Hormones
work of Prof. Don Catlin

- "Next generation cheating”
- "losing on artificial hormones”
- Testosterone, stimulants, growth hormone, diuretics, masking compounds, erythropoietin (EPO), more
- New steroids THG tetrahydrogestrinone
- Testosterone synthetic has lower 13C/12C
- Balco (Bay Area Laboratory Cooperative)
- health (and legal and career) dangers
- baseball worship of record holders
<table>
<thead>
<tr>
<th>Communication</th>
<th>Chemical Messengers</th>
<th>Mechanism of Transmission</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Ions, small molecules</td>
<td>Direct movement through gap junctions linking cytosol of adjacent cells</td>
<td>Ions flowing between cardiac muscle cells</td>
</tr>
<tr>
<td>Paracrine</td>
<td>Local hormones</td>
<td>Diffusion through interstitial fluid to nearby cells bearing receptors</td>
<td>Prostaglandins</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Hormones</td>
<td>Carried in the bloodstream to near or distant cells bearing receptors</td>
<td>Insulin</td>
</tr>
<tr>
<td>Synaptic</td>
<td>Neurotransmitters</td>
<td>Diffusion from a neuron across a narrow space (synaptic cleft) to a cell bearing receptors</td>
<td>Acetylcholine</td>
</tr>
</tbody>
</table>
1. Endocrine cells release hormone.
2. Hormone enters capillary and is carried throughout the body in the blood.
3. Hormone leaves capillaries and diffuses to all cells through interstitial fluid.
4. Hormone only influences target cells with matching receptors.

Hormone does not affect tissues that lack receptors for it.
1. A peptide or amino acid-based hormone binds to a receptor on the plasma membrane.

2. Hormone-receptor binding activates an enzyme that catalyzes the synthesis of a second-messenger, such as cAMP.

3. The second messenger activates other enzymes.

4. The activated enzymes catalyze specific reactions. Different hormones and different receptor types cause different enzymes to be activated and produce different products or changes.
A steroid hormone diffuses through the plasma membrane.

The hormone binds to a receptor in the nucleus or to a receptor in the cytoplasm that carries it into the nucleus.

The hormone-receptor complex binds to DNA and causes RNA polymerase to bind to a nearby promoter site for a specific gene.

RNA polymerase catalyzes the transcription of DNA into messenger RNA (mRNA).

The mRNA leaves the nucleus, then attaches to a ribosome and directs the synthesis of a specific protein product.
Hypothalamus produces ADH and oxytocin, regulatory hormones for anterior pituitary

Pituitary gland
- anterior pituitary: ACTH, TSH, GH, PRL, FSH, LH, and MSH
- posterior pituitary: releases oxytocin and ADH

Thyroid gland
thyroxine, calcitonin

Thymus gland
(atrophies during adulthood) thymosins

Adrenal glands (one at each kidney)
- medulla: epinephrine, norepinephrine
- cortex: glucocorticoids (cortisol), aldosterone, testosterone

Pancreas islet cells
insulin, glucagon

Parathyroid glands (on posterior surface of thyroid gland)
parathyroid hormone

Heart
atrial natriuretic peptide

Kidneys
erythropoietin

Digestive tract
several hormones /see Chapter 34

Gonads
- testes (male): androgens, especially testosterone
- ovaries (female): estrogens, progesterone

Figure 37-1  Biology: Life on Earth, 8/e
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1. Neurosecretory cells of hypothalamus produce releasing and inhibiting hormones.

2. Releasing or inhibiting hormone secreted into capillaries feeding anterior lobe of pituitary.

3. Hormone is secreted into the blood by endocrine cells of anterior pituitary.

1. Neurosecretory cells of hypothalamus produce oxytocin and ADH.

2. Oxytocin and ADH are secreted into the blood via capillaries in posterior pituitary.
Pituitary

• (1) posterior pituitary
• (2) anterior pituitary as "master gland"
• (and the other glands it controls)
• (3) anterior pituitary
• (effects not mediated through other glands)
1. Suckling stimulates nerves in breast.

2. Nerve impulses are sent to hypothalamus.

3. Neurosecretory cells of hypothalamus release oxytocin from endings in the posterior pituitary.

4. Oxytocin is released and carried in blood to the breast.

5. Oxytocin binds receptors on milk gland muscles, causing milk to be squeezed out.

Figure 37-8 Biology: Life on Earth, 8/e
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Posterior pituitary

- neurosecretion from hypothalamus
- (peptides)
- oxytocin (milk, delivery)
- (synthetic to induce labor)
- Covered in Excretion lecture: ADH action on kidney vasopressin (ADH), H2O and blood pressure
- alcohol, caffeine inhibit anti [diuresis] hormone
1 Neurosecretory cells of hypothalamus secrete TSH-releasing hormone.

