



Animal Hormones and Hormone Action

Hormones are organic substances, which can be protein, steroidal, or amine in nature. They are produced by the **endocrine** system which consists of glands from which hormones are secreted. When stimulated, these ductless glands release their hormones directly into the bloodstream, which transports them throughout the body. When the hormone reaches its specific target organ, it imposes its particular effect. Compared to neuronal communication, the transmission of hormones is slower, their effects are more widespread and their duration of action is longer lasting (Table 1).

Table 1. Endocrine and nervous co-ordination.

Property	Hormonal	Nervous
Co-ordinator	Amine, protein or steroid hormone	Electrical impulse
Origin	Endocrine gland	Sensory receptor
Mode of transmission	Bloodstream	Nerves
Speed of distribution	Slow	Rapid
Target	Tissues	Muscle or gland
Effects	Diverse and non-specific	Specific
Duration	Often long-lasting	Very short period

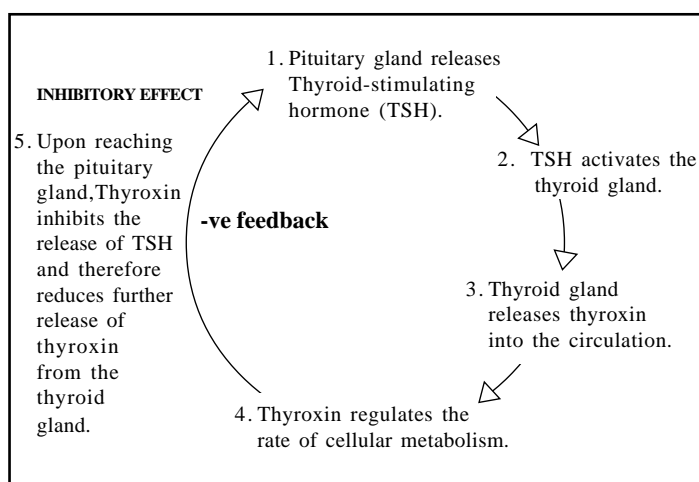
Although the function of hormones is commonly linked to homeostasis e.g. regulation of blood sugar, hormones also function to control growth and reproduction and influence behaviour.

Hormone release and its regulation

Proteinaceous hormones such as insulin, are released from their cells by **exocytosis**. In contrast, steroid hormones such as oestrogen, are released from their cells by simple transfer through the plasma membrane. The secretion of hormones from their glands is governed by two feedback mechanisms.

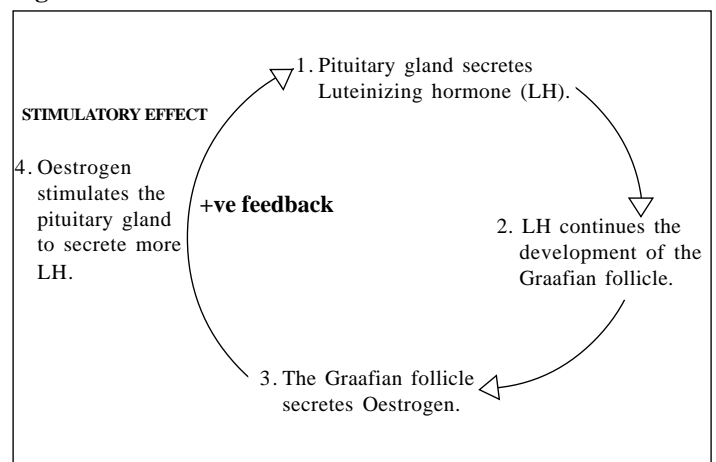
(a) **Negative feedback** (e.g. the control of the release of thyroxin) is the most common mechanism which operates to limit further hormone release from its gland (Fig 1a).

Fig 1a. Negative feedback



(b) **Positive feedback** (e.g. the control of the release of LH)

Fig 1b. Positive feedback



How do hormones act?

