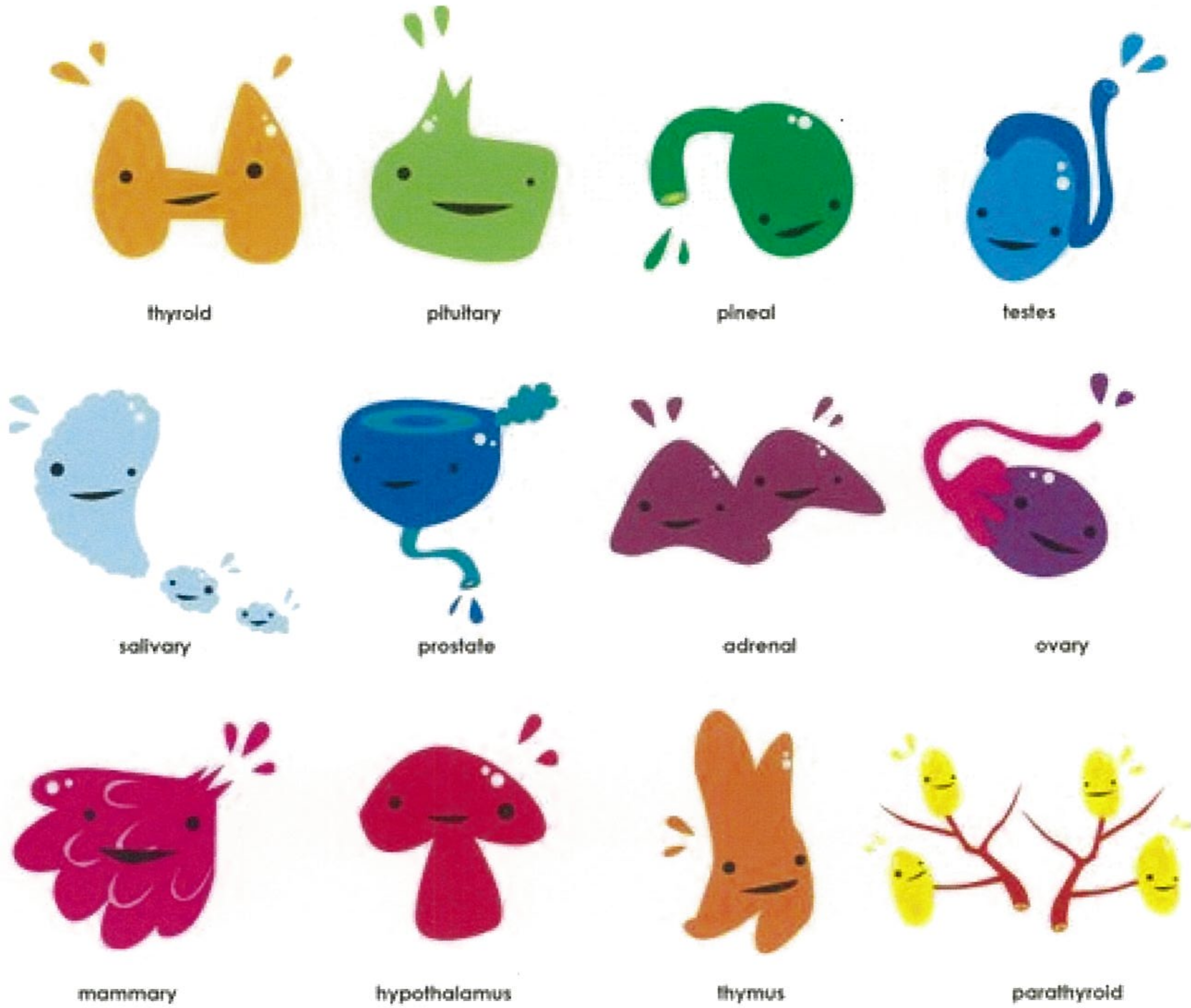
Human Biology Preparation Course Booklet 2018

Chapter 2: Chemical Messengers



Learned reflexes

The protective reflexes mentioned above are present from birth. More complex motor patterns appear during a baby's development – including reflexes such as suckling, chewing or following movements with the eyes. These innate reflexes are determined genetically.

Some complex motor patterns are learned and are called . Muscular adjustments required to maintain balance while riding a bike, jamming on the brakes of a car to avoid a dangerous situation or catching a ball are all acquired reflexes. They are learned through constant repetition.

Homeostasis

Have you ever run to catch a bus or a train, or perhaps run up several flights of stairs? After such vigorous activity you may have been sweating, your face may have been red, you would have been breathing heavily, and you would have been able to feel your heart beating forcefully and rapidly. All these responses would have occurred automatically, without any conscious thought on your part. Such responses are a part of homeostasis. is the process of keeping the environment inside the body fairly constant.

Our body cells work best at a particular temperature, when surrounded by fluid with a particular pH, when given a constant supply of oxygen and glucose, and when wastes are constantly removed. Maintaining these, and other optimum conditions for cell functioning, is all part of homeostasis.

Homeostatic mechanisms help us to be independent of our external environment. For example, if you suddenly plunge into a cold swimming pool, the cells of your brain, liver, stomach, heart and other internal organs will continue to function normally despite the sudden change in external temperature (Figure 6.3).

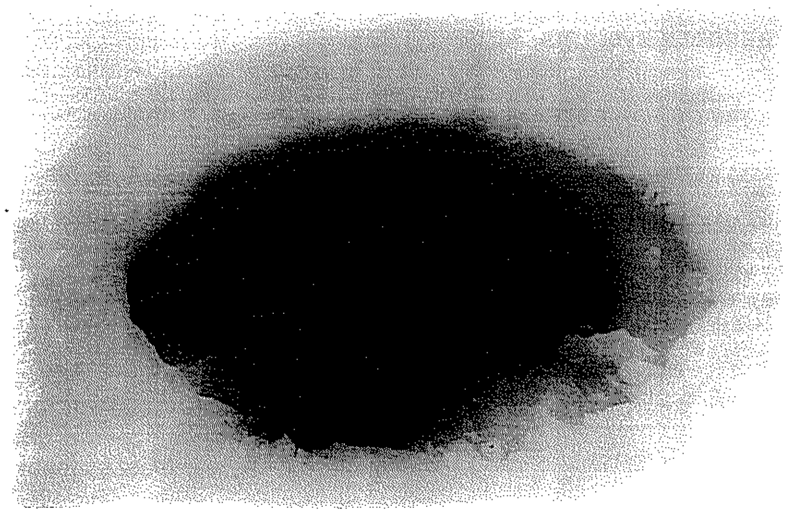


Figure 6.3 Homeostasis makes us relatively independent of the external environment.

The body's cells are surrounded by fluid, and it is the composition and temperature of this fluid that must be maintained within very fine limits. The important aspects of the internal environment that the body needs to regulate include:

- core body temperature
- pH and concentrations of dissolved substances in the body fluids
- concentration of glucose in the blood
- concentration of oxygen and carbon dioxide in the blood and other body fluids
- blood pressure
- concentration of metabolic wastes.

The maintenance of this steady state does not mean that nothing changes. Instead, there is a dynamic equilibrium in which the input and output of materials and energy are balanced. All the systems of the body contribute to homeostasis, not only to supply the cells' needs, but also to maintain a constant cellular environment.

To maintain homeostasis the body must be able to both sense changes in the internal and external environment and compensate for those changes. The nervous and endocrine systems are the main sensory and controlling body systems and, in the case of homeostasis, they operate through feedback systems, many of which involve negative feedback. Homeostasis of specific aspects of the body's internal environment will be considered in Chapters 7 and 8.

Tolerance limits

Many factors can vary in the human body. For example, oxygen concentration in the tissues, salt concentration, temperature and glucose concentration all rise and fall a little. If there is too big a rise or too big a fall then things start to go wrong with the way the body works.

are the upper and lower limits to a range of factors. Within these limits the body functions normally. A rise above, or a fall below, the normal range means that the individual's tolerance limits have been exceeded and dysfunctions will occur.

Feedback systems

A feedback system is a circular situation in which the body responds to a change, or stimulus, with the response altering the original stimulus. In the case of a negative feedback system, the response causes the stimulus, or variable, to change in a direction opposite to that of the original change.

