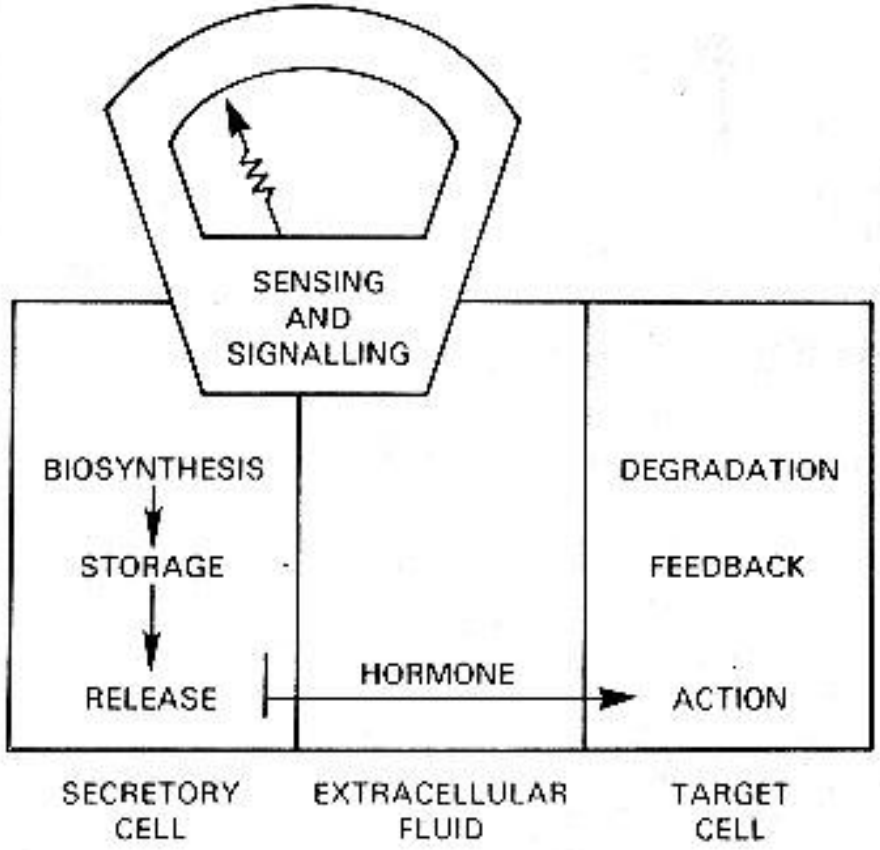
Endocrine System

Sensing and signaling

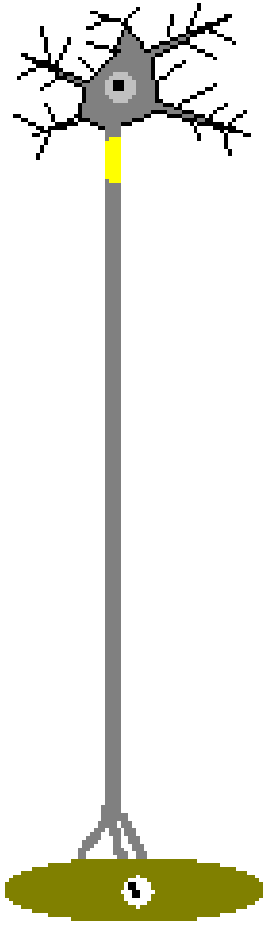


Endocrine “glands” synthesize and store hormones. These glands have a sensing and signaling system which regulate the duration and magnitude of hormone release via feedback from the target cell.

Endocrine vs. Nervous System

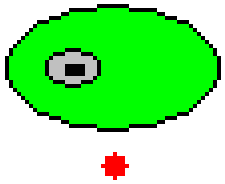
- Major communication systems in the body
- Integrate stimuli and responses to changes in external and internal environment
- Both are crucial to coordinated functions of highly differentiated cells, tissues and organs
- Unlike the nervous system, the endocrine system is anatomically discontinuous.

Nervous system

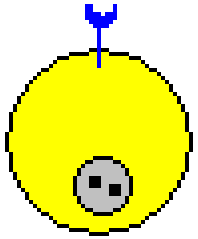


•**The nervous system** exerts point-to-point control through nerves, similar to sending messages by conventional telephone. Nervous control is electrical in nature and fast.

The endocrine system



- **The endocrine system** broadcasts its hormonal messages to essentially all cells by secretion into blood and extracellular fluid. Like a radio broadcast, it requires a receiver to get the message - in the case of endocrine messages, cells must bear a *receptor* for the hormone being broadcast in order to respond.



Hormones travel via the bloodstream to target cells

Systems of Internal Communication

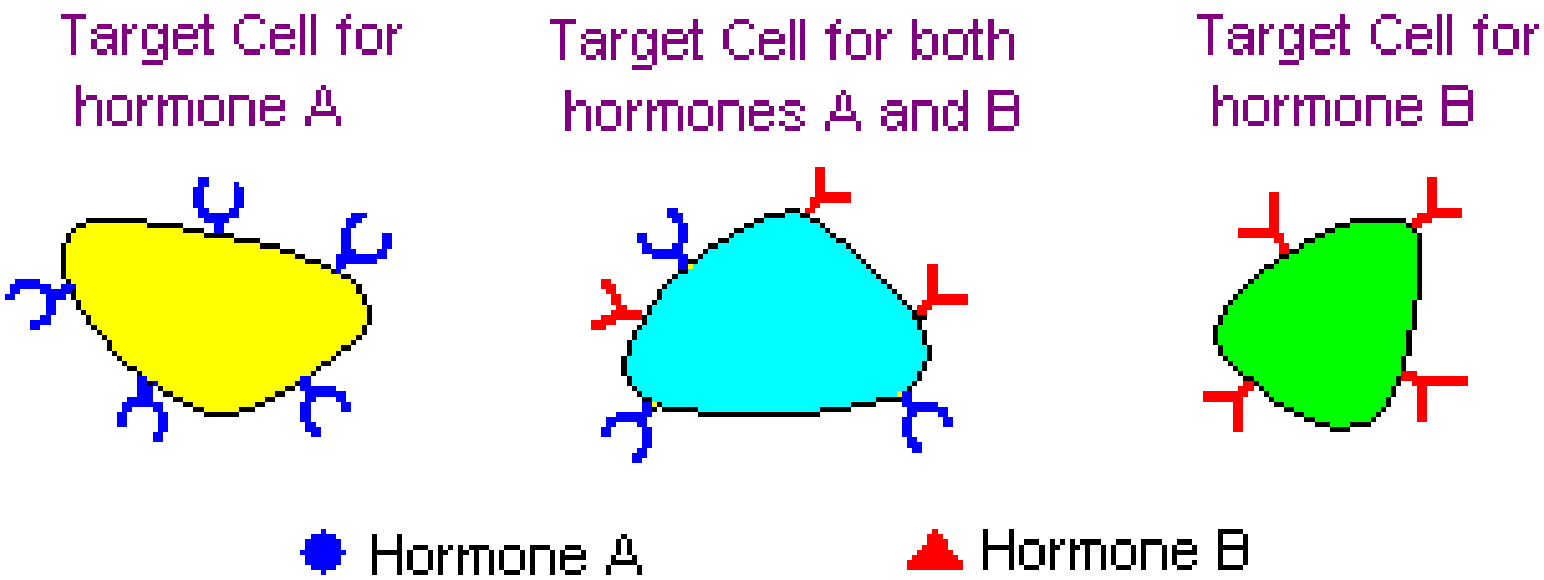
- The **nervous system** conveys high-speed electrical signals along specialized cells called **neurons**.
- The **endocrine system**, made up of **endocrine glands**, secretes hormones that coordinate slower but longer-acting responses to stimuli.

