Endocrine system

Coordination & regulation

Glands

Hormones
Endocrine system structures

- **Anatomy** - Dispersed system of glands that communicate with each other & all body cells via **hormones**.
- **Endocrine glands**: secrete chemical messages onto extracellular surface
  - Pituitary, adrenal, testes, etc.
- **Hormones**: Chemical messages that produce metabolic changes in other cells, sometimes far from site of secretion.
  - Steroids, proteins, etc.
Endocrine system function

- Physiology - Regulate and coordinate
  - Energy metabolism
  - Growth
  - Development
  - Reproduction
  - Homeostasis

- Unlike CNS
  - Uses *cardiovascular system* to deliver messages.
  - Messages are *hormones*. 
Types of signaling

- **Endocrine**: Classically, the *bloodstream* is used for message delivery
- **Paracrine**: Nearby cells are stimulated
- **Autocrine**: Secreting cell is stimulated.
  - Cytokines, growth factors
Types of cell signaling

- **Synaptic**: Neurons secrete molecules (*neurotransmitters*), at synapses
  - Short distance diffusion
  - Sensation, cognition, memory, movement

- **Neurohormones**: Neurons secrete molecules that travel through bloodstream to reach target cells
Classes

- Peptides, polypeptides & proteins (large)
- Amines (small)
- Steroids (med)

- Solubility affects mechanism of delivery
  - Diffusion or Transport
  - Alone or with a chaperone
Solubility: Secretion & Transport

• Water soluble - receptors are usually on cell membranes
• Lipid-soluble - Receptors are inside cell
Polar hormones & Signal Transduction

- PM receptor activates second messenger
  - Activate enzymes
  - Rearrange cytoskeleton
  - Alter gene transcription

- Epinephrine $\rightarrow$ G-protein $\rightarrow$ cAMP $\rightarrow$ increase energy availability
Non-polar hormones & Signal transduction

- **Hormone - receptor complex forms**
  - In cytoplasm (steroids)
  - Nucleus (non-steroid, Vit. D)
- **H-R complex binds to DNA or transcription factors**
  - Gene transcription
Same hormone, multiple effects

- Hormones can have multiple, often antagonistic effects
  - Bind to different receptors
  - Activate different signal transduction pathways
Organization of pathways

• **Negative feedback** - typical of homeostatic regulation

• **Positive feedback** - typical of initiating and sustaining short term changes or accomplishing quick tasks.

• **Antagonistic actions**
Negative Feedback

- Set point
- Disturbance initiates endocrine response
Negative feedback

- Autoregulatory
- Stimulus: Low pH food bolus
- Endocrine cells release secretin
- Travel to target cells
- Targets release bicarbonate
- Bicarbonate raises pH; reduces stimulus
Antagonistic actions

- Regulation of **Blood Glucose**
- Amount of glucose (and therefore, access to quick energy) in the blood

- Pancreatic cells produce, store and secrete two hormones, **insulin** and **glucagon**, which control level of glucose in the blood
Blood glucose increases

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.

Homeostasis: Blood glucose level (about 90 mg/100 mL)
Regulation of Blood Glucose: Insulin
Blood glucose drops

Homeostasis: Blood glucose level (about 90 mg/100 mL)

Blood glucose level rises.

STIMULUS: Blood glucose level falls.

Alpha cells of pancreas release glucagon.

Liver breaks down glycogen and releases glucose.

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Regulation of Blood Glucose: Glucagon
Nervous & Endocrine systems are intertwined

- **Neurosecretory** cells in Brain - Arthropods
- **Neurosecretory (Hypothalamic)** cells & **Pituitary Gland** - Chordates
Regulation of molt & metamorphosis

Brain cells secrete PTTH, which induces protothoracic gland to release ecdysone

Ecdysone promotes development

When Juvenile hormone is high, molting occurs

When JH is low, metamorphosis occurs
Hypothalamus: The integrator that initiates many hormone pathways.
Hypothalamus-Pituitary Anatomy

• Hypothalamus - links Central Nervous System & Endocrine system

• Posterior pituitary

• Direct connection to blood vessels
Posterior Pituitary Hormones

- Oxytocin pathway – 2 effects
- Stimulus: suckling
- Hormone: oxytocin
- Targets: mammary gland cells – secrete milk
- Continued suckling increases milk production
Posterior Pituitary Hormones

- ADH pathway
- Signal: ↑ Blood osmolality
- Hormone: ↑ ADH secretion
- Responses: Increases water reclamation
- Increases thirst.
  - More fluid in blood = ↓ in blood osmolality
Anterior Pituitary - Cascades

Tropic effects only:
- FSH
- LH
- TSH
- ACTH

Nontropic effects only:
- Prolactin
- MSH

Nontropic and tropic effects:
- GH

Neurosecretory cells of the hypothalamus

Portal vessels

Hypothalamic releasing and inhibiting hormones

Endocrine cells of the anterior pituitary
Pituitary hormones

Hormone cascade:
- FSH and LH
  - Testes or ovaries
- TSH
  - Thyroid
- ACTH
  - Adrenal cortex
- Prolactin
  - Mammary glands
- MSH
  - Melanocytes
- GH
  - Liver, bones, other tissues

