Course: Animal form and function

Chapter: 4

COMMUNICATION III:

- THE ENDOCRINE SYSTEM

AND CHEMICAL MESSENGERS,

- MECHANISM OF HORMONE ACTION,
- AN OVERVIEW OF VERTEBRATE ENDOCRINE SYSTEM.

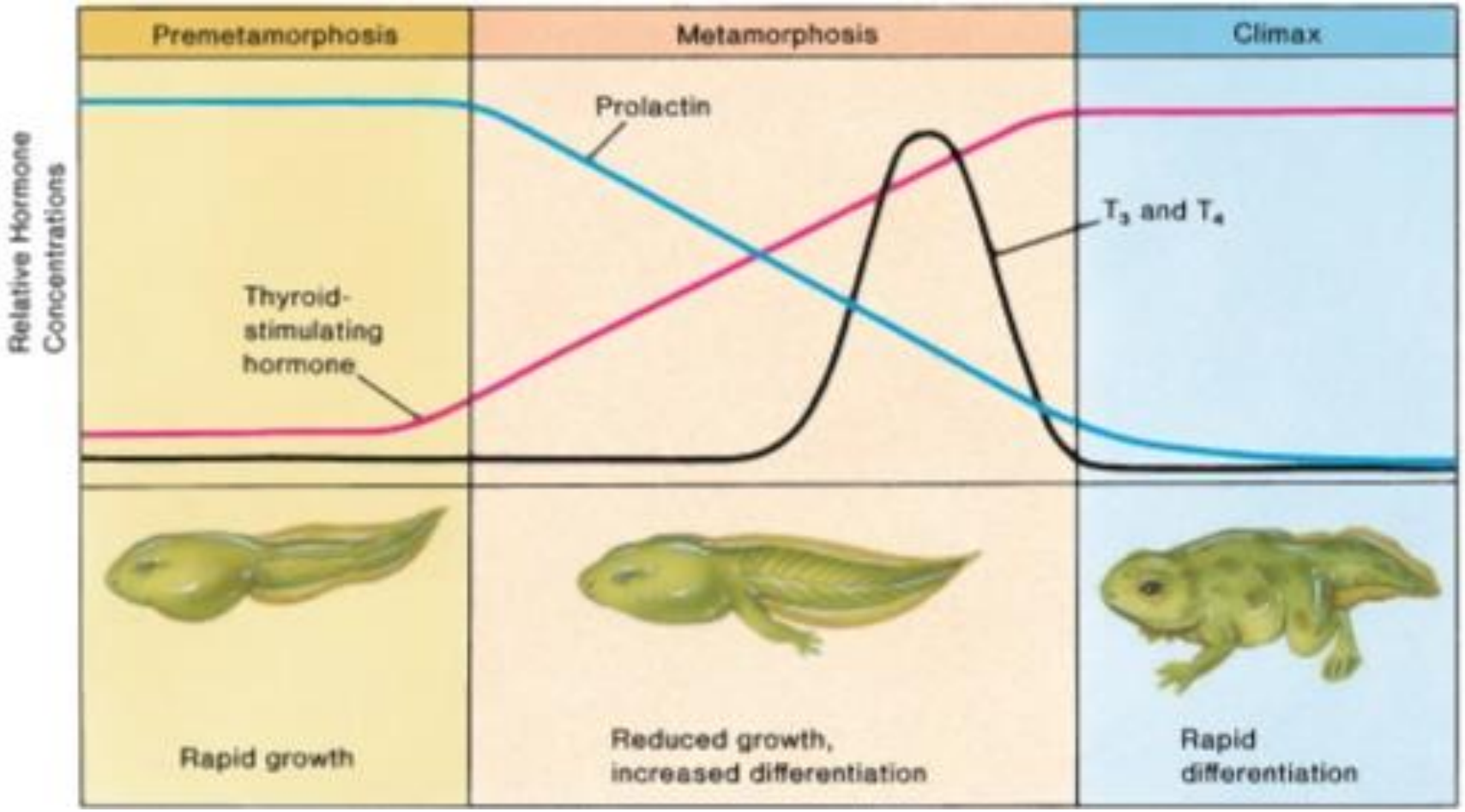


Fig: Frog Tadpole Metamorphosis. The thyroid hormones triiodothyronine (T3) and thyroxine (T4) regulate the metamorphosis of an aquatic frog tadpole into a semi terrestrial or terrestrial adult. The anterior pituitary secretes thyroid-stimulating hormone, which regulates thyroid gland activity. During the pre metamorphosis (tadpole) stage, the pituitary and thyroid glands are relatively inactive. This keeps the concentration of thyroid-stimulating hormones, T3 and T4, at low concentrations. The high prolactin concentration in tadpoles stimulates larval growth and prevents metamorphosis. During metamorphosis, the concentrations of the thyroid hormones markedly increase, and prolactin decreases. These hormonal fluctuations induce rapid differentiation, climaxing in the adult frog.

