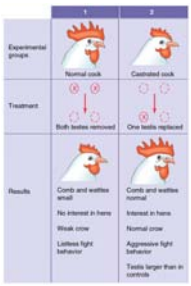
Lecture 14&15
18&20 Feb 2008

Vertebrate Physiology
ECOL 437 (MCB/VetSci 437)
Univ. of Arizona, spring 2008

Kevin Bonine & Kevin Oh

1. Endocrine Physiology (Ch14)
2. Reproductive Physiology (Ch15)



http://eebweb.arizona.edu/eeb_course_websites.htm

Housekeeping, 18 February 2008

Upcoming Readings
Today: Ch14
Wed 20 Feb: Ch14&15
LAB Wed 20 Feb: 4 readings on website
Fri 22 Feb: no lecture, work on proposal
Monday 25 Feb: Ch15, Ch17?
Wed 27 Feb: Research Question Due
Wed 27 Feb: Ch17
LAB Wed 27 Feb: muscle readings on website
Fri 29 Feb: Ch17

Lab discussion leaders: 20 Feb
1pm – Virsheena, Mathew S. Arturo
3pm – Kat, Clif, Amber

Lab discussion leaders: 27 Feb
1pm – Steve & Cassia
3pm – Kevin & Jennifer

The Edges of Life Lecture Series

The Edges of Life – 7pm at Centennial Hall

Wednesday, February 20
Life's Human Edge: *Changing Perspectives on the End of Life*
Michael Gill, Associate Professor, Philosophy
Nothing looms with more certainty than the final edge of one's own life. But in fact, the edge between life and death is anything but clear. This lecture will address the attempts that have been made to define the line between life and death and will explore the biological, legal, ethical, and spiritual debates that have raged around that line.

Wednesday, March 5
Life's Technological Edge: The Singularity is Near: When Humans Transcend Biology
Ray Kurzweil, *via Teleportec Teleporter*
Founder, Chairman and Chief Executive Officer, Kurzweil Technologies
Humanity is on the edge of a vast transformation, when what it means to be human will be both enriched and challenged. Inventor and futurist Ray Kurzweil will introduce this radically optimistic singularity, an era when we break our genetic shackles to create a nonbiological intelligence trillions of times more powerful than today. In this new world, humans will transcend biological limitations to achieve entirely new levels of progress and longevity.
This lecture co-sponsored by: UA College of Engineering and UA College of Science

These do not count as physiology lectures.

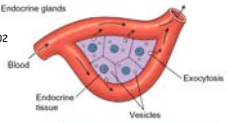
Martin Wikelski, Princeton

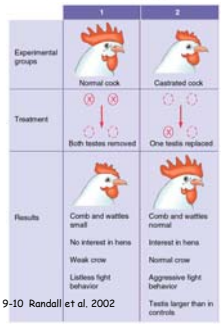
Endocrine System

-Hormone action often amplified by second messenger cascade

-Hormones often released in very low concentrations
Made them difficult to study!

9-9 Randall et al. 2002





9-10 Randall et al. 2002

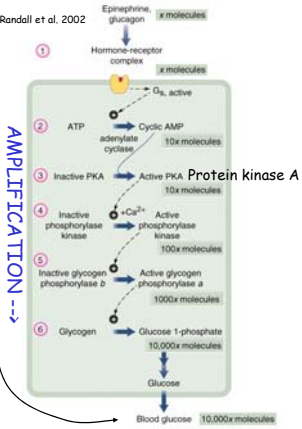
1. cAMP

Glycogenolysis Example:
(glycogen-> glucose)

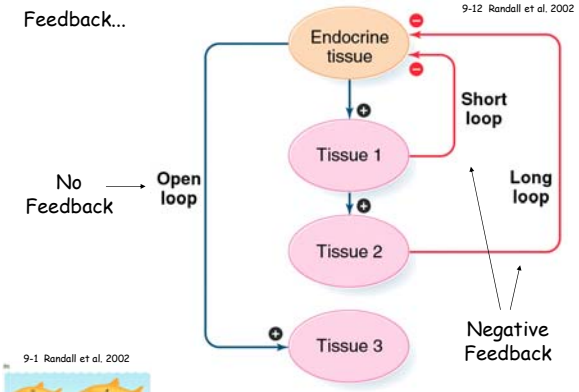
-Epi (muscle)
-Glucagon (liver)

Goal is to increase blood [glucose]

9-22 Randall et al. 2002



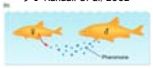
Feedback...



