SLE 132 – Form and Function
Excretory organs

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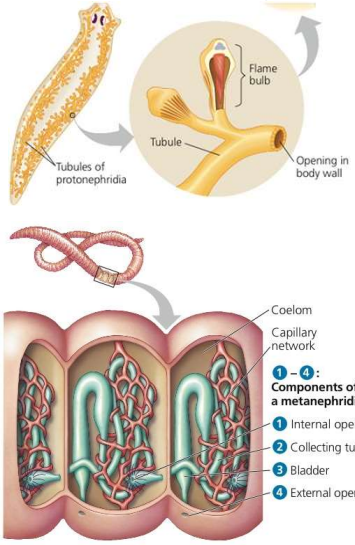
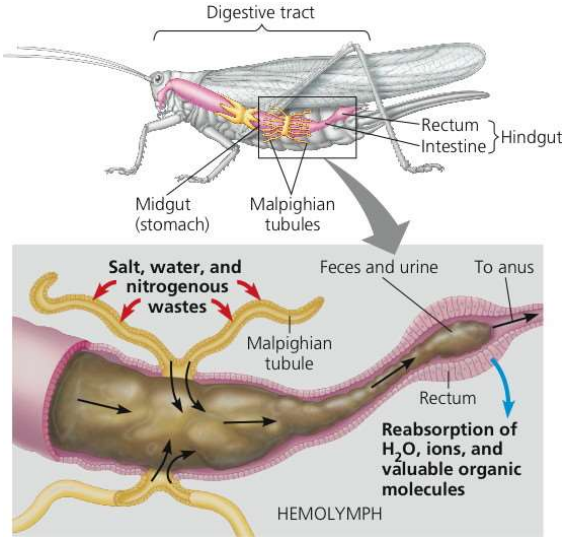
Excretory Organs

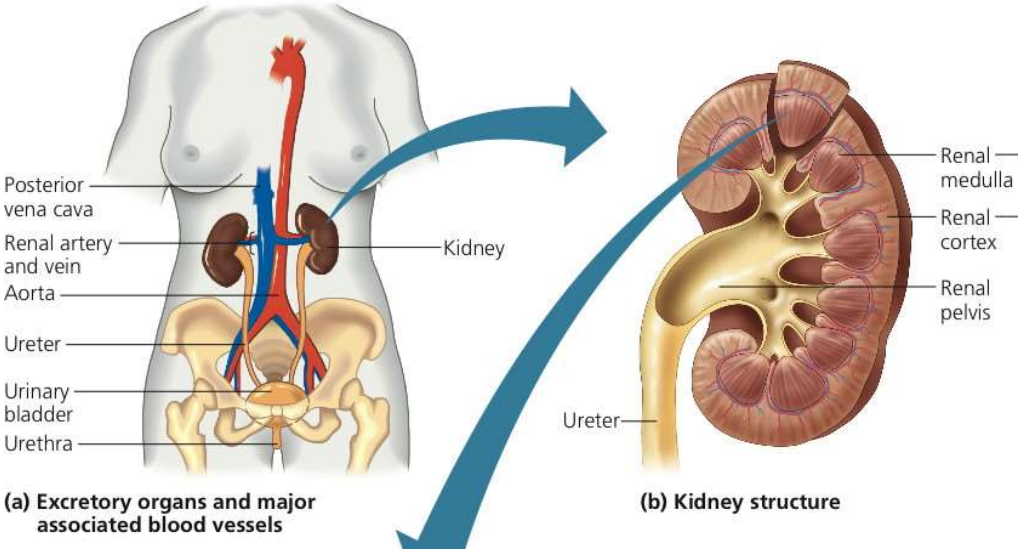
- Across animal phyla there is a common thread to osmoregulation and excretion
- Most groups use a **variant of a tubular system**,
  i.e. A series of tubes for excretion and osmoregulation
- All have different names and different formats but are based on the same principles
- Examples
  - **Flatworms:** protonephridia
  - **Earthworms:** metanephridia
  - **Insects:** Malpighian tubules
  - **Vertebrates:** kidneys (these have many excretory tubules)