Hormones work by acting as:

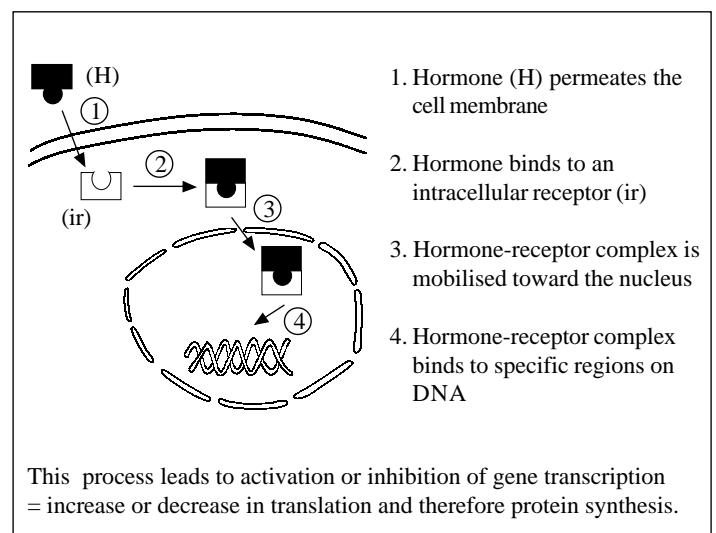
1. Secondary messengers

- (i) Hormones bind to a cell surface receptor
- (ii) This stimulates production of a messenger molecule e.g. cyclic adenosine monophosphate (AMP)
- (iii) AMP activates or inhibits enzyme pathways, e.g. promotes the conversion of glycogen to glucose

2. Gene activators

Gene activation is summarised in Fig 2.

Fig 2. Gene activation system



Hormonal Effects

The nature and effects of the most frequently examined hormones are summarised in Table 2.

Table 2. Hormonal effects

Hormone	Nature	Gland	Effect
Adrenaline	Amine	Adrenal medulla	Increases heart and breathing rates, increases glycogenolysis and muscle tone, preparing the body for "fight and flight" responses.
Insulin	Protein	Pancreas (islets of Langerhans)	Converts glucose to glycogen in liver and muscles
Glucagon	Peptide	Pancreas (islets of Langerhans)	Converts glycogen to glucose
Anti-diuretic	Peptide	Posterior lobe of Pituitary gland	Stimulates water reabsorption by kidney tubules
Aldosterone	Steroid	Adrenal cortex	Stimulates reabsorption of sodium ions by kidney tubules and reduces potassium reabsorption
Follicle stimulating hormone (FSH)	Glycoprotein	Anterior lobe of pituitary gland	Stimulates maturation of follicles (females) and stimulates production of sperm (males)
Luteinizing hormone (LH)	Glycoprotein	Anterior lobe of pituitary gland	Triggers ovulation and the development of corpus luteum
Oestrogen	Steroid	Ovary	Develops female sexual characteristics and the repair of the uterus lining.
Progesterone	Steroid	Ovary	Prepares the uterus for implantation
Testosterone	Steroid	Testis	Develops male sexual characteristics

Regulation of the reproductive system by hormones

Table 2 indicates that hormones influence reproductive systems such as:

- (a) Puberty and the production of gametes in males and females
- (b) The menstrual cycle
- (c) Libido

These regulatory functions are illustrated in Fig 3 and Fig 4.