Advantages of using chemical messengers or Hormones

- Chemical molecules can spread to all tissues through the blood.
- Chemical signals can persist longer than electrical ones.
- Many different kinds of chemicals can act as hormones; different hormones can target different tissues.

A cell is a target because is has a specific receptor for the hormone

Most hormones circulate in blood, coming into contact with essentially all cells. However, **a given hormone usually affects only a limited number of cells, which are called target cells. A target cell responds to a hormone because it bears receptors for the hormone.**



Principal functions of the endocrine system

- Maintenance of the internal environment in the body (maintaining the optimum biochemical environment).
- Integration and regulation of growth and development.
- Control, maintenance and instigation of sexual reproduction, including gametogenesis, coitus, fertilization, fetal growth and development and nourishment of the newborn.

Hormones

- A **hormone** is a chemical signal that is secreted into the circulatory system and communicates regulatory messages within the body.
- Hormones may reach all parts of the body, but only certain types of cells, **target cells**, are equipped to respond.

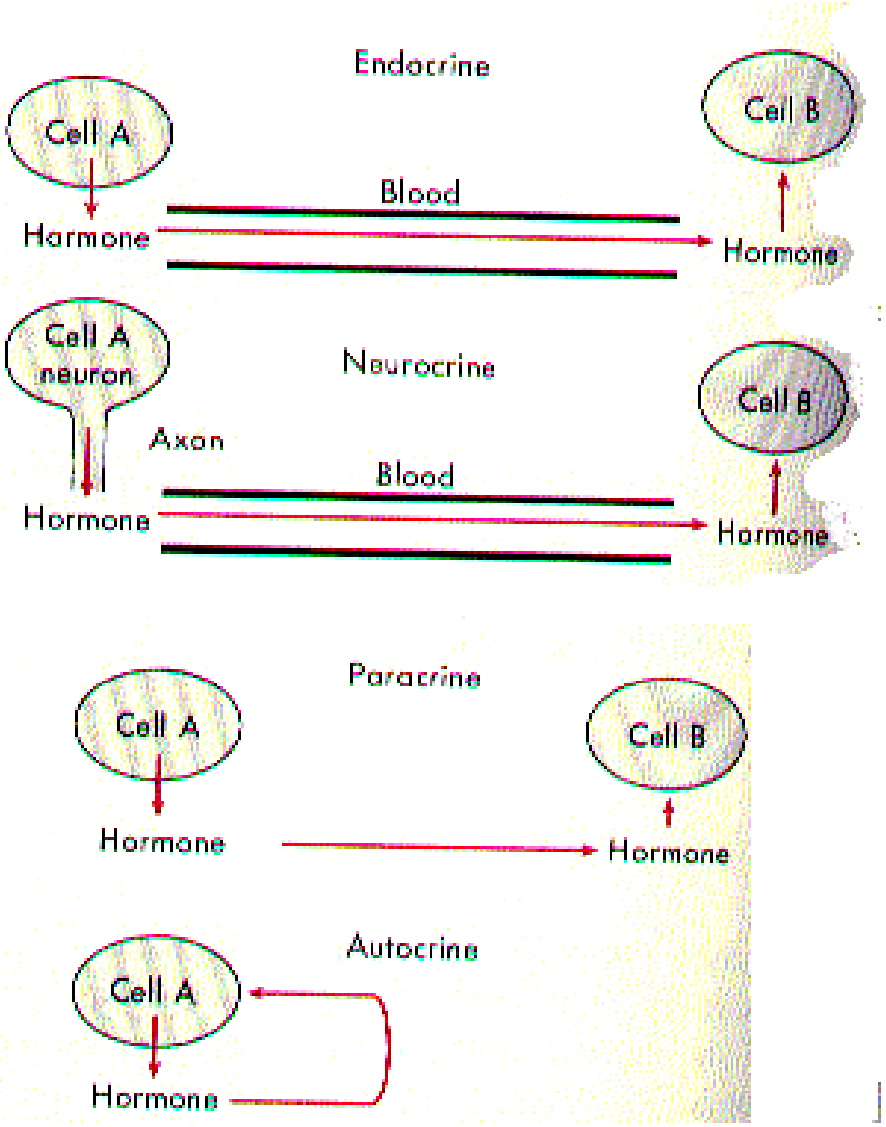
Hormones

- **Hormones** convey information via the bloodstream to target cells throughout the body.
- **Pheromones** carry messages outside the body – to other individuals.

Hormones

- Signaling by any of these molecules involves three key events:
  - Reception
  - Signal transduction
  - Response

Types of cell-to-cell signaling



Classic endocrine hormones travel via bloodstream to target cells;

neurocrine are released via synapses and travel via the bloostream;

paracrine hormones act on adjacent cells and

autocrine hormones are released and act on the cell that secreted them. Also, intracrine hormones act within the cell that produces them.

Response vs. distance traveled

Endocrine action: the hormone is distributed in blood and binds to distant target cells.

Paracrine action: the hormone acts locally by diffusing from its source to target cells in the neighborhood.

Autocrine action: the hormone acts on the same cell that produced it.

