Human Physiology
(Chemical Coordination and Integration)

Endocrine Glands and Hormones

- Endocrine glands are ductless glands that secrete hormones which are released into the blood and transported to a distantly located target organ.
- In current definition hormone is non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.
- Invertebrates possess very simple endocrine systems with few hormones whereas vertebrates have a large number of hormones and provide coordination.

Resonate the Concept

Prothoracicotropic Hormone (PTTH) also called Brain Hormone

- Molting and pupation require the hormone, PTTH, secreted by a two pairs of cells in the brain of the larva called **corpora cardiaca**.
- If these cells are cut out of the brain of a full-grown larva, pupation does not occur. If transplanted somewhere else in the caterpillar's body, pupation occurs normally.
- PTTH does not drive pupation directly but, as its name suggests, acts on the **prothoracic glands**.

Ecdysone

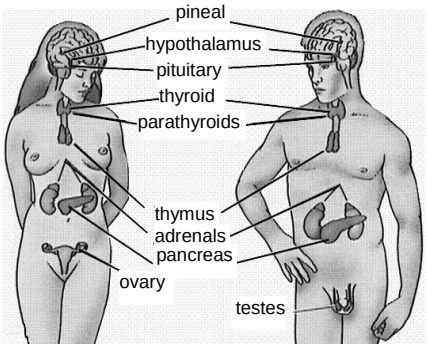
- There are two prothoracic glands located in the thorax. Under the influence of PTTH, they secrete the steroid hormone **ecdysone**.
- Acting together, PTTH and ecdysone trigger every molt: larva-to-larva as well as pupa-to-adult.

Juvenile Hormone (JH)

- Juvenile hormone is secreted by two tiny glands behind the brain, the corpora allata.
- As long as there is enough JH, ecdysone promotes larva-to-larva molts. With lower amounts of JH, ecdysone promotes pupation. Complete absence of JH results in formation of the adult.In mammals which breed seasonally, the testes descend into scrotum only during the breeding season, example Rat, Bat and Otter.

Human Endocrine System

- The endocrine system constitutes the endocrine glands and hormone producing diffused tissues/cells located in different parts of our body.
- Pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus, testis and ovary are the organised endocrine bodies in our body.
- In addition to these, some other organs, e.g., gastrointestinal tract, liver, kidney, heart also produce hormones.



Human Endocrine System

Test your resonance with concept

1. Body co-ordination is exhibited by
(1) Blood vascular system (2) Nervous system
(3) Endocrine system (4) Nervous and endocrine system

2. Which one of the following is not a gland?
(1) Pancreas (2) Pituitary (3) Adrenal (4) Kidney

3. What is hormone?
(1) Glandular secretion (2) Enzyme
(3) Chemical messenger (4) Organic complex substance

4. Which of the following is not necessarily a property of all hormones
(1) Information carrying (2) Secreted in low amounts
(3) Short half-life (4) Proteinaceous

5. Endocrine glands produce or Action of endocrine glands is mediated through
(1) Hormones (2) Enzymes (3) Minerals (4) Vitamins

Answers
1. (4) **2.** (4) **3.** (3) **4.** (4) **5.** (1)

The Hypothalamus

- The hypothalamus regulates a wide spectrum of body functions.
- It contains several groups of neurosecretory cells called **nuclei** which produce hormones.
- These hormones regulate the synthesis and secretion of pituitary hormones.
- However, hypothalamus produces two types of hormones - the **releasing hormones,** which stimulate secretion of pituitary hormones and the **inhibiting hormones,** which inhibit secretions of pituitary hormones. For example a hypothalamic hormone called **gonadotrophin releasing hormone (GnRH**) stimulates the pituitary synthesis and release of gonadotrophins. On the other hand, somatostatin from the hypothalamus inhibits the release of growth hormone from the pituitary.
- These hormones originating in the hypothlamic neurons, pass through axons and are released from their nerve endings. These hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary. The posterior pituitary is under the direct neural regulation of the hypothalamus.

Pituitary (Hypophysis)

- The pituitary gland, which is also known as the **hypophysis** is the most complex of the endocrine glands both structurally and functionally.
- It is a small nut-like gland about 1.6 centimeter in diameter. It is present on the ventral side of the brain in the region of the diencephalon, just behind the optic chiasma.
- It is attached to the hypothalamus by a stalk-like structure called infundibulum. It lies in the **sella turcica**, a depression in the **sphenoid bone**.
- Through the secretion of several hormones, pituitary exercises a control over other endocrine glands. Hence, it has been nick named as **master gland**.
- Most of the pituitary hormones (except GH and MSH) are called **tropic hormones** or **tropins**. **A hormone which stimulates the secretions of other endocrine glands or endocrine cells is called a tropic hormone (trop = to turn on).**

- The pituitary is divided structurally and functionally into an **anterior lobe** or **adenohypophysis** and a **posterior lobe** or **neurohypophysis**.
- Between these two lobes, there is a small, relatively avascular zone called the **intermediate lobe** or **pars intermedia** which is rudimentary in humans**.**
- Embryologically, the pituitary gland has a double origin.
- The adenohypophysis arises from the roof of the pharynx as a small outgrowth called **Rathke's pouch.** Thus, it is **ectodermal** in origin.
- The neurohypophysis arises as a downgrowth of the brain tissue. Thus, it is **neuroectodermal** in origin.
- There are two types of cells, chromophils (acidophils and basophils) and chromophobes in the adenohypophysis.
- Neurohypophysis consists of large metabolically inactive cells called **pituicytes** and nonmedullated nerve fibres.
- ADH and oxytocin are both stored in Herring bodies found in the neurohypophysis.

