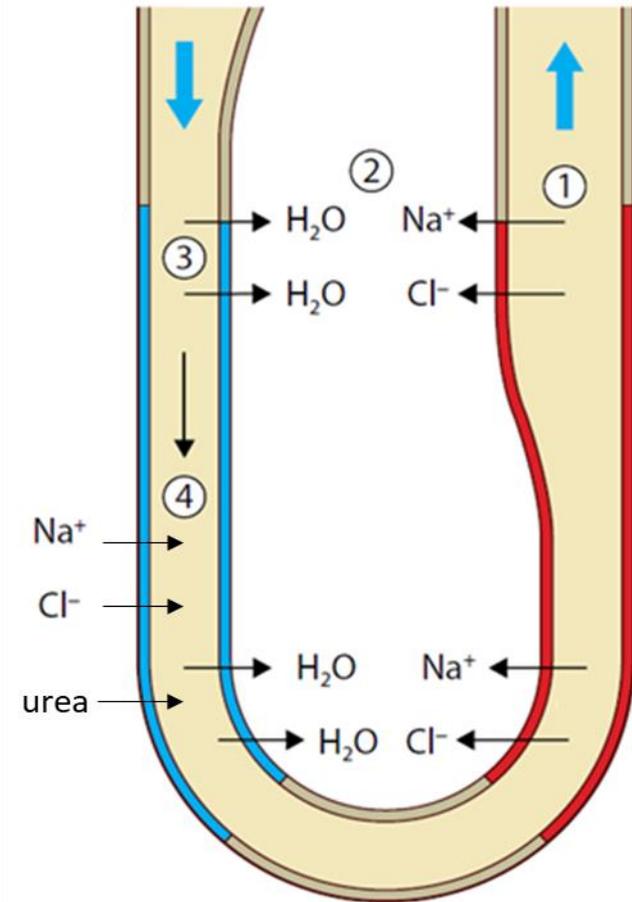
**1.  $\text{Na}^+$  &  $\text{Cl}^-$  ions move out** of the tube

→ **By active transport**

→ Into tissue fluid of medulla space

**2. High concentrations of  $\text{Na}^+$  &  $\text{Cl}^-$  ions in the medulla space**

→ **Renal fluid become more dilute** and enters distal convoluted tubule



# Selective Reabsorption @ Loop of Henle (LOH)

@ Descending limb

- Permeable to both water &  $\text{Na}^+$  &  $\text{Cl}^-$  ions

Due to high concentrations of solute in the medulla...

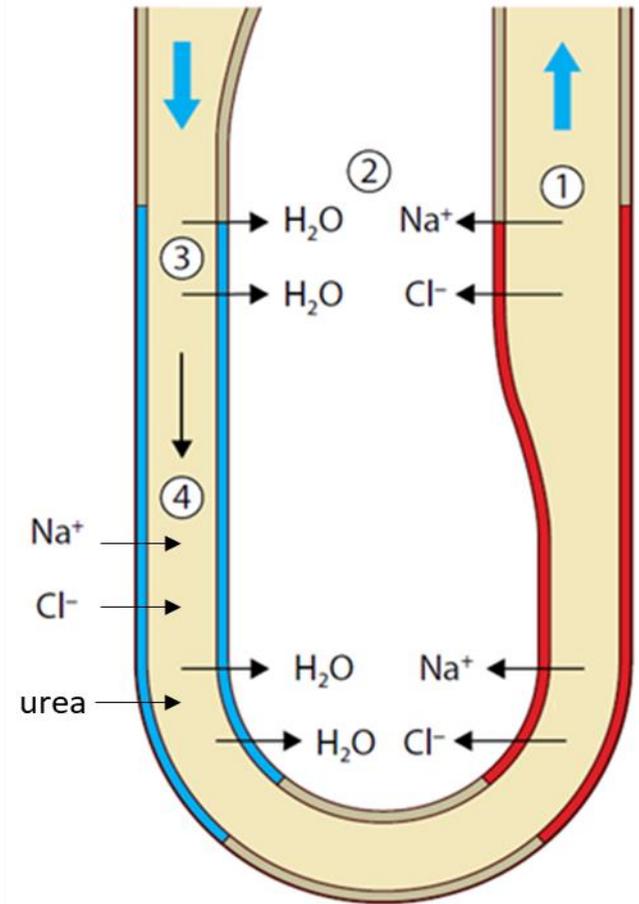
3. **Water moves out** into medulla tissue fluid

→ By **osmosis**

→ Water is reabsorbed

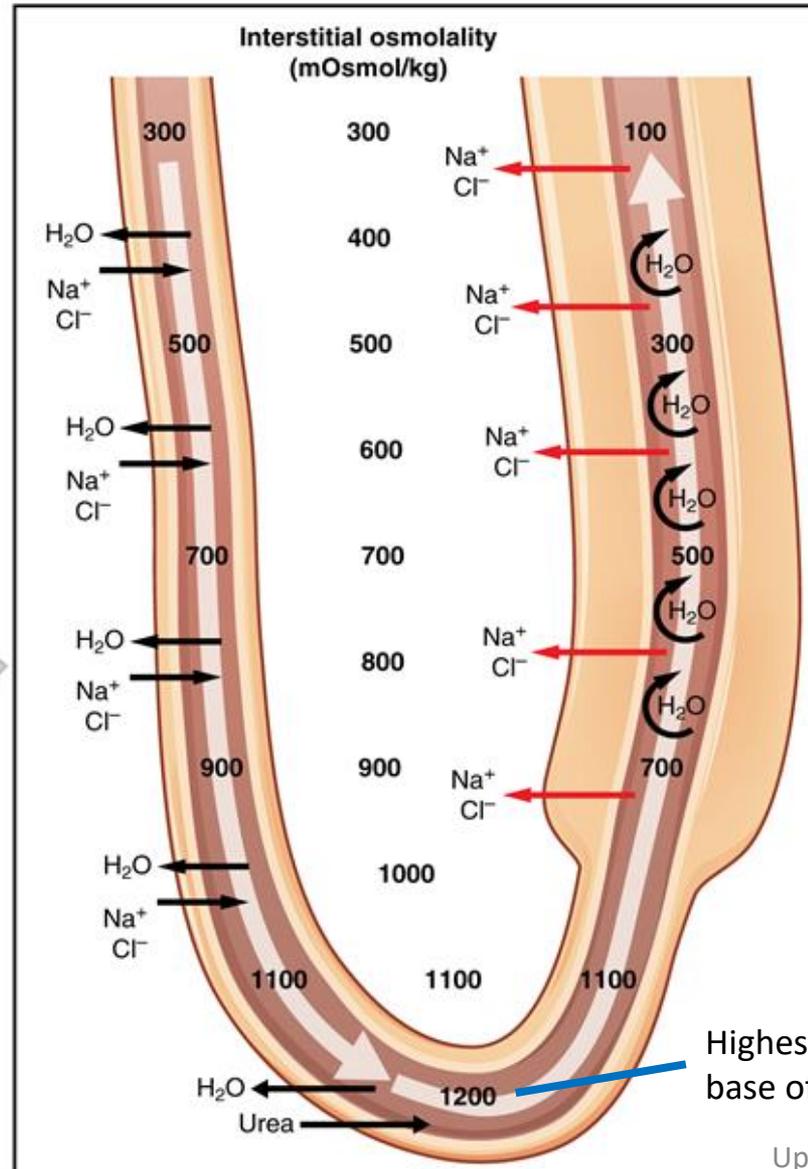
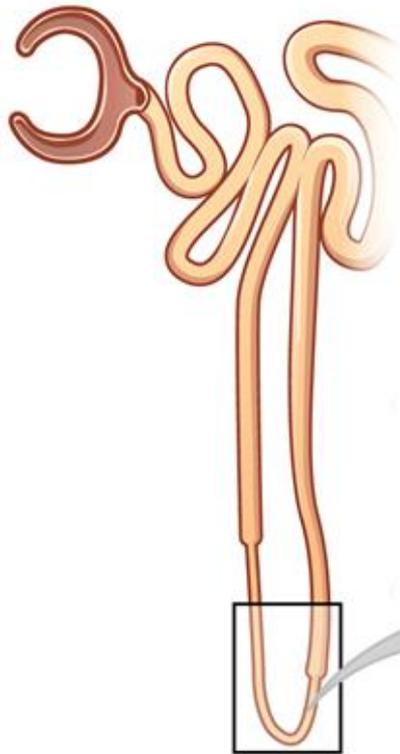
4. Urea,  **$\text{Na}^+$  &  $\text{Cl}^-$  ions in medulla space diffuse into descending limb**

→ Fluid in the descending limb becomes very concentrated as it moves down the loop



# Selective Reabsorption @ Loop of Henle (LOH)

Ascending limb:  
 $\text{Na}^+$  and  $\text{Cl}^-$  move out by active transport  
 $\rightarrow$  Renal fluid decreases in solute concentration, increases in water potential



Descending limb:  
 $\text{H}_2\text{O}$  move out,  $\text{Na}^+$  and  $\text{Cl}^-$  move in  
 $\rightarrow$  Renal fluid increases in solute concentration

Longer loop will result in higher concentrations of solute built up in medulla space, more water reabsorption, more conc urine formed!

Highest solute concentration is at base of loop!