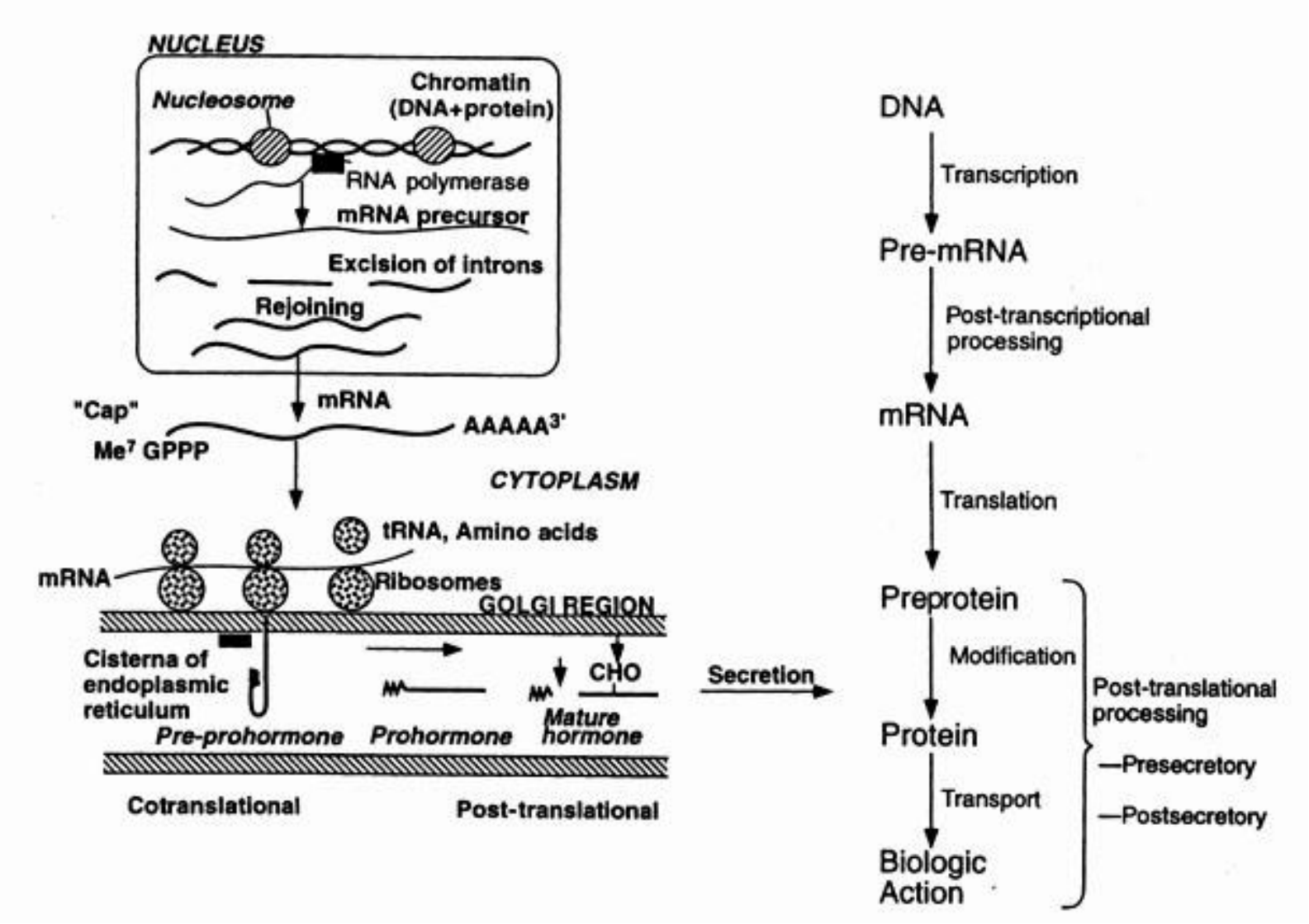
Types of hormones

- **Hormones are categorized into four structural groups, with members of each group having many properties in common:**
  - Peptides and proteins
  - Amino acid derivatives
  - Steroids
  - Fatty acid derivatives - Eicosanoids

Peptide/protein hormones

- Range from 3 amino acids to hundreds of amino acids in size.
- Often produced as larger molecular weight precursors that are proteolytically cleaved to the active form of the hormone.
- Peptide/protein hormones are water soluble.
- Comprise the largest number of hormones– perhaps in thousands

Peptide/protein hormone synthesis



Glands

- Many hormones are secreted by ductless **endocrine glands**.
  - Obtain raw materials from and secrete hormones directly into the bloodstream.

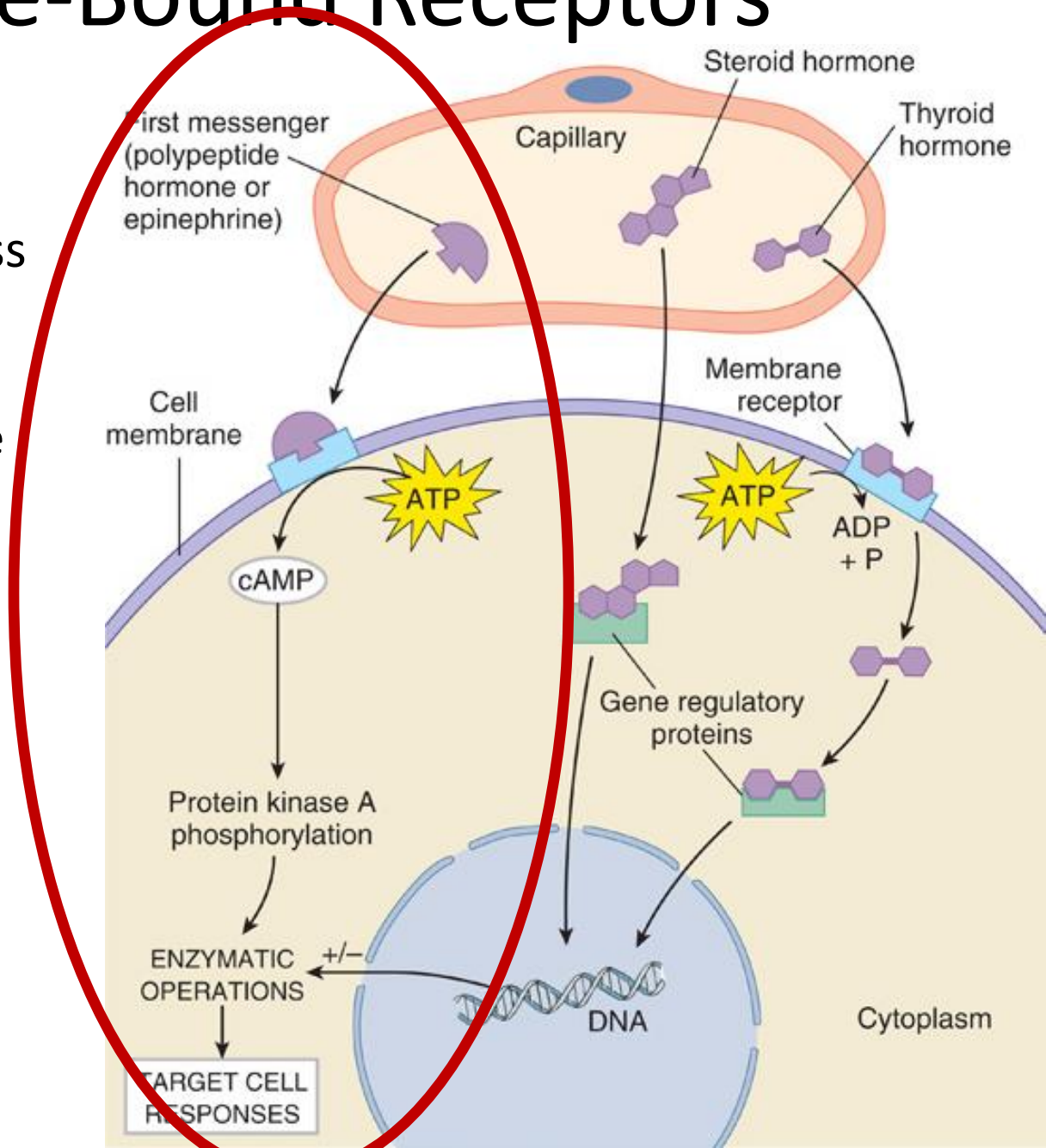
- **Exocrine glands** have ducts for discharging secretions onto a free surface.
  - Sweat glands, salivary glands, enzyme-secreting glands in the digestive tract.

The Chain of Command

- The **hypothalamus** regulates the neuroendocrine system, maintaining homeostasis in the body.
  - The hypothalamus can use motor nerves to send short-lived electrical messages or hormones to send chemical messages with a longer duration.
- The hypothalamus produces different "releasing" hormones that travel to the **pituitary gland**.
- Each releasing hormone stimulates the pituitary to release a corresponding hormone which travels to an endocrine gland and causes it to start producing a particular endocrine hormone.

