# Chapter 19: Chemical Coordination and Integration

## Exercises — Exercises

Q1 Define the following:
(a) Exocrine gland
(b) Endocrine gland
(c) Hormone

SOLUTION

(a) Exocrine gland:
Glands that possess ducts through which their secretions are released onto an epithelial surface or into a body cavity. Examples: salivary glands, gastric glands, liver, pancreas (exocrine part). Their secretions (enzymes, mucus, bile) act locally at the site of delivery.

(b) Endocrine gland:
Ductless glands that release their secretions (hormones) directly into the blood. Because they lack ducts, hormones are transported via the circulatory system to target organs located at a distance. Examples: pituitary, thyroid, adrenal, pancreas (islets of Langerhans), gonads, parathyroid, thymus, pineal gland.

(c) Hormone:
Non-nutrient chemical messengers produced in trace amounts by endocrine glands (or specialised cells) and released into the blood. They act as intercellular messengers, reaching specific target tissues/organs and regulating their metabolism, growth, and physiological functions. Classic examples: insulin (pancreas), thyroxine (thyroid), adrenaline (adrenal medulla).

Answer: (a) Exocrine gland: ducted gland releasing secretions onto a surface. (b) Endocrine gland: ductless gland releasing hormones directly into blood. (c) Hormone: non-nutrient intercellular chemical messenger produced in trace amounts, transported via blood to regulate target organ functions.

Q2 Diagrammatically indicate the location of the various endocrine glands in our body.

SOLUTION

The human body has the following endocrine glands at the indicated locations (as in Figure 19.1 of the textbook):

Head/Brain region (top to bottom):
- Hypothalamus: basal part of the diencephalon (forebrain); lies above the pituitary
- Pineal gland: dorsal side of the forebrain
- Pituitary gland: located in a bony cavity called sella turcica; attached to hypothalamus by a stalk; sits below the hypothalamus

Neck region:
- Thyroid gland: two lobes on either side of the trachea, connected by an isthmus
- Parathyroid glands (4): embedded on the dorsal (back) surface of each thyroid lobe (two per lobe)

Thorax/Chest:
- Thymus: located between the lungs, behind the sternum on the ventral side of the aorta

Abdomen:
- Pancreas (Islets of Langerhans): composite gland in the abdominal cavity
- Adrenal glands (pair): one above each kidney (suprarenal position)

Pelvic region:
- Ovary (pair, in females): in the lower abdominal/pelvic cavity
- Testis (pair, in males): in the scrotal sac outside the abdominal cavity

Diagram description (Figure 19.1 layout, front view of the body):
Starting from the top — Hypothalamus and Pineal at the head; Pituitary just below hypothalamus; Thyroid and Parathyroid at the neck; Thymus in the upper chest; Pancreas and Adrenal glands in the mid-abdomen; Ovary (female) or Testis (male) in the lower abdomen/pelvis.

Key labels to include in the diagram: Hypothalamus, Pineal, Pituitary, Thyroid, Parathyroid, Thymus, Pancreas, Adrenal, Ovary (in female), Testis (in male).

Answer: Endocrine glands from head to pelvis: Hypothalamus and Pineal (forebrain), Pituitary (sella turcica below hypothalamus), Thyroid and Parathyroid (neck, around trachea), Thymus (chest behind sternum), Pancreas and Adrenal (abdomen), Ovary (female, pelvic) or Testis (male, scrotal sac).

Q3 List the hormones secreted by the following:
(a) Hypothalamus (b) Pituitary (c) Thyroid (d) Parathyroid
(e) Adrenal (f) Pancreas (g) Testis (h) Ovary
(i) Thymus (j) Atrium (k) Kidney (l) G-I Tract

SOLUTION

(a) Hypothalamus:
Releasing hormones (RH) and inhibiting hormones (IH) that regulate pituitary secretions. Key examples: Gonadotrophin Releasing Hormone (GnRH), Thyrotrophin Releasing Hormone (TRH), Corticotrophin Releasing Hormone (CRH), Growth Hormone Releasing Hormone (GHRH), Somatostatin (growth hormone-inhibiting hormone), Prolactin Inhibiting Hormone (PIH).