Fig 3. Male reproductive system

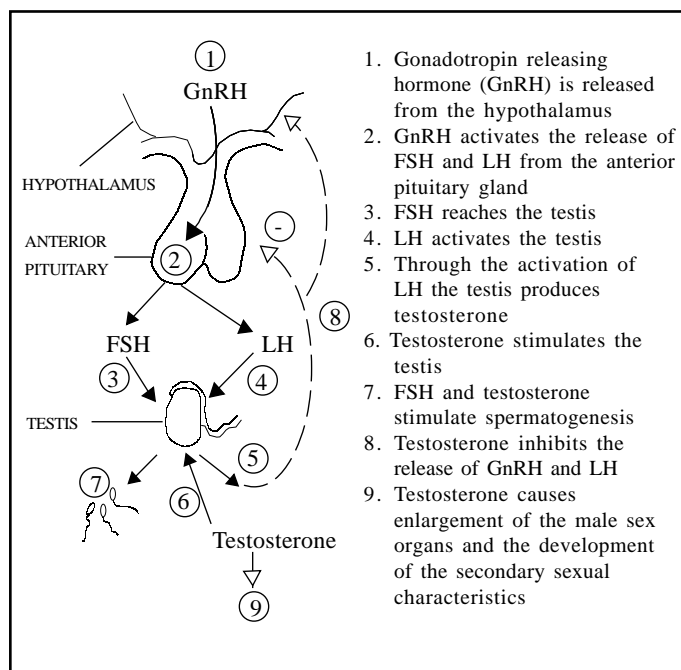
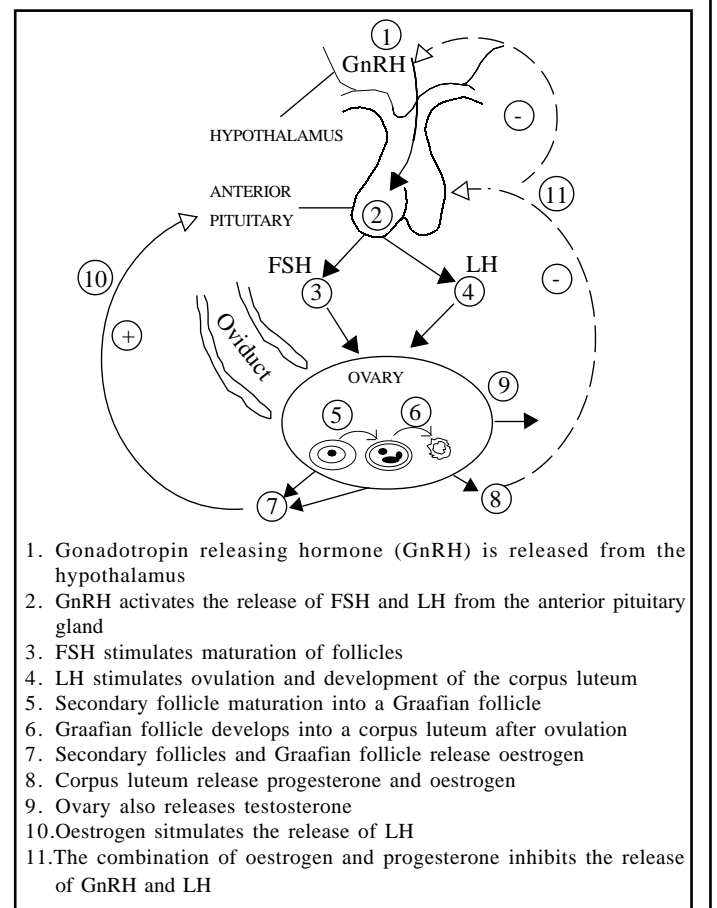


Fig 4. Female reproductive system



Regulation of water and electrolytes

Regulation of the water and electrolyte balance is mediated by anti-diuretic hormone (ADH) and aldosterone.

Anti-diuretic hormone (ADH)

ADH is released from the posterior lobe of the pituitary gland in response to changes in osmotic pressure of blood.

(a) Increased osmotic pressure of blood.

This can be caused by:

- (i) Water deprivation
- (ii) Solute ingestion
- (iii) Diarrhoea

A low water concentration (high osmotic pressure) is detected by osmoreceptors in the hypothalamus which stimulates the posterior pituitary gland to release ADH. The hormone is transported by the bloodstream around the body, eventually reaching the kidneys where it **increases the permeability** of the distal convoluted tubule and the collecting ducts. Consequently an increased volume of water from the glomerular filtrate is reabsorbed into the blood, thereby diluting it and reducing the osmotic pressure to normal.

(b) Decreased osmotic pressure of blood

This can be caused by excessive fluid ingestion. An increase in the water concentration is again detected by osmoreceptors in the hypothalamus which subsequently stops stimulating the posterior pituitary gland to release ADH. Correspondingly, the permeability of the distal convoluted tubule and the collecting ducts is reduced. Therefore a reduced volume of the glomerular filtrate is reabsorbed into the blood and this increases the osmotic pressure to normal.