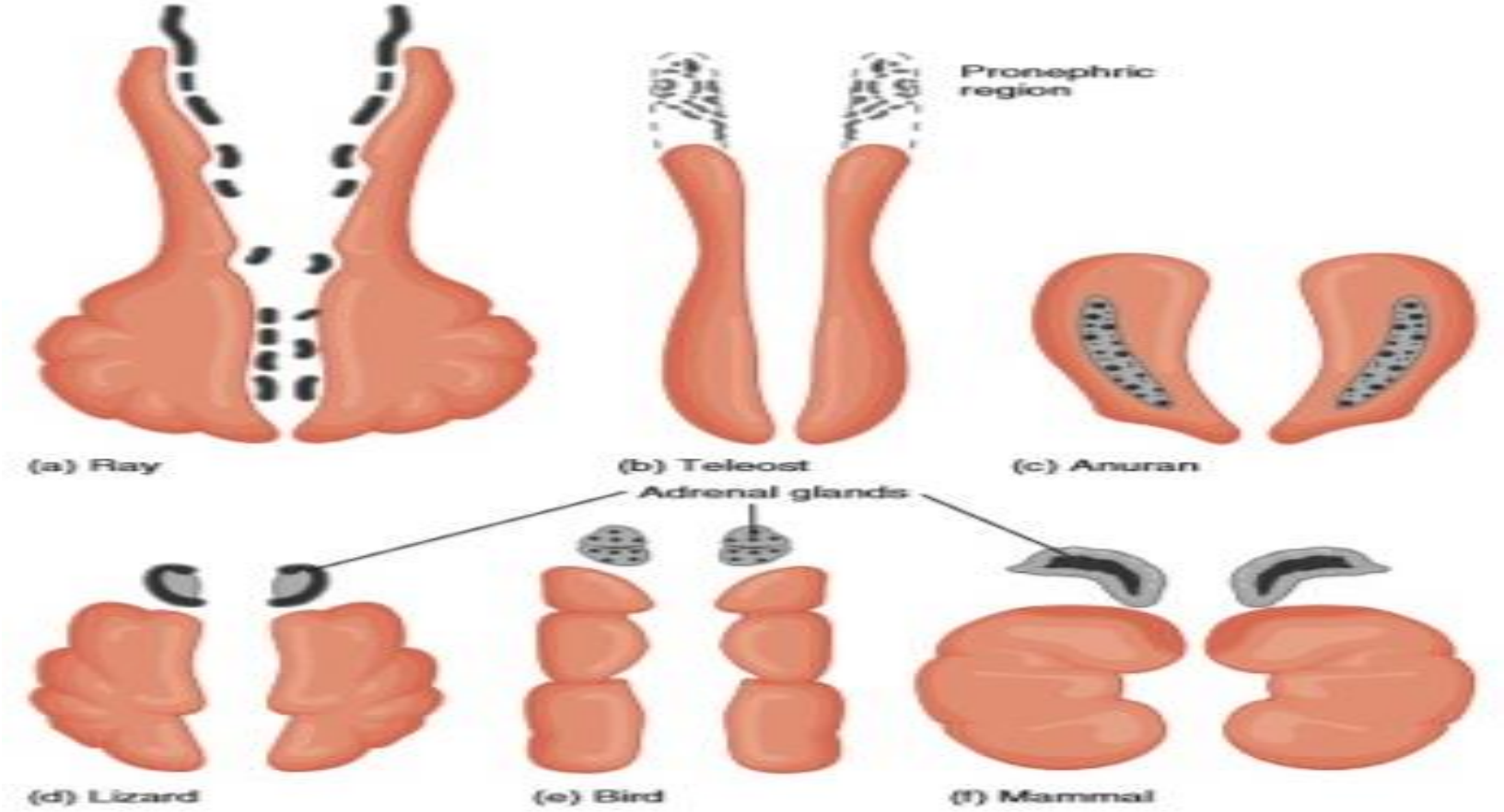


Fig: Chromaffin Tissue and Adrenal Glands in Selected Vertebrates. The chromaffin tissue (steroidogenic) produces steroid hormones and is shown in gray. The aminogenic tissue that produces norepinephrine and epinephrine is shown in black. The kidneys are shown in brown. Note the reversed location of the two components in lizards and mammals. (a) In jawless and cartilaginous fishes (elasmobranchs), aminogenic tissue develops as clusters near the kidneys. (b) In teleosts, the chromaffin tissue is generally at the anterior end of the kidney (pronephric region). (c) In anurans, the chromaffin tissue is interspersed in a diffuse gland on the ventral surface of each kidney. (d) In lizards, the chromaffin tissue forms a capsule around the steroidogenic-producing tissue. (e) In birds, the chromaffin tissue is interspersed within an adrenal capsule. (f) In most mammals, the chromaffin tissue forms an adrenal medulla, and the steroidogenic tissue forms the cortex.

ENDOCRINE SYSTEM OF BIRDS AND MAMMALS

The endocrine glands in birds include:

- ovary,
- testes,
- adrenals,
- pituitary,
- thyroid,
- pancreas,
- parathyroids,
- pineal,
- hypothalamus,
- thymus,
- ultimobranchial
- bursa of Fabricius

