Homeostasis 1: Intro to the ANS and Endocrine System

Definition and Overview:

- Body's ability to dynamically maintain a relatively stable inside environment- in order to meet its needs- even though the outside world changes continuously

→ *eg* Blood levels of vital nutrients, heart activity, blood pressure/supply to all tissues, waste levels

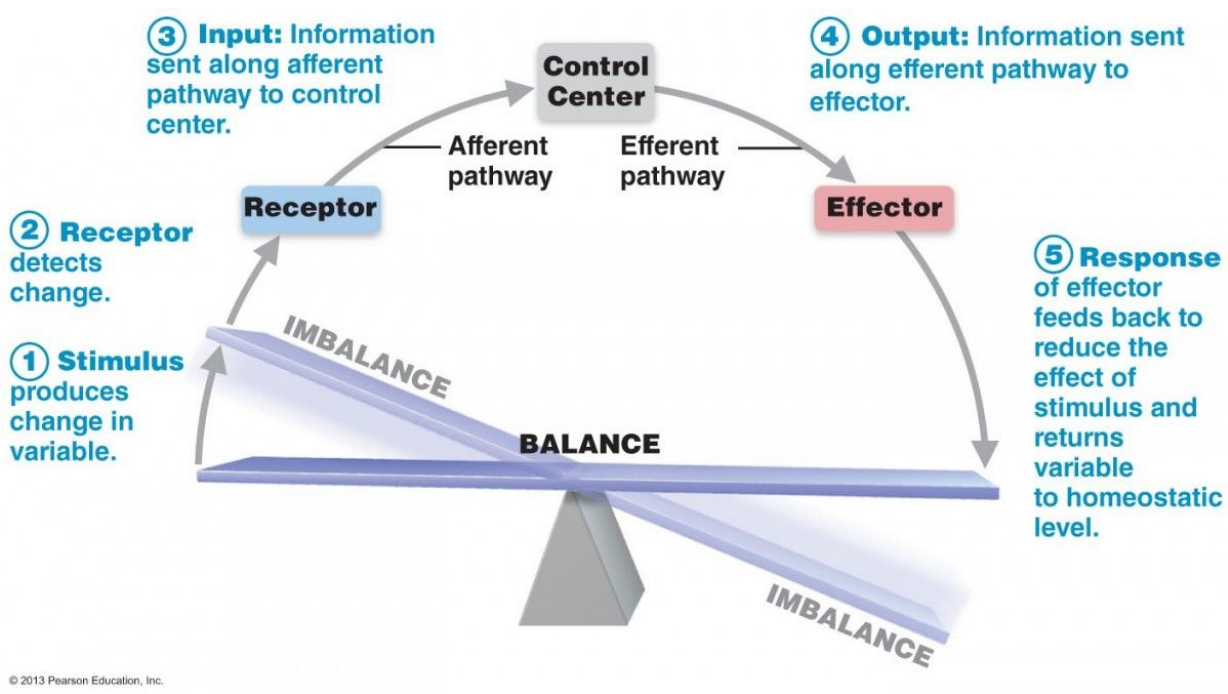
- *Complex*: Virtually every organ system plays a role

→ Wide variety of chemical, thermal and neural factors interact, chiefly via nervous and endocrine system

Components:

- **Receptors:** Sensor monitors a variable in body
- **Control Center:** Determines set point - desired level/range for variable
- **Effector:** Means for control center's response

→ Most control *via negative feedback*

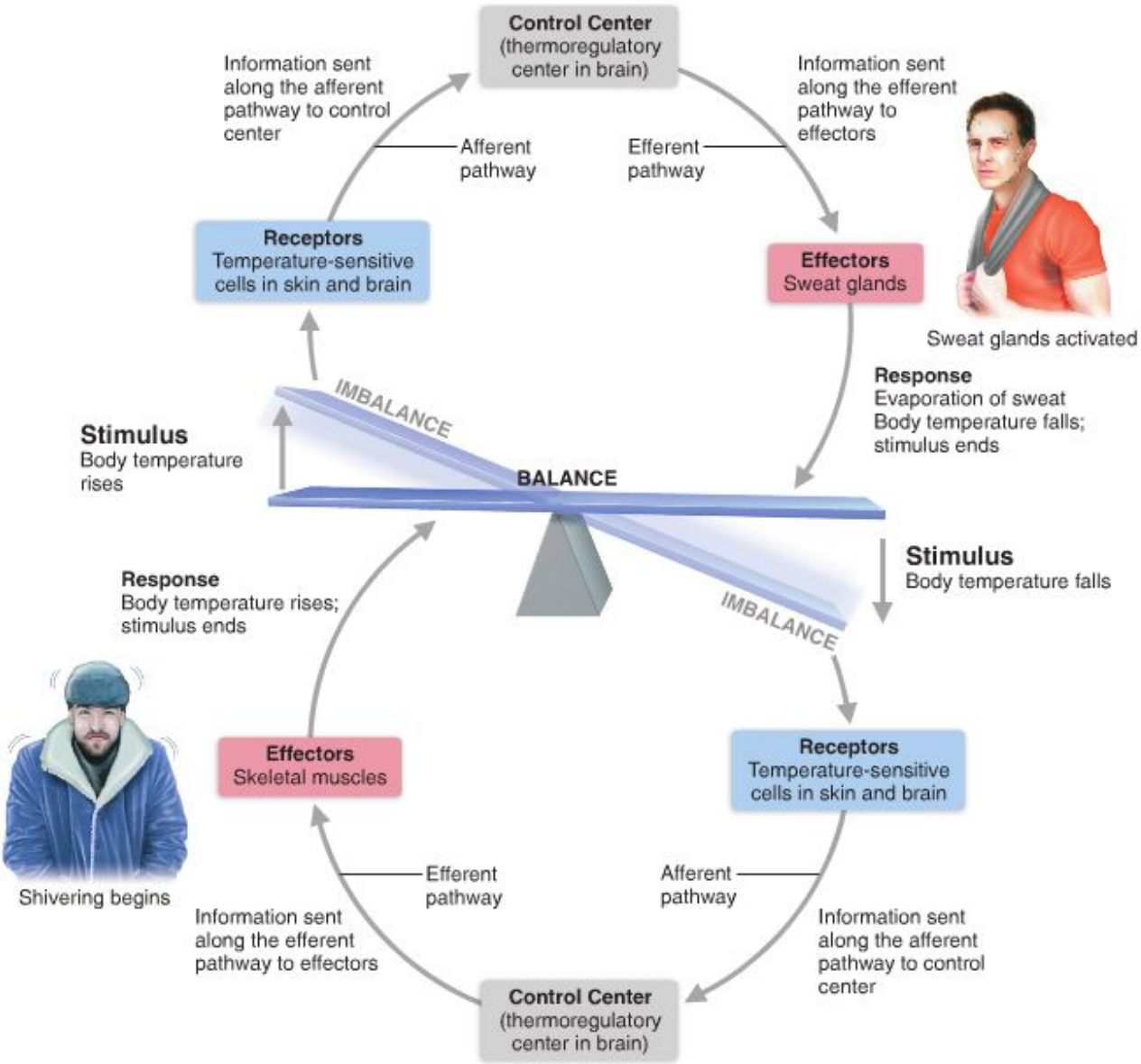


Negative Feedback Mechanisms

- Response of effector to a stimulus shuts off/reduces original stimulus
- Returns system to ideal state