Examples of excretory systems FYI



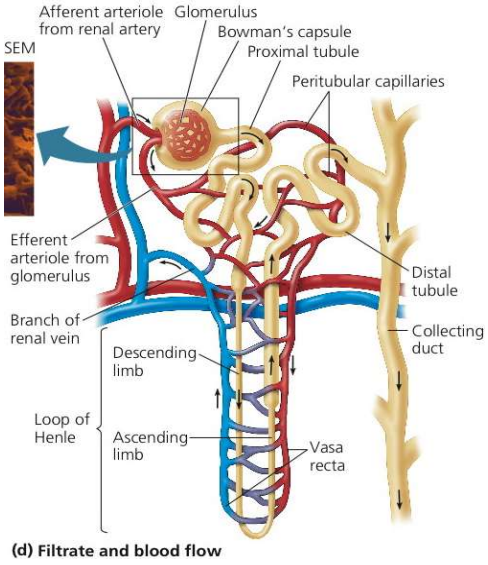


Human Excretory system

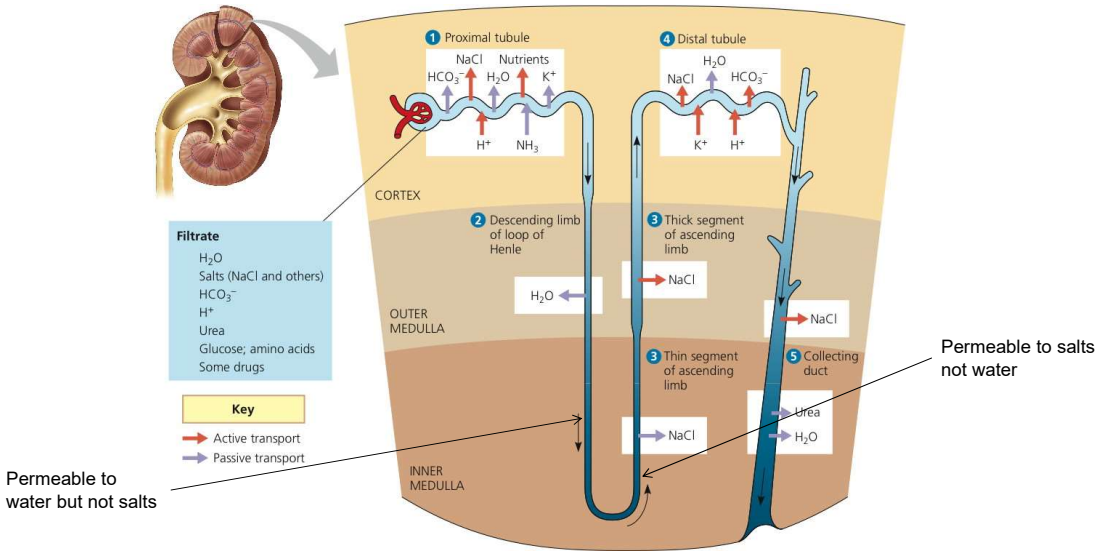


The nephron is the functional unit of the human kidney

- Inside each nephron is:
  - Bowman's capsule (and glomerulus)
  - Proximal tubule
  - Loop of Henle
  - Distal tubule
  - Collecting duct (common tubule for many nephrons)
- Each part of the nephron has a distinct function



The nephron is the functional unit of the human kidney

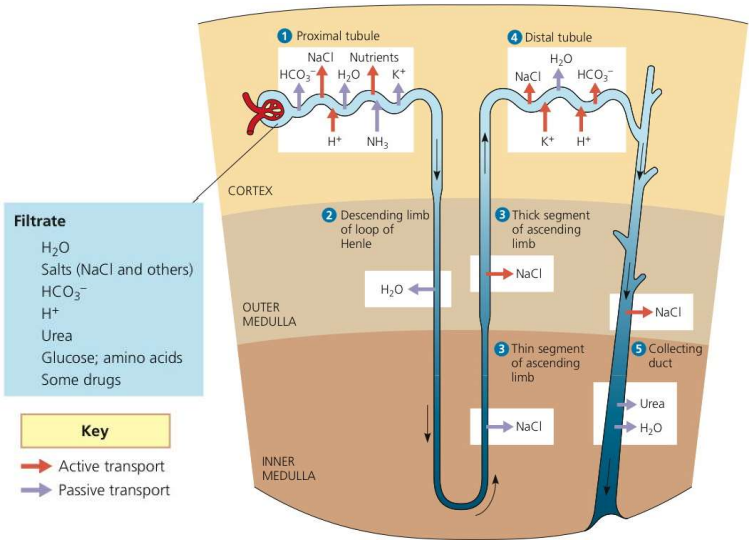


1. Function of the Bowman's Capsule and glomerulus

- In the glomerulus:
  - **Filtration** occurs – filtrate forced out of the blood by blood pressure into Bowman's capsule. Filtrate contains:
    - Water
    - Urea (nitrogenous wastes)
    - Nutrients (glucose, amino acids, vitamins)
    - Ions (Na^+, Cl^-, K^+, H^+, HCO_3^-)
    - Some small molecules like drugs and poisons
  - **Left in the blood:** proteins, blood cells.

The Bowman's Capsule and Glomerulus

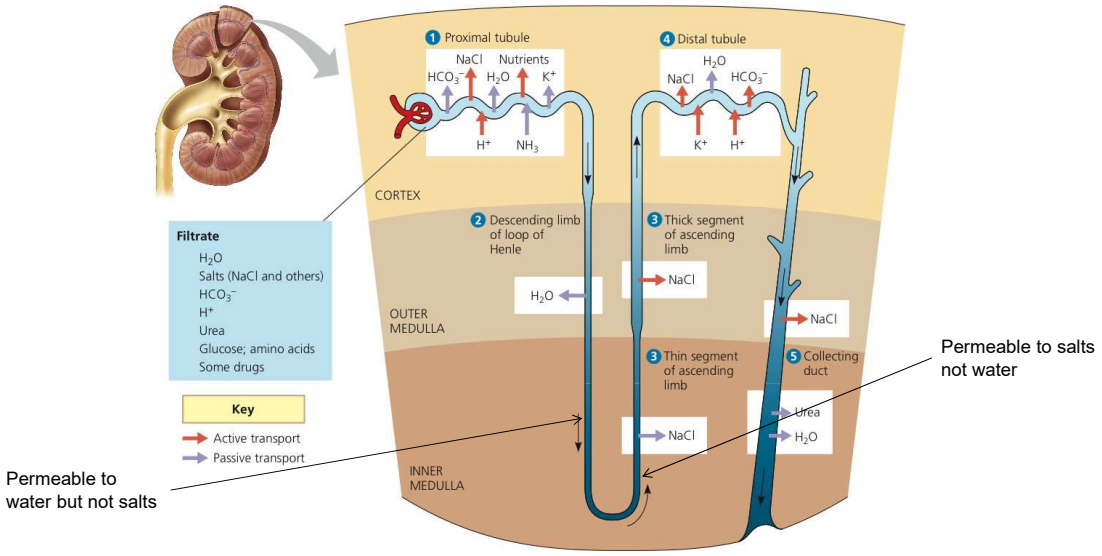
Blood pressure forces filtrate out of the many capillaries of the glomerulus into the Bowman's capsule