9-12 Randall et al. 2002

No Feedback → Open loop

9-1 Randall et al. 2002



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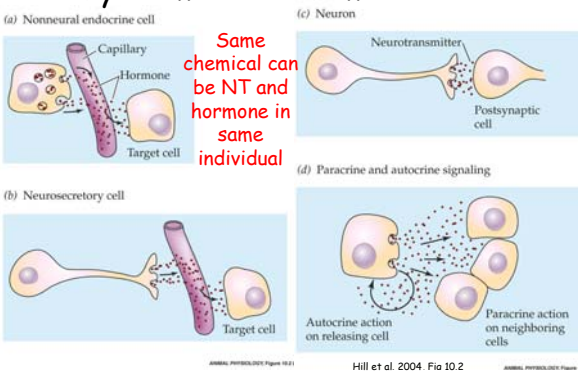
Endocrine and Nervous Systems Have Similarities



Same chemical can be NT and hormone in same individual

Hill et al. 2004. Fig 10.2

Chap 14. Endocrine System – Glands and Hormones

Secretions with consequences

All cells secrete, but
Specialized secretory cells grouped into glands
Secrete same specialized substance (e.g., hormone)

Nervous System neurotransmitter acts near and fast

Other secretions, such as hormones, may act more distantly and over a longer time period

9

Categories of cellular secretions:

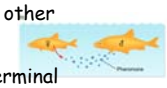
Autocrine – affect the secreting cell directly

Paracrine – affect neighboring cells
e.g., histamine and inflammation

Endocrine – release into bloodstream

Exocrine – release onto epithelial surface
e.g., sweat onto skin, bile into digestive system

Pheromone – exocrine secretion to signal other individuals



Neuroendocrine – secretion from axon terminal into blood stream

Neurosecretory cells and Neurohormones control much of the endocrine system

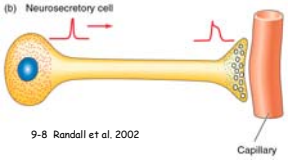
10

Neuroendocrine Systems

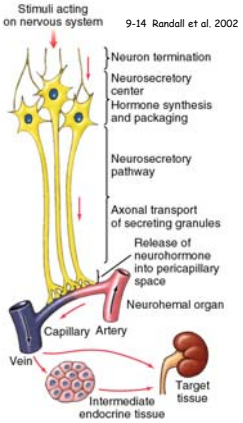
Neurosecretory cells secrete neurohormones

Axon terminates into neurohemal organ

Neurohormones often [effect] other glands/hormones



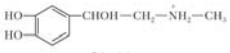
9-8 Randall et al. 2002



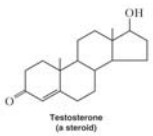
9-14 Randall et al. 2002

Three Hormone Classes

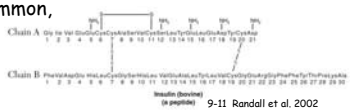
1 Amines – small
(e.g., epinephrine, norepi, thyroid, melatonin)



2 Steroid Hormones from cholesterol
(e.g., testosterone, estrogen)



3 Peptide Hormones – common, large, complex
(e.g., insulin, ADH, GH)



9-11 Randall et al. 2002

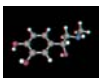
TABLE 14.2 Peptide, steroid, and amine hormones

Property	Peptides	Steroids	Amine hormones: Catecholamines	Amine hormones: Thyroid hormones	Amine hormones: Melatonin
Site of secretion	Most sites in Table 14.1, except adrenal cortex and medulla, thyroid gland, and pineal gland	Adrenal cortex, gonads, and placenta	Adrenal medulla	Thyroid gland	Pineal gland
Structure	Chains of amino acids	Derived from cholesterol	Derived from tyrosine	Derived from tyrosine and iodine	Derived from tryptophan
Solubility	Water-soluble	Lipid-soluble	Water-soluble	Lipid-soluble	Water-soluble
Synthesis and storage	Synthesized at rough ER, processed in Golgi apparatus; stored in vesicles in advance of use	Synthesized on demand in intracellular compartments; not stored	Synthesized in the cytoplasm and stored in vesicles ("chromaffin granules")	Made prior to use and stored in a colloid island within the gland	Synthesized in the cytoplasm and stored in vesicles
Secretion	Exocytosis	Simple diffusion through cell membrane	Exocytosis	Simple diffusion through cell membrane	Exocytosis
Transport	Dissolved in plasma; some bound to carrier proteins	Bound to carrier proteins	Dissolved in plasma	Bound to carrier proteins	Dissolved in plasma
Half-life	Minutes	Hours	Seconds to minutes	Days	Minutes
Location of receptor molecules	Surface of target cell membrane	Cytoplasm or nucleus (some steroids bind to cell-surface receptors)	Surface of target cell membrane	Nucleus	Surface of target cell membrane
Action at target cell	Activate second-messenger systems or alter membrane channels	Alter gene expression; activated genes initiate transcription and translation	Activate second-messenger systems	Alter gene expression; activated genes initiate transcription and translation	Activate second-messenger systems
Response of target cell	Change activity of preexisting proteins, some of which may induce new protein synthesis	Synthesize new proteins; some may change activity of preexisting proteins	Change activity of preexisting proteins	Synthesize new proteins	Change activity of preexisting proteins

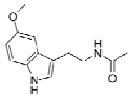
Sources: After Sherwood 2004; Silverthorn 2004; and Widmaier, Raff, and Strang 2004.

