Endocrine System
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Endocrine System Lecture Objectives

- Describe the location, histologic components, and embryologic origin of the pituitary gland.
- List the hormones produced by the anterior and posterior pituitary and know their general function.
- Describe the location, histologic components, and embryologic origin of the thyroid gland.
- List the hormones made by the thyroid gland and know their general function.
- Describe the location, cell types and hormone of the parathyroid glands.
Endocrine System Lecture Objectives

• Describe the location, cortical layers, and medulla of the adrenal glands.

• List the hormones made in the cortex and medulla, and know their general function.

• Describe the location of the pancreas, and the structure and cellular components of a typical pancreatic islet.

• List the hormones made by the islet cells and know their general function.

• Describe the location, cell types, and hormone produced by the pineal gland.
Endocrine System Lecture Outline

- Introduction
- Pituitary
- Thyroid
- Parathyroid
- Adrenal
- Pancreas
- Pineal
Endocrine System Lecture Outline

- Introduction
General Features of the Endocrine System

- Endocrine organs secrete hormones through the blood (no ducts!).
- Hormones travel elsewhere and have effects on different tissues.
- The classical endocrine system consists of all the organs we will discuss in this lecture.
- Male and female reproductive systems also have endocrine functions (we’ll discuss these later).
Endocrine System in a Nutshell

Hypothalamus

Pituitary

Endocrine organ
(for example, thyroid)
Endocrine System in a Nutshell

- **Hypothalamus**: The hypothalamus tells the pituitary what to do.
- **Pituitary**: The pituitary tells the endocrine organ what to do.
- **Endocrine organ (thyroid)**: The endocrine organ releases hormone.
Endocrine System in a Nutshell

The hypothalamus is like a CEO but we don’t talk about it much (not many diseases there)

The pituitary is like a COO. It basically tells everyone what to do.

The endocrine organ is the worker drone. Poor guy.
Endocrine System in a Nutshell

There are negative feedback loops that tell the system when to stop producing hormone.
Endocrine System Lecture Outline

• Introduction
• Pituitary
Located in the sella turcica (Turkish saddle) in the sphenoid bone.

Connected to the hypothalamus

Two lobes:
  • Anterior (adenohypophysis)
  • Posterior (neurohypophysis)
Pituitary gland
Development of the Pituitary Gland

- Diencephalon
- Cerebral vesicle
- Hypophysial diverticulum (Rathke’s pouch)
- Neurohypophysial diverticulum
- Notochord
- Stomatodeum
- Former site of buccopharyngeal membrane
- Forming pituitary gland
Development of the Pituitary Gland
Ugh! Just give me the bottom line.

Anterior pituitary: derived from oral ectoderm.
Posterior pituitary: derived from floor of developing brain.

This makes sense, given what the lobes look like (anterior = glandular epithelium, posterior = neural tissue).
Cranial nerves
Bones of the head
Pharyngeal arches

Bones of most of the body
Muscles of the entire body
Pharyngeal arches
Connective tissue
Dermis

Central nervous system
Posterior pituitary

Neuroectoderm

Urogenital system

Intermediate plate mesoderm

Heart
Hematopoietic system
Pharyngeal arches
Connective tissue

Surface ectoderm
Epidermis, hair, and nails
Anterior pituitary

Paraxial mesoderm

Endoderm
Lining of GI tract

Lateral plate mesoderm
Anterior and posterior pituitary
Pituitary stalk
Anterior and posterior pituitary
Anterior Pituitary (Adenohypophysis)

- Composed of cords of glandular epithelial cells separated by capillaries.
- Makes and secretes a bunch of hormones.
- Subdivisions
  - Pars distalis (biggest and most important part)
  - Pars tuberalis (superior extension of pars distalis)
  - Pars intermedia (separates pars distalis from pars nervosa)
Anterior pituitary

<table>
<thead>
<tr>
<th>Anterior pituitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pars tuberalis</td>
</tr>
<tr>
<td>Pars intermedia</td>
</tr>
<tr>
<td>Pars distalis</td>
</tr>
</tbody>
</table>