2. Function of Proximal tubule and Loop of Henle

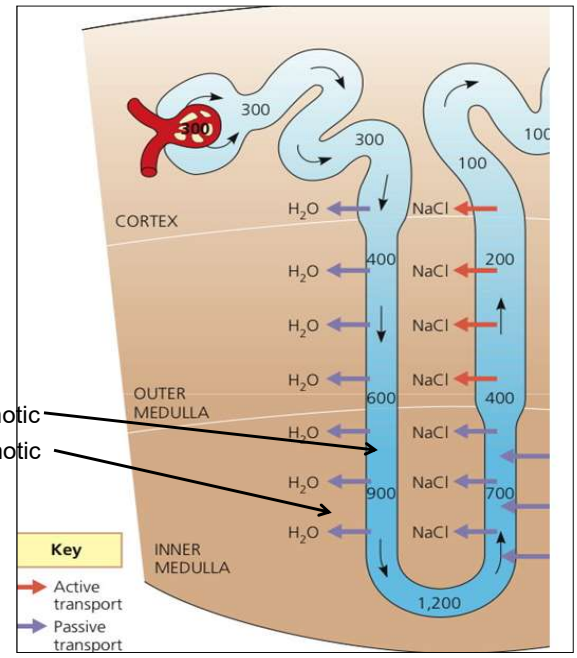
- In the proximal tubules
  - **Active reabsorption** of Na^+, Cl^- and nutrients
  - **Passive reabsorption** of water K^+, and HCO_3^-
  - Secretion of H^+, NH_3
- In the Loop of Henle
  - As the filtrate passes down the Loop of Henle, <u>water moves out passively</u> (medulla is hyper osmotic)
  - As the filtrate passes up the other side of the Loop of Henle, <u>NaCl moves out</u> passively at first, then actively

The nephron is the functional unit of the human kidney



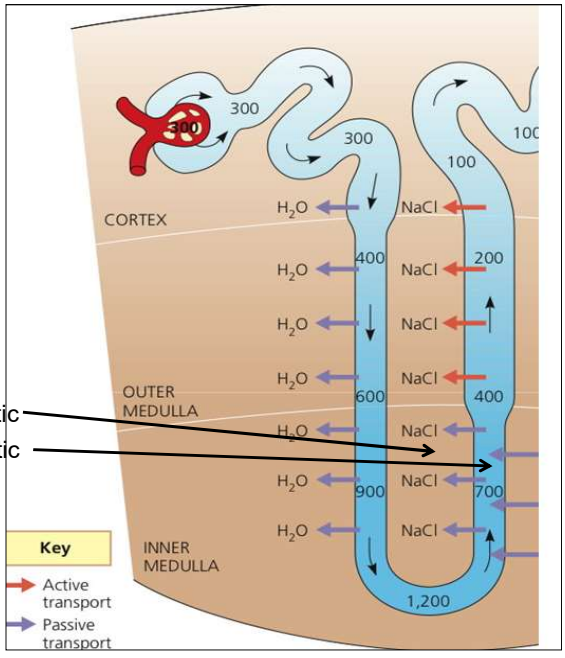
Descending loop

- As the filtrate passes down the Loop of Henle, <u>water moves out passively</u>
- Moving down, filtrate becomes **more concentrated**



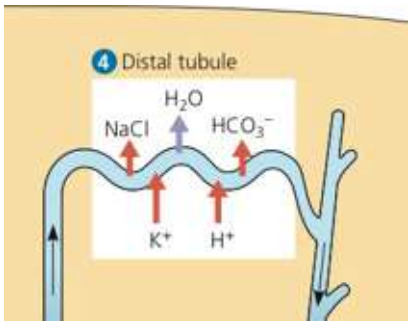
Ascending loop

- Hyper- osmotic filtrate moves up, <u>NaCl moves out</u> passively, then actively.
- Medulla is hypo osmotic to fluid in tubules
- Moving up, filtrate becomes **less concentrated**