# Selective Reabsorption

## @ Distal Convoluted Tubule (DCT)

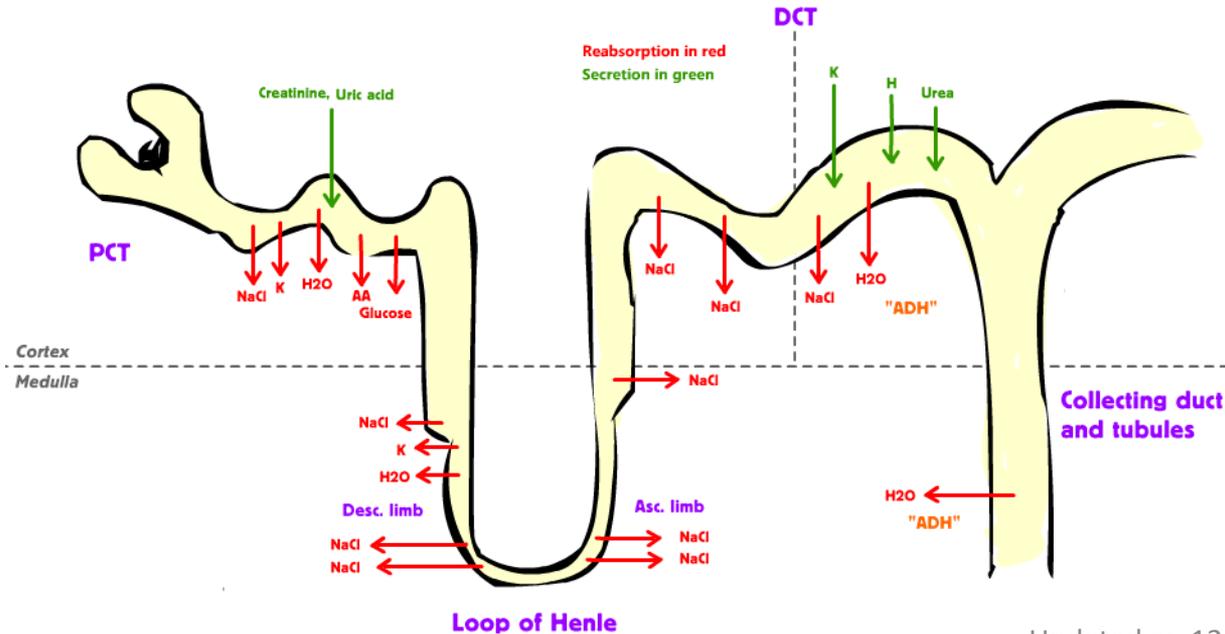
- Located in the cortex

**1st part of DCT = Similar to LOH** (ascending limb)

- $\text{Na}^+$  &  $\text{Cl}^-$  ions again actively transported into blood

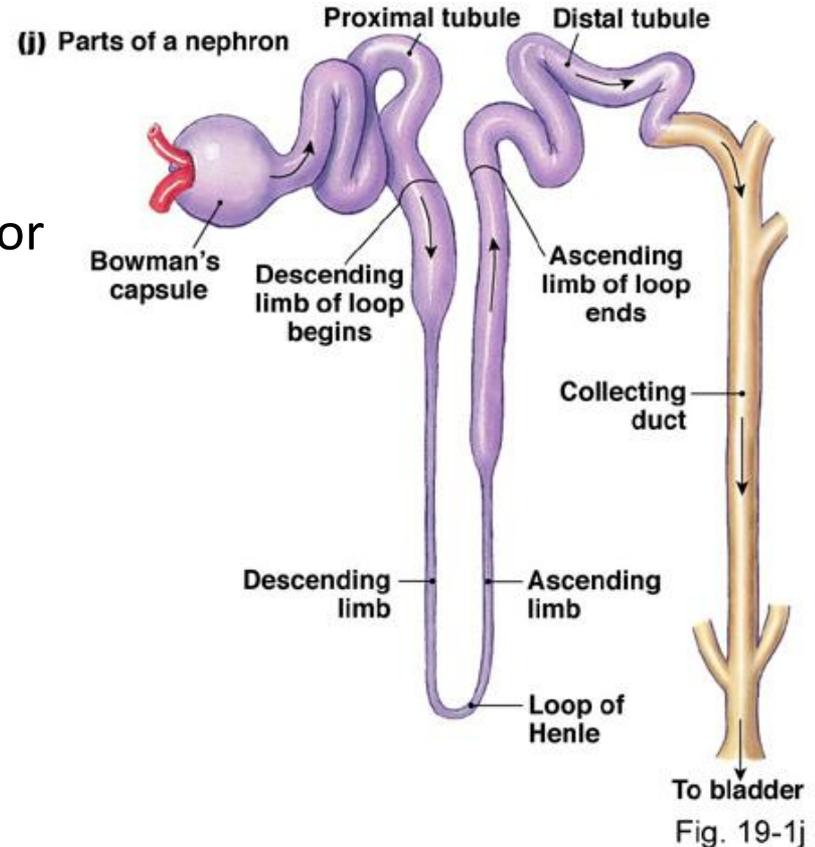
**2nd part of DCT = Similar to collecting duct**

- Water is reabsorbed into blood
- Plus secretion of  $\text{K}^+$ ,  $\text{H}^+$  ions and urea into lumen from blood



# Selective Reabsorption @ Collecting Duct

- Located at medulla
- For osmoregulation
- So water reabsorption can be switched on or off
- Usually, tissue fluid of medulla has high concentrations of solutes
- So **water moves out** of collecting duct
- High reabsorption of water back into blood
- Formation of urine
- Rate of water reabsorption is controlled by **ADH (antidiuretic hormone)**



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# Osmoregulation

## Hypothalamus

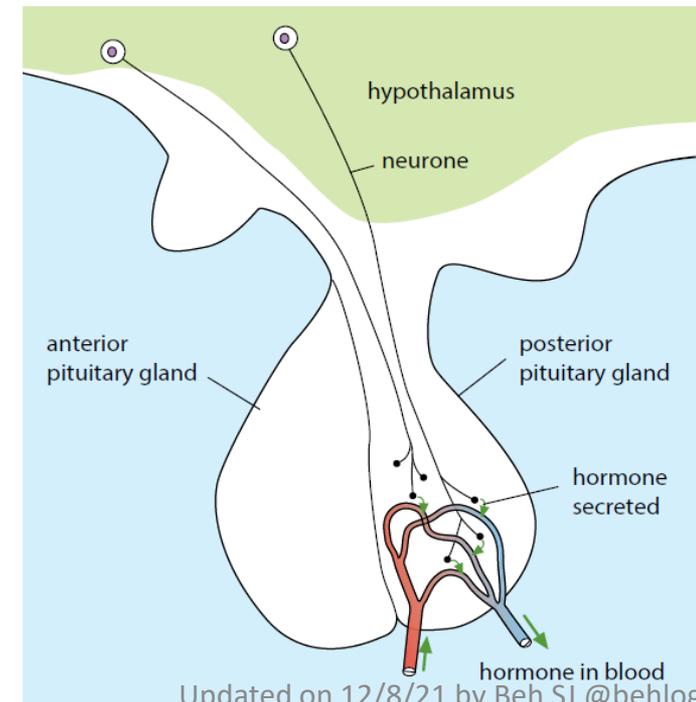
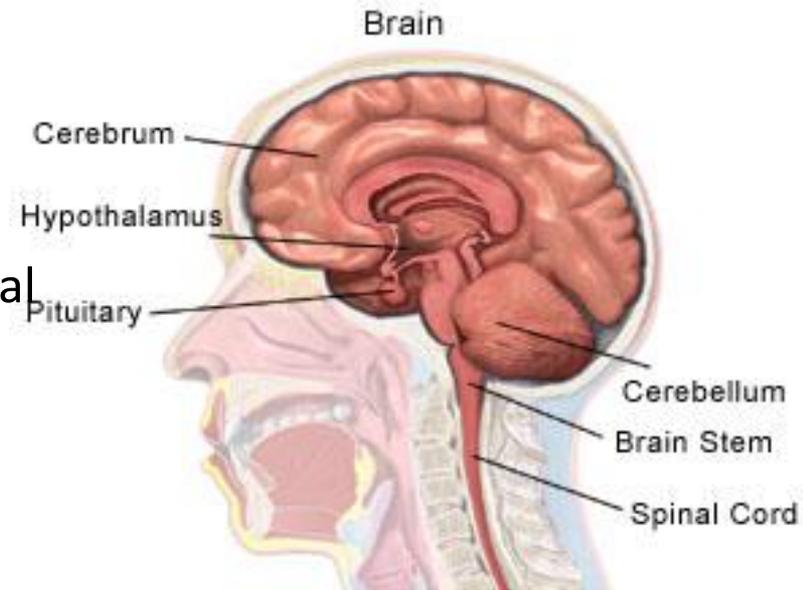
- Osmoregulation = control of the water potential of body fluids
- Uses **negative feedback** mechanism

**Stimuli:** Water potential of blood is **low**

**Receptor:** **Osmoreceptors** at the **hypothalamus** detect water potential of blood

**Effector:** Neurosecretory cells of the hypothalamus send nerve impulse to **posterior pituitary glands**

- **ADH (antidiuretic hormone)** released from posterior pituitary
- Enter blood stream
- Target organ: Distal convoluted tubule / **collecting duct** of kidneys

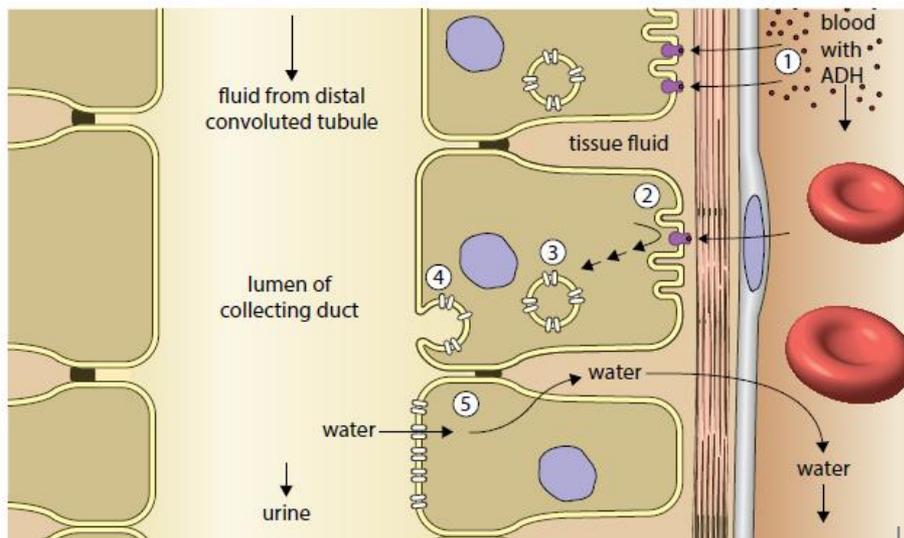


# Osmoregulation

## ADH

### Response:

1. **ADH** in blood **bind to receptors** on plasma membrane of distal convoluted tubule / collecting duct
2. **Activates a series of enzyme-controlled reactions** / enzyme cascade in cells  
→ Production of active phosphorylase enzyme
3. **Vesicles containing aquaporins fuse with plasma membrane** of lumen side

