Animal & Plant Regulation

Hormones

Animal Regulation

Hormones

Preface

- Animal **hormones** are chemical signals that are secreted into the circulatory system and communicate regulatory messages within the body

- Hormones reach all parts of the body, but only target cells have receptors for that hormone

Insect metamorphosis is regulated by hormones

Preface

- Two systems coordinate communication throughout the body: the endocrine system and the nervous system

- The **endocrine system** secretes hormones that coordinate slower but longer-acting responses including reproduction, development, energy metabolism, growth, and behavior

- The **nervous system** conveys short-lived and high-speed electrical signals along specialized cells called neurons; these signals regulate other cells

HORMONES BIND TO TARGET RECEPTORS & TRIGGER SPECIFIC RESPONSES

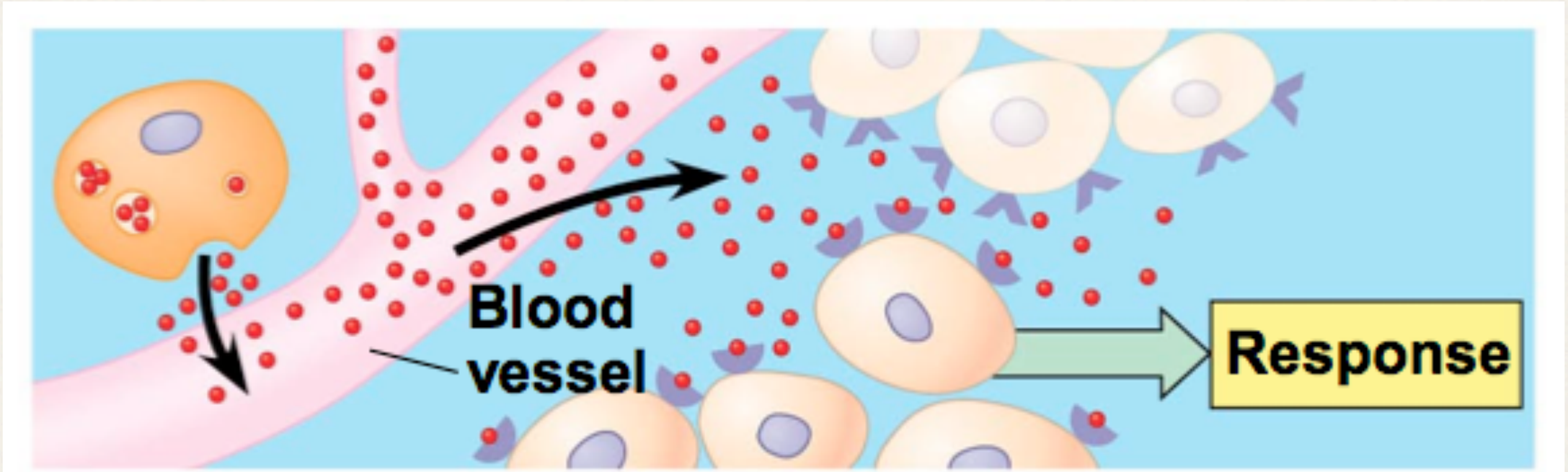
- I. MAIN IDEA: Hormones and other signaling molecules bind to target receptors, triggering specific response

Intercellular Communication:

- The ways that signals are transmitted between animal cells are classified by two criteria
  - The type of secreting cell
  - The route taken by the signal in reaching its target
- Hormones secreted into extracellular fluids by endocrine cells reach their targets via the bloodstream
- Endocrine signaling maintains homeostasis, mediates responses to stimuli, regulates growth and development

Intercellular Communication: Endocrine Signaling

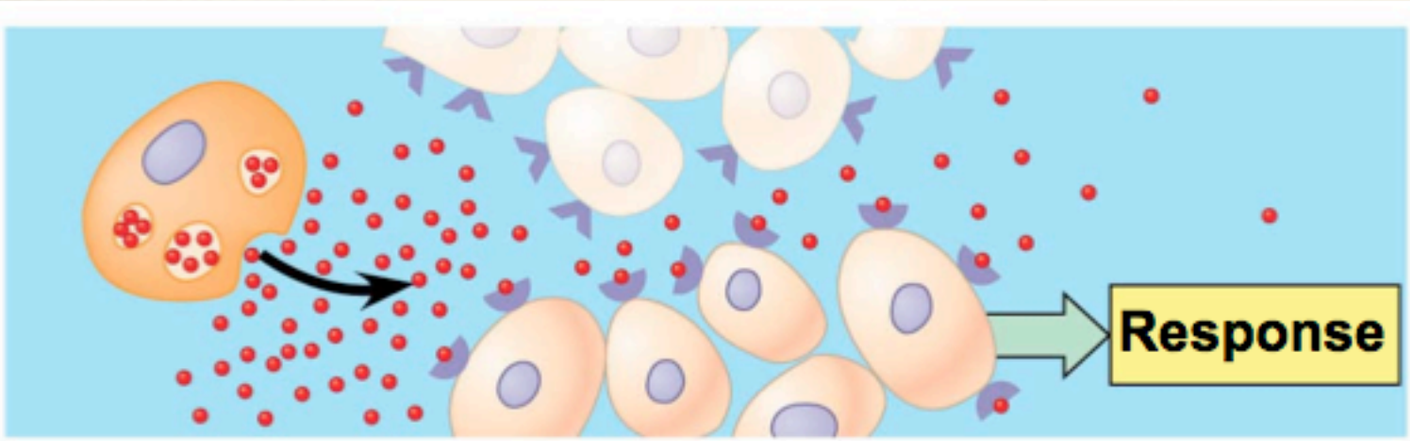
- In **endocrine signaling**, secreted molecules diffuse into the blood stream and trigger responses in target cells anywhere in the body.



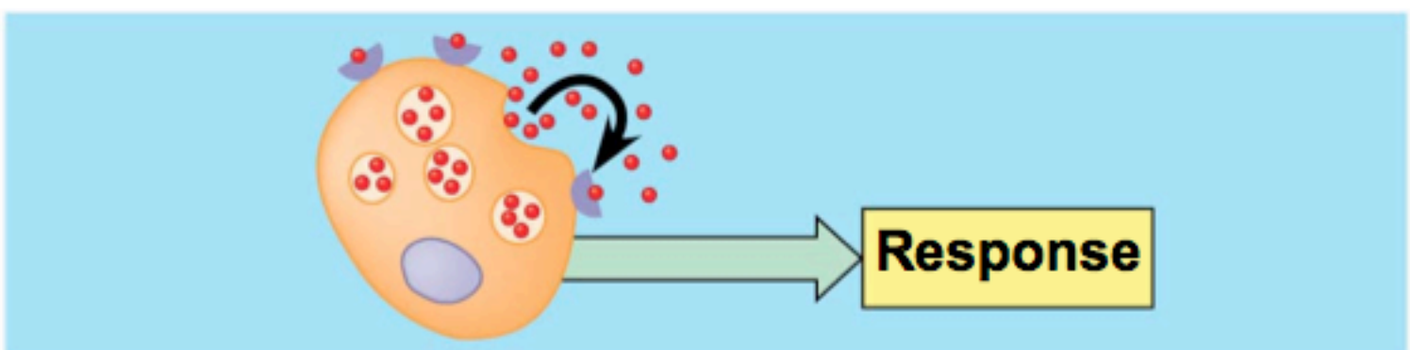
(a) Endocrine signaling

Intercellular Communication: Paracrine & Autocrine Signaling

- **Local regulators** are molecules that act over short distances, reaching target cells solely by diffusion



(b) Paracrine signaling



(c) Autocrine signaling

- In **paracrine signaling**, secreted molecules diffuse locally and trigger a response in nearby cells.

- In **autocrine signaling**, secreted molecules diffuse locally and trigger a response in the cells that secrete them.

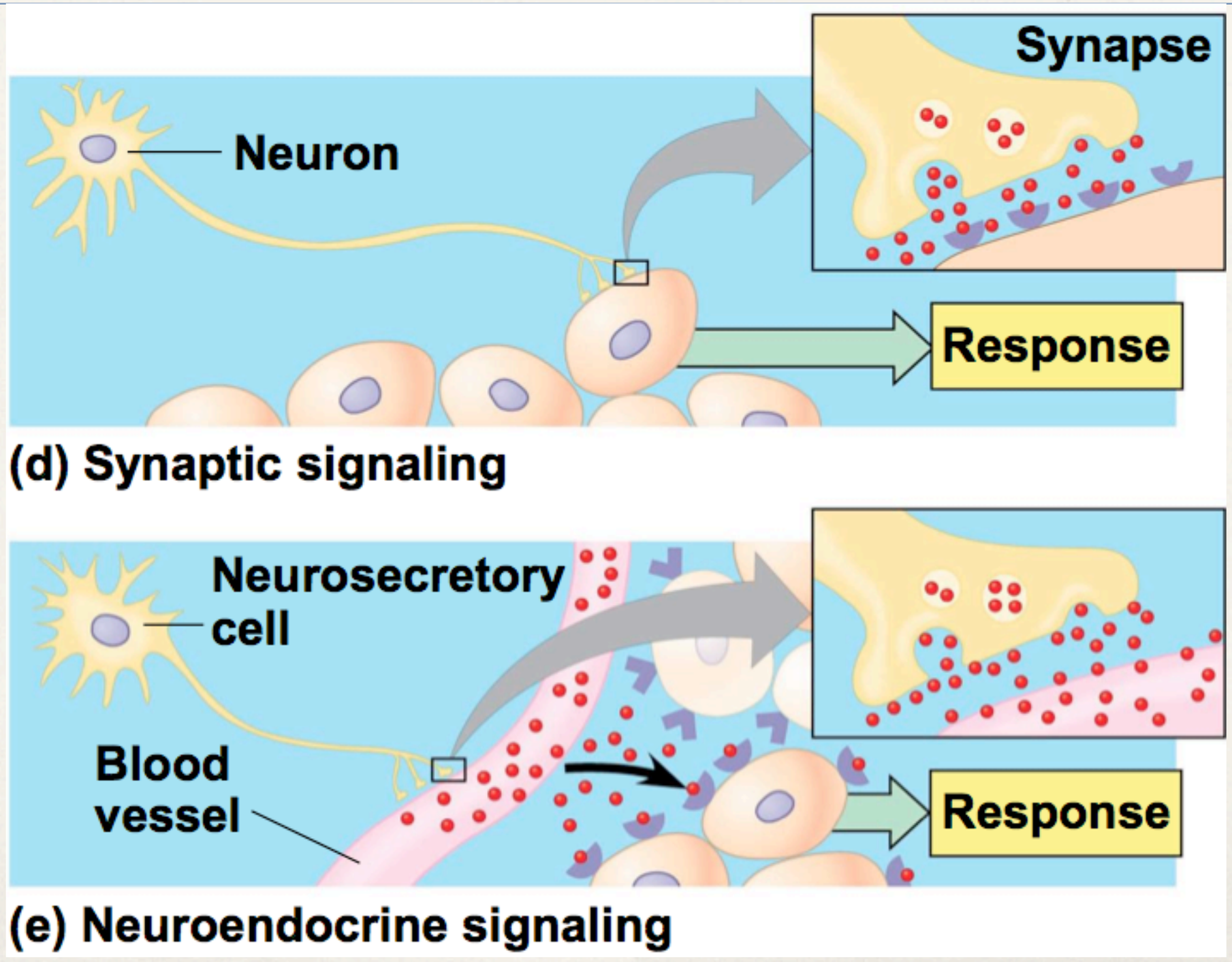
Intercellular Communication: Synaptic Signaling

- In synaptic signaling,neurons form specialized junctions with target cells, called synapses

- At synapses, neurons secrete molecules called **neurotransmitters** that diffuse short distances and bind to receptors on target cells

- In neuroendocrine signaling, specialized neurosecretory cells secrete molecules called **neurohormones** that travel to target cells via the bloodstream

Intercellular Communication: Synaptic Signaling



Signaling by Pheromones

- Members of the same animal species sometimes communicate with **pheromones**, chemicals that are released into the environment

- Pheromones serve many functions, including marking trails leading to food, a wide range of functions that include defining territories, warning of predators, and attracting potential mates