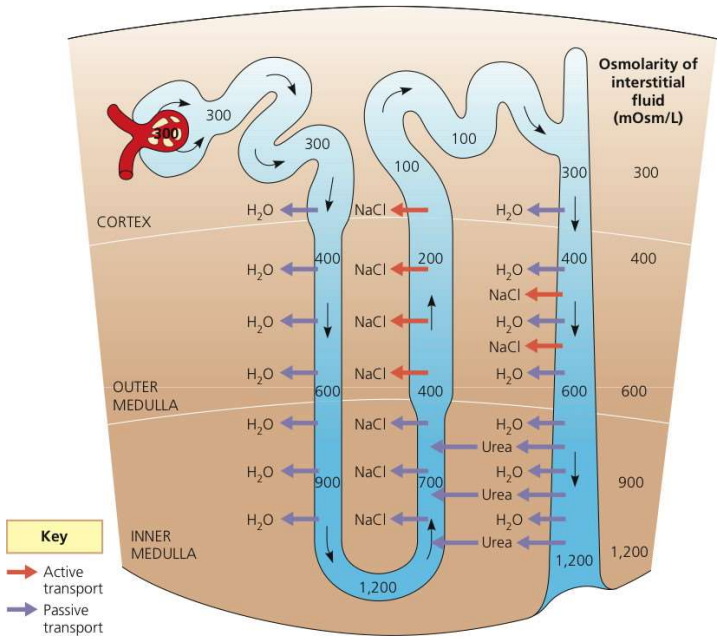
3. Distal Tubule and Collecting Duct

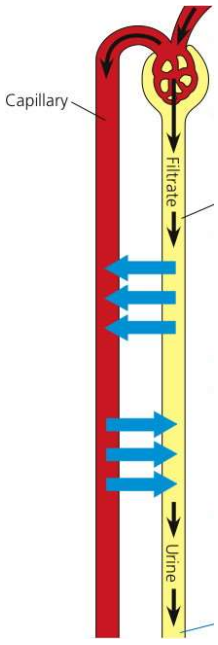
- In the **distal tubule**
  - Further re absorption of Na^+, Cl^- , and HCO_3^- ions
  - Some secretion of H^+, K^+, drugs and poisons
  - further passive re absorption of water



3. Distal Tubule and Collecting Duct

- In the **collecting duct**
  - Water is reabsorbed
  - More active re absorption of Na^+, Cl^-
  - re absorption of small amounts of urea
  - Deep in the medulla, this urea helps make the interstitial fluid so **concentrated** that the water passively re absorbed from the loop of Henle nearby





Same 4 important processes involved in all mammals

- **Filtration**
  - Under pressure
- **Re absorption**
  - Both active and passive
  - Good molecules
- **Secretion**
  - Mainly of H^+ and K^+, stops the blood from becoming too acidic
  - Waste molecules
- **Excretion**
  - from the collecting ducts into ureter and then to bladder

The ultimate adaptation to life on land: Some animals require no drinking water

- The mulgara obtain water from the insects and other animals they eat as well as from metabolism
- The produce **very concentrated urine** due to an extra long Loop of Henle

▲ **Figure 44.17** **The Australian spinifex hopping mouse (*Notomys alexis*) produces the most concentrated urine amongst all mammals.**

Complete the nephron activity available on Moodle in Week 4 – During class activities (10 – 15 minutes)

SLE 132 – Form and Function
Hormones and the Endocrine System

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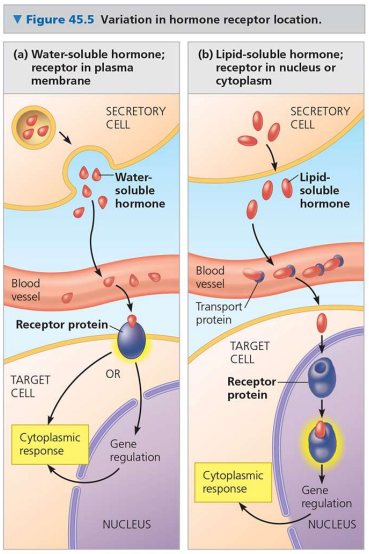
Animal Hormones

- Chemicals used to regulate functions of the animal body.
- Very important in:
  - **Controlling whole-body activities**, for example metabolic rate, growth, maturation and reproduction
  - In **homeostasis**
- Travel in blood or haemolymph to all parts of the body
- Only **certain target cells** respond (others ignore)
- Are produced in:
  - **Endocrine glands** positioned throughout body
  - **Other organs** (liver, digestive tract)

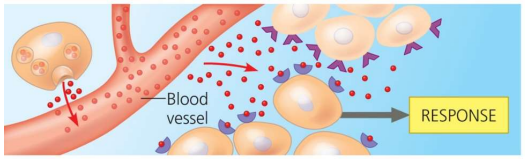
How do hormones act?

- **Very specific**
- Only cells with a specific receptor will respond to stimulus
- Start a **signal transduction pathway**

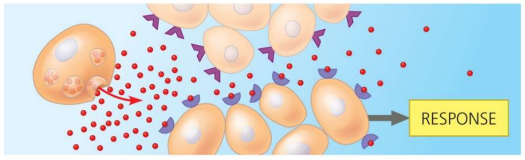


▼ **Figure 45.5** Variation in hormone receptor location.

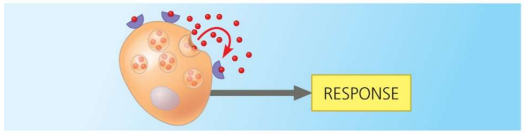
WHAT IF? *Suppose you are studying a cell's response to a particular hormone. You observe that the cell produces the same response to the hormone whether or not the cell is treated with a chemical that blocks transcription. What can you surmise about the hormone and its receptor?*



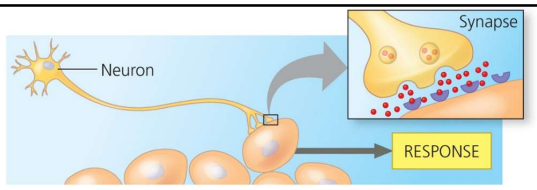
(a) In **endocrine signalling**, secreted molecules diffuse into the blood-stream and trigger responses in target cells anywhere in the body.



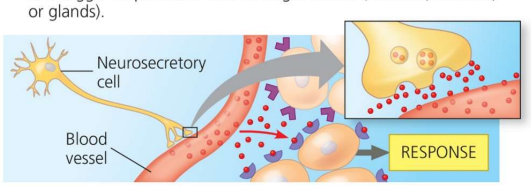
(b) In **paracrine signalling**, secreted molecules diffuse locally and trigger a response in neighbouring cells.