Hill et al. 2004 ANIMAL PHYSIOLOGY, Table 14.2

Amines – small
(e.g., epi, norepi, thyroid)



Modified Amino Acids
1. catecholamines (epi, norepi, dopamine; tyrosine)
2. thyroid (lipid soluble; tyrosine)
3. melatonin (tryptophan)



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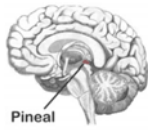
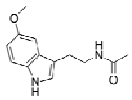


Melatonin



Pineal Gland
Retina
GI Tract

Produced at Night
Circadian Rhythms
Suprachiasmatic Nucleus (SCN) in Hypothalamus

Antioxidant
Immune System Support
Suppress libido? (LH, FSH)

15

Glandular Secretion
Response to stimulus

Hormone
Neurotransmitter
Action Potential
etc. (e.g., osmolarity and ADH)

Storage before Secretion
Large molecules easily stored because can't leave readily
Small molecules often stored bound to accessory proteins
Some molecules actively/continuosly taken into vesicles
Steroid hormones (lipid soluble) tend to leak out soon
Hydrophobic steroid and thyroid hormones move in blood, bound to carrier proteins

16

TABLE 14.1 Summary of major blood-borne hormones in mammals *(Part 1)*

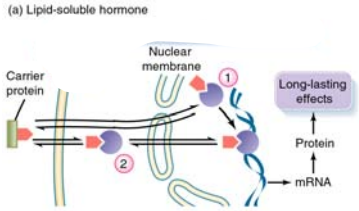
Endocrine tissue	Hormone	Class of molecule	Main functions
Adrenal cortex	Aldosterone (mineralocorticoid)	All steroids	Stimulates Na reabsorption and K secretion in kidney
	Androgens		Act on bone to cause growth spurt at puberty; increase sex drive in females by action on brain
	Glucocorticoids		Part of stress response; affect metabolism of many tissues to increase blood glucose and cause protein and fat catabolism
Adrenal medulla	Epinephrine and norepinephrine	Catecholamines	Part of stress response; influence cardiovascular function and organic metabolism of many tissues

Sources: After Bentley 1998; Henderson 2000; Schmidt-Nielsen 1997; Sherwood 2004; Silverthorn 2004; and Widmaier, Raff, and Strang 2004.

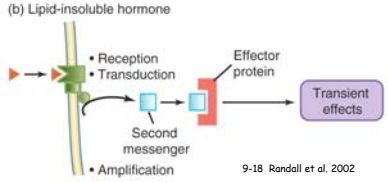
ETC…

Hill et al. 2004 ANIMAL PHYSIOLOGY, Table 14.1 (Part 1)

1. Lipid Soluble



2. Lipid Insoluble



9-18 Randall et al. 2002

Hormone *ACTION!*
Where are the receptors?

1. Lipid Soluble
   - Steroid and Thyroid Hormones (~long-lived)
   - Through Membrane
   - Bind cytoplasmic receptors, then to Nucleus
   - Directly affect transcription (therefore long-term)

2. Lipid Insoluble
   - Bind cell-surface receptors
   - Often one or more 2nd messengers
   - Amplification

   ~ Rapid, short-duration responses

19

Hormone *ACTION!* (receptors etc.)

2. Lipid Insoluble Hormones and Intracellular Signaling

A few receptors with direct catalytic activity, but most via 2nd messengers :

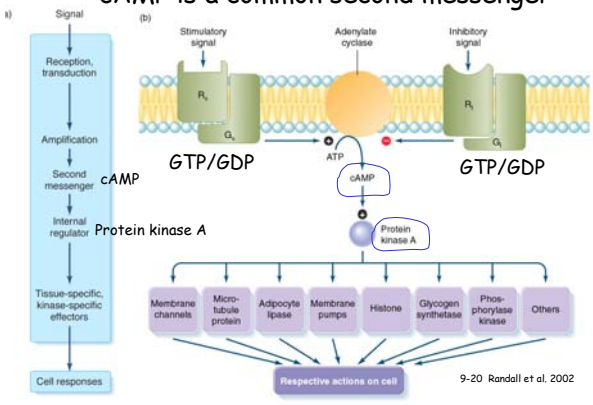
Possible 2nd messengers:

1. cAMP, cGMP (cyclic nucleotide monophosphates)
2. IP_3, DAG (diacylglycerol; inositol phospholipids)
3. Ca^{2+} ions

General Model of Hormone Binding and Intracellular Signaling:

20

cAMP is a common second messenger



9-20 Randall et al. 2002

Randall et al. 2002

Table 9-6 Some hormone-induced responses mediated by the cAMP pathway

Signal	Tissue	Cellular response
Stimulatory		
Epinephrine (β-adrenoreceptors)	Skeletal muscle	Breakdown of glycogen
	Fat cells	Increased breakdown of lipids
	Heart	Increased heart rate and force of contraction
	Intestine	Fluid secretion
	Smooth muscle	Relaxation
Thyroid-stimulating hormone (TSH)	Thyroid gland	Thyroxine secretion
ADH (vasopressin)	Kidney	Reabsorption of water
Glucagon	Liver	Breakdown of glycogen
Serotonin	Salivary gland (blowfly)	Fluid secretion
Prostaglandin I_2	Blood platelets	Inhibition of aggregation and secretion
Inhibitory		
Epinephrine (α_2-adrenoreceptors)	Blood platelets	Stimulation of aggregation and secretion
	Fat cells	Decreased lipid breakdown
Adenosine	Fat cells	Decreased lipid breakdown

Source: Berridge, 1985.