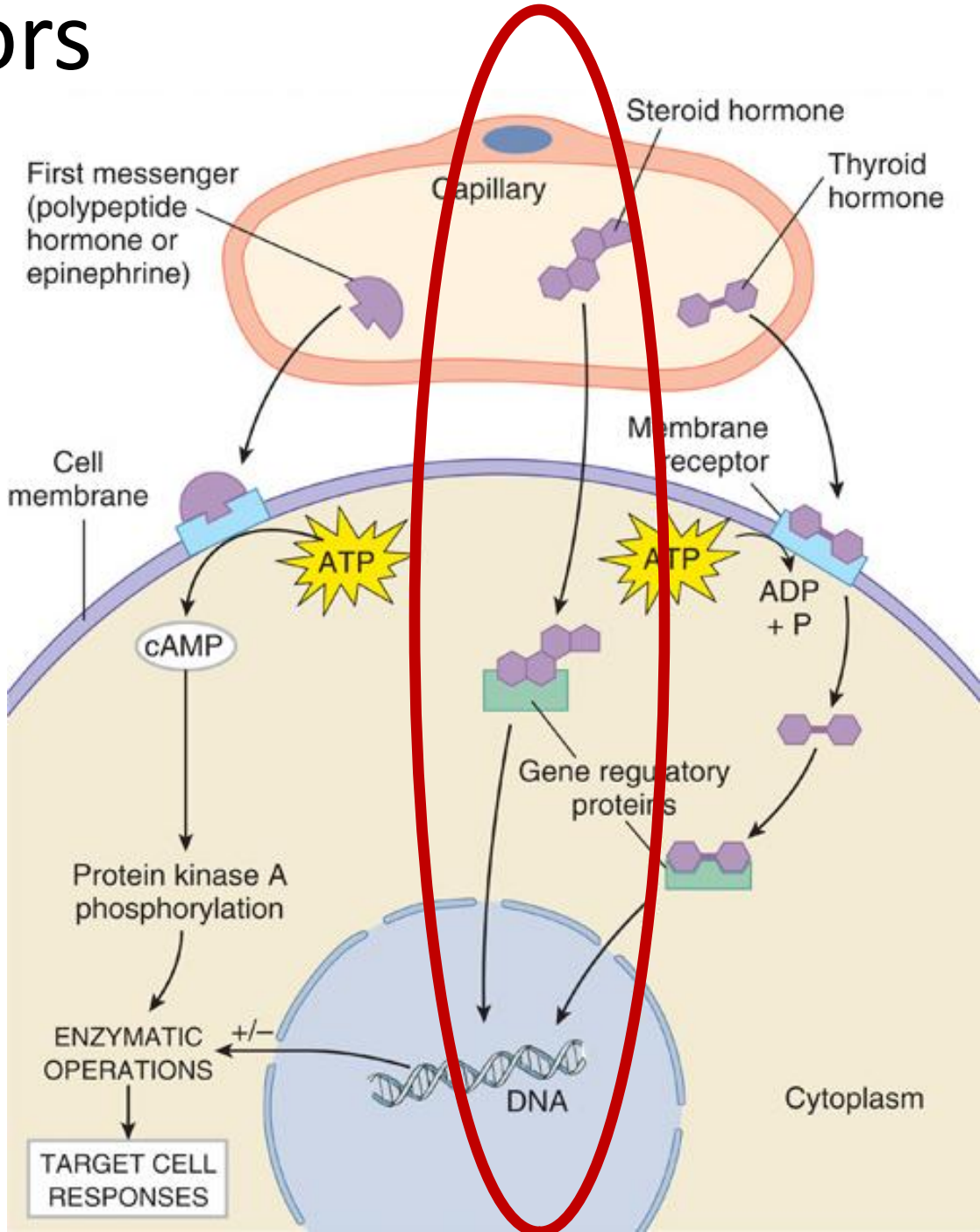
Membrane-Bound Receptors

- Many hormones are too large, or too polar, to pass through plasma membranes.
  - Bind to transmembrane proteins that act as receptor sites on target cell membranes.
    - Hormone is **first messenger**.
    - Causes activation of a **second messenger** in the cytoplasm.
      - cAMP



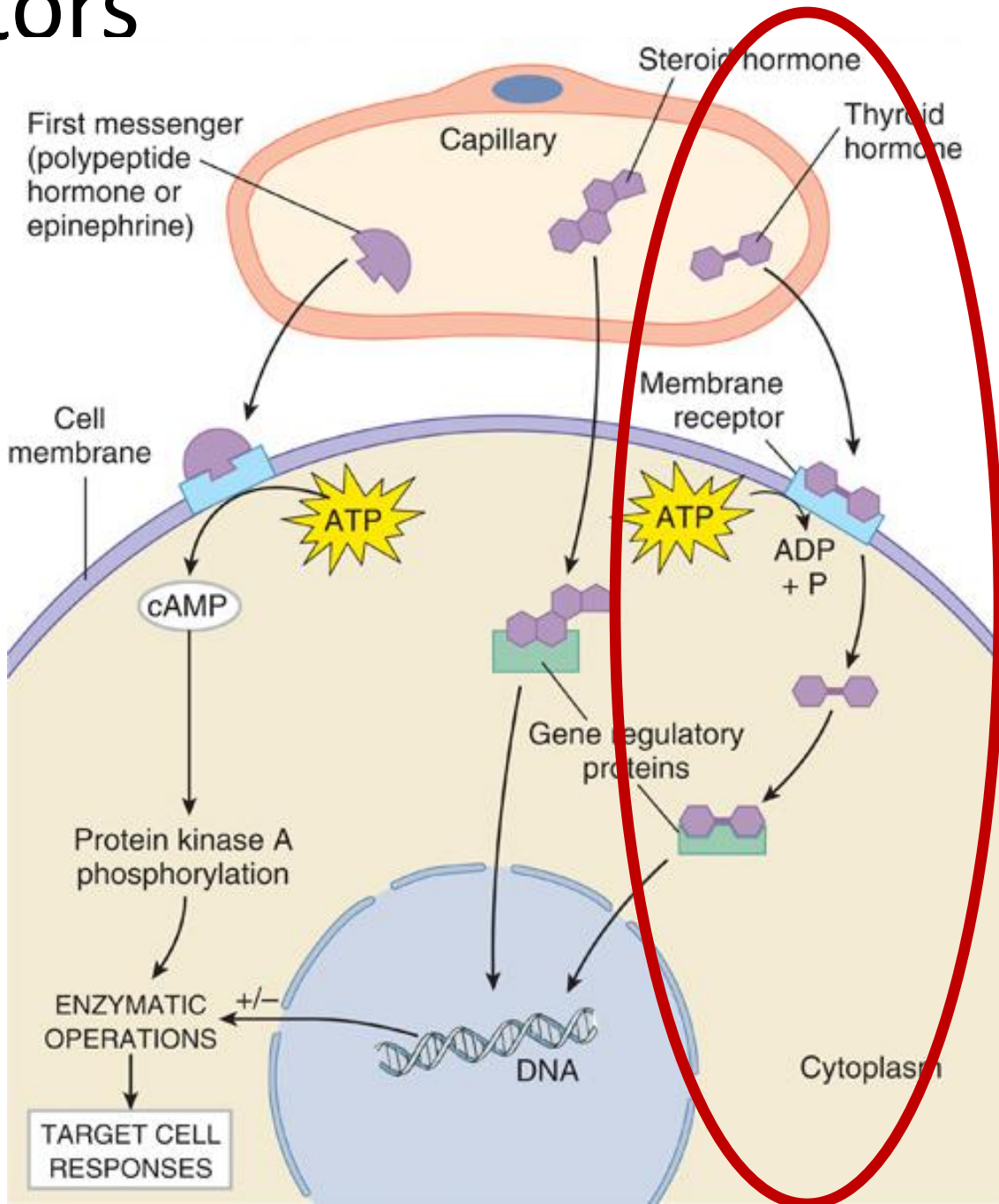
Nuclear Receptors

- **Steroid hormones** are lipid soluble molecules that bind to hormone receptors in the cytoplasm of the target cell.
  - Site of activity is the nucleus.
- Steroids are manufactured from cholesterol.
- Estrogen, progesterone, testosterone, cortisol.