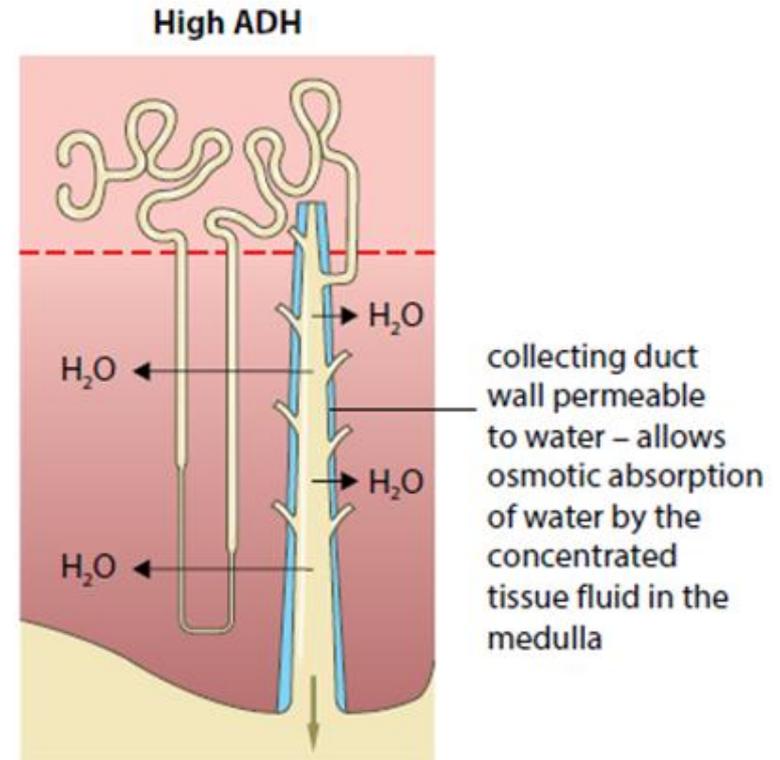


# Osmoregulation

## ADH

### Result:

- **ADH increases membrane permeability of collecting duct**
- Increases water reabsorption
- **More water flows out of** distal convoluted tubule/ **collecting duct into blood** down water potential gradient
- So **smaller volume of more conc urine** produced
- Water potential of blood increases
- **Returns to norm / set-point**



small volumes of concentrated urine produced

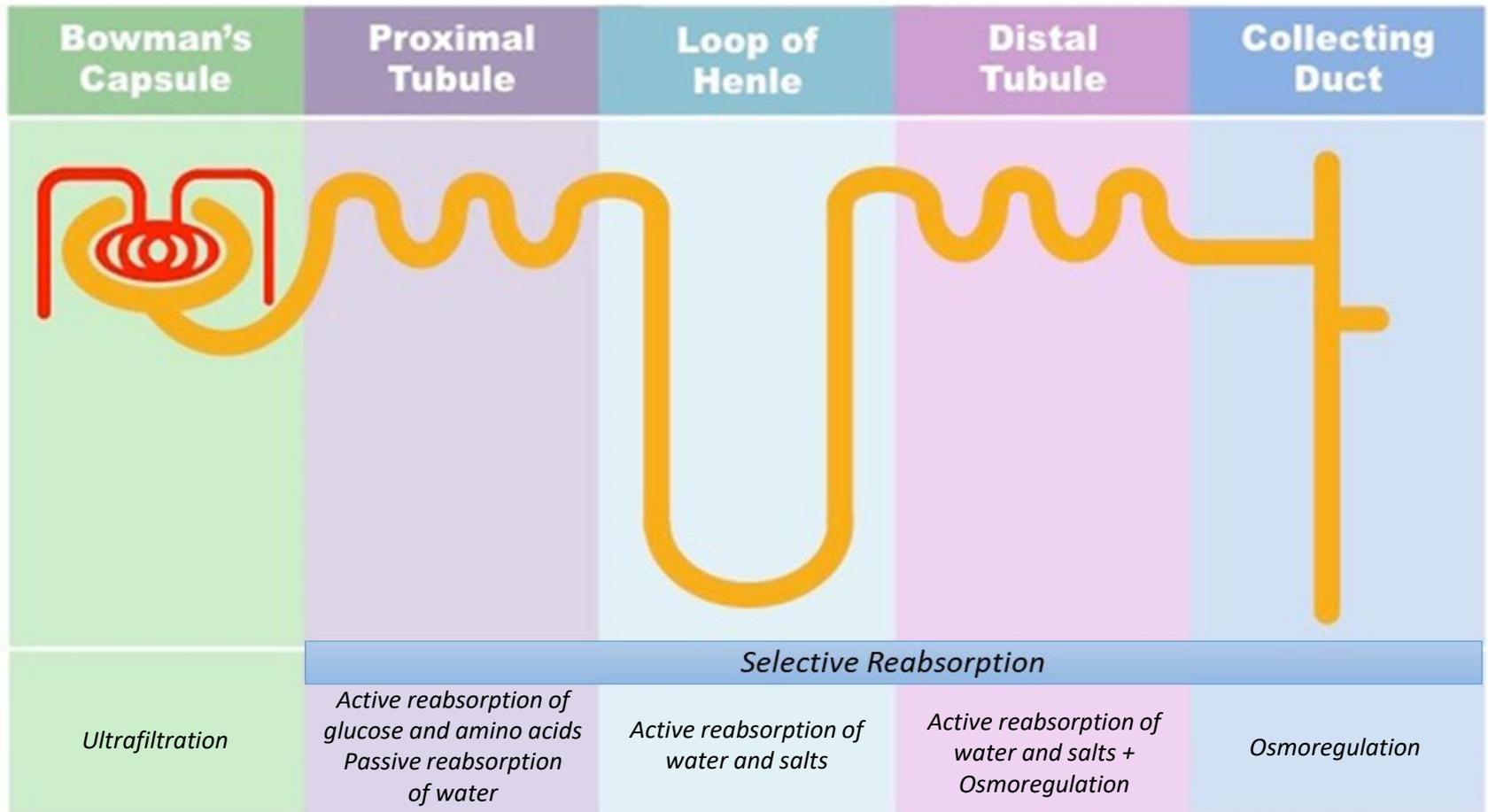
# Osmoregulation

What if there is an **increase in the water potential of blood?**

- Osmoreceptors no longer stimulated
- Neurons **stop secreting ADH**
- Aquaporins move out of cell surface membrane of collecting duct, back into vesicles in the cytoplasm
- Collecting duct is less permeable to water
- **Dilute urine and larger volume of urine produced**
- Water potential of blood decreases
- **Returns to set point**