Aldosterone

Aldosterone is produced by the cortical regions of the adrenal glands. Aldosterone:

- (a) stimulates the reabsorption of sodium into the blood stream
- (b) stimulates the secretion of potassium into the urine

Secretion of aldosterone occurs when there has been:

- (i) a low sodium intake
- (ii) a high potassium intake
- (iii) water depletion

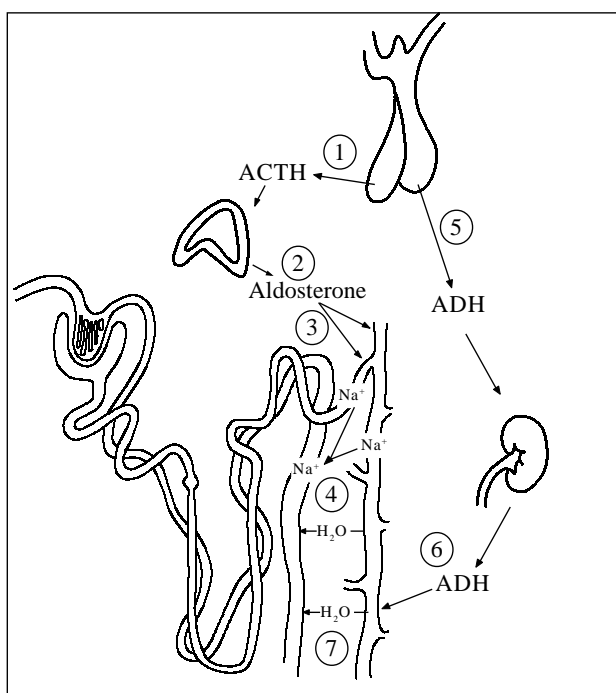
Subsequently aldosterone acts on the **distal convoluted tubule** and collecting ducts increasing the numbers of sodium channels that are open and the activity of the Na^+ , K^+ -ATPase pump.

The water- electrolyte balance

Variations in plasma aldosterone and ADH levels usually occur in parallel. For example, the release of aldosterone increases the reabsorption of sodium from the glomerular filtrate into the blood stream. This therefore increases the osmotic pressure of the blood. Subsequently, the increased osmotic pressure leads to the secretion of ADH which increases the reabsorption of water from the glomerular filtrate into the blood (Fig 5).

Exam Hint - Don't even attempt to learn this topic if you are not sure that you understand water potential (osmotic pressure). Although this topic looks difficult, once you have grasped water potential it really is just common sense. When revising, draw a flow diagram beginning with the condition which someone would be experiencing e.g. thirst and work your way through until the system makes sense.

Fig 5. Regulation of the electrolyte and water balance



1. Adrenocorticotrophic hormone (ACTH) is released from the anterior pituitary gland in response to stress.
2. ACTH then stimulates the adrenal cortex to release aldosterone.
3. Aldosterone stimulates reabsorption of sodium from the distal convoluted tubules and the collecting ducts into the surrounding blood vessels.
4. The water potential of the blood is reduced which subsequently leads to the movement of water by osmosis into these blood vessels too.
5. Anti-diuretic hormone (ADH) is released from the posterior pituitary gland in response to a low water concentration in the blood.
6. ADH increases the permeability of the collecting ducts to water.
7. Water is reabsorbed by the surrounding blood vessels by osmosis.

Regulation of the blood glucose concentration

Insulin and glucagon are secreted from the islets of Langerhans - clusters of cells which are distributed throughout the pancreas. Insulin reduces the blood glucose concentration, glucagon increases it (Fig 6).

Insulin

Consumption of food (especially carbohydrates), stimulates the secretion of insulin. Insulin reduces the blood glucose concentration by:

- (a) Transfer of glucose into cells in which it is catabolised to release adenosine triphosphate (ATP) and heat.
- (b) Conversion of glucose to glycogen in the liver and muscle for short term storage.
- (c) Promotion of fat storage and inhibition of its conversion to glucose.
- (d) Increase in the synthesis of proteins.