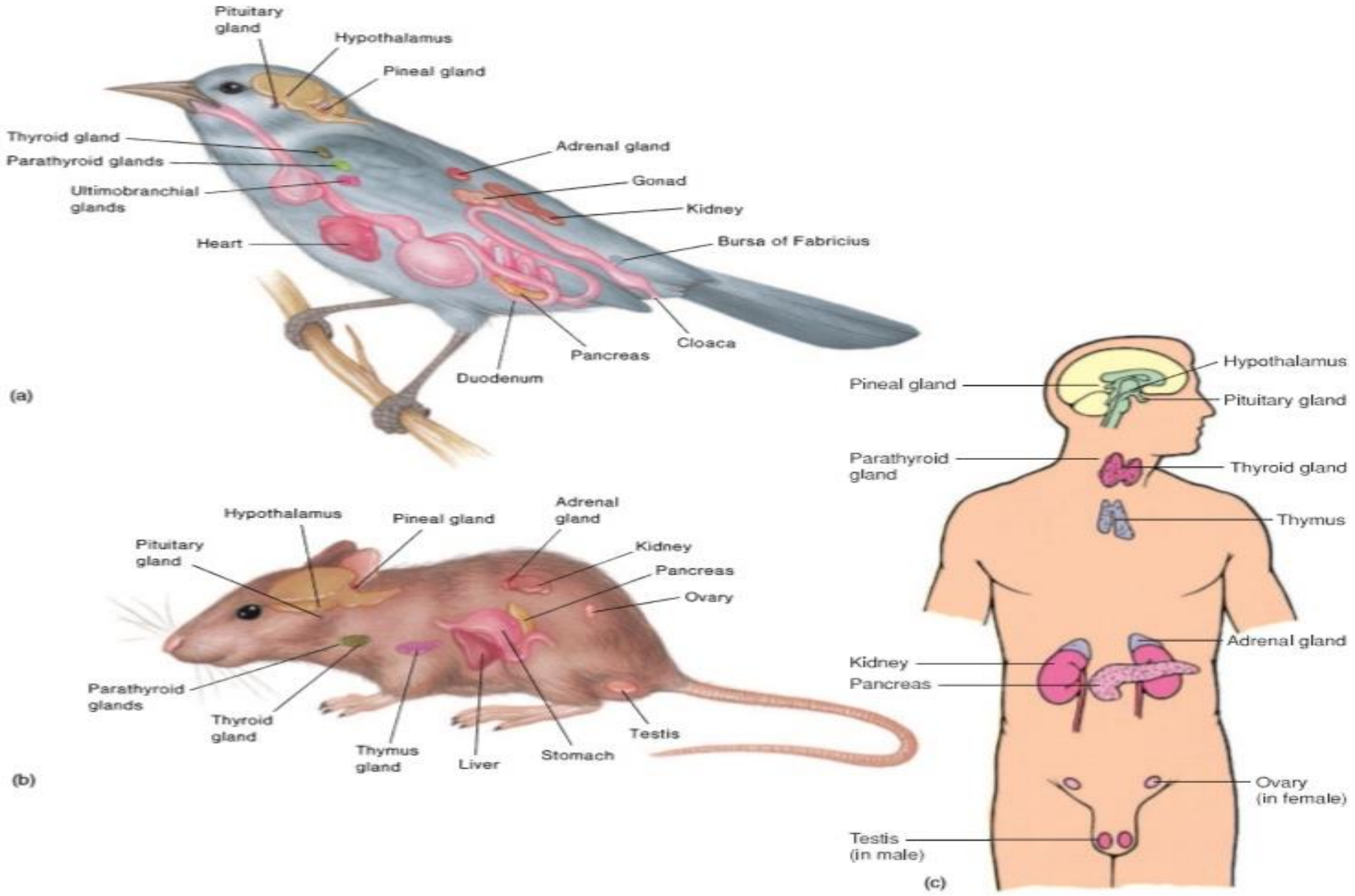


Fig: Endocrine Glands of Birds and Mammals. Locations of the major endocrine glands of (a) a bird, (b) a rat, and (c) a human.

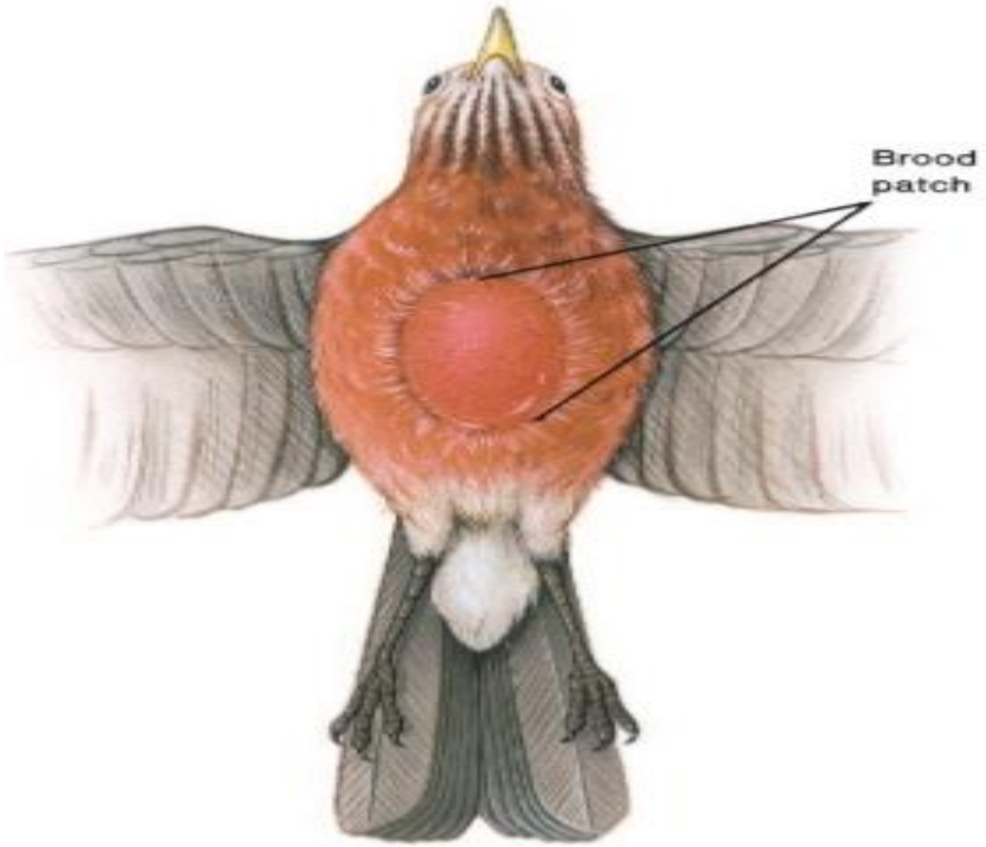


Fig: A Bird's Brood Patch. In this example, a robin's single brood patch appears (due to the effect of the hormone prolactin) a few days before eggs are laid. Prolactin causes the down feathers to drop from the abdomen of the incubating robin, and the bare patch becomes swollen and richly supplied with blood vessels. After laying the eggs, the robin settles on its nest and brings this warm patch in contact with its eggs, thereby transferring heat to the developing embryos.

TABLE 25.1
MAJOR VERTEBRATE ENDOCRINE TISSUES AND HORMONES

SOURCE	HORMONES	TARGET CELLS AND PRINCIPAL ACTIONS
Anterior lobe of pituitary (adenohypophysis)	Somatotropin (STH, or growth hormone [GH])	Stimulates growth of bone and muscle; promotes protein synthesis; affects lipid and carbohydrate metabolism; increases cell division
	Adrenocorticotropic hormone (ACTH)	Stimulates secretion of adrenocortical steroids; is involved in stress response
	Thyrotropin (TSH) of thyroid-stimulating hormone	Stimulates thyroid gland to synthesize and release thyroid hormones concerned with growth, development, metabolic rate
	Endorphins	Decrease pain
	Gonadotropins: Luteinizing or interstitial cell-stimulating hormone (LH or ICSH)	In ovary: Forms corpora lutea; secretes progesterone; probably acts in conjunction with FSH
		In testis: Stimulates the interstitial cells, thus promoting the secretion of testosterone
	Follicle-stimulating hormone (FSH)	In ovary: Stimulates growth of follicles; functions with LH to cause estrogen secretion and ovulation
		In testis: Acts on seminiferous tubules to promote spermatogenesis
	Prolactin (PRL)	Initiates milk production by mammary glands; acts on crop sacs of some birds; stimulates maternal behavior in birds
Intermediate or posterior lobe of pituitary	Melanocyte-stimulating hormone (MSH)	Expands amphibian melanophores; contracts iridophores and xanthophores; promotes melanin synthesis; darkens the skin; responds to external stimuli
Posterior lobe of pituitary (neurohypophysis) releases these hormones produced by the hypothalamus	Antidiuretic hormone (ADH or vasopressin)	Elevates blood pressure by acting on arterioles; promotes reabsorption of water by kidney tubules
	Oxytocin	Affects postpartum mammary gland, causing ejection of milk; promotes contraction of uterus; has possible action in parturition and in sperm transport in female reproductive tract