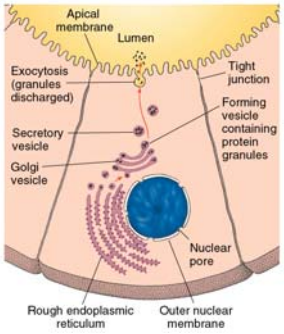
Glandular Secretion

Secretory Vesicles

Exocytosis – common release mechanism

Regulation via Calcium –

free cytosolic calcium concentration is correlated with exocytosis (including of NT, hormones, etc.)



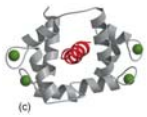
9-2 Randall et al. 2002

23

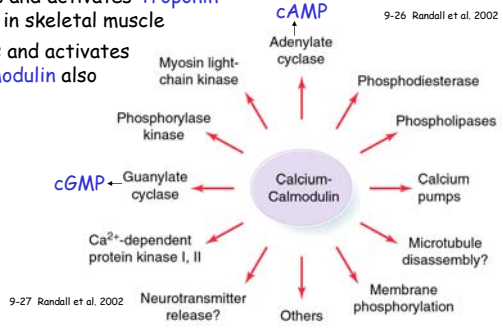
Ca^{2+} ions
- Intracellular stores (ER)
- Influx from extracellular fluid

1- binds and activates Troponin C in skeletal muscle

2- binds and activates Calmodulin also

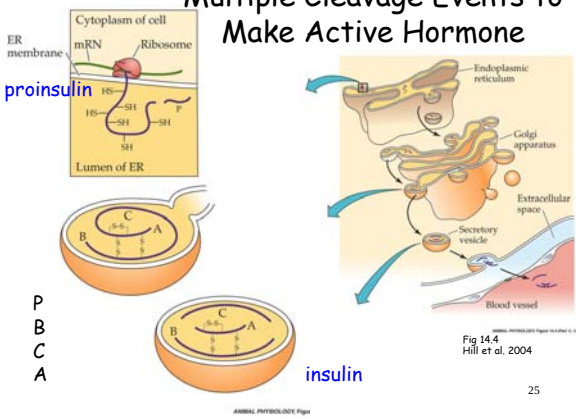


9-26 Randall et al. 2002



9-27 Randall et al. 2002

Multiple Cleavage Events to Make Active Hormone



proinsulin

P
B
C
A

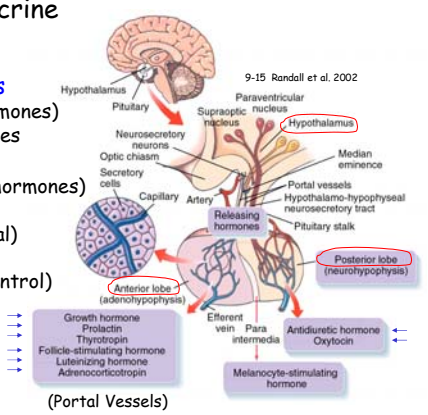
insulin

Fig 14.4
Hill et al. 2004

Major Endocrine Players

Hypothalamus
- (~7 neurohormones)
- mostly peptides

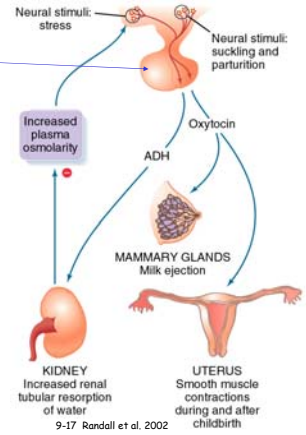
Pituitary (9 hormones)
1. *Anterior* (~nonneuronal)
2. *Posterior* (~neuronal control)



9-15 Randall et al. 2002

(Portal Vessels)

Posterior Pituitary



9-17 Randall et al. 2002

Oxytocin – uterine contractions, milk ejection

Antidiuretic Hormone (ADH) - water retention in kidney

Both are peptide hormones

Both are similar and highly conserved…

Posterior Pituitary

Randall et al. 2002
Table 9–4 Variant forms of neurohypophyseal nonapeptide hormones

Peptide	Positions of amino acid residues* 1	2	3	4	5	6	7	8	9	Animal group
Lysine vasopressin	Cys	Tyr	Phe	Gln	Asn	Cys	Pro	Lys	Gly—(NH_2)	Pigs and relatives
Arginine vasopressin	Cys	Tyr	Phe	Gln	Asn	Cys	Pro	Arg	Gly—(NH_2)	Mammals
Oxytocin	Cys	Tyr	Ile	Gln	Asn	Cys	Pro	Leu	Gly—(NH_2)	Mammals
Arginine vasotocin	Cys	Tyr	Ile	Gln	Asn	Cys	Pro	Arg	Gly—(NH_2)	Reptiles, fishes, and birds
Isotocin	Cys	Tyr	Ile	Ser	Asn	Cys	Pro	Ile	Gly—(NH_2)	Some teleosts
Mesotocin	Cys	Tyr	Ile	Gln	Asn	Cys	Pro	Ile	Gly—(NH_2)	Reptiles, amphibians, and lungfishes
Glumitocin	Cys	Tyr	Ile	Ser	Asn	Cys	Pro	Gln	Gly—(NH_2)	Some elasmobranchs

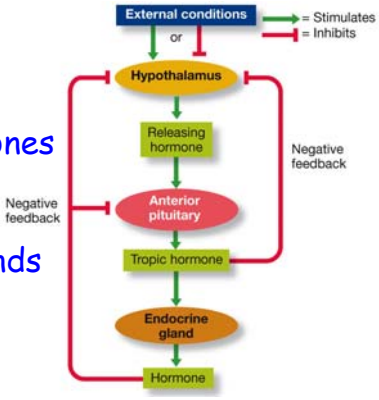
*The cysteine residues in positions 1 and 6 of each peptide are bridged by a disulfide bond.
Source: Frieden and Lipner, 1971.