Hormones of the Adenohypophysis (anterior lobe)

(1) GH (Growth hormone, somatotropin, somatotropic hormone, STH)

- **GH** is secreted by adenohypophysis.
- It increases the rate of protein synthesis.
- It is useful in nitrogen, carbohydrate and lipid metabolism.
- **Controls normal growth** of the body and tissues like the bones and muscles.
- Normal secretion of **GH** is essential for proper growth in children.
- **Hyposecretion** of **GH** in children causes **infantilism-** stunted growth, reduced rate of metabolism and delay in attaining sexual puberty. The child will be a dwarf called a **midget** and the condition is known as **pituitary dwarfism**, mentally normal.
- **Hypersecretion** of **GH** in children leads to **pituitary gigantism**. Such children are called **pituitary giants**.
- **Hyposecretion** in adults may cause **Simmond's disease.** It is characterized by atrophy of body tissues and premature ageing.
- **Hypersecretion** in adults causes **acromegaly**. It result in resumption of growth of only certain bones in the body such as those of the fingers, toes, face etc. It leads to disproportionately large hands, feet and greatly increased cheek bones, jaws, eyebrow ridges, nose etc.

(2) TSH (Thyroid stimulating hormone, thyrotropic hormone, thyrotropin)

- **TSH** is secreted by adenohypophysis.
- It stimulates the development and normal functioning of the thyroid gland and release of thyroxine.
- Stimulates the thyroid gland to uptake iodine controls the secretion of thyroxine.
- **Hyposecretion** of TSH leads to hypothyroidism and atrophy of thyroid gland.
- **Hypersecretion** of TSH leads to hyperthyroidism.

(3) ACTH (Adrenocorticotropic hormone)

- ACTH is secreted by adenohypophysis.
- It is necessary for the development, maintenance of adrenal cortex.
- It stimulates release of the cortical hormones.
- Increases the rate of protein and fat catabolism.

- **Hyposecretion** of ACTH results in Addison's disease. The disease is characterized by weight loss, muscle weakness, fatigue, low blood pressure, and sometimes darkening of the skin in both exposed and nonexposed parts of the body.
- **Hypersecretion** of ACTH causes **Cushing's disease**. This disease is characterized by obesity of the trunk, face and buttocks; cyanosis of the face, hands and feet; excessive growth of hair; demineralisation of bones; growth of moustache and beard in women and loss of sexual functions.

(4) Gonadotropins

(i) FSH (Follicle stimulating hormone or spermatogenic hormone or gametokinetic factor).

- FSH is secreted by **gonadotropes** of the adenohypophysis.
- In women, FSH initiates the growth of ovarian follicles –oogenesis. It stimulates the secretion of **estrogen** by the ovarian follicles. It promotes growth and maturation of the Graafian follicle in the ovary. FSH along with LH, regulates the normal menstrual cycle.
- In men, FSH promotes the development of seminiferous tubules and plays an important role in the production of sperms by the testes.

Resonate the Concept
• Apart from hormones there are other chemical messengers such as neurotransmitters and paracrine substances. The neurotransmitters are released at the terminals of axons. They have local effects. The paracrine substances are also local regulators. They are chemical signals between the cells of an organ regulating functions of one another. E.g., Cytokines of immune system, prostaglandins present in almost every tissue. The prostaglandins promote inflammation, ovulation, gamete transport, etc.

(ii) LH (Luteinizing hormone, ICSH)

- LH is secreted by **gonadotropes** of the adenohypophysis.
- In women, LH stimulates the final maturation of the ovarian follicles. Together with estrogens, it brings about **ovulation** and prepares the uterus for **implantation** of the fertilized ovum. Therefore, it is called the **ovulatory hormone**. It helps in the **formation of corpus luteum** which secretes the hormone **progesterone**. Along with FSH it regulates the normal menstrual cycle.
- In men, LH stimulates the **interstitial cells** or **cells of Leydig** of the testes to secrete the male sex hormone **testosterone.** Hence, in the male body, it is referred to as **interstitial cell stimulating hormone** or **ICSH**.

(5) PRL (Prolactin, mammotropin lactogenic hormone, luteotropic hormone, LTH)

PRL is secreted by mammatropes of the adenohypophysis.

- In women, prolactin maintains the secretion of **estrogen** and **progesterone** by the ovary and **maintains the corpus luteum**. It stimulates the growth of mammary glands and **production of milk** in the females after child birth.
- In men, it increases the stimulatory effects of LH on the Leydig cells and testosterone on its target cells.

Resonate the Concept
FSH and LH are called gonadotropic hormones or gonadotropins because they regulate the growth and functional activities of the gonads and accessory genital organs.

Hormones of the intermediate lobe

- MSH (Melanocyte stimulating hormone or melanotropin)
- MSH is secreted by **pars intermedia**.
- It regulates the formation of **melanin** in the skin, eyes and brain.
- It regulates the distribution pigment granules in the melanocytes of the skin.
- In the absence skin may become pale.

Hormones of the Neurohypophysis (posterior lobe)

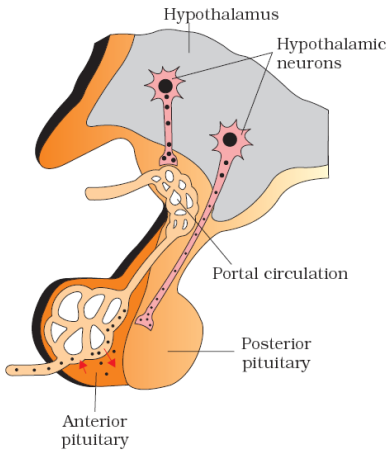
The neurohypophysis of the pituitary **does not secrete any hormone**. However, it **stores** and releases two important hormones namely **ADH (Antidiuretic hormone)** and **OT (oxytocin)**.