Take, for example, a variable such as the concentration of glucose in the blood. When we exercise, our muscles use up glucose to release the energy required for muscle contraction. The muscles absorb glucose from the blood and consequently the blood glucose level tends to fall. This is the stimulus. The liver responds by releasing more glucose into the blood (Figure 6.4). Thus, the response has caused the blood glucose level to go up, which is the *opposite* of the fall in glucose that initiated the response. In this way the blood glucose level is maintained within a range that is acceptable for efficient cellular functioning.

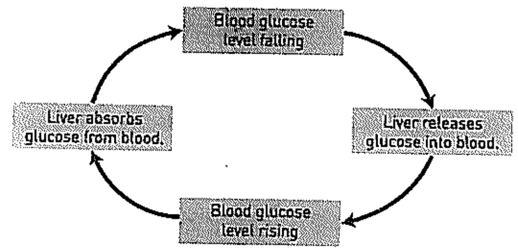


Figure 6.4 An example of a feedback system. In this case the feedback loop is controlling the body's blood glucose level

Each kidney contains about 1.2 million microscopic units called nephrons. The [illegible] is the functional unit of the kidney; that is, it is the nephrons that carry out the kidney's role in excretion and water regulation. Figure 7.11 shows a nephron and explains how it functions. Detailed information about the structure and function of the nephron was covered in *Human Perspectives Units 1 & 2 ATAR*.

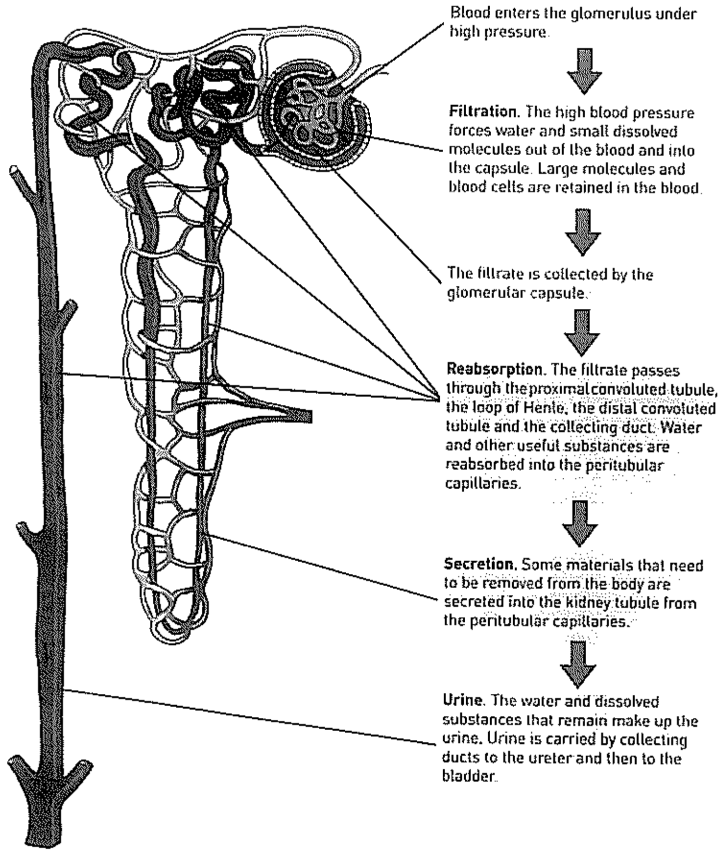


Figure 7.11 The functional unit of the kidney is the nephron.

Control of water loss by the kidneys

The volume and composition of urine produced by the kidneys depends on how much water there is in the body fluids. If you drink a large volume of water, you will quite soon produce a large volume of dilute urine. If you become dehydrated, through not drinking enough water, you will produce a smaller volume of concentrated urine.

Approximately 99% of the water filtered through the glomeruli of the kidneys is reabsorbed. This reabsorption occurs through the walls of the kidney tubules along their entire length. However, the reabsorption occurring at the proximal convoluted tubule and loop of Henle (nephron loop) is by osmosis, while reabsorption at the distal convoluted tubule and collecting tubule is active reabsorption. The level of active reabsorption is controlled by a hormone known as [illegible]

ADH is produced by the hypothalamus and released from the posterior lobe of the pituitary (see page 26). The permeability of the walls of the distal convoluted tubule and collecting duct is controlled by ADH. When the concentration of ADH in the blood plasma is high, the tubules are very permeable to water, and thus water is able to leave the tubule and enter the surrounding capillary network. This outward flow of water from the fluid within the tubules reduces its volume and hence increases the concentration of the materials remaining. On the other hand, when the concentration of ADH in the plasma is low, the tubules are not very permeable to water, and little water is reabsorbed into the plasma of the blood. In this situation, the fluid within the tubules remains fairly dilute, as its volume is not reduced to any significant extent.

The action of ADH in controlling water balance is another example of a feedback process maintaining the internal environment of the body. The mechanism for the process is described below and illustrated in Figure 7.12.