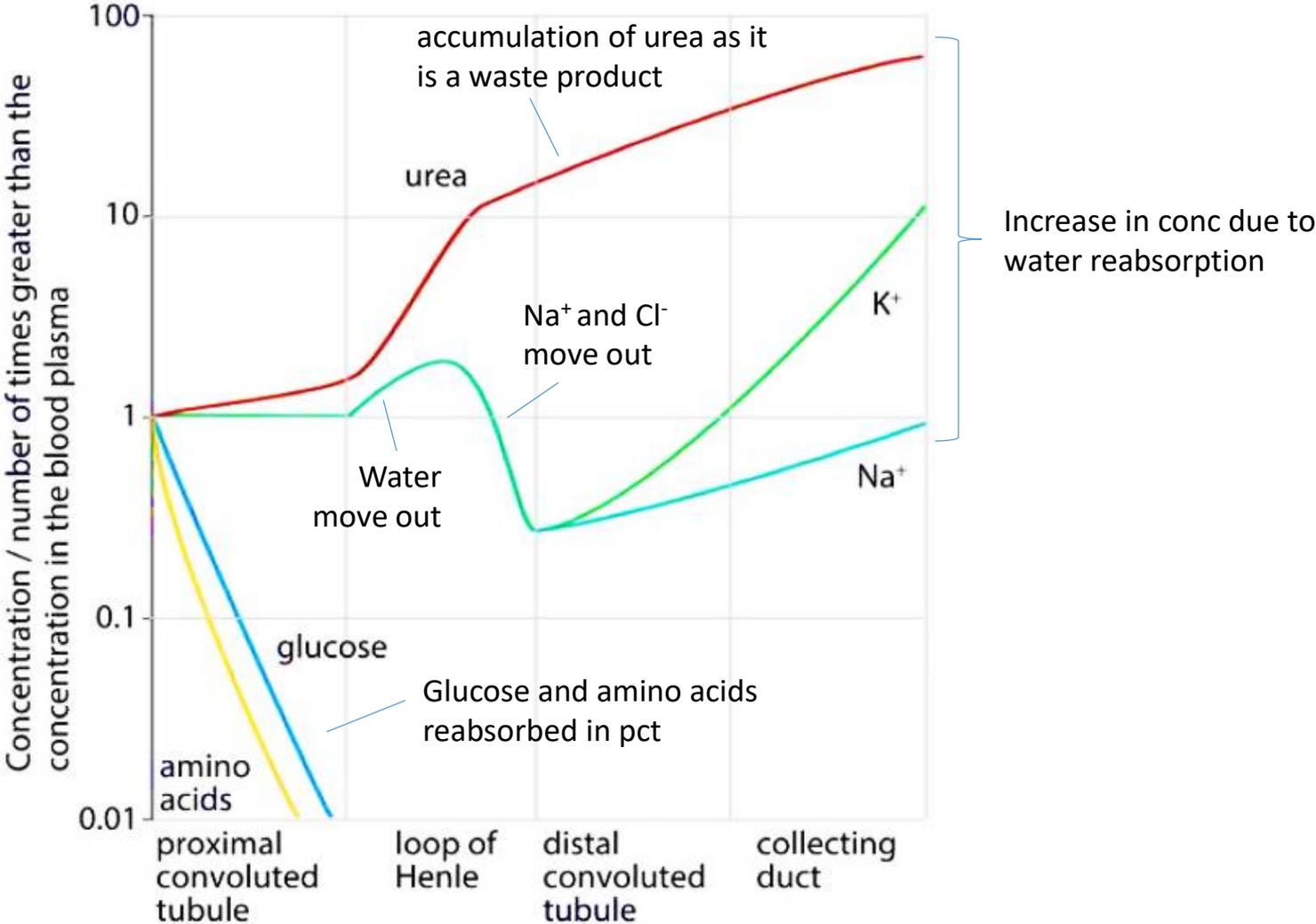
# Summary



Urinary System, part 2: Crash Course A&P #39

<https://www.youtube.com/watch?v=DlqyyvTI3k>

# Summary



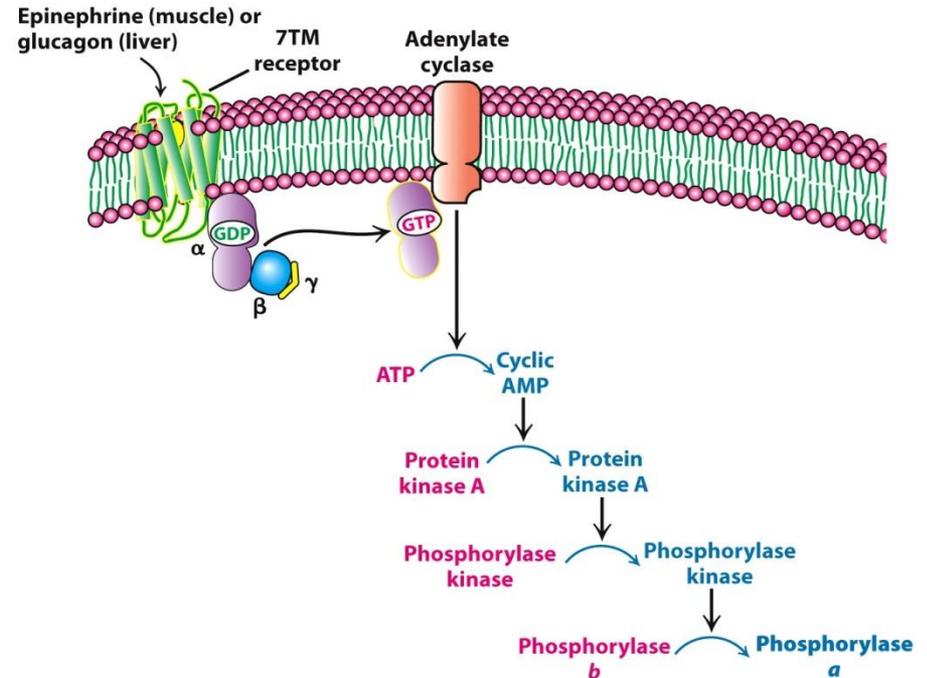
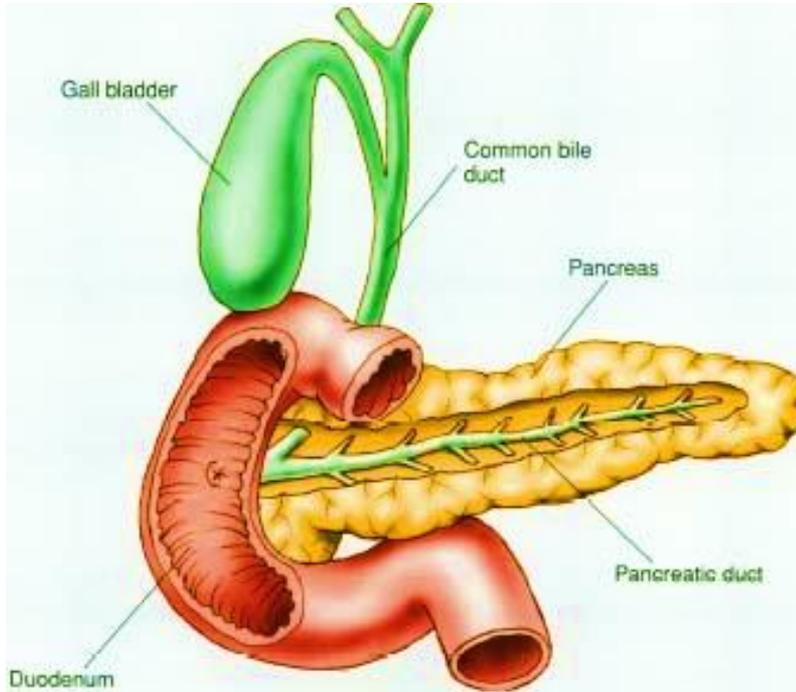
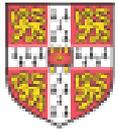


Figure 21.16  
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# A2 Level Chapter 14 HOMEOSTASIS

## PART 2 of 3

### CONTROL OF BLOOD GLUCOSE CONCENTRATION

# Chapter Outline

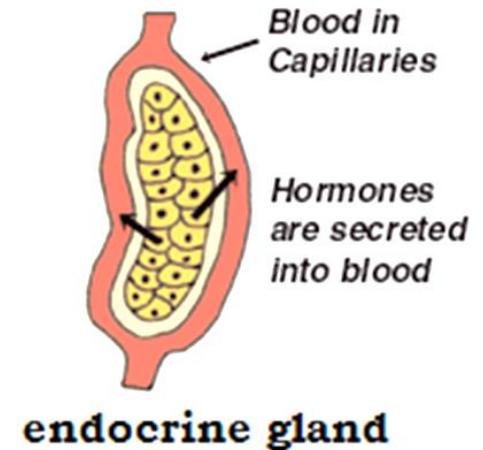
## **Part 2: Control of Blood Glucose Concentration**

- Endocrine vs Exocrine Glands
- Hormones + Receptors
- The Pancreas
- **Insulin vs Glucagon**
- **Glucagon and Adrenaline**
  - **cAMP = second messenger**
- Diabetes mellitus
- Urine Analysis, Dip Stick Tests and Biosensors

# Endocrine vs Exocrine Glands

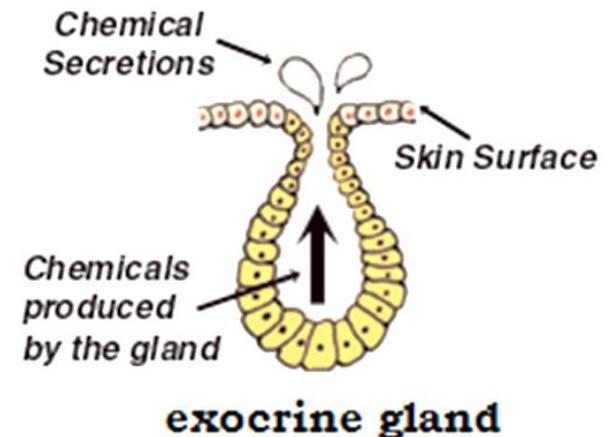
## 1) Endocrine glands

- Secretory cells
- Releases secretions directly into **blood** capillaries in the glands
- Secretions: **Hormones**
- E.g. pituitary glands, thyroid, adrenal, ovary, testes, *pancreas*



## 2) Exocrine glands

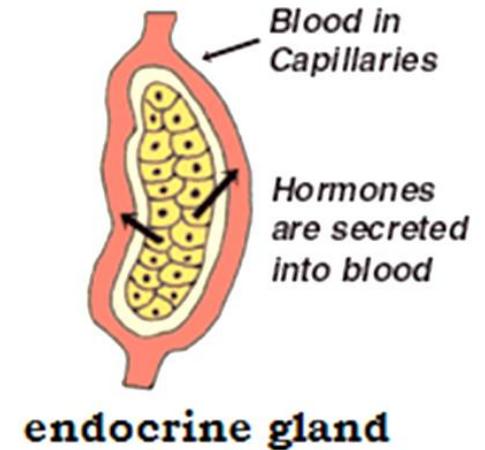
- Secretory cells
- Releases secretion into **ducts/tubes** (not blood capillaries)
- Secretions: **Not hormones**
- E.g. stomach, salivary glands, *pancreas*



# Hormones

- Secreted by **endocrine glands**
- Hormones can be **globular proteins** OR **steroids**
- E.g. **Insulin – protein hormone**

**Testosterone – steroid hormone**



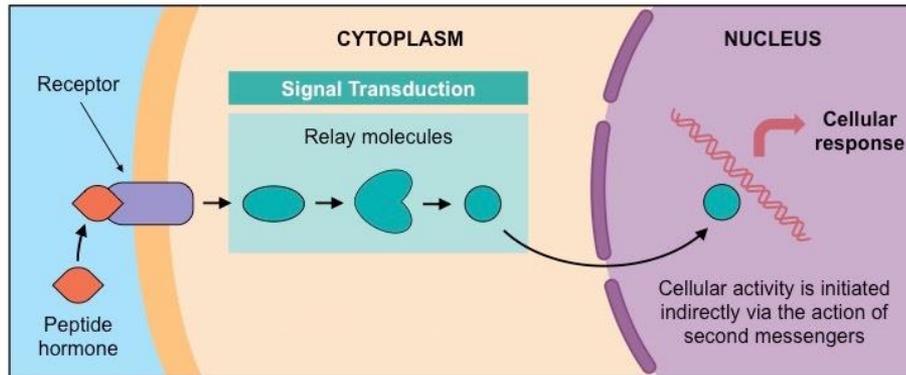
## Characteristics:

