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Histology of the Endocrine System

M1 - Endocrine/Reproduction Sequence

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Department of Cell and Developmental Biology
University of Michigan Medical School

Winter, 2009
Hormone delivery

(a) Endocrine

Hormone delivery through blood vessels to target cells.

(b) Paracrine

Local hormone delivery between cells.

(c) Neuroendocrine

Neurosecretion involving neurons and target cells.

(d) Neurotransmitter

Neurotransmitters released at synapses.
Endocrine system

- **Pituitary (hypophysis)**
  - Anterior pituitary
  - Posterior pituitary

- **Adrenal gland (suprarenal)**
  - Adrenal cortex
  - Adrenal medulla

- **Thyroid gland**
  - Follicles
  - Parafollicular cells

- **Parathyroid gland**

Considered in other lectures:
- Endocrine pancreas
- Male
- Female
- Enteroendocrine
PITUITARY
Location of pituitary

- hypothalamus
- sella turcica (bone)
- optic chiasm
- pituitary gland
Pituitary development

FIGURE 21.4. Development of the pituitary gland. This diagram shows sequential stages (a to c) in the development of the pituitary gland.
Pituitary nomenclature

Optic chiasma
3rd ventricle
Extension of pars intermedia into brain substance
Process of pars intermedia
Anterior lobe
Intraglandular cleft
Pars intermedia

Posterior lobe

Please also see Ross and Pawlina. Histology: Text and Atlas, 5th ed, 2006, fig 21.3b, pg 689
## Cells and hormones of the anterior pituitary

<table>
<thead>
<tr>
<th>LM staining</th>
<th>Cell type</th>
<th>Hormone</th>
<th>Releasing (+) or inhibiting (-) horm.</th>
</tr>
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<tbody>
<tr>
<td>Acidophil</td>
<td>Somatotrope</td>
<td>Growth hormone (GH) = somatotropin</td>
<td>GHRH (+)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Somatostatin (-)</td>
</tr>
<tr>
<td>Acidophil</td>
<td>Mammotrope = lactotrope</td>
<td>Prolactin (PRL)</td>
<td>[Dopamine (-) estrogen (+)]</td>
</tr>
<tr>
<td>Basophil</td>
<td>Thyrotrope</td>
<td>Thyroid stimulating hormone (TSH) = thyrotropin</td>
<td>TRH (+)</td>
</tr>
<tr>
<td>Basophil</td>
<td>Gonadotrope</td>
<td>Luteinizing hormone (LH), follicle stimulating hormone (FSH); both = gonadotropin</td>
<td>GnRH (+)</td>
</tr>
<tr>
<td>Basophil (human)</td>
<td>Corticotrope</td>
<td>Adrenocorticotropicin (ACTH) = corticotropin</td>
<td>CRH (+)</td>
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</table>
Pituitary, low power LM
Image of cords of cells in anterior pituitary removed.
Original here: Bailey's textbook of histology.
72(700)6
Anterior pituitary, LM, trichrome stain

Sinusoid

Basophil

Acidophil

Chromophobe
Immunocytochemical localization of growth hormone, LM
Immunocytochemical localization of luteinizing hormone in gonadotropes, fluorescence
Anterior pituitary, EM
Pathway of hormone secretion

Figure 17-8. Diagram illustrating the secretory pathway of a mammatrope. Small granules are formed in the Golgi complex and subsequently fuse to form larger granules, often of irregular outline. During lactation, they are discharged by exocytosis, but after the young are weaned, excess granules fuse with lysosomes and are destroyed by autophagy. (After Smith, R. E., and M. G. Farquhar. J. Cell Biol. 31:319, 1966.)

Fawcett. Histology, ed 11, p 486
Cytoplasm of prolactin-secreting cell (lactotrope), EM

- Golgi
- Secretory granule
- Rough ER
Fig. 5. Peripheral cytoplasm of a mammotroph from a lactating rat, depicting several secretory granules (sg) lined up facing the perivascular spaces and undergoing discharge by exocytosis. The membranes of several granules are in continuity with the cell membrane at the points indicated by arrows. B, Basement membrane. × 42,000.
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Regulation of the anterior pituitary

**FIGURE 5-1.** Hypothalamic neurosecretory neurons and hypothalamo-hypophyseal portal vessels.
Regulation of anterior pituitary, detail

O'Riordan et al. 1988, p. 47
SEM of pituitary: portal veins, capillaries, corrosion vascular cast
Posterior pituitary

• **Hormones**
  – Antidiuretic hormone (ADH = arginine vasopressin)
  – Oxytocin

• **Neurosecretion**
  – Hormones synthesized as part of larger proteins (neurophysins) in neuron cell bodies of hypothalamus.
  – Transported in axons to pars nervosa (hormone cleaved from neurophysin).
  – Hormone secreted from axon terminals into capillaries.

• **Pituicytes**
  – Specialized glia of pars nervosa.
Posterior pituitary, diagram
Posterior pituitary, LM

Axon cross sections?