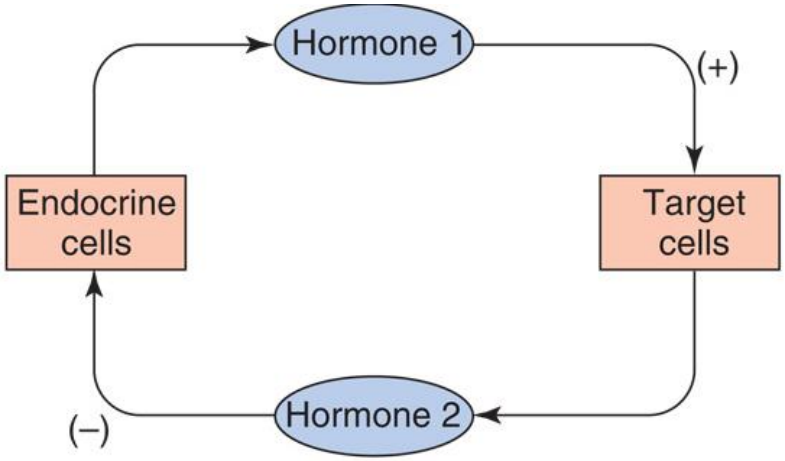
Nuclear Receptors

- Thyroid hormones and insect-molting hormone (ecdysone) also act through nuclear receptors.
  - Binds to transmembrane protein that uses ATP to move it into the cell.

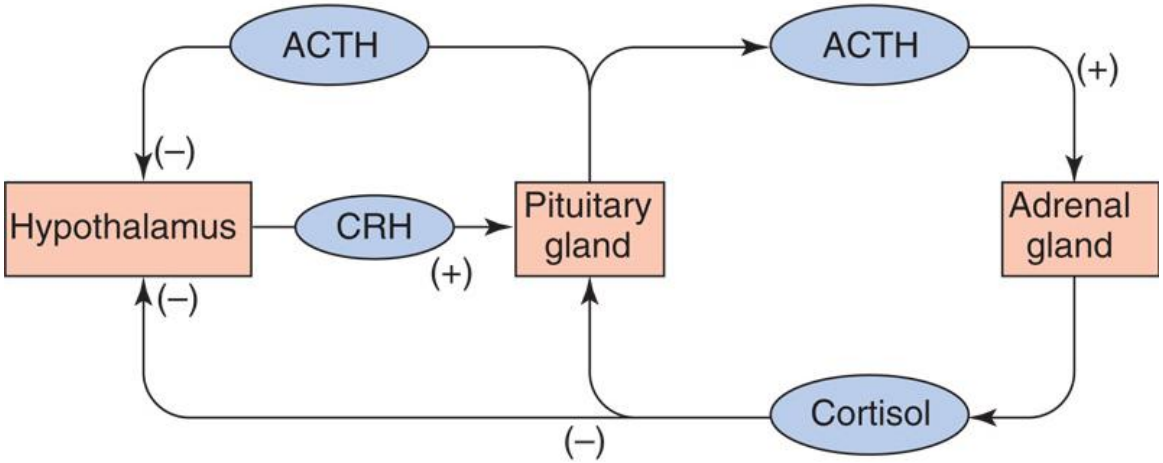


Control Pathways and Feedback Loops

- A common feature of control pathways is a feedback loop connecting the response to the initial stimulus.
- **Negative feedback** regulates many hormonal pathways involved in homeostasis.



General negative feedback system



Specific example of a negative feedback system

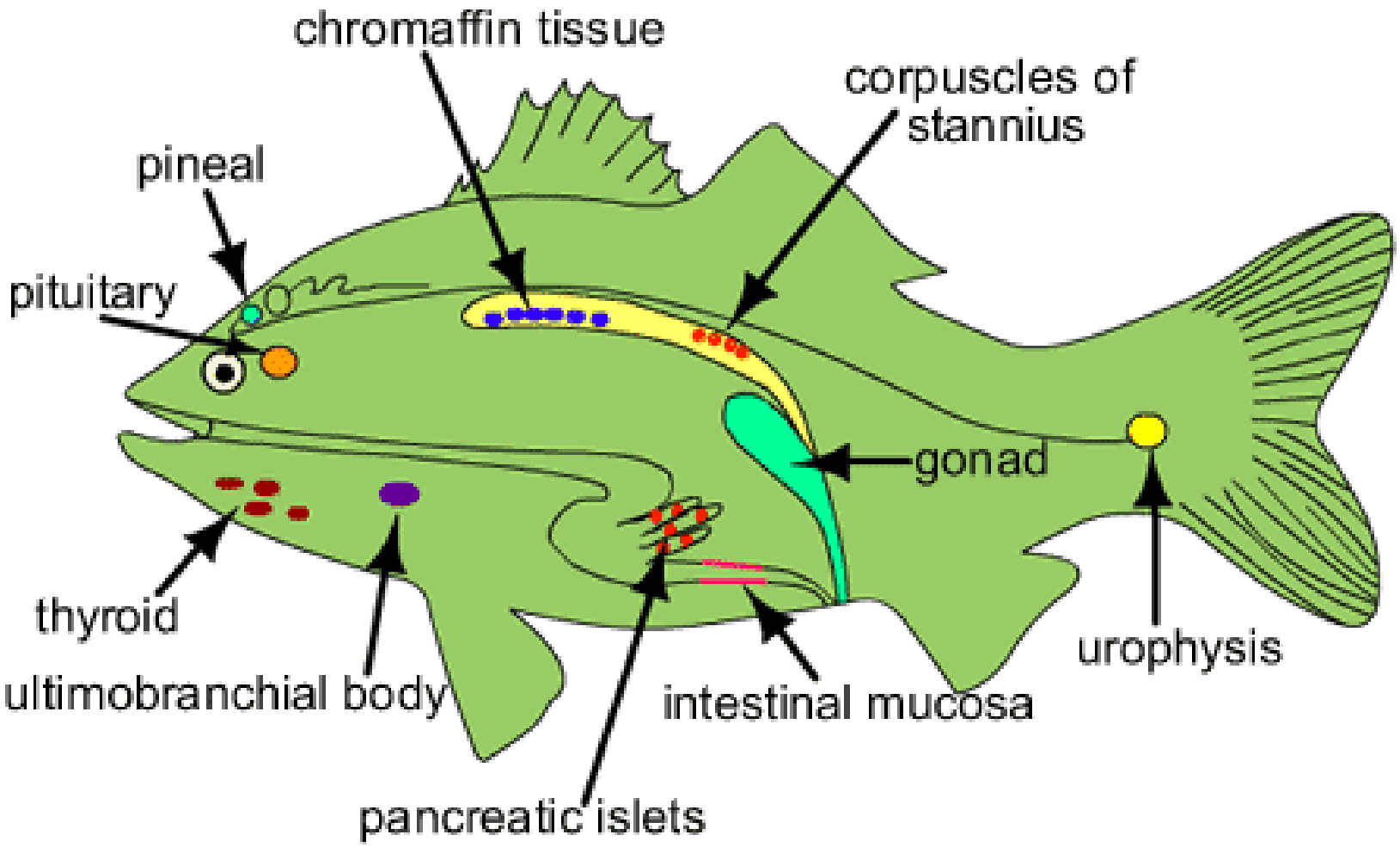
Endocrine glands of fishes

Ductless gland which release their secretory product directly into the blood or lymph.