1. Small molecules, chemical messengers
2. Needed in small quantities
3. Secreted quickly upon receiving a stimulus
4. Short life span, quickly broken down by enzymes/excreted via urine
5. Transported in the **blood stream** to target cells
6. Specific – bind to **receptors** on target cells  
Receptors can be **on cell surface membrane** OR **inside cell**

# Hormone Receptors

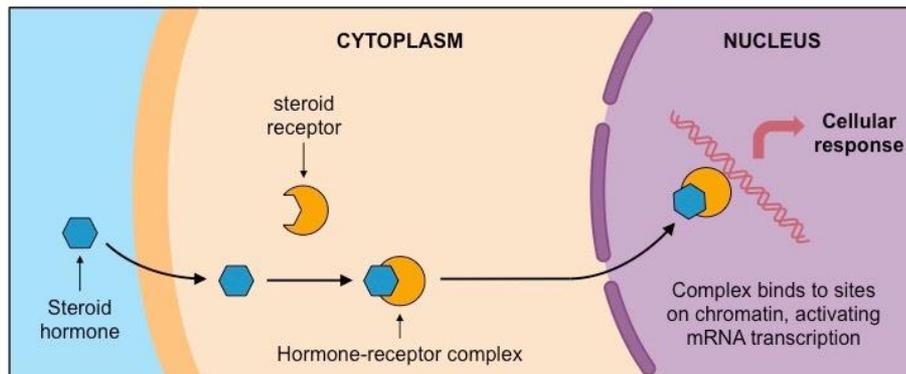
1) Receptors for **protein hormones** – on **plasma membrane**

→ **water soluble**, cannot pass through plasma membrane



2) Receptors for **steroid hormones** – in **cytoplasm**

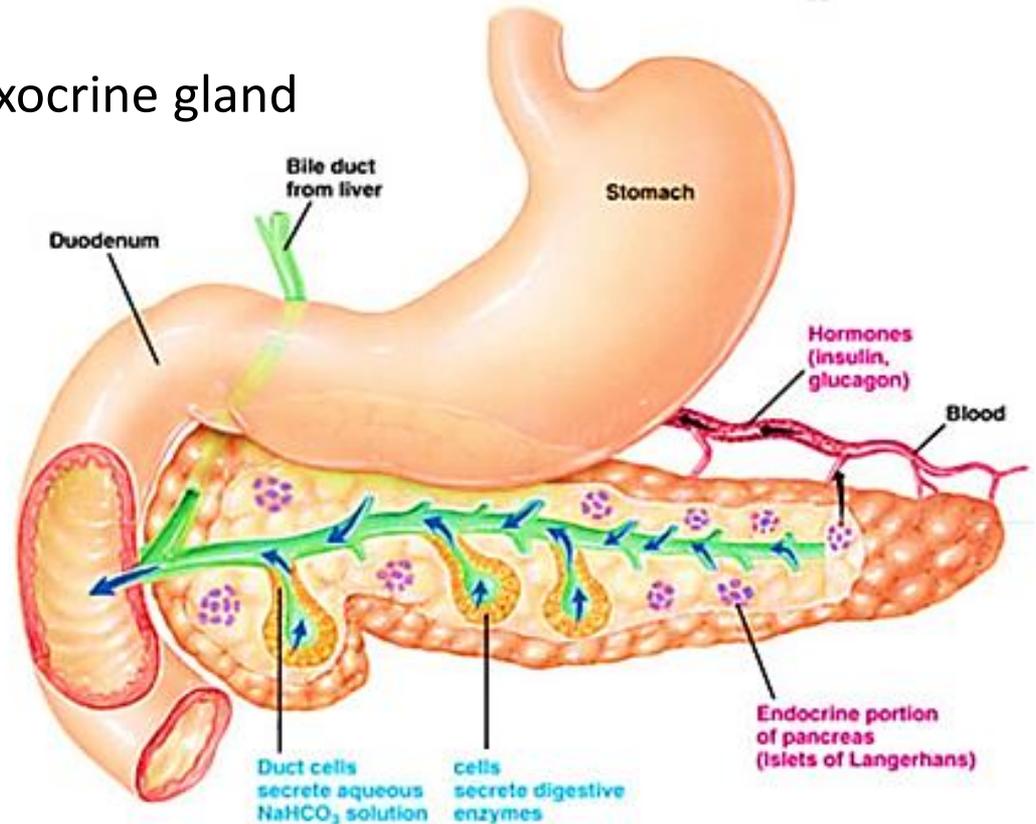
→ **lipid soluble**, can pass easily through plasma membrane