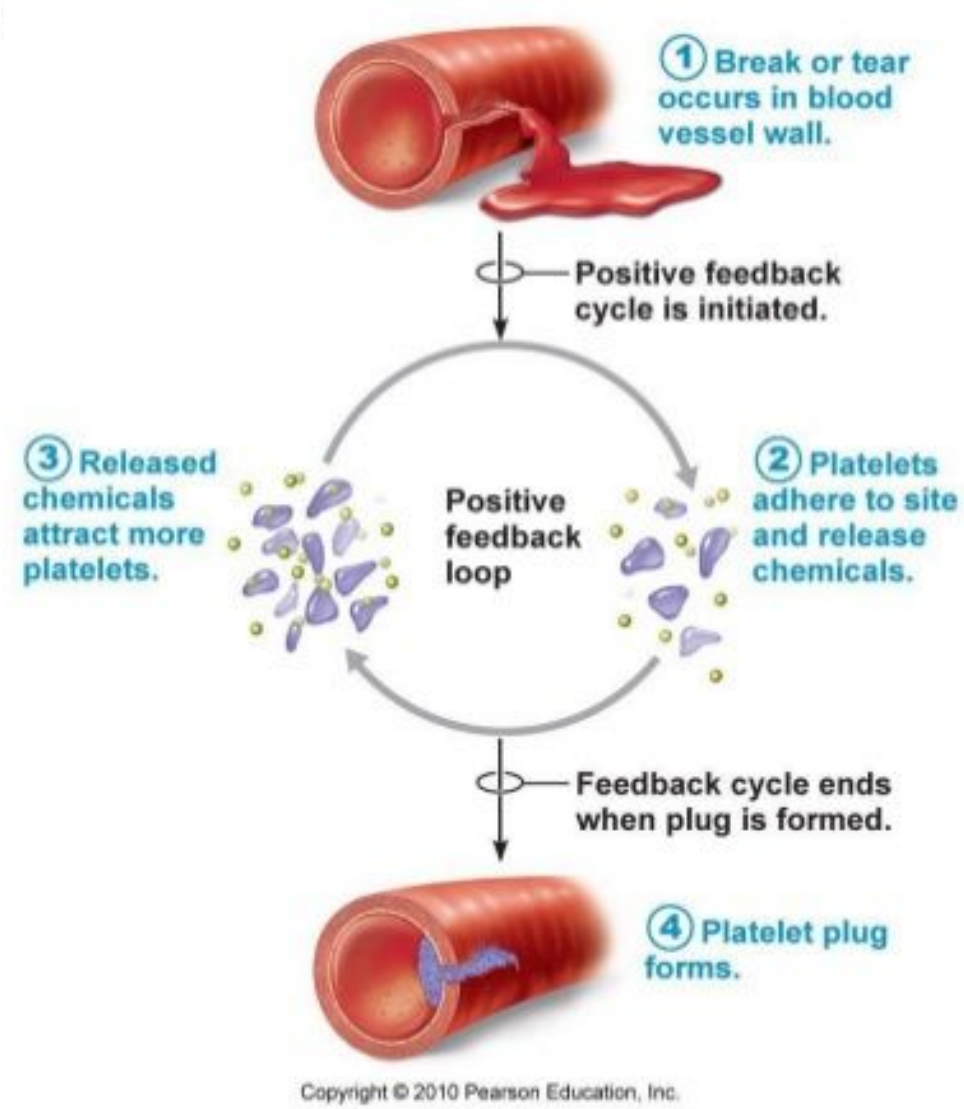
Examples:

- *Body temperature* (shown)
- Insulin control of *blood sugar* - rise in blood sugar
- Increased secretion of *insulin* which raises blood sugar



Positive Feedback Mechanisms

- Response of effector feeds back to enhance the effect of the stimulus and accelerates the response, *eg:*
    - Enhancement of labour contractions by oxytocin from hypothalamus
        - Both continue to increase: More contractions→ ← more oxytocin
    - Blood clotting (Nov)
- Both typical positive feedback cascades self-perpetuating
    - Can race out-of-control, so not used for movement-to-movement homeostasis