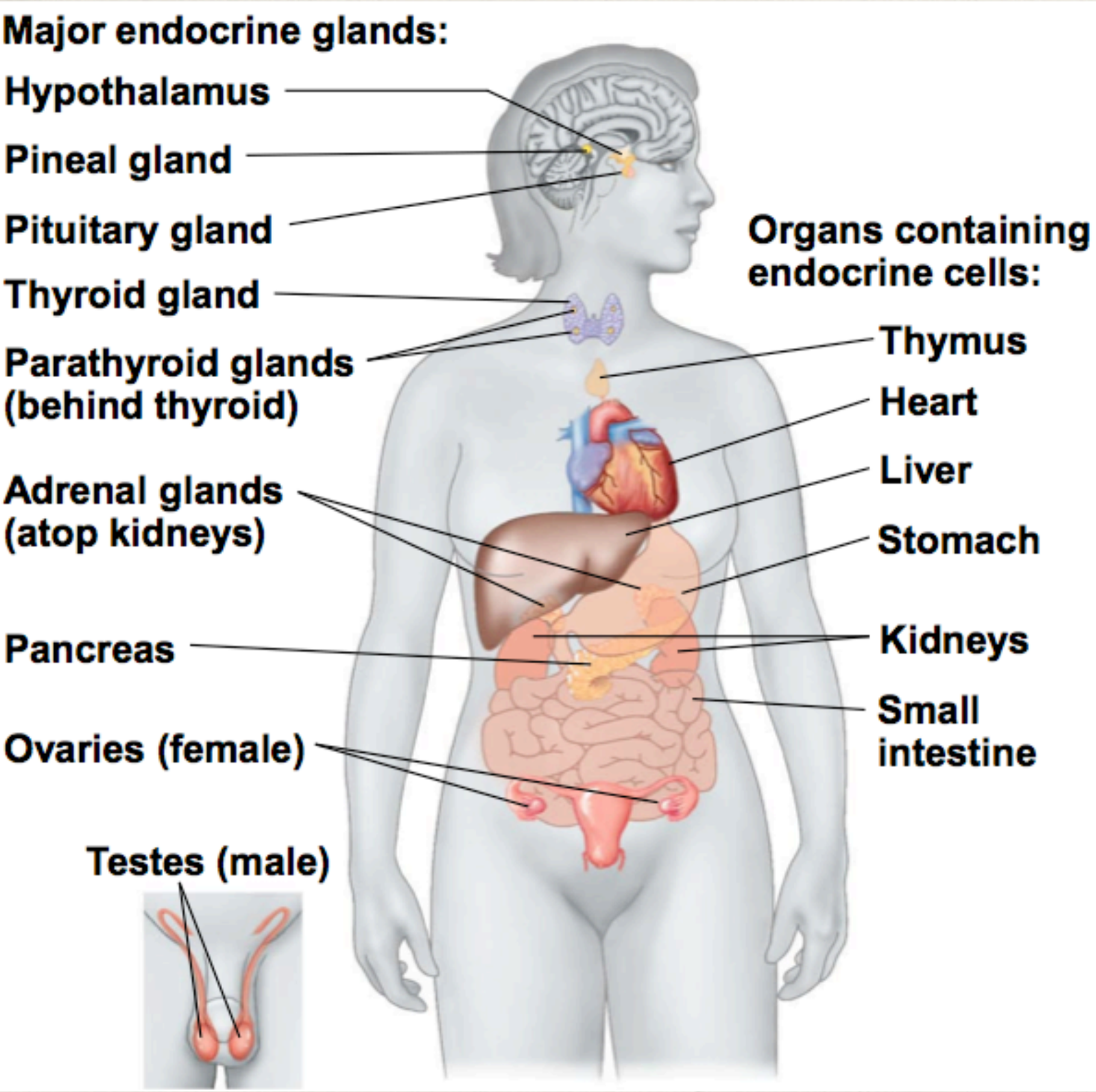
Endocrine Tissues & Organs

- In some tissues, endocrine cells are grouped together in ductless organs called **endocrine glands**

- Endocrine glands secrete hormones directly into surrounding fluid

- These contrast with exocrine glands,which have ducts and which secrete substances onto body surfaces or into cavities

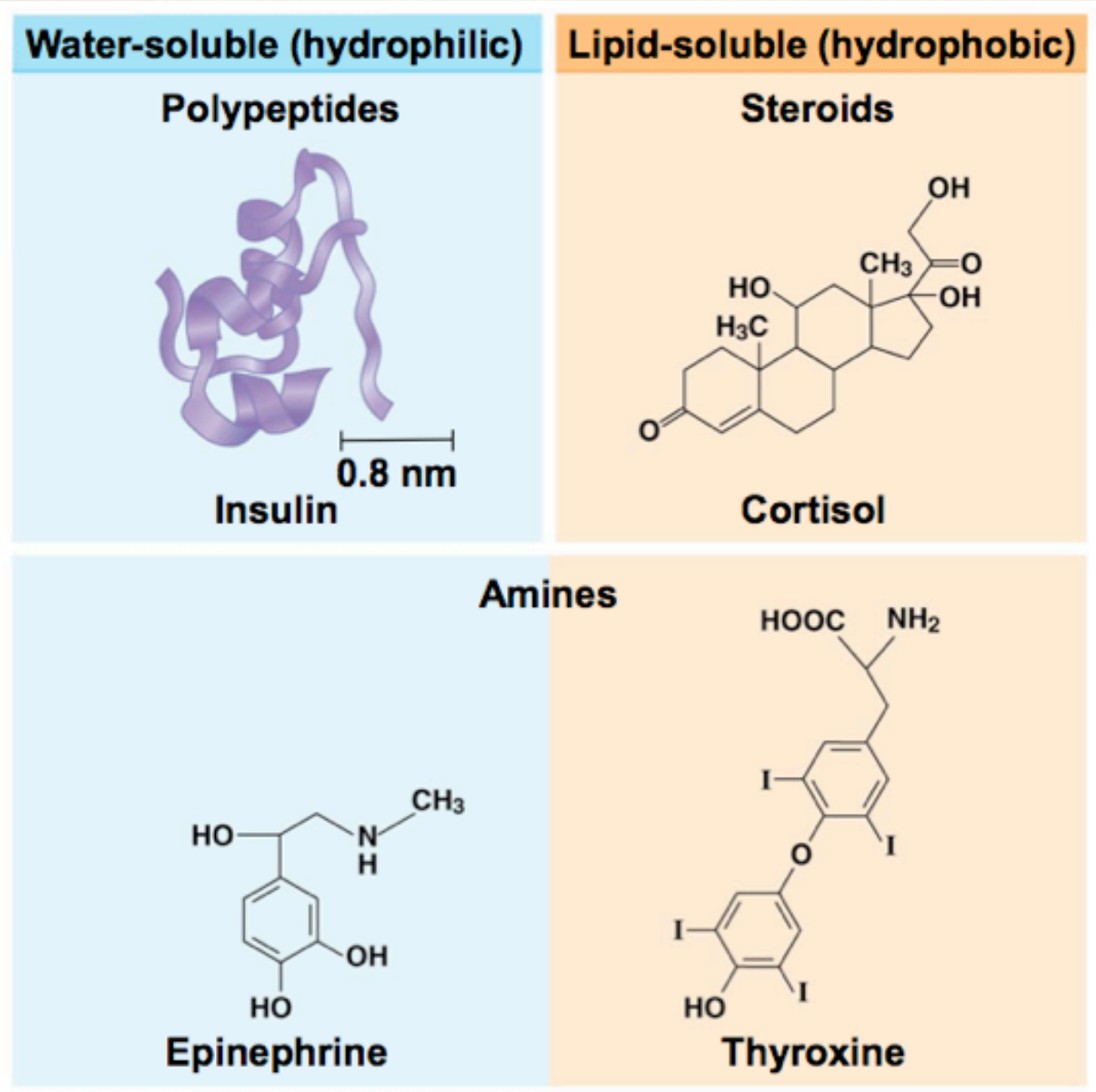
Endocrine Tissues & Organs



Chemical Classes of Hormones

- Three major classes of molecules function as hormones in vertebrates
  - *Polypeptides (proteins and peptides),*
  - *Amines derived from amino acids,*
  - *Steroid hormones*

- **Lipid-soluble hormones(steroid hormones) pass easily through cell membranes, while water- soluble hormones (polypeptides and amines) do not**



- The solubility of a hormone correlates with the location of receptors inside or on the surface of target cells

Cellular Response Pathways

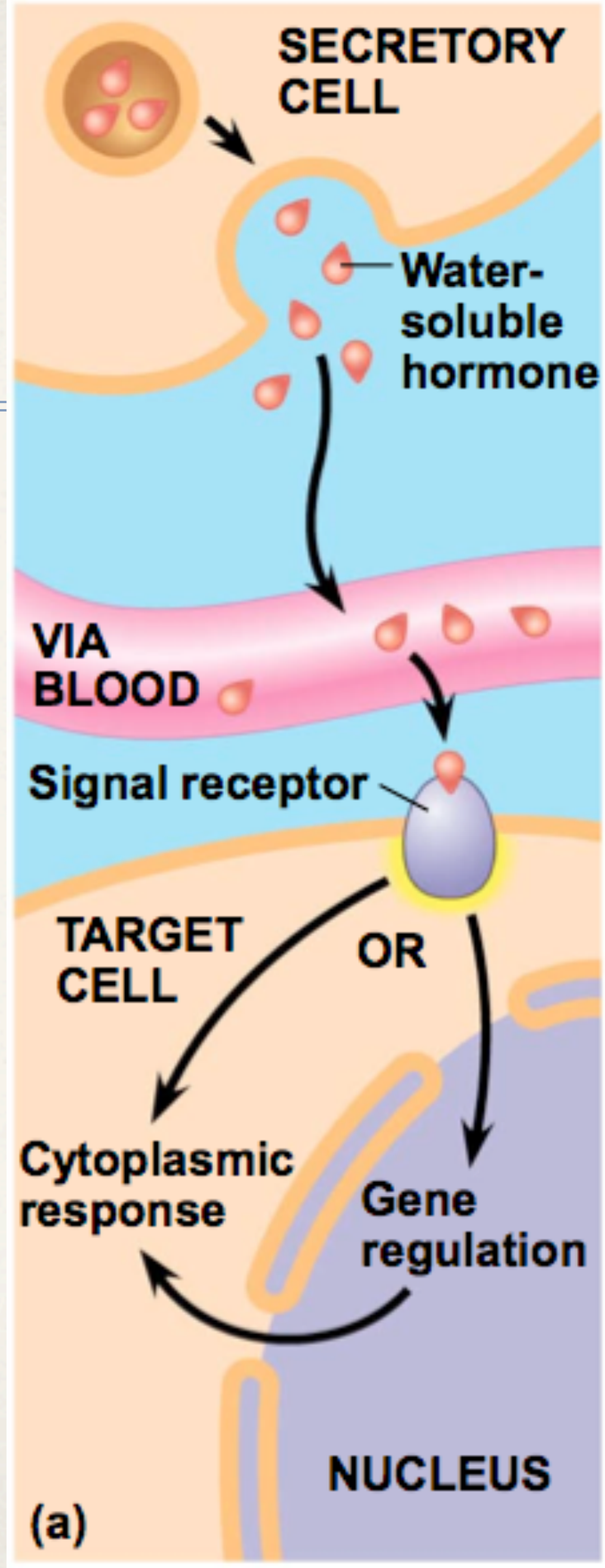
- Water and lipid soluble hormones differ in their paths through a body

  - Water-soluble hormones are secreted by exocytosis, travel freely in the bloodstream, and bind to cell-surface receptors

  - Lipid-soluble hormones diffuse across cell membranes, travel in the bloodstream bound to transport proteins, and diffuse through the membrane of target cells

Pathway for Water-Soluble Hormones

- Binding of a hormone to its receptor initiates a **signal transduction** pathway leading to responses in the cytoplasm, enzyme activation, or a change in gene expression