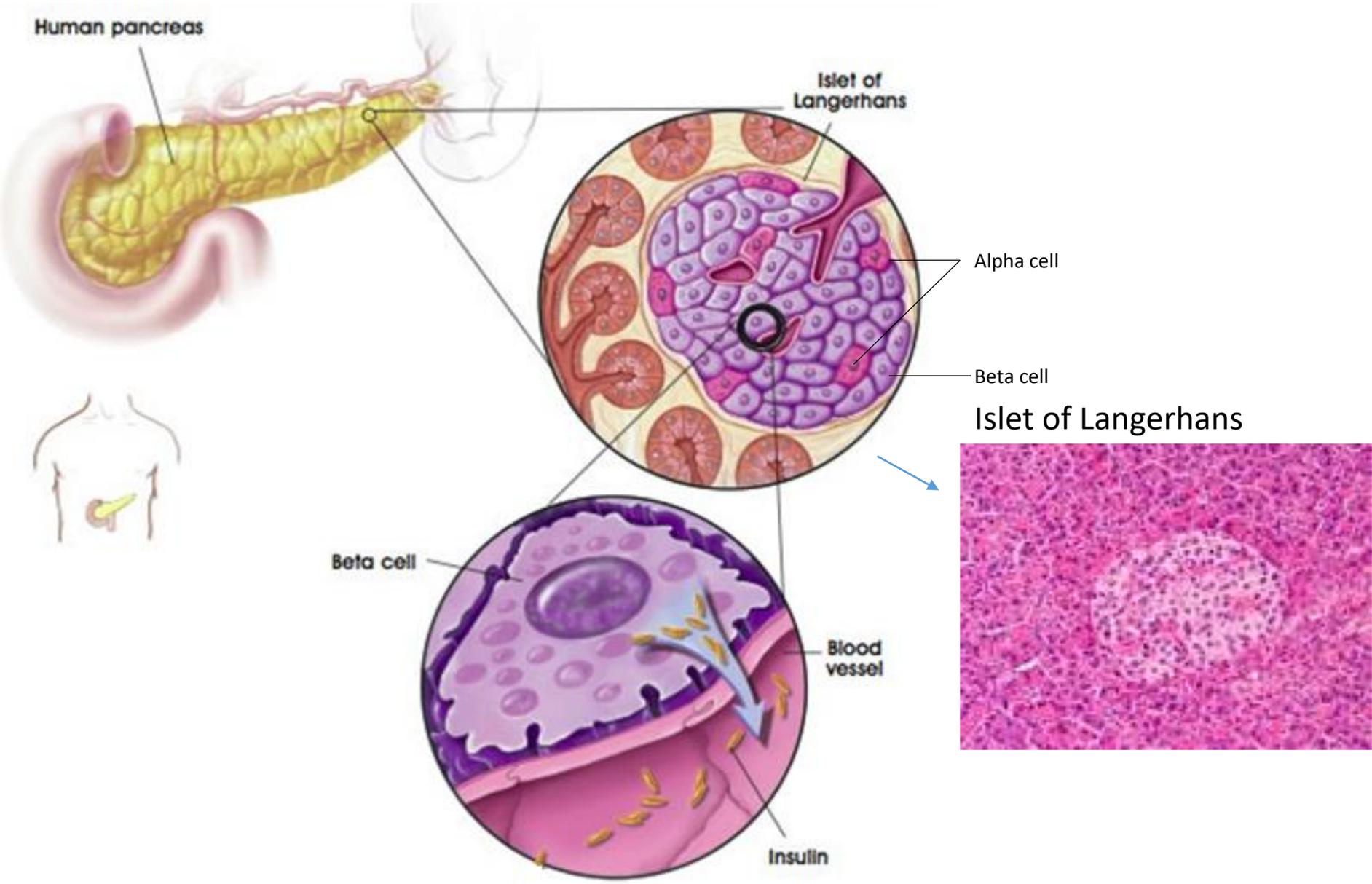
# The Pancreas

- Acts as **BOTH** endocrine and exocrine gland

- **Exocrine** – secretes pancreatic juice
  - Via pancreatic duct to duodenum



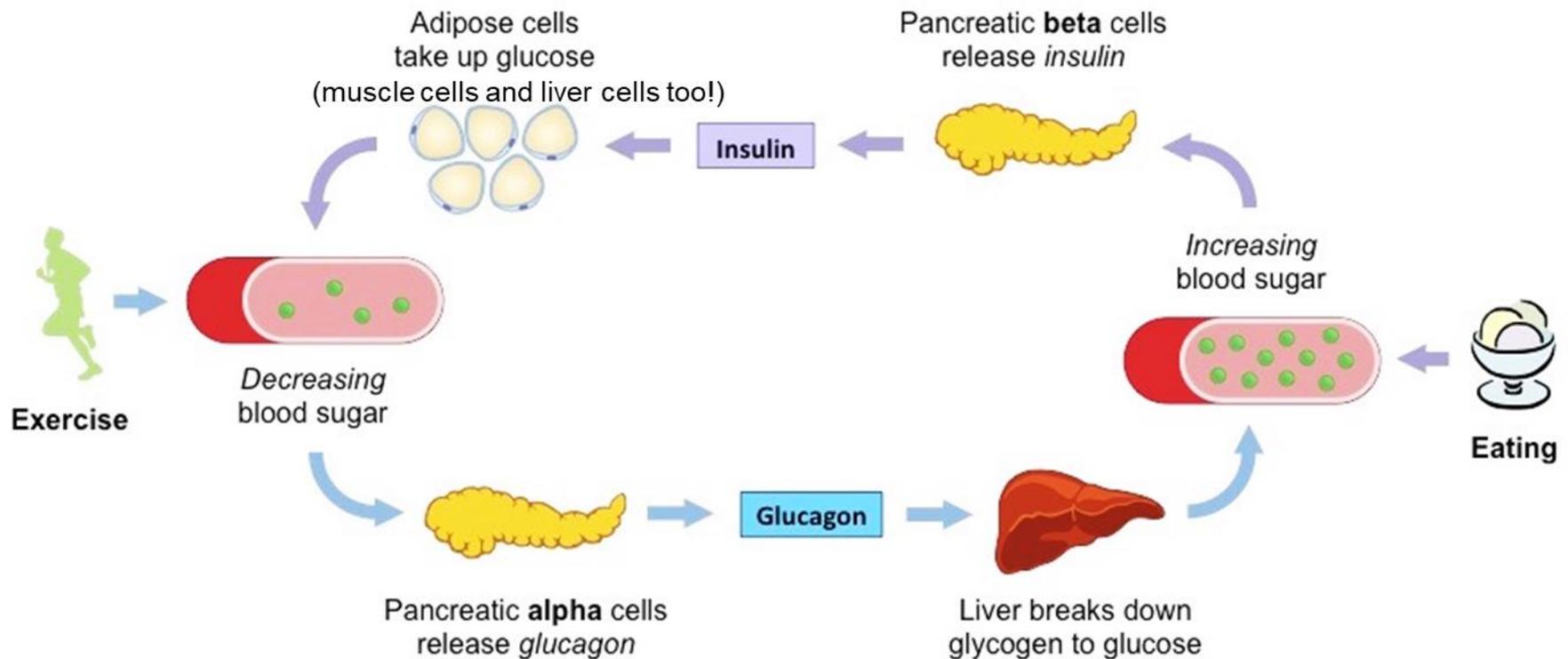
- **Endocrine** – secretes insulin and glucagon hormones into blood
  - **Islets of Langerhans** (group of secretory cells) composed of:
    - **Alpha cells** that secrete **glucagon**
    - **Beta cells** that secrete **insulin**



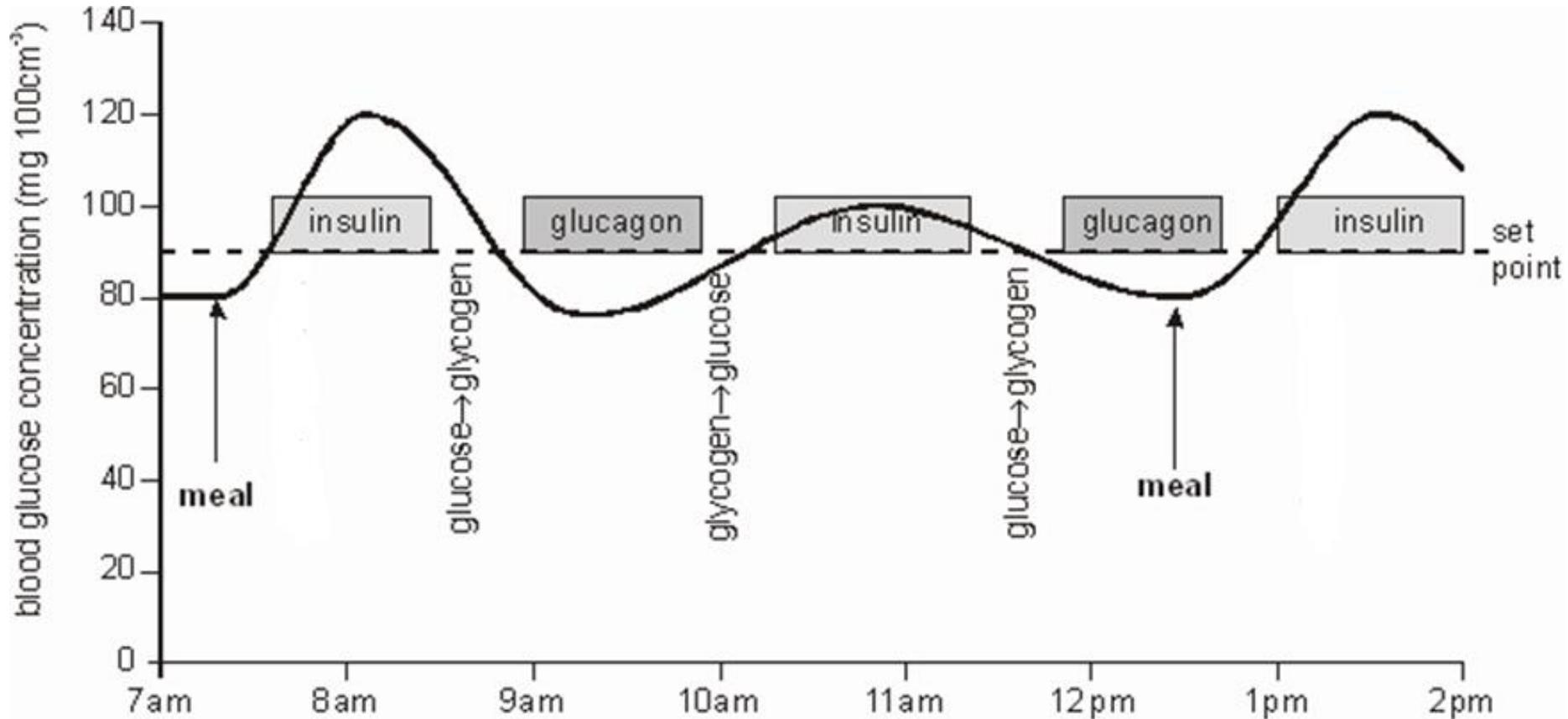
# Insulin vs Glucagon

Glucagon and insulin are antagonistic hormones

- **Glucagon** secreted by **alpha cells** → used to **increase** blood sugar
- **Insulin** secreted by **beta cells** → used to **decrease** blood sugar



# Oscillating Graph of Blood Glucose Level against Time



# Insulin

**Stimuli:** Blood glucose level increases

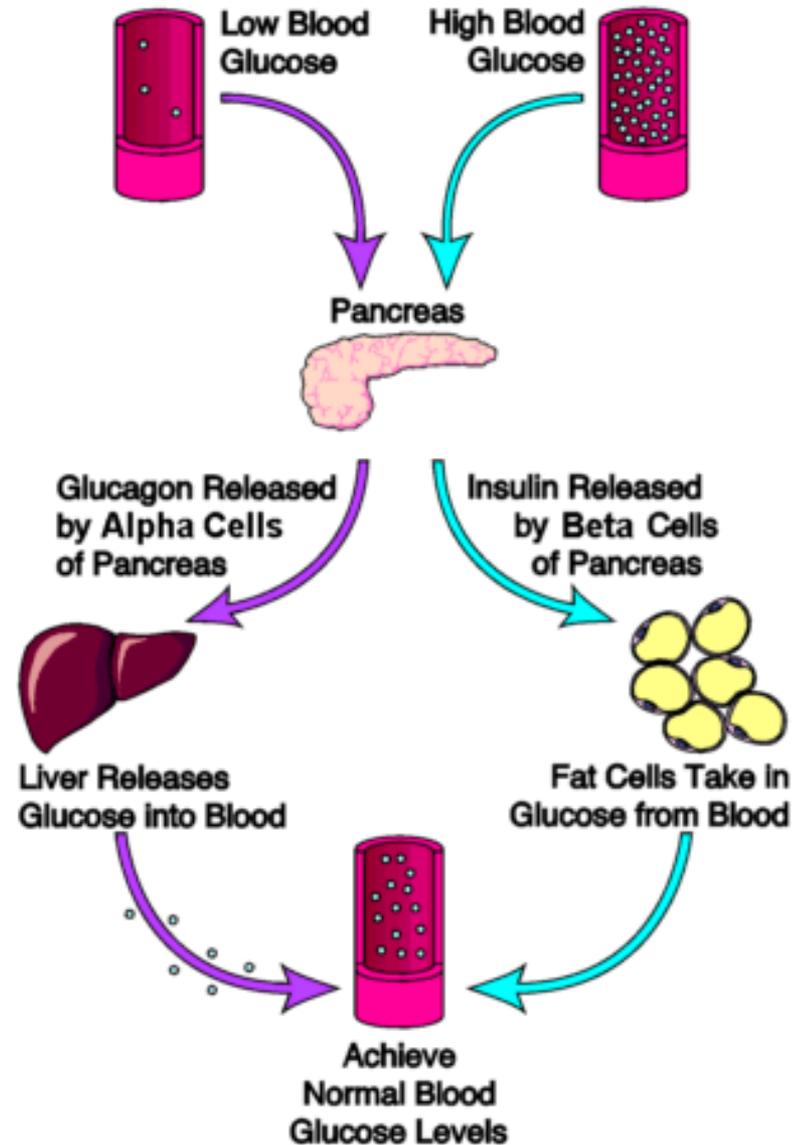
**Receptors:** Detected by  $\alpha$  cells and  $\beta$  cells in islet of Langerhans of the pancreas