ADH

Similar, highly conserved peptide hormones

Tropic Hormones

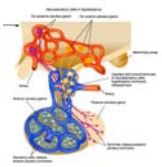
Multiple Glands

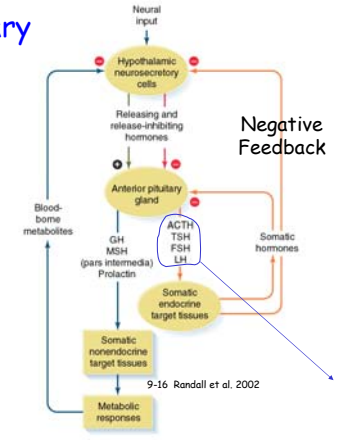


Anterior Pituitary

Tropic hormones = act on other endocrine tissues

(e.g., adrenal cortex, thyroid, gonads)





9-16 Randall et al. 2002

Tropic Hormones of Anterior Pituitary

Table 9-3 Tropic hormones of the anterior pituitary gland

Hormone	Structure	Target tissue	Primary action in mammals	Regulation*
Adrenocorticotropic hormone (ACTH)	Peptide	Adrenal cortex	Increases synthesis and secretion of steroid hormones by adrenal cortex	Cortical-releasing hormone (CRH) stimulates release; ACTH slows release of CRH
Follicle-stimulating hormone (FSH)	Glycoprotein	Ovarian follicles (female); seminiferous tubules (male)	In female, stimulates maturation of ovarian follicles; in male, increases sperm production	GnRH stimulates release; inhibin and steroid sex hormones inhibit release
Luteinizing hormone (LH)	Glycoprotein	Ovarian interstitial cells (female); testicular interstitial cells (male)	In female, induces final maturation of ovarian follicles, estrogen secretion, ovulation, corpus luteum formation, and progesterone secretion; in male, increases synthesis and secretion of androgens	GnRH stimulates release; inhibin and steroid sex hormones inhibit release
Thyroid-stimulating hormone (TSH)	Glycoprotein	Thyroid gland	Increases synthesis and secretion of thyroid hormones	TRH induces secretion; thyroid hormones and somatostatin slow release

ACTH

FSH

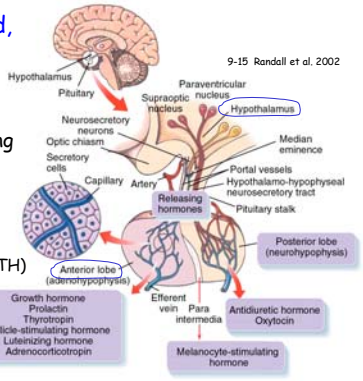
LH

TSH

*See Table 9-2 for key to abbreviations.

Randall et al. 2002

In response to cold, fright, pain etc…



9-15 Randall et al. 2002

Hypothalamus
-corticotropin-releasing hormone

Portal vessel

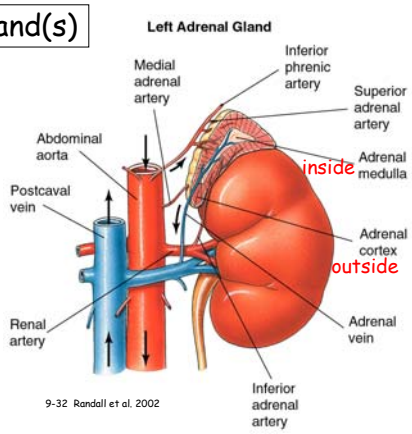
Anterior Pituitary
-Adrenocorticotropin (ACTH)

Blood Stream

Adrenal Cortex
(corticosterone; stress hormones)

32

Adrenal Gland(s)

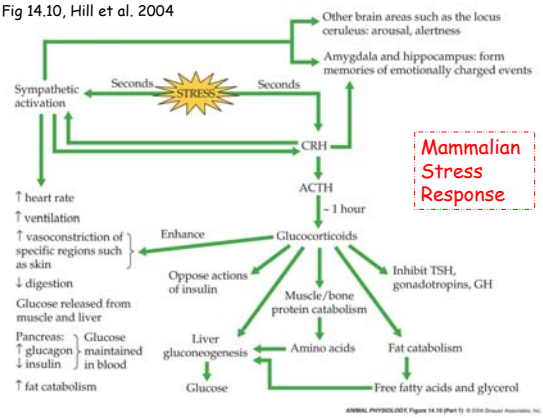


Catecholamines
(from medulla)

Glucocorticoids
(from cortex)