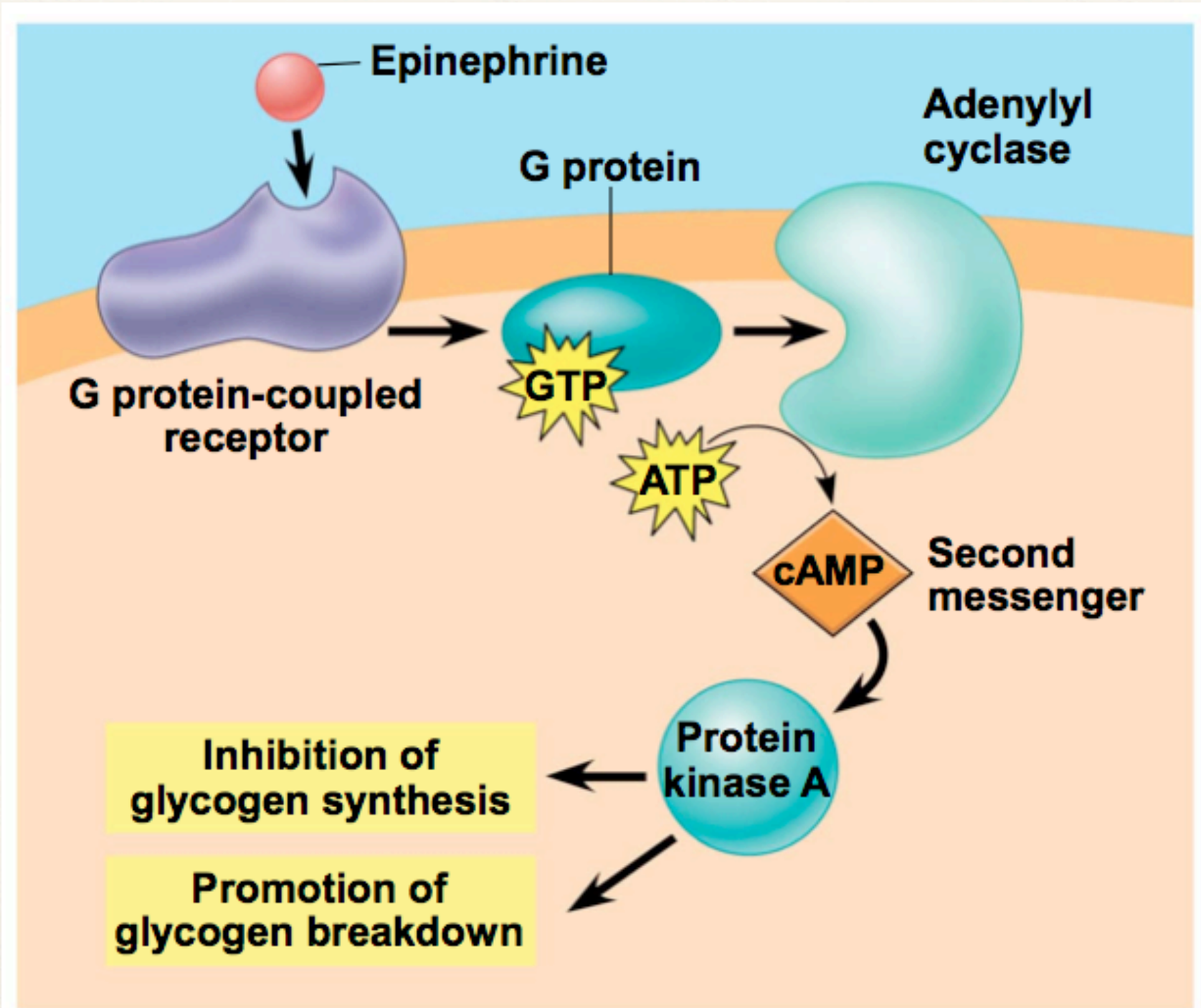
Water-Soluble Hormone Example

- The hormone **epinephrine** has multiple effects in mediating the body's response to short-term stress

- Epinephrine binds to receptors on the plasma membrane of liver cells

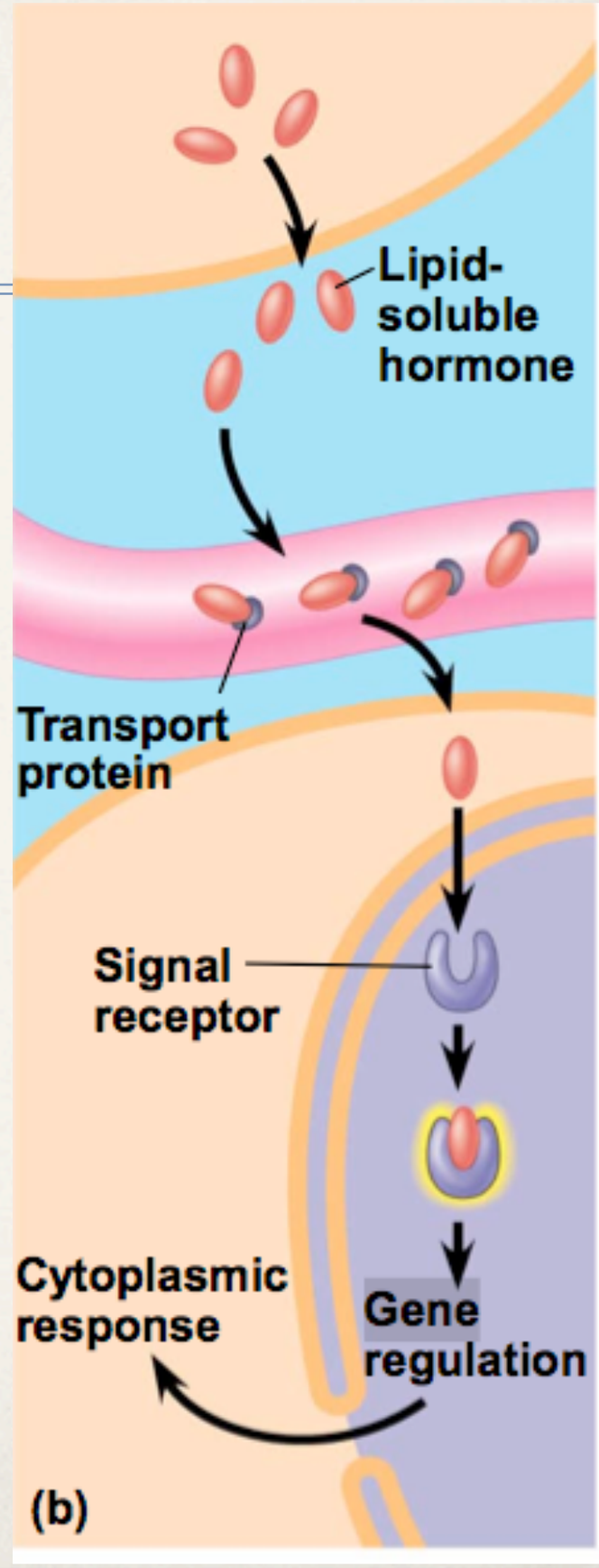
- This triggers the release of messenger molecules that activate enzymes and result in the release of glucose into the bloodstream

Epinephrine



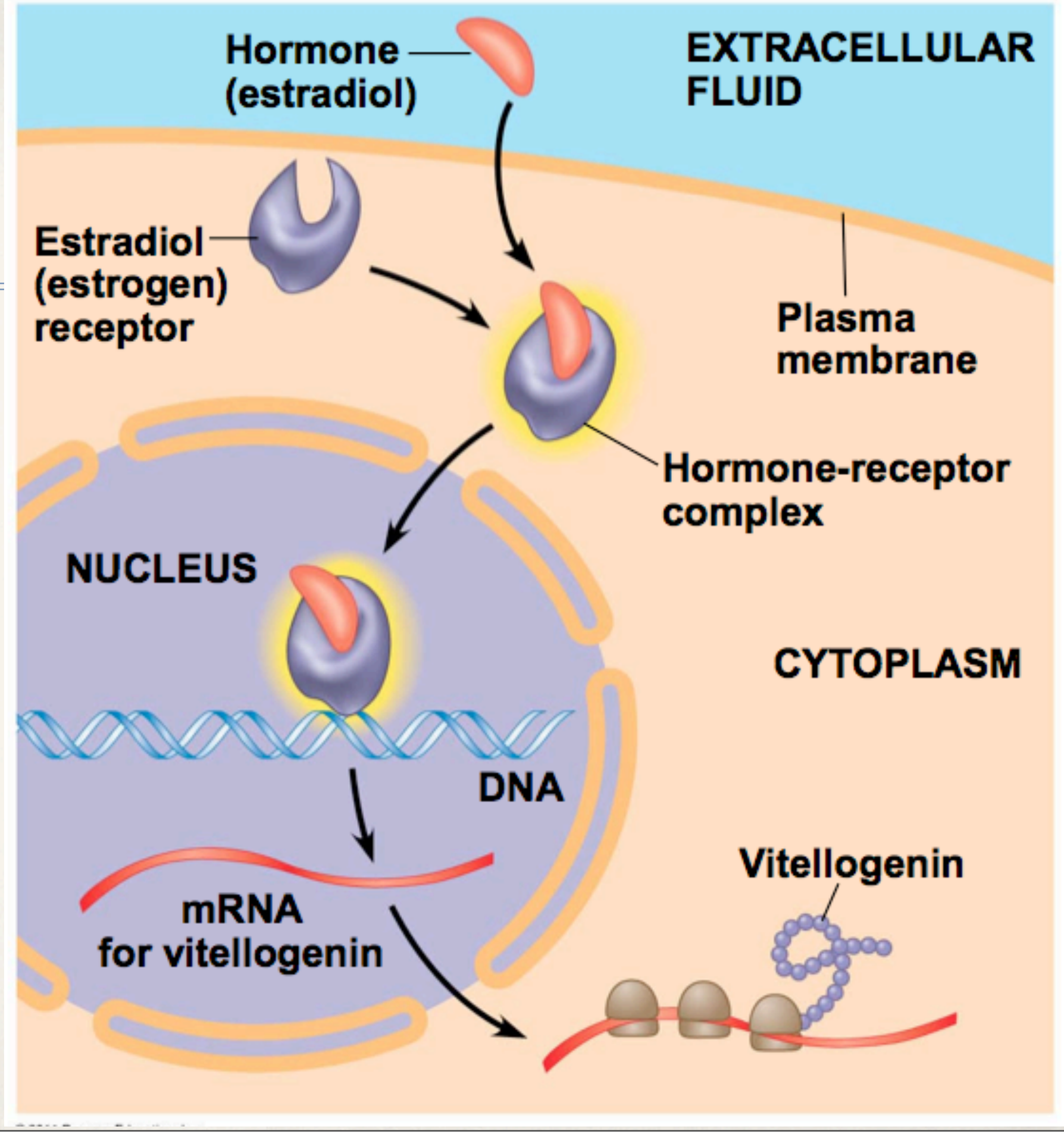
Pathway for Lipid-Soluble Hormones

- The response to a lipid-soluble hormone is usually a change in gene expression
- Steroids, thyroid hormones,and the hormonal form of vitamin D enter target cells and bind to protein receptors in the cytoplasm or nucleus
- Protein-receptor complexes then act as transcription factors in the nucleus, regulating transcription of specific genes

