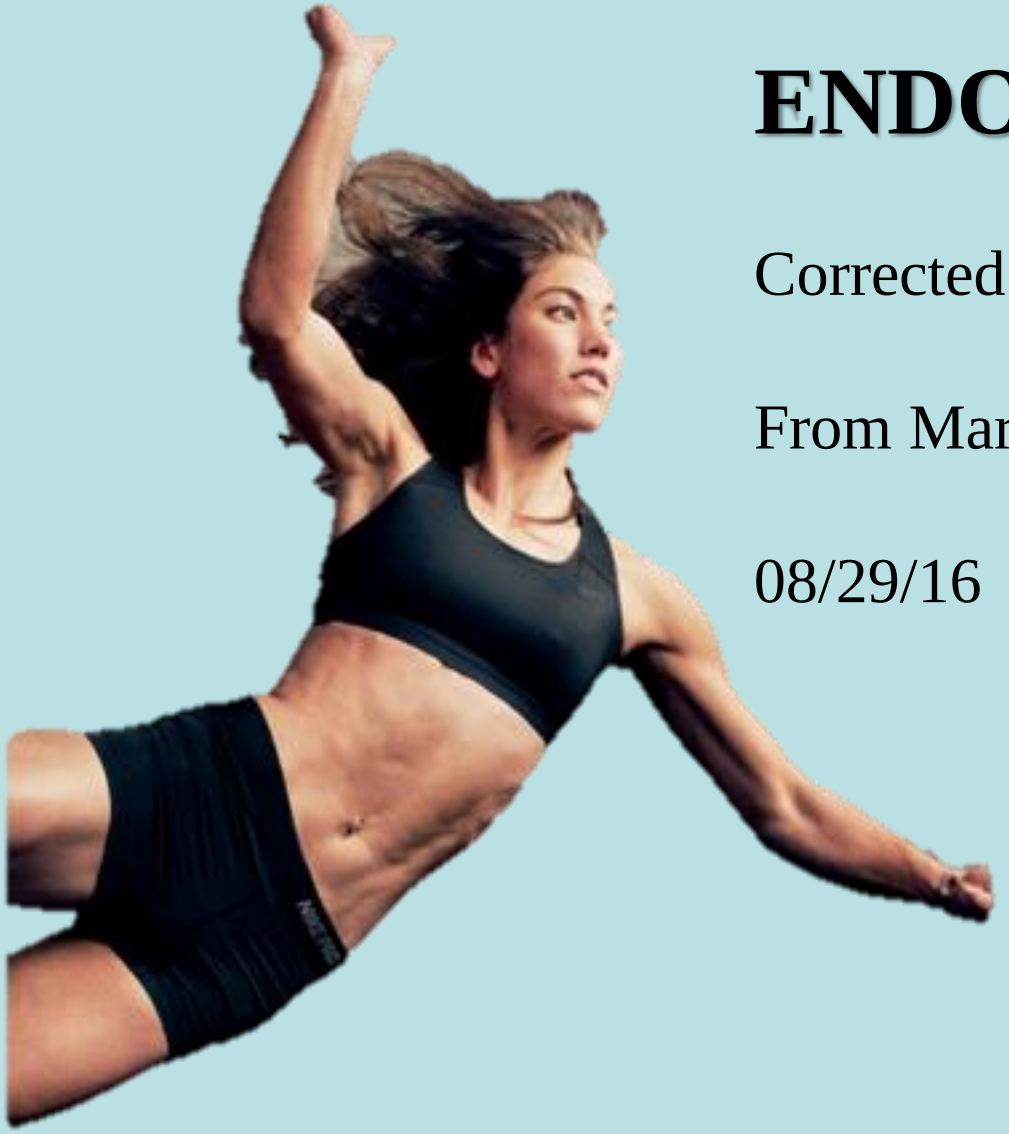


ENDOCRINE SYSTEM

Corrected by Dr. C.Gerin

From Marieb

08/29/16

The Endocrine System

Anatomy: “ana” = separate from; “tomy”= cut open => dissection

Physiology: “logy” = study; “physio” =related to natural functioning =>study of living organism

Introduction

- The nervous system and the endocrine system work together: neuro-endocrine system
  - The nervous system: produces short-term, very specific responses
  - The endocrine system: produces long-lasting, more general responses

Major Endocrine Organs

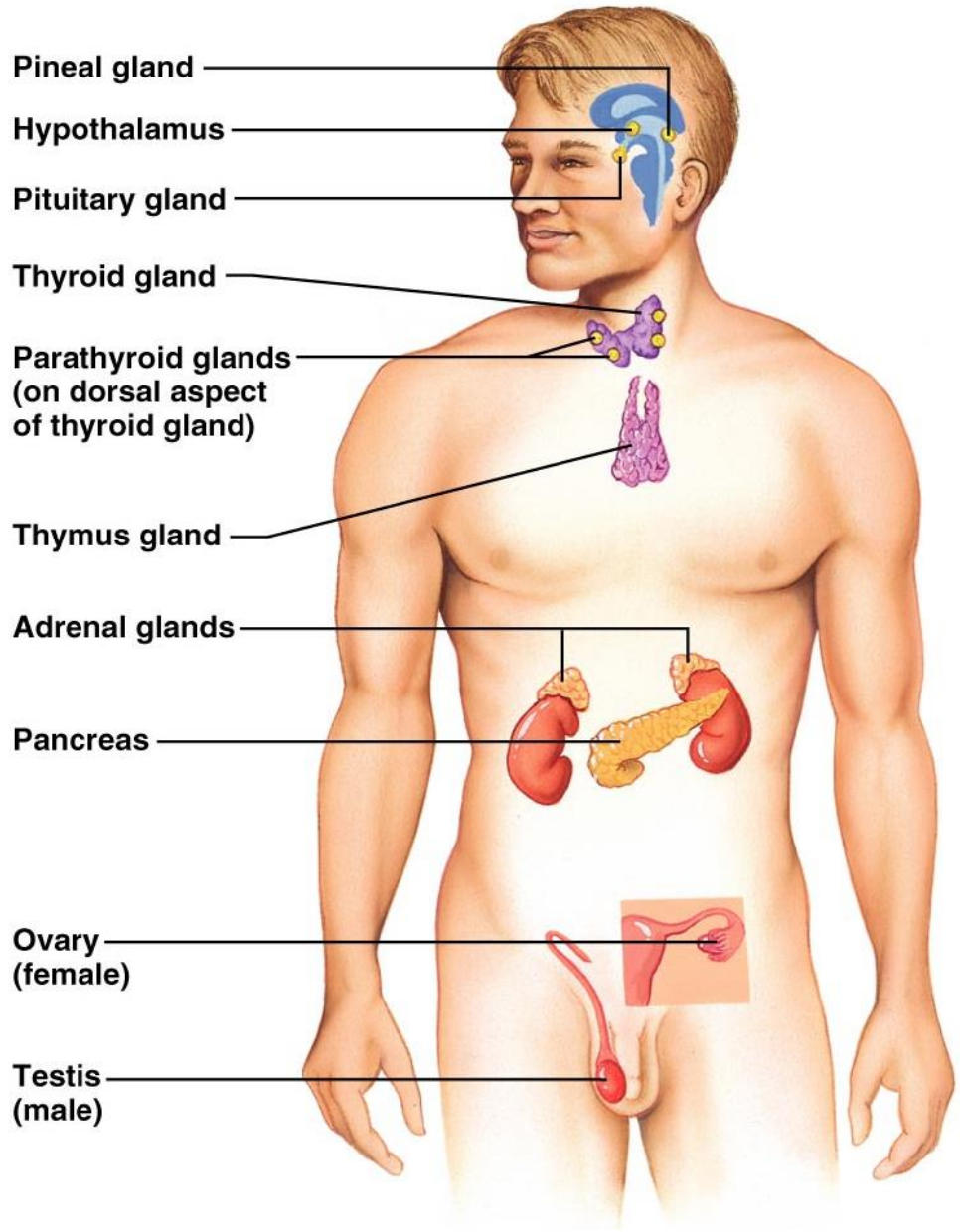


Figure 16.1

Autocrines and Paracrines

- Autocrines – chemicals that exert effects on the same cells that secrete them
- Paracrines – locally acting chemicals that affect cells other than those that secrete them
- These are not considered hormones since hormones are long-distance chemical signals

Introduction

- The endocrine system releases chemicals called **hormones : protein or lipids (steroid)**
  - Secreted by a gland or gland-like structure
  - Travel in bloodstream
  - target organ or tissue distant
  - Therefore, response = **distant site in the body**

- The main endocrine organs are:$$$$$
  - **Epiphysis = Pineal gland (pine cone; melatonine)**
  - **Hypothalamus**
  - **Pituitary gland = Hypophysis**
  - **Thyroid gland**
  - **Parathyroid glands**
  - **Thymus gland**
  - **Suprarenal glands**
  - **Pancreas**
  - **Reproductive glands**

An Overview of the Endocrine System

- Other endocrine tissues are:
  - **Heart**
  - **Kidney**
  - **Adipose cells**
  - **Digestive tract**

The Endocrine System$$$$$$

RH

SH

H

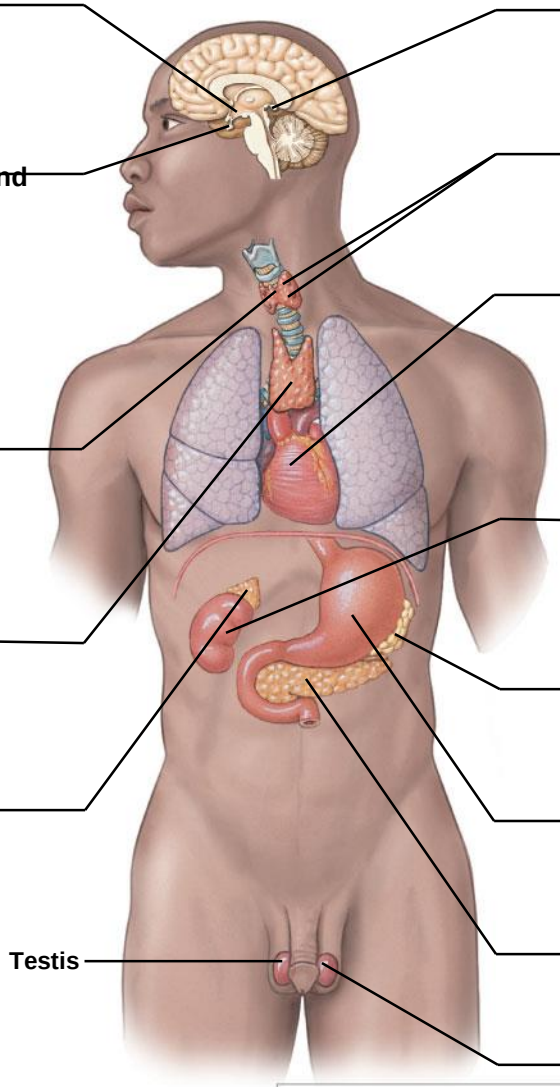
Hypothalamus
Production of ADH, oxytocin, and regulatory hormones SRH IRH