9-32 Randall et al. 2002

Fig 14.10, Hill et al. 2004



Mammalian Stress Response

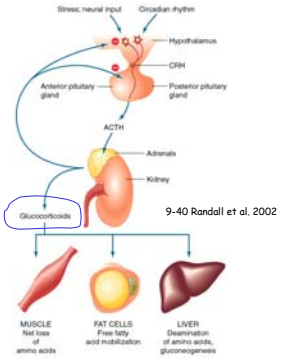
Glucocorticoids

(from adrenal cortex)

Includes 'Stress Hormones'
Cortisol, cortisone, corticosterone

Released in response to ACTH (Adrenocorticotropin) from Anterior Pituitary

Steroid hormones (lipid soluble) derived from cholesterol



9-40 Randall et al. 2002

(mobilize a.a.s and glucose, suppress immune system etc.)

35

Vasopressin from Anterior Pituitary

Blood loss:
↑ vasopressin → ↑ water reabsorption at kidney
↑ aldosterone → ↑ Na reabsorption at kidney

↑ fluid retention

↑ blood volume

↑ blood pressure

Negative Feedback Loop

More on aldosterone and other kidney hormones later

Fig 14.10, Hill et al. 2004

Water and Electrolyte Balance Hormones

Randall et al. 2002

Table 9-8 Mammalian hormones involved in regulating water and electrolyte balance

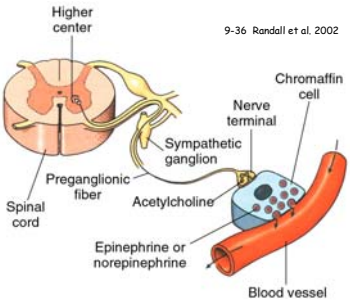
Hormone	Tissue of origin	Structure	Target tissue	Primary action	Regulation
Antidiuretic hormone (ADH, vasopressin)	Posterior pituitary	Nonapeptide	Kidneys	Increases water reabsorption (cAMP pathway)	Increased plasma osmotic pressure or decreased blood volume stimulates release
Post. Pit., signal from Hypothal					
Atrial natriuretic peptide (ANP)	Heart (atrium)	Peptide	Kidneys	Reduces Na^+ and water reabsorption	Increased venous pressure stimulates release
Calcitonin	Thyroid (parafollicular cells)	Peptide	Bones, kidneys	Decreases release of Ca^{2+} from bone; increases renal Ca^{2+} and PO_4^{3-} excretion	Increased plasma Ca^{2+} stimulates secretion
Mineralocorticoids (e.g., aldosterone)	Adrenal cortex	Steroid	Distal kidney tubules	Promotes reabsorption of Na^+ from urinary filtrate	Angiotensin II stimulates secretion
Parathyroid hormone (PTH)	Parathyroid gland	Peptide	Bones, kidneys, intestine	Increases release of Ca^{2+} from bone; with calcitriol increases intestinal Ca^{2+} absorption; decreases renal Ca^{2+} excretion	Decreased plasma Ca^{2+} stimulates secretion

Calcitonin decrease Ca^{++} in blood; PTH increase Ca^{++} in blood

Fight/flight, exertion

Catecholamines
(adrenal medulla)
- Epi, Norepi

Secretion regulated by sympathetic preganglionic cholinergic neurons



9-36 Randall et al. 2002

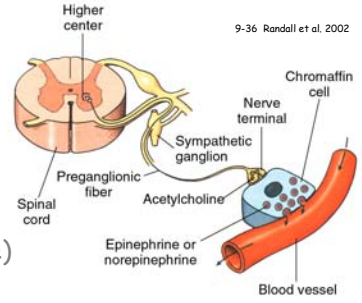
Catecholamine receptors are Alpha and Beta adrenoreceptors

Alpha – smooth muscle contraction

Beta1 – cardiac muscle stimulant
Beta2 – broncho/vaso dilation

Fight/Flight

Catecholamines from adrenal medulla (e.g. epinephrine)



9-36 Randall et al. 2002

Secretion regulated by sympathetic neurons

Response includes bronchodilation, vasodilation to major muscles, vasoconstriction to stomach and skin, increased heart rate, mobilization of resources

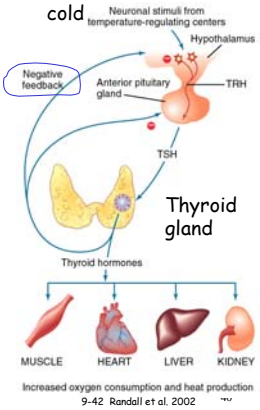
Thyroid Hormone (aka Thyroxine)

T_3 and T_4 (# of iodines)

lipid soluble

Development, maturation, protein synthesis, metabolism

Being cold can stimulate

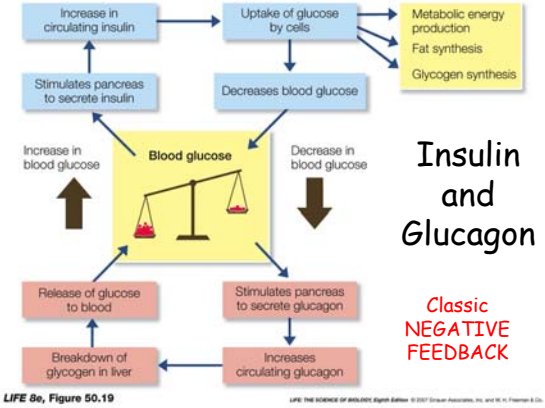


9-42 Randall et al. 2002

Thyroxine and Thyroid Gland

Hypothyroid Goiter
(e.g. not enough iodine in diet)