Different types of endocrine glands regulate sexual activity and reproduction, growth, osmotic pressure, general metabolic activities such as the storage of fat and the utilization of foodstuffs, blood pressure, and certain aspects of skin colour. In fishes following endocrine glands are present:

- **The pituitary gland or Hypophysis**
- **Thyroid Gland**
- **Interrenal bodied and Chromaffin cells**
- **Corpuscles of Stannius**
- **Ultimobranchial Glands**
- **Urohypophysis**
- **Pancreatic islets**
- **Juxtaglomerular Cells**
- **Pineal gland**

Fish Endocrine Glands



On the basis of their organization and functions classified into :

i) **Chief endocrine gland. eg. –Pituitary, thyroid,**

ii) **The organs performing both endocrine and exocrine function. eg.-Kidney, gonads, intestine.**

iii) **Scattered cells with endocrine functions: These are generally present in digestive tract called as paracrine.**

According to the chemical nature hormones are divided into:

i) **Steroid: testosterone, estradiol secreted by sex glands**

ii) **Protein or peptide : secreted by Pituitary, thyroid, interrenal tissue.**

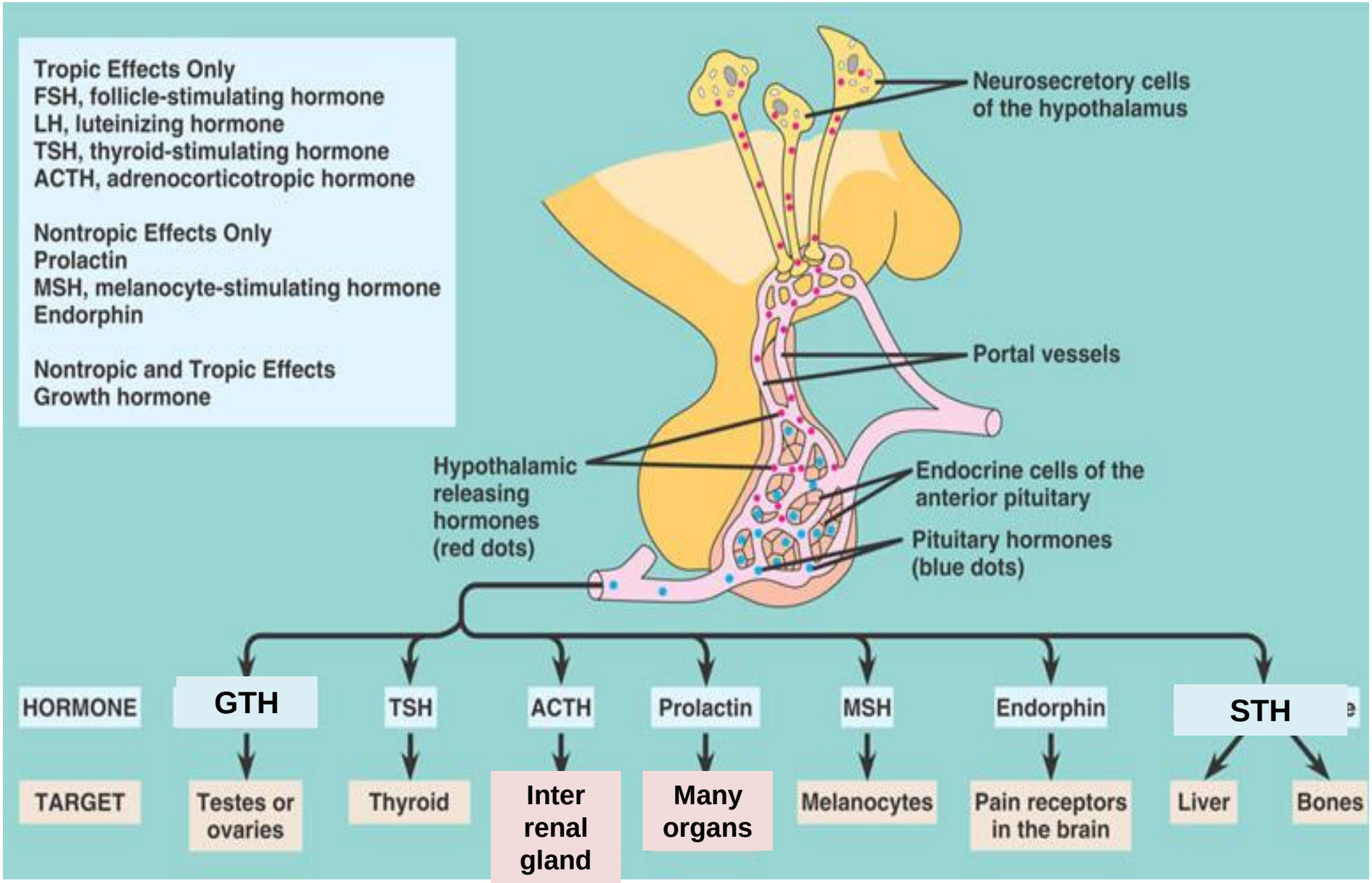
iii) **Amino acids analogues: epinephrine and norepinephrine and collectively called catecholamines.**

The pituitary gland or Hypophysis

- **Location**: Ventral surface of brain below optic chiasma.

- **Origin**: Two parts of pituitary gland are derived from two different components. Neurohypophysis develops from the floor of the embryonic diencephalons. Adenohypophysis developes from the dorsal evagination of the ectodermal part of buccal cavity called Rathke's pouch. This pouch later looses its connection from the buccal cavity and remains permanently connected to neurohypophysis during the rest of the life. The hypophysis in adult fish remains attached with it by a stalk is called infundibular stalk or neurohypophyal stalk and occupies a position on the underside of the brain; in the region of diencephalon.

Part of Pituitary	Division	Cell types	Secretions	Functions
Adenohypophysis	Proximal pars distalis	Thyrotrophs	Thyrotropins e.g TSH	Regulates the growth and secretion from thyroid
		Gonadotrophs	Gonadotropin e.g. FSH (follicular stimulating hormone) and LH (leutinizing hormone)	Regulates secretion of gonadal hormone, spermatogenesis and oogenesis
		Somatotrophs	Somatotropins e.g.GH (Growth hormone)	Increase growth and BMR of the fish body
	Rostral pars distalis	Lactotrophs	Prolactin	Regulation of osmoregulation and melanogenesis
		Corticotrophs	Corticotropin viz. ACTH	Regulates secretion of corticotropins from adrenal gland.
	Pars intermedia		MSH and MCH (melanophore dispersing and melanophore contracting hormone)	Regulates the concentration and dispersion of pigments within melanophores.
Neurohypophysis	Pers-nervosa		Vasopression and oxytocin	Regulates osmoregulation, salt-water balance, mating and egg laying


Tropic Effects Only
FSH, follicle-stimulating hormone
LH, luteinizing hormone
TSH, thyroid-stimulating hormone
ACTH, adrenocorticotropic hormone
Nontropic Effects Only
Prolactin
MSH, melanocyte-stimulating hormone
Endorphin
Nontropic and Tropic Effects
Growth hormone
Neurosecretory cells of the hypothalamus
Portal vessels
Hypothalamic releasing hormones (red dots)
Endocrine cells of the anterior pituitary
Pituitary hormones (blue dots)
HORMONE
GTH
TSH
ACTH
Prolactin
MSH
Endorphin
STH
TARGET
Testes or ovaries
Thyroid
Inter renal gland
Many organs
Melanocytes
Pain receptors in the brain
Liver
Bones

Pituitary (Hypophysis) Hormone

Prolactin: secreted by par distalis (rostral) of pituitary functions predominantly in freshwater regulation.

1. The most general role involves increasing the retention of certain ions by the epithelia of the gills, kidneys and urinary bladder and decreasing the permeability of external surfaces to water.