Hypophysis=Pituitary Gland
Pars distalis (anterior lobe):
ACTH, TSH, GH, PRL, FSH, LH, and MSH
Neurohypophysis (posterior lobe):
Release of oxytocin and ADH

Thyroid Gland
Thyroxine (T_4)
Triiodothyronine (T_3)
Calcitonin (CT)

Thymus (Undergoes atrophy during adulthood)
Thymosins

Suprarenal Glands
Each suprarenal gland is subdivided into:
Medulla:
Epinephrine (E)
Norepinephrine (NE)
Cortex:
Cortisol, corticosterone, aldosterone, androgens



Pineal Gland= epiphysis
Melatonin

Parathyroid Glands (on posterior surface of thyroid gland)
Parathyroid hormone (PTH)

Heart
Natriuretic peptides:
Atrial natriuretic peptide (ANP)
Brain natriuretic peptide (BNP)

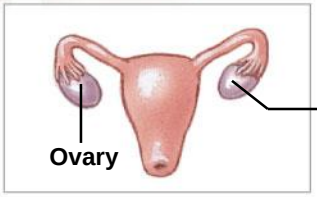
Kidney
Erythropoietin (EPO)
Calcitriol
(Chapters 19 and 26)

Adipose Tissue
Leptin
Resistin

Digestive Tract
Numerous hormones CCK,…
(detailed in Chapter 25)

Pancreatic Islets
Insulin, glucagon

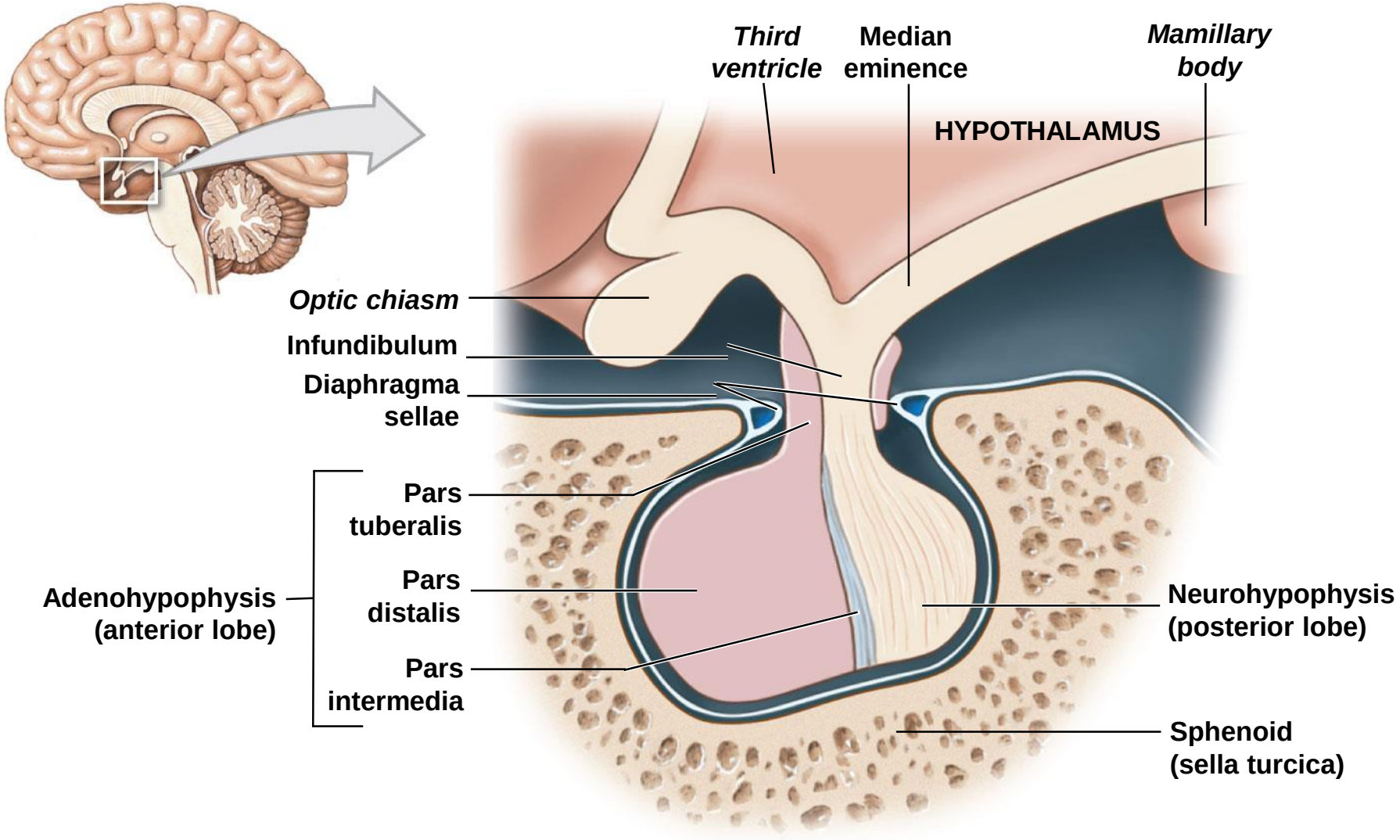
Gonads
Testes (male):
Androgens (especially testosterone), inhibin
Ovaries (female):
Estrogens, progestins, inhibin



KEY TO PITUITARY HORMONES

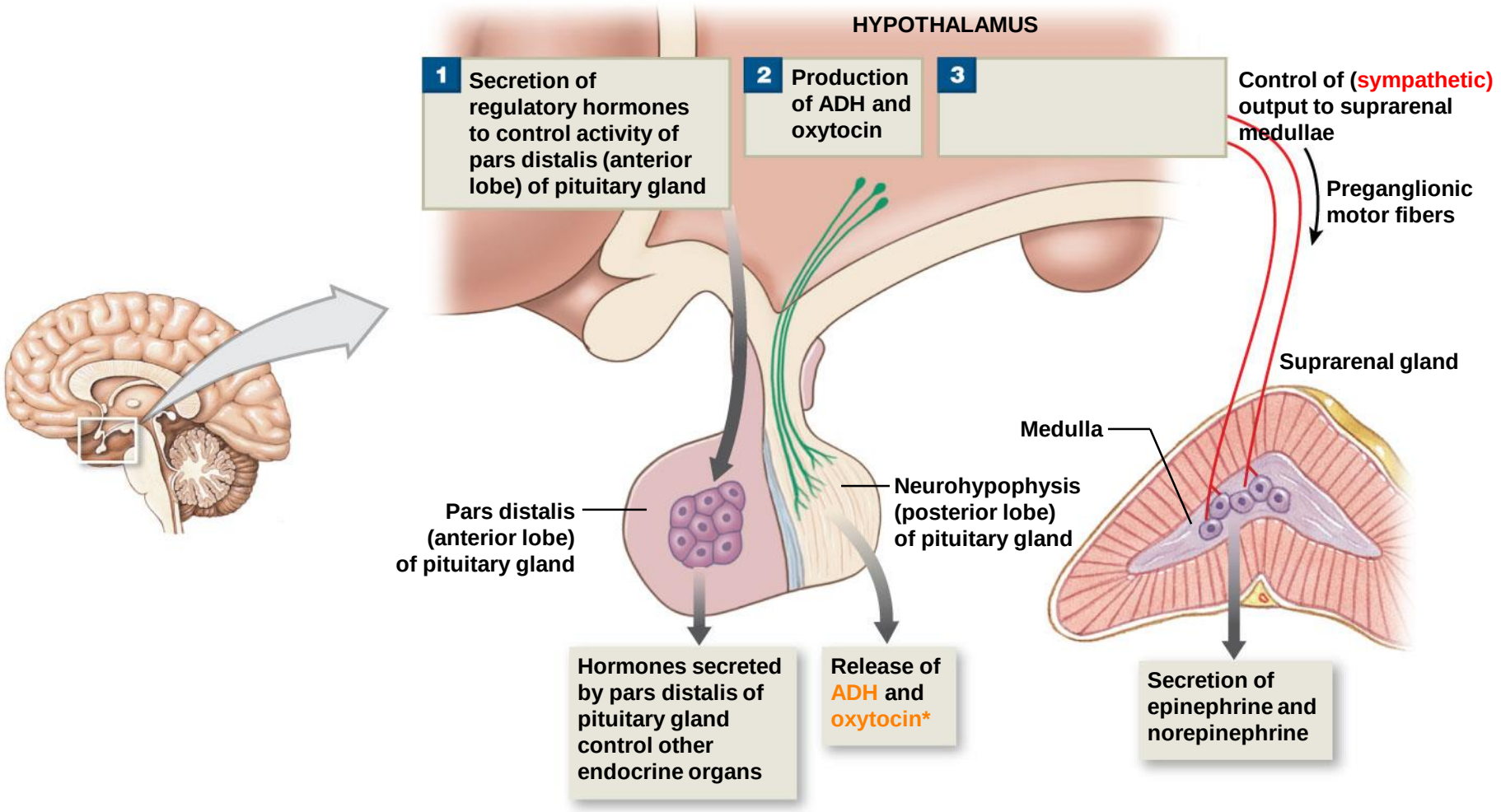
ACTH	Adrenocorticotropic hormone
TSH	Thyroid-stimulating hormone
GH	Growth hormone
PRL	Prolactin
FSH	Follicle-stimulating hormone
LH	Luteinizing hormone
MSH	Melanocyte-stimulating hor*mone
ADH	Antidiuretic hormon (= AVP=Vasopressine