Hyperthyroid Goiter
(e.g. 1. thyroxine receptors on hypothalamus or anterior pituitary don't work,
or
2. receptor for thyroid stimulating hormone is activated by autoimmune antibody)



Insulin and Glucagon

Classic NEGATIVE FEEDBACK

Insulin and Glucagon Regulate blood [glucose]

- Insulin in response to high [glu]
- Glucagon in response to low [glu]

Both from pancreatic gland:
Insulin from beta cells
Glucagon from alpha cells

Leads to glucose uptake into tissues ETC.

Causes glycogenolysis and glucose release from tissues (liver, muscles)

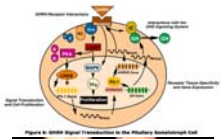
Type 1 Diabetes
-when beta cells decrease insulin production
Type 2 Diabetes
-when insulin receptor signal pathway defective

43

Growth Hormone

Metabolic and developmental effects

From Anterior Pituitary



Often has opposite effect of insulin

-Stimulates gluconeogenesis
-Reserves glucose for NS
-Promotes use of fatty acids as fuel

Works with Thyroid hormone in growth and development

abnormality

Gigantism / Acromegaly

Growth Hormone

\+ -Gigantism
-Acromegaly

\- Dwarfism

Vertebrate Reproduction

46

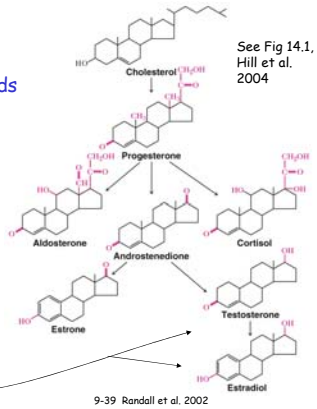
Asexual
Parthenogenetic
Whiptail
Lizards

47

Reproductive Hormones

Steroid Hormones from Adrenal cortex and Gonads

Hypothalamus
↓
GnRH
↓
Anterior Pituitary
↓
FSH, LH
↓
Gonads, Adrenal Cortex



See Fig 14.1, Hill et al. 2004

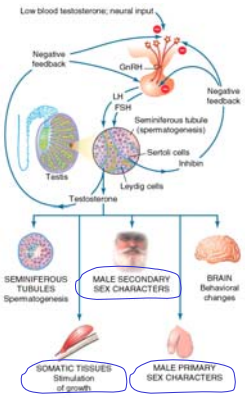
9-39 Randall et al. 2002

Male Sex Hormones

Testosterone and other androgens

Released from Leydig Cells in response to LH, FSH

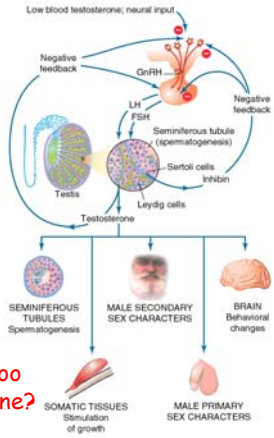
FSH binding to Sertoli cells stimulates spermatogenesis



9-46 Randall et al. 2002

Steroid Abuse

Homeostasis & Negative Feedback



What happens if you take too much exogenous testosterone?

Female Sex Hormones

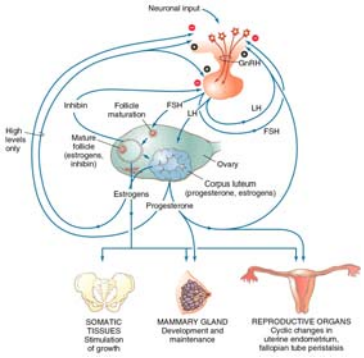
Estrogens

Ova created and stored before birth (mammals and birds)

Repro cycle in 2 phases:

Follicular and Luteal

FSH stimulates beginning of follicular phase -> development of ovarian follicles



9-47 Randall et al. 2002

Follicular Phase

1- FSH ⇑

Causing follicular maturation

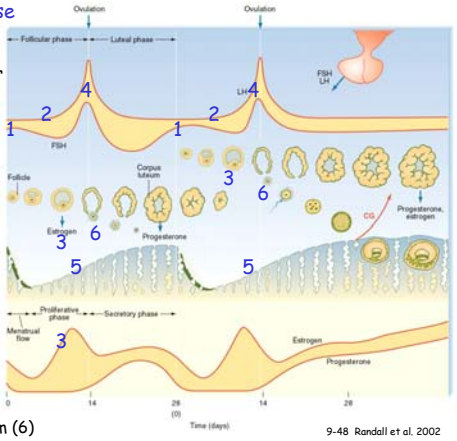
2- LH ⇑

FSH and LH help generate Estrogen (3)

This Estrogen causes hypothal and ant. pit. to release spike of LH and FSH leading to ovulation (4)