(b) Pituitary gland:
Pars distalis (anterior pituitary): Growth Hormone (GH), Prolactin (PRL), Thyroid Stimulating Hormone (TSH), Adrenocorticotrophic Hormone (ACTH), Luteinizing Hormone (LH), Follicle Stimulating Hormone (FSH).
Pars intermedia: Melanocyte Stimulating Hormone (MSH).
Neurohypophysis/Posterior pituitary (synthesised by hypothalamus, stored and released here): Oxytocin, Vasopressin (ADH).

(c) Thyroid gland:
Thyroxine (T4 / tetraiodothyronine), Triiodothyronine (T3), Thyrocalcitonin (TCT).

(d) Parathyroid gland:
Parathyroid Hormone (PTH) — a peptide hormone.

(e) Adrenal gland:
Adrenal medulla: Adrenaline (Epinephrine), Noradrenaline (Norepinephrine) — collectively called catecholamines.
Adrenal cortex: Glucocorticoids (mainly Cortisol), Mineralocorticoids (mainly Aldosterone), small amounts of androgenic steroids.

(f) Pancreas:
Alpha-cells: Glucagon.

Beta-cells: Insulin.

(g) Testis:
Androgens — mainly Testosterone (secreted by Leydig/interstitial cells).

(h) Ovary:
Estrogens (secreted by growing ovarian follicles), Progesterone (secreted by corpus luteum).

(i) Thymus:
Thymosins (peptide hormones).

(j) Atrium (heart):
Atrial Natriuretic Factor (ANF).

(k) Kidney:
Erythropoietin (secreted by juxtaglomerular cells).

(l) Gastrointestinal (G-I) Tract:
Gastrin, Secretin, Cholecystokinin (CCK), Gastric Inhibitory Peptide (GIP).

Answer: Hypothalamus: releasing/inhibiting hormones (GnRH, somatostatin, etc.); Pituitary: GH, PRL, TSH, ACTH, LH, FSH (anterior), MSH (intermedia), oxytocin, ADH (posterior); Thyroid: T3, T4, TCT; Parathyroid: PTH; Adrenal: adrenaline, noradrenaline (medulla), cortisol, aldosterone, androgenic steroids (cortex); Pancreas: glucagon (alpha cells), insulin (beta cells); Testis: androgens/testosterone; Ovary: estrogens, progesterone; Thymus: thymosins; Atrium: ANF; Kidney: erythropoietin; G-I tract: gastrin, secretin, CCK, GIP.

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Q4 Fill in the blanks:
Hormones — Target gland
(a) Hypothalamic hormones — _____
(b) Thyrotrophin (TSH) — _____
(c) Corticotrophin (ACTH) — _____
(d) Gonadotrophins (LH, FSH) — _____
(e) Melanotrophin (MSH) — _____

SOLUTION

(a) Hypothalamic hormones — Anterior Pituitary (adenohypophysis)
Hypothalamic releasing and inhibiting hormones reach the pituitary through the portal circulatory system and regulate the synthesis and secretion of anterior

pituitary hormones.

(b) Thyrotrophin (TSH) — Thyroid gland
TSH stimulates the synthesis and secretion of thyroid hormones (T3 and T4) from the thyroid gland.

(c) Corticotrophin (ACTH) — Adrenal cortex
ACTH stimulates the synthesis and secretion of glucocorticoids (e.g., cortisol) from the adrenal cortex.

(d) Gonadotrophins (LH, FSH) — Gonads (Testis in males; Ovary in females)
LH and FSH stimulate gonadal activity. In males: LH stimulates androgen secretion from testis; FSH + androgens regulate spermatogenesis. In females: LH induces ovulation and maintains corpus luteum; FSH stimulates growth of ovarian follicles.