2. It also increase the glomerular filtration rate in the kidney.

3. It increase the ATPase activity in kidney and urinary bladder but decrease ATPase activity in the gills.

Somatotropin hormone (STH)

- STH also known as growth hormone secreted from pars distalis (caudal) of pituitary.

- In general it stimulates appetite and growth and prevents liver hypertrophy.

Melanocyte stimulating hormones (MSH)

- MSH secreted from pars distalis (caudal) of pituitary and acts directly to disperse (enlarge) melanocytes in fish skin, thereby darkening a fish's coloration. MSH is not the only hormone which influence melanophores, Melatonin from the pineal organ causes melanophores to contract, giving a bleaching effect on fish coloration.

- Fish which adapt to a change of background color in less than 10 minutes do so entirely or mostly by neural mechanisms. Fish which require longer than 10 minutes have primarily hormonal controls.

Adrenocorticotropic hormones (ACTH)

- ACTH secreted by pars distalis (rostral) of pituitary and stimulates production of cortisol and other corticosteroids by the interrenal glands and chromaffin cells.

Thyrotropsin (Thyroid Stimulating Hormone)

- TSH secreted by pars distalis (caudal) of pituitary and stimulates the thyroid gland to produce and/or release thyroxin

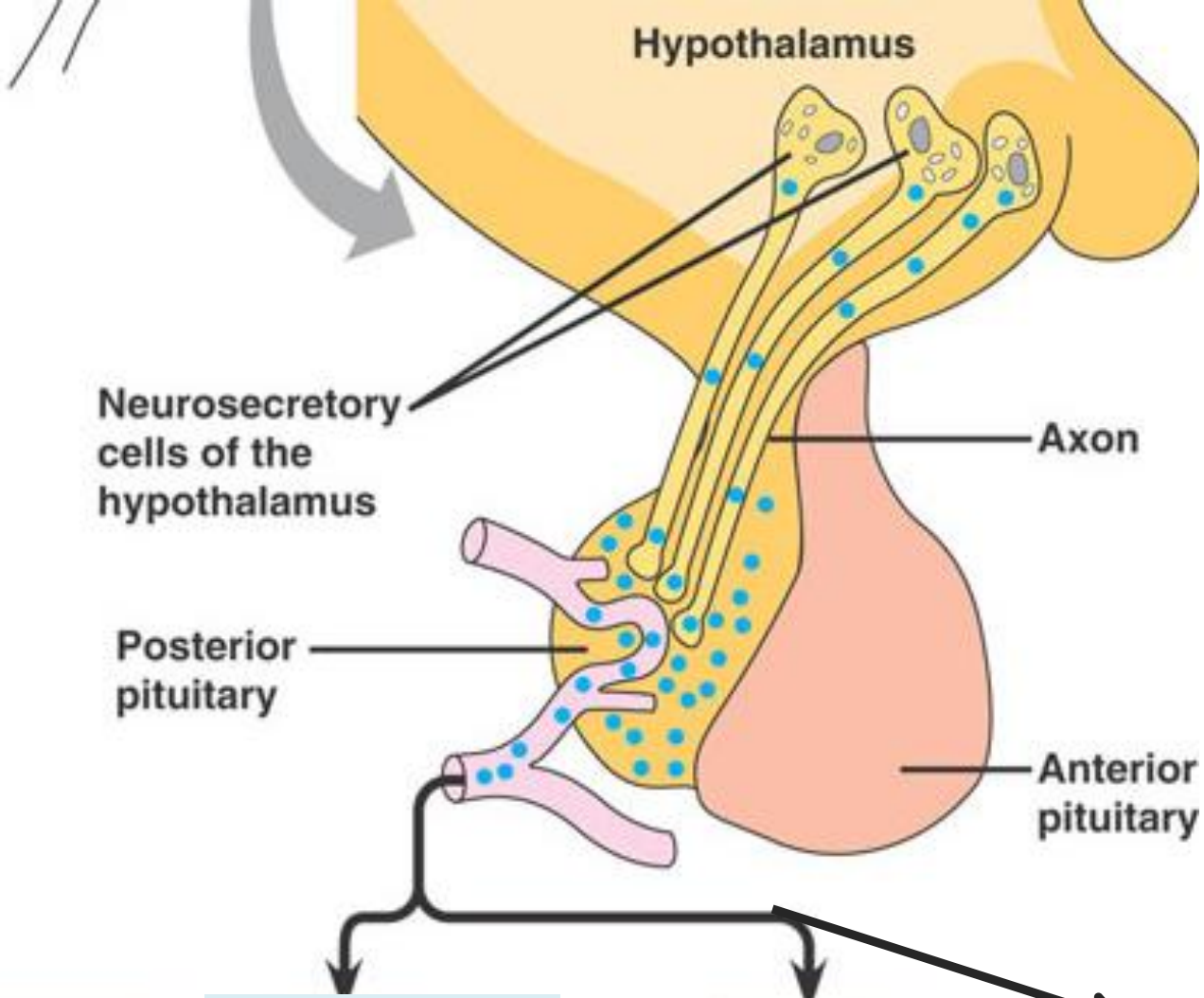
Gonadotropin Hormones (GTH)

Fishes have two gonadotropin hormone namely Gonadotropin Hormone I (GTH I) and Gonadotropin Hormone II (GTH II) which are secreted by pars distalis (caudal) of pituitary.

Release of GTH I and GTH II from pituitary is under the influence of Gonadotropin Releasing Hormone (GnRH) of hypothalamus

These hormones stimulates gonads (ovary and testes) to release the male (testosterone) and female(progesterone and estrogen) sex homones for egg and sperm production.

GTH I stimulates vitellogenesis and GTH II oocytes maturation, egg release and spawning



HORMONE	Arginine Vasotocin	Oxytocin	Isotocin
TARGET	Osmoregulation and contraction of smooth muscle	Osmoregulation, contraction of smooth muscle	Ovary and ovarian muscle contraction

Neurohypophysis (Hypothalmus) Hormones

- Hypothalamus or Neurohypophysis produce two hormones in fish- **oxytocin** and **arginine vasotocin** (AVT).
- **Oxytocin**: influences osmoregulation by producing vasoconstriction in gill blood vessels.
- **AVT** in contracting arteriolar smooth muscle to maintain or increase blood pressure could also influence osmoregulation by increasing the amount of glomerular filtration.
- AVT is not the agent causing ovarian and oviduct smooth muscle contractions in livebearing fish but the other hormone **isotocin** is responsible for that.

Thyroid gland

Origin: The thyroid gland in fishes arises from the floor of the pharynx as a median evagination**.**
Location: The location of thyroid gland varies considerably in different fish species; such as-

In cyclostomes, follicles of thyroid are dispersed around the ventral aorta and do not form compact capsulated structure.
In bony fishes, it may lie under the 1st branchial arch on each side.
In many teleosts, it is found along the afferent branchial arteries of the gills.
In other teleosts, the follicles of thyroid migrate to distant unusual localities, such as the liver, kidney, brain, eye, gut, spleen, gonad etc. as in platyfish.

Shape: The shape of the gland is also variable depending on various fish group; such as -
In cyclostomes, the thyroid is in the form of follicles.
In many teleosts, thyroid becomes a diffused structure as small masses of follicles.
In elasmobranches and bony fishes, thyroid is compact structure.
In dipnoi, thyroid comprises a pair of interconnected lobes.