2 Releasing hormone causes anterior pituitary to secrete thyroid-stimulating hormone (TSH).

3 TSH causes thyroid to secrete thyroxine, which increases cellular metabolic rate throughout the body.

4 Thyroxine inhibits TSH-releasing hormone and TSH release by negative feedback.
Anterior pituitary

- releasing (and inhibiting) hormones (peptides)
- pituitary stalk Portal system
- Anterior pituitary and its hormones (peptides)
- Thyroid hormones Influence on metabolism,
- Negative feedback with pituitary Hypothalamus - TRF-> + Ant. Pituit. -TSH->+ Thyroid -> thyroxine-- neck thyroxin (T4), triiodothyroxine (T3)
- iodine, sea food (and iodized salt)T3 and T4
<table>
<thead>
<tr>
<th>Endocrine Gland</th>
<th>Hormone</th>
<th>Type of Chemical</th>
<th>Principal Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothalamus (to anterior pituitary)</td>
<td>Releasing and inhibiting hormones</td>
<td>Peptides</td>
<td>At least nine hormones; releasing hormones stimulate release of hormones from anterior pituitary; inhibiting hormones inhibit release of hormones from anterior pituitary</td>
</tr>
</tbody>
</table>
| Anterior pituitary                     | Follicle-stimulating hormone (FSH)     | Peptide          | **Females:** stimulates growth of egg follicles, estrogen secretion, perhaps ovulation  
**Males:** stimulates spermatogenesis                                                      |
|                                        | Luteinizing hormone (LH)               | Peptide          | **Females:** stimulates ovulation, growth of corpus luteum, and secretion of estrogen and progesterone.  
**Males:** stimulates secretion of testosterone                                              |
|                                        | Thyroid-stimulating hormone (TSH)      | Peptide          | Stimulates thyroid to release thyroxine                                                                                                           |
|                                        | Adrenocorticotropic hormone (ACTH)     | Peptide          | Stimulates adrenal cortex to release hormones, especially glucocorticoids, such as cortisol                                                    |
|                                        | Growth hormone (GH)                    | Peptide          | Stimulates growth, protein synthesis, and fat metabolism; inhibits sugar metabolism                                                              |
|                                        | Prolactin (PRL)                        | Peptide          | Stimulates milk synthesis in and secretion from mammary glands                                                                                   |
|                                        | Melanocyte-stimulating hormone (MSH)   | Peptide          | Promotes synthesis of brown skin pigment, melanin                                                                                                |
| Hypothalamus (via posterior pituitary) | Antidiuretic hormone (ADH)             | Peptide          | Promotes reabsorption of water from kidneys; constricts arterioles                                                                               |
|                                        | Oxytocin                               | Peptide          | **Females:** stimulates contraction of uterine muscles during childbirth, milk ejection, and maternal behaviors  
**Males:** may facilitate ejaculation of sperm                                                      |
| Thyroid                                | Thyroxine                              | Amino acid derivative | Increases metabolic rate of most body cells; increases body temperature; regulates growth and development                                           |
| Parathyroid                            | Parathyroid hormone                    | Peptide          | Increases blood calcium by stimulating calcium release from bones, absorption by intestines, and reabsorption by the kidneys  |

Table 37-3 part 1  Biology: Life on Earth, 8/e  
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<table>
<thead>
<tr>
<th>Endocrine Gland</th>
<th>Hormone</th>
<th>Type of Chemical</th>
<th>Principal Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pancreas</td>
<td>Insulin</td>
<td>Peptide</td>
<td>Decreases blood glucose levels by increasing uptake of glucose into cells and converting glucose to glycogen, especially in liver; regulates fat metabolism</td>
</tr>
<tr>
<td></td>
<td>Glucagon</td>
<td>Peptide</td>
<td>Converts glycogen to glucose, raising blood glucose levels</td>
</tr>
<tr>
<td>Ovaries*</td>
<td>Estrogen</td>
<td>Steroid</td>
<td>Causes development of female secondary sexual characteristics and maturation of eggs; promotes growth of uterine lining</td>
</tr>
<tr>
<td></td>
<td>Progesterone</td>
<td>Steroid</td>
<td>Stimulates development of uterine lining and formation of placenta</td>
</tr>
<tr>
<td>Testes*</td>
<td>Testosterone</td>
<td>Steroid</td>
<td>Stimulates development of genitalia and male secondary sexual characteristics; stimulates spermatogenesis</td>
</tr>
<tr>
<td>Adrenal medulla</td>
<td>Epinephrine (adrenaline) and norepinephrine (noradrenaline)</td>
<td>Amino acid derivatives</td>
<td>Increase levels of sugar and fatty acids in blood; increase metabolic rate; increase rate and force of contractions of the heart; constrict some blood vessels</td>
</tr>
<tr>
<td>Adrenal cortex</td>
<td>Glucocorticoids (cortisol)</td>
<td>Steroid</td>
<td>Increase blood sugar; regulate sugar, lipid, and fat metabolism; anti-inflammatory effects</td>
</tr>
<tr>
<td></td>
<td>Aldosterone</td>
<td>Steroid</td>
<td>Increases reabsorption of salt in kidney</td>
</tr>
<tr>
<td></td>
<td>Testosterone</td>
<td>Steroid</td>
<td>Causes masculinization of body features, growth</td>
</tr>
</tbody>
</table>