(c) In **autocrine signalling**, secreted molecules diffuse locally and trigger a response in the cells that secrete them.



(d) In **synaptic signalling**, neurotransmitters diffuse across synapses and trigger responses in cells of target tissues (neurons, muscles, or glands).



(e) In **neuroendocrine signalling**, neurohormones diffuse into the bloodstream and trigger responses in target cells anywhere in the body.

▲ **Figure 45.2** **Intercellular communication by secreted molecules.** In each type of signalling, secreted molecules (•) bind to a specific receptor protein (◡) expressed by target cells. Some receptors are located inside cells, but for simplicity, here all are drawn on the cell surface.

Which cells respond to hormones?

A target cell must have the appropriate receptors to receive the relevant hormone message.

Receptors can be:

- On cell membrane (**non-steroid hormones**)
- In the cytoplasm (**steroid hormones**)

A target cell also has to have **appropriate signal transduction pathways** (sets of signal/receptor proteins within the cell)

Hormone effects

Different effects in different organisms:

e.g. **Prolactin**

- milk synthesis in mammals
- delays metamorphosis in frogs
- regulates salt and water balance in fish

The same hormone can stimulate different responses in different types of cells, depending on receptors and pathway molecules.

e.g. **Parathyroid hormone** – calcium uptake in kidneys, calcium release in bones

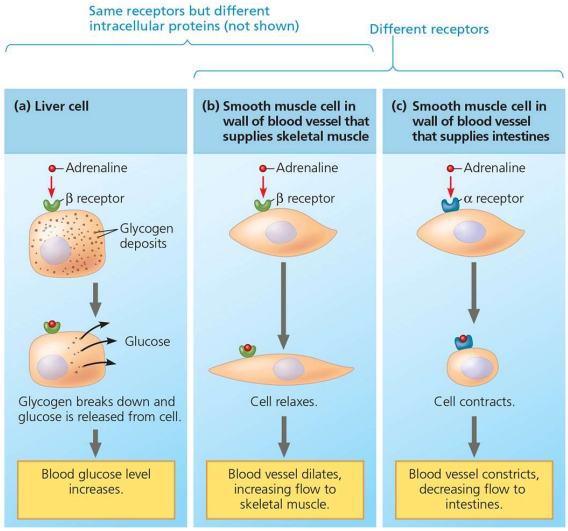
Epinephrine (Adrenalin)

Constriction of capillaries in intestine

Dilation of capillaries in muscle

Glycogen breakdown in liver to release glucose into the bloodstream

Results in coordinated, whole body response.



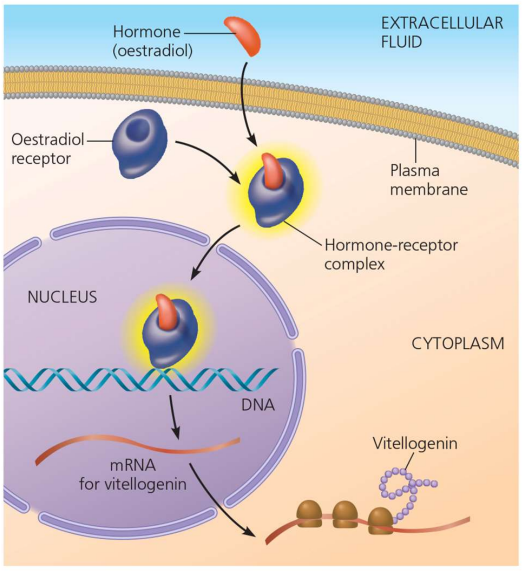
▲ **Figure 45.8** **One hormone, different effects.** Adrenaline, the primary "fight-or-flight" hormone, produces different responses in different target cells. Target cells with the same receptor exhibit different responses if they have different signal transduction pathways or effector proteins; compare (a) with (b). Target cells with different receptors for the hormone may also exhibit different responses; compare (b) with (c).

Chemical nature of hormones

- Hormones affect the target cells by two main signalling mechanisms
- The two signalling mechanisms relate to two different chemical types of hormones
  - **Steroid** hormones (e.g. Testosterone)
  - **Non steroid** hormones (e.g. Insulin)

Steroid hormones

- Are lipids so <u>can cross cell membranes</u>
  - Synthesized from cholesterol
- Hormone receptor is **inside the cell** (often in the nucleus)
- **Always affect gene expression**
  - Stimulate the production of proteins
- **In humans:** secreted by ovaries, testes and adrenal cortex



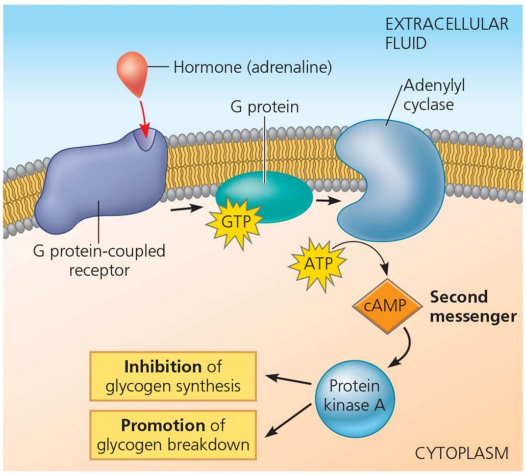
▲ **Figure 45.7** Direct regulation of gene expression by a steroid hormone receptor.