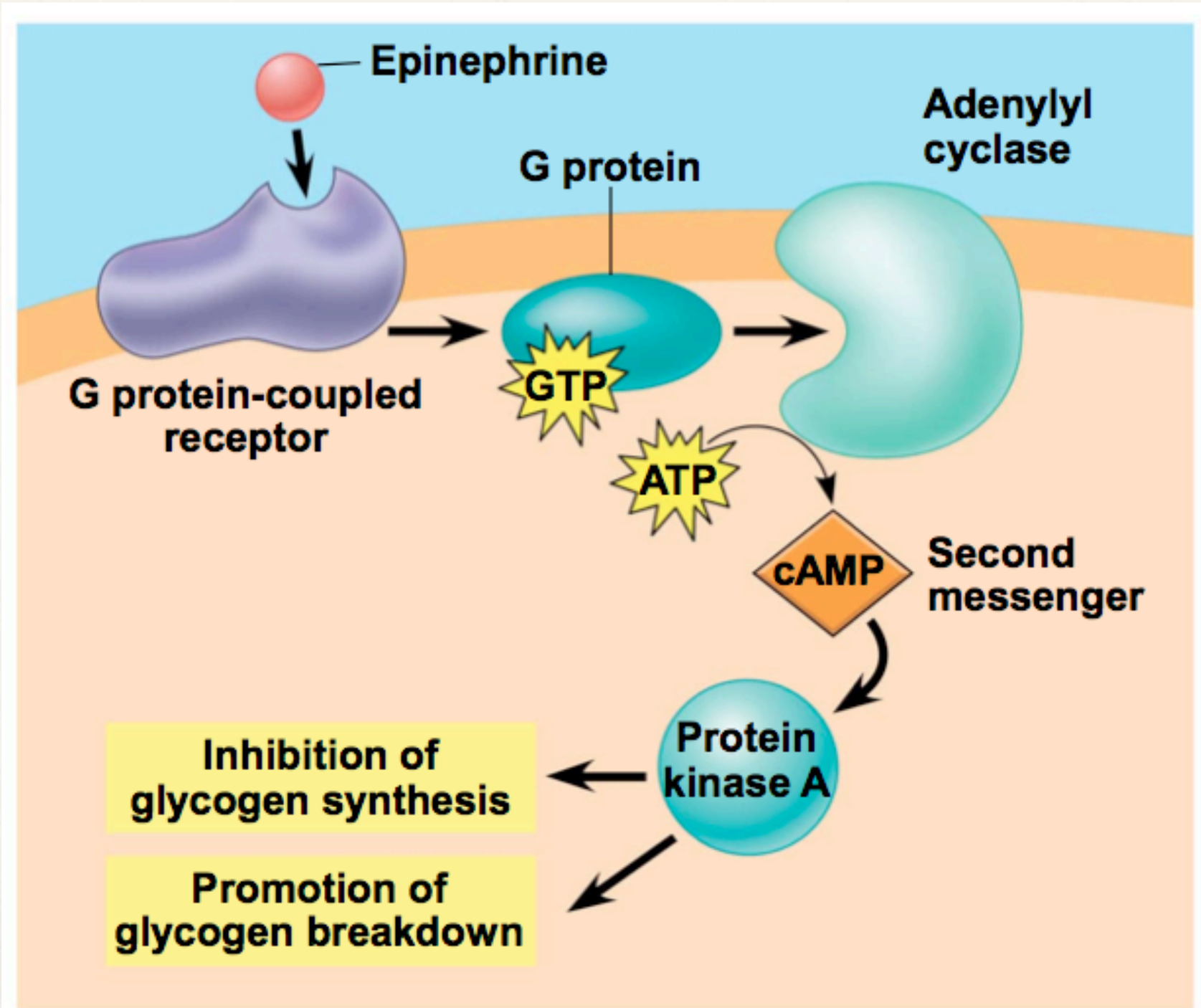


Lipid-Soluble Hormone

Example



Epinephrine



Multiple Effects of Hormones

- The same hormone may have different effects on target cells that have
  - Different receptors for the hormone
  - Different signal transduction pathways
    - Take for example epinephrine

Same receptors but different intracellular proteins (not shown)

Different receptors

Different cellular responses

Different cellular responses

Epinephrine

β receptor

Glycogen deposits

Glycogen breaks down and glucose is released from cell.

(a) Liver cell

Epinephrine

β receptor

Vessel dilates.

(b) Skeletal muscle blood vessel

Epinephrine

α receptor

Vessel constricts.

(c) Intestinal blood vessel

Signaling by Local Regulators

- Local regulators are secreted molecules that link neighboring cells or directly regulate the secreting cell
  - Local regulators are essentially hormones that do not travel via the bloodstream

- Types of local regulators
- – **Cytokines** and **growth factors**
- – **Nitric oxide (NO)**
- – **Prostaglandins**

...nitric oxide

- neurotransmitter and local regulator

- Blood O_2 falls -----> cells in blood vessel's walls release NO ------> NO binds to smooth muscle cells -----> binding activates an enzyme -----> enzyme relaxes smooth muscle -----> smooth muscle dilates -----> vasodilatation increases blood flow to to tissues

...prostaglandins

- local regulator, with many roles

- Copulation: found in semen, prostaglandins stimulate the muscles of the female's uterine wall to contract, helping sperm reach the egg

- Labor: cells in the placenta release prostaglandins, excites cells of the uterus and induces labor

- Immunity: prostaglandins promote fever, inflammation and intensifies the sensation of pain

- Injury: prostaglandins helps blood to clot

- Digestion: prostaglandins helps to protect the lining of the stomach

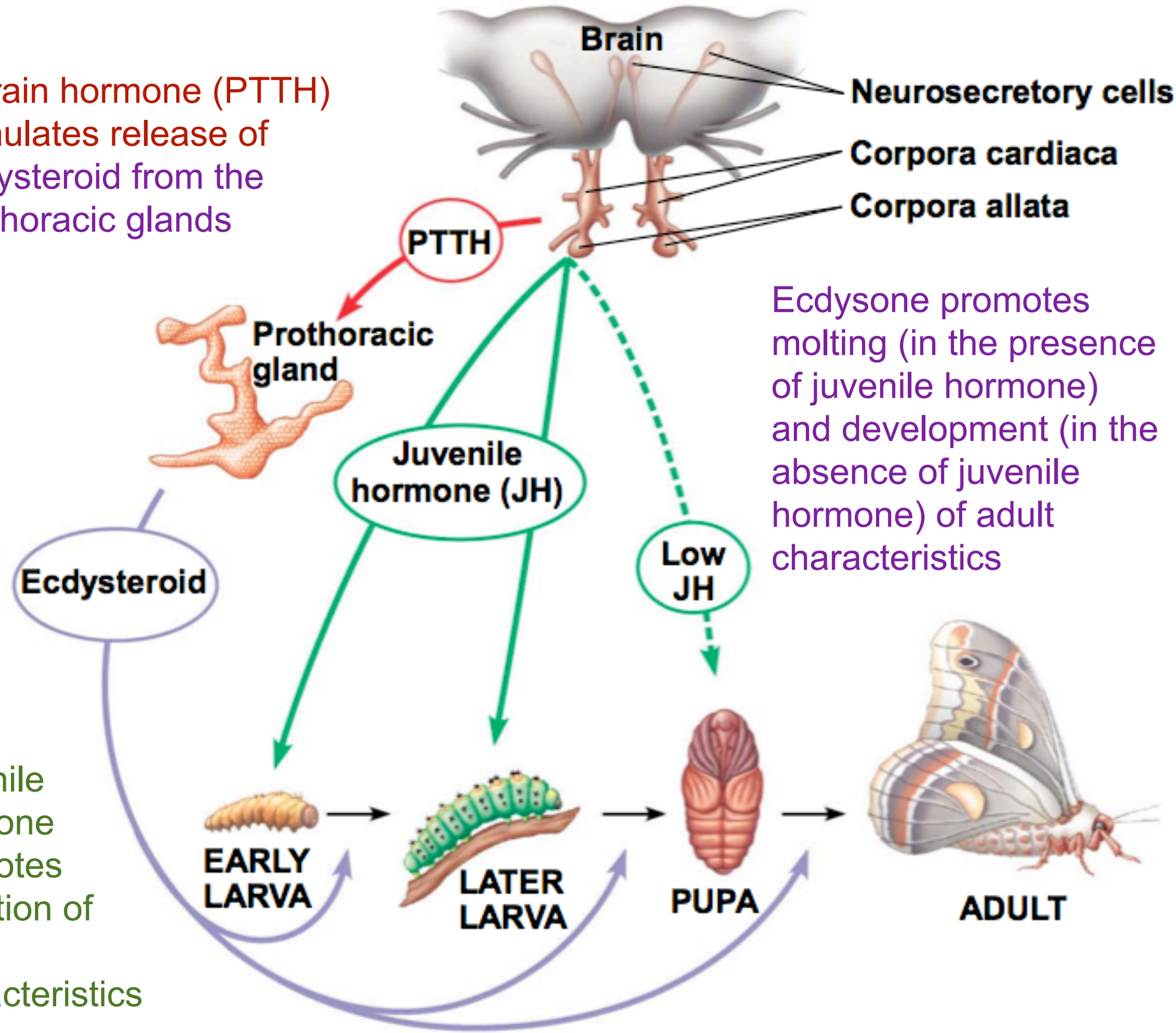
Coordination of Nueroendocrine and Endocrine Signaling

- The endocrine and nervous systems generally act coordinately to control reproduction and development

- For example,in larvae of butterflies and moths, the signals that direct molting originate in the brain

  - In insects, molting and development are controlled by a combination of hormones

A brain hormone (PTTH) stimulates release of ecdysteroid from the prothoracic glands



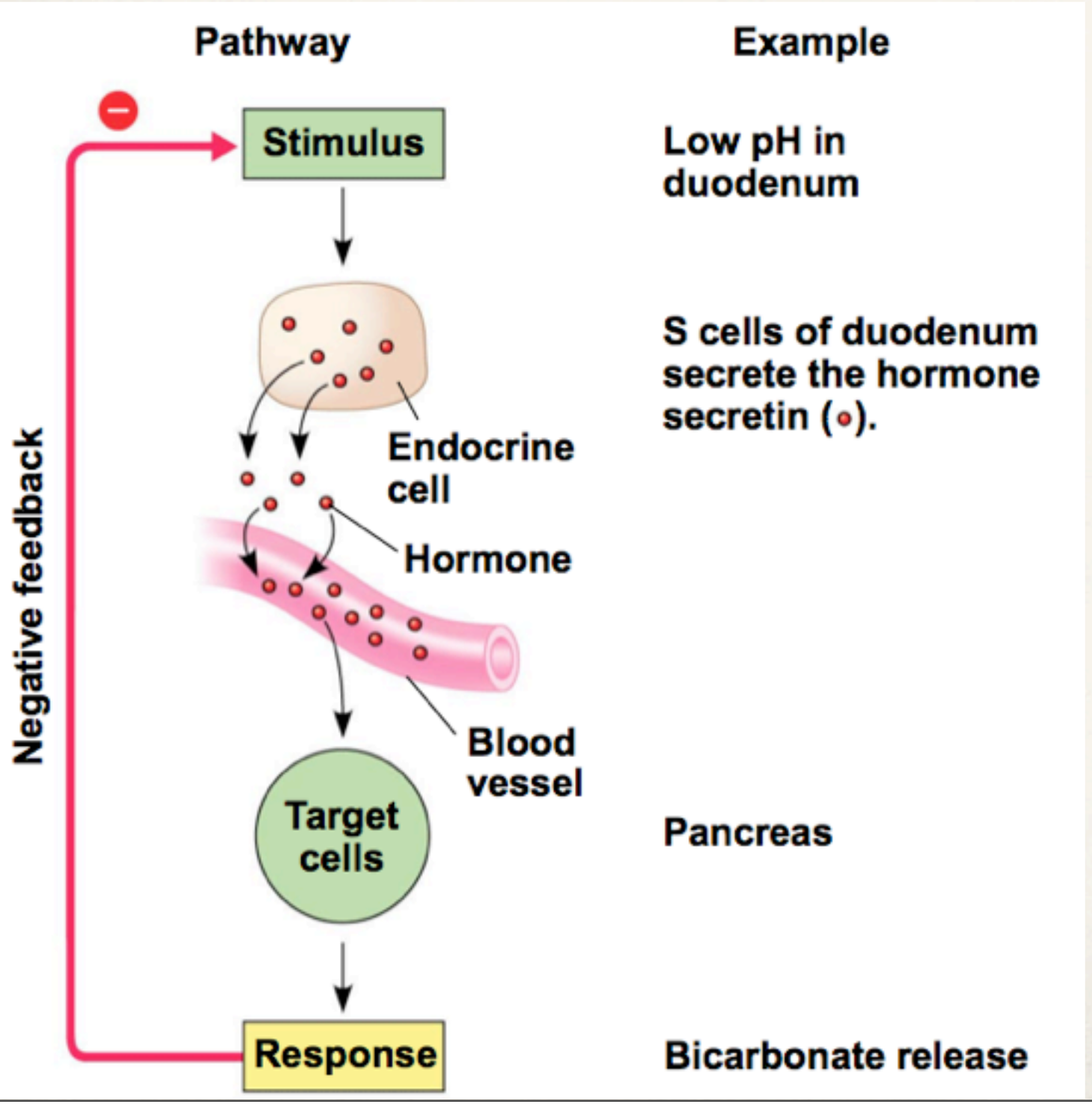
Ecdysone promotes molting (in the presence of juvenile hormone) and development (in the absence of juvenile hormone) of adult characteristics