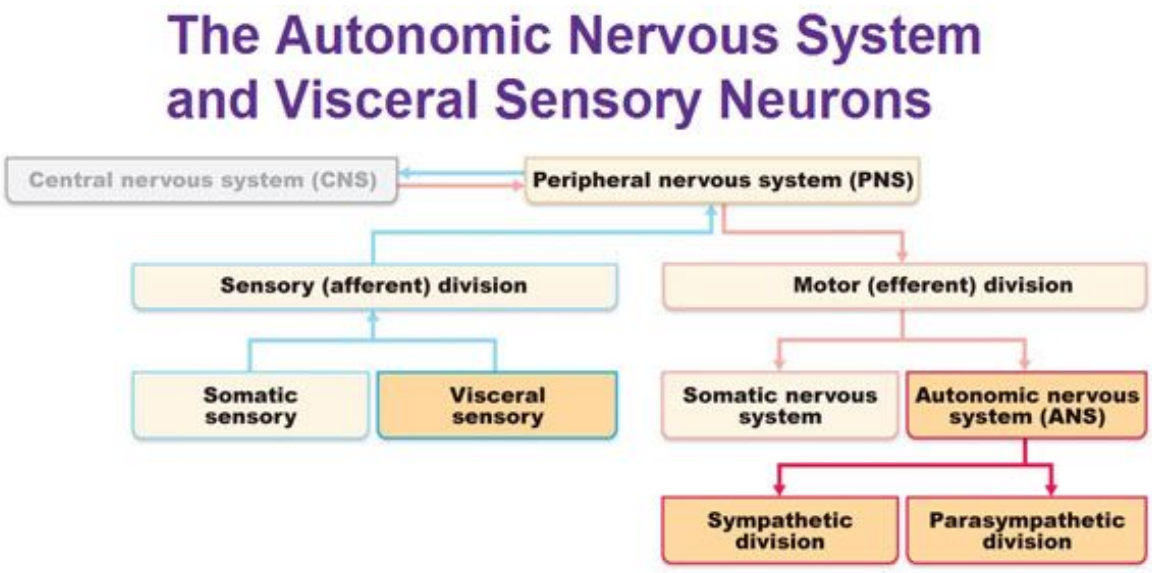


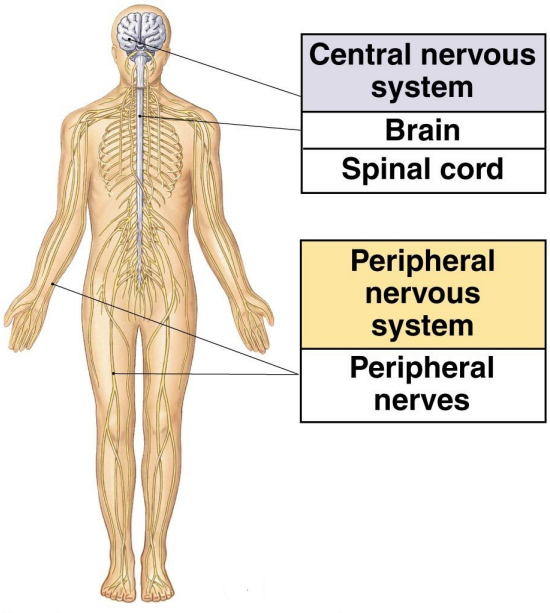
Definition: 'Homeostatic Imbalance'

Definition:

- Most diseases - and normal aging- can be regarded as a result of disturbance of homeostasis
- Examples of *Homeostatic Imbalance* will be given throughout course, as we've already seen
- *DO NOT* confuse 'homeopathy' with 'homeostasis'

Place of ANS In Nervous System





***Autonomic Nervous System: "The system of motor neurons that innervates smooth and cardiac muscle and glands" *(p 528)*

We will see in subsequent lectures that there is a sensory component to the Autonomic Nervous System.

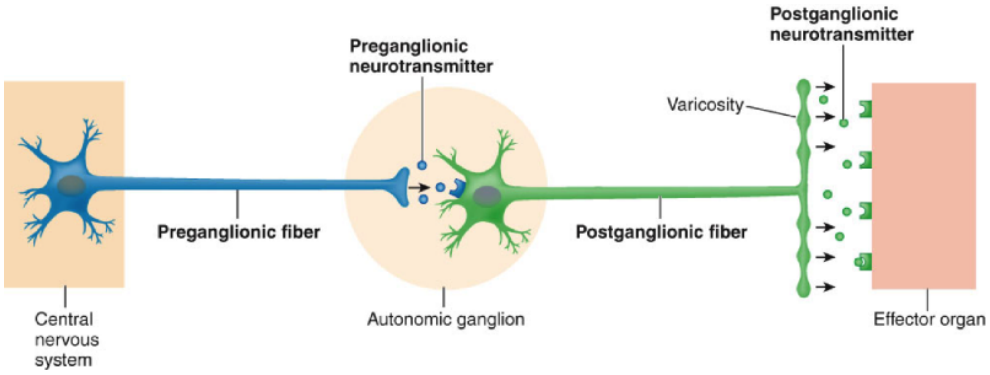
The Autonomic Nervous System

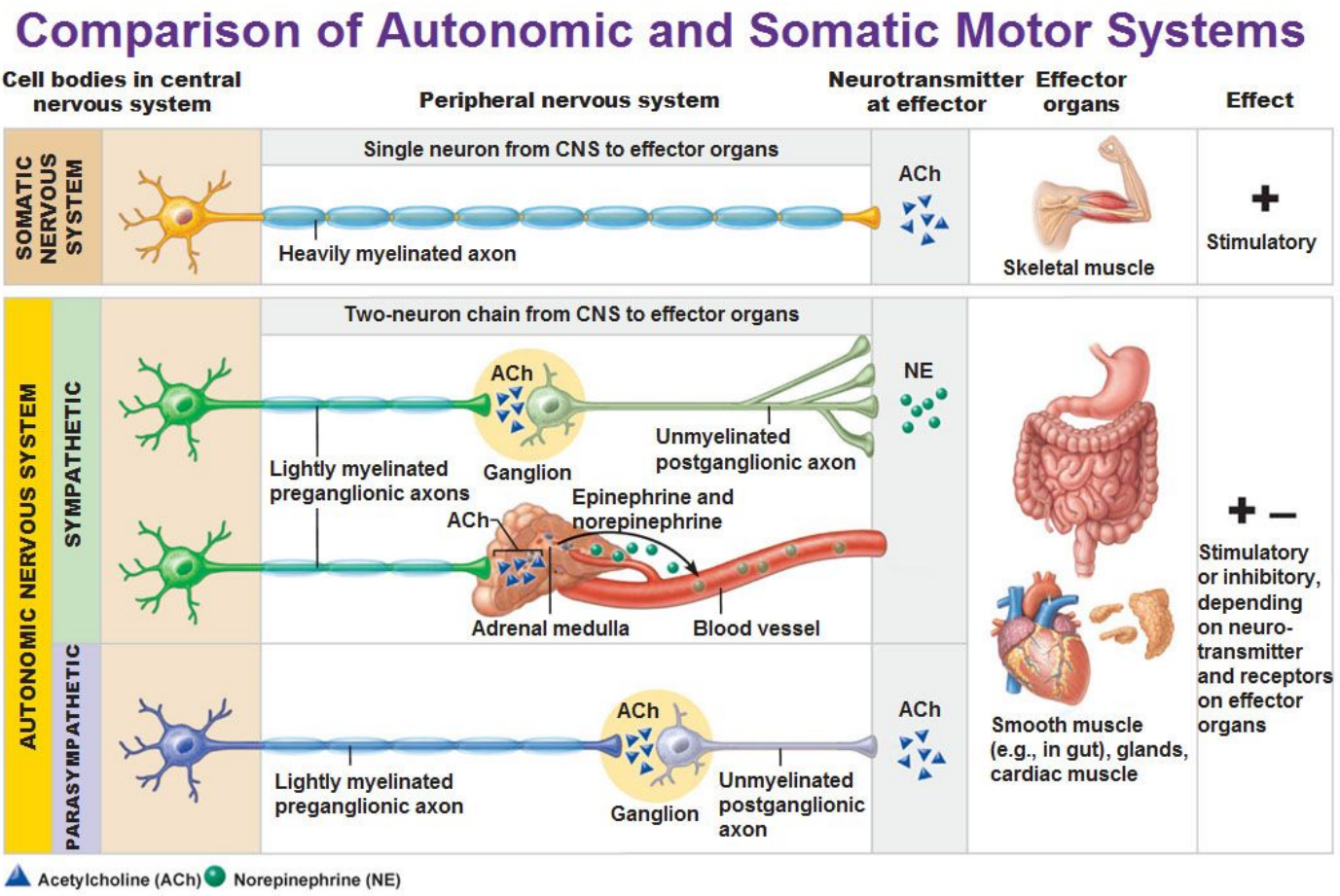
- Principle System that stabilizes our internal environment
    - Motor neurons: Innervates smooth/cardiac muscle, glands
        - Respond to sensory signals from internal (visceral) organs
    - General Functions:
        - Ensures optimal support for body activities
        - Shunts blood to 'needy' areas
        - Speeds up/slows down heart (increased HR, decreased HR)
        - Blood Pressure (BP), body temperature (T), increase or decrease
        - Stomach secretions increase or decrease
    - *Mostly* without our awareness, attention or control
        - *Aka* involuntary nervous system or general visceral motor system