Hypothalamus	Thyroid-stimulating hormone (TSH)	Stimulates release of TSH by anterior pituitary
	Adrenocorticotropin-releasing hor-mone (CRH)	Stimulates release of ACTH by anterior pituitary
	Gonadotropin-releasing hormone(GnRH)	Stimulates gonadotropin release by anterior pituitary
	Prolactin-inhibiting factor (PIF)	Inhibits prolactin release by anterior pituitary
	Somatostatin	Inhibits release of STH by anterior pituitary
Thyroid gland	Thyroxine, triiodothyronine	Affect growth, amphibian metamorphosis, molting, metabolic rate in birds and mammals, development
	Calcitonin	Lowers blood calcium level by inhibiting calcium reabsorption from bone
Parathyroid glands	Parathormone	Regulates calcium concentration
Pancreas, islet cells	Insulin (from beta cells)	Promotes glycogen synthesis and glucose utilization and uptake from blood
	Glucagon (from alpha cells)	Raises blood glucose concentration
Adrenal cortex	Glucocorticoids (e.g., cortisol)	Promote synthesis of carbohydrates and breakdown of proteins; initiate antiinflammatory and antiallergic actions; mediate response to stress
	Mineralocorticoids (e.g., aldosterone)	Regulate sodium retention and potassium loss through kidneys, and water balance
Adrenal medulla	Epinephrine (adrenaline)	Mobilizes glucose; increases blood flow through skeletal muscle; increases oxygen consumption; increases heart rate
	Norepinephrine	Elevates blood pressure; constricts arterioles and venules
Testes	Androgens (e.g., testosterone)	Maintain male sexual characteristics; promote spermatogenesis
Ovaries	Estrogens (e.g., estradiol)	Maintain female sexual characteristics; promote oogenesis
Corpus luteum	Progesterone	Maintains pregnancy; stimulates development of mammary glands

The endocrine glands in mammals include:

- Pituitary Gland (Hypophysis)
  - Adenohypophysis
  - Neurohypophysis
- Thyroid Gland
- Parathyroid Glands
- Adrenal Glands
  - Adrenal Cortex
  - Adrenal Medulla
- Gonads
- Thymus

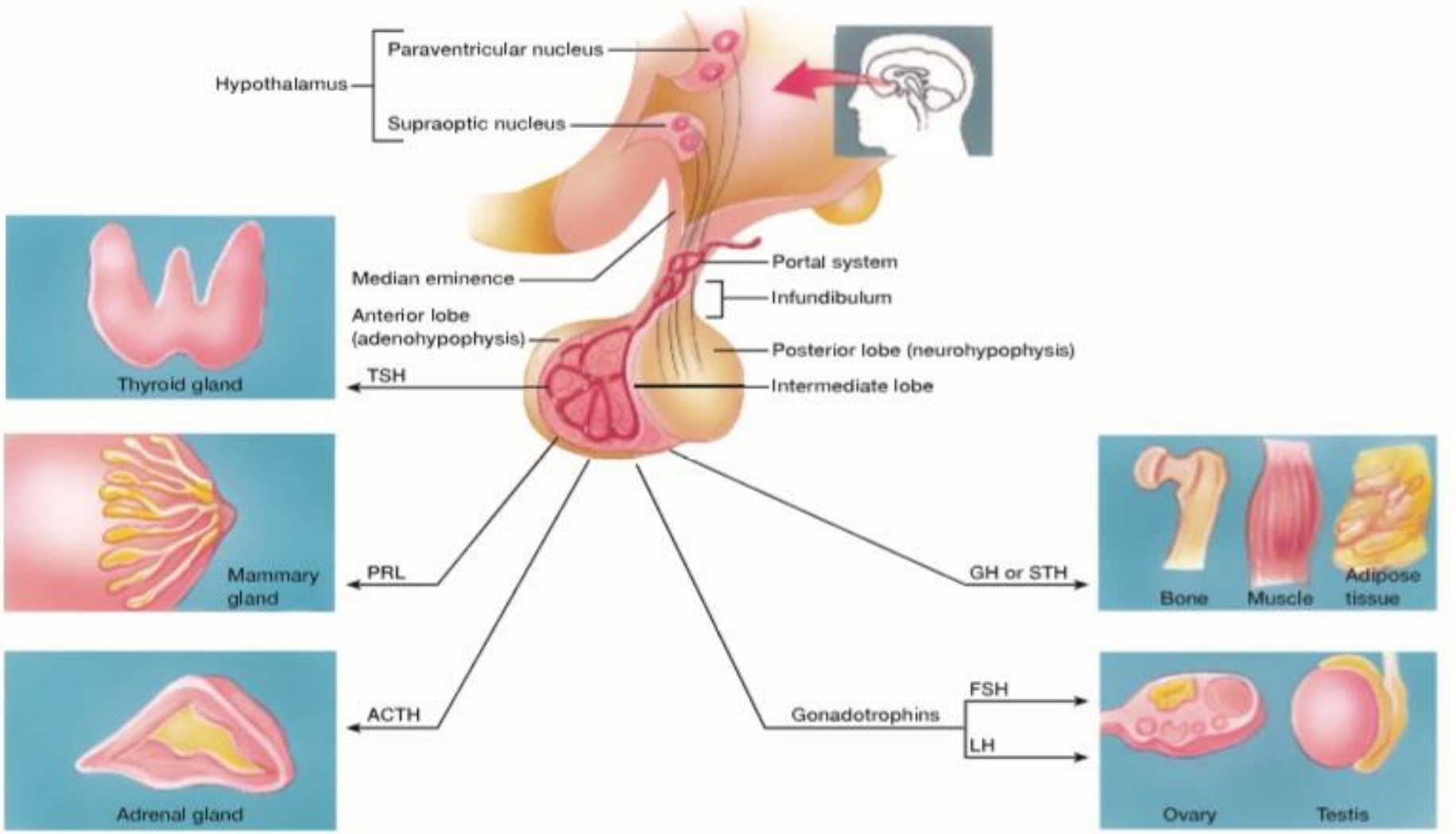


Fig: Functional Links between the Pituitary Gland and the Hypothalamus. Target areas for each hormone are shown in the corresponding box. The blood vessels that make up the hypothalamic-hypophyseal portal system provide the functional link between the hypothalamus and the adenohypophysis, and the axons of the hypothalamic neurosecretory cells provide the link between the hypothalamus and the neurohypophysis. (TSH thyroidstimulating hormone; PRL prolactin; ACTH adrenocorticotropic hormone; GH growth hormone; STH somatotropin; FSH follicle-stimulating hormone; LH luteinizing hormone.)

Division of pituitary gland

- It consists of two main parts that originate from different type of cells.