Figure Gross Anatomy and Histological Organization of the Pituitary Gland and Its Subdivisions$$$$$



a Relationship of the pituitary gland to the hypothalamus

Figure 19.2 Hypothalamic Control over Endocrine Organs



An Overview of the Endocrine System

- The Hypothalamus (RH)
  - **Secretes regulatory hormones (RH)**
    - Stimulating releasing hormones (SRH)
    - inhibiting releasing hormones (IRH)
  - **Acts as an endocrine organ**
    - Releases antidiuretic hormone (ADH)= arginine vasopressine (AVP) and oxytocin to the pituitary gland
  - **Contains autonomic nervous system centers**

The Pituitary Gland = HYPOPHYSIS

- The Adenohypophysis = SH
  - Consists of five different cell types
    - **Thyrotropes**: release thyroid-stimulating hormone (TSH)
    - **Corticotropes**: release adrenocorticotropic hormone (ACTH) and melanocyte-stimulating hormone (MSH)
    - **Gonadotropes**: release follicle-stimulating hormone (FSH) and luteinizing hormone (LH), prolactin* (PRL)

Hormones of the hypothalamic-pituitary-end organ axis[1]

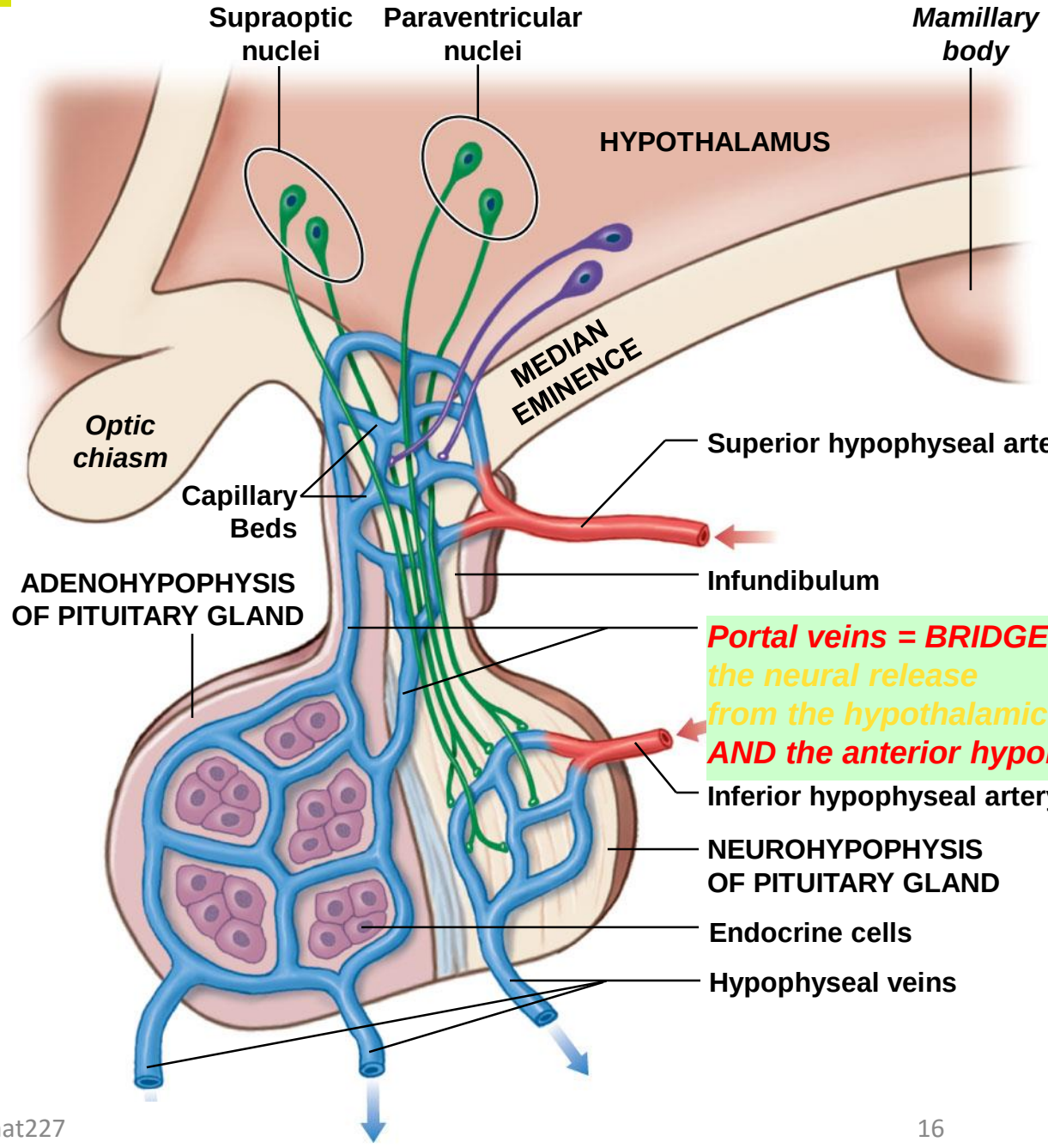
	HPT axis	HPA axis	HPG axis	Growth	Lactation
Hypothalamic hormone	TRH	CRH	GnRH	GHRH	Dopamine (inhibitor)
Pituitary hormone	TSH	ACTH	LH and FSH	GH	Prolactin
End organ	Thyroid	Adrenal	Gonads (Testes or ovaries)	Liver	Breast gland
Product	Thyroxine	Cortisol	Testosterone or estradiol	IGF-1	Milk (no feedback)

Insulin-like growth factor 1 (IGF-1), also called somatomedin C => IGH => role in childhood growth and continues to have anabolic effects in adults.

The Pituitary Gland

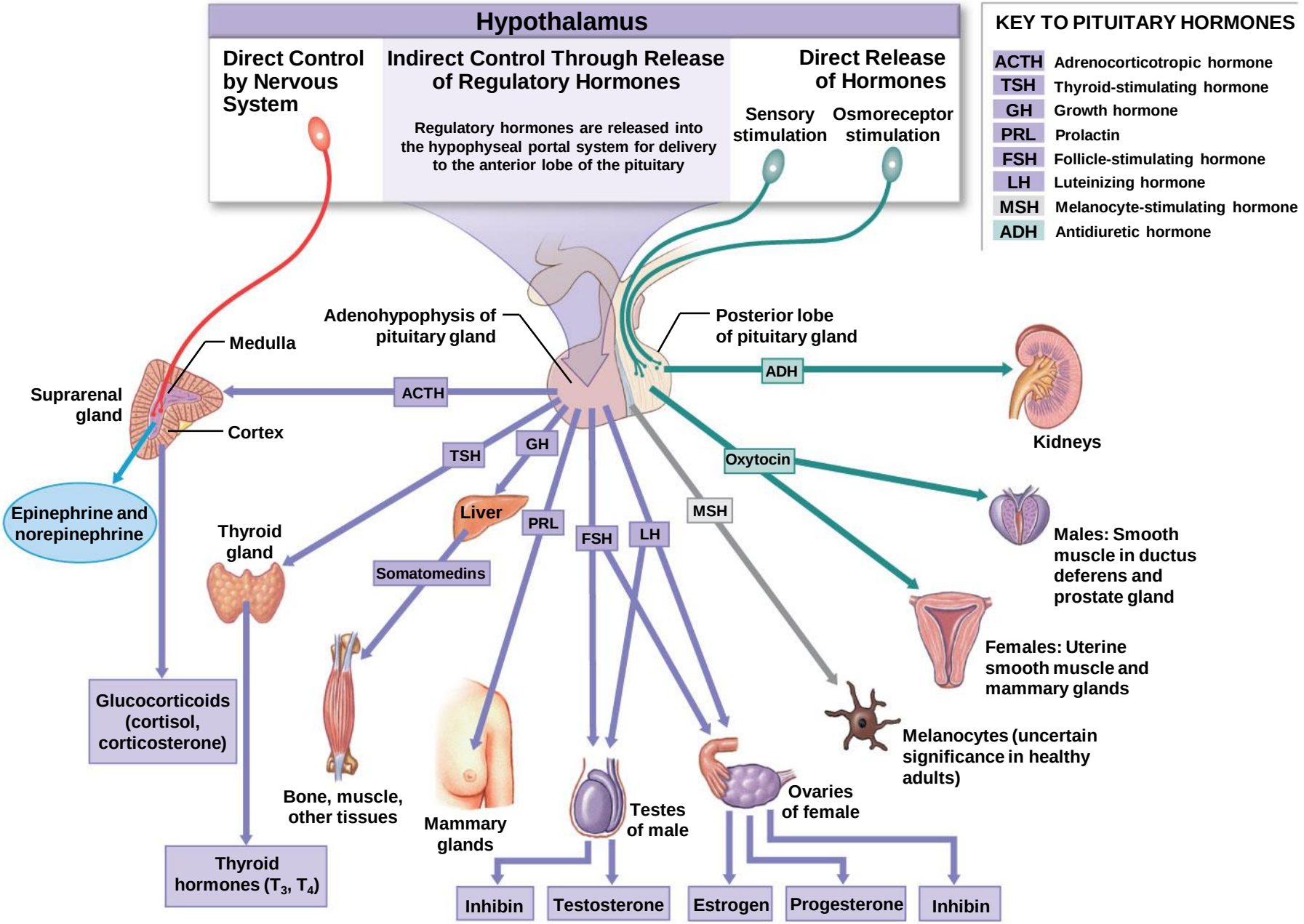
- The Hypophyseal Portal System
  - Within the infundibulum is a plexus of capillaries
    - Capillaries are **fenestrated**
    - **R**egulatory hormones leave the hypothalamus and pass through the portal vessels to the adenohypophysis

Figure The Pituitary Gland and the Hypophyseal Portal System$$$$$$



as Benjamin Cummings

Figure 19.4 Pituitary Hormones and Their Targets$$$$



CONCLUSION

- NERVOUS SYSTEM:
  - LOCAL RELEASE and LOCAL ACTION
- ENDOCRINE SYSTEM:
  - Gland SECRETION , BLOOD TRANSPORT, DISTANT ACTION
- Epiphyseal Gland= Pineal Gland
- Hypothalamus =RH (RHLH=GnRH)
- Anterior Hypophysis = SH (FSH)
- Target Organ: Gonades