Somatic/Autonomic Nervous Systems

Differ as Follows:

- Organs Innervated (***Effectors***)
    - Somatic Nervous System: Skeletal muscle
    - Autonomic Nervous System: Smooth/cardiac muscle, glands
- Connections with Effectors (***Efferent Pathways***)
    - *Somatic*: 1-neuron chain. Axons → organs innervated
    - *Autonomic*: 2-neuron chain, intermediate **ganglion**
        1. **Preganglionic neuron** in CNS
            a. *Preganglionic axon* synapses in ganglion with 2nd neuron
        2. **Postganglionic neuron** outside of CNS or in PNS
            a. *Postganglionic axon* → effector





	Somatic	Autonomic
Target Organ	Skeletal muscle	Smooth/cardiac muscle, glands
Pathway	Thick, myelinated axon from spinal cord to skeletal muscle	Two-neuron chain: Preganglionic neuron originates in brain or spinal cord- preganglionic axon synapses with 2nd motor neuron (postganglionic) in ganglion outside CNS, -postganglionic axon to effector organ
Axonal Fibers	No ganglia	Has ganglia
Neurotransmitter	Rapid conduction of impulses	Conduction is slow; preganglionic axons are thin

		& lightly myelinated; postganglionic axons are thinner & unmyelinated
Effect	Look ^	Look ^

Body's response to changing external/internal conditions involves <u>both</u> somatic and autonomic nervous systems.

<u>ANS Divisions</u>

ANS has two arms:

- Usually produce opposite effects for homeostasis:
    - Parasympathetic: Digestion, Defecation, Diuresis
    - Sympathetic: Exercise, Excitement, Emergency

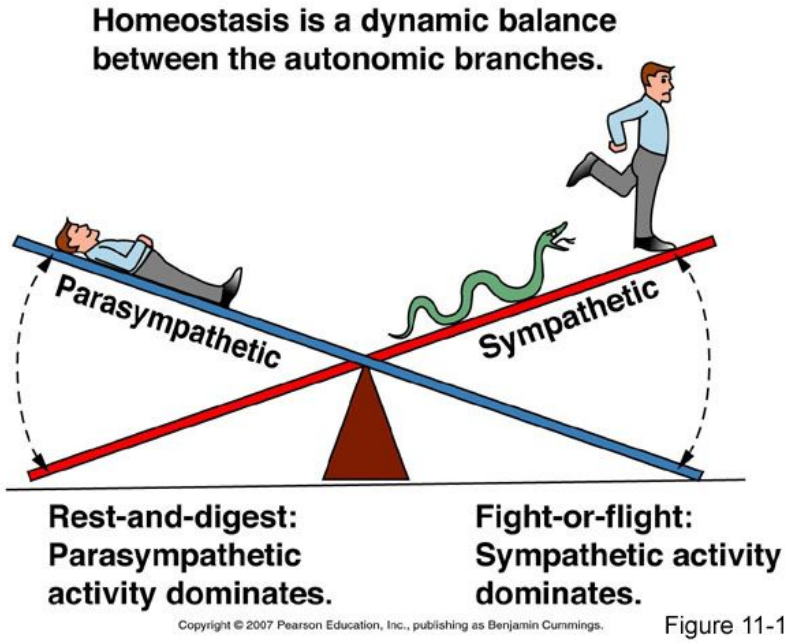


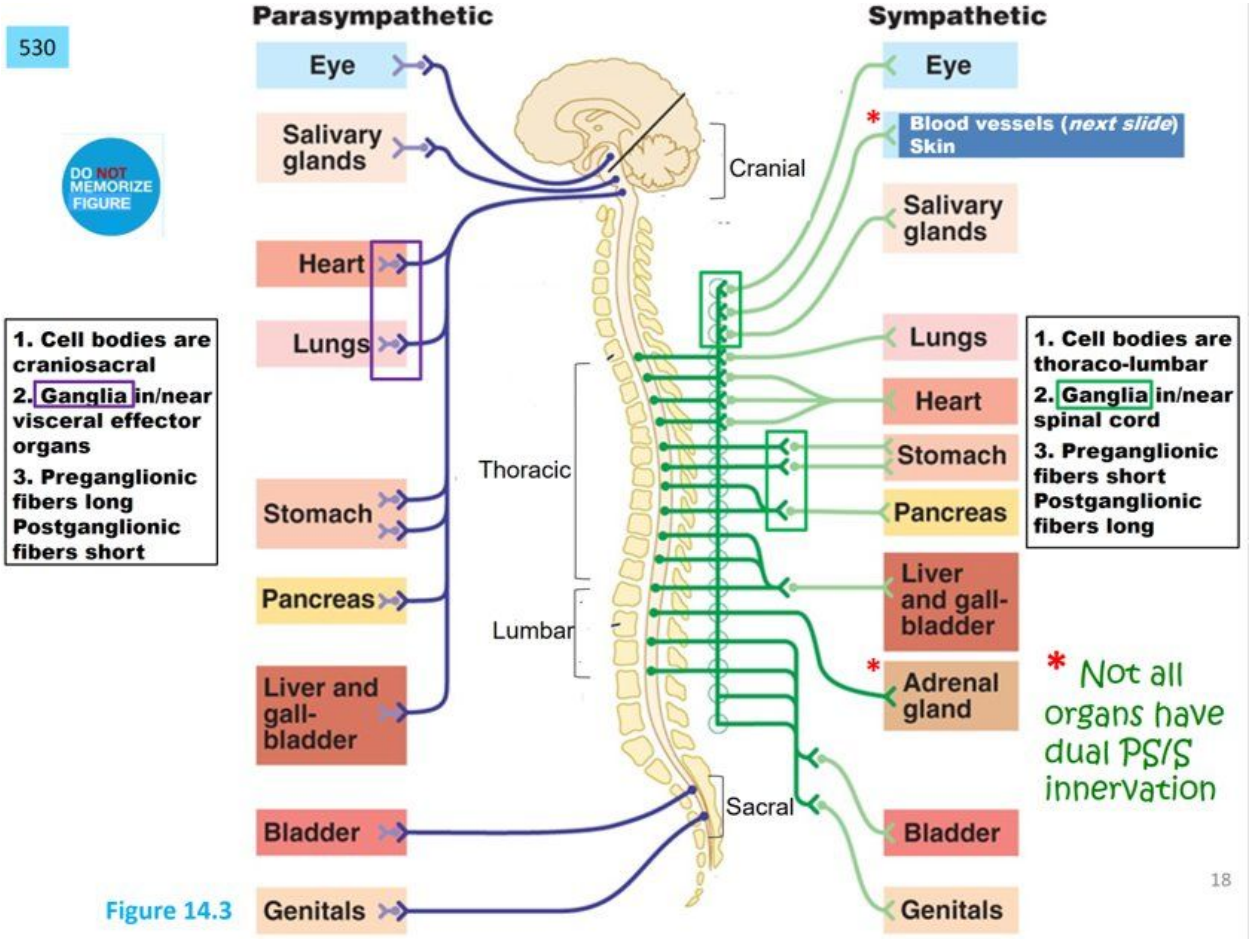
Figure 11-1

Parasympathetic Nervous System (PSNS)