(i) ADH (Antidiuretic hormone or Vasopressin or Pitressin)

- ADH is primarily secreted by the **supraoptic nerve cells** of the **hypothalamus** and stored in the neurohypophysis.
- It causes contraction of smooth muscles.
- It brings about constriction of arterioles and increases the BP.
- It is called the antidiuretic hormone because it influences reabsorption of water in the nephrons of the kidneys. Thus, it has an effect on the urine output.
- **Hyposecretion** of ADH results in the excretion of large quantities of dilute urine. This condition is called **diabetes insipidus** or **water diuresis**. It results in quick dehydration of the body and unquenchable thirst.
- **Hypersecretion** of ADH results in the production of little quantities of concentrated urine. This condition is called **antidiuresis**.

(ii) OT (Oxytocin) or Pitocin

- OT is primarily secreted by the **paraventricular nerve cells** of the hypothalamus and stored in the neurohypophysis.
- It stimulates contraction of the smooth muscle cells of the uterus. These contractions in a normal woman help in sucking the semen received during sexual intercourse.
- It is released in large quantities just prior to child birth in a pregnant woman to stimulate contraction of uterus for easy child birth.
- It is called the **birth hormone** or **swift birth hormone**.
- It also plays a role in the **ejection of milk** from the lactating breast.



Pituitary Gland

Resonate the Concept
• The neural system provides a rapid coordination among organs fast but short-lived. • As the nerve fibres do not innervate all cells of the body so the cellular functions are regulated by hormones. • The neural system and the endocrine system jointly coordinate and regulate the physiological functions in the body.

The Pineal Gland

The pineal gland which is located on the dorsal side of forebrain secretes **melatonin** hormone**.**

- Melatonin plays a role in regulation of diurnal rhythm of our body like sleep-wake cycle, body temperature.
- Also influences metabolism, pigmentation, the menstrual cycle as well as our defense capability.

Test your resonance with concept

1. Vasopressin is concerned with
(1) General metabolism (2) Regulation of heart beat
(3) Urine formation (4) Child birth

2. Inadequate production of STH in early life may result in
(1) Gigantism (2) Acromegaly (3) Sterility (4) Dwarfism

3. Somatostatin is secreted by
(1) Hypothalamus (2) Pituitary (3) Pineal (4) Thyroid

4. Thyrotropin-Releasing Factor (TRF) is produced by
(1) Cerebrum (2) Optic lobe (3) Cerebellum (4) Hypothalamus

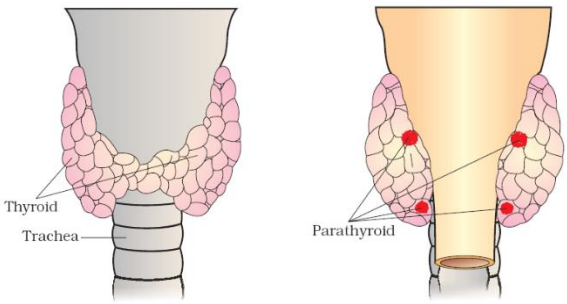
5. The hormone that have influence on other endocrine glands of the body such as thyroid, gonad etc. are secreted by
(1) Anterior pituitary (2) Posterior pituitary (3) Pars intermedia (4) Pars tuberalis

Answers

1. (3) **2.** (4) **3.** (1) **4.** (4) **5.** (1)

Thyroid Gland

- The thyroid gland is composed of two lobes attached to trachea and connected by isthmus.
- The thyroid gland is composed of follicles and stromal tissues. Each thyroid follicle is composed of follicular cells, enclosing a cavity. These follicular cells synthesise two hormones**, tetraiodothyronine** or **thyroxine (T_4)** and **triiodothyronine (T_3).**
- Iodine is essential for the normal rate of hormone synthesis in the thyroid.
- Deficiency of iodine in our diet results in hypothyroidism and enlargement of the thyroid gland, commonly called **goitre**.



Thyroid and Parathyroid Glands

- Hypothyroidism during pregnancy causes stunted growth in baby (**cretinism**), mental retardation, low intelligence quotient, abnormal skin, deaf-mutism, etc. In adult women, hypothyroidism may cause menstrual cycle to become irregular.
- **Myxedema** is a condition marked by thickening and swelling of the skin caused by insufficient production of thyroid hormones by the thyroid gland. The function of thyroid hormones is to regulate your metabolism. Myxedema is associated with other symptoms of underactive thyroid, also called hypothyroidism, including lethargy, weight gain, fatigue, depression, and cold sensitivity, among others.
- Hypothyroidism is more common in women, especially those over the age of 50, and can be caused by a viral infection, certain medications, radiation exposure, autoimmune disease, or inherited or congenital disorders. Myxedema is caused by hypothyroidism and occurs more frequently when hypothyroidism is left untreated. Your health care professional can order simple blood tests to determine whether you have hypothyroidism, which can lead to myxedema.
- Due to cancer of the thyroid gland or due to development of nodules of the thyroid glands, the rate of synthesis and secretion of the thyroid hormones is increased to abnormal high levels leading to a condition called **hyperthyroidism**.

Resonate the Concept
In amphibians thyroxine is required for metamorphosis of tadpole into adult. In birds shedding of feathers is induced by thyroxine.

- **Hypersecretion** of TSH leads to hyperthyroidism which leads to **Graves' disease** is an autoimmune disease (overactive immune response). It most commonly affects the thyroid, causing it to grow to twice its size or more (goiter), be overactive, with related hyperthyroid symptoms such as weight loss, frequent defecation, disturbed sleep, and irritability. It can also affect the eyes, causing bulging eyes (exophthalmos).
- Thyroid hormones play an important role in the regulation of the basal metabolic rate, red blood cell formation and metabolism of carbohydrates, proteins and fats; maintenance of water and electrolyte balance. Thyroid gland also secretes thyrocalcitonin (TCT) which regulates the blood calcium levels.