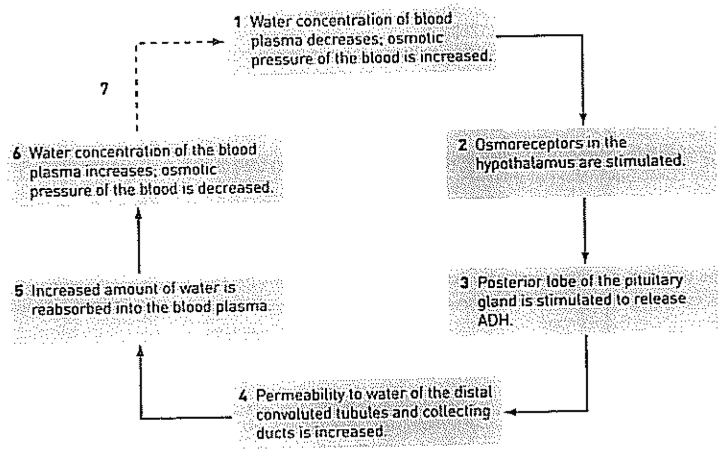
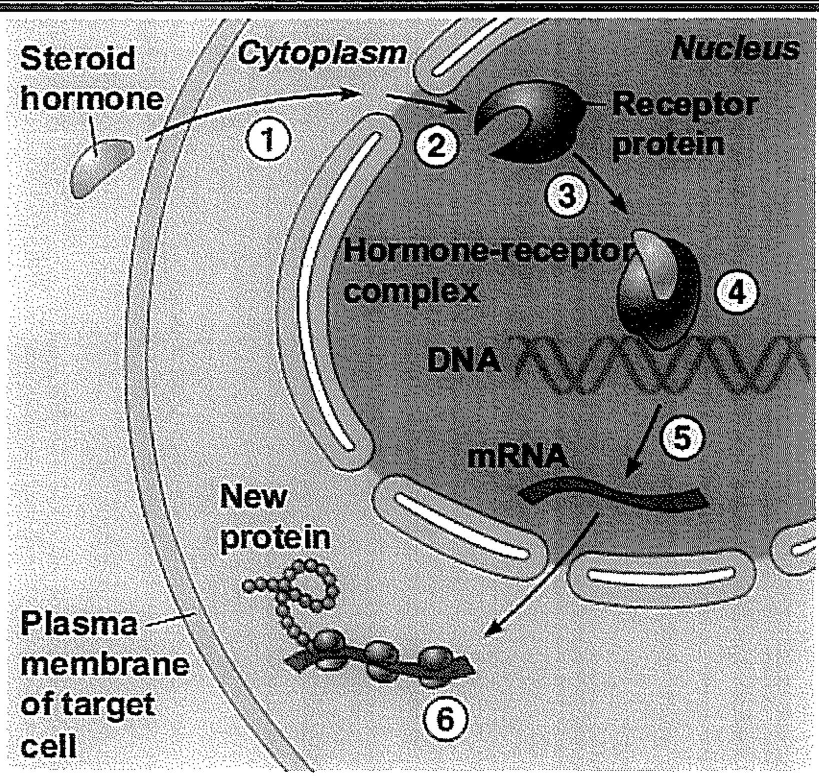
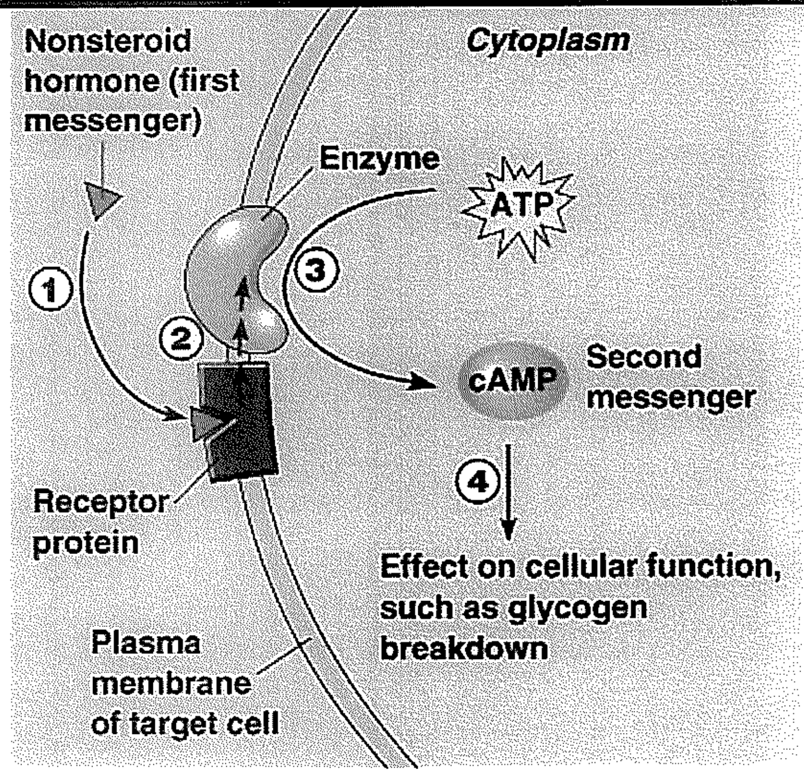
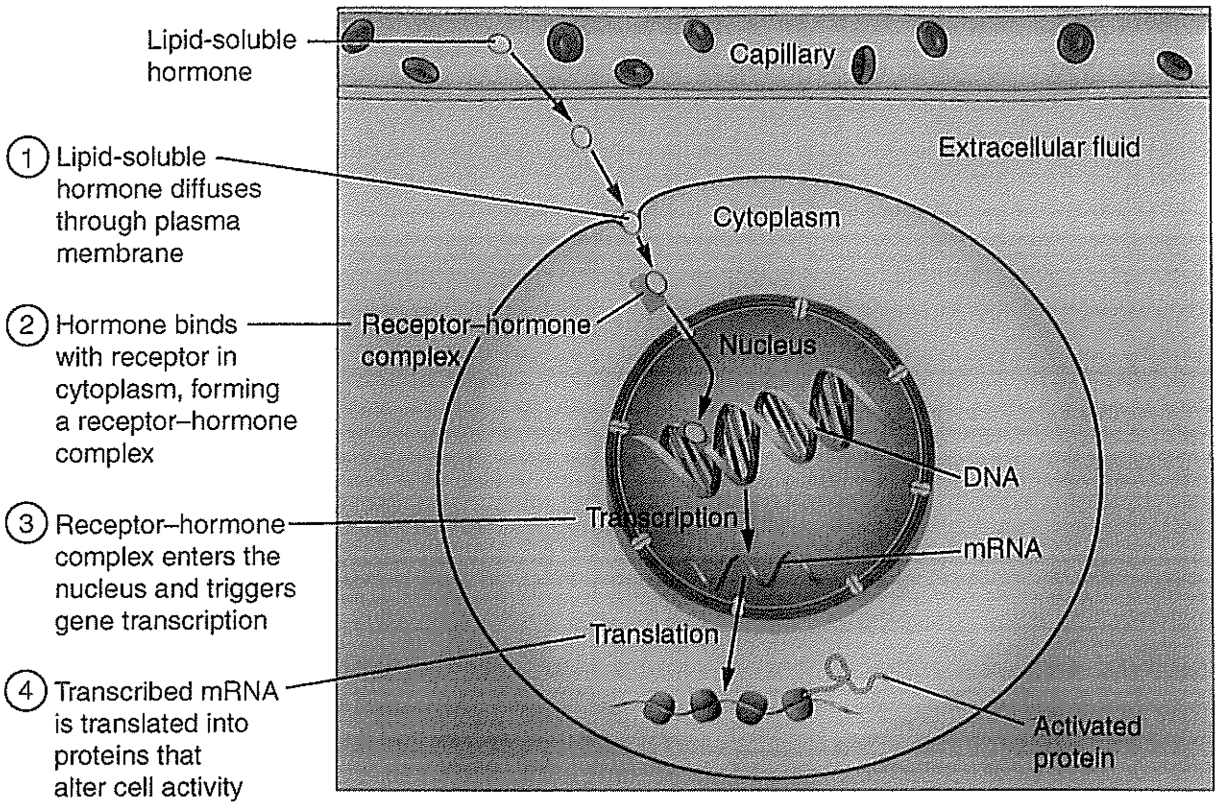
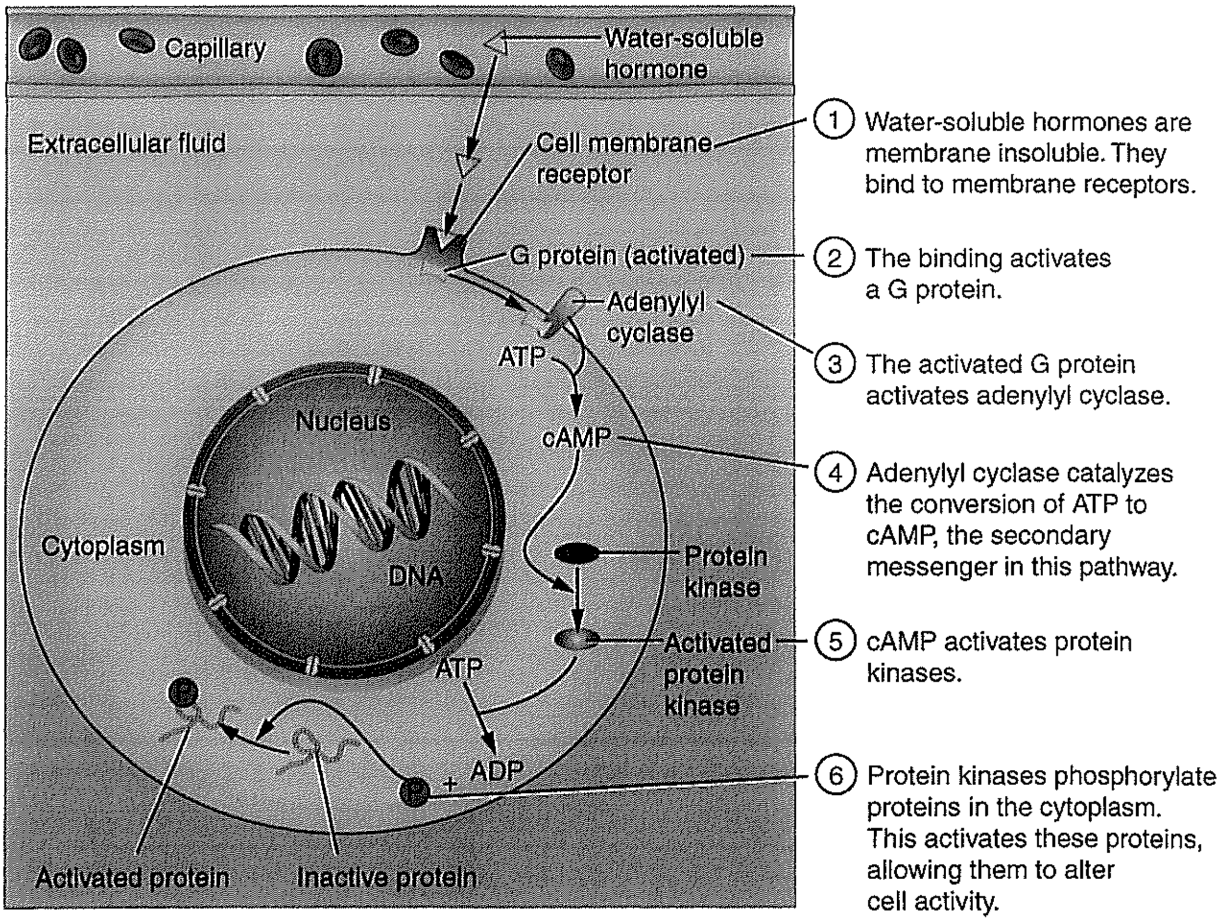


Figure 7.12 The regulation of water output by antidiuretic hormone (the numbers refer to the points listed in the text)

1 If a decreased amount of water is in the blood, such as would result from increased loss of water through sweat, the water concentration of the blood plasma would decrease. This means the osmotic pressure of the blood is raised.
2 Osmoreceptors in the hypothalamus detect the increased osmotic pressure of the blood.
3 The hypothalamus stimulates the posterior lobe of the pituitary gland to release ADH into the bloodstream.
4 ADH is carried all over the body by the blood but it affects its target organs, which are the nephron tubules in the kidney. The permeability to water of the distal convoluted tubules and the collecting ducts is increased.
5 More water is then reabsorbed into the blood plasma from the tubules and ducts.
6 The reabsorption of water increases the water concentration in the plasma and so the osmotic pressure of the blood is decreased.
7 The response is decreased osmotic pressure of the blood. This has eliminated or reduced the original stimulus that was increasing osmotic pressure of the plasma. Negative feedback has occurred.