(e) Melanotrophin (MSH) — Melanocytes (pigment cells of the skin)
MSH acts on melanocytes and regulates skin pigmentation. Note: MSH acts on a cell type rather than a discrete endocrine gland.

Answer: (a) Anterior pituitary; (b) Thyroid gland; (c) Adrenal cortex; (d) Gonads (testis/ovary); (e) Melanocytes (skin).

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Q5 Write short notes on the functions of the following hormones:
(a) Parathyroid hormone (PTH)
(b) Thyroid hormones
(c) Thymosins
(d) Androgens
(e) Estrogens
(f) Insulin and Glucagon

SOLUTION

(a) Parathyroid Hormone (PTH):
PTH is a peptide hormone secreted by parathyroid glands; it is a hypercalcemic hormone (raises blood Ca2+ levels). Functions:
1. Stimulates bone resorption (demineralisation/dissolution of bone), releasing Ca2+ into blood.
2. Stimulates reabsorption of Ca2+ by renal tubules, reducing urinary calcium loss.
3. Increases Ca2+ absorption from digested food in the intestine.

Together with thyrocalcitonin (TCT), PTH maintains calcium homeostasis in the body.

(b) Thyroid Hormones (T3 and T4):
Synthesised from tyrosine and iodine; iodine deficiency causes goitre. Functions:
1. Regulate the basal metabolic rate (BMR) — essential for normal energy metabolism.
2. Support red blood cell (RBC) formation (erythropoiesis).
3. Control metabolism of carbohydrates, proteins, and fats.
4. Maintain water and electrolyte balance.
5. During development: essential for normal maturation of the central nervous system (CNS); deficiency in pregnancy causes cretinism (stunted growth, mental retardation).
6. Regulate the menstrual cycle in adult women.
The thyroid also secretes thyrocalcitonin (TCT), which decreases blood calcium levels (hypocalcemic).

(c) Thymosins:
Peptide hormones secreted by the thymus gland. Functions:
1. Play a major role in differentiation of T-lymphocytes, which provide cell-mediated immunity.
2. Promote production of antibodies, thereby also contributing to humoral immunity.
Thymus degenerates in old age, reducing thymosin production and weakening immune responses in elderly individuals.

(d) Androgens:
Steroid hormones (mainly testosterone) secreted by Leydig cells of testis. Small amounts also from adrenal cortex. Functions:
1. Regulate development, maturation, and functions of male accessory sex organs (epididymis, vas deferens, seminal vesicles, prostate, urethra).
2. Stimulate growth of facial, axillary, and pubic hair; deeper voice; increased muscular growth; aggressiveness.
3. Play a major stimulatory role in spermatogenesis.
4. Influence male sexual behaviour (libido) through action on the central nervous system.
5. Produce anabolic effects on protein and carbohydrate metabolism.

(e) Estrogens:

Steroid hormones synthesised by growing ovarian follicles. Functions:
1. Stimulate growth and activities of female secondary sex organs.
2. Support development of growing ovarian follicles.
3. Responsible for appearance of female secondary sex characters (high-pitched voice, fat deposition in hips, etc.).
4. Promote development of mammary glands.
5. Regulate female sexual behaviour.

(f) Insulin and Glucagon:
Both are peptide hormones secreted by Islets of Langerhans in the pancreas.

Insulin (from beta-cells) — hypoglycemic hormone:
1. Enhances cellular glucose uptake and utilisation by hepatocytes and adipocytes.
2. Stimulates glycogenesis (conversion of glucose to glycogen) in target cells.
3. Lowers blood glucose levels — maintains glucose homeostasis.
Deficiency leads to diabetes mellitus (hyperglycemia, glycosuria, ketone body formation).