Parathyroid Gland

- Present on the back side of the thyroid gland, one pair each in the two lobes of the thyroid gland. The parathyroid glands secrete a peptide hormone called **parathyroid hormone (PTH).**
- PTH increases the Ca^{2+} levels in the blood. It acts on bones and stimulates bone resorption (dissolution/ demineralisation). PTH also stimulates reabsorption of Ca^{2+} by the renal tubules and increases Ca^{2+} absorption from the digested food. PTH is a **hypercalcemic** hormone, i.e., it increases the blood Ca^{2+} levels.
- Along with TCT, helps in calcium balance in the body.
- **Hypersecretion of parathormone** draws more calcium from the bones which results in **softening, bending and fracturing of bones.** This condition is known as **osteoporosis**. In osteoporosis the bone mineral density (BMD) is reduced, bone microarchitecture is disrupted, and the amount and variety of non-collagenous proteins in bone is altered.
- **Hyposecretion of parathormone lowers the calcium ion concentration in the blood due to excretion of calcium ions in the urine.** This results in the **hyperexcitability of nerves and muscles, causing cramps and convulsions causing** sustained contractions of the muscles of the larynx, face, hand and feet. This disorder is known as **parathyroid tetany**. The **parathyroid tetany** is an abnormal condition characterized by periodic painful muscular spasms and tremors, caused by faulty calcium metabolism and associated with diminished function of the parathyroid glands.

Test your Resonance with concept

1. Similarity between the secretion of thyroid and adrenal is that both the secretions
(1) Are proteins (2) Are steroid
(3) Increase glucose metabolism (4) Control mineral metabolism

2. Disease caused by deficiency of iodine is
(1) Goitre (2) Myxodema (3) Cretinism (4) Tetany

3. Proper development of the bone depends on
(1) Epinephrine (2) Thyroxine (3) Parathormone (4) Vasopressin

4. Hypoparathyroidism results to
(1) Upset in metabolism (2) Improper gonodial function
(3) Convulsions and tetany (4) Nervousness and wasting

5. Parathormone induces
(1) Increase in serum calcium level (2) Decrease in serum potassium level
(3) Increase in blood sugar level (4) Decrease in blood sugar level

Answers

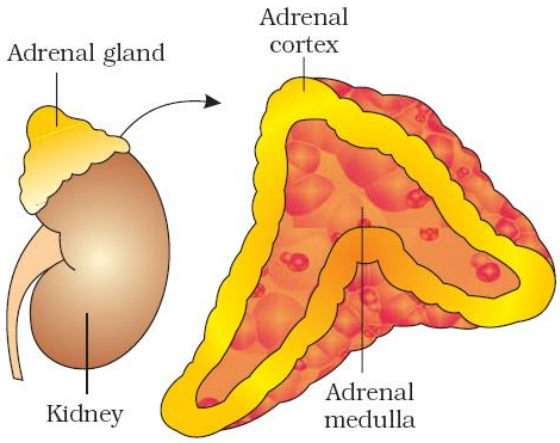
1. (3) **2.** (1) **3.** (3) **4.** (3) **5.** (1)

Thymus

- The thymus gland is a lobular structure located on the dorsal side of the heart and the aorta.
- Plays a role in the development of the immune system.
- This gland secretes the peptide hormones called **thymosins**.
- Thymosins play a major role in the differentiation of T- lymphocytes, which provide **cell-mediated immunity**. It also promotes production of antibodies for **humoral immunity**.
- Thymus is degenerated in old individuals resulting in weak immune responses

Adrenal Gland

- We have a pair of adrenal gland, one at the anterior part of each kidney
- The gland is composed of two types of tissues. The central **medulla,** and outer **cortex**.



T.S of adrenal gland

Hormones of Medulla

- The adrenal medulla secretes two catecholamine hormones called **adrenaline or epinephrine** and **noradrenaline or norepinephrine**.
- Because of the fact that adrenaline and noradrenaline are rapidly secreted in response to stress of any kind and during emergency situations they are called **emergency hormones** or **hormones of Fight**, **Flight** and **Fear**.
- These hormones increase alertness, pupilary dilation, piloerection (raising of hairs), sweating etc. Both the hormones increase the heart beat, the strength of heart contraction and the rate of respiration. Stimulate the breakdown of glycogen and increased concentration of glucose in blood, the breakdown of lipids and proteins.

Hormones of Cortex

- The adrenal cortex has three layers, **zona reticularis** (inner layer), **zona fasciculata** (middle layer) and **zona glomerulosa** (outer layer).
- The adrenal cortex secretes many hormones, commonly called **corticoids.**
- The corticoids, which are involved in carbohydrate metabolism are called **glucocorticoids**. Eg. **Cortisol**. Glucocorticoids stimulate, gluconeogenesis, lipolysis and proteolysis; and inhibit cellular uptake and utilisation of amino acids. Cortisol is also involved in maintaining the cardio-vascular system and kidney functions. Glucocorticoids, particularly cortisol, produces anti- inflamatory reactions and suppresses the immune response. Cortisol stimulates the RBC production.
- Corticoids, which regulate the balance of water and electrolytes in our body are called **mineralocorticoids**. E.g. **Aldosterone** stimulates the reabsorption of Na^+ and water and excretion of K^+ and phosphate ions and helps in the maintenance of electrolytes, body fluid volume, osmotic pressure and blood pressure.
- Androgenic steroids secreted by the adrenal cortex play a role in the growth of axial hair, pubic hair and facial hair during puberty.