STEROID HORMONE	PROTEIN / AMINE HORMONE
	
MODE OF ACTION:	MODE OF ACTION:
EFFECT ON TARGET CELL:	EFFECT ON TARGET CELL:

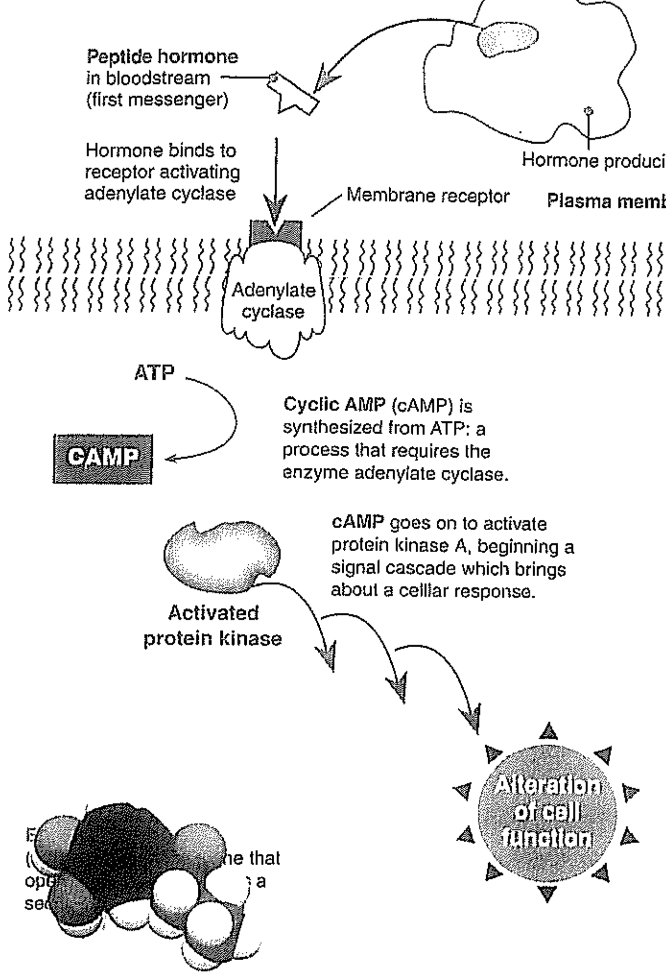

Lipid-soluble hormone
Capillary
Extracellular fluid
Cytoplasm
1 Lipid-soluble hormone diffuses through plasma membrane
2 Hormone binds with receptor in cytoplasm, forming a receptor–hormone complex
Receptor–hormone complex
Nucleus
DNA
3 Receptor–hormone complex enters the nucleus and triggers gene transcription
Transcription
mRNA
Translation
4 Transcribed mRNA is translated into proteins that alter cell activity
Activated protein


Capillary
Water-soluble hormone
Extracellular fluid
Cell membrane receptor
1 Water-soluble hormones are membrane insoluble. They bind to membrane receptors.
G protein (activated)
2 The binding activates a G protein.
Adenylyl cyclase
3 The activated G protein activates adenylyl cyclase.
ATP
cAMP
4 Adenylyl cyclase catalyzes the conversion of ATP to cAMP, the secondary messenger in this pathway.
Nucleus
Cytoplasm
DNA
Protein kinase
Activated protein kinase
5 cAMP activates protein kinases.
ATP
+ ADP
6 Protein kinases phosphorylate proteins in the cytoplasm. This activates these proteins, allowing them to alter cell activity.
Activated protein
Inactive protein

Signal Transduction

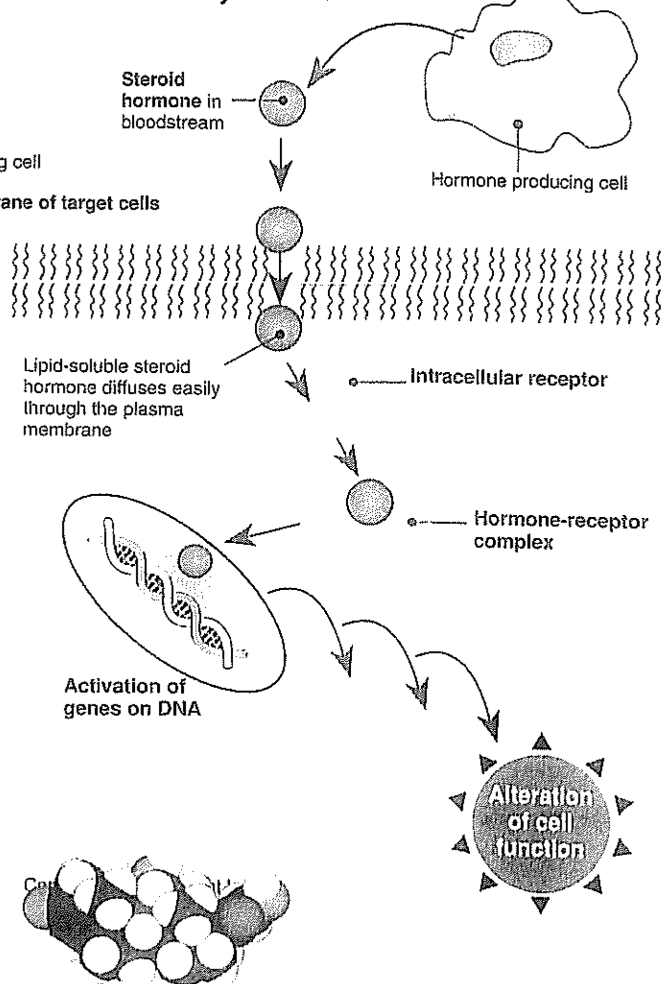
Once released, a hormone is carried in the blood to affect specific target cells. Water soluble hormones are carried free in the blood, whilst steroid and thyroid hormones are carried bound to plasma proteins. Target cells have receptors to bind the hormone, initiating a cascade of reactions which results in a specific target cell response (e.g. protein synthesis, change in membrane permeability, enzyme activation, or secretion). **Peptide hormones** operate by interacting with transmembrane receptors and activating a second messenger system (e.g. cyclic AMP). **Steroid hormones** enter the cell to interact directly with intracellular cytoplasmic receptors. Once the target cell responds, the response is recognized by the hormone-producing cell through a feedback signal and the hormone is degraded.

Activation By Second Messenger



Cyclic AMP is a **second messenger** linking the hormone to the cellular response. Cellular concentration of cAMP increases markedly once a hormone binds and the cascade of enzyme-driven reactions is initiated.

Gene Activation by Steroids



Steroid hormones alter cellular function through direct activation of genes. Once inside the target cell, steroids bind to intracellular receptor sites, creating hormone-receptor complexes that activate specific genes.