Juvenile hormone promotes retention of larval characteristics

FEEDBACK REGULATION & ANTAGONISTIC HORMONE PAIRS ARE COMMON

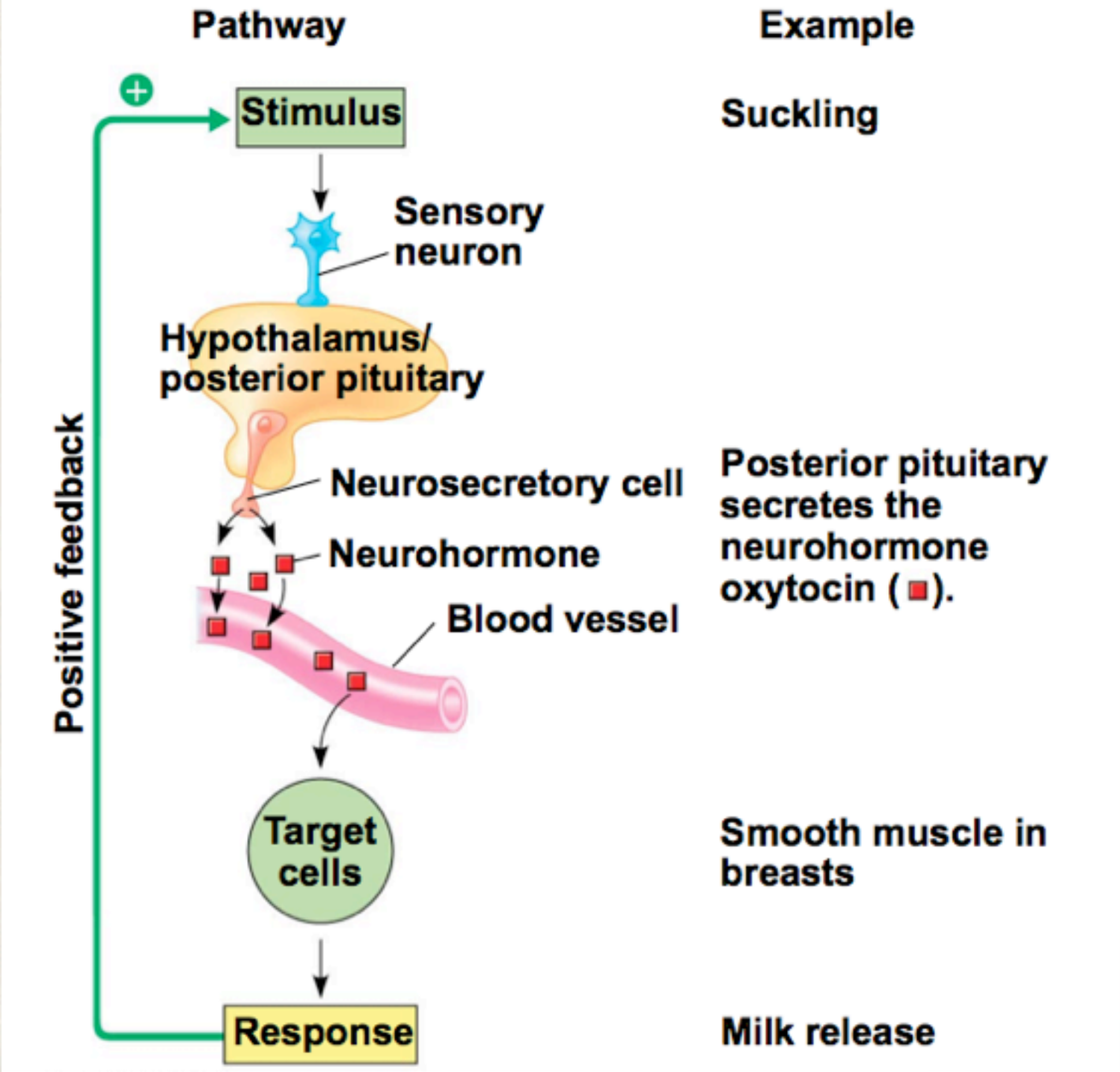
- II. MAIN IDEA: Hormonal pathways must be regulated and often they are regulated by pairs of antagonistic pairs of hormones

Simple Hormone Pathway



Hormones are released from an endocrine cell, travel through the bloodstream, and interact with specific receptors within a target cell to cause a physiological response

Neuroendocrine Pathway



In a simple neuroendocrine pathway,the stimulus is received by a sensory neuron, which stimulates a neurosecretory cell

The neurosecretory cell secretes a neurohormone, which enters the bloodstream and travels to target cells

Feedback Regulation

- A **negative feedback** loop inhibits a response by reducing the initial stimulus, thus preventing excessive pathway activity

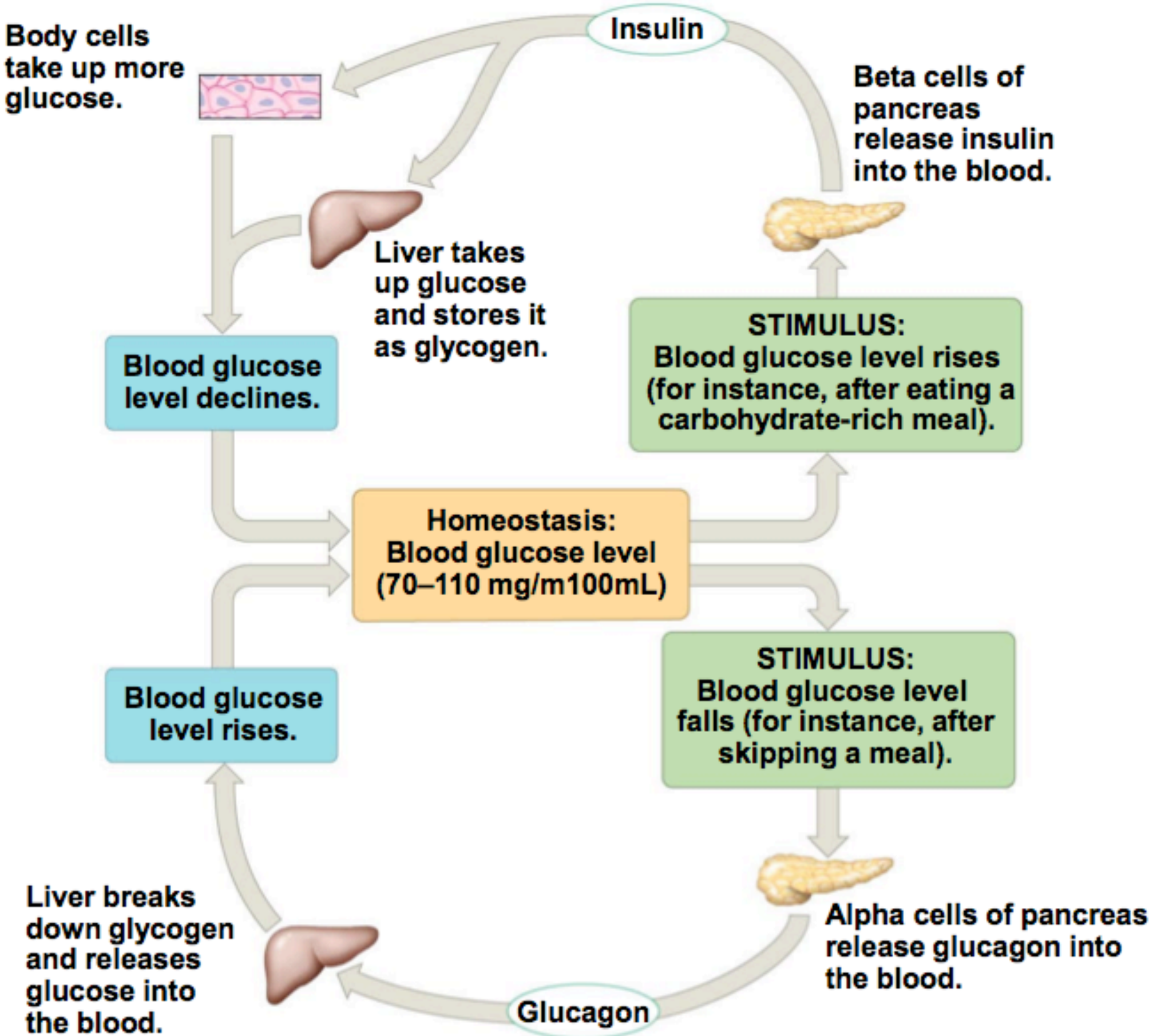
- A **Positive feedback** loop reinforces a stimulus to produce an even greater response

Insulin & Glucagon: Control of Blood Glucose

- **Insulin** (decreases blood glucose) and **glucagon** (increases blood glucose) are antagonistic hormones that help maintain glucose homeostasis

- The pancreas has clusters of endocrine cells called pancreatic islets with alpha cells that produce glucagon and beta cells that produce insulin

- This is an example of negative feedback!


Body cells take up more glucose.
Insulin
Beta cells of pancreas release insulin into the blood.
Liver takes up glucose and stores it as glycogen.
Blood glucose level declines.
STIMULUS: Blood glucose level rises (for instance, after eating a carbohydrate-rich meal).
Homeostasis: Blood glucose level (70–110 mg/m100mL)
Blood glucose level rises.
STIMULUS: Blood glucose level falls (for instance, after skipping a meal).
Liver breaks down glycogen and releases glucose into the blood.
Alpha cells of pancreas release glucagon into the blood.
Glucagon

Target Tissues for Insulin & Glucagon

- Insulin reduces blood glucose levels by
  - – Promoting the cellular uptake of glucose
  - – Slowing glycogen breakdown in the liver
  - – Promoting fat storage, not breakdown
- Glucagon increases blood glucose levels by
  - – Stimulating conversion of glycogen to glucose in the liver
  - – Stimulating breakdown of fat and protein into glucose

Diabetes Mellitus

- It is caused by a deficiency of insulin or a decreased response to insulin in target tissues

- It is marked by elevated blood glucose levels, which kidneys can not reabsorb

- Excessive urine is produced and sugar is lost in the urine.

- ***TypeI diabetes mellitus*** **(insulin-dependent) is an autoimmune disorder in which the immune system destroys pancreatic beta cells**

- ***TypeII diabetes mellitus*** **(non-insulin-dependent) involves insulin deficiency or reduced response of target cells due to change in insulin receptors**

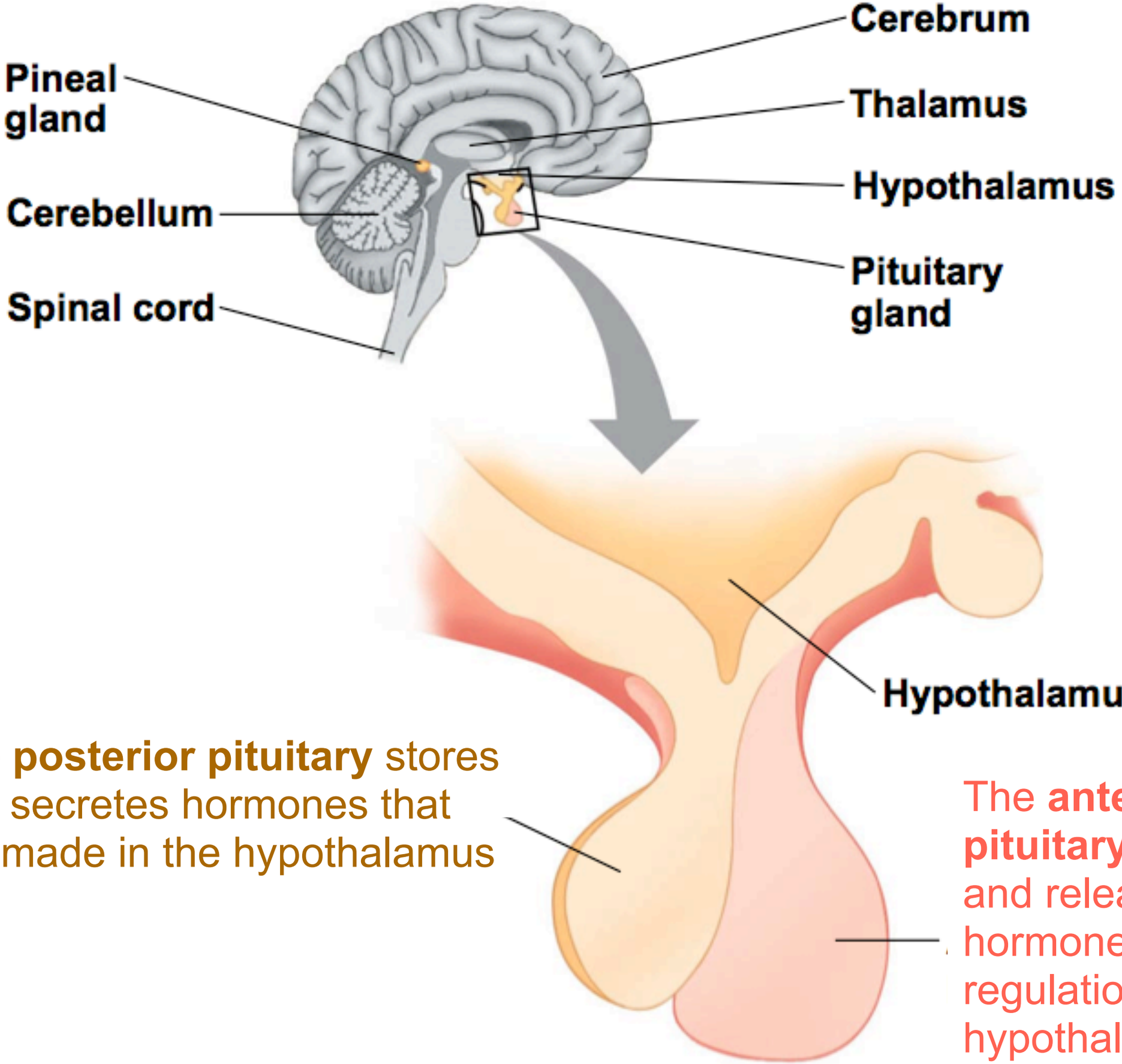
HYPOTHALAMUS & PITUITARY ARE CENTRAL TO ENDOCRINE REGULATION

- III. MAIN IDEA: The nervous system plays a critical role in the regulation of the endocrine system and its hormones.