Pancreas

- The pancreas is an exocrine and an endocrine gland.
- For its endocrine function, it has islets of Langerhans. These islets have β-cells (beta) or B cells, α-cells (alpha) or A cells and δ-cells (delta) or D cells.
- The β-cells secrete insulin and α-cells secrete glucagon. Both are proteinaceous hormones regulating the blood glucose levels.
- The δ-cells secrete a hormone called somatostatin. It inhibits the digestion and absorption of nutrients. It also inhibits the secretion of insulin and glucagon.
- The blood glucose level in a normal healthy person ranges from 70 mg to 110 mg per 100 ml. of the blood (serum) and it is called 'norm' or 'set point'.
- The blood glucose level has to be maintained constantly above the minimum level because the brain depends on the supply of blood glucose as its sole source of energy. It uses energy at a constant rate.
- Even the other body organs use the blood glucose as a source of energy.
- The decrease in the blood glucose level below the normal initially brings about anxiety, palpitation, tremor, sweating etc. Later it results in confusion, slurred speech, convulsions, coma and finally death.
- Insulin is known as a hypoglycemic factor as it reduces the increased blood glucose level to normal.

Insulin has the following effects on the carbohydrate metabolism.

1. It induces glycogenesis in the liver and skeletal muscle.
2. It inhibits glycogenolysis and gluconeogenesis in the liver.
3. It enhances the absorption of glucose by the cells from the blood for storage and oxidation. (The liver, brain and working muscles do not depend on insulin for the uptake of glucose).
4. It induces the synthesis of enzymes of glucose metabolism such as glucokinase, phosphofructokinase and pyruvate kinase. Thus the oxidation of glucose to release the energy is favoured.
5. It increases the absorption of glucose by the adipose tissue from the blood. The absorbed glucose is converted into triglycerides. This process is called **Lipogenesis** and it is enhanced by the insulin.

   Thus all these activities of insulin brings the increased blood glucose level back to 'norm'. Apart from these insulin promotes uptake of amino acids by muscle and liver for protein synthesis.

- **Glucagon** is **antagonistic** or **'counter regulatory hormone'** to insulin. It opposes many actions of insulin. Glucagon is a hyperglycemic factor and tends to elevate the blood glucose level to 'norm' by the following actions.

  1. It induces glycogenolysis in the liver. The glucose is released into the blood.
  2. It induces the uptake of amino acids by the liver and their conversion into glucose (This is known as **gluconeogenesis**).
  3. It inhibits the synthesis of certain enzymes of glucose metabolism (glucokinase, phospho -fructokinase and pyruvate kinase).
  4. It decreases glycogen synthesis.

  Thus all these activities bring back the blood glucose level to 'norm'.

- **Diabetes mellitus** (DM) is usually caused due to the deficiency of insulin or decreased response by the cells to insulin.
- **Definition:** Diabetes mellitus is a metabolic disorder marked by increased output of urine with sugar (glucose).
- The absence or deficiency of insulin leads to the accumulation of glucose in the blood.
- The diabetics are characterized by the following changes:

1. **Hyperglycemia:** Abnormal increase in blood sugar level (usually above 160 mg. per 100 ml. of serum).
2. **Glycosuria (Glucosuria) :** Excretion of sugar through the urine. This is due to increased blood sugar levels. The kidneys fail to absorb the glucose completely from the urine if the blood glucose level goes beyond 160 mg per 100 mL of blood.
3. **Polyuria:** Production of large amounts of urine. The kidney tubules cannot absorb completely the glucose from the primary urine. Hence the glucose remains in the urine and interferes with the osmotic absorption of water by the kidney tubules from the urine. This leads to polyuria.
4. **Polydipsia:** Increased thirst. The diabetics due to the loss of water through urine in large quantities have polydipsia.
5. **Polyphagia:** Due to deficiency of intracellular glucose appetite is increased. Hence diabetics have an urge to eat large quantity of food (This is known as **polyphagia**).
6. **Acidosis and ketosis:** Due to absence of normal oxidation of glucose, cells utilize large amount of fats for oxidation to get energy. This leads to production of large quantities of acetic acid. Part of it is converted to aceto acetic acid that in turn is converted to acetone and b hydroxybutyric acid.
   These organic acids cause acidosis of the blood (increase in acidity of the blood is called **acidosis**) and increased level of acetone leads to ketosis of the blood. The acidosis leads to coma followed by the death of the individual.

7. **Lipolysis (breaking down of lipids):** The lipid synthesis decreases in the adipose tissue and it releases the fatty acids into the blood. The blood lipid level increases.
8. **Gluconeogenesis:** The insulin is a protein anabolic hormone. In its absence, the protein metabolism is shifted to catabolism resulting in the breakdown of tissue proteins especially muscle proteins leading to the wasting of muscle and elevated levels of blood amino acids. This favours gluconeogenesis. Increased blood glucose level promotes atherosclerosis.
    - In addition to these, there will be long term complications. These include degenerative changes in vascular and nervous systems.
    - Heart diseases are more common in diabetics.
    - Damage of blood vessels in kidney and retina is also seen resulting in **renal failure (nephropathy)** and **blindness (retinopathy)**.
    - Impaired flow of blood to the extremities can result in the tissue damage and gangrene formation.
    - The inflammation of nerves leading to **neuritis (neuropathy)** is often seen in diabetic patients.
    - In a diabetic a proper diet, exercise and drugs can play a major role in keeping the blood sugar level under check.

Types of diabetes

There are two types of diabetes

Type I - Juvenile diabetes or Insulin Dependent Diabetes Mellitus (IDDM):

As the disorder usually occurs in the childhood it is called **Juvenile diabetes**. In this the **β-cells** of the pancreas are destroyed and the patient has to be given insulin daily.