Testosterone

- A chemical produced by cells in **testes and ovaries** in females
- Passes through blood to a range of target cells
  - Simulates cell **growth and division**
    - e.g. Muscle development strength and endurance
    - e.g. Bone marrow – more red blood cells
    - e.g. Sperm production

Non steroid hormones

- All synthesized from **amino acids**
- Do not enter the cells, but <u>bind to plasma membrane</u>
- Act by **modifying the action of proteins**
  - e.g. Making a protein an active enzyme
- **Most hormones** are in this category



▲ **Figure 45.6** **Signal transduction triggered by a cell-surface hormone receptor.**

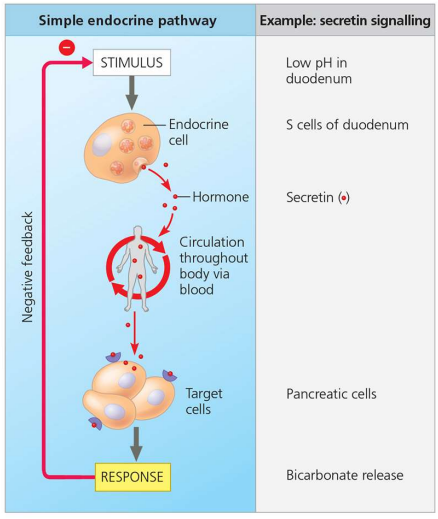
Endocrine Glands

- Secrete hormones
- These glands have no ducts – secrete into the blood (Exocrine glands have ducts like salivary glands)
- Long distance regulators
- Often interact with other control system: the nervous system

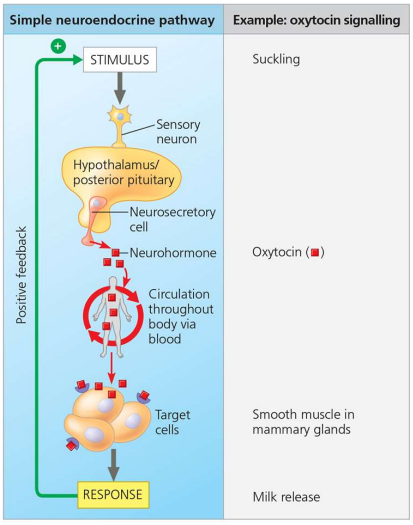
The Endocrine system and The Nervous system are linked

The two systems often interact as both involved in **internal communication and regulation**

Neurosecretory cells are considered to be a **specialised nerve cells** that secretes hormone into the blood stream in response to nerve signals



▲ **Figure 45.10 A simple endocrine pathway.** Endocrine cells respond to a change in some internal or external variable—the stimulus—by secreting hormone molecules that trigger a specific response by target cells. In the case of secretin signalling, the simple endocrine pathway is self-limiting because the response to secretin (bicarbonate release) reduces the stimulus (low pH) through negative feedback.



▲ **Figure 45.11 A simple neuroendocrine pathway.** Sensory neurons respond to a stimulus by sending nerve impulses to a neurosecretory cell, triggering secretion of a neurohormone. Upon reaching its target cells, the neurohormone binds to its receptor, triggering a specific response. In oxytocin signalling, the response increases the stimulus, forming a positive-feedback loop that amplifies signalling.

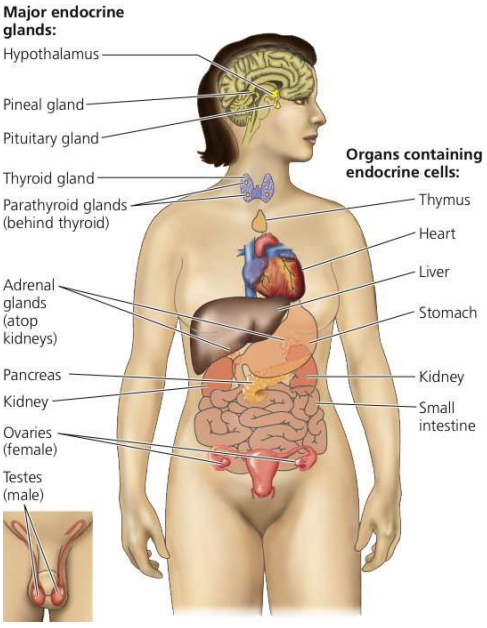
Some organs not usually considered endocrine also secrete hormones

Some organs with primarily non-endocrine functions that also have the ability to secrete hormones

- The digestive system is the source of at least 8 hormones including **gastrin**
- The liver secretes **insulin-like growth factors** (IGFs)
- The heart – **atrial natriuretic peptide** (reduces blood pressure)
- Kidney - **cholecalciferol** (inactive form of Vitamin D_3)

Human endocrine system

- >12 endocrine glands involved
- > 50 hormones made and secreted
  - Have a variety of functions
- Examples to be discussed
  - **Hypothalamus**
  - **Pituitary gland**
  - **pancreas**



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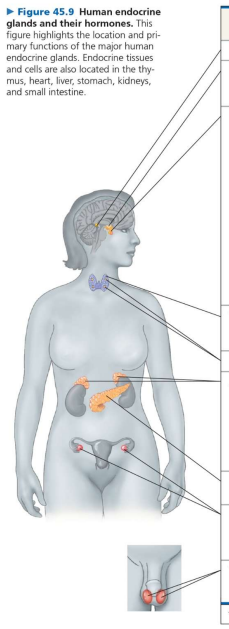