Hypophyseal fossa in sella turcica of sphenoid bone

Anterior pituitary
Pituitary: super low-power view

- Pars distalis (PD)
- Pars tuberalis (PT)
- Pars intermedia (PI)
- Infundibular stalk (IS)
- Pars nervosa (PN)
Anterior pituitary
Anterior pituitary: acidophils, basophils, chromophobes
Hormones of the Anterior Pituitary

Anterior pituitary makes and secretes:

- Growth hormone (GH)
- Prolactin (PL)
- Follicle-stimulating hormone (FSH)
- Luteinizing hormone (LH)
- Adrenocorticotropic hormone (ACTH)
- Thyroid stimulating hormone (TSH)
## ROS* of Anterior Pituitary Hormones

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Stimulates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth hormone</td>
<td>growth of bones and many other functions</td>
</tr>
<tr>
<td>Prolactin</td>
<td>milk secretion</td>
</tr>
<tr>
<td>Follicle stimulating hormone</td>
<td>ovarian follicle development and spermatogenesis</td>
</tr>
<tr>
<td>Luteinizing hormone</td>
<td>ovarian follicle development and testicular hormone secretion</td>
</tr>
<tr>
<td>Adrenocorticotropic hormone</td>
<td>secretion of glucocorticoids and androgens by adrenal cortex.</td>
</tr>
<tr>
<td>Thyroid-stimulating hormone</td>
<td>secretion of thyroid hormone by thyroid gland</td>
</tr>
</tbody>
</table>

* Ridiculously Oversimplified Summary
Posterior Pituitary (Neurohypophysis)

- Composed of neural tissue (mostly axons).
- Subdivisions
  - Pars nervosa (biggest and most important part)
  - Median eminence (floor of the hypothalamus)
  - Infundibulum and infundibular stalk (axons traveling from hypothalamus to pars nervosa)
Pituitary: super low-power view

Pars distalis (PD)

Pars tuberalis (PT)

Pars intermedia (PI)

Infundibular stalk (IS)

Pars nervosa (PN)
Posterior pituitary
Posterior pituitary: axons and pituicytes (glial cells)
Posterior pituitary: Herring body
Posterior pituitary doesn’t make hormones! It secretes hormones made by the hypothalamus.

Herring bodies are dilated portions of axons containing hormone-filled vesicles.

Hormones:
- Antidiuretic hormone (ADH)
- Oxytocin
BAHS* of Posterior Pituitary Hormones

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Stimulates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antidiuretic hormone</td>
<td>Water reabsorption in the kidney</td>
</tr>
<tr>
<td>Oxytocin</td>
<td>Contraction of uterine smooth muscle in labor. Contraction of breast cells to allow milk let down.</td>
</tr>
</tbody>
</table>

* Boring as heck summary
**VIS\(^*\) of Oxytocin**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Stimulates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpersonal connection</td>
<td>Trust</td>
</tr>
<tr>
<td>Orgasm</td>
<td>Pleasure AND connection with that particular person</td>
</tr>
<tr>
<td>Intimate relationship</td>
<td>Monogamy</td>
</tr>
<tr>
<td>Sports teams</td>
<td>Better performance</td>
</tr>
</tbody>
</table>

\(^*\) Very interesting summary
Hypothalamo-hypophyseal portal system
Control of the Anterior Pituitary

Hypothalamus
The hypothalamus produces and releases hormones that stimulate or (less commonly) inhibit hormone secretion from the anterior pituitary.

Target organs
Hormones produced by target organs exert negative feedback on both the hypothalamus and the anterior pituitary. Too much hormone turns off production/secretion for a while. Nice!
Endocrine System Lecture Outline

• Introduction
• Pituitary
• Thyroid
Development of the Thyroid Gland

Originates from foramen cecum; descends along thyroglossal duct (which later disappears), in front of the hyoid and larynx, to its position in front of the trachea (by week 7).
Thyroid duct cyst

Lingual thyroid

Thyroglossal duct cyst

Developmental abnormalities of the thyroid
Thyroid gland gross anatomy
Thyroid follicles containing colloid
Thyroid Gland

• Composed of round follicles lined by simple squamous to cuboidal epithelium and filled with colloid.

• Follicular cells synthesize thyroid hormones (T3 and T4) and secrete them into the blood.

• Hypothalamus releases TRH (thyrotropin releasing hormone), which makes pituitary release TSH (thyroid stimulating hormone), which makes thyroid release thyroid hormone.
Thyroid hormone synthesis, easy version

- Follicular cells synthesize thyroglobulin (a protein backbone) and secrete it into the colloid.
- Follicular cells take up iodide from the blood and attach it to tyrosine residues on thyroglobulin, forming T3 and T4 (thyroid hormones), which stay attached to thyroglobulin until needed.
- When stimulated by TSH, follicular cells eat a bit of colloid, digest it in a vesicle, cleave off the T3 and T4 and release it into the blood.
Uptake of colloid by endocytosis

Lysosome & colloid droplet fuse

Digestion by enzymes releases thyroid hormones (T₃, T₄)

Synthesis and Iodination of Thyroglobulin

- Colloid
- Apical vesicle containing thyroglobulin
- Mannose incorporation
- Thyroglobulin synthesis
- Amino acids
- Iodide
- Iodinated thyroglobulin

Release of Thyroid Hormone

- Uptake of colloid by endocytosis
- Lysosomes
- Digestion by enzymes releases thyroid hormones (T₃, T₄)
- Thyroid-stimulating hormone bound to receptor
- Lysosomal enzyme synthesis
- (T₃, T₄)

Synthesis and Iodination of Thyroglobulin:

- Iodinated thyroglobulin in colloid
- Thyroglobulin synthesis
- Mannose incorporation
- Amino acids
- Iodide

Release of Thyroid Hormone:

- Uptake of colloid by endocytosis
- Lysosome & colloid droplet fuse
- Digestion by enzymes releases thyroid hormones (T₃, T₄)
- Thyroid-stimulating hormone bound to receptor
- Lysosomal enzyme synthesis
- (T₃, T₄)
What Does Thyroid Hormone Do?

• Quick answer: increase growth and metabolism.

• More detailed answer: stimulate mitochondrial protein synthesis, increase absorption of carbohydrates, regulate fat metabolism, promote cell growth.

• Bottom line: it increases basal metabolic rate and revs up most bodily functions (increases heart rate, raises body temperature, increases nervous reactivity, increases GI motility...the list goes on).
Parafollicular Cells (C Cells)

- Derived from neural crest ectoderm.
- Located between follicular cells and between follicles.
- Parafollicular cells are larger cells with clear cytoplasm and small secretory granules containing calcitonin.
- Calcitonin is made in response to high blood calcium (it’s not affected by a pituitary hormone!).
- Calcitonin lowers blood calcium levels by inhibiting osteoclastic resorption.
Parafollicular (C) cell
Endocrine System Lecture Outline

- Introduction
- Pituitary
- Thyroid
- Parathyroid
Parathyroid glands gross anatomy
Parathyroid Glands

- Four glands on posterior surface of thyroid.
- Main function: secrete parathyroid hormone (PTH) to regulate calcium levels.
- PTH raises calcium levels in response to low serum calcium (it’s not under pituitary control!).
- Two main cell types: chief cells (secrete PTH) and oxyphils (function unknown).
Parathyroid gland: super low-power view
Parathyroid gland: adipose tissue
Parathyroid gland: chief cells
Parathyroid gland: oxyphil cells
Endocrine System Lecture Outline

- Introduction
- Pituitary
- Thyroid
- Parathyroid
- Adrenal
Adrenal gland gross anatomy
The Adrenal Cortex and Medulla

Adrenal cortex is on the outside
  • Originates from mesoderm
  • Produces steroids (mineralocorticoids, glucocorticoids and sex steroids)

Adrenal medulla is on inside
  • Originates from neural crest
  • Produces epinephrine and norepinephrine
Cranial nerves
Bones of the head
Pharyngeal arches
Adrenal medulla

Central nervous system
Posterior pituitary

Neuroectoderm

Urogenital system

Intermediate plate mesoderm

Paraxial mesoderm

Surface ectoderm

Epidermis, hair, and nails
Anterior pituitary

Bones of most of the body
(everything except the head)
Muscles of the entire body
Pharyngeal arches
Connective tissue
Dermis

Endoderm

Lining of GI tract

Lateral plate mesoderm

Heart
Hematopoietic system
Pharyngeal arches
Connective tissue
Adrenal cortex
Adrenal gland histology

Cortex

Medulla

Adrenal gland histology
Cells form spherical clusters ("glomerula" – but different than the kidney’s glomerula) and produce mineralocorticoids (mostly aldosterone).

- Aldosterone production is stimulated mostly by angiotensin II (only slightly by ACTH).
- Aldosterone helps regulate water and electrolytes by stimulating sodium reabsorption by the kidney.
Adrenal cortex: glomerulosa
Zona Fasciculata

• Cells form straight columns (fascicles) separated by sinusoids.
• Cells make glucocorticoids (mainly cortisol), and small amount of androgens.
• Cortisol synthesis is stimulated by ACTH.
• Glucocorticoids affect carbohydrate, fat and protein metabolism and increase blood glucose levels.
• Glucocorticoids depress the immune system by decreasing the number of circulating lymphocytes.
Zona Reticularis

- Cells form an irregular network (reticulum).
- Cells make sex steroids (mostly androgens) and a small amount of glucocorticoids.
Adrenal cortex: fasciculata and reticularis
Adrenal medulla

- Contains chromaffin cells (modified sympathetic neurons lacking axons and dendrites) and a few sympathetic ganglion cells.
- Chromaffin cells produce catecholamines (mostly epinephrine and a little norepinephrine) when stimulated by preganglionic sympathetic neurons.
- Catecholamines are the “fight or flight” hormones. They increase blood glucose, increase heart rate, increase blood flow to heart and skeletal muscle, and decrease blood to non-essential organs.
Adrenal medulla: ganglion cell and chromaffin cells
Adrenal gland histology

- Zona glomerulosa
- Zona fasiculata
- Zona reticularis
- Medulla
Hormones:
- Mineralocorticoids
- Glucocorticoids
- Sex hormones

Zones of the adrenal gland:
- Zona glomerulosa
- Zona fasiculata
- Zona reticularis

Medulla:
- Adrenalin
- Noradrenalin

Adrenal gland hormones
Adrenal gland hormones

Hormones:
- Mineralocorticoids
- Glucocorticoids
- Sex hormones

Zones:
- Zona glomerulosa
- Zona fasiculata
- Zona reticularis

Components:
- Adrenalin
- Noradrenalin

Functions:
- Salt
- Sugar
- Sex
Endocrine System Lecture Outline

- Introduction
- Pituitary
- Thyroid
- Parathyroid
- Adrenal
- Pancreas
Pancreas

• The pancreas has both exocrine (ducts) glands and endocrine (ductless) glands.

• The exocrine glands produce digestive enzymes; we’ll discuss these in the Pancreas, Liver and Gallbladder lecture.

• The endocrine glands produce mostly hormones that regulate blood glucose: glucagon, insulin, and somatostatin. They also produce pancreatic polypeptide, which helps regulate the digestive system.
Pancreatic islets (of Langerhans)
Pancreatic islet (of Langerhans)
Islet Cells and Hormones

A (alpha) cells
• Located at periphery of the islet
• Secrete glucagon when blood glucose is low
• Glucagon raises blood glucose

B (beta) cells
• Most numerous type of cell in islet
• Secrete insulin when blood glucose is high
• Insulin decreases blood glucose by making cells take up glucose and making the liver synthesize glycogen
Aldehyde fuchsin stain (stains insulin dark purple)
Other, Less Numerous Islet Cells and Hormones

D (delta) cells
- Secrete somatostatin
- Somatostatin inhibits release of insulin and glucagon

F cells
- Secrete pancreatic polypeptide
- Pancreatic polypeptide inhibits release of digestive enzymes
- Also causes relaxation of gallbladder and decreases secretion of bile
Endocrine System Lecture Outline

• Introduction
• Pituitary
• Thyroid
• Parathyroid
• Adrenal
• Pancreas
• Pineal
Pineal Gland

• Located in brain near posterior third ventricle
• Two main cell types: pinealocytes and glial cells
• Pinealocytes occur in clusters and produce melatonin (which helps induce sleep) in response to light.
• “Brain sand” (corpora arenacea) are globules of basophilic calcified material that can be seen radiologically.
Pineal gland

pinealocytes

corpus arenaceum

Pineal gland
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