Figure 17.8 Autonomic Distribution of the Parasympathetic Output

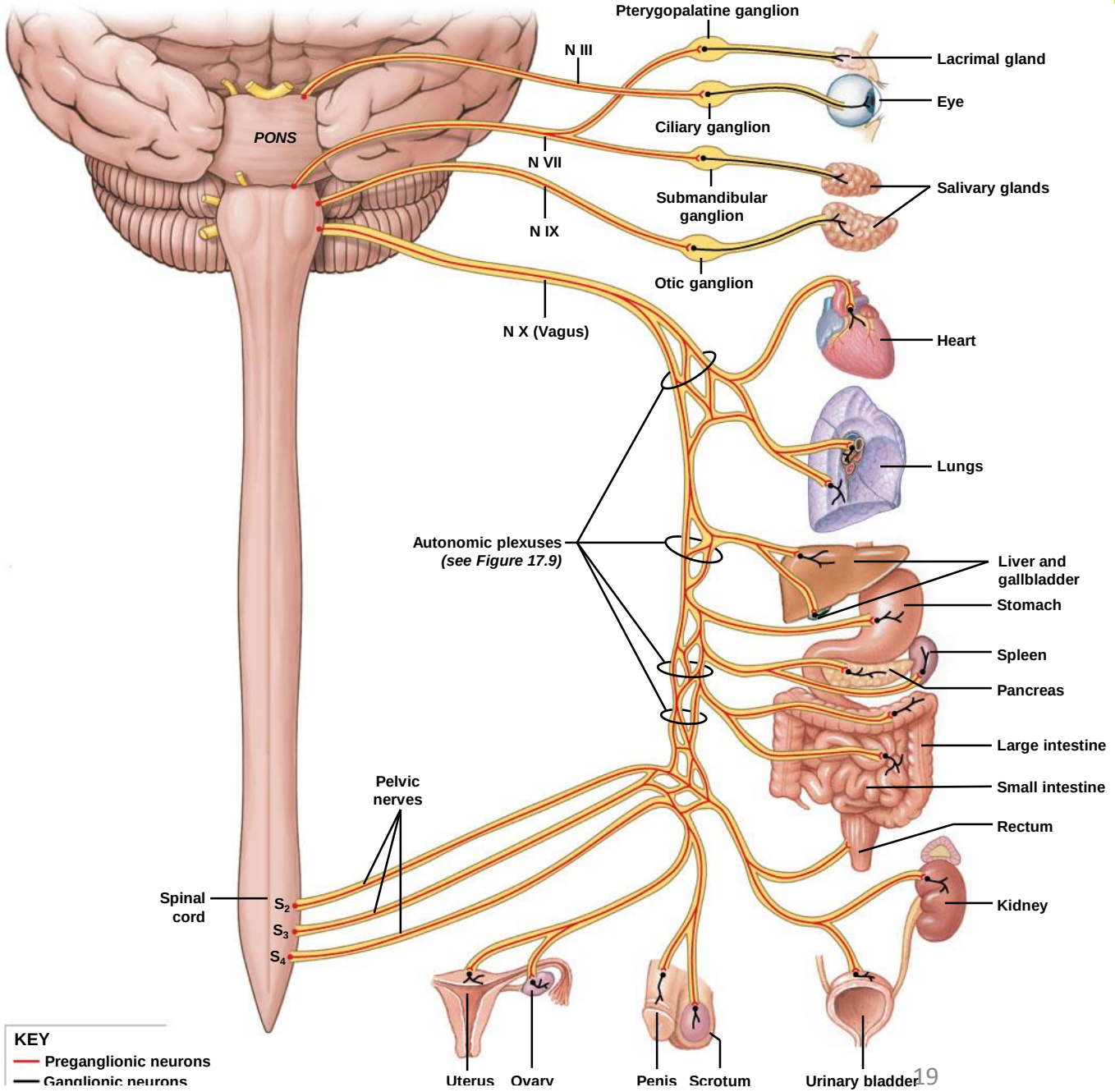


Figure 17.4 Anatomical Distribution of Sympathetic Postganglionic Fibers

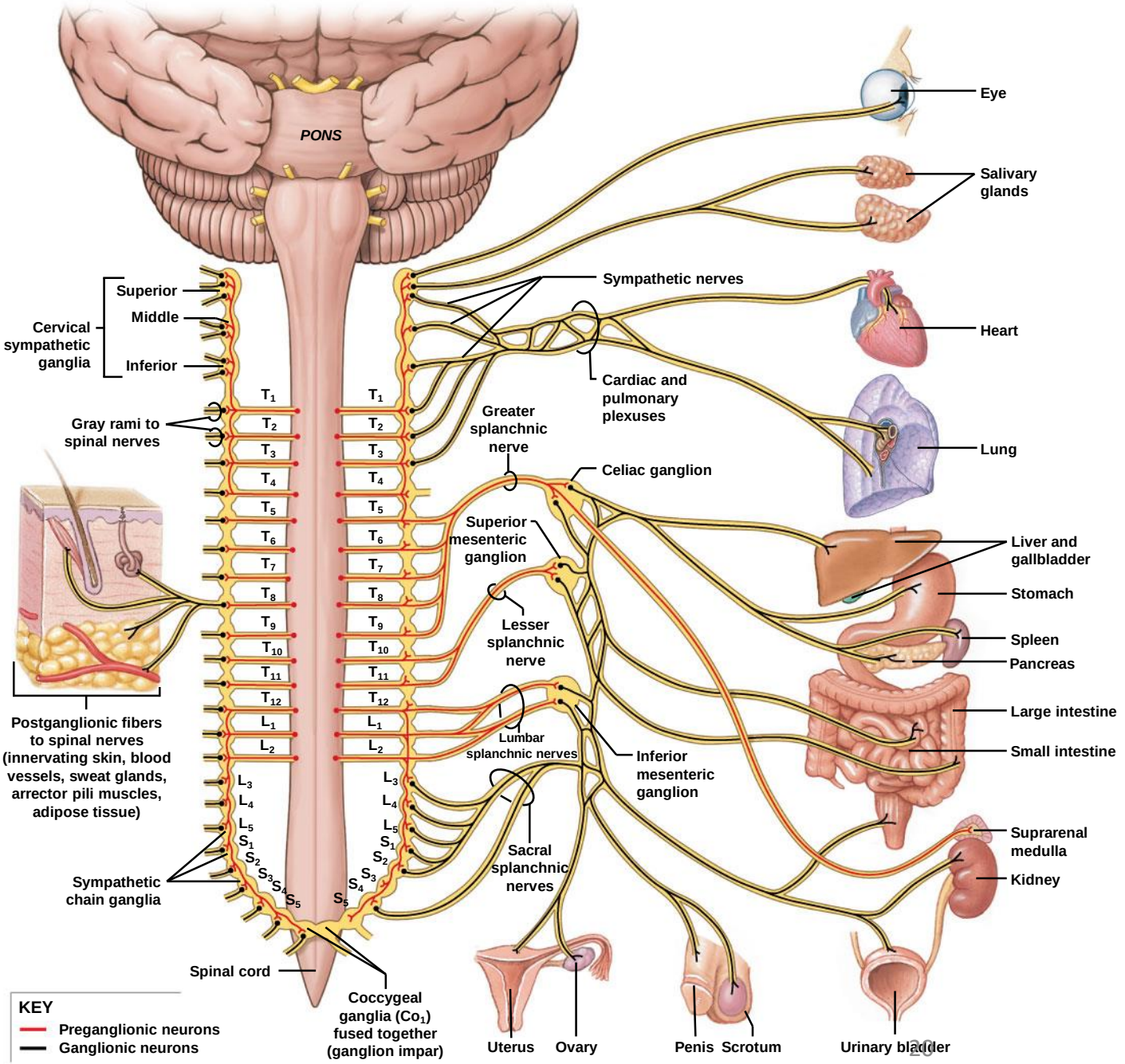
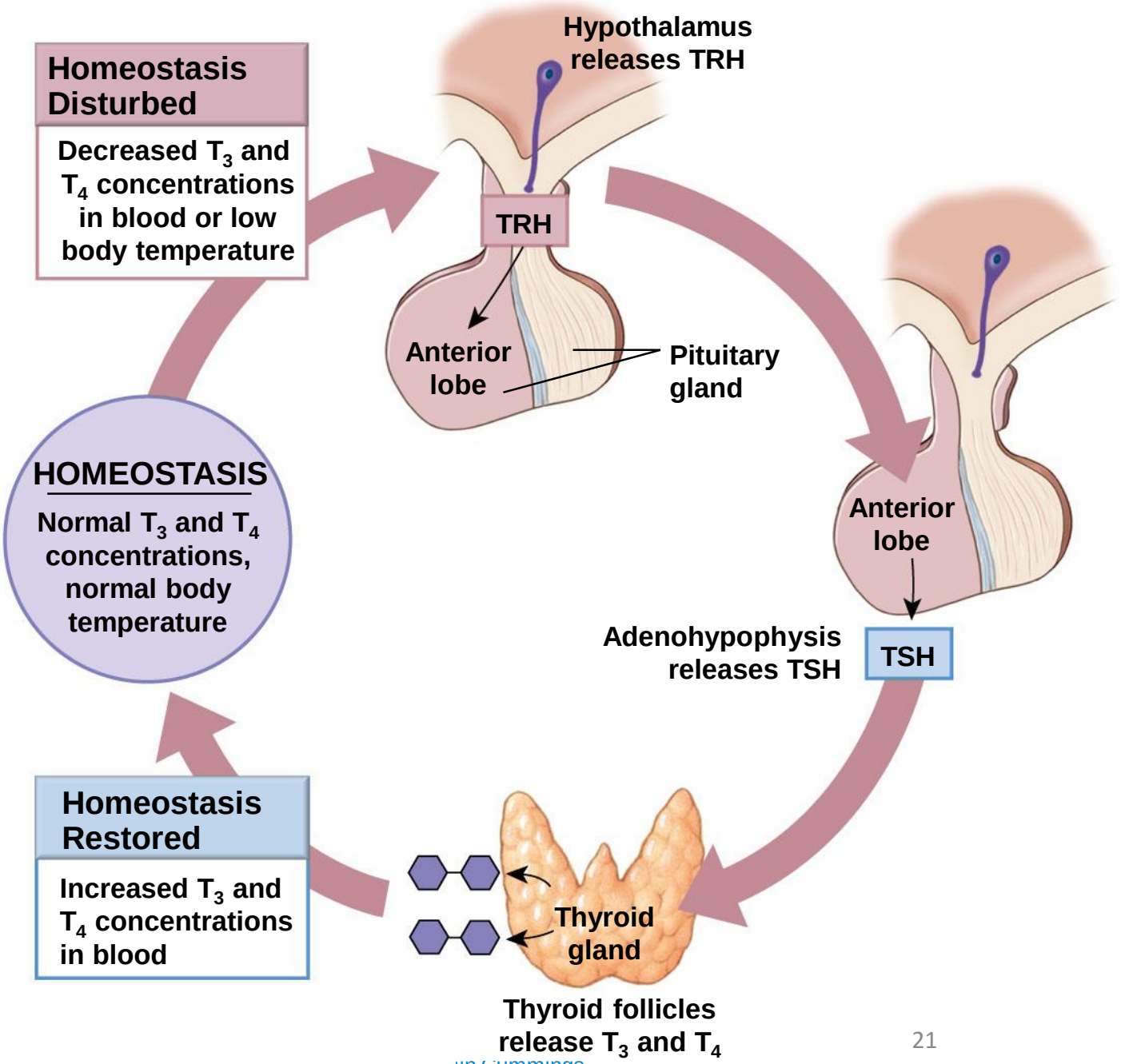