Coordination of Endocrine & Nervous Systems in Vertebrates

- The **hypothalamus** receives information from the nervous system and initiates responses through the endocrine system

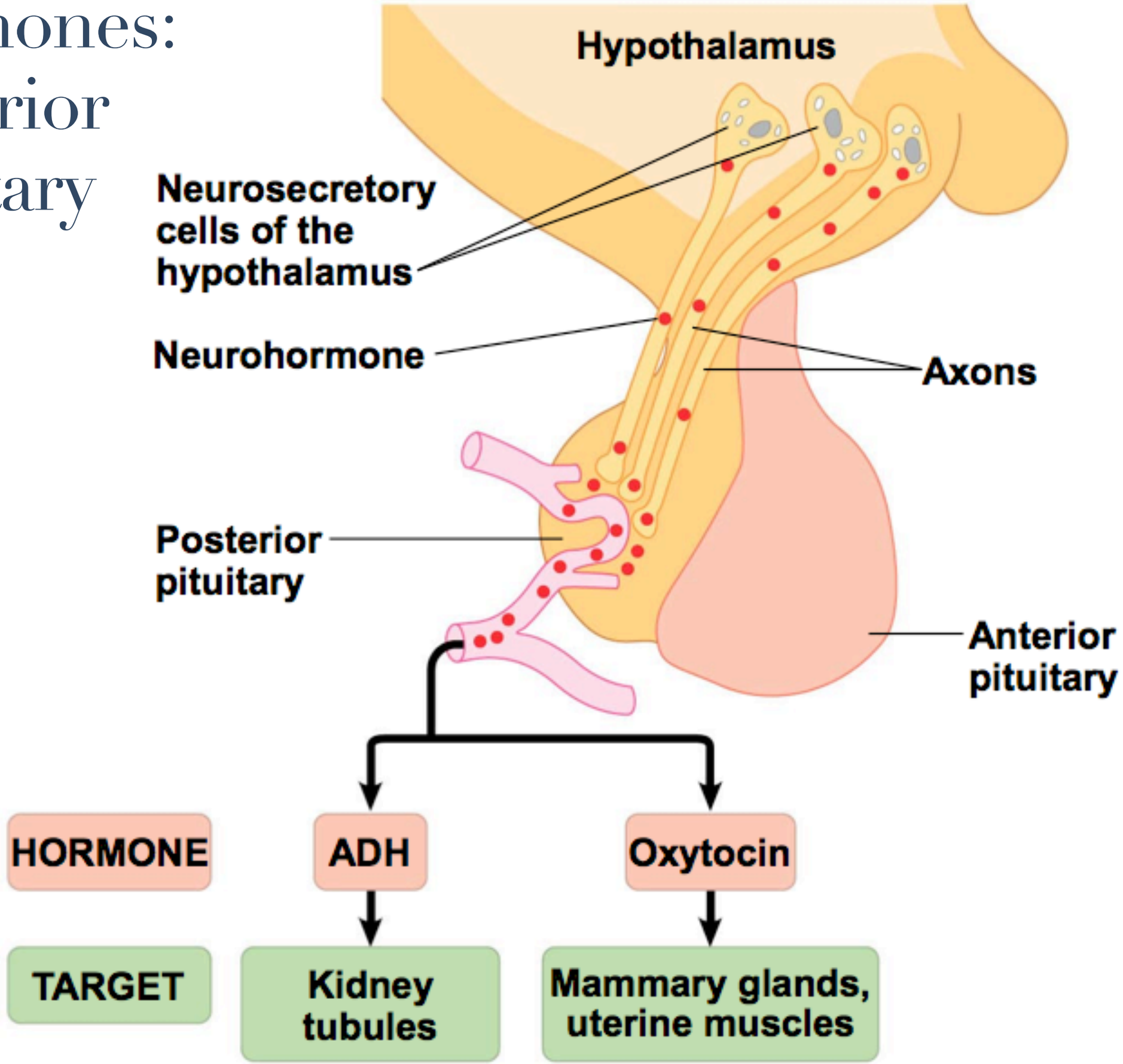
- Attached to the hypothalamus is the **pituitary gland** composed of the posterior pituitary and anterior pituitary



The **posterior pituitary** stores and secretes hormones that are made in the hypothalamus

The **anterior pituitary** makes and releases hormones under regulation of the hypothalamus

Hormones: Posterior Pituitary

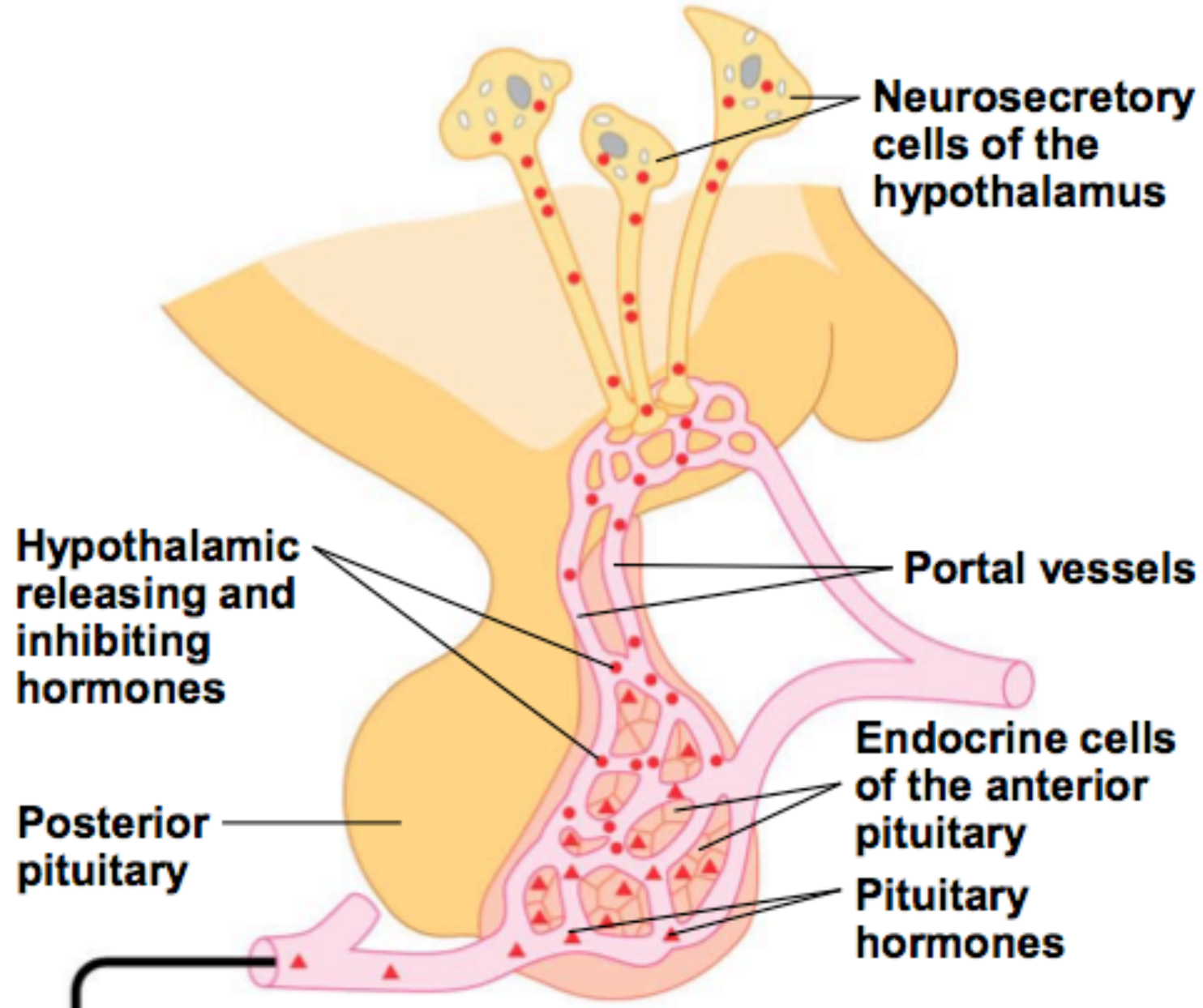


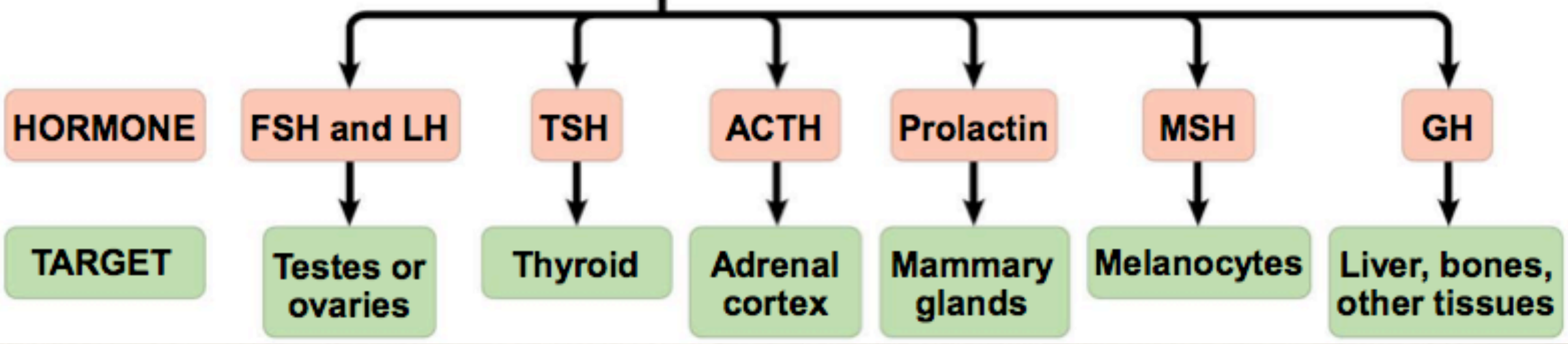
Tropic effects only:
FSH
LH
TSH
ACTH

Nontropic effects only:
Prolactin
MSH

Nontropic and tropic effects:
GH

Hormones: Anterior Pituitary

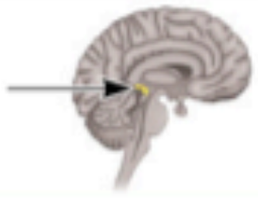




Major Human Endocrine Glands and Some of Their Hormones

Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus 	Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Posterior pituitary gland (releases neurohormones made in hypothalamus) 	Oxytocin	Peptide	Stimulates contraction of uterus and mammary gland cells	Nervous system
	Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance
Anterior pituitary gland 	Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
	Prolactin	Protein	Stimulates milk production and secretion	Hypothalamic hormones
	Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates production of ova and sperm	Hypothalamic hormones
	Luteinizing hormone (LH)	Glycoprotein	Stimulates ovaries and testes	Hypothalamic hormones
	Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid gland	Hypothalamic hormones
	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Hypothalamic hormones
Thyroid gland 	Triiodothyronine (T_3) and thyroxine (T_4)	Amines	Stimulate and maintain metabolic processes	TSH
	Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands 	Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood

Major Human Endocrine Glands and Some of Their Hormones (continued)

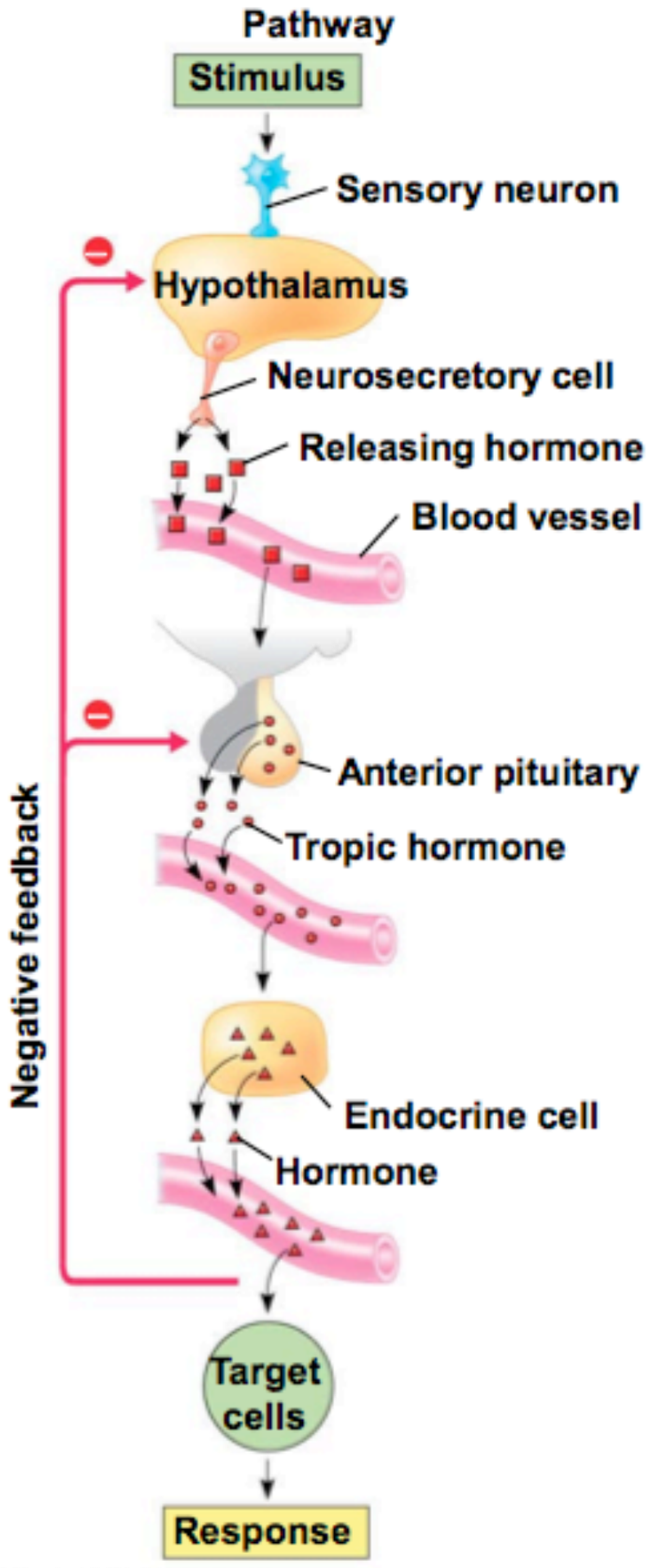
Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Pancreas 	Insulin	Protein	Lowers blood glucose level	Glucose in blood
	Glucagon	Protein	Raises blood glucose level	Glucose in blood
Adrenal glands 				
Adrenal medulla	Epinephrine and norepinephrine	Amines	Raise blood glucose level; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex	Glucocorticoids	Steroids	Raise blood glucose level	ACTH
	Mineralocorticoids	Steroids	Promote reabsorption of Na^+ and excretion of K^+ in kidneys	K^+ in blood; angiotensin II
Gonads 				
Testes	Androgens	Steroids	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries 	Estrogens	Steroids	Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics	FSH and LH
	Progestins	Steroids	Promote uterine lining growth	FSH and LH
Pineal gland 	Melatonin	Amine	Involved in biological rhythms	Light/dark cycles

Thyroid Regulation: A Hormone Cascade Pathway

- A hormone can stimulate the release of a series of other hormones, the last of which activates a nonendocrine target cell; this is called a hormone cascade pathway

- The release of thyroid hormone results from a hormone cascade pathway involving the hypothalamus, anterior pituitary, and thyroid gland

- Hormone cascade pathways typically involve negative feedback


Pathway
Example
Stimulus
Cold
Sensory neuron
Hypothalamus
Hypothalamus secretes thyrotropin-releasing hormone (TRH).
Neurosecretory cell
Releasing hormone
Blood vessel
Anterior pituitary
Anterior pituitary secretes thyroid-stimulating hormone (TSH, also known as thyrotropin).
Tropic hormone
Negative feedback
Endocrine cell
Thyroid gland secretes thyroid hormone (T_3 and T_4).
Hormone
Target cells
Body tissues
Response
Increased cellular metabolism

Disorders of Thyroid Function & Regulation

- Hypothyroidism,too little thyroid function,can produce symptoms such as
  - – Weight gain, lethargy, cold intolerance
- Hyperthyroidism,excessive production of thyroid hormone, can lead to
  - – High temperature, sweating, weight loss, irritability and high blood pressure
- Malnutrition can alter thyroid function

Disorders of Thyroid Function & Regulation

- **Graves disease**, a form of hyperthyroidism caused by autoimmunity, is typified by protruding eyes

- *Thyroid hormone* refers to a pair of hormones

- – **Triiodothyronin** (**T3**), with three iodine atoms

- – **Thyroxine** (**T4**) with four iodine atoms

- Insufficient dietary iodine leads to an enlarged thyroid gland, called a goiter

Evolution of Hormone Function

- Over the course of evolution the function of a given hormone may diverge between species
  - For example, **Prolactin** also has a broad range of activities in vertebrates
- **Melanocyte-stimulatinghormone (MSH)** regulates skin color in amphibians, fish, and reptiles by controlling pigment distribution in melanocytes
- In mammals, MSH plays additional roles in hunger and metabolism in addition to coloration

Evolution of Hormone Function

- Thyroid hormone plays a role in metabolism across many lineages, but in frogs has taken on a unique function: stimulating the resorption of the tadpole tail during metamorphosis

Tropic & Nontropic Hormones

- **Nontropic hormones** do NOT regulate other glands or endocrine cells.
  - *For example: MSH and Prolactin*
- **Tropic hormones** regulate the function of endocrine cells or glands
  - Three primarily tropic hormones are
    - *Follicle-stimulating hormone (FSH), Luteinizing hormone (LH), Adrenocorticotropic hormone (ACTH)*

Tropic & Nontropic Hormones

- **Growth hormone (GH)** is secreted by the anterior pituitary gland and has tropic and nontropic actions

- It promotes growth directly and has diverse metabolic effects

- It stimulates production of growth factors

  - *An excess of GH can cause gigantism,while a lack of GH can cause dwarfism*

ENDOCRINE GLANDS REGULATE HOMEOSTASIS, DEVELOPMENT & BEHAVIOR

- IV. MAIN IDEA: Endocrine glands respond to stimuli and regulate a broad range of activities including: homeostasis, stress, development and behavior.

Parathyroid Hormone & Vitamin D: Control of Blood Calcium

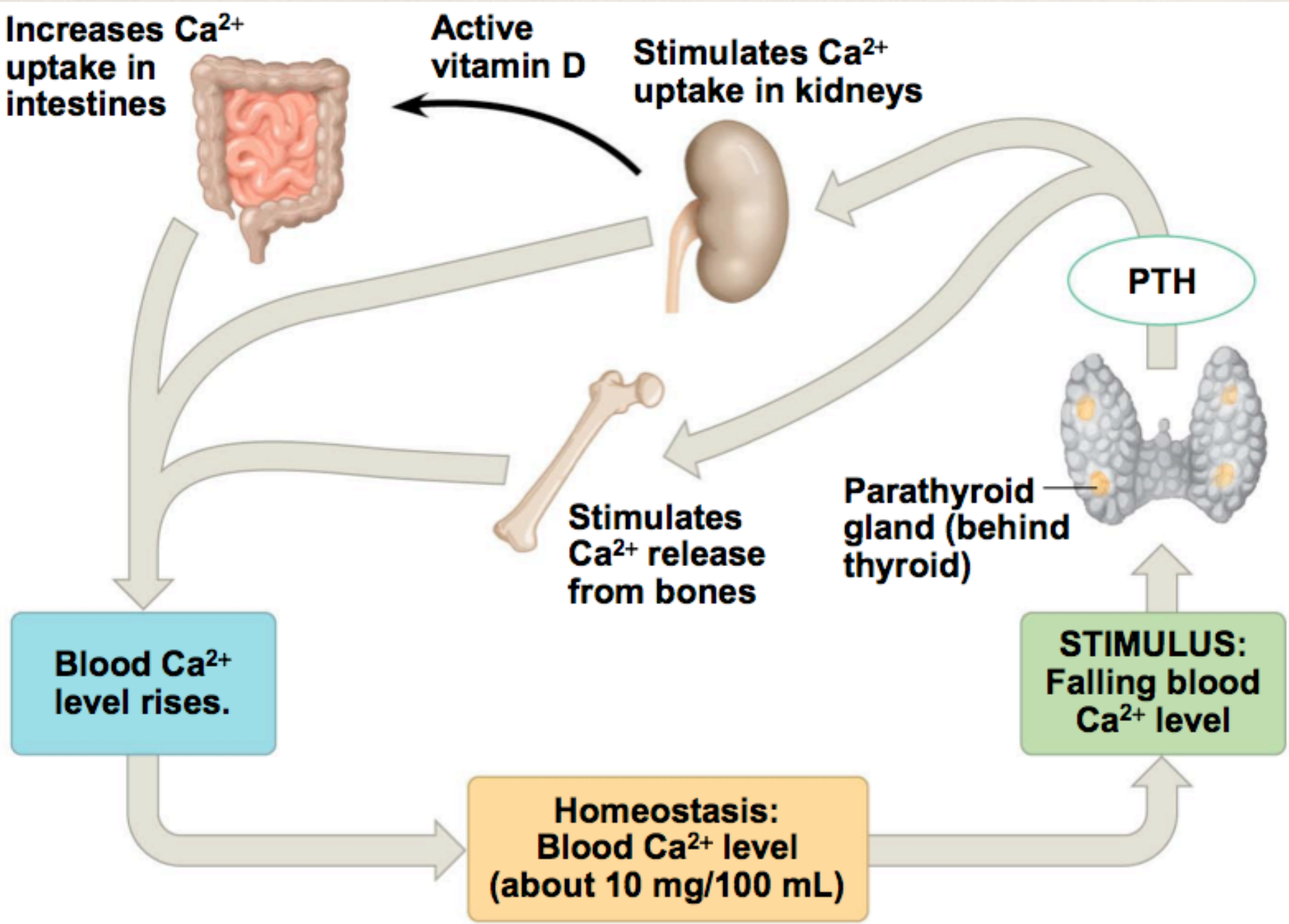
- Homeostatic control of blood calcium is critical to survival.
  - Too little and the muscles contract convulsively and develop into into *tetany* a potentially fatal condition.
  - Too much and precipitates of calcium phosphate can form in organs and lead to widespread organ damage and death

Parathyroid Hormone & Vitamin D: Control of Blood Calcium

- Two antagonistic hormones regulate the homeostasis of calcium (Ca2+) in the blood of mammals

- – **Parathyroid hormone (PTH)** is released by the parathyroid glands

- – **Calcitonin** is released by the thyroid gland


Increases Ca^{2+} uptake in intestines
Active vitamin D
Stimulates Ca^{2+} uptake in kidneys
PTH
Parathyroid gland (behind thyroid)
Stimulates Ca^{2+} release from bones
Blood Ca^{2+} level rises.
Homeostasis: Blood Ca^{2+} level (about 10 mg/100 mL)
STIMULUS: Falling blood Ca^{2+} level