Anterior pituitary gland (Adeno hypophysis):

- It is an up growth of glandular epithelium from the pharynx.
- It secrete peptide hormones.

Posterior pituitary gland (neurohypophysis):

- It is formed from the nervous tissue and nerve cells, surrounding by supporting glial cells (pituicytes).
- It stores hormones secreted by the hypothalamus.

Hormones produced by anterior pituitary gland

- Growth hormone (GH)
- Thyroid-stimulating hormone (TSH)
- Adrenocorticotrophic hormone (ACTH)
- Prolactin (PRL)
- Gonadotrophins
  I. Luteinizing hormone (LH)
  II. Follicle-stimulating hormone (FSH)

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

- it affects all parts of the body that are concerned with growth.
- It directly induces the cell division necessary for growth and protein synthesis in most types of cells by stimulating the uptake of amino acids, RNA synthesis, and ribosome activity.

2) Thyrotropin, or thyroid-stimulating hormone (TSH)

- stimulates the thyroid gland's synthesis and secretion of thyroxine, the main thyroid hormone.

3) Adrenocorticotropic hormone (ACTH)

- stimulates the adrenal gland to produce and secrete steroid hormones called glucocorticoids (cortisol).
- Secretion of ACTH is regulated by the secretion of corticotropin-releasing factor from the hypothalamus.

4) Prolactin (PRL)

- It plays an essential role in many aspects of reproduction.
- For example, it stimulates reproductive migrations in many mammals, such as elk and caribou.
- Prolactin also enhances mammary gland development and milk production in female mammals.

5) Gonadotropins

The adenohypophysis produces two gonadotropins (hormones that stimulate the gonads):

I. luteinizing hormone

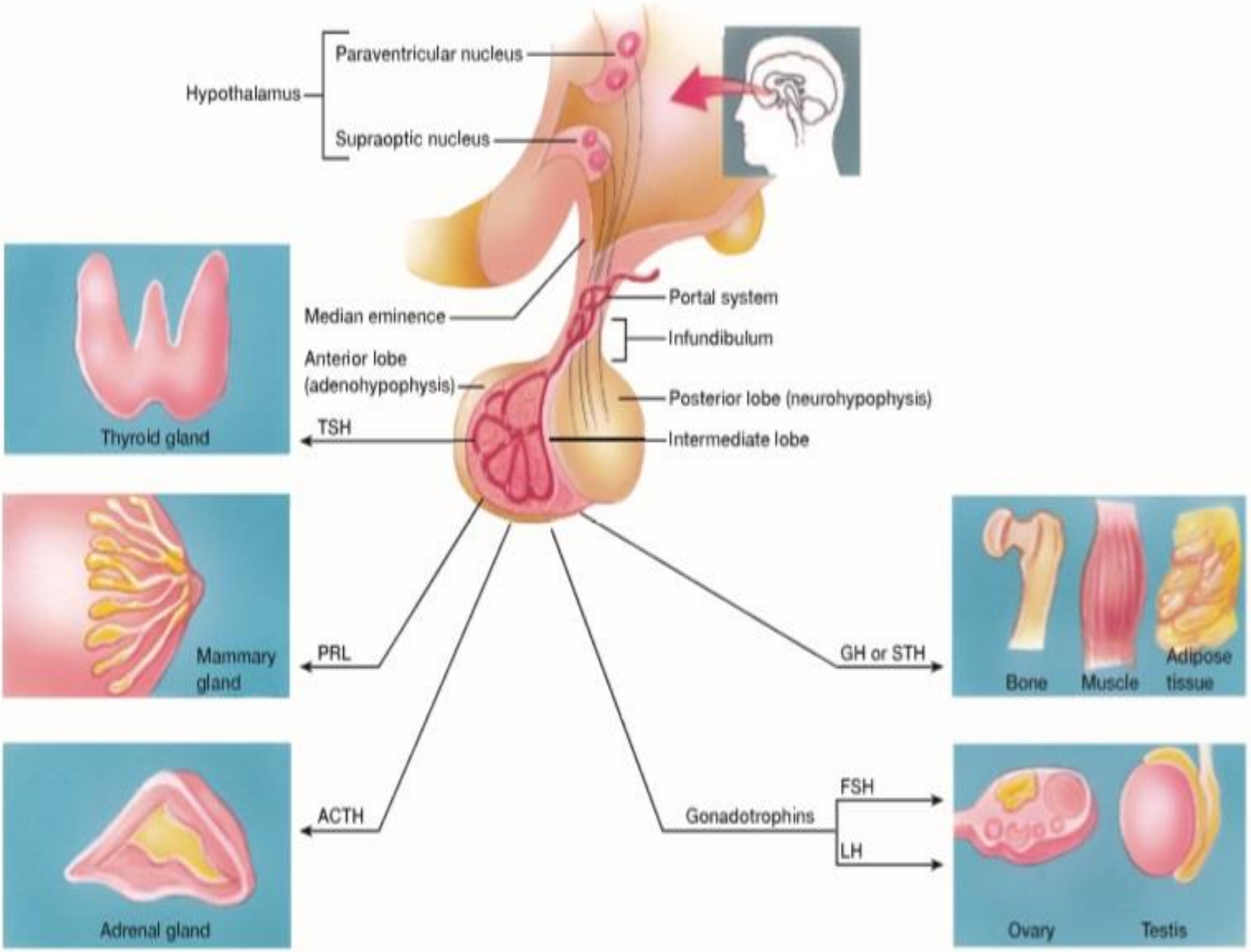
In the female, an increase of LH in the blood stimulates **ovulation**, the release of a mature egg(s) from an ovary. In the male, the target cells of LH are cells in the testes that secrete the male hormone testosterone.

II. Follicle stimulating hormone.

In the female, follicle-stimulating hormone (FSH) stimulates the follicular cells in the ovaries to develop into mature eggs and to produce estrogen. In the male, FSH stimulates the cells of the testes to produce sperm.

6) pineal gland (or pineal body)

- ✓ It is shaped like a pine cone.
- ✓ Its distinctive cells evolved from the photoreceptors of lower vertebrates;
- ✓ They synthesize melatonin, and are most active in the dark.
- ✓ Light inhibits the enzymes needed for **melatonin** synthesis.
- ✓ Melatonin can affect many physiological processes and adjust them to diurnal and seasonal cycles.