Figure The Regulation of Thyroid Secretion



NOW

- GROSS ANATOMY DISSECTION
- MODEL OBSERVATION
- DESCRIPTION
- LAB EXERCISES

Hormones

- Hormones – chemical substances secreted by cells into the extracellular fluids to the blood stream
  - Regulate the metabolic function of other cells
  - Have lag times ranging from seconds to hours
  - Tend to have prolonged effects
  - Are classified as amino acid-based hormones, or steroids
- Eicosanoids – biologically active lipids with local hormone–like activity

Hormone Action

- Hormones alter target cell activity by one of two mechanisms
  - Second messengers:
    - Regulatory G proteins
    - Amino acid–based hormones
  - Direct gene activation
    - Steroid hormones
- The precise response depends on the type of the target cell

Mechanism of Hormone Action

- Hormones produce one or more of the following cellular changes in target cells
  - Alter plasma membrane permeability
  - Stimulate protein synthesis
  - Activate or deactivate enzyme systems
  - Induce secretory activity
  - Stimulate mitosis

Amino Acid-Based Hormone Action: cAMP Second Messenger

- Hormone (first messenger) binds to its receptor, which then binds to a G protein
- The G protein is then activated as it binds GTP, displacing GDP
- Activated G protein activates the effector enzyme adenylate cyclase
- Adenylate cyclase generates cAMP (second messenger) from ATP
- cAMP activates protein kinases, which then cause cellular effects

Amino Acid-Based Hormone Action: cAMP Second Messenger

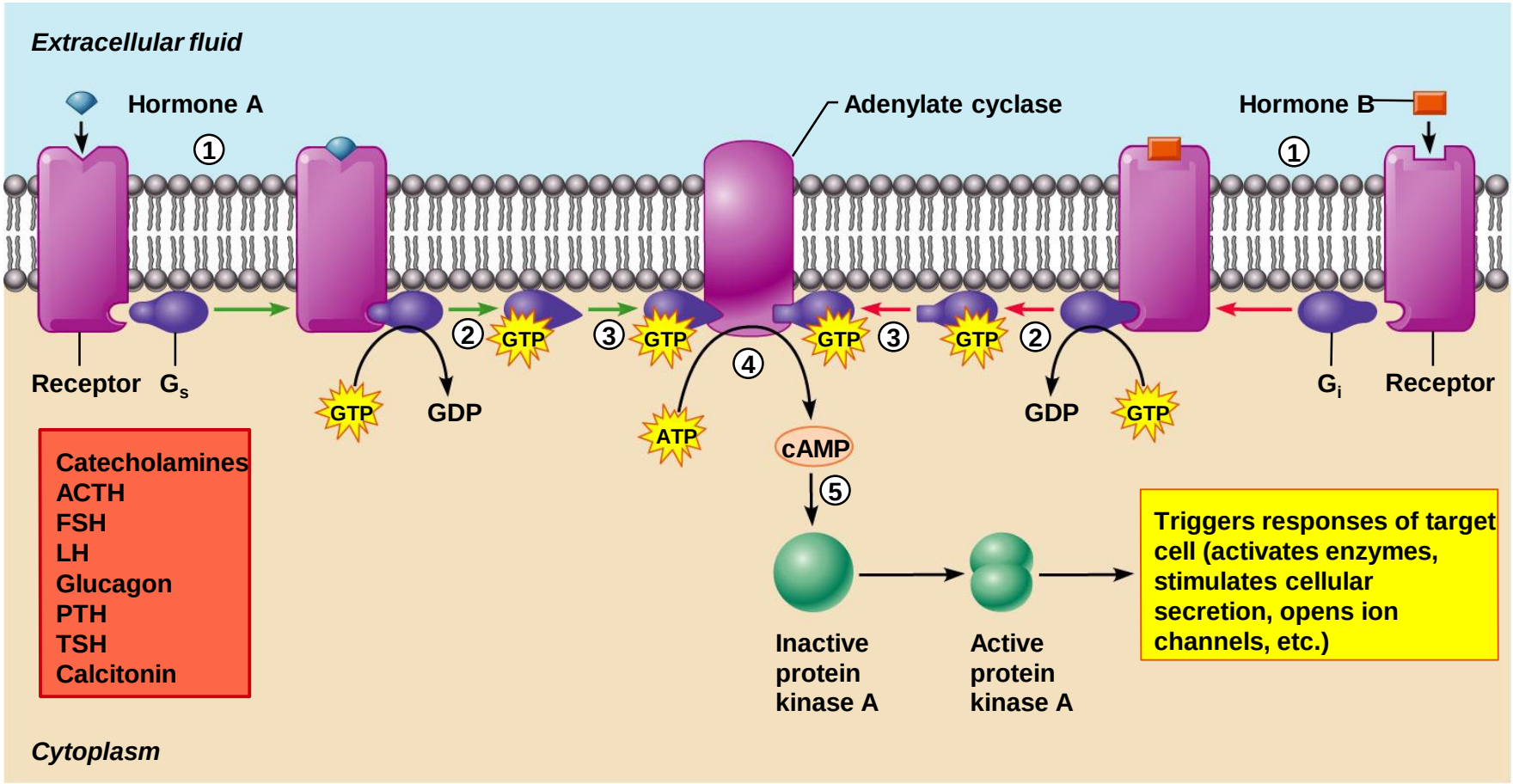


Figure 16.2

Amino Acid-Based Hormone Action: PIP-Calcium

- Hormone binds to the receptor and activates G protein
- G protein binds and activates phospholipase
- Phospholipase splits the phospholipid PIP_{2*} into diacylglycerol (DAG) and IP_3 (both act as second messengers)
- DAG activates protein kinases; IP_3 triggers release of Ca^{2+} stores
- Ca^{2+} (third messenger) alters cellular responses**

Amino Acid-Based Hormone Action: PIP Mechanism

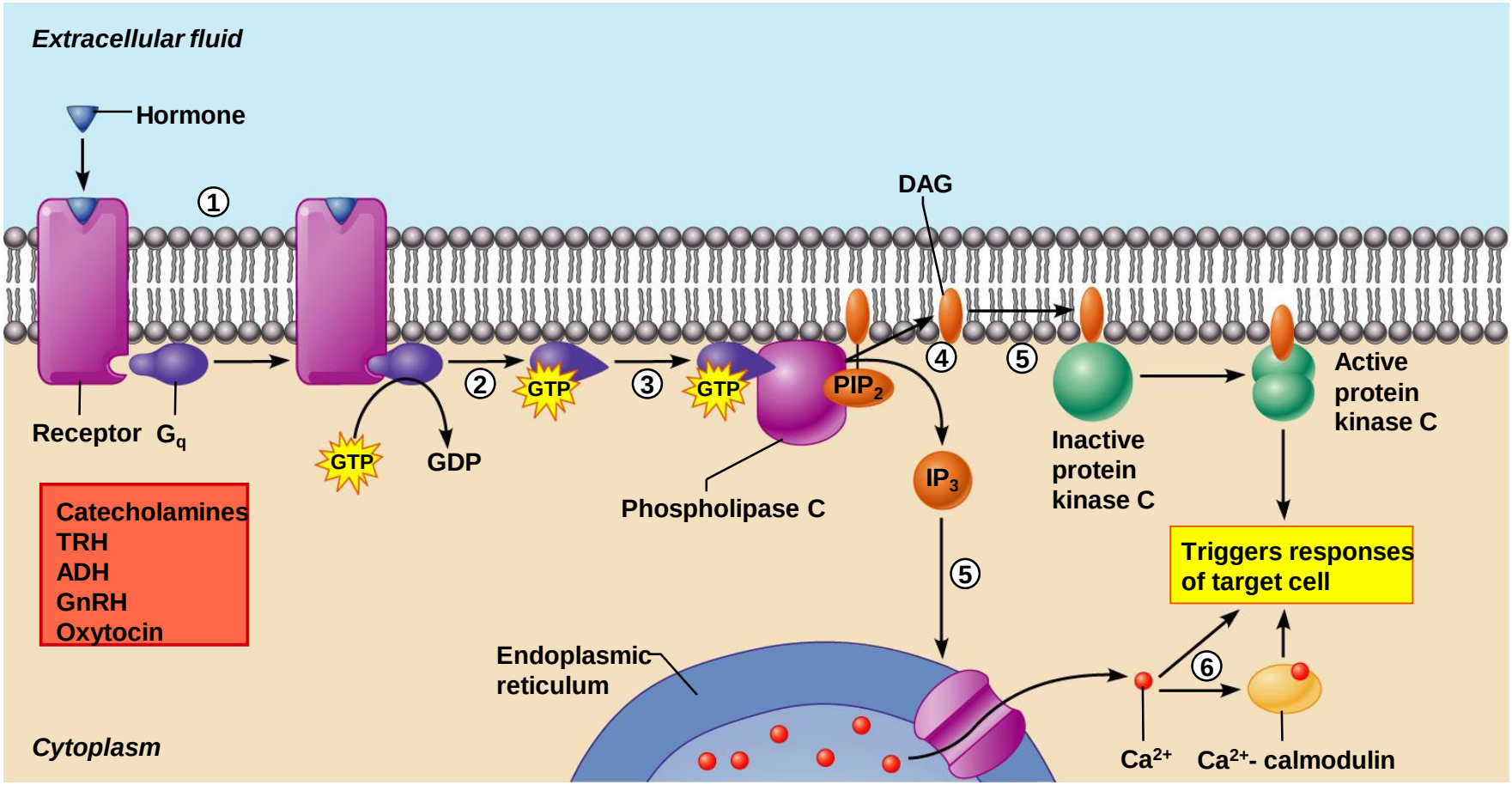


Figure 16.3

Steroid Hormones

- This interaction prompts DNA transcription to produce mRNA
- The mRNA is translated into proteins, which bring about a cellular effect