Table 37-3 part 2 Biology: Life on Earth, 8/e © 2008 Pearson Prentice Hall, Inc.
<table>
<thead>
<tr>
<th>Endocrine Gland</th>
<th>Hormone</th>
<th>Type of Chemical</th>
<th>Principal Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineal gland</td>
<td>Melatonin</td>
<td>Amino acid derivative</td>
<td>Regulates seasonal reproductive cycles and sleep–wake cycles; may regulate onset of puberty</td>
</tr>
<tr>
<td>Thymus Kidney</td>
<td>Thymosin</td>
<td>Peptide</td>
<td>Stimulates maturation of cells of immune system</td>
</tr>
<tr>
<td></td>
<td>Renin</td>
<td>Peptide</td>
<td>Acts on blood proteins to produce hormone (angiotensin) that regulates blood pressure</td>
</tr>
<tr>
<td></td>
<td>Erythropoietin</td>
<td>Peptide</td>
<td>Stimulates red blood cell synthesis in bone marrow</td>
</tr>
<tr>
<td>Heart</td>
<td>Atrial natriuretic peptide (ANP)</td>
<td>Peptide</td>
<td>Increases salt and water excretion by kidneys; lowers blood pressure</td>
</tr>
<tr>
<td>Digestive tract&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Secretin, gastrin, cholecystokinin, and others</td>
<td>Peptides</td>
<td>Control secretion of mucus, enzymes, and salts in digestive tract; regulate peristalsis</td>
</tr>
<tr>
<td>Fat cells</td>
<td>Leptin</td>
<td>Peptide</td>
<td>Regulates appetite; stimulates immune function; promotes blood vessel growth; required for onset of puberty</td>
</tr>
</tbody>
</table>

<sup>a</sup>See Chapters 40 and 41.

<sup>b</sup>See Chapter 34.
Non-trophic hormones

- GH - 200 a.a. - bone, muscle, not fat,
- GH - gigantism (bones grow long if too much GH when young),
- dwarfism (if too little GH when young),
- acromegaly (bones grow too thick if too much GH when already grown up,
- danger of GH abuse, abuse by body builders, dangers of extracts,
- now available through recombinant DNA research
gonadotropins

- "Master Gland"
- sex hormones from pituitary:
  - LH (female) = ICSH (male); (luteinizing) (interstitial cell)
  - FSH (follicle)
Adrenal medulla secretes epinephrine and norepinephrine.

Adrenal cortex secretes glucocorticoids, testosterone, and aldosterone.
Adrenal cortex

- Adrenal cortex - Glucocorticoids stimulate metabolism, inhibits inflammation.
- Mineralocorticoids, the best known being Aldosterone helps kidney retain salt
- Adrenalectomy causes salt loss and salt appetite.
- Sweat glands are not as efficient at retaining salt as kidney.
- That is why "Gatorade" (electrolyte) is used by athletes.
More

• Salt is also lost in cystic fibrosis (mutation of CFTR, cystic fibrosis transmembrane conductance regulator)
## Table 37-2  The Chemical Diversity of Vertebrate Hormones

<table>
<thead>
<tr>
<th>Chemical Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amino acid derivatives</td>
<td>norepinephrine</td>
</tr>
<tr>
<td>(synthesized from one or two amino acids)</td>
<td><img src="image" alt="norepinephrine" /></td>
</tr>
<tr>
<td></td>
<td>thyroxine</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="thyroxine" /></td>
</tr>
<tr>
<td>Peptides and proteins</td>
<td>oxytocin</td>
</tr>
<tr>
<td>(synthesized from multiple amino acids)</td>
<td><img src="image" alt="oxytocin" /></td>
</tr>
<tr>
<td>Steroids</td>
<td>testosterone</td>
</tr>
<tr>
<td>(synthesized from cholesterol)</td>
<td><img src="image" alt="testosterone" /></td>
</tr>
<tr>
<td></td>
<td>estrogen</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="estrogen" /></td>
</tr>
<tr>
<td>Prostaglandins</td>
<td>prostaglandin E1</td>
</tr>
<tr>
<td>(synthesized from fatty acids)</td>
<td><img src="image" alt="prostaglandin E1" /></td>
</tr>
</tbody>
</table>