Pituicyte nucleus
Nerve endings for hormone release, posterior pituitary
Pars intermedia, between anterior and posterior pituitary, human, LM.

Poorly developed and of doubtful function in humans.
Pars intermedia, rat pituitary, LM

Anterior  Intermediate  Posterior

Rathke's pouch
Adrenal (suprarenal) gland

- Zona glomerulosa
  - Produces aldosterone
- Zona fasciculata
  - Produces cortisol
- Zona reticularis
  - Produces some cortisol and androgen

MEDULLA
- Produces epinephrine and norepinephrine
Location of the adrenal (suprarenal) gland, human
A transverse section through the left adrenal of a man 72 years old.
Adrenal cortex

• **Zona glomerulosa**
  – Main hormone: Aldosterone (a mineralocorticoid).
  – General function: Maintain blood electrolyte balance.
  – Main control: Angiotensin II.

• **Zona fasciculata**
  – Main hormone: Cortisol (a glucocorticoid).
  – General function: Includes regulating glucose and fatty acid metabolism, and response to stress.
  – Main control: Pituitary ACTH.

• **Zona reticularis**
  – Hormones: Some cortisol and androgens.
  – Function and control: Similar to zona fasciculata.
Adrenal blood vessels

Adrenal blood vessels, corrosion vascular cast, SEM
Zona glomerulosa (source of aldosterone), LM
Zona fasciculata (source of cortisol), LM

Zona fasciculata
Smooth ER in the cytoplasm of a zona fasciculata cell, EM
Zona reticularis, LM

- Zona reticularis
- Zona fasciculata
- Medulla
Adrenal medulla

• **Hormones**
  – Epinephrine (adrenalin) and norepinephrine (noradrenalin), both catecholamines. Two cell types, one for E and one for N.
  – Main control: Preganglionic sympathetic innervation.

• **Embryonic source**
  – From neural crest cells, same as postganglionic sympathetic neurons. Although adrenal medulla cells do not have dendrites or axons, they behave like postganglionic sympathetic neurons, releasing norepinephrine/epinephrine in response to preganglionic sympathetic stimulation.

• **Also called "chromaffin cells"**
  – Cells of the adrenal medulla are examples of "chromaffin cells," containing catecholamine granules that stain brown with potassium dichromate. Neurons of sympathetic ganglia are also chromaffin cells. The term is used in pathology.
Adrenal medulla, LM

Zona reticularis

Medulla
EM of adrenal medulla: norepinephrine and epinephrine cells

Norepinephrine

Epinephrine

Nucleus
Production of norepinephrine and epinephrine in the cytosol

Tyr
→ Tyr
→ Dopa
→ Dopamine
→ Norepinephrine or epinephrine
→ NE/E NE/E

secretory granule

Regents of the University of Michigan
THYROID GLAND
Location of thyroid gland

- Larynx behind
- Thyroid cartilage
- Pyramidal Lobe
- Right and left lobes
- Isthmus of thyroid
- Trachea
Thyroid gland

• **Thyroid follicles**
  – Thyroid hormones: thyroxine (T4), triiodothyronine (T3).
  – Synthesis: A very large protein, thyroglobulin (660 kDa), is synthesized and then secreted into the follicle lumen. It is later taken up and broken down (with lysosomes) to yield T4 and T3.
  – General function: To increase the body's metabolic rate.
  – Main control: Pituitary TSH.

• **Parafollicular cells (= C-cells)**
  – Hormone: Calcitonin.
  – General function: Lower serum calcium.
  – Main control: Serum calcium level.
Thyroid follicle

Modified from Hedge 1987
Thyroid, low power LM

Blood vessel

Hadley Kirkman (Stanford) slide collection, slide 18
Thyroid follicles, LM
Thyroid follicles, LM

Hadley Kirkman (Stanford) slide collection, slide K27
Thyroid capillary beds, corrosion vascular cast, SEM
Production of thyroid hormones by a follicular cell

Synthesize thyroglobulin and then secrete it into the colloid. Iodinate tyrosine residues on thyroglobulin. When stimulated by pituitary TSH, take up the thyroglobulin and break it down in lysosomes to release thyroid hormones T3 and T4.

Modified from Junqueira and Carneiro, 10th ed., 2003, page 426, fig. 21-19 by R. Mortensen
Thyroid follicular cell, EM

Porter and Bonneville, 1968, Fine structure of cells and tissues, 3rd ed
### Table 5. Causes of Goiter (increase in thyroid size)