Hypothalamus
Paraventricular nucleus
Supraoptic nucleus
Median eminence
Portal system
Infundibulum
Anterior lobe
(adenohypophysis)
Posterior lobe (neurohypophysis)
Intermediate lobe
TSH
Thyroid gland
PRL
Mammary gland
GH or STH
Bone
Muscle
Adipose tissue
ACTH
Adrenal gland
Gonadotrophins
FSH
LH
Ovary
Testis

Thyroid Gland:

The thyroid gland is in the neck, anterior to the trachea. Two of its secretions are:

I. **thyroxine**

II. **triiodothyronine,**

} influence **overall growth, development, and metabolic rates.**

III. **Calcitonin:**

- helps control extracellular levels of **calcium ions (Ca2)** by promoting the deposition of these ions into bone tissue when their concentrations rise.
- Once calcium returns to its homeostatic concentration, thyroid cells decrease their secretion of calcitonin.

Parathyroid Glands:

- ✓ The parathyroid glands are tiny, pea-sized glands embedded in the thyroid lobes,
- ✓ usually two glands in each lobe
- ✓ The parathyroids secrete parathormone (PTH), which regulates the concentrations of calcium (Ca2) and phosphate (HPO24) ions in the blood.

When the calcium concentration in the blood bathing the parathyroid glands is low, PTH secretion increases and has the following effects:

- ❑ It stimulates bone cells to break down bone tissue and release calcium ions into the blood.
- ❑ It also enhances calcium absorption from the small intestine into the blood.
- ❑ Finally, PTH promotes calcium reabsorption by the kidney tubules to decrease the amount of calcium excreted in the urine.

SOME OTHER MAJOR SOURCES OF VERTEBRATE HORMONES

GLAND/ORGAN	HORMONE	FUNCTION	TARGET AREA
Placenta	Estrogens, progesterone, human chorionic gonadotropin (hCG), human chorionic somatomammotropin (hCS)	Maintain pregnancy	Ovaries, mammary glands, uterus
Digestive tract	Secretin	Stimulates release of pancreatic juice to neutralize stomach acid	Cells of pancreas
	Gastrin	Stimulates digestive enzymes and HCl in stomach	Stomach mucosa
	Cholecystokinin (CCK)	Stimulates release of pancreatic enzymes and bile from gallbladder	Pancreas, gallbladder
Heart	Atriopeptin	Lowers blood pressure, maintains fluid balance	Blood vessels, kidneys
Kidneys	Erythropoietin	Stimulates red blood cell production	Bone marrow
	Urotensin	Stimulates constriction of arteries	Major arteries
	Calcitrol	Aids in the absorption of dietary calcium and phosphorus	Small intestine
Adipose tissue	Leptin	Suppresses appetite	Brain

Adrenal Glands :

I. Adrenal Cortex:

Glucocorticoids (cortisol)

- ✓ help regulate overall metabolism and the concentration of blood sugar.
- ✓ They also function in defense responses to infection or tissue injury.

Aldosterone

- ✓ helps maintain concentrations of solutes (such as sodium) in the extracellular fluid
- ✓ Aldosterone also promotes sodium reabsorption in the kidneys and, thus, water reabsorption; hence, it plays a major role in maintaining the homeostasis of extracellular fluid.

Sex hormones (androgens, estrogens).

- ✓ sex hormones that the adrenal cortex secretes have only a slight effect on male and female gonads.
- ✓ These sex hormones consist mainly of weak male hormones called **androgens** and lesser amounts of female hormones called **estrogens.**

II. Adrenal Medulla

- ✓ The adrenal medulla is under neural control.
- ✓ It contains neurosecretory cells that secrete

i. epinephrine (adrenaline) ii. norepinephrine (noradrenaline).

- ✓ Both of which help control heart rate and carbohydrate metabolism.
- ✓ During times of excitement, emergency, or stress, the adrenal medulla contributes to the overall mobilization of the body through the sympathetic nervous system.

❖ **In response to epinephrine and norepinephrine:**

- ✓ the heart rate increases,
- ✓ blood flow increases to many vital organs,
- ✓ The airways in the lungs dilate, and more oxygen is delivered to all cells of the body.
- ✓ This group of events is sometimes called the **"fight-or flight"** response and permits the body to react strongly and quickly to emergencies.