Type II - Adult onset diabetes or Non Insulin Dependent Diabetes Mellitus (NIDDM):

As this disorder is seen usually adulthood it is known as **adult onset diabetes**. This is due to decrease in the response by the cells for insulin. The patient may be secreting normal or excess amount of insulin but the cells have developed resistance to insulin.

Resonate the Concept

Insulin was extracted in crude form for the first time by **Frederick Banting** and **Charles Best** (1922). They tied off the pancreatic duct (in the dogs) and allowed degeneration of exocrine part to occur. Later they removed the pancreas and extracted the insulin from the crushed tissues at temperatures below freezing.

Resonate the Concept

- **Glycogenesis:** This is the process of converting glucose into glycogen. This occurs whenever there is excess of blood glucose.
- **Glycogenolysis:** This is the process of breaking down the glycogen into glucose. This occurs whenever the blood glucose level falls below normal.
- **Gluconeogenesis:** This is the process of converting non-carbohydrates such as amino acids (proteins) and fats into glucose. This occurs whenever the blood glucose level falls below normal and glycogen reserve gets exhausted in the liver and also when there is a greater availability of amino acids and fatty acids.
- **Hypoglycemia**: When the blood glucose level falls below the normal, then it is known as hypoglycemia.
- **Hyperglycemia**: When the blood sugar level rises above the normal then it is known as hyperglycemia.

Test your Resonance with concept

1. The gland which acts to resist stress
(1) Adrenal (2) Parathyroid (3) Pineal (4) Thyroid

2. The secretion of aldosterone by adrenal cortex is directly controlled by
(1) Blood Plasma K^+ ion concentration (2) Plasma Ca^{2+} ion concentration
(3) Level of blood angiotensin (4) (1) and (3) are correct

3. Angiotensin is derived from plasma protein "angiotensinogen'' by the action of renin and other nervous stimuli. Angiotensin stimulates the following
(1) Thyroid (2) Adrenal (3) Ovary (4) Thymus

4. Diabetes insipidus is caused due to the deficiency of
(1) Oxytocin (2) Insulin (3) Vasopressin (4) Glucagon

5. A person suffering from diabetes insipidus will pass what amount of urine per day
(1) 1 litre (2) ½ litre (3) 3 litres (4) 1.5 litres

Answers

1. (1) **2.** (3) **3.** (2) **4.** (3) **5**. (3)

Gonads

Testes and Ovary are **primary sex organs** of male and female respectively.

Testis

- Testis performs the dual function.
- It is an **exocrine gland**, a cytogenic gland producing sperms and an **endocrine gland** producing testosterone.
- Eighty percent of testis is composed of highly coiled seminiferous tubules involved in spermatogenesis.
- The endocrine cells secreting testosterone are called **Leydig cells** or **interstitial cells**.
- These are located in connective tissue between seminiferous tubules.
- The Leydig cells under the influence of LH of pituitary secrete testosterone (male sex hormone) which has following functions.

1. It induces spermatogenesis in the testes.
2. It brings about the development of accessory reproductive structures in males such as epididymises, vasa deferentia, seminal vesicles, prostate gland, urethra and also the penis and scrotum, brings about expressions of secondary sexual characters such as beard and moustache, induces better development of skeletal and muscular tissues and brings about enlargement of thyroid cartilage of larynx forming Adam's apple.
3. It regulates sex drive / libido in male.
4. Sertoli cells of testes secrete a hormone called **Inhibin.** This inhibits release of GnRF (Gonadotropin releasing factor) from the hypothalamus. As a result the pituitary does not secrete FSH and LH.

Ovaries

Ovary secretes Oestrogen, Progesterone, Relaxin and Inhibin.

Oestrogen

1. Oestrogen is the female sex hormone secreted by the **Graafian follicle** and **corpus luteum** of the ovary.

2. Oestrogen is responsible for development of accessory reproductive structures like uterus, fallopian tube, development of secondary sexual characters of the female such as rounded contours of the body, high pitch voice, induces development of mammary glands, responsible for growth of endometrium (the endometrium becomes thick with development of glands and increased supply of blood), and controls menstrual cycles (this function is performed along with progesterone).
3. The presence of normal menstrual cycle reflects the health of uterus and fertility of the female. Oesterogen increases protein anabolism.

Progesterone

1. Progesterone is a steroid hormone secreted by the corpus luteum of the ovary under the influence of LH of pituitary.
2. Progesterone is indispensable for pregnancy. (The endometrial glands of the uterus become functional and endometrium is prepared for implantation).
3. It induces development of mammary glands for milk secretion and desensitizes the uterus to the actions of oxytocin and prostaglandins.
4. It inhibits the release of FSH and LH.

Relaxin

1. Proteinaceous hormone secreted both by the ovary (corpus luteum) and placenta.
2. Relaxin softens fibrous cartilage at pubic symphysis thereby relaxes and widens the pelvis at the time of parturition.

Inhibin

1. Inhibin is secreted by corpus luteum.
2. It is a proteinaceous hormone.
3. It inhibits the release of GnRF from the hypothalamus and pituitary does not release FSH and LH.

Hormones of heart, kidney and gastrointestinal tract

- Hormones are also secreted by some tissues which are not endocrine glands.
- For example, the atrial wall of our heart secretes **atrial natriuretic factor** (ANF), which decreases blood pressure. By dilating blood vessels.
- The juxta glomerular cells of kidney produce **erythropoietin** which stimulates erythropoiesis (formation of RBC).
- Gastro-intestinal tract secrete four hormones, namely **gastrin, secretin, cholecystokinin** (**CCK**) and **gastric inhibitory peptide (GIP)**. Gastrin stimulates the secretion of hydrochloric acid and pepsinogen. Secretin acts on the exocrine pancreas and stimulates secretion of water and bicarbonate ions. CCK acts on both pancreas and gall bladder and stimulates the secretion of pancreatic enzymes and bile juice, respectively. GIP inhibits gastric secretion and motility.
- Several other non-endocrine tissues secrete hormones called **growth factors.** These factors are essential for the normal growth of tissues and their repairing/regeneration.