- Rest/ Digest:
    - Minimizes body energy use
    - Maintenance: digestion/elimination
    - BP/HR: low normal levels
    - Eyes adapt for close-up vision:
        - Move medially, lens flattens, pupils constrict

Sympathetic Nervous System (SNS)

- Fight or Flight:
    - Mobilize body during activity
    - HR / BP/ respiration rate increases
    - Dry mouth
    - Cold/ sweaty skin
    - Dilated pupils
    - Constricts blood
    - Vessels: shunts blood to heart /skeletal muscles
    - Provides energy: bronchioles dilate, more glucose from liver



<u>Interactions of the ANS Divisions</u>

Most organs have dual parasympathetic (PS) / sympathetic (S) innervation

- **Antagonistic** Interactions: PSNS/SNS oppose each other
    - Dynamic - precisely controls viscera
    - *eg* Heart/lungs/ GI (fight/flight *vs* rest-digest)

        - One or other usually predominates
    - **Cooperative** PS and S, *eg* in genitalia
        - PS-erection. S-ejaculation/vaginal contraction
    - #? Predominates or found exclusively
        - Sympathetic **tone**: eg blood vessels: vasomotor fibers firing → vasoconstriction. Raises BP or shunts blood to needy areas
        - Parasympathetic **tone**: *eg* heart, digestive/urinary tract smooth muscle, some glands. During stress, SNS can override PSNS

Unique Roles of Sympathetic Division:

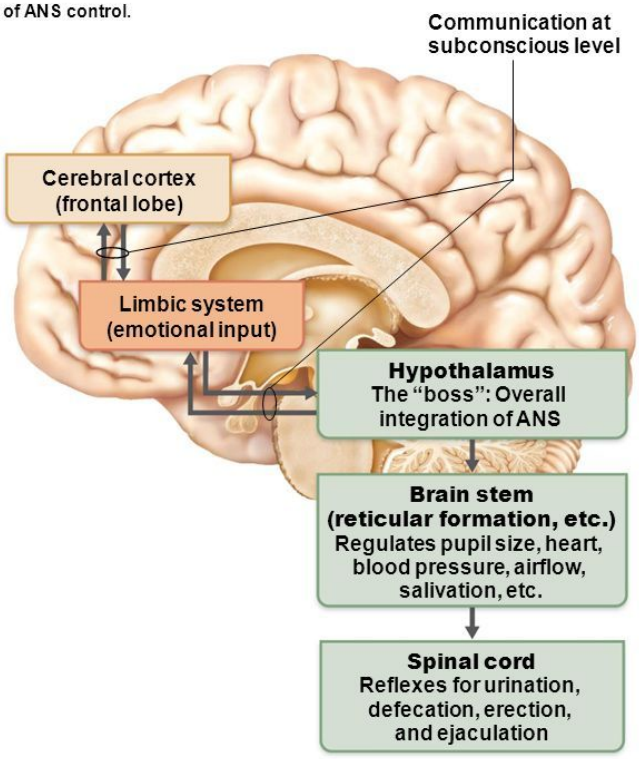
- Blood shunting from skin/abdominal viscera to needy organs in circulatory shock (decreases BP) or if ^ skeletal muscle exertion
- Thermo regulatory responses to heat: skin blood vessels dilate/sweat glands activated
- Release of enzyme renin from kidney → increases BP
- Adrenal Medulla hormones (epinephrine/norepinephrine): Increases glucose/metabolic rate/ muscle contractions, mobilizes fat [fight/flight]

Control of Autonomic Function

Regulation of ANS by CNS

- **Hypothalamus** ("the boss")
    - Anterior (PSNS) / Posterior (SNS)
    - HR/ BP/ T/ water balance/ endocrine activity
    - Mediates fear, other emotions *via* amygdala/ other limbic system structures
- **Brain Stem**
    - Most direct influence
    - HR/ blood vessel diameter/ GI/ eye
- **Spinal Cord**
    - Defecation/ micturition/ erection/ ejaculation

Figure 14.8 Levels of ANS control.



- **Cerebral cortex**
  - Modifies ANS, generally hypothalamus through connections to the limbic system, but . . .
    - Frightening memory: Increases HR (S)
    - Think of food: mouth waters (P)
    - Biofeedback: control *eg* HR, BP
  - Manage migraine, headaches, stress, reduce heart attack risk…"time-consuming, expensive, frustrating"

Endocrine System: Introduction

Comparison of Nervous and Endocrine Systems

- Nervous System:
  - Electrochemical impulses
  - Responses within milliseconds, short-lived
  - Targets (*eg* nerves, organs, glands, muscles) 1 metre
- Endocrine System

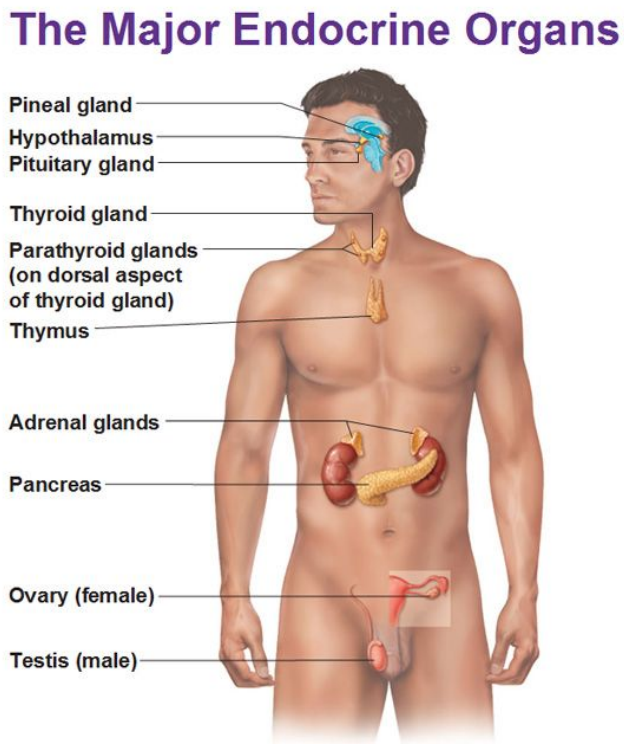
- Chemical messengers ('hormones')
- Responds after seconds or even days, long-lasting
- Targets (*eg* other organs, glands)