1. Describe the two mechanisms by which a hormone can bring about a cellular response:

   (a) ____

   ____

   (b) ____

   ____

2. State in what way these two mechanisms are alike: ____

   ____

   ____

3. Explain how a very small amount of hormone is able to exert a disproportionately large effect on a target cell:

   ____

   ____

   ____

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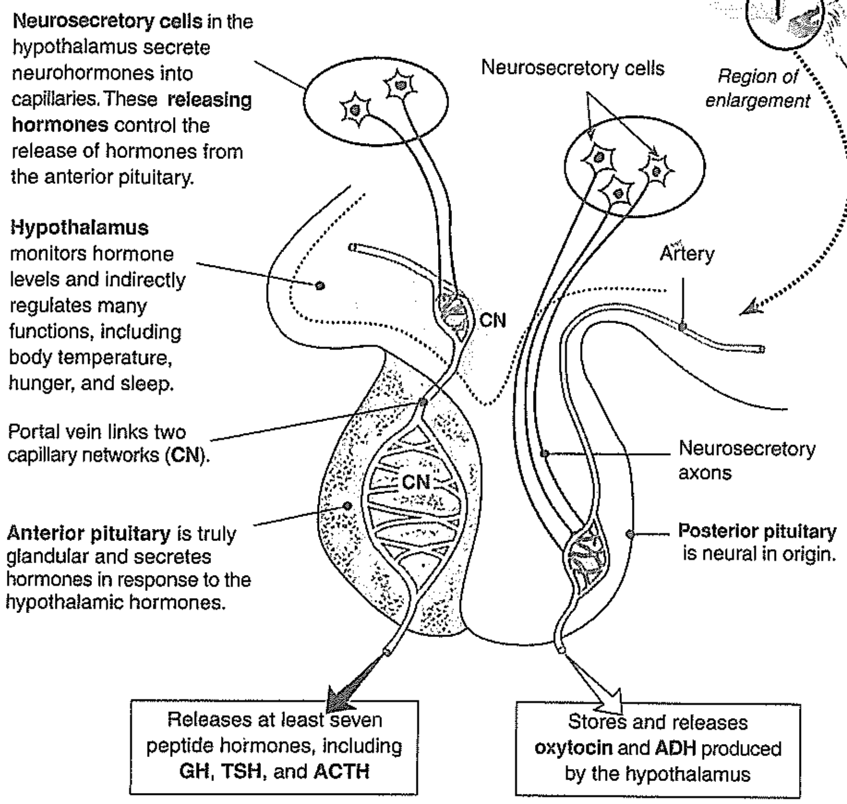
Related activities: Hormonal Regulatory Systems, Cell Signaling
Web links: Signal Transduction, Peptide Hormone Action

The Hypothalamus and Pituitary

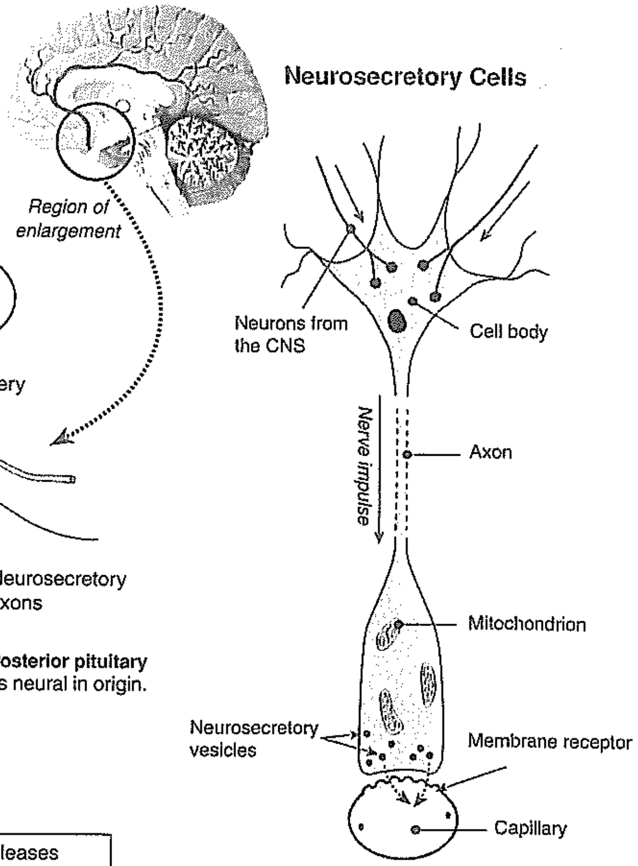
The **hypothalamus** is located below the thalamus, just above the brain stem and the pituitary gland, with which it has a close structural and functional relationship. Information comes to the hypothalamus through sensory pathways from sensory receptors. On the basis of this information, the hypothalamus controls and integrates many basic physiological activities (e.g. temperature regulation, food and fluid intake, and sleep), including the reflex activity of the **autonomic nervous system**.

One of the most important functions of the hypothalamus is to link the nervous system to the endocrine system (via the pituitary). The hypothalamus contains **neurosecretory cells**. These are specialized secretory neurons, which are both nerve cells and endocrine cells. They produce hormones (usually peptides) in the cell body, which are packaged into droplets and transported along the axon. At the axon terminal, the **neurohormone** is released into the blood in response to nerve impulses.

The Role of the Hypothalamus



Neurosecretory Cells



1. (a) Explain how the anterior and posterior pituitary differ with respect to their relationship to the hypothalamus:

(b) Explain how these differences relate to the nature of the hormonal secretions for each region:

2. Describe the role of the neurohormones released by the hypothalamus:

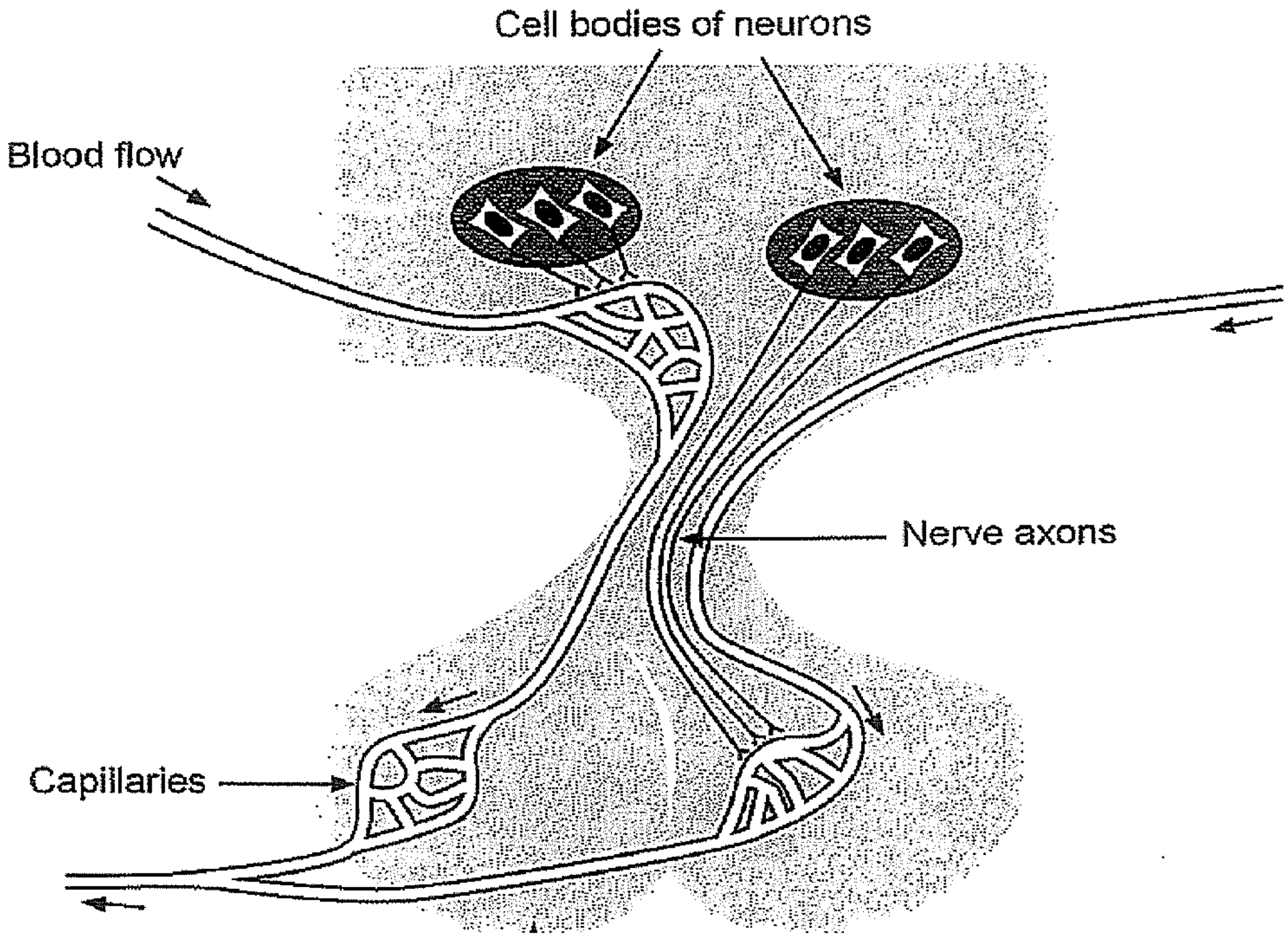
3. Explain why the adrenal and thyroid glands atrophy if the pituitary gland ceases to function:

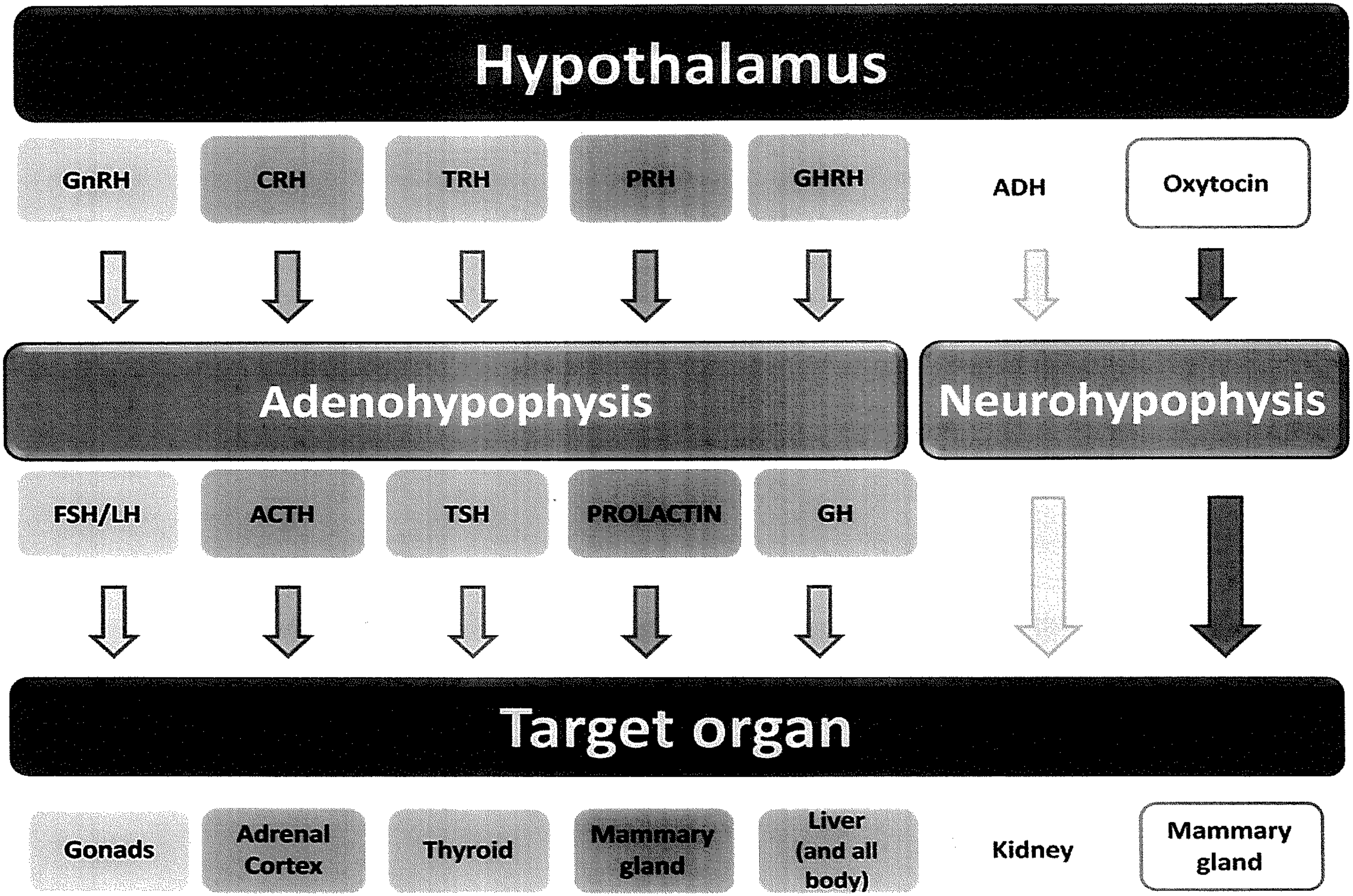
4. Although the anterior pituitary is often called the master gland, the hypothalamus could also claim that title. Explain:

The Endocrine System

ISBN: 978-1-877462-26-9

Related activities: Hormones of the Pituitary, The Stress Response


Cell bodies of neurons
Blood flow
Nerve axons
Capillaries



Hypothalamus
GnRH
CRH
TRH
PRH
GHRH
ADH
Oxytocin
Adenohypophysis
Neurohypophysis
FSH/LH
ACTH
TSH
PROLACTIN
GH
Target organ
Gonads
Adrenal Cortex
Thyroid
Mammary gland
Liver (and all body)
Kidney
Mammary gland

Hormones of the Pituitary

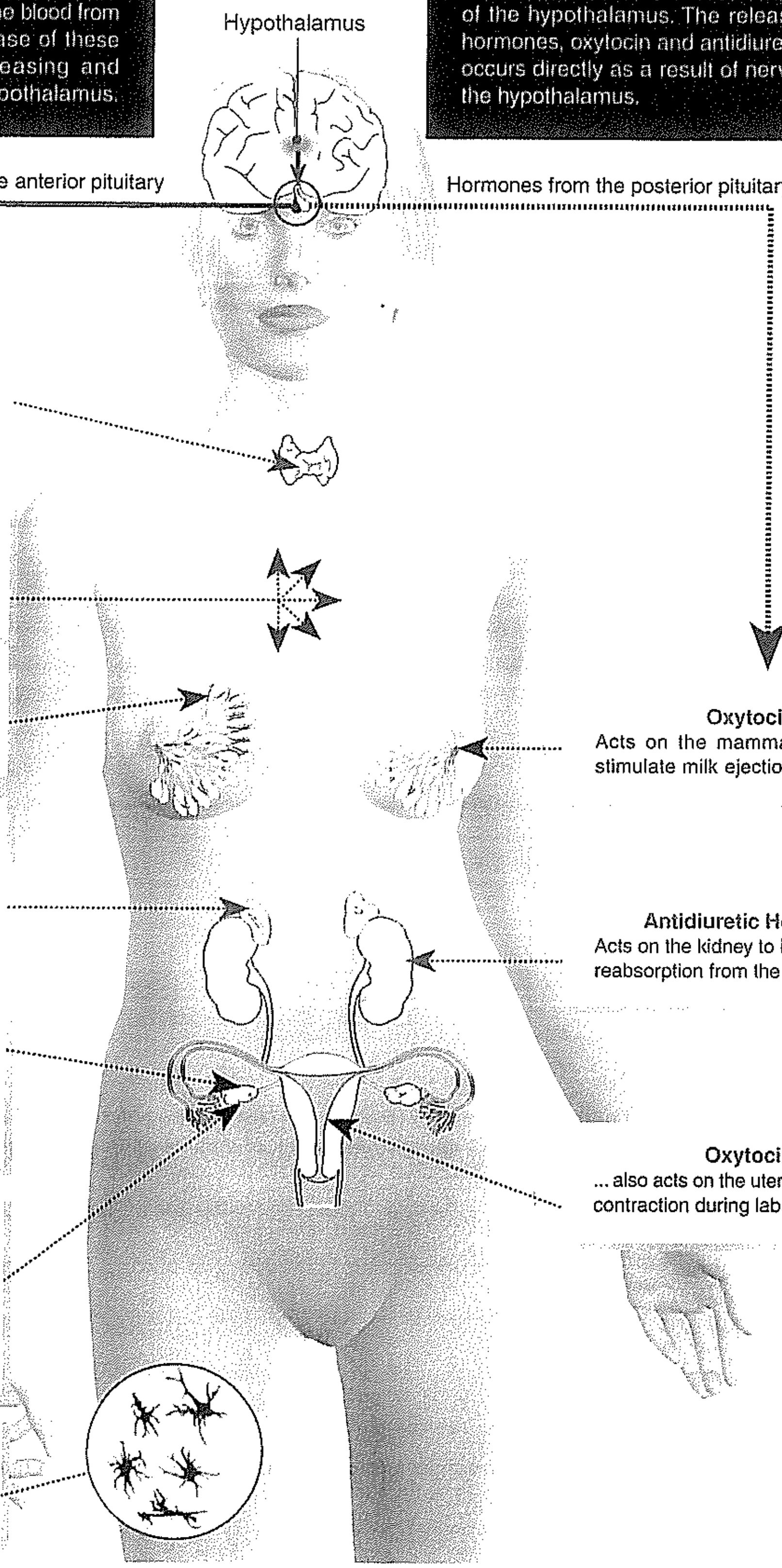
The **pituitary gland** (or hypophysis) is a tiny endocrine gland, about the size of a pea, hanging from the inferior surface of the hypothalamus. It has two regions or lobes, each with different structure and origin. The **posterior pituitary** is neural (nervous) in origin and is essentially an extension of the hypothalamus. Its neurosecretory cells have their cell bodies in the hypothalamus, and release oxytocin and ADH directly into the bloodstream in response to nerve impulses. The **anterior pituitary** is connected to the hypothalamus by blood vessels and receives releasing and inhibiting hormones (factors) from the hypothlamus via a capillary network. These releasing hormones regulate the secretion of the anterior pituitary's hormones.