(endometrium 5)

= release of ovum (6)



9-48 Randall et al. 2002

Luteal Phase

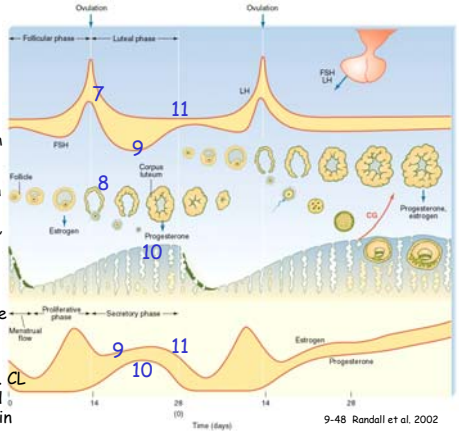
7- FSH, LH ⇓
Estrogen ⇓

8- LH changes ruptured follicle into corpus luteum

9- corpus luteum secretes estrogen and progesterone which inhibit FSH, LH release from anterior pituitary by slowing GnRH

10- progesterone leads to richer endometrium

11- without fert. CL degenerates and cycle begins again

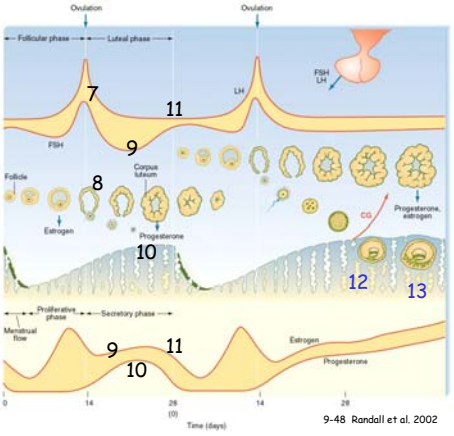


9-48 Randall et al. 2002

Luteal Phase

12- with fert. Chorionic gonadotropin maintains CL, maintaining high levels of estrogen and progesterone; maintaining endometrium; follicular development inhibited

13- Placenta takes over hormone production

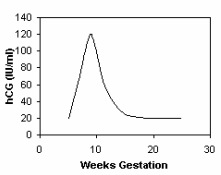


9-48 Randall et al. 2002

Dear Cecil:
I just hit 40 and still have an unanswered question from my teens that has always bothered me. Aerosmith in "Sweet Emotion" sings about being accused of impregnating a girl. At the end of the verse they sing, "can't catch me 'cause the rabbit done died," referring to a pregnancy test. Arguments start over just what this test entails. Most say the bunny will die, but can't agree as to why. Some say the rabbit will always die because they kill it before they take its blood (which seems pretty dumb). Some say they inject it with some fluid taken from the woman and it dies a horrible, convulsive death. And some say they have to dissect the rabbit after it has been injected. This was before those home test kits, but wasn't there a better way? --Joe Shredl, Colonial Heights, Virginia

55

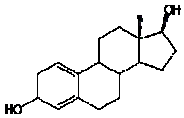
Chorionic gonadotropin
hCG
eCG



56

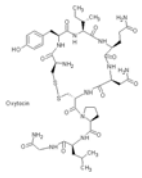
Birth Control Pills?

Progesterone and Estradiol – mimic early pregnancy and inhibit ovulation



Parturition (Birth)

Oxytocin released in response to cervical stretch
Oxytocin causes uterine smooth muscle contractions



Positive Feedback Loop

57

Lactation

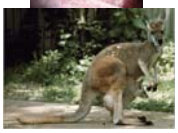
Decreased progesterone levels and presence of prolactin (milk production) and oxytocin (milk ejection) and other hormones

Antibodies
Vitamins

joey

Mechanosensory feedback

Dopamine inhibits prolactin secretion



marsupial

58

Randall et al. 2002

Table 9-9 **Important mammalian reproductive hormones**

Hormone	Tissue of origin	Structure	Target tissue	Primary action	Regulation
Primary sex hormones					
Estradiol-17β (estrogens)	Ovarian follicle, corpus luteum, adrenal cortex	Steroid	Most tissues	Promotes development and maintenance of female characteristics and behavior, oocyte maturation, and uterine proliferation	Increased FSH and LH levels stimulate secretion
Progesterone	Corpus luteum, adrenal cortex	Steroid	Uterus, mammary glands	Maintains uterine secretion; stimulates mammary duct formation	Increased LH and prolactin levels stimulate secretion
Testosterone (androgens)	Testes (Leydig cells), adrenal cortex	Steroid	Most tissues	Promotes development and maintenance of male characteristics and behavior and spermatogenesis	Increased LH level stimulates secretion
Other Hormones					
Oxytocin	Posterior pituitary	Nonapeptide	Uterus, mammary glands	Promotes smooth muscle contraction and milk ejection	Cervical distention and suckling stimulate release; high progesterone inhibits release
Prolactin (PL)	Anterior pituitary	Peptide	Mammary glands (alveolar cells)	Increases synthesis of milk proteins and growth of mammary glands; elicits maternal behavior	Continuous secretion of PL-inhibiting hormone (PIH) normally blocks release; increased estrogen and decreased PIH secretion permit release

59