- **Processes Controlled by Endocrine System**
  - Reproduction
  - Growth and development
  - Electrolyte/ water/ nutrient balance in blood
  - Cellular metabolism and energy balance
  - Mobilization of body defenses

<u>Endocrine System: Introduction</u>

Endocrine Glands:

- Ductless - release *hormones* into blood circulation
- Relatively small compared to other organs (*eg* brain, heart, liver)
- Widely scattered about body as shown
  - Some organs (*eg* pancreas, ovaries, testes) contain endocrine tissue - acts locally



Three Chemical Classes of Hormones:

- Amino acid based
    - Single amino acid (*eg* epinephrine) to long polymers (polypeptides, proteins)
    - Water-soluble: can't cross plasma membrane
- Steroids
    - Related to/ synthesized from cholesterol (Cholesterol is NOT a hormone)
    - Lipid-soluble: can cross plasma membrane
- Eicosanoids
    - *Eg* Leukotrienes, prostaglandins
    - Don't fit definition of true hormones
        - Act locally within cell that secretes them ('**autocrines**') or on nearby cells ('**paracrines**')
    - Discussed in subsequent chapters on *eg* pain, inflammation, allergies, blood clotting, childbirth

<u>Mechanism of Hormone Action</u>

A Hormone Alters Cellular Activity

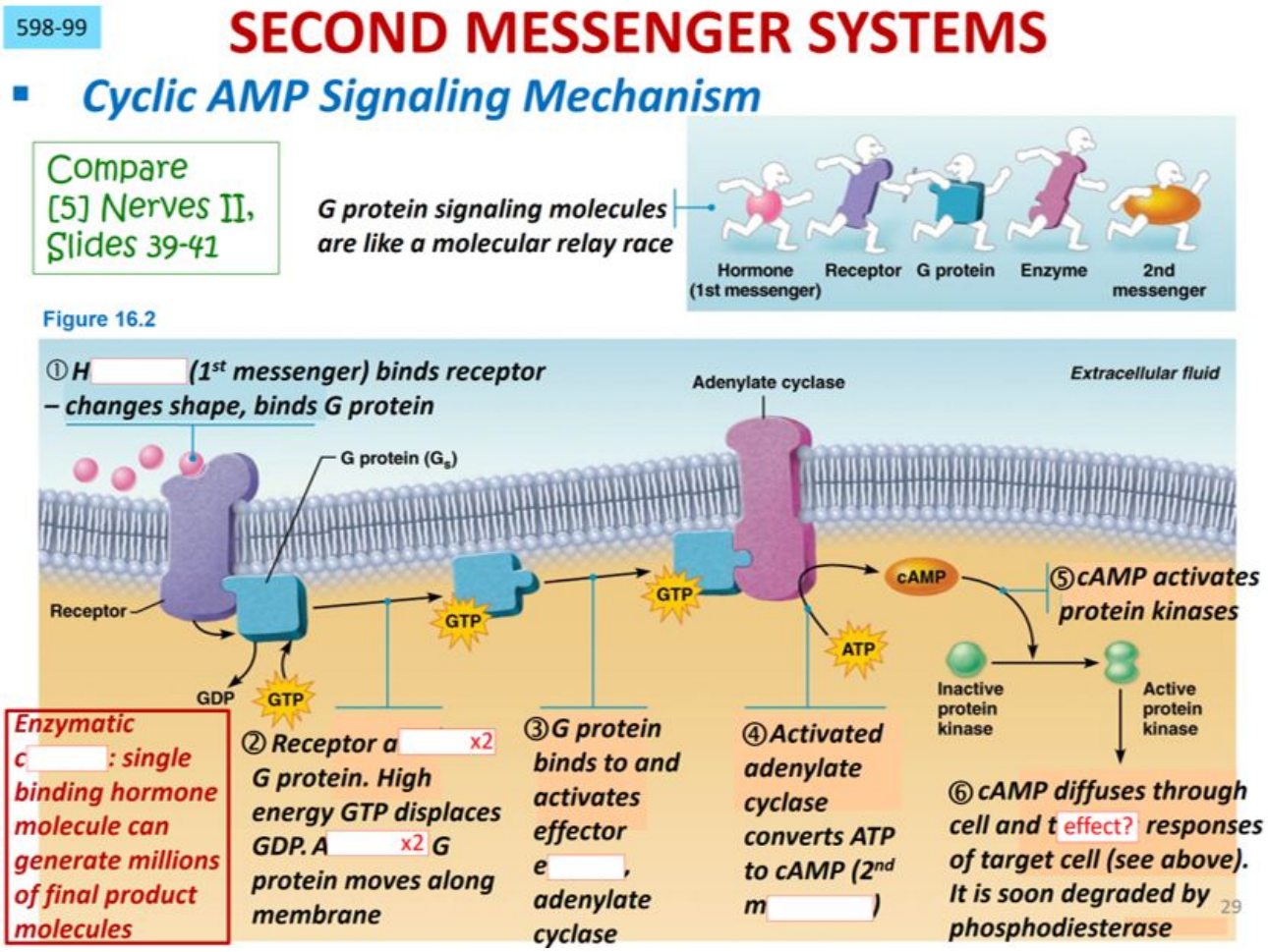
- Effects only those tissue cells with specific receptors for it - 'target cells'
    - **<u>Nb</u>** Effect depends on target cell, not on hormone
- Effects typically one or more of the following:
    - Alters plasma membrane potential/ permeability by opening/closing ion channels
    - Stimulates synthesis of proteins/enzymes within cell
    - Activates/deactivates enzymes
    - Induces secretory activity
    - Stimulates mitosis

Hormones Act at Receptors in One of Two Ways:

- **Receptor on plasma membrane**
    - Water-soluble hormones (ie amino acids, peptides) that can't directly pass through membrane
    - **2nd- messenger system**
- **Receptor inside the cell:** located inside the cell

- Lipid-soluble hormones (*ie* steroids and thyroid hormone) - *can* pass through membrane
- **Direct gene activation** takes place within cell