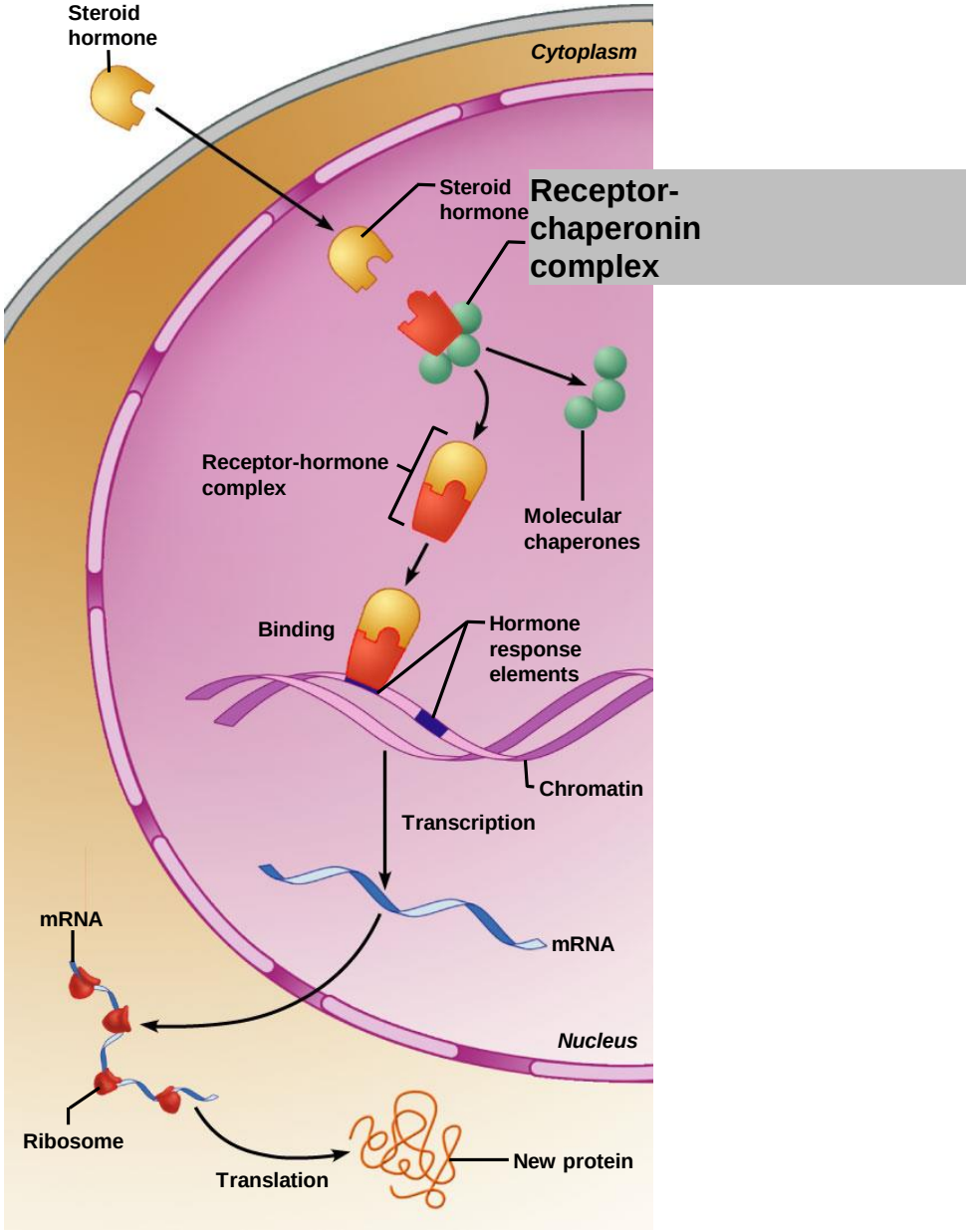


Figure 16.4

Target Cell Specificity

- Hormones circulate to all tissues but only activate cells referred to as target cells
- Target cells must have specific receptors to which the hormone binds
- These receptors may be intracellular or located on the plasma membrane

Target Cell Specificity

- Examples of hormone activity
  - ACTH receptors are only found on certain cells of the adrenal cortex
  - Thyroxin receptors are found on nearly all cells of the body

Target Cell Activation

- Target cell activation depends on three factors
  - Blood levels of the hormone
  - Relative number of receptors on the target cell
  - The affinity of those receptors for the hormone
- Up-regulation – target cells form more receptors in response to the hormone
- Down-regulation – target cells lose receptors in response to the hormone

Hormone Concentrations in the Blood

- Hormones circulate in the blood in two forms – free or bound
  - Steroids and thyroid hormone are attached to plasma proteins*
  - All others are unencumbered

Hormone Concentrations in the Blood

- Concentrations of circulating hormone reflect:
  - Rate of release
  - Speed of inactivation and removal from the body
- Hormones are removed from the blood by$$$$$:
  - Degrading enzymes
  - The kidneys
  - Liver enzyme systems

Interaction of Hormones at Target Cells

- Three types of hormone interaction
  - Permissiveness – one hormone cannot exert its effects without another hormone being present
  - Synergism – more than one hormone produces the same effects on a target cell
  - Antagonism – one or more hormones opposes the action of another hormone

Control of Hormone Release

- Blood levels of hormones:
  - Are controlled by negative feedback systems
  - Vary only within a narrow desirable range
- Hormones are synthesized and released in response to:
  - Humoral stimuli (blood)
  - Neural stimuli
  - Hormonal stimuli

Humoral Stimuli

- Humoral stimuli – secretion of hormones in direct response to changing blood levels of ions and nutrients
- Example: concentration of calcium ions in the blood
  - Declining blood Ca^{2+} concentration stimulates the parathyroid glands to secrete PTH (parathyroid hormone)
  - PTH causes Ca^{2+} concentrations to rise and the stimulus is removed

Humoral Stimuli

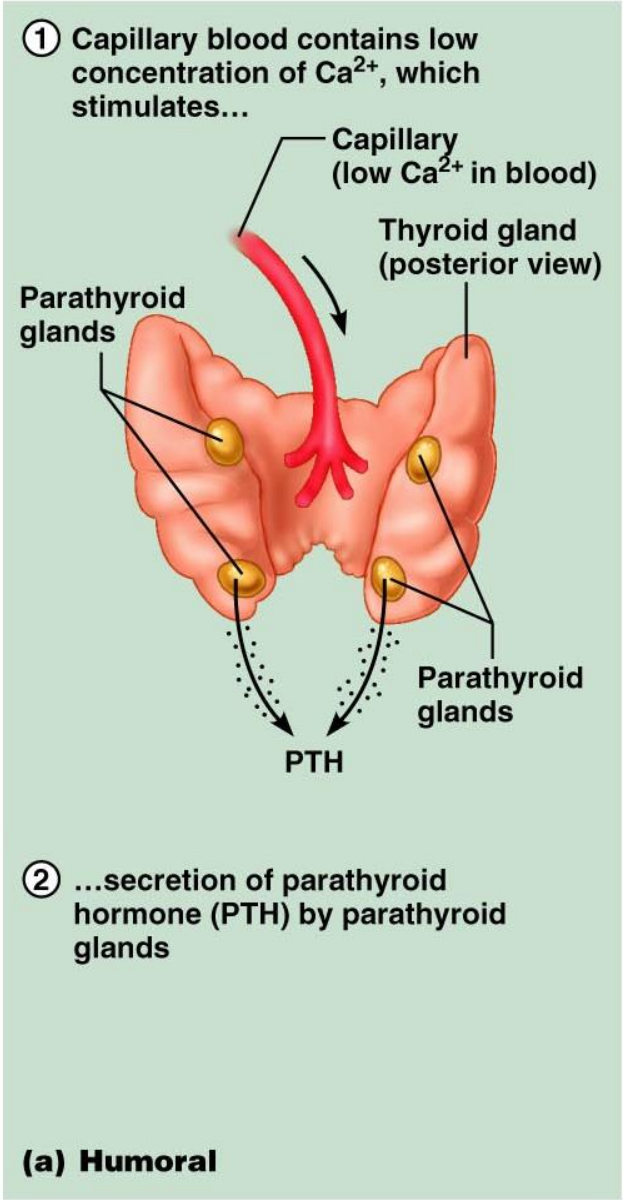


Figure 16.5a

Neural Stimuli

- Neural stimuli – nerve fibers stimulate hormone release
  - Preganglionic sympathetic nervous system (SNS) fibers stimulate the adrenal medulla to secrete catecholamines* NA, A
    - http://upload.wikimedia.org/wikipedia/commons/8/89/Noradrenalin_-_Noradrenaline.svg
    - http://upload.wikimedia.org/wikipedia/commons/3/36/Adrenalin_-_Adrenaline.svg