Glucagon

Following the release of insulin, excessive exercise or insufficient intake of carbohydrates, the levels of blood glucose fall. The body responds by secreting glucagon into the bloodstream, which transports the hormone to the liver where its causes:

- (a) The conversion of liver glycogen into glucose (glycogenolysis)
- (b) The formation of glucose from proteins and fats (gluconeogenesis)

Newly synthesised glucose is then released from the liver into the blood stream

Insulin deficiency and Diabetes Mellitus

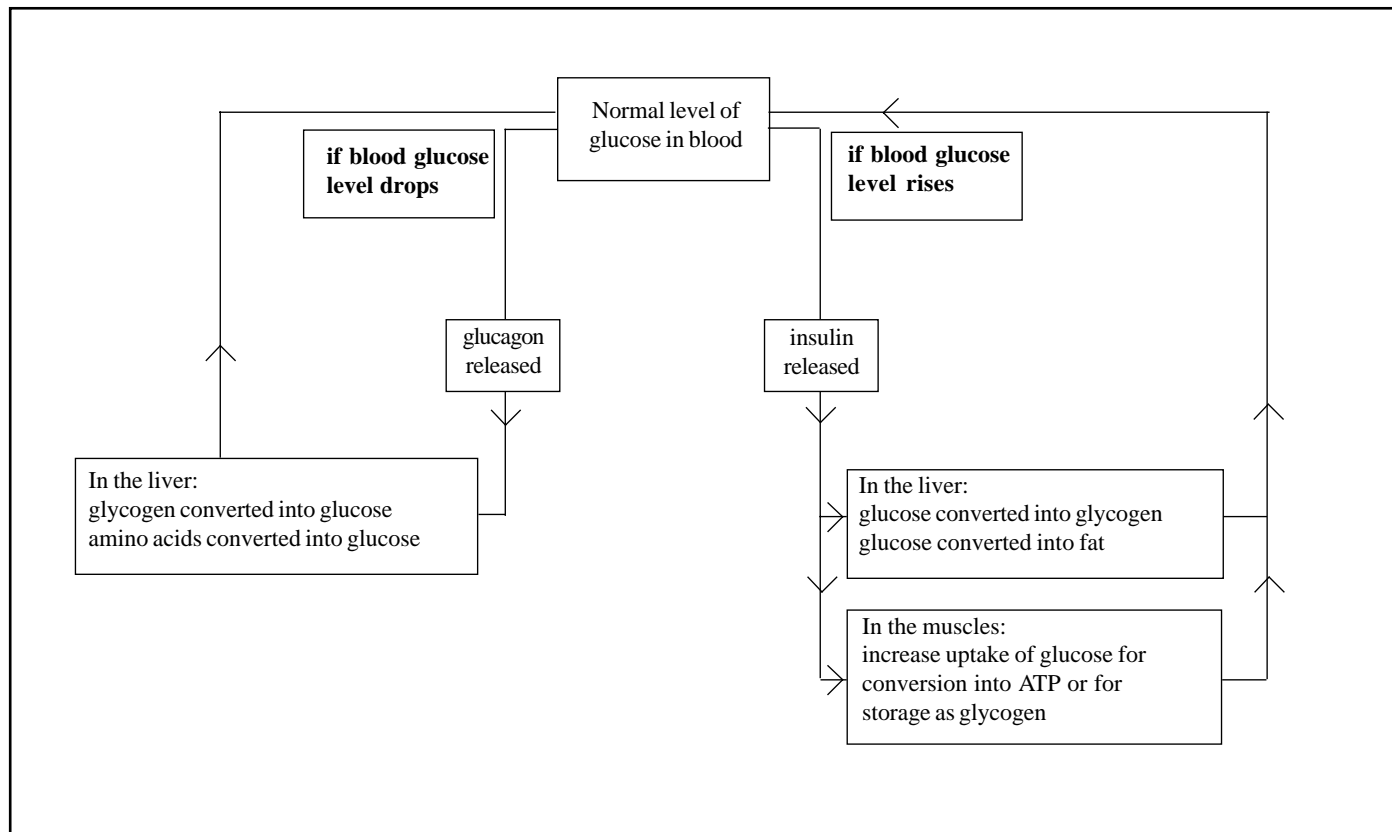
Patients with Diabetes Mellitus have blood glucose concentrations that exceed the normal range as a consequence of reduced insulin secretion. The principal symptoms of Diabetes Mellitus include:

- (a) Raised blood glucose concentrations (hyperglycaemia)
- (b) Increased urinary sugar levels (glycosuria)
- (c) Increased glucose in the urine increases its osmotic concentration, this leads to less reabsorption from the collecting ducts and thus increased urine output (diuresis)

Typical Exam Questions

1. How does insulin decrease blood glucose concentration?
2. Where are the receptors which detect blood glucose concentration?

Fig 6. The control of blood glucose concentration.



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