Parathyroid Hormone & Vitamin D: Control of Blood Calcium

- **PTH** increases the level of blood Ca2+
  - – It releases Ca2+ from bone and stimulates reabsorption of Ca2+ in the kidneys
  - – It also has an indirect effect, stimulating the kidneys to activate vitamin D, which promotes intestinal uptake of Ca2+ from food
- **Calcitonin** decreases the level of blood Ca2+
  - – It stimulates Ca2+ deposition in bones and secretion by kidneys

Adrenal Hormones: Responses to Stress

- The adrenal glands are adjacent to the kidneys
- Each **adrenal gland** actually consists of two glands:
  - the *adrenal medulla* (inner portion) and
  - the *adrenal cortex* (outer portion)

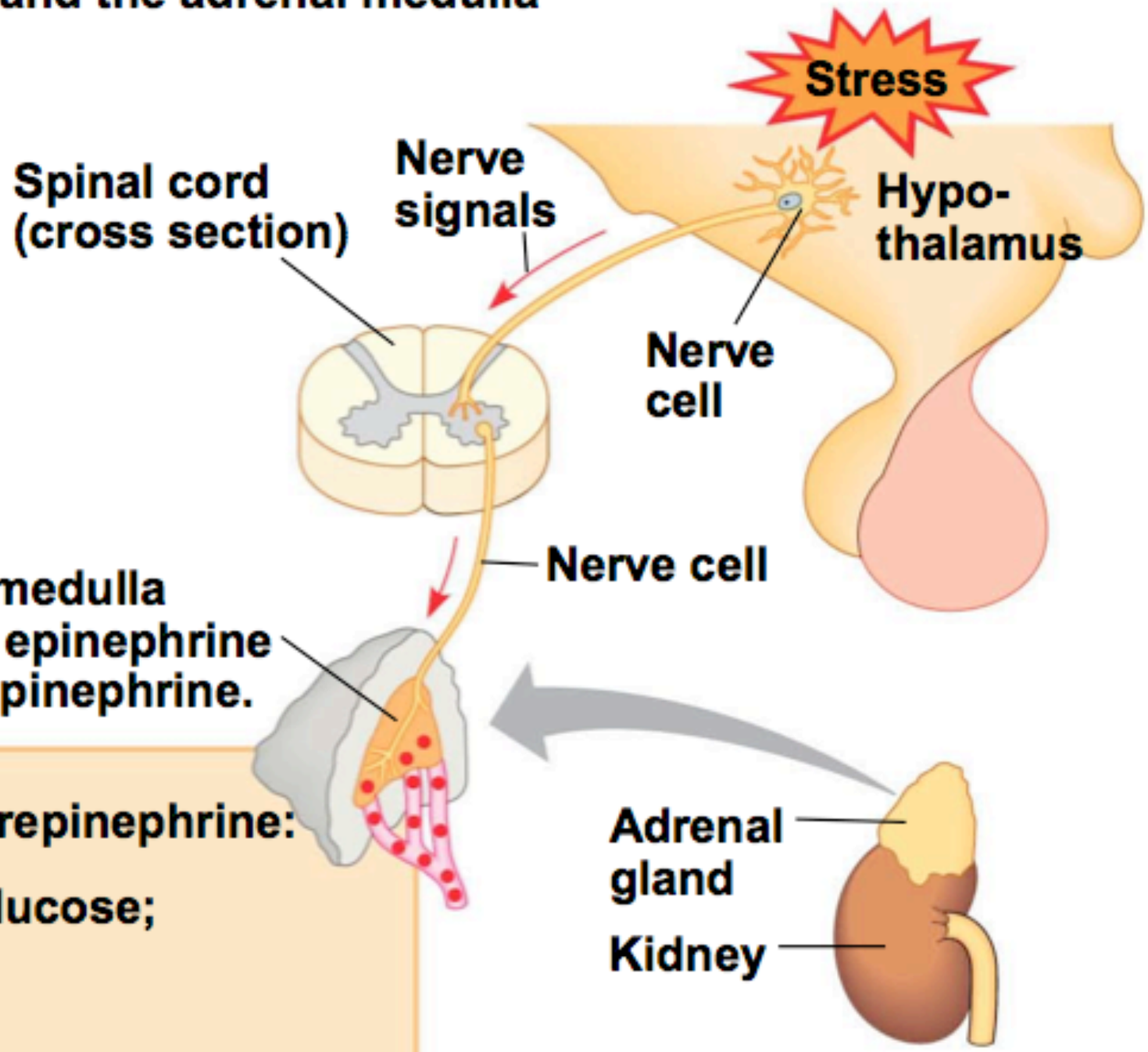
Catecholamines From the Adrenal Medulla

- The adrenal medulla secretes epinephrine (adrenaline) and **norepinephrine** (noradrenaline)
- These hormones are members of a class of compounds called **catecholamines**
- They are secreted in response to stress-activated impulses from the nervous system
- They mediate various fight-or-flight responses

Adrenal Medulla continued

- **Epinephrine (adrenaline)** and **Norepinephrine**
  - – Trigger the release of glucose and fatty acids into the blood
  - – Increase oxygen delivery to body cells
  - – Direct blood toward heart, brain, and skeletal muscles, and away from skin, digestive system, and kidneys
- The release of epinephrine and norepinephrine occurs in response to involuntary nerve signals

Short-term stress response and the adrenal medulla



Effects of epinephrine and norepinephrine:

- Glycogen broken down to glucose; increased blood glucose
- Increased blood pressure
- Increased breathing rate
- Increased metabolic rate
- Change in blood flow patterns, leading to increased alertness and decreased digestive, excretory, and reproductive system activity

Steroid Hormones from the Adrenal Cortex

- The adrenal cortex releases a family of steroids called **corticosteroids** in response to stress

- These hormones are triggered by a hormone cascade pathway via the hypothalamus and anterior pituitary (ACTH)

- Humans produce two types of corticosteroids: **glucocorticoids** and **mineralocorticoids**

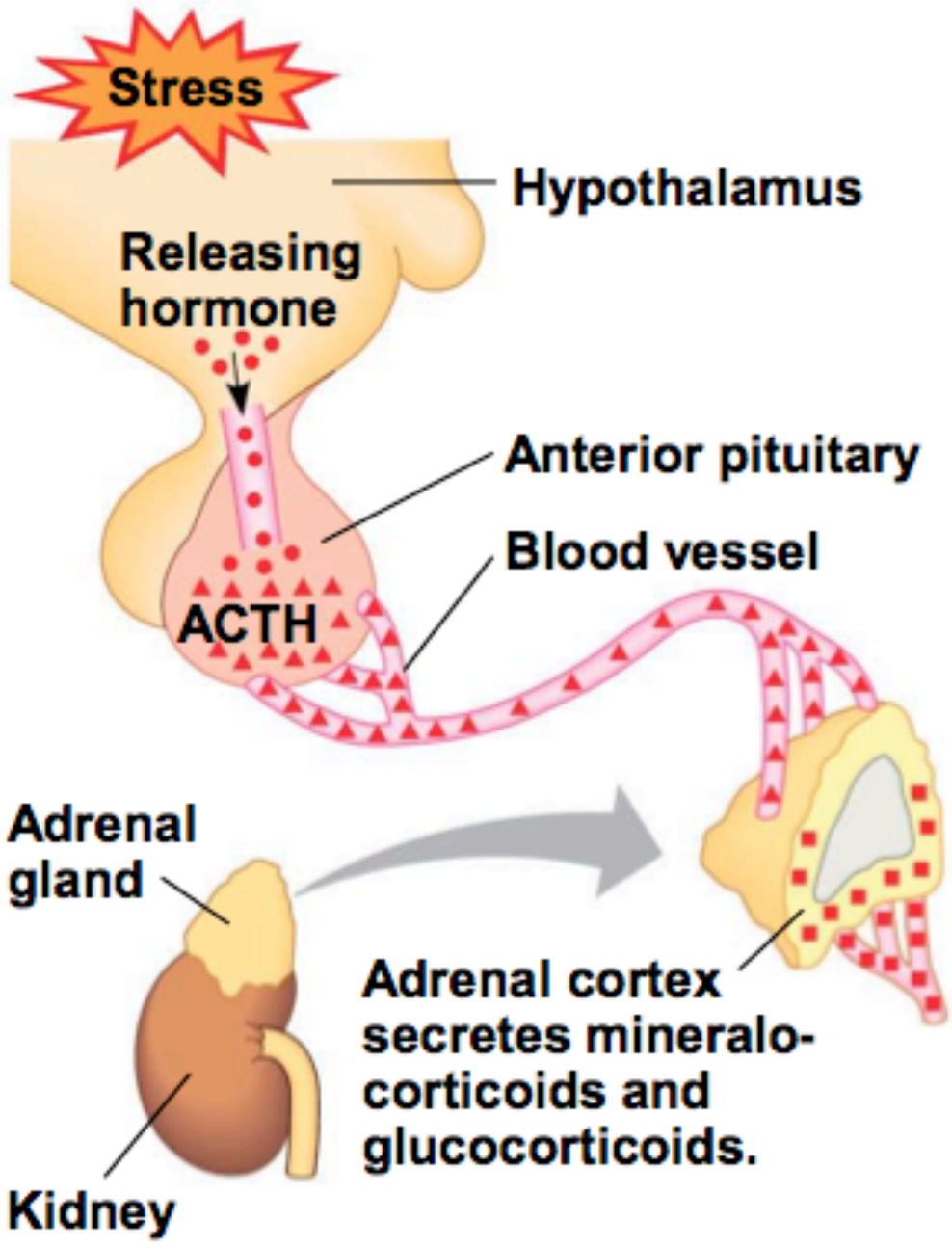
Adrenal Cortex continued

- **Glucocorticoids**,such as cortisol,influence glucose metabolism and the immune system

- **Mineralocorticoids**, such as aldosterone, affect salt and water balance

- The adrenal cortex also produces small amounts of steroid hormones that function as sex hormones

Long-term stress response and the adrenal cortex



Effects of mineralocorticoids:

- Retention of sodium ions and water by kidneys
- Increased blood volume and blood pressure

Effects of glucocorticoids:

- Proteins and fats broken down and converted to glucose, leading to increased blood glucose
- Partial suppression of immune system

Gonadal Sex Hormones

- The gonads, testes and ovaries, produce most of the sex hormones:
  - androgens,
  - estrogens,
  - and progestins
- All three sex hormones are found in both males and females, but in significantly different proportions

Gonadal Sex Hormones

- The testes primarily synthesize **androgens**, mainly **testosterone**, which stimulate development and maintenance of the male reproductive system

- Testosterone causes an increase in muscle and bone mass and is often taken as a supplement to cause muscle growth, which carries health risks

EXPERIMENT

Alfred Jost, wondered whether gonadal hormones instruct an embryo to develop as male or female in accord with its chromosome set. Working with rabbit embryos still in the mother's uterus, at a stage before sex differences are observable, he surgically removed the portion of each embryo that would form form testes or ovaries. When the baby rabbits were born, he made a note of both the chromosomal sex and the sexual differentiation of the genital structures.

RESULTS

Chromosome Set	Appearance of Genitalia	
	No surgery	Embryonic gonad removed
XY (male)	Male	Female
XX (female)	Female	Female

CONCLUSION

In rabbits, male development requires a hormonal signal from the male gonad. In the absence of this signal, all embryos develop as female. He later demonstrated that embryos developed male genitalia if the surgically removed gonad was replaced with a crystal of testosterone. The process of sex determination occurs in a highly similar manner in all mammals, including humans.

Gonadal Sex Hormones

- **Estrogens**, most importantly **estradiol**, are responsible for maintenance of the female reproductive system and the development of female secondary sex characteristics

- In mammals, progestins, which include **progesterone**, are primarily involved in preparing and maintaining the uterus

- Synthesis of the sex hormones is controlled by FSH and LH from the anterior pituitary

Endocrine Disruptors

- Between 1938 and 1971 some pregnant women at risk for complications were prescribed a synthetic estrogen called diethylstilbestrol (DES)

- Daughters of women treated with DES are at higher risk for reproductive abnormalities, including miscarriage, structural changes, and cervical and vaginal cancers

- DES is an endocrine disruptor, a molecule that interrupts the normal function of a hormone pathway, in this case, that of estrogen

Melatonin & Biorhythms

- The **pineal gland**, located in the brain,secretes **melatonin**
- Light/dark cycles control release of melatonin
- Primary functions of melatonin appear to relate to biological rhythms associated with reproduction

Coming Next Year...

In the meantime if you wish use the headings in the slides that follow as a guide or roadmap to chapter 39 in Campbells

Plant Regulation

Hormones

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