ANTERIOR PITUITARY

The anterior pituitary releases at least seven **peptide hormones** (below) into the blood from simple secretory cells. The release of these hormones is regulated by releasing and inhibiting hormones from the hypothalamus.

POSTERIOR PITUITARY

The posterior pituitary develops as an extension of the hypothalamus. The release of its two hormones, oxytocin and antidiuretic hormone, occurs directly as a result of nervous input to the hypothalamus.



Thyroid Stimulating Hormone
Inceases synthesis and secretion of thyroid hormones (T_3 and thyroxine) from the thyroid gland.

Growth Hormone
Stimulates protein synthesis and growth in most tissues; one of the main regulators of metabolism.

Prolactin
Stimulates growth of the mammary glands and synthesis of milk protein.

Adrenocorticotrophic Hormone
Usually abbreviated to ACTH, this hormone increases synthesis and secretion of hormones (aldosterone and cortisol) from the adrenal cortex.

Follicle Stimulating Hormone
In females: Stimulates maturation of the ovarian follicles.
In males: Increases the production of sperm in the seminiferous tubules.

Luteinizing Hormone
In females: Stimulates secretion of ovarian hormones, ovulation, and formation of the corpus luteum.
In males: Stimulates synthesis and secretion of testosterone .

Melanophore Stimulating Hormone
Increases melanin synthesis and dispersal in the skin's melanocytes.

Oxytocin
Acts on the mammary glands to stimulate milk ejection (let down)...

Antidiuretic Hormone
Acts on the kidney to increase water reabsorption from the filtrate (urine).

Oxytocin
... also acts on the uterus to stimulate contraction during labor.

Related activities: The Endocrine System, The Hypothalamus and Pituitary, The Stress Response

Hormones in the Pituitary Gland

Hormone	Posterior/Anterior	Target Organ	Effect
G			
O			
A			
T			
F			
L			
A			
P			

QUESTIONS: ENDOCRINE SYSTEM, WEEK 1

1. Define homeostasis.

2. What is meant by a feedback system? Outline the difference between a negative and positive feedback

3. Explain the difference between endocrine and exocrine glands and give 3 examples of each.

4. Define hormone.

5. What is a target organ?

6. Hormones and nerve impulse are similar in that they carry 'messages'. Outline a difference/s between hormones and nerves

7. Hormones are specific. What does this mean and how is specificity achieved?

8. What is the difference between a hormone and a paracrine?

9. There are two main types of hormones, which enter the cell in different ways. Using the two diagrams below: *(recap cell membrane structure)*

a) Identify which hormone is shown and state whether it is lipid or water soluble *(how are you going to remember which is which?)*

b) Label all components (some may require you to explain what is occurring).

c) Explain how it specifically affects the functioning of the cell once inside.

DIAGRAM A

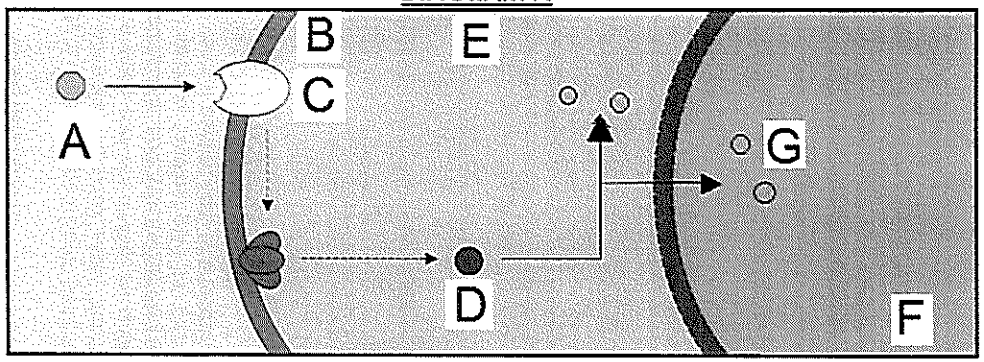
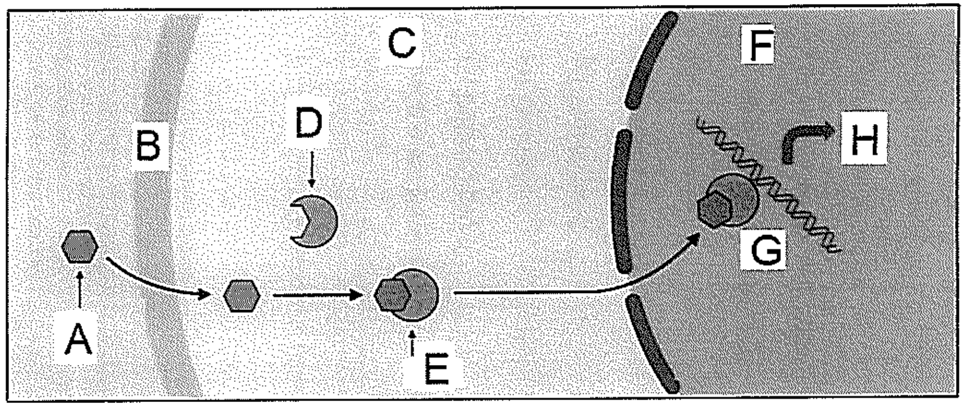


DIAGRAM B



10. Give an example of a hormone that is lipid soluble and water soluble.

11. Explain how hormones change the functioning of cells

12. Describe enzyme amplification.

13. Explain why the addition of more and more hormone does not continue to increase the intensity or rate of the response.

14. Once a hormone has brought about a response, what happens to the hormone?

15. What is a synthetic hormone?

16. Although a patient may be on hormone replacement therapy to improve their deficiency/symptoms (e.g. in post-menopausal women), synthetic hormones can also cause negative impacts on the body. Describe two impacts.

The Endocrine System

The endocrine glands are distributed throughout the body, frequently associated with the organs of other body systems. Under appropriate stimulation they secrete **hormones**, which are carried in the blood to exert a specific metabolic effect on target cells. After exerting their effect, hormones are broken down and excreted from the body. Although a hormone circulates in the blood, only the targets respond. Hormones may be amino acids, peptides, proteins (often modified), fatty acids, or steroids. Some basic features of the human endocrine system are explained below. The hypothalamus, although part of the brain and not strictly an endocrine gland, contains neurosecretory cells, and links the nervous and endocrine systems. The hypothalamus, together with the pituitary, adrenal, and thyroid glands, form a central axis of endocrine control that regulates much of the body's metabolic activity.

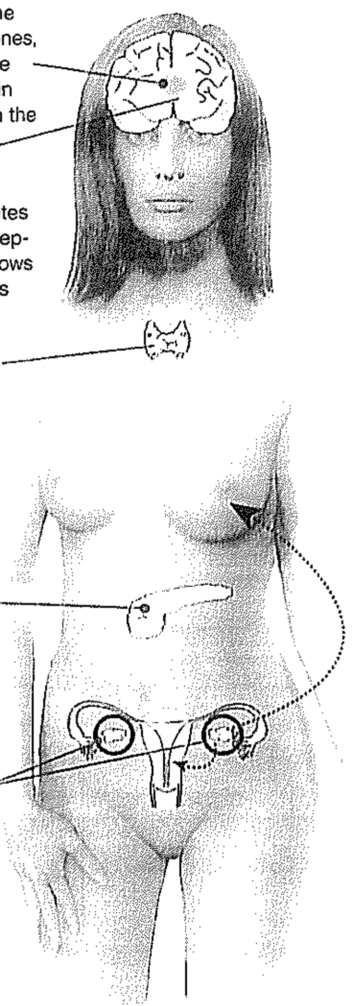
Hypothalamus
Coordinates nervous and endocrine systems. Secretes releasing hormones, which regulate the hormones of the anterior pituitary. Produces oxytocin and ADH, which are released from the posterior pituitary.