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Iodine deficiency</td>
<td></td>
</tr>
<tr>
<td>B. Excessive intake of goitrogen</td>
<td>1. Natural goitrogen</td>
</tr>
<tr>
<td></td>
<td>2. Iatrogenic goitrogen</td>
</tr>
<tr>
<td></td>
<td>3. Industrial goitrogen</td>
</tr>
<tr>
<td>C. Hereditary defect in thyroid hormone synthesis</td>
<td>1. Iodide-trapping defect</td>
</tr>
<tr>
<td></td>
<td>2. Iodide-organification defect</td>
</tr>
<tr>
<td></td>
<td>3. Iodotyrosyl-coupling defect</td>
</tr>
<tr>
<td></td>
<td>4. Thyroid hormone release defect</td>
</tr>
<tr>
<td></td>
<td>5. Iodotyrosine dehalogenase defect</td>
</tr>
<tr>
<td></td>
<td>6. Defect associated with abnormal serum iodoprotein</td>
</tr>
<tr>
<td>D. Increased need for thyroid hormone</td>
<td>1. Puberty</td>
</tr>
<tr>
<td></td>
<td>2. Pregnancy</td>
</tr>
<tr>
<td></td>
<td>3. Menstruation</td>
</tr>
<tr>
<td></td>
<td>4. Lactation</td>
</tr>
<tr>
<td>E. Pituitary or hypothalamic dysfunction</td>
<td></td>
</tr>
<tr>
<td>F. Primary thyroid disease</td>
<td></td>
</tr>
</tbody>
</table>
Functional states of thyroid follicles

Normal
Underactive = hypoactive
Overactive = hyperactive

Image of thyroid follicles removed. Original here: 0'Riordan, 2nd ed, p 160.
Underactive (hypoactive) thyroid follicles, LM
Overactive (hyperactive) thyroid follicles
Thyroid gland

- **Parafollicular cells (= C-cells)**
  - Hormone: Calcitonin.
  - General function: Lowers serum calcium.
  - Main control: Serum calcium level.
C cell location in thyroid

Follicular Cells

Colloid
Thyroglobulin

Blood

T4
T3

C Cell (calcitonin)
C-cell in thyroid follicular epithelium, LM
Immunocytochemical localization of calcitonin in C cells, LM
Parafollicular cell (C cell), EM
# Regulation of serum calcium

<table>
<thead>
<tr>
<th>Parathyroid hormone (from parathyroid)</th>
<th>Ca$^{++}$↑</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcitonin (thyroid parafollicular cells)</td>
<td>Ca$^{++}$↓</td>
</tr>
</tbody>
</table>
PARATHYROID GLAND
Location of the four parathyroid glands on the back of the thyroid
Parathyroid gland

• Chief (or principal) cells
  – Hormone: Parathyroid hormone (PTH).
  – Main function: Raises serum calcium, lowers serum phosphate.
  – Main control: Serum calcium level.

• Oxyphil cells
  – Occasional cells or small clusters.
  – Function unknown.
  – Name means "acid [stain] loving" (Greek).
Parathyroid gland (mostly chief cells), low power LM
Parathyroid, chief cells, one oxyphil (arrow), LM
Parathyroid capillary bed, corrosion vascular cast, SEM
Oxyphil cell, EM diagram

Nucleus

Mitochondrion
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Slide 4: O’Riordan et al., 2nd ed, page 5
Slide 10: A. Kent Christensen
Slide 11: Humio Mizoguti, Kobe Univ Sch Med, slide 515
Slide 13: Stan Erlandsen Medical Histology slide collection, slide MH 9/B/4
Slide 14: Stan Erlandsen Medical Histology slide collection, slide MH-9B3
Slide 15: A. Kent Christensen
Slide 16: A. Kent Christensen
Slide 17: EM taken by Larry Kahn, in AKC lab, in 1980
Slide 18: Fawcett. Histology, ed 11, p 486
Slide 19: Marilyn Farquhar in Memoirs of the Society for Endocrinology, number 19, fig 2, p 86.
Slide 20: Marilyn Farquhar in Memoirs of the Society for Endocrinology, number 19, figs 2 and 3, p 88.
Slide 21: Marilyn Farquhar in Memoirs of the Society for Endocrinology, number 19, fig 5, p 89.
Slide 22: A. Kent Christensen
Slide 23: Hedges, 1987, p. 86
Slide 24: O’Riordan et al 1988, p 47
Slide 27: O’Riordan et al 1988, p 47
Slide 28: A. Kent Christensen
Slide 29: Weiss Histology, ed 5, p. 1070
Slide 30: Humio Mizoguti, Kobe Univ Sch Med, slide 516
Slide 31: A. Kent Christensen
Slide 33: Source Undetermined
Slide 35: Bailey’s Histology
Slide 37: Hadley Kirkman slide collection, slide K285
Slide 38: Humio Mizoguti, Kobe Univ Sch Med, slide 547
Slide 40: Virginia Black chapter, in Weiss Histology, 6th ed, p. 1039
Slide 41: Humio Mizoguti, Kobe Univ Sch Med, slide 548
Slide 42: Humio Mizoguti, Kobe Univ Sch Med, slide 549
Slide 43: Stan Erlandsen Medical Histology slide collection, slide MH 9/F/4
Slide 44: Long and Jones 1967
Slide 45: Humio Mizoguti, Kobe Univ Sch Med, slide 550
Slide 47: Humio Mizoguti, Kobe Univ Sch Med, slide 565
Slide 48: Stan Erlandsen Medical Histology Slide Collection, slide MH 9/G/2-P