Chemical Coordination and Integration

10 Chapter

1 INTRODUCTION

- **Significance** : As the nerve fibres do not innervate all cells of the body and the cellular functions require continuous regulation, hence the role of endocrine system is integrated with neural system.

2 ENDOCRINE GLANDS AND HORMONES

Endocrine glands (Ductless) glands —secrete→ Hormones —form→ Endocrine system & Neural system → Together regulate physiological functions in the body

Endocrine system → Invertebrates (few hormones); Vertebrates (many hormones)

HORMONES

- Released into blood and transported to target organ
- Non-nutrient chemicals
- Act as intercellular messengers
- Produced in trace amounts

3 HUMAN ENDOCRINE SYSTEM

Fig. : Location of endocrine glands

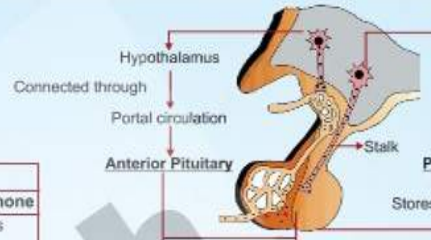
- **Other organs with diffused tissues and cells:** gastrointestinal tract, heart, liver and kidneys

5 PINEAL GLAND

- **Location:** Dorsal side of forebrain
- **Hormone released:** Melatonin
- **Basic functions:**
  - Regulate 24 hours diurnal rhythm of our body (sleep wake cycle)
  - Influence body metabolism, temperature, pigmentation, menstrual cycle and defense capabilities

4 HYPOTHALAMUS AND PITUITARY GLAND

- Hypothalamus contains several groups of neurosecretory cells called **nuclei** which produce hormones that regulate synthesis and secretions from pituitary gland enclosed in bony cavity, **Sella tursica**.



TYPES OF HYPOTHALAMIC HORMONES

	Example	Target	Released hormone
Releasing hormone	GnRH	Pituitary	Gonadotrophins
Inhibiting hormone	Somatostatin	Pituitary	×

Hormones of Pituitary	Basic function
Growth hormone (GH)	Growth of body
Thyroid stimulating hormone (TSH)	Synthesis and secretion of thyroid hormones by thyroid gland
Adrenocorticotropic hormone (ACTH)	Synthesis and secretion of steroid hormones from adrenal cortex
Follicle stimulating hormone (FSH)	Male – Regulates spermatogenesis along with androgens Female – Stimulates growth and development of ovarian follicles
Gonadotrophins (stimulate gonadal activity)	
Luteinising hormone (LH)	Male – Stimulates the synthesis and secretion of androgens Female – Induces ovulation of fully mature Graafian follicle, maintains corpus luteum
Prolactin	Regulates the growth of the mammary glands and formation of milk in them
Melanocyte stimulating hormone (MSH) by pars intermedia	Acts on the melanocytes of skin and regulates pigmentation of skin

Hormones released	Basic functions
Oxytocin	○ Acts on smooth muscles and stimulates their contraction ○ Stimulates vigorous contractions of uterus at the time of child birth ○ Milk ejection from mammary glands
Vasopressin/ADH/ Anti-diuretic hormone	○ Acts at kidney and stimulates resorption of water and electrolytes by the distal tubules ○ Reduces loss of water through urine **(Diuresis)**

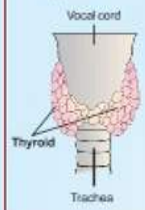
ACROMEGALY

Serious complications of hypersecretion of GH in middle age can leads to premature death if unchecked. The disease is hard to diagnose in early stages and often goes undetected for many years, until changes in external features become noticeable.