Second Messenger Systems

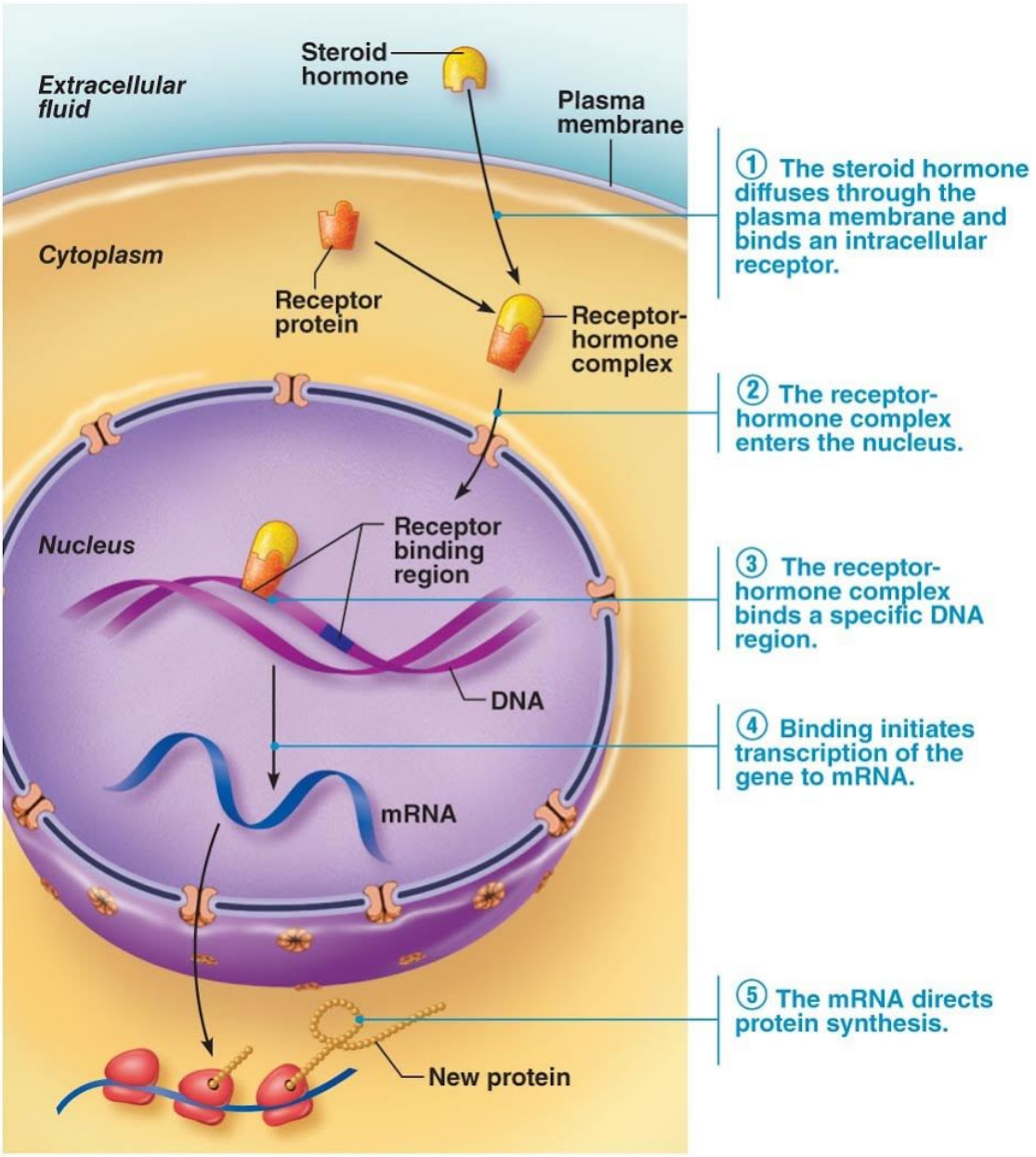


Direct Gene Activation

Intracellular Signalling Mechanism

- Steroid hormone shown. Also with thyroid hormone. Both lipid soluble: cross membrane
- Binding to DNA (step 3) 'turns on' a gene
- Steps 4 & 5: Transcription and translation

** Step 5 (eg enzymes that induce metabolic activity, structural or exportable protein)



Endocrine Gland Stimuli

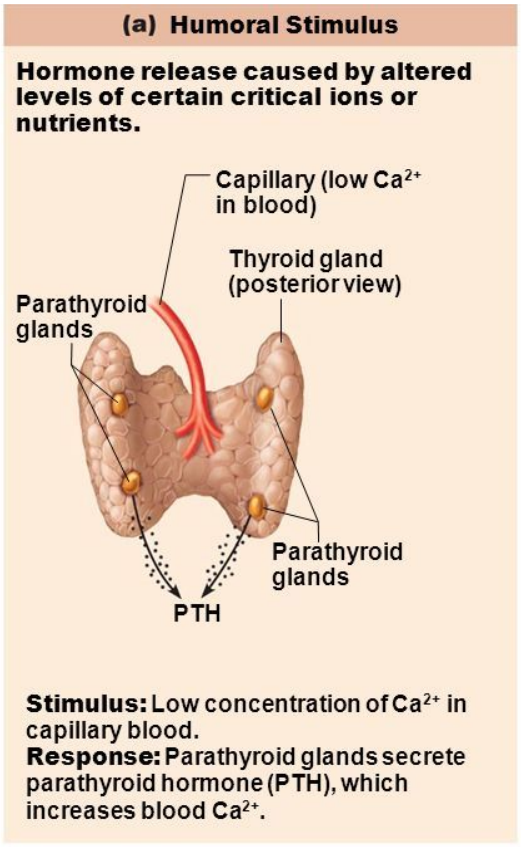
Control of Endocrine Glands

- Three types of stimuli cause release of hormones
    - **Humoral Stimuli**
        - Direct response to blood levels of substances under their control
    - **Neural Stimuli**
        - Nerve fibers innervate endocrine glands
    - **Hormonal Stimuli**

        - Hormonal control release of other hormones
- **Central Nervous System Modulation**
    - If need be, maintains homeostasis by taking priority over above three stimuli
        - *Eg* Under stress, endocrine 'thermostat' that maintains blood glucose 5.0 - 6.1 nmol/L range overridden by hypothalamus

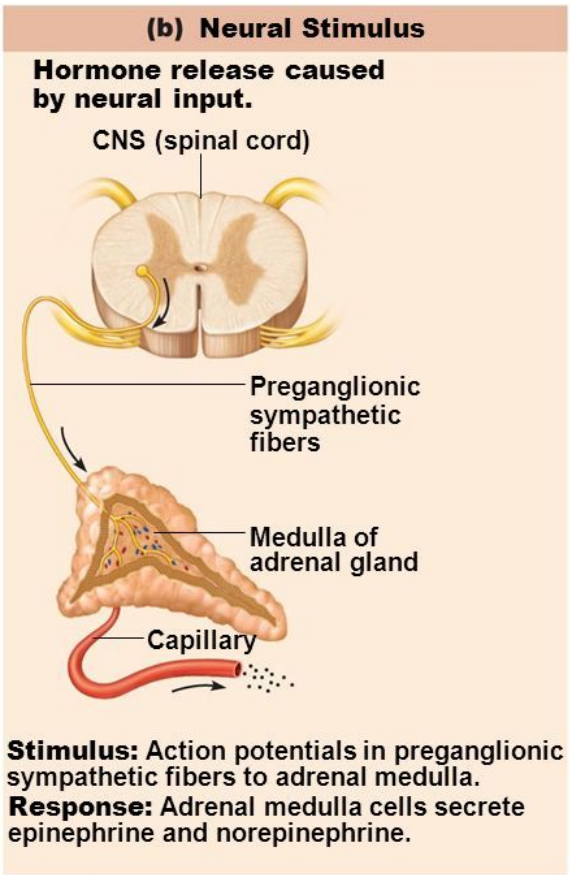
Humoral

- Some endocrine glands manufacture and secrete hormones in direct response to changing blood levels of *eg* critical ions and nutrients
    - Control by **negative feedback**: as blood level rises, hormone secretion increases
        - Also in Types 2 and 3 below
- Examples: [Ca++] increases/decreases: Ca++ levels rise/fall
    - Parathyroid Hormone: [Ca++] Increases or decreases
    - Insulin: [blood glucose] Increases
    - Aldosterone: [Na+] Decreases or [K+] Increases