Test your Resonance with concept

1. The hormone that maintains the secretory activity of the corpus luteum as well as the increase in the size of the mammary glands is
(1) Estrogen (2) Luteinizing (3) Luteotrophin (4) Gonadotrophin

2. Testosterone, a hormone responsible for the development of secondary sexual characteristics in male is produced by the
(1) Spermatogonia (2) Seminiferous tubules
(3) Anterior lobe of the pituitary (4) Cells that lie between seminiferous tubules

3. Which part of the ovary in mammals acts as an endocrine gland after ovulation?
(1) Stroma (2) Germinal epithelium
(3) Graafian follicle (4) Vitelline membrane

4. Continued secretion of milk is maintained by
(1) Prolactin (2) Progesterone (3) Estrogen (4) Relaxin

5. The hormone that acts during parturition (child birth) but which has more effect on lactation is
(1) Progesterone (2) Prolactin (3) Oxytocin (4) Vasopressin

Answers

1. (2) **2.** (4) **3.** (3) **4.** (1) **5.** (3)

Mechanism of hormone action

- Hormones produce their effects on target tissues by binding to hormone receptors located in the target tissues.
- Hormone receptors present on the cell membrane of the target cells are called **membrane-bound receptors** and the receptors present inside the target cell are called **intracellular receptors**, mostly **nuclear receptors** (present in the nucleus).
- Binding of a hormone to its receptor leads to the formation of a hormone-receptor complex which is specific to hormones.
- Hormone-Receptor complex formation leads to certain biochemical changes in the target tissue.
- The location of the hormone receptor depends on the chemical nature of the hormone. On the basis of their chemical nature, hormones can be divided into groups:
  (i) peptide, polypeptide, protein hormones (e.g., insulin, glucagon, pituitary hormones, hypothalamic hormones, etc.)
  (ii) steroids (e.g., cortisol, testosterone, estradiol and progesterone)
  (iii) iodothyronines (thyroid hormones)
  (iv) amino-acid derivatives (e.g., epinephrine).

The **water soluble hormones** (polypeptides, glycoproteins and catecholamines) cannot pass through the plasma membrane; hence their receptors are located on the outer surface of the membrane.
The water soluble hormones have their action mediated through **second messengers**. When these hormones bind to their specific receptors of the plasma membrane specific membrane proteins become activated to generate second messengers. Cyclic AMP, phospholipase C, inositol triphosphate, diacyl glycerol and Ca^{++} act as second messenger. Cyclic AMP second messenger system has the following sequence of events to effect the action of hormone.

1. The hormone binds to its specific membrane receptor of the target cell.
2. G proteins linked to specific receptors activate the enzyme adenylate cyclase.
3. Activated adenylate cyclase converts ATP to cyclic AMP.
4. Cyclic AMP activates protein kinase enzymes of the cytoplasm.
5. Protein Kinase phosphorylates (adding phosphate groups to) the other enzymes of the cytoplasm.
6. The phosphorylation of specific enzymes may enhance or inhibit their activity.
7. This alters the metabolism of the target cell in the required direction as per the specific hormone action.

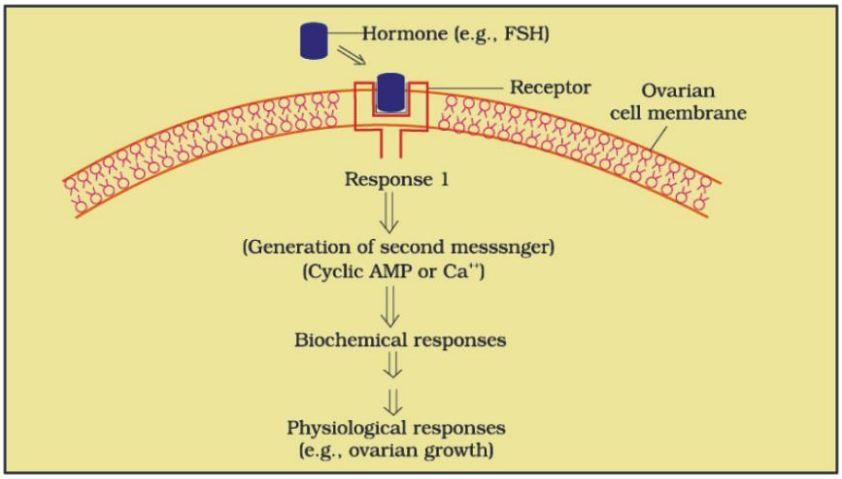
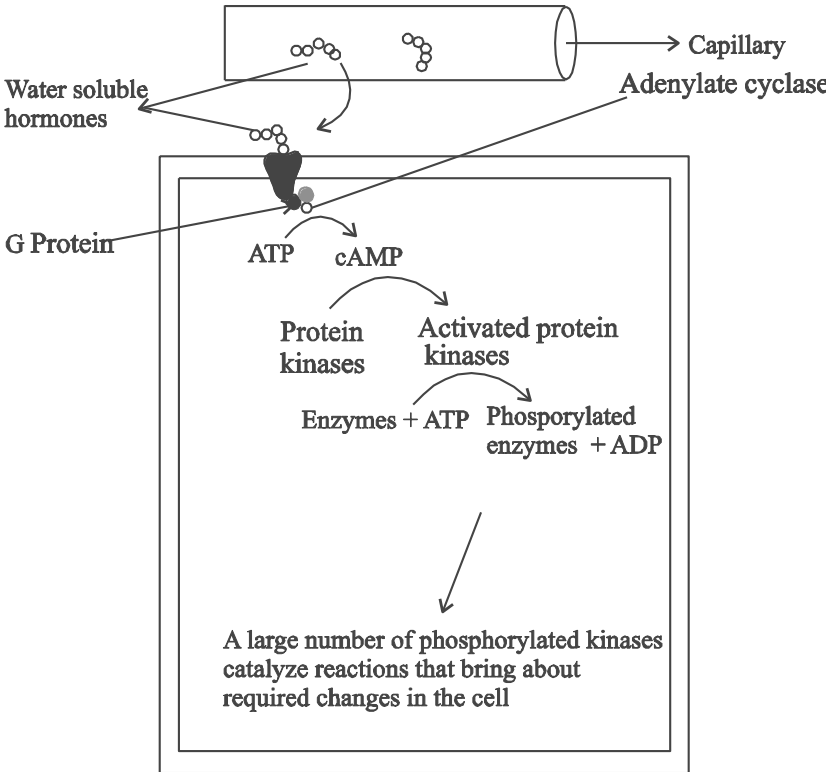