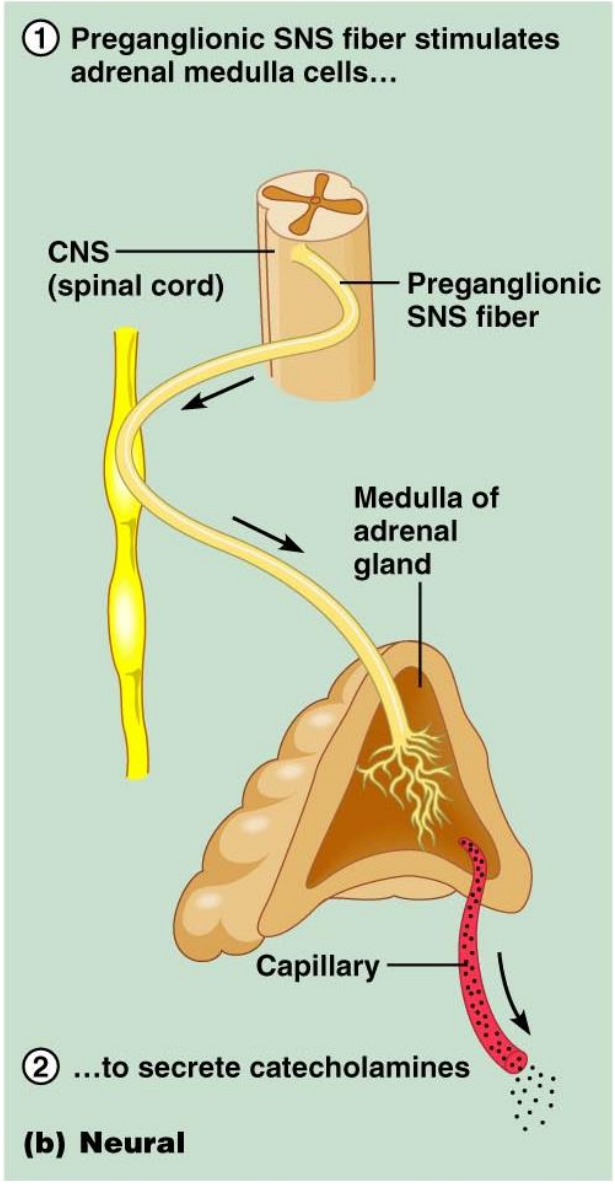


Figure 16.5b

Hormonal Stimuli

- Hormonal stimuli – release of hormones in response to hormones produced by other endocrine organs
  - The hypothalamic hormones stimulate the anterior pituitary
  - In turn, pituitary hormones stimulate targets to secrete still more hormones

Hormonal Stimuli$$$$

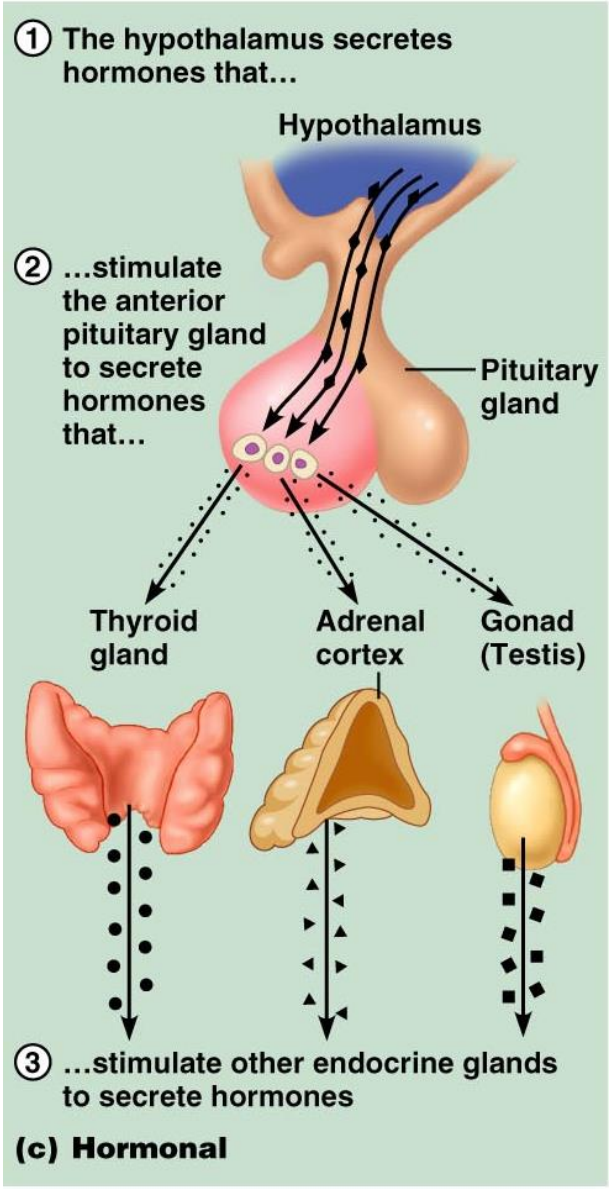


Figure 16.5c

Nervous System Modulation

- The nervous system can override normal endocrine controls
  - For example, control of blood glucose levels
    - Normally the endocrine system maintains blood glucose
    - Under stress, the body needs more glucose
    - The hypothalamus and the sympathetic nervous system are activated to supply ample glucose

Major Endocrine Organs: Pituitary Gland (Hypophysis)

- Pituitary gland – two-lobed organ that secretes nine major hormones
- Neurohypophysis – posterior lobe (neural tissue) and the infundibulum
  - Receives, stores, and releases hormones from the hypothalamus
- Adenohypophysis – anterior lobe, made up of glandular tissue
  - Synthesizes and secretes a number of hormones

Major Endocrine Organs: Pituitary Gland (Hypophysis)

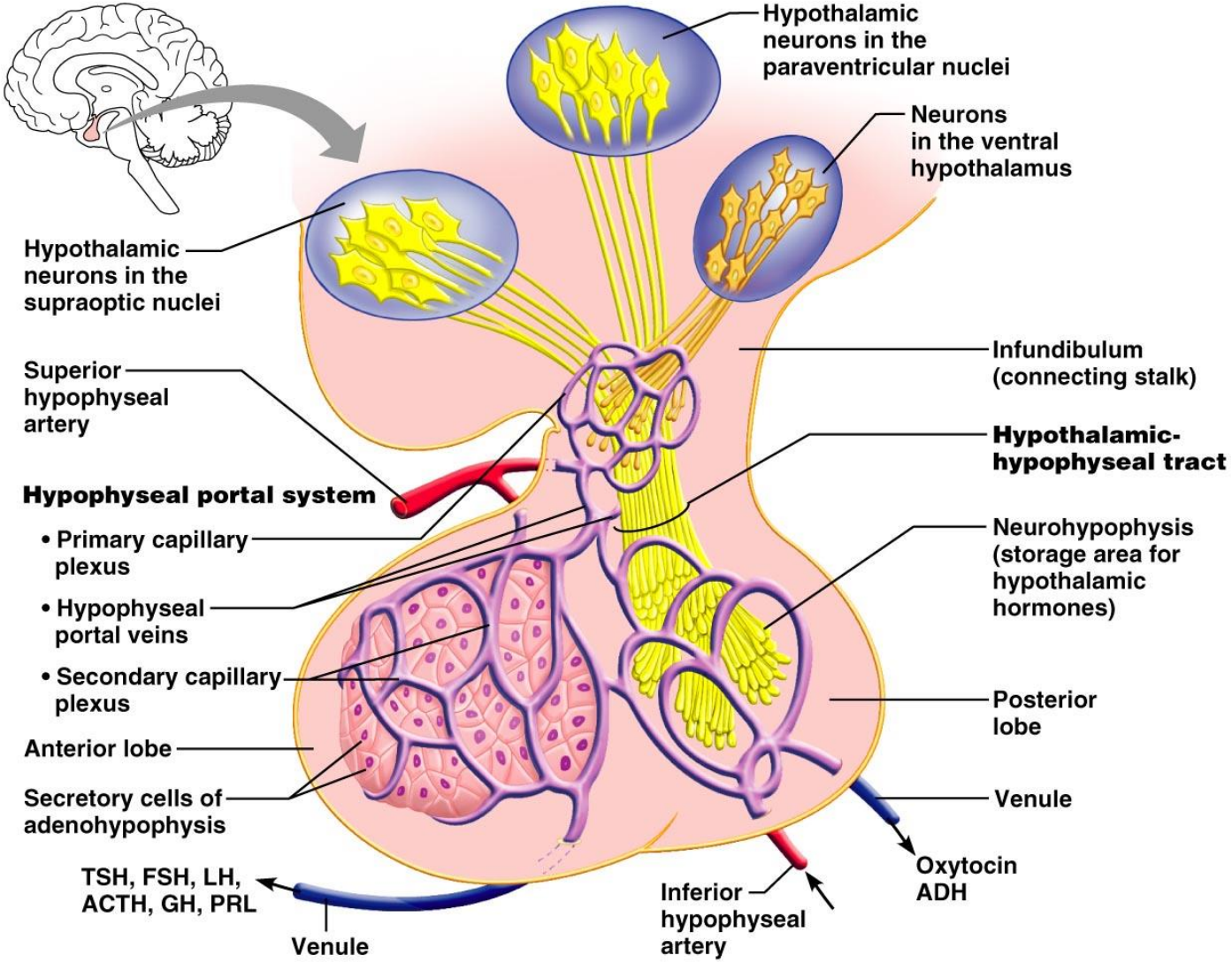


Figure 16.6

Pituitary-Hypothalamic Relationships: Posterior Lobe

- The posterior lobe is a downgrowth of hypothalamic neural tissue
- Has a neural connection with the hypothalamus (hypothalamic-hypophyseal tract)
- Nuclei (of what?) of the hypothalamus synthesize oxytocin and antidiuretic hormone (ADH)

Pituitary-Hypothalamic Relationships: Anterior Lobe

- The anterior lobe of the pituitary is an outpocketing of the oral mucosa
- There is no direct neural contact with the hypothalamus

Pituitary-Hypothalamic Relationships: Anterior Lobe

- There is a vascular connection, the hypophyseal portal system, consisting of:
  - The primary capillary plexus
  - The hypophyseal portal veins
  - The secondary capillary plexus