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General AP hormone pathway

- Begins with releasing hormone
- Serial stimulation endocrine glands or nonendocrine cells by hormones
- Negative feedback
Anterior Pituitary - Cascades

Regulates function of endocrine glands

Targets nonendocrine tissues

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GH

Hormones:
- HORMONE
- FSH and LH
- TSH
- ACTH
- Prolactin
- MSH
- GH

Targets:
- TARGET
- Testes or ovaries
- Thyroid
- Adrenal cortex
- Mammary glands
- Melanocytes
- Liver, bones, other tissues
Prolactin

- Glycoprotein
  - 199 A.A.
- Huge # of functions in mammals....
- Humans:
  - Mammary growth
  - Milk production
  - Neurogenesis & gliogenesis
Anterior Pituitary

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Neurosecretory cells of the hypothalamus
Portal vessels
Endocrine cells of the anterior pituitary
Pituitary hormones

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FSH & LH

- Glycoproteins
- “Tropic Hormones”
  - Specifically: “gonad”otropic
- Ovaries and Testis function
- Sperm and egg production
• GnRH -> FSH, LH
  – Stimulate follicular development
• Follicle cells secrete estradiol
  – Low levels \textit{inhibit} GnRH release
  – High levels \textit{promote} release, increased sensitivity to LH, & endometrial development
• LH surge induces ovulation
• Promotes corpus luteum (CL) development
• CL secretes progesterone & estradiol
  – \textit{Inhibit} GnRH release
  – Low FHS & LH causes disintegration of CL & endometrial sloughing
TSH

• Glycoprotein
• Tropic Hormone
  – Increases thyroid gland’s synthesis of $T_3$ & $T_4$
• Increases metabolic & growth rate & thermogenesis
  – Increases CO, HR, ventilation rate, BMR, metabolism of proteins and carbohydrates
  – Potentiates the effects of catecholamines (i.e. increases sympathetic activity)
  – Potentiates brain development
Thyroid hormones

Selenium → Enzyme in target cells

Thyroxine (T₄)

Triiodothyronine (T₃) (more active)

Iodine

Hypothalamus

TRH

Anterior pituitary

TSH

Thyroid

T₃, T₄

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Results of Deficiency

- Results of Iodine deficiency:
  - No iodine, no synthesis of Thyroid hormones-
  - No reduction in TSH
  - Thyroid cells enlarge, producing a goiter
  - During pregnancy, brain development is retarded leading to cretinism – mild to severe forms
GOITER
Results of Deficiency

- Amphibian metamorphosis
  - TSH drives limb development
Other Thyroid hormones

- What type of feedback mechanism controls TRH synthesis?
  
  A. Positive  
  B. Negative  
  C. Antagonistic
Other Thyroid hormones

• Produces & secretes *Calcitonin*
  – Lowers blood $\text{Ca}^{2+}$
  – Stimulates osteoblast metabolism
  – Increases $\text{Ca}^{2+}$ storage and bone density
Parathyroid gland

- Parathyroid hormone Increases blood $\text{Ca}^{2+}$
Anterior Pituitary

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Portal vessels
Endocrine cells of the anterior pituitary
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Hypothalamic releasing and inhibiting hormones

HORMONE
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TARGET
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HPA Axis

- Include *multiple* endocrine glands
- Ex: Glucocorticoid pathway regulates glucose (energy) availability; includes
  - Hypothalamus
  - Pituitary
  - Adrenal
  - HPA axis
Adrenal gland

- Ad = “on top of”
- STRESS hormones
Acute & chronic pathways

Stress

Hypothalamus

Releasing hormone

Anterior pituitary

ACTH

Blood vessel

Adrenal cortex

Adrenal medulla

Adrenal gland

Kidney

Spinal cord

Nerve signals

Nerve cell
Adrenal gland hormones

- **Adrenal MEDULLA**
  - Catecholamine release
    - Epinephrine (adrenaline)
    - Norepinephrine (noradrenaline)
  - Released by ACh - neurotransmitter
  - **Acute** stress responses
    - Increase BP, breathing rate, metabolic rate, glycogen catabolism
    - Modifies patterns of blood flow
  - Makes glucose and O₂ more available for ATP production.

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Adrenal gland hormones

- Adrenal MEDULLA
- Adrenal CORTEX
  - Responds to endocrine cues (ACTH), not neuronal
  - **Corticosteroids**
    - Mineralocorticoids
    - *Glucocorticoids*
  - Response to **Chronic** stress
    - Gluconeogenesis
    - Immune suppression
      - Slower immune response to attack and delayed wound healing
    - Retarded growth & development
Glucose metabolism (get energy)  
Salt and Water balance  
Also important in homeostasis....
Sex steroids

• Found in both sexes
  – Released via FSH and LH from WHERE???
  – Affect growth, development, and sex characteristics
  – Androgens - primarily MALE
  – Estrogens – primarily FEMALE
  – Progestins – also primarily FEMALE
Melatonin (amine)
Melatonin (amine)

- Similar functions to MSH in some animals
- Humans: daily rhythms
  - Day/light actions
- Much research examining effects