**Effectors:**

$\beta$  cells secrete more insulin into blood

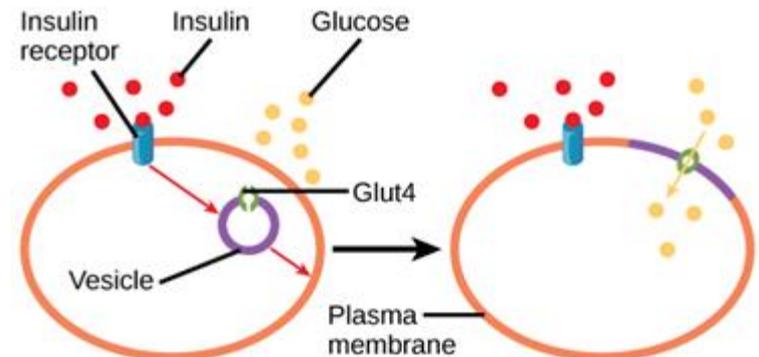
$\alpha$  cells stop secreting glucagon

Insulin acts on liver cells, muscle cells and adipose (fat) cells



# Insulin

1. Insulin **bind to receptors** on cell surface membrane of **liver cells/muscle cells /adipose cells**
2. **Increase permeability of membrane to glucose** in liver and muscle cells
  - Trigger vesicles with glucose transporter proteins (GLUT proteins) to move & fuse with plasma membrane
  - More facilitated diffusion of glucose into cells
3. **Increase glucose uptake / absorption from blood**
  - Stimulate activation of enzyme glucokinase → phosphorylates glucose
  - Glucose trapped in cells
4. **Increase rate of respiration of glucose**



In the presence of insulin, Glut4 vesicles fuse with the plasma membrane.

Glut4 allows glucose to enter the cell.

# Insulin

5. **Increase conversion of glucose → glycogen** (glycogenesis)

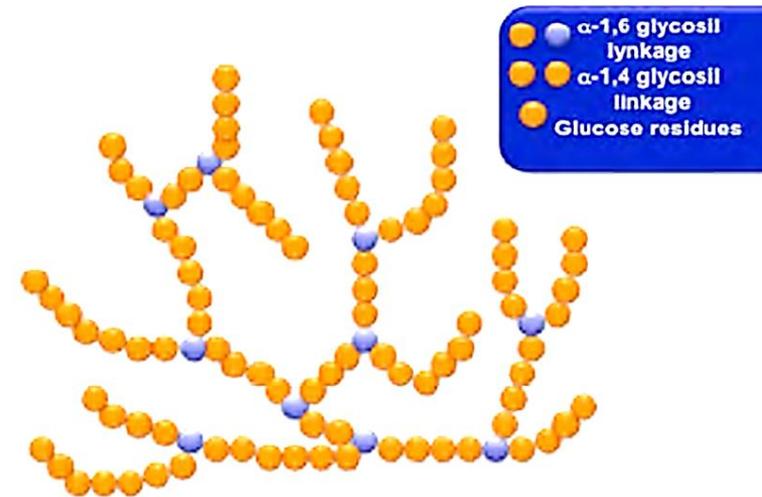
• By activating two enzymes (phosphofructokinase, **glycogen synthetase**)

→ Store in liver and muscles

6. **Increase protein and lipid synthesis**

7. **Inhibit secretion of glucagon from  $\alpha$  cells**

→ Inhibit glycogen breakdown into glucose (glycogenolysis)



8. Inhibit **production of glucose** from proteins and fats (gluconeogenesis)

Result:

• **Decrease in glucose concentration** and **return to norm / set point**

# Glucagon

Stimuli: **Blood glucose level decreases**

Receptors: **Both  $\alpha$  &  $\beta$  cells** in islet of Langerhans of the pancreas

Effectors:

**$\alpha$  cells secrete glucagon** into blood

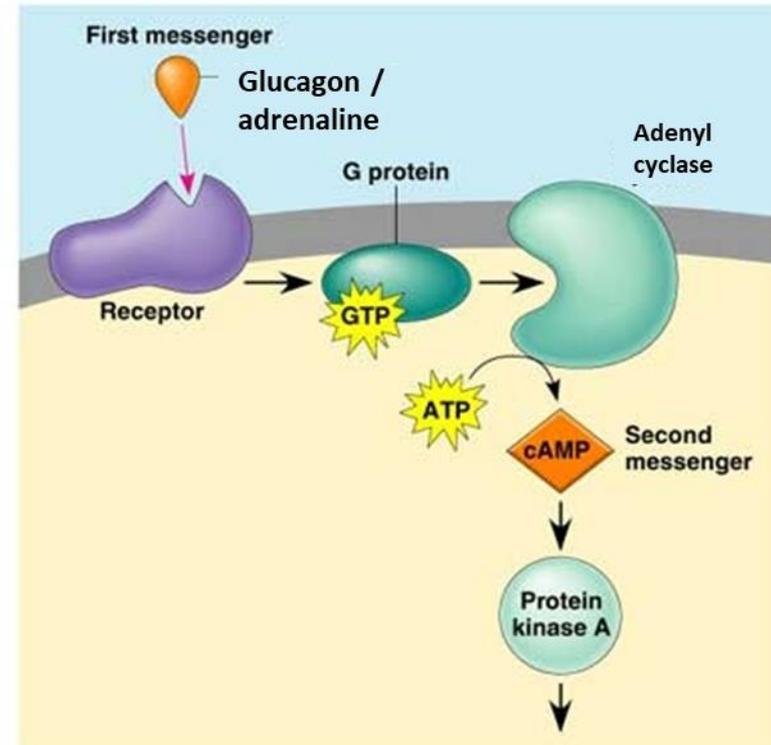
$\beta$  cells stop secreting insulin

Glucagon acts on **liver cells ONLY**



# Glucagon

1. Glucagon **binds to receptor** on cell surface membrane of liver cells
  - Receptor changes shape
2. Activates G proteins
  - Which activates adenyl cyclase
3. Adenyl cyclase produces **cyclic AMP (cAMP)**
  - From ATP
  - cAMP acts as the **second messenger**
  - Activates protein kinase
  - Triggers an **enzyme cascade** / a series of enzyme-controlled reactions
  - Signal is amplified

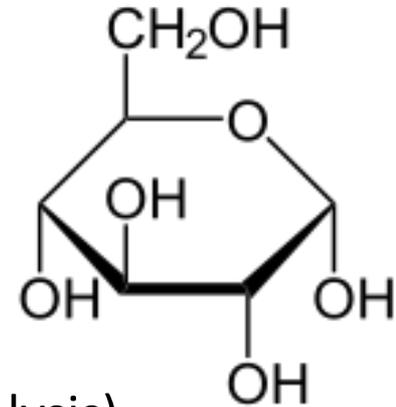


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# Glucagon

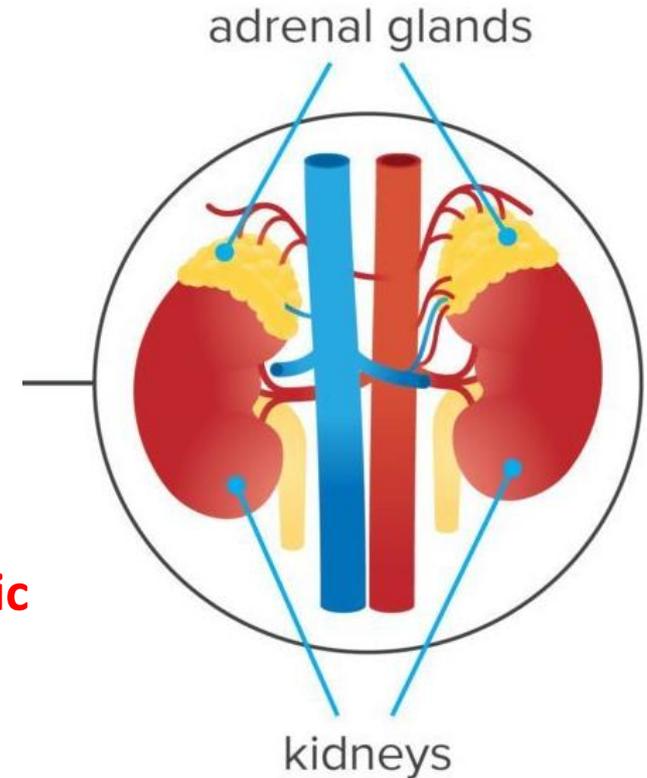
## Response:

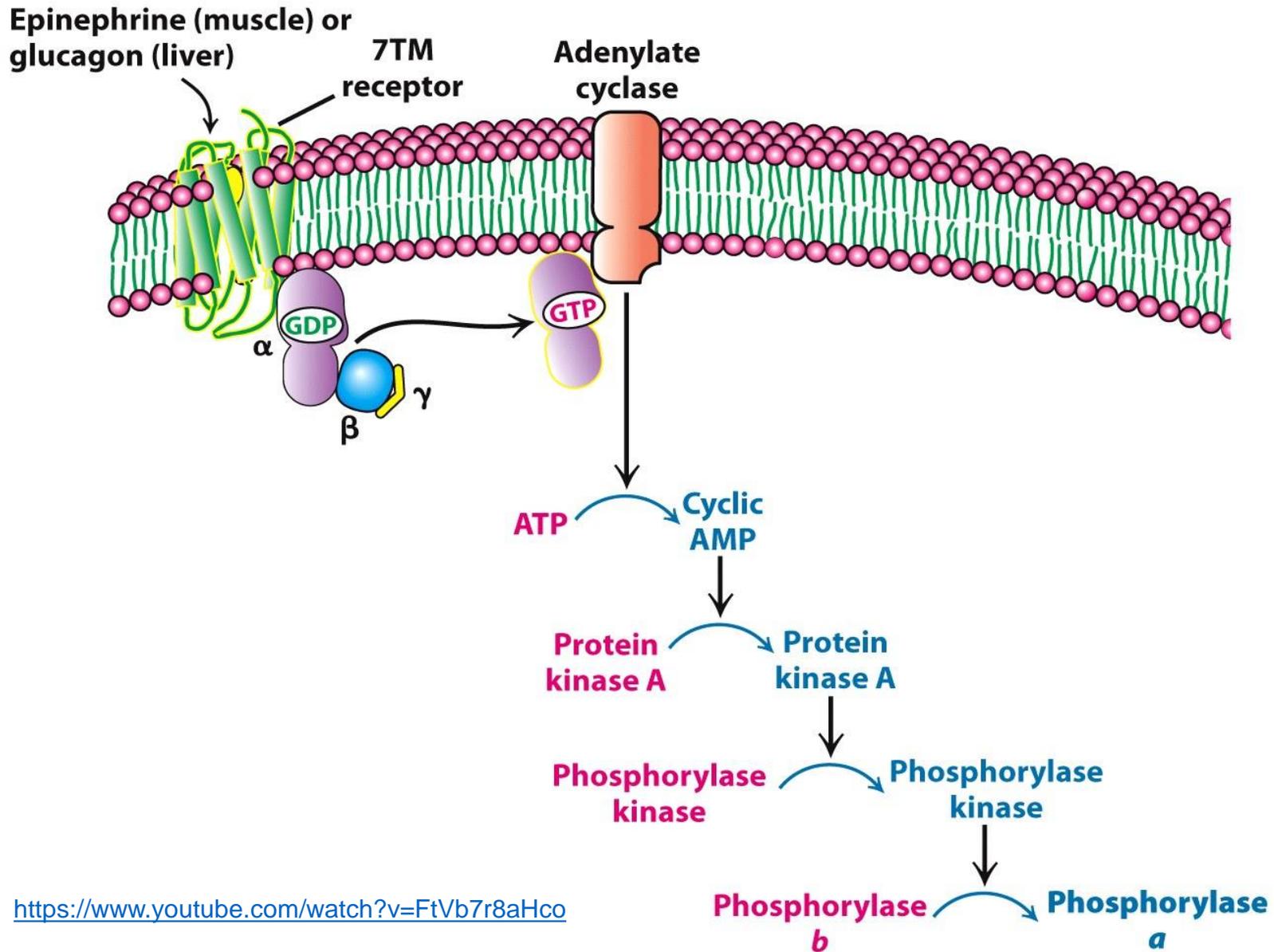
4. cAMP activates enzyme **glycogen phosphorylase**
  - Increase breakdown of **glycogen to glucose** (glycogenolysis)
  5. Use **fatty acids and proteins as respiratory substrate** instead of glucose
  6. Increase **production of glucose** from proteins and fats (gluconeogenesis)
- Glucose diffuse through GLUT proteins from liver
  - Liver **releases glucose into blood**
  - **Increase in blood glucose conc.** and **return to norm / set point**



# Adrenaline

- “Fight or flight” hormone
- Produced during exercise and stress
- Secreted by **adrenal gland into blood**
- **To increase glucose levels in blood**
- So muscles can undergo **aerobic / anaerobic respiration and produce more ATP**
- Functions like **glucagon**





<https://www.youtube.com/watch?v=FtVb7r8aHco>

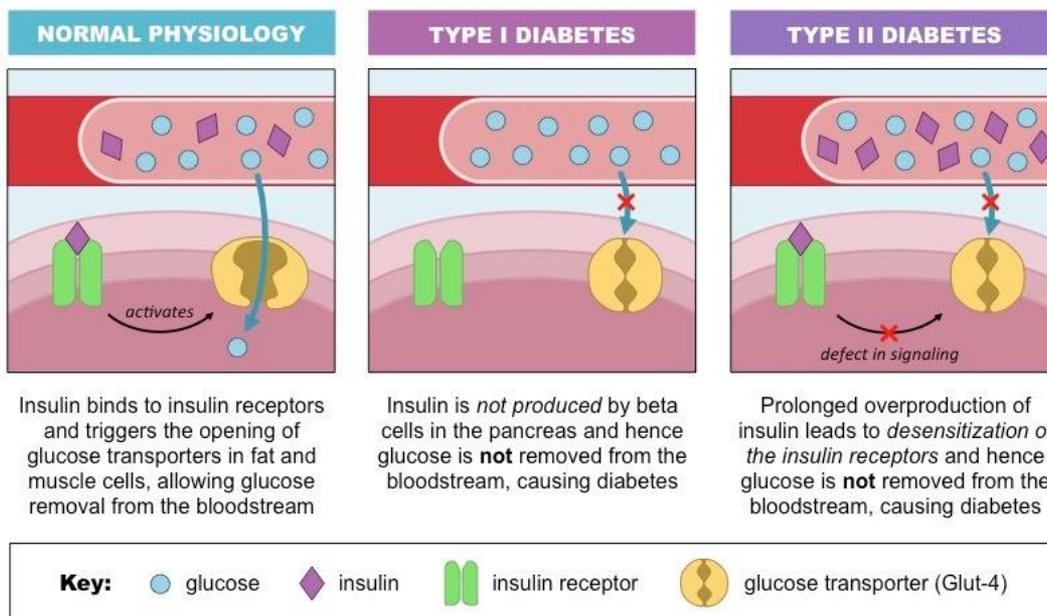
**Figure 21.16**  
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# Diabetes Mellitus



- **High glucose concentration in blood**

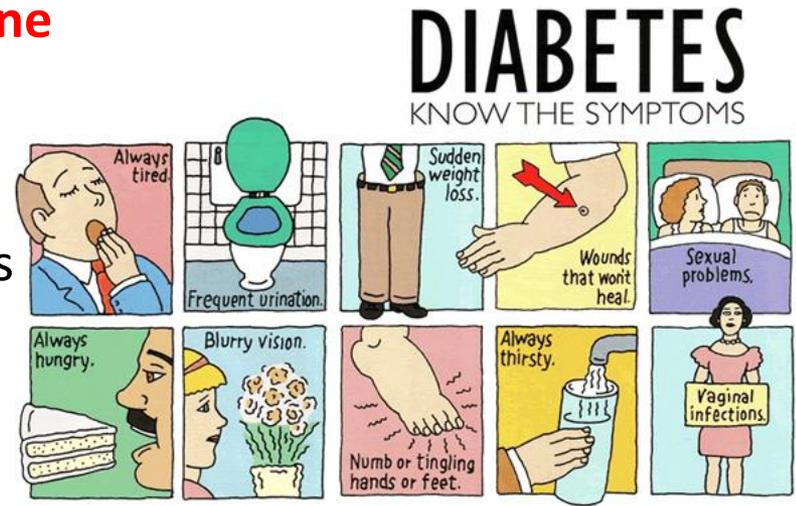
Type I Insulin-Dependent Diabetes Mellitus (IDDM)	Type II Non Insulin Dependent Diabetes Mellitus (NIDDM)
Usually occurs during childhood (early onset)	Usually occurs during adulthood (late onset)
Body does not <i>produce</i> sufficient insulin	Body does not <i>respond</i> to insulin production
Caused by the destruction of $\beta$ -cells (autoimmune)	Caused by the down-regulation of insulin receptors
Requires insulin injections to regulate blood glucose	Controlled by managing diet and lifestyle



# Diabetes Mellitus

- Symptoms same in both forms
- **High glucose concentration in blood and urine**

- Due to glucose not taken up by cells
- Less glucose converted to glycogen / fat
- Not all glucose can be reabsorbed in kidneys



- **Decrease in water potential of blood**

- **Water and salts move out of cells down concentration gradient**

→ *Dehydration, production of dilute urine, loss of salts and cramps*

→ Detected by osmoreceptors in hypothalamus → *feeling thirsty*

- **Fat and proteins used in respiration** instead of glucose → *weight loss*

→ Build up of keto acids / ketones in blood → *blood pH lowers, can cause coma*

# Urine Analysis

Urine can be collected from patient to test



Presence of **glucose and keto acids/ketones** in urine:

- Not all glucose is reabsorbed at the PCT
- **May have diabetes mellitus**

Long-term presence of **proteins** in urine:

- Most protein molecules do not pass through the basement membrane at the Bowman's capsule
- Other protein should be reabsorbed at the PCT
- **May have kidney infection or disease affecting the glomeruli**
- **Also associated with high blood pressure**
- Short-term common during high fever, vigorous exercise, pregnancy etc

# Dip stick tests

- Used to **measure glucose concentration in urine** (not blood!)
- Specific test for glucose detection



- 1) **Glucose oxidase** and **peroxidase** immobilised onto pad on dipstick
- 2) Dip stick lowered into urine



- 4) Compare with colour chart

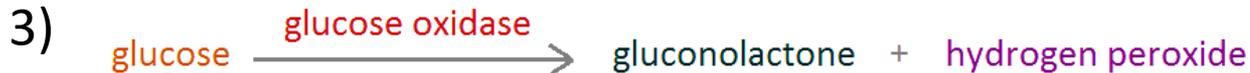


- Darkness of colour is proportional to concentration of glucose
- **The more glucose present, the darker the colour!**

# Biosensors

- Biosensors can directly **measure glucose concentration in blood**
- Reusable, more precise

- 1) **Glucose oxidase** immobilized on pad
- 2) Place small sample of blood on pad and insert into machine



- **Small electric current** is generated at the same time

- 4) Current detected by electrode
- Current amplified and reading is produced
  - Gives numerical value of blood glucose concentration
  - **More glucose present, greater current, greater reading from bio sensor**



# Chapter Outline

## **Part 3: Homeostasis in Plants** (to be continued later...)

- Stomata
- Structure and Function of Guard Cells
- Stoma Opening and Closing Mechanism
- Role of **Abscisic Acid** During Water Stress
  - calcium ions = second messenger