Glucagon (from alpha-cells) — hyperglycemic hormone:
1. Acts mainly on hepatocytes, stimulating glycogenolysis (glycogen breakdown), raising blood glucose.
2. Stimulates gluconeogenesis, further raising blood glucose.
3. Reduces cellular glucose uptake and utilisation.
Together, insulin and glucagon maintain blood glucose homeostasis.

Answer: (a) PTH: hypercalcemic — stimulates bone resorption, renal Ca2+ reabsorption, intestinal Ca2+ absorption. (b) Thyroid hormones: regulate BMR, erythropoiesis, carbohydrate/protein/fat metabolism, water-electrolyte balance, CNS development. (c) Thymosins: T-lymphocyte differentiation (cell-mediated immunity) and antibody production (humoral immunity). (d) Androgens: male secondary sex characters, spermatogenesis, accessory sex organ development, libido, anabolic effects. (e) Estrogens: female secondary sex characters, follicle development, mammary gland growth, sexual behaviour. (f) Insulin: hypoglycemic (glycogenesis, glucose uptake); Glucagon: hyperglycemic (glycogenolysis, gluconeogenesis).

Q6 Give example(s) of:
(a) Hyperglycemic hormone and hypoglycemic hormone
(b) Hypercalcemic hormone
(c) Gonadotrophic hormones
(d) Progestational hormone
(e) Blood pressure lowering hormone
(f) Androgens and estrogens

SOLUTION

(a) Hyperglycemic hormone: Glucagon (secreted by alpha-cells of pancreatic Islets of Langerhans) — raises blood glucose by stimulating glycogenolysis and gluconeogenesis.
Hypoglycemic hormone: Insulin (secreted by beta-cells of pancreatic Islets of Langerhans) — lowers blood glucose by enhancing glucose uptake, utilisation, and glycogenesis.

(b) Hypercalcemic hormone: Parathyroid Hormone (PTH), secreted by parathyroid glands — raises blood $Ca^{2+}$ levels by stimulating bone resorption, renal $Ca^{2+}$ reabsorption, and intestinal $Ca^{2+}$ absorption.
(Note: Thyrocalcitonin/TCT from thyroid is the hypocalcemic hormone — it lowers blood calcium.)

(c) Gonadotrophic hormones:
Luteinizing Hormone (LH) and Follicle Stimulating Hormone (FSH) — both secreted by the anterior pituitary (pars distalis). They stimulate gonadal activity (production of sex hormones and gametogenesis) in both males and females.

(d) Progestational hormone: Progesterone — secreted by the corpus luteum of the ovary. It supports and maintains pregnancy and stimulates alveoli formation and milk secretion in the mammary glands.

(e) Blood pressure lowering hormone: Atrial Natriuretic Factor (ANF) — secreted by the atrial wall of the heart. ANF causes dilation of blood vessels when blood pressure rises, thereby reducing blood pressure.

(f) Androgens: Testosterone (primary androgen secreted by Leydig cells of testis). Small amounts of androgenic steroids are also secreted by adrenal cortex.
Estrogens: Estradiol/Estrogen — secreted by growing ovarian follicles in females. Small amounts may also be produced in males by adrenal cortex and testis.

Answer: (a) Hyperglycemic: Glucagon; Hypoglycemic: Insulin. (b) Hypercalcemic: PTH. (c) Gonadotrophins: LH and FSH. (d) Progestational: Progesterone. (e) Blood pressure lowering: ANF (atrial natriuretic factor). (f) Androgens: Testosterone (testis); Estrogens: Estradiol/Estrogen (ovary).

Q7 Which hormonal deficiency is responsible for the following:
(a) Diabetes mellitus
(b) Goitre
(c) Cretinism

SOLUTION

(a) Diabetes mellitus:
Caused by deficiency of insulin (secreted by beta-cells of Islets of Langerhans in pancreas) and/or insulin resistance (target cells fail to respond to insulin). Without adequate insulin action, blood glucose levels remain persistently high (hyperglycemia), glucose is lost in urine (glycosuria), and harmful ketone bodies are formed. Diabetic patients are treated with insulin therapy.

(b) Goitre:
Caused by deficiency of iodine in the diet, leading to hypothyroidism. When iodine is insufficient, the thyroid gland cannot synthesise adequate T3 and T4. In response, TSH secretion from the pituitary increases (due to loss of negative feedback), stimulating the thyroid to enlarge in a compensatory attempt to produce more hormone. This enlargement of the thyroid gland is called goitre.

(c) Cretinism:
Caused by deficiency of thyroid hormones (T3 and T4) during foetal development and early childhood (i.e., hypothyroidism during pregnancy or in newborns). Thyroid hormones are essential for normal development and maturation of the central nervous system and skeletal growth. Their deficiency results in stunted growth, mental retardation, low intelligence quotient (IQ), abnormal skin, and deaf-mutism in the child.

Answer: (a) Diabetes mellitus: insulin deficiency (or insulin resistance). (b) Goitre: iodine deficiency causing hypothyroidism and compensatory thyroid enlargement. (c) Cretinism: thyroid hormone (T3/T4) deficiency during foetal/early postnatal development.

Q8 Briefly mention the mechanism of action of FSH.

SOLUTION

FSH (Follicle Stimulating Hormone) is a protein/peptide hormone secreted by the anterior pituitary (pars distalis). Being a peptide hormone, it cannot cross the cell membrane of target cells. Its mechanism of action is as follows:

1. FSH binds to specific membrane-bound receptors on the surface of target cells (ovarian follicle cells in females; Sertoli cells in males). Each receptor is specific to FSH only.

2. Binding forms a hormone-receptor complex on the cell membrane, which activates a membrane-associated enzyme (typically adenylate cyclase).

3. This leads to generation of a second messenger — cyclic AMP (cAMP) — inside the cell.

4. cAMP activates intracellular enzymes (protein kinases), which phosphorylate target proteins and trigger a cascade of biochemical reactions.

5. These biochemical changes regulate the physiological response:
- In females: FSH stimulates growth and development of ovarian follicles and estrogen synthesis.
- In males: FSH (along with androgens) regulates spermatogenesis in seminiferous tubules.

In summary: FSH acts via a membrane-bound receptor and a second messenger (cAMP) mechanism to regulate target cell metabolism and reproductive functions.

Answer: FSH (peptide hormone) binds to membrane-bound receptors on target cells (ovarian follicles in females, Sertoli cells in males), forming a hormone-receptor complex that activates adenylate cyclase, generating cAMP (second messenger). cAMP activates protein kinases, triggering biochemical cascades that stimulate follicle growth and estrogen secretion (females) or spermatogenesis (males).

Q9 Match the following:
Column I — Column II
(a) T4 — (i) Hypothalamus
(b) PTH — (ii) Thyroid
(c) GnRH — (iii) Pituitary
(d) LH — (iv) Parathyroid

SOLUTION

(a) T4 -- (ii) Thyroid

T4 = Thyroxine (tetraiodothyronine), synthesised and secreted by the follicular cells of the thyroid gland.

(b) PTH -- (iv) Parathyroid

PTH = Parathyroid Hormone, a peptide hormone secreted by the parathyroid glands (four in number, located on the dorsal surface of thyroid lobes).

(c) GnRH -- (i) Hypothalamus

GnRH = Gonadotrophin Releasing Hormone, a releasing hormone produced by neurosecretory cells (nuclei) of the hypothalamus. It stimulates the anterior pituitary to synthesise and release LH and FSH.

(d) LH -- (iii) Pituitary

LH = Luteinizing Hormone, secreted by the pars distalis (anterior pituitary). In males it stimulates testosterone secretion from Leydig cells; in females it induces ovulation and maintains corpus luteum.

Summary of matches: (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii).

Answer: (a) T4 - (ii) Thyroid; (b) PTH - (iv) Parathyroid; (c) GnRH - (i) Hypothalamus; (d) LH - (iii) Pituitary.