Histology: The thyroid gland is composed of a large number of follicles forming a shape of a hollow ball and consisting of a single layer of epithelial cells that encloses a fluid filled space. These follicles are bound together by connective tissue. The gland is highly vascular and the epithelium surrounding the follicle may be thick or thin and the height of the cells depends upon its secretory activity. The epithelium mainly composed of two types of cells- the chief cells are cuboidal or columnar in shape with clear cytoplasm and colloid cells, contain droplets of secretory material.

Secretion: **Thyroid hormone is secreted by the thyroid gland and synthesized after extracting inorganic iodine from the blood and combining it with tyrosine.**

i) **Monoiodotyrosine (MIT)**
ii) **Di-iodotyrosine (DIT)**
iii) **Thyroxin (T_3 and T_4)**

Functions of Thyroid Hormones

i) **It plays a important role in oxygen consumption.**

ii) **Influence the growth** and nitrogen metabolism **of fish.**

iii) **Involved in carbohydrate metabolism.**

iv) **Influenced in osmoregulation.**

v) **Influence maturtion, reproduction and migration.**

vi) **In brown and rainbow trout T_3 is essential for adaptation to sea water.**

vii) **Scale and bone formation in fishes is also influenced by thyroxine.**

Interrenal bodies and Chromaffin Cells

Adrenal System: Adrenal system in fishes is quite different from that of mammals. The two components of adrenal system i.e. interrenal bodies and chromaffin cells.

Location: These are embedded in the tissue of the head kidney.

Origin: Mesodermal layer of embryo

Secretion: Corticosteroid (Cortisol, Cortisone, Corticosterone) from interrenal cells under the influence of ACTH from pituitary
Catecholamines (Epinephrine and Norepinephrine) from chromaffin cells under the influence of ACTH from pituitary. Catecholamines secret during the stress and also known as Stress hormone

Function:
Promote utilization of steroid fat
Carbohydrate metabolism
Water metabolism
Protein catabolism
Sodium retention
Electrolyte metabolism

The Corpuscles of Stannius

Location: Attached to or embedded in kidneys of holosteans and teleosts

Origin: the corpuscles of stannius orginate as outgrowths from the pronephric or the mesonephric duct of the kidney.

Nature: Proteinous

Secretion: Hypocalcin

Colour: Pink or white

Function: Regulates calcium balance

The Ultimobranchial Glands

It is also known as post-branchial bodies or suprapericardial bodies or ultimobranchial bodies.

Location: Sac-like structures between ventral wall of esophagus and sinus venosus.

Origin: Ultimobranchial gland develops embryologically from the epithelium of the last or ultimate gill pouch.

Secretion: Calcitonin

Function: Regulates calcium level in blood.

Urohypophysis

It is also known as Urophysis or caudal Neusecretory organ.

Location: This gland is in the form of a swelling at the posterior end of the caudal spinal cord i.e. in the tail of the teleosts.

Secretion: Urotensins I-IV

Function:
Metabolic regulations.
Increase salt retention in kidney and gills
Increase GFR

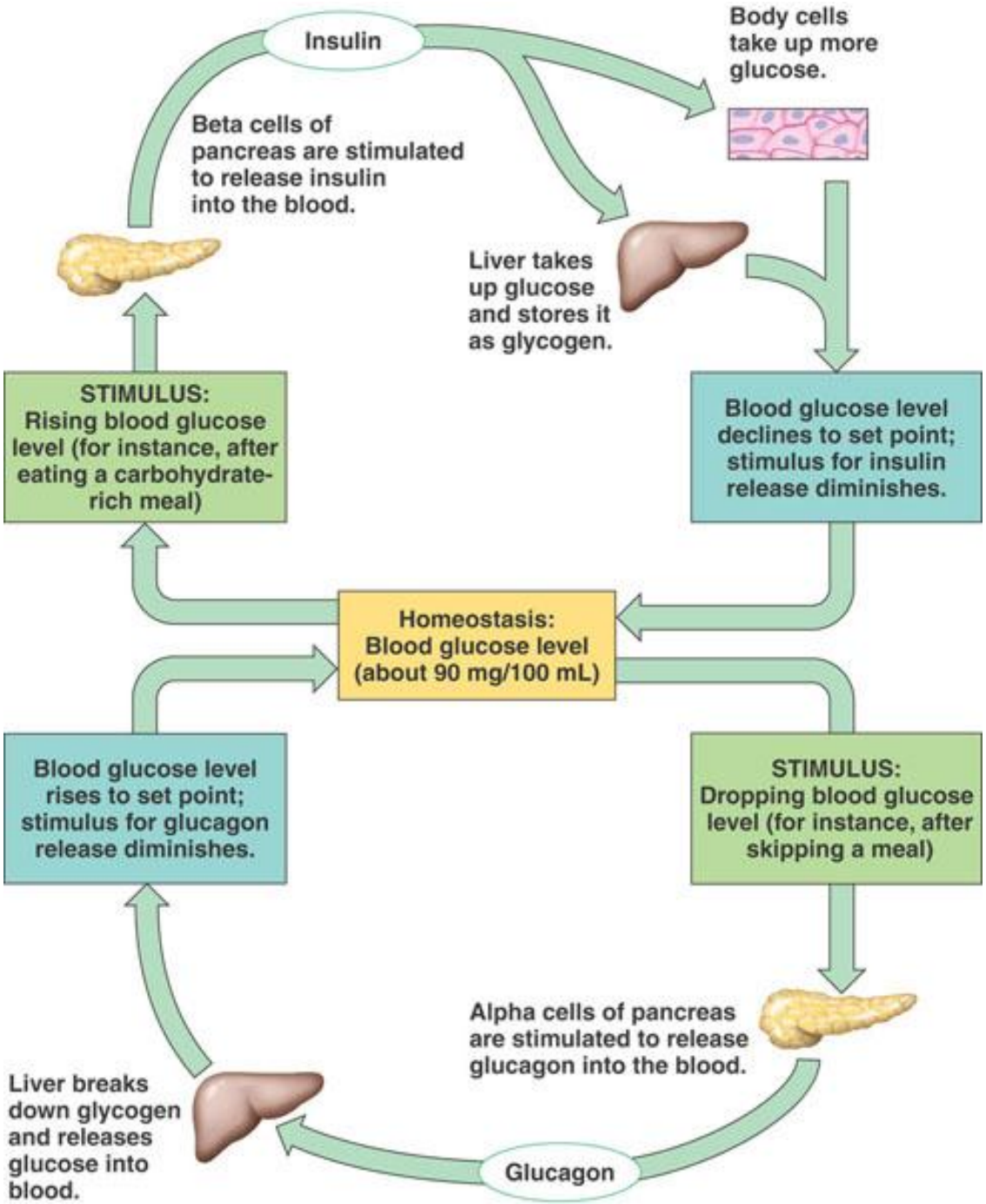
Pancreatic islets

Location: Gut walls in larval Lampreys; hepatopancreas in most bony fishes. Most of the fishes are semi-diabetics in nature because of their poor regulation of blood glucose.

Embryonic Origin: Mesoderm

Secretion: Insulin

Function: Carbohydrate metabolism



Glucose Homeostasis

The **islets of Langerhans** in the pancreas secrete insulin and glucagon.

- **Insulin** removes glucose from the blood.
- **Glucagon** returns glucose to the blood.

Pineal gland

Location/Origin:The Pineal organ of the fish arises as a postero-mid dorsal evagination of the epithalamus.

Secretion: Melatonin

Function: Photosensory and secretory function

Juxtaglomerular Cells (RAS System)

Location: Beside the glomerulus in the kidney

Juxtaglomrerular cells contain renin granules. Renin convert angiotensin I into angiotensin II.

Angiotensin II raise blood pressure and increase kidney function