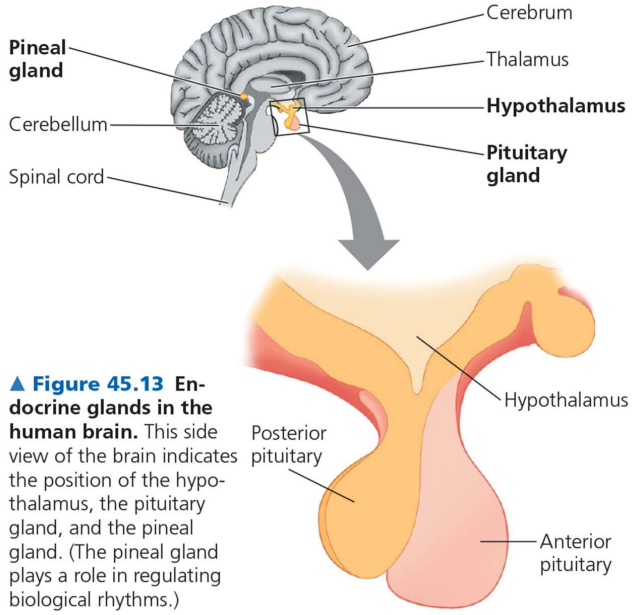
▶ **Figure 45.9 Human endocrine glands and their hormones.** This figure highlights the location and primary functions of the major human endocrine glands. Endocrine tissues and cells are also located in the thymus, heart, liver, stomach, kidneys, and small intestine.

Endocrine gland	Hormones
Pineal gland	• **Melatonin:** Participates in regulation of biological rhythms.
Hypothalamus	• **Hormones released from posterior pituitary (oxytocin** and **vasopressin)** • **Releasing and inhibiting hormones:** Regulate anterior pituitary
Pituitary gland	
Anterior pituitary	• **Follicle-stimulating hormone (FSH)** and **luteinising hormone (LH):** Stimulate ovaries and testes • **Thyroid-stimulating hormone (TSH):** Stimulates thyroid gland • **Adrenocorticotropic hormone (ACTH):** Stimulates adrenal cortex • **Prolactin:** Stimulates mammary gland cells • **Growth hormone (GH):** Stimulates growth and metabolic functions
Posterior pituitary	• **Oxytocin:** Stimulates contraction of smooth muscle cells in uterus and mammary glands • **Vasopressin:** (also called **antidiuretic hormone, ADH**): Promotes retention of water by kidneys; influences social behaviour and bonding
Thyroid gland	• **Thyroid hormone (T_3 and T_4):** Stimulates and maintains metabolic processes • **Calcitonin:** Lowers blood calcium level
Parathyroid glands	• **Parathyroid hormone (PTH):** Raises blood calcium level
Adrenal glands	
Adrenal medulla	• **Adrenaline** and **noradrenaline:** Raise blood glucose level; increase metabolic activities; constrict certain blood vessels
Adrenal cortex	• **Glucocorticoids:** Raise blood glucose level • **Mineralocorticoids:** Promote reabsorption of Na^+ and excretion of K^+ in kidneys
Pancreas	• **Insulin:** Lowers blood glucose level • **Glucagon:** Raises blood glucose level
Ovaries (female)	• **Oestrogens*:** Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics • **Progestins*:** Promote uterine lining growth
Testes (male)	• **Androgens*:** Support sperm formation; promote development and maintenance of male secondary sex characteristics

* Found in both males and females, but with a major role in one sex

The Hypothalamus

- A collection of neuro-secretory cells at base of brain
- Is a **link between nervous and endocrine systems**: way in which sensory input can be responded to by endocrine system
- **Receives input** from nerves throughout the body and other parts of the brain
  - e.g. About season/& availability of mates
- **Is the master control centre** of the endocrine system
  - Works closely with pituitary gland



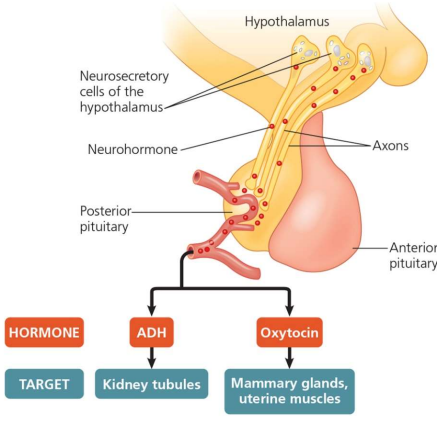
▲ **Figure 45.13 Endocrine glands in the human brain.** This side view of the brain indicates the position of the hypothalamus, the pituitary gland, and the pineal gland. (The pineal gland plays a role in regulating biological rhythms.)

Hypothalamus and Posterior Pituitary

Neurosecretory cells in hypothalamus

- **Synthesize hormones** that run down axons into posterior pituitary where they are stored and released into blood
- **ADH** -> target cells in the kidneys
- **Oxytocin**-> target cells in the mammary glands and uterus