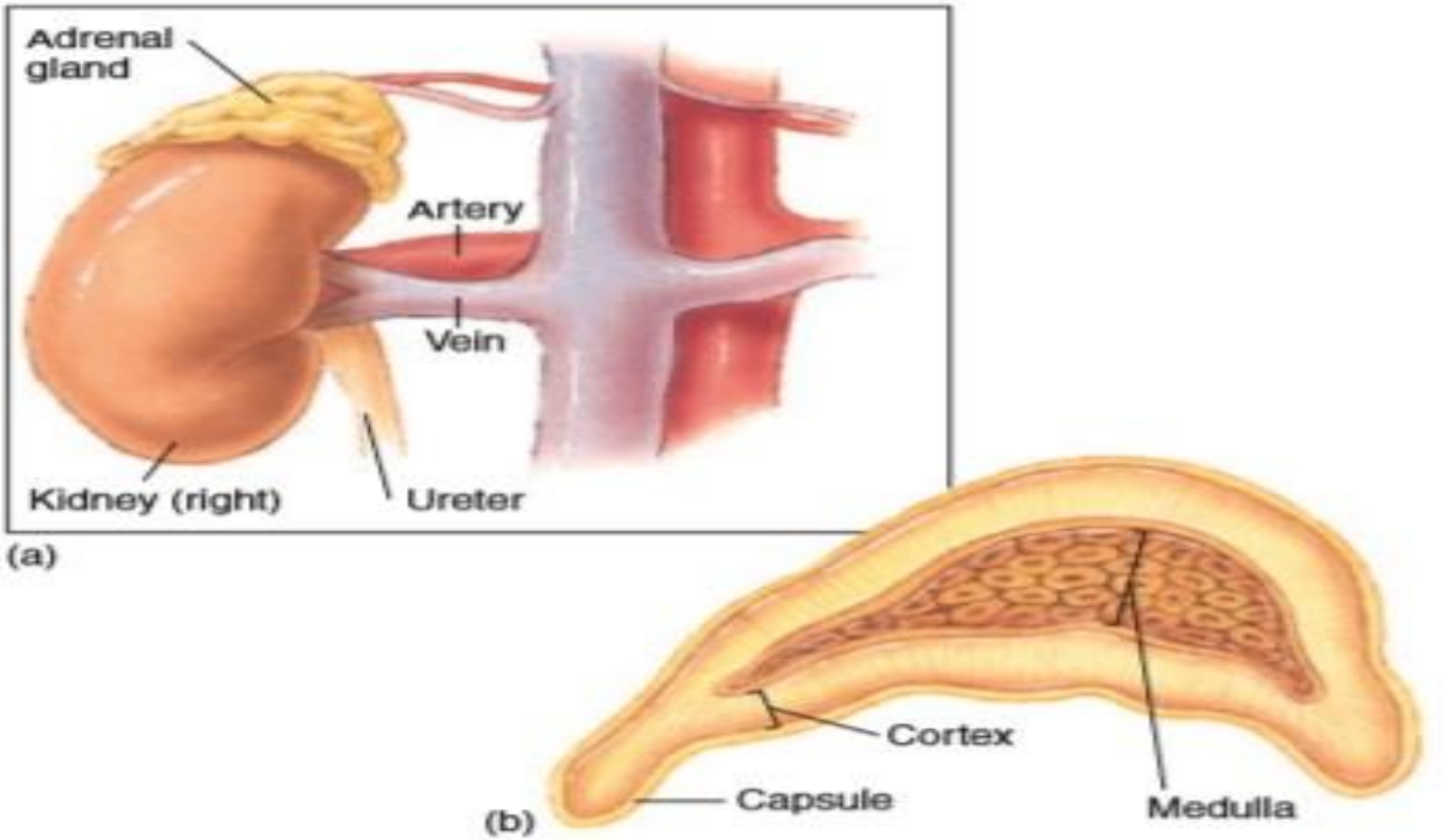


Fig: Adrenal Gland of a Mammal. (a) An adrenal gland sits on top of each kidney. (b) Each gland contains two structurally, functionally, and developmentally distinct regions. The outer cortex is endocrine and produces glucocorticoids (cortisol), mineralocorticoids (aldosterone), and androgens (sex hormones). The inner medulla is nervous tissue that produces epinephrine (adrenaline) and norepinephrine (noradrenaline).

Pancreas :

- ✓ The pancreas is an elongated, fleshy organ posterior to the stomach
- ✓ It functions both as an exocrine (with ducts) gland to secrete digestive enzymes and as an endocrine (ductless) gland.
- ✓ The pancreas contains **200,000 to 2,000,000** pancreatic islets scattered throughout the gland.
- ✓ Each islet contains four special groups of cells, called **alpha (), beta (), delta (), and F cells.**
- ✓ The alpha cells produce the hormone **glucagon,** and beta cells produce **insulin**.
- ✓ The delta cells secrete **somatostatin**.
- ✓ F cells secrete a pancreatic polypeptide that is released into the bloodstream after a meal and inhibits somatostatin secretion, gallbladder contraction, and the secretion of pancreatic digestive enzymes.

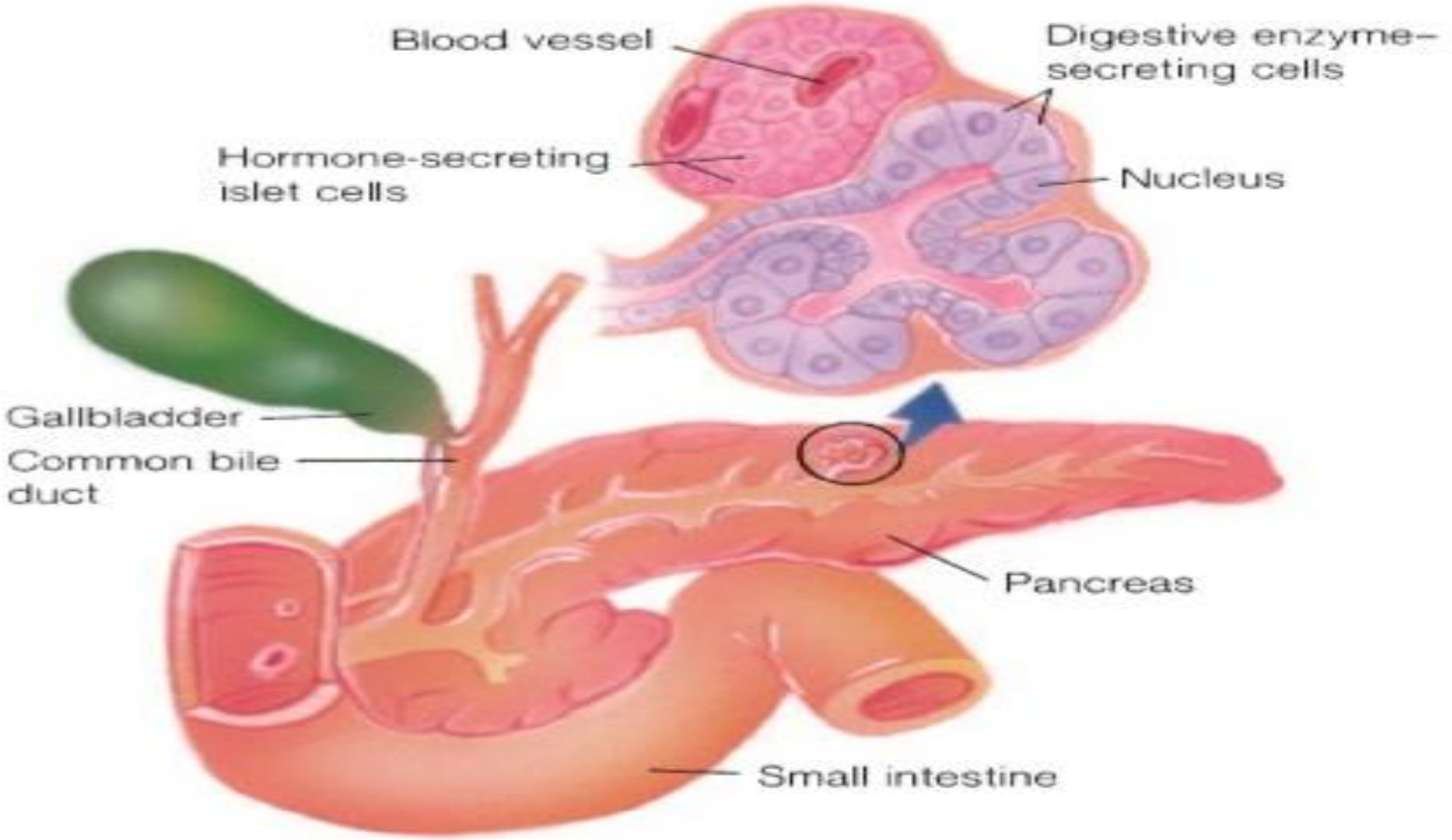


Fig: Pancreas. The hormone-secreting cells of the pancreas are arranged in clusters or islets closely associated with blood vessels. Other pancreatic cells secrete digestive enzymes into ducts.