Pineal
This small gland in the brain secretes melatonin, which regulates the sleep-wake cycle. Melatonin secretion follows a circadian rhythm and coordinates reproductive hormones too.

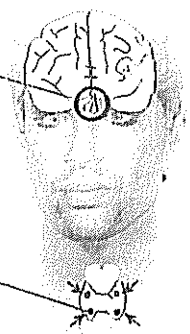
Thyroid gland
Secretes thyroxine, an iodine containing hormone needed for normal growth and development. Thyroxine stimulates metabolism and growth via protein synthesis.

Pancreatic islets
Specialized α and β endocrine cells in the pancreas produce glucagon and insulin. Together, these control blood sugar levels.

Ovaries (in females)
The ovaries produce estrogen and progesterone.
These hormones control and maintain female characteristics, stimulate the menstrual cycle, maintain pregnancy, and prepare the mammary glands for lactation.



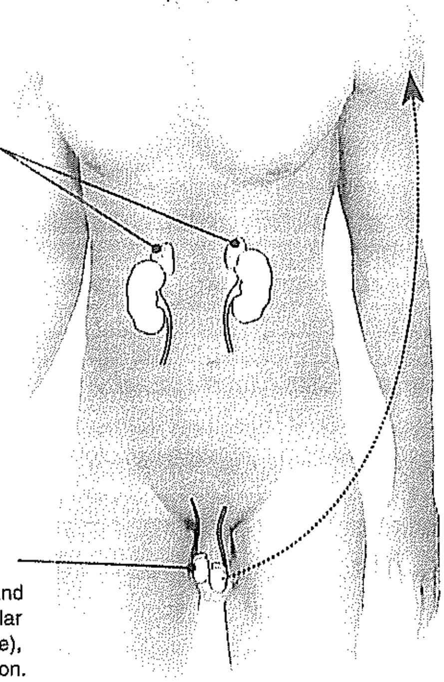
Pituitary gland
The pituitary is located below the hypothalamus. It secretes at least nine hormones that regulate the activities of other endocrine glands.



Parathyroid glands
On the surface of the thyroid, they secrete PTH (parathyroid hormone), which regulates blood calcium levels and promotes the release of calcium from bone. High levels of calcium in the blood inhibit PTH secretion.

Adrenal glands
The adrenal medulla produces epinephrine (adrenaline) and norepinephrine (noradrenaline) responsible for the fight or flight response. The adrenal cortex produces various steroid hormones, including cortisol (response to stress) and aldosterone (sodium regulation).

Testes (in males)
The testes of males produce testosterone, which controls and maintains "maleness" (muscular development and deeper voice), and promotes sperm production.



1. Explain how a hormone is different from a neurotransmitter: ____________________

____

2. Using ruled lines, connect each of the following endocrine glands with its correct role in the body

(a) Pituitary gland — The hormone from this gland regulates the levels of calcium in the blood

(b) Ovaries — Master gland secreting at least nine hormones, including growth hormone and TSH

(c) Pineal gland — Produces hormones involved in the regulation of metabolic rate

(d) Parathyroid glands — Secretes melatonin to regulate sleep patterns and cycles of reproductive hormones

(e) Thyroid — Produce estrogen and progesterone in response to hormones from the pituitary

3. Review the three types of stimuli for hormone release and describe a specific example of each:

(a) Hormonal stimulus: ____________________

(b) Humoral stimulus: ____________________

(c) Neural stimulus: ____________________

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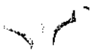
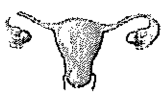
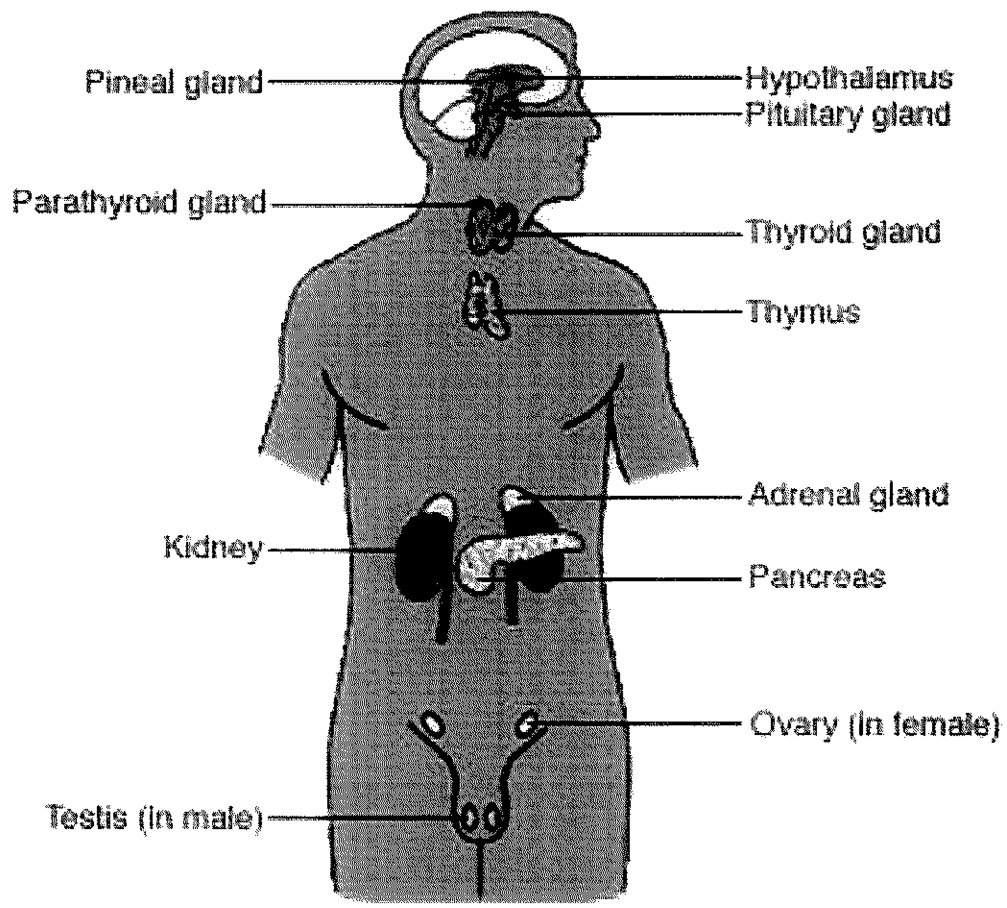
Table 45.1 Major Human Endocrine Glands and Some of Their Hormones

Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus 	Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Posterior pituitary gland (releases neurohormones made in hypothalamus) 	Oxytocin	Peptide	Stimulates contraction of uterus and mammary gland cells	Nervous system
	Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance
Anterior pituitary gland 	Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
	Prolactin (PRL)	Protein	Stimulates milk production and secretion	Hypothalamic hormones
	Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates production of ova and sperm	Hypothalamic hormones
	Luteinizing hormone (LH)	Glycoprotein	Stimulates ovaries and testes	Hypothalamic hormones
	Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid gland	Hypothalamic hormones
	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Hypothalamic hormones
Thyroid gland 	Triiodothyronine (T_3) and thyroxine (T_4)	Amine	Stimulate and maintain metabolic processes	TSH
	Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands 	Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood
Pancreas 	Insulin	Protein	Lowers blood glucose level	Glucose in blood
	Glucagon	Protein	Raises blood glucose level	Glucose in blood
Adrenal glands 				
Adrenal medulla	Epinephrine and norepinephrine	Amines	Raise blood glucose level; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex	Glucocorticoids	Steroid	Raise blood glucose level	ACTH
	Mineralocorticoids	Steroid	Promote reabsorption of Na^+ and excretion of K^+ in kidneys	K^+ in blood; angiotensin II
Gonads				
Testes 	Androgens	Steroid	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries 	Estrogens	Steroid	Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics	FSH and LH
	Progestins	Steroid	Promote uterine lining growth	FSH and LH
Pineal gland 	Melatonin	Amine	Involved in biological rhythms	Light/dark cycles


Pineal gland
Hypothalamus
Pituitary gland
Parathyroid gland
Thyroid gland
Thymus
Adrenal gland
Kidney
Pancreas
Ovary (in female)
Testis (in male)