PLAY

***InterActive Physiology* ®: The Hypothalamic Pituitary Axis**

Pituitary-Hypothalamic Relationships: Anterior Lobe

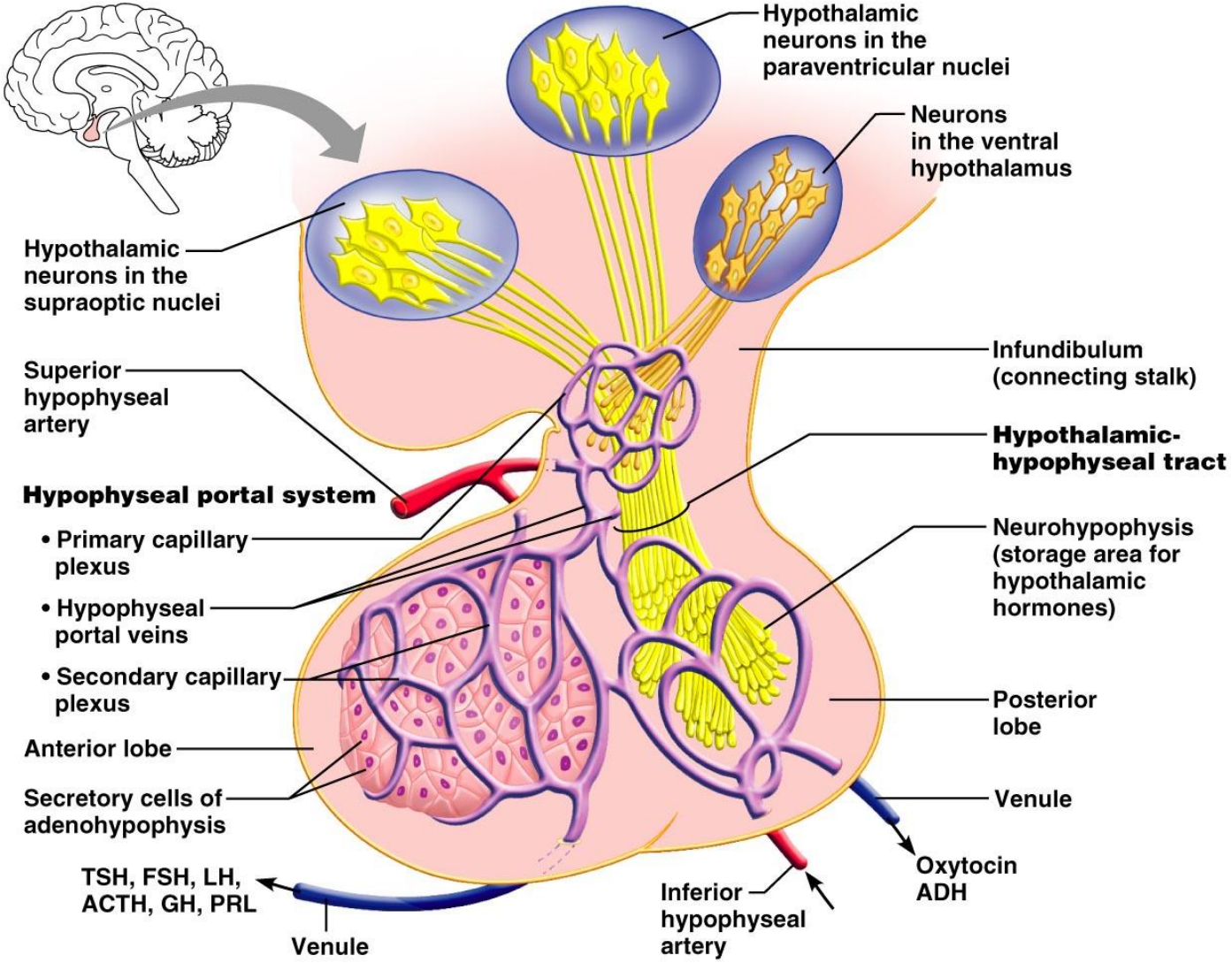


Figure 16.6

Adenophypophyseal Hormones

- The six hormones of the adenohypophysis:
  - Abbreviated as GH, TSH, ACTH, FSH, LH, and PRL
  - Regulate the activity of other endocrine glands
- In addition, pro-opiomelanocortin (POMC):
  - Has been isolated from the pituitary
  - Is split into ACTH, opiates, and MSH

Activity of the Adenophypophysis

- The hypothalamus sends a chemical stimulus to the anterior pituitary
  - Releasing hormones stimulate the synthesis and release of hormones
  - Inhibiting hormones shut off the synthesis and release of hormones

Activity of the Adenophypophysis

- The tropic hormones that are released are:
  - Thyroid-stimulating hormone (TSH)
  - Adrenocorticotropic hormone (ACTH)
  - Follicle-stimulating hormone (FSH)
  - Luteinizing hormone (LH)

Growth Hormone (GH)

- Produced by somatotropic cells of the anterior lobe that:
  - Stimulate most cells, but target bone and skeletal muscle
  - Promote protein synthesis and encourage the use of fats for fuel
- Most effects are mediated indirectly by somatomedins

Growth Hormone (GH)

- Antagonistic hypothalamic hormones regulate GH
  - Growth hormone–releasing hormone (GHRH) stimulates GH release
  - Growth hormone–inhibiting hormone (GHIH) inhibits GH release

Metabolic Action of Growth Hormone

- GH stimulates liver, skeletal muscle, bone, and cartilage to produce insulin-like growth factors
- Direct action promotes lipolysis and inhibits glucose uptake

Metabolic Action of Growth Hormone

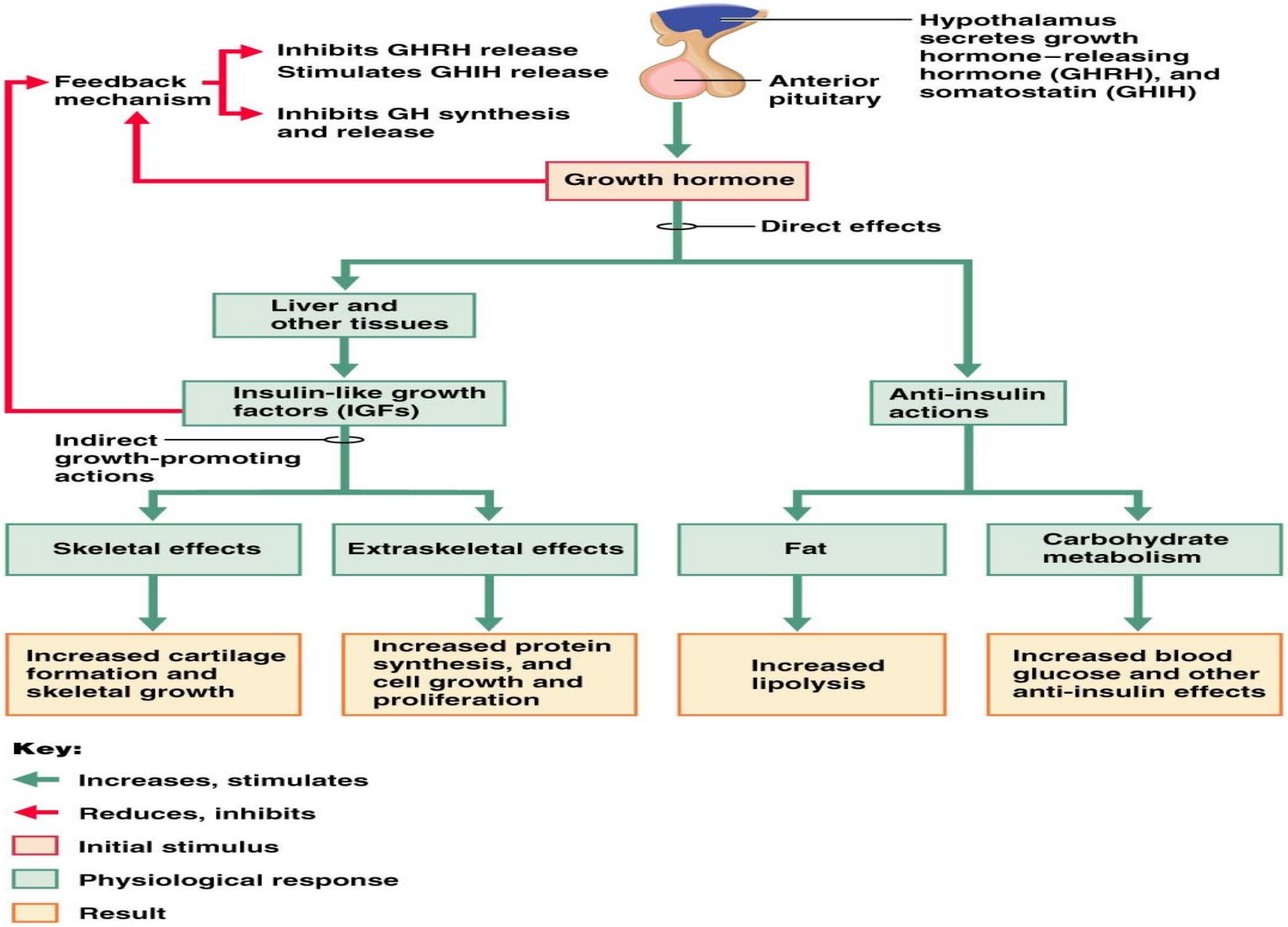


Figure 16.7

Thyroid Stimulating Hormone (Thyrotropin)

- Stimulates the normal development and secretory activity of the thyroid
- Triggered by hypothalamic peptide thyrotropin-releasing hormone (TRH)
- Rising blood levels of thyroid hormones act on the pituitary and hypothalamus to block the release of TSH

Adrenocorticotropic Hormone (Corticotropin)

- Stimulates the adrenal cortex to release corticosteroids
- Triggered by hypothalamic corticotropin-releasing hormone (CRH) in a daily rhythm
- Internal and external factors such as fever, hypoglycemia, and stressors can trigger the release of CRH

Gonadotropins

- Gonadotropins – follicle-stimulating hormone (FSH) and luteinizing hormone (LH)
  - Regulate the function of the ovaries and testes
  - FSH stimulates gamete (egg or sperm) production
  - Absent from the blood in prepubertal boys and girls
  - Triggered by the hypothalamic gonadotropin-releasing hormone (GnRH) during and after puberty

Functions of Gonadotropins

- In females
  - LH works with FSH to cause maturation of the ovarian follicle
  - LH works alone to trigger ovulation (expulsion of the egg from the follicle)
  - LH promotes synthesis and release of estrogens and progesterone

Functions of Gonadotropins

- In males
  - LH stimulates interstitial cells of the testes to produce testosterone
  - LH is also referred to as interstitial cell-stimulating hormone (ICSH)

Prolactin (PRL)

- In females, stimulates milk production by the breasts
- Triggered by the hypothalamic prolactin-releasing hormone (PRH)
- Inhibited by prolactin-inhibiting hormone (PIH)
- Blood levels rise toward the end of pregnancy
- Suckling stimulates PRH release and encourages continued milk production

The Posterior Pituitary and Hypothalamic Hormones

- Posterior pituitary – made of axons of hypothalamic neurons, stores antidiuretic hormone (ADH) and oxytocin
- ADH and oxytocin are synthesized in the hypothalamus
- ADH influences water balance
- Oxytocin stimulates smooth muscle contraction in breasts and uterus
- Both use PIP-calcium second-messenger mechanism