Fig. Diagramatic representation of the mechanism of hormone action: (a) Protein hormone

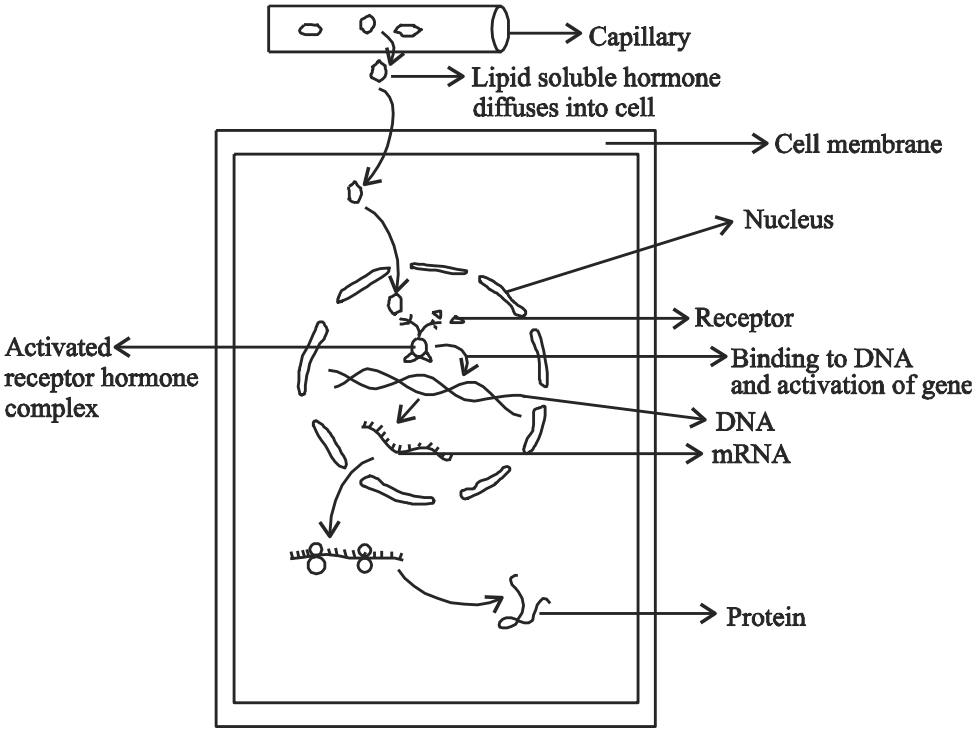


Water soluble hormone action

The **lipophilic hormones** (steroids and thyroxin) can pass through the plasma membrane and enter into their target cells, hence the receptors for these hormones are located within the nucleus and cytoplasm.

The lipophilic steroid hormones and thyroid hormones pass through the plasma membrane and get bound to a specific intracellular receptor. These receptors are commonly located within the nucleus.

Once these nuclear hormone receptors are activated by their binding to specific hormone, they alter the gene expression. They may switch on or off specific genes on the nuclear DNA. The transcription of DNA occurs and the newly formed mRNA directs the synthesis of specific enzyme proteins. These enzymes alter the metabolism of the cell in the required direction as per the intended action of hormone.



Lipophilic hormone action

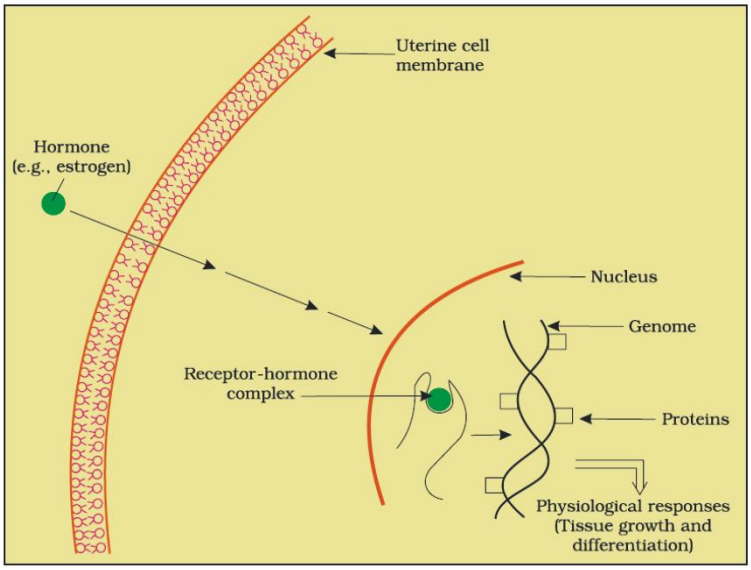


Fig. Diagramatic representation of the mechanism of hormone action: (b) Steroid hormone