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 cell 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 of Hormones

- 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 -> G-protein -> cAMP -> 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

Same receptors but different intracellular proteins (not shown)

(a) Liver cell
(b) Skeletal muscle blood vessel
(c) Intestinal blood vessel
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
Hypothalamus: The integrator that initiates many hormone pathways
Pituitary

Anterior

Posterior
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
• ↑ Blood osmolality = ↑ ADH
  – Increases water retention
  – Increases thirst.
  – More fluid in blood = ↓ in blood osmolality

• ALCOHOL AFFECTS ADH.

• HOW?
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: FSH and LH, TSH, ACTH, Prolactin, MSH, GH

TARGET: Testes or ovaries, Thyroid, Adrenal cortex, Mammary glands, Melanocytes, 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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- LH
- TSH
- ACTH

Nontropic effects only:
- Prolactin
- MSH

Nontropic and tropic effects:
- GH

Hormones:
- FSH and LH
- TSH
- ACTH
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- GH

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

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

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

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- FSH
- LH
- TSH
- ACTH

Nontropic effects only:
- Prolactin
- MSH

Nontropic and tropic effects:
- GH
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 inhibit GnRH release
  – High levels promote release, increased sensitivity to LH, & endometrial development
• LH surge induces ovulation
• Promotes corpus luteum (CL) development
• CL secretes progesterone & estradiol
  – Inhibit GnRH release
  – Low FSH & LH causes disintegration of CL & endometrial sloughing
TSH

- Glycoprotein
- Tropic Hormone
  - Affects thyroid gland’s release of its hormones, $T_3$ & $T_4$
- Increases metabolic rate & thermogenesis
- Increases rates of growth and development
Thyroid hormones

Thyroxine ($T_4$)

Triiodothyronine ($T_3$) (more active)

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Thyroid hormones, cont.

- Growth and development
  - Cretinism – mental and growth retardation
- Need Iodine for hormone synthesis
  - No iodine, no synthesis ->
  - No reduction in TSH
  - Thyroid cells enlarge, leading to...

IODINE

Hypothalamus

TRH

Anterior pituitary

TSH

Thyroid

T₃

T₄

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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 Ca$^{2+}$
  – Stimulates osteoblast metabolism
  – Increases Ca$^{2+}$ storage and bone density
Parathyroid gland

- Parathyroid hormone Increases blood Ca\textsuperscript{2+}
Anterior Pituitary

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

Nontropic effects only:
- Prolactin
- MSH

Nontropic and tropic effects:
- GH

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

Spinal cord

Nerve signals

Nerve cell

Adrenal gland

Kidney

Adrenal cortex

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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.
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