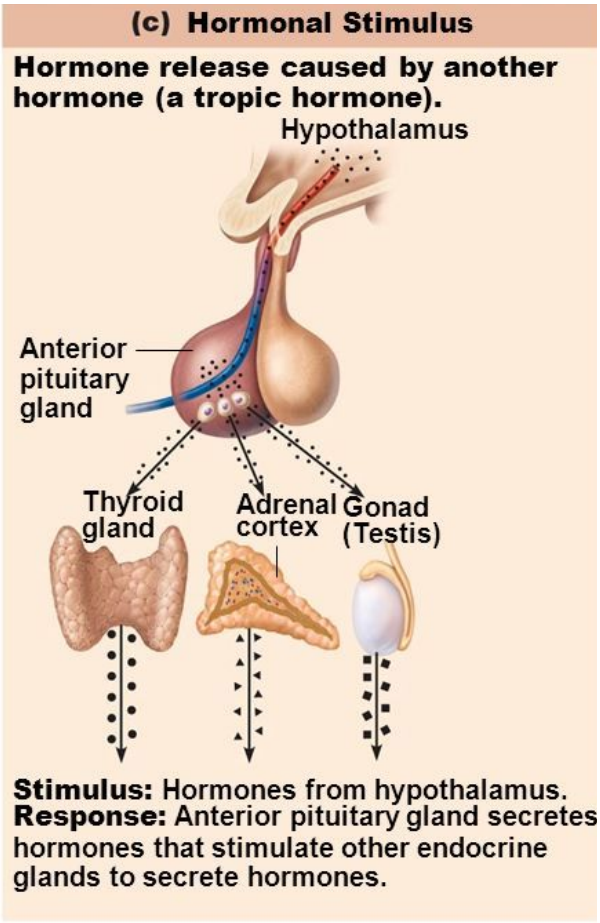
Neural

- In a few cases, nerve fibers stimulate hormone release
    - Classic example is the stress response: sympathetic nervous system stimulates cells of adrenal medulla to release norepinephrine and epinephrine
        - Recall that norepinephrine and epinephrine also act as neurotransmitters (* BIG difference)



Hormonal

- Many endocrine glands release hormones in response to hormones produced by other endocrine glands
    - Hypothalamus produces releasing/ inhibiting hormones: act on pituitary
    - Pituitary hormones in turn stimulate other endocrine glands
    - **Hypothalamic-pituitary-target organ 'axis'** negative feedback loop: "core of endocrinology"

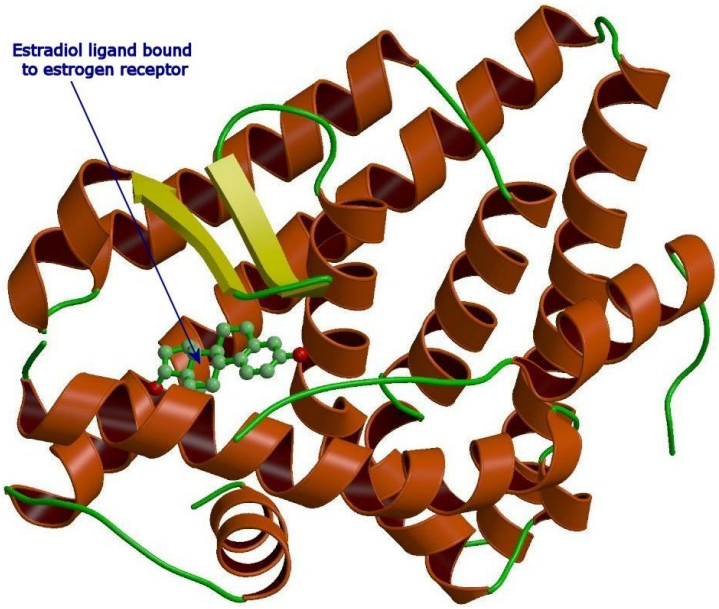


<u>Hormone Receptor</u>

Allow Hormone to 'Talk' to Target Cell

- Must be receptor on cell membrane/ in cytoplasm specific to (*ie* that recognize) hormone
    - *Eg* Insulin receptors on cells that need glucose
- Hormone 'molecular trigger': initiates preprogrammed response when binds to receptors
- Response increases as each increases:
    - Blood levels of hormone
    - Number of receptors
    - Affinity (binding strength)

- Receptor #'s can increase or decreases (**up-/down-regulate**) in response to high /low levels of hormone: hyper/desensitizes target cells



602-3

HORMONE ACTIVITY

- ***Half-Life, Onset, and Duration*** DO NOT MEMORIZE ME
  - Circulate '**free**' or '**bound**' to plasma protein carriers
    - **Half-Life** ($T_{½}$, how long it stays around) depends on how quickly it is deactivated and removed from body
      - Degraded by enzymes or excreted by kidneys/liver
      - Varies from fraction of a minute – a week
  - **Onset of Action**: immediate – hours/days
  - **Duration of Action**: 10 seconds to several hours
  - **Interaction at Target Cells**:
    - *Permissiveness*: 1 ***hormone*** needs presence of a 2nd for its full effect
    - *Synergism*: 2 ***hormones*** act together – effect greater than sum of each acting individually
    - *Antagonism*: 1 ***hormone*** opposes actions of a 2nd

Hormones: Summary

Table 16.1 Comparison of Lipid- and Water- Soluble Hormones

	Lipid-Soluble	**Water-Soluble**
Examples	All steroid hormones, thyroid hormone	All amino acid based hormones except thyroid hormone
Sources	Adrenal cortex, gonads, thyroid gland	All other endocrine glands
Stored in secretory vesicles	No	Yes
Transport in Blood	Bound to plasma proteins	Free
Half-life in blood	Long (removed by liver)	Short (removed by kidneys)
Location of receptors	Inside cell	On plasma membrane
Mechanism of Action	Activates gene protein synthesis	Act through second-messenger