Role of Pancreas in regulation of blood glucose concentrations:

- ✓ When glucose concentrations in the blood are high, such as after a meal, beta cells secrete insulin. Insulin promotes the uptake of glucose by the body's cells, including liver cells, where excess glucose can be converted to glycogen (a storage polysaccharide).
- ✓ Insulin and glucagon are crucial to the regulation blood glucose concentrations.
- ✓ When the blood glucose concentration is low, alpha cells secrete glucagon.
- ✓ Glucagon stimulates the breakdown of glycogen into glucose units, which are released into the bloodstream to raise the blood glucose concentration to the homeostatic level.

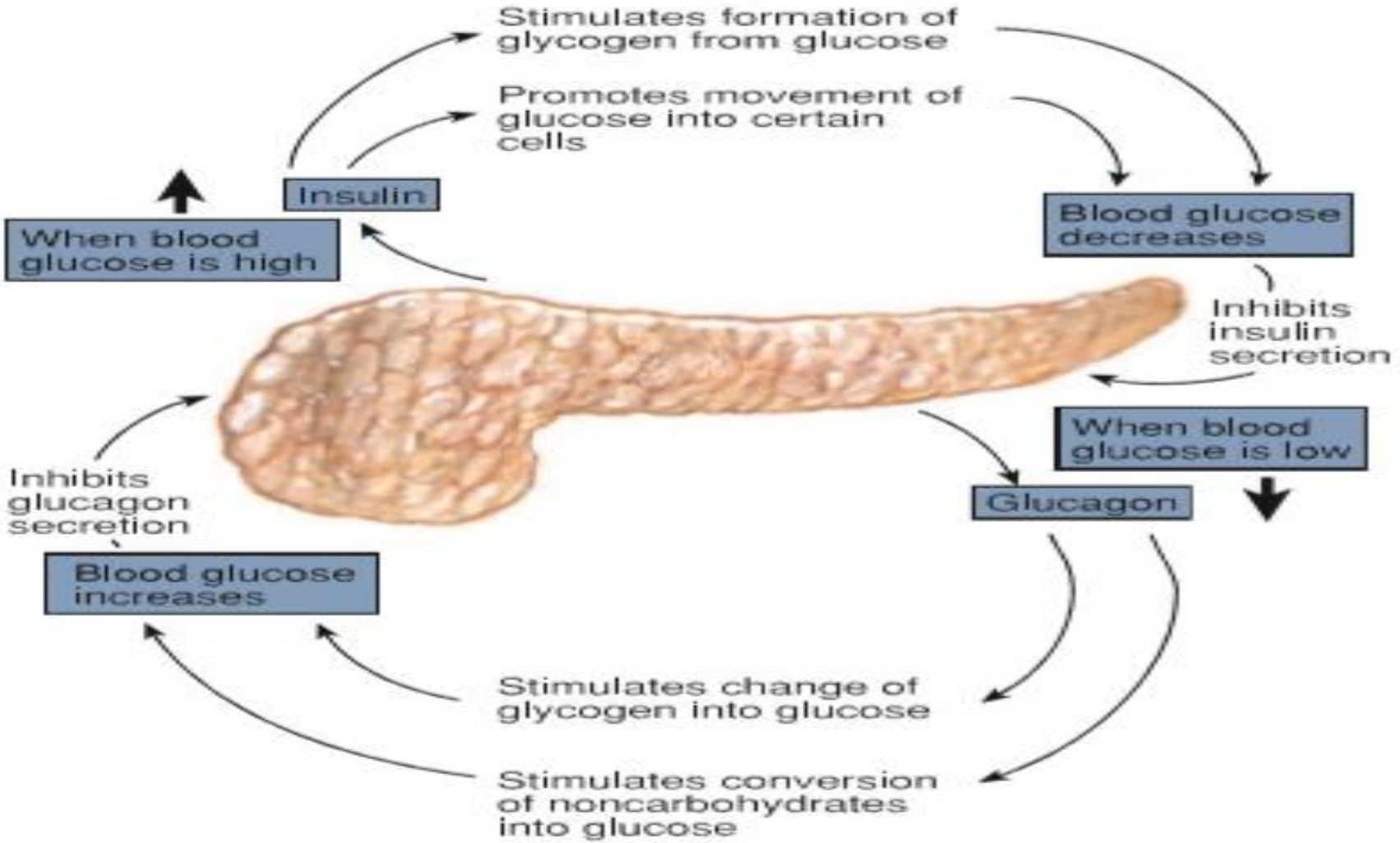


Fig: Two Pancreatic Hormones (Insulin and Glucagon) Regulate the Concentration of Blood Glucose. The negative feedback mechanism for regulating glucagon and insulin secretion helps maintain a relatively stable blood glucose concentration.

Gonads :

- ✓ **Gonads (ovaries and testes)** secrete hormones that help regulate reproductive functions.
- ✓ In the male, the testes secrete **testosterone.**

Functions of testosterone:

- ✓ It acts with luteinizing and follicle-stimulating hormones that the adenohypophysis produces to stimulate spermatogenesis.
- ✓ Testosterone is also necessary for the growth and maintenance of the male sex organs,
- ✓ It promotes the development and maintenance of sexual behavior,
- ✓ In humans, testosterone stimulates the growth of facial and pubic hair, as well as enlargement of the larynx.
- ✓ The testes also produce **inhibin**, which inhibits the secretion of FSH.

Four major classes of ovarian hormones help to regulate female reproductive functions.

- ✓ **Estrogens (estrin, estrone, and estradiol)** help regulate the menstrual and estrus cycles
- ✓ and the development of the mammary glands and
- ✓ other female secondary sexual characteristics.
- ✓ The **progestins (primarily progesterone)** also regulate the menstrual and estrus cycles, and the development of the mammary glands, and aid in placenta formation during pregnancy.
- ✓ **Relaxin**, which is produced in small quantities, softens the opening of the uterus (cervix) at the time of delivery.
- ✓ The ovaries also produce **inhibin**, which inhibits the secretion of FSH

Thymus gland:

- ✓ Thymus gland is near the heart.
- ✓ It is large and conspicuous in young birds and mammals, but diminishes in size throughout adulthood.
- ✓ The major hormonal product of the thymus is a family of peptide hormones, including **thymopoietin (TP)** and **alpha1** and **beta4 thymosin**, that appear to be essential for the normal development of the immune system.