Posterior pituitary is an <u>extension of brain</u>



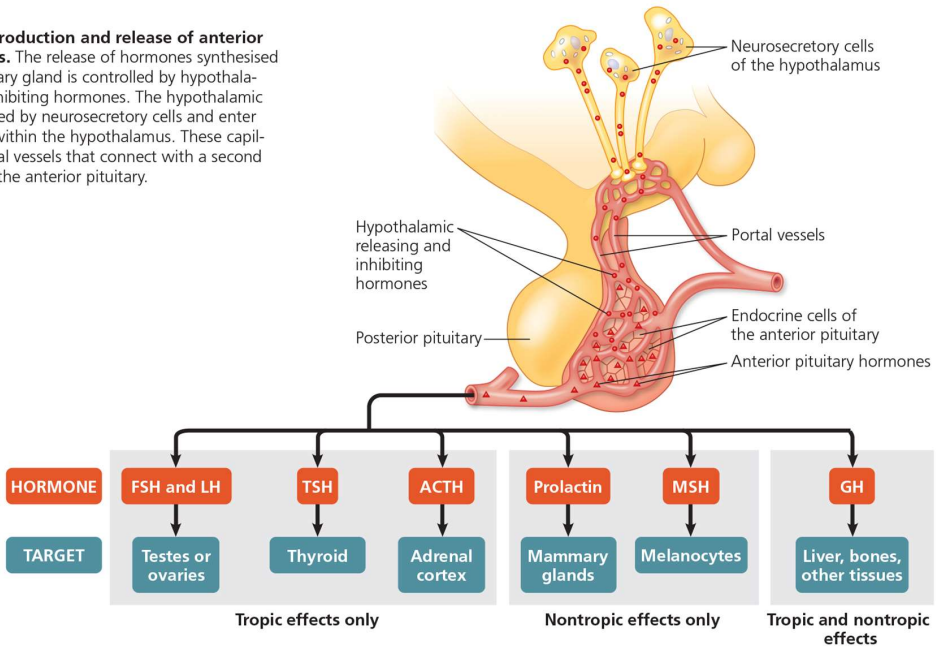
▲ **Figure 45.14 Production and release of posterior pituitary hormones.** The posterior pituitary gland is an extension of the hypothalamus. Certain neurosecretory cells in the hypothalamus make antidiuretic hormone (ADH) and oxytocin, which are transported to the posterior pituitary, where they are stored. Nerve signals from the brain trigger release of these neurohormones.

The Hypothalamus and Anterior Pituitary

Neuro-secretory cells in hypothalamus produce:

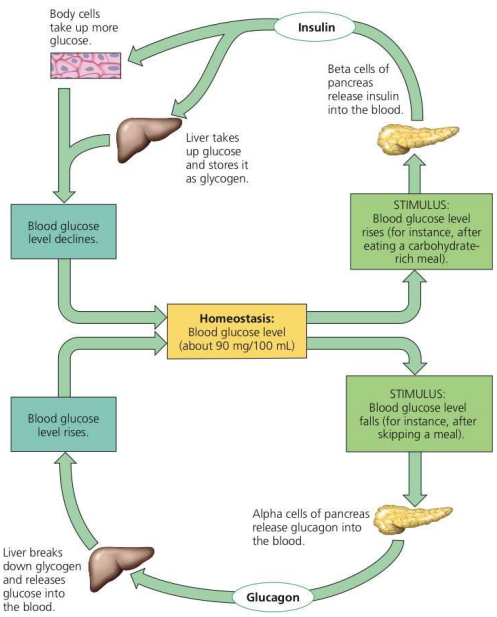
- **Releasing hormones**
  - –Make the anterior pituitary secrete hormones
- **Inhibiting hormones**
  - –Make the anterior pituitary stop secreting hormones
- The anterior pituitary synthesises a range of hormones
  - – Made up of glandular tissue

► Figure 45.15 Production and release of anterior pituitary hormones. The release of hormones synthesised in the anterior pituitary gland is controlled by hypothalamic releasing and inhibiting hormones. The hypothalamic hormones are secreted by neurosecretory cells and enter a capillary network within the hypothalamus. These capillaries drain into portal vessels that connect with a second capillary network in the anterior pituitary.



Feedback mechanisms control hormones levels and maintain homeostasis

- Negative feedback involves the presence of antagonistic (opposing) hormones
- Example: Regulation of sugar levels
  - Controlled by opposing action of 2 hormones
  - Released by Pancreas
    - **Insulin**
      (causes uptake of glucose/ storage as glycogen)
    - **Glucagon**
      (causes breakdown of glycogen into glucose)
  - Function to regulate glucose levels in blood
  - And hence maintain homeostasis



Target tissues for insulin and glucagon

- **Insulin reduces blood glucose** levels by:
  - Promoting the cellular uptake of glucose
  - Slowing glycogen breakdown in the liver
  - Promoting fat storage
- **Glucagon increases blood glucose** levels by:
  - Stimulating conversion of glycogen to glucose in the liver
  - Stimulating breakdown of fat and protein into glucose

Diabetes mellitus

Type I diabetes mellitus **(insulin-dependent)**

- an autoimmune disorder
- immune system destroys pancreatic beta cells (which produce/store insulin)

Type II diabetes mellitus **(non-insulin-dependent)**

- involves insulin deficiency or reduced response of target cells
- due to change in insulin receptors (unable to take up glucose)

Review of Sugar Regulation in the body

https://www.youtube.com/watch?v=ao7S9DD79QQ

Summary of Endocrine glands

- **Hypothalamus**
  - Link with nervous tissue
  - Produces ADH, Oxytocin
  - produces releasing and inhibiting hormones -> anterior pituitary glands and adrenal glands
- **Anterior Pituitary gland**
  - Produces TSH, ACTH, Growth hormone, Prolactin, FSH and LH.
- **Pancreas**
  - Insulin and Glucagon

Quick Question

Which of the following structures does not produce/make hormones?

a) Hypothalamus
b) Thyroid
c) Anterior Pituitary
d) Heart
e) All of the above make hormones

Quick Question

A lipid-soluble hormone is likely to bind to a receptor located where on/in the cell?

a) On the outer surface of the cell

b) Within the cell

c) Always within the nucleus