DISORDERS

Disease	Age	Cause	Symptoms
Pituitary dwarfism		Hyposecretion of GH	Stunted growth
Gigantism		Hypersecretion of GH	Abnormal growth of the body
Acromegaly	Middle age	Hypersecretion of GH	Severe disfigurement especially of face
Diabetes insipidus	–	Hyposecretion of ADH	Diminished ability of the kidney to conserve water leading to water loss and dehydration

6 GLANDS OF THORACIC REGION

	Location/Feature	Number	Hormones	Basic functions
Thyroid 	○ Side of trachea ○ **Bilobed structure** connected through a thin flap of connective tissue called **isthmus** ○ Consists of **follicles** made up of follicular cells enclosing a cavity, in stromal tissue • **Iodine is essential for the normal rate of hormone synthesis in the thyroid gland**	1	T_4 (thyroxine) or tetraiodothyronine T_3 (triiodothyronine)	○ Regulate basal metabolic rate (**BMR**) ○ Control metabolism of carbohydrates, proteins and fats. ○ Maintain water and electrolyte balance ○ Regulate development and maturation of CNS ○ Support process of RBC formation (**erythropoiesis**) and regulates menstrual cycle
			Thyrocalcitonin (TCT) (**Protein** hormone)	Regulates blood Ca^{+2} levels
Parathyroid 	○ Back side of the thyroid gland • **Thyrocalcitonin and parathormone play a significant role in calcium homeostasis**	4	Parathyroid hormone/ PTH (**peptide** hormone)	○ Increase level of Ca^{+2} (**hypercalcemic**) ○ Acts on bones and stimulates the process of bone resorption (**dissolution/ demineralisation**) ○ Stimulates the reabsorption of Ca^{+2} by the renal tubules. ○ Increases Ca^{+2} absorption from digested food.
Thymus	○ **Lobular structure** located between lungs behind sternum on ventral side of aorta • **Degenerates in old age so immune responses become weak**	1	Thymosins (**peptide** hormones)	○ Play a role in differentiation of T-lymphocytes, thus provide **cell mediated immunity** ○ Promote production of antibodies thereby providing **humoral immunity**.

7 DISORDERS OF THYROID GLAND

○ **Hypothyroidism**

Cause

• Iodine deficiency in diet during pregnancy and after birth

1. **Goitre:** Enlargement of thyroid gland
2. **Cretinism:** Stunted growth, mental retardation, low intelligence quotient abnormal skin and deaf-mutism
3. In adult women, menstrual cycle can become irregular

○ **Hyperthyroidism**

Cause

• Cancer of the thyroid gland
• Development of nodules of the thyroid gland

1. **Exopthalmic goitre or Graves' disease:**
   • Enlargement of thyroid gland
   • Protrusion of eyeballs
   • Increase in BMR and weight loss.

8 ADRENAL GLAND

○ **One pair** located on anterior part of kidneys

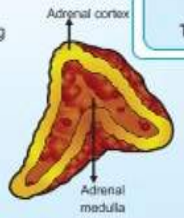
Adrenal gland

Adrenal cortex

	Hormone	Functions
Zona glomerulosa (outer most layer)	Main Glucocorticoid is **cortisol**	○ Stimulates gluconeogenesis, lipolysis and proteolysis ○ Inhibit cellular uptake and utilisation of amino acids, maintains the cardiovascular system and the kidney functions ○ Produces anti-inflammatory reactions and suppresses immune response ○ Stimulate glomerular filtration rate ○ Stimulate RBC production
Zona fasciculata (middle layer)	Major Mineralocorticoid is **aldosterone**	○ Stimulates reabsorption of Na^+ and H_2O and excretion of K^+ and PO_4^- ions, thus helps in maintenance of electrolytes, body fluid volume, osmotic pressure and blood pressure.
Zona reticularis (inner layer)	Androgenic steroid	○ Play a role in growth of axial hair, pubic hair and facial hair during puberty.

Adrenal medulla (Centrally located)

	Functions
Adrenaline/epinephrine	○ Increase alertness, pupilary dilation, piloerection, sweating ○ Increase heart beat, the strength of heart contraction and the rate of respiration ○ Stimulate breakdown of glycogen resulting in an increased concentration of glucose in blood. ○ Increase breakdown of lipids and proteins
Nor-adrenaline/nor-epinephrine or Catecholamines or Emergency/fight/flight hormones	



9 PANCREAS

Pancreas: A **composite** gland whose main hormones **maintain glucose homeostasis**

- Endocrine part
- Exocrine part

1 to 2 million **Islets of Langerhans** (1-2% of pancreatic tissue)

Major cells: α-cells, β-cells

Secretes peptide hormones: **Glucagon**, **Insulin**

	Glucagon	Insulin
○ **Target**	Hepatocytes	Hepatocytes, Adipocytes
○ **Stimulates**	Glycogenolysis, gluconeogenesis	Glycogenesis
○ **Blood glucose level**	↑ (**Hyperglycemic**)	↓ (**Hypoglycemic**)
○ **Glucose** uptake and utilisation by cells	↓	↑

DISORDER

○ **Diabetes mellitus** – Caused by prolonged hyperglycemia

Characteristics – Loss of glucose in urine, Ketone bodies formation

Treatment – Insulin therapy

Disorder	Cause	Characteristic
Addison's disease	Underproduction of hormones of adrenal cortex	Alters carbohydrate metabolism causing acute weakness and fatigue

10 GONADS → Primary sex organs: Form gametes and secrete hormones

Parameter	Male (Testis)	Female (ovary)
Location	Scrotal sac (outside abdomen)	in abdomen
Structure responsible	Leydig cells/ interstitial cells	Ovarian follicles and corpus luteum
Steroid hormone	Androgens mainly **testosterone**	**Estrogen** / **Progesterone**

Function

- Development and maturation of male accessory sex organs.
- Stimulate spermatogenesis
- Acts on CNS and influence male sexual behaviour (**libido**)
- Stimulate muscular growth, growth of facial and axillary hair, aggressiveness and low pitch of voice.
- Produce **anabolic** (synthetic) effects on protein and carbohydrate metabolism

Estrogen

- Growth and activities of female secondary sex organs
- Stimulate development of growing follicles
- Regulate sexual behaviour
- Appearance of secondary sex characters like mammary gland development, high pitch etc.

Progesterone

- Supports pregnancy
- Stimulates formation of alveoli (store milk and milk secretion

11 HORMONES OF HEART, KIDNEY AND GASTROINTESTINAL TRACT

Tissue	Organ	Hormone	Basic function
Atrial wall	Heart	ANF	When blood pressure increases, it dilates blood vessels to reduce blood pressure.
Juxtaglomerular cells (JG cells)	Kidney	Erythropoietin	Stimulates **erythropoiesis**
Endocrine cells in different parts of gastro-intestinal tract	GIT	Gastrin	Acts on gastric glands and stimulates secretion of HCl and pepsinogen
		GIP/gastric inhibitory peptide	Inhibits gastric secretions and motility
		Cholecystokinin	Acts on exocrine part of pancreas and gall bladder to stimulate secretion of pancreatic enzymes and bile juice
		Secretin	Acts on exocrine part of pancreas and stimulates secretion of water and bicarbonates
Non-endocrine tissue		Growth factors	Essential for normal growth, repair and regeneration of tissues

All these given hormones are peptide hormones.

12 MECHANISM OF HORMONE ACTION

- Hormone receptors are located in the target tissue only
- Each receptor is specific to one hormone only
- Most intracellular receptors are present in the nucleus
- Steroid hormones and iodothyronines enter the target cell
- Hormones acting through extracellular receptors do not enter the target cell

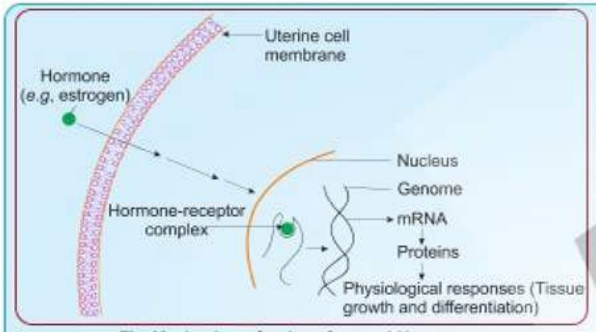


Fig: Mechanism of action of a steroid hormone

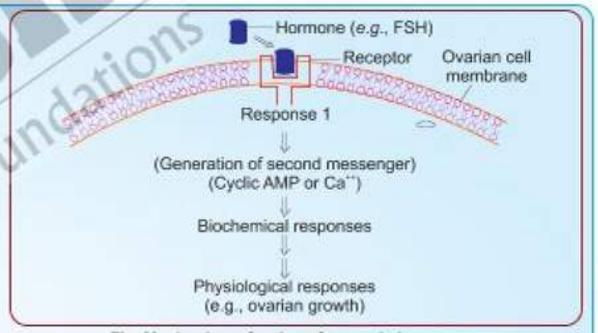


Fig: Mechanism of action of a protein hormone

Classification of Hormones

Based on chemical nature

Steroids – Cortisol, testosterone, estradiol, progesterone
Iodothyronines – Thyroid hormones
Bind to
Intracellular/Nuclear receptors

Amino acid derivatives – Epinephrine
Peptide, Polypeptide, Protein – Insulin, glucagon, pituitary and hypothalamic hormones etc.
Bind to
Extracellular/Membrane bound receptors

Interact with: Genome and regulate gene expression and chromosome functions

Hormone receptor complex

Generate: Second messengers cAMP, IP_3, Ca^{+2} etc

Brings biochemical changes in target tissue

Cumulative effect

Results in physiological and developmental effects

Sharpen Your Understanding

1. How many of the given hormones play a significant role in calcium balance in the body? [NCERT Pg. 335]

   a. Parathormone b. Thyrocalcitonin
   c. Thymosin d. Thyroxine

   (1) a and c (2) b and c
   (3) c and d (4) a and b

2. Select the **incorrect** one w.r.t. cortisol [NCERT Pg. 337]

   (1) Anti-inflammatory response
   (2) Suppress RBC production
   (3) Suppress immune response
   (4) Anti-allergic hormone

3. Hormones can be described by all the given features **except** [NCERT Pg. 331]

   (1) Non-nutrient chemicals
   (2) Produced in traces
   (3) Act as intercellular messenger
   (4) Always work by suppressing gene expression

4. Read the following features in a baby and choose the disorder in which they are well observed? [NCERT Pg. 335, 336]

   a. Abnormal skin
   b. Low intelligence quotient
   c. Deaf-mutism
   d. Stunted growth
   e. Mental retardation

   (1) Cretinism
   (2) Graves' disease
   (3) Exophthalmic goitre
   (4) Simple goitre

5. Which one is **not** a secondary messenger? [NCERT Pg. 340]

   (1) IP_3 (2) Ca^{+2}
   (3) cAMP (4) ATP

6. Select the iodine containing hormone [NCERT Pg. 334, 340]

   (1) Cortisol (2) Thyroxine
   (3) Adrenaline (4) Glucagon

7. Which is **not** the exact function of insulin hormone? [NCERT Pg. 337]

   (1) Promote synthesis of fat from glucose
   (2) Target tissues are liver and muscles
   (3) Increase glycogen content in liver and muscles
   (4) Stimulate protein breakdown

8. Which of the following **cannot** be included in the same chemical group? [NCERT Pg. 340]

   (1) Cortisol
   (2) Estradiol
   (3) Progesterone
   (4) Epinephrine

NCERT Based MCQs

9. Which of the given hormone binds with extracellular membrane receptors? [NCERT Pg. 340]

   (1) FSH (2) Estrogen
   (3) Aldosterone (4) Progesterone

10. Anatomically pars distalis and pars intermedia are together included in [NCERT Pg. 333]

    (1) Neurohypophysis
    (2) Adenohypophysis
    (3) Posterior lobe of pituitary
    (4) Anterior lobe of hypothalamus

11. Which of the given disorder is **not** related with growth hormone? [NCERT Pg. 333]

    (1) Acromegaly (2) Dwarfism
    (3) Gigantism (4) Graves' disease

12. How many of the following conditions given can result in goitre? [NCERT Pg. 334, 335]

    a. Hyposecretion of thyroxine
    b. Hypersecretion of thyroxine
    c. Excess iodine in blood
    d. Less iodine in diet

    (1) One
    (2) Two
    (3) Three
    (4) Four

13. Select the **mismatch** of hormone and its site of action [NCERT Pg. 332]
    (1) Melanocyte stimulating hormone – Skin cells
    (2) Adrenocorticotrophic hormone – Adrenal cortex
    (3) Follicle stimulating hormone – Ovary
    (4) Gonadotrophin releasing hormone – Gonads

14. Which of the following gland grow to the maximum size uptil puberty and then degenerates gradually? [NCERT Pg.335]
    (1) Pituitary (2) Thyroid
    (3) Thymus (4) Parathyroid

15. When blood glucose level drops below the set point, the release of which hormone promotes the release of glucose in blood? [NCERT Pg. 337]
    (1) Insulin (2) Somatostatin
    (3) Glucagon (4) Parathormone

16. Complete the analogy w.r.t. hormone responsible for sexual behaviour.
    Male : Androgens
    Female : X [NCERT Pg. 339]
    (1) Progesterone (2) Estrogen
    (3) Prolactin (4) Cortisol

17. Which hormone is produced by pituitary gland to regulate basal metabolic rate of a child? [NCERT Pg. 332]
    (1) TSH (2) GH
    (3) Thyroxine (4) Somatostatin

18. Which of the following hormone triggers ovulation and stimulates conversion of ovarian follicles into corpus luteum? [NCERT Pg. 338]
    (1) Progesterone (2) LH
    (3) TSH (4) Estrogen

19. Match the columns and select the **correct** option [NCERT Pg. 339]

Column-I	Column-II
a. Gastrin	(i) Inhibits gastric secretion
b. Gastric inhibitory peptide (GIP)	(ii) Stimulates secretions of pancreatic juice
c. Secretin	(iii) Stimulates secretion of water and bicarbonate from pancreas
d. Cholecystokinin (CCK)	(iv) Stimulates secretion of HCl

    (1) a(ii), b(iii), c(i), d(iv)
    (2) a(iv), b(i), c(iii), d(ii)
    (3) a(ii), b(i), c(iii), d(iv)
    (4) a(i), b(ii), c(iv), d(iii)

20. Choose the **mismatch** [NCERT Pg. 338-339]
    (1) Progesterone – Maintenance of pregnancy and development of mammary glands
    (2) Erythropoietin – Secreted by bone marrow and stimulates erythropoiesis
    (3) Estrogen – Stimulates growth and activities of secondary sex organs in female and development of growing ovarian follicles
    (4) Growth factors – Secreted by non-endocrine tissue and are essential for repair and regeneration of tissues

Thinking in Context

1. The neural and _____ system jointly coordinate and regulate the physiological functions in the body. [NCERT Pg. 331]
2. In humans, MSH is secreted by _____. [NCERT Pg. 333]
3. Bony cavity called _____ in a skull bone encloses pituitary gland. [NCERT Pg. 333]
4. _____ pair of parathyroid glands are present on the back side of each lobe of thyroid gland [NCERT Pg. 335]
5. Hormone responsible for anti-diuresis is _____. [NCERT Pg. 334]
6. A peptide hormone named _____ plays a major role in the differentiation of T-lymphocytes. [NCERT Pg. 335]

7. _____ hormone regulates diurnal rhythm of our body. [NCERT Pg. 334]

8. Underproduction of hormones of adrenal cortex, results in alteration in carbohydrate metabolism that leads to _____ disease [NCERT Pg. 336]

9. _____ is the main mineralocorticoid in our body. [NCERT Pg. 337]

10. Middle layer of adrenal cortex is called _____. [NCERT Pg. 337]

11. _____ hormone plays a major role in the muscular growth and low pitch of voice in males. [NCERT Pg. 338]

12. _____ hormones are rapidly secreted in response to short term stress. [NCERT Pg. 336]

13. Endocrine gland present on either side of trachea is _____. [NCERT Pg. 334]

14. Hyperglycemic hormone produced by α-cells of islets of Langerhans is _____. [NCERT Pg. 337]

15. ANF is a __X__ hormone produced by __Y__ which __Z__ blood pressure. [NCERT Pg. 339]

16. Vigorous contractions of uterus during child birth is due to _____ hormone. [NCERT Pg. 334]

❑ ❑ ❑

17. Diabetes mellitus is due to hypo-secretion of __'A'__ whereas diabetes insipidus is due to hypo-secretion of __'B'__ hormone. [NCERT Pg. 334]

18. Catecholamines secreted by adrenal medulla are _____ and _____. [NCERT Pg. 336]

19. Hormones regulate gene expression by interacting with the genome are _____ and _____. [NCERT Pg. 340]

20. __X__ and __Y__ hormones are synthesized by hypothalamus and are transported axonally to neurohypophysis. [NCERT Pg. 333]