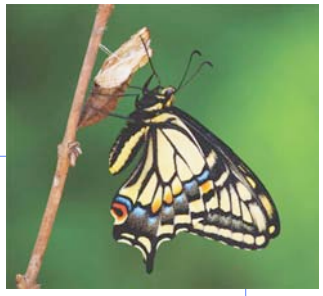