Table 37-2  Biology: Life on Earth, 8/e
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Adrenal medulla

- Epinephrine, (alias adrenalin) - activates body
- Autonomic (vs voluntary) motor control: sympathetic (vs parasympathetic)
- Sympathetic nervous system uses norepinephrine at postganglionic synapses. Sympathetic - "fight or flight"
- Helps in metabolism to release glucose to blood stream
- Muscles activity up, peripheral circulation and digestion inhibited Heart rate goes up
High blood glucose

Insulin released from pancreas

Glucose enters body cells to supply energy

Low blood glucose

Glucagon released from pancreas

Liver converts glucose to glycogen

Body cells use more fat for energy

Increased blood glucose

Liver breaks down glycogen into glucose

Figure 37-12 Biology: Life on Earth, 8/e
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Pancreas. H&E (Low) blood vessel (V), islet of Langerhans (L)
Glucose (insulin and Glucagon) and diabetes

- pancreas,
- which is largely a digestive exocrine gland,
- islets of Langerhans endocrine
- the beta cells make insulin
- the alpha cells make glucagon
- Insulin- sugar uptake into cells (blood sugar down),
- make glycogen in muscle & liver
Diabetes mellitus

- Type 1 autoimmune disease beta cells are destroyed, young people, insulin dependent
- inject insulin - protein, must inject
- Type 2, older people, genetic, correlated with overweight, non-insulin dependent
- sugar in urine-Eye problems (too many new blood vessels - angiogenesis) and cardiovascular problems
- Brain is not insulin-dependent - coma from too much insulin because no glucose for brain
Glucagon

- Glucagon mobilizes sugar to blood like adrenalin
- Sugar regulates insulin and glucagon
low blood calcium

normal blood calcium

release of PTH from parathyroids.

calcium release from bone

Figure 37-11  Biology: Life on Earth, 8/e
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Calcium homeostasis

- Parathyroid - parathormone - blood Ca2+ up (from bones) near thyroid gland in neck
- Also Thyroid - thyrocalcitonin - blood Ca2+ down
- Vitamin D sunlight, rickets, fish oil, hormone, absorption from gut
- Osteoporosis - bone deterioration with age especially in women
- Ca2+ very important, muscle (later), nerve (later)
Estrogen

- Menopause (pause in the menes) ["change of life" at about 50] - lack of estrogen.
- Hot flashes Osteoporosis -
- Hotly contested (a lot of negative press lately), partly because estrogen increases chances of breast cancer.
- There is a drug, Tamoxifen that blocks estrogen's effects, differently in different tissues.
1. A peptide or amino acid-based hormone binds to a receptor on the plasma membrane.

2. Hormone-receptor binding activates an enzyme that catalyzes the synthesis of a second-messenger, such as cAMP.

3. The second messenger activates other enzymes.

4. The activated enzymes catalyze specific reactions. Different hormones and different receptor types cause different enzymes to be activated and produce different products or changes.
A steroid hormone diffuses through the plasma membrane.

The hormone binds to a receptor in the nucleus or to a receptor in the cytoplasm that carries it into the nucleus.

The hormone-receptor complex binds to DNA and causes RNA polymerase to bind to a nearby promoter site for a specific gene.

RNA polymerase catalyzes the transcription of DNA into messenger RNA (mRNA).

The mRNA leaves the nucleus, then attaches to a ribosome and directs the synthesis of a specific protein product.
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<thead>
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<tbody>
<tr>
<td><strong>Steroids</strong></td>
<td><strong>testosterone</strong></td>
</tr>
<tr>
<td>(synthesized from cholesterol)</td>
<td><img src="image1" alt="Steroid Structure" /></td>
</tr>
<tr>
<td></td>
<td><strong>estrogen</strong></td>
</tr>
<tr>
<td></td>
<td><img src="image2" alt="Estrogen Structure" /></td>
</tr>
<tr>
<td><strong>Prostaglandins</strong></td>
<td><strong>prostaglandin ( E_1 )</strong></td>
</tr>
<tr>
<td>(synthesized from fatty acids)</td>
<td><img src="image3" alt="Prostaglandin Structure" /></td>
</tr>
</tbody>
</table>

Table 37-2 part 2  Biology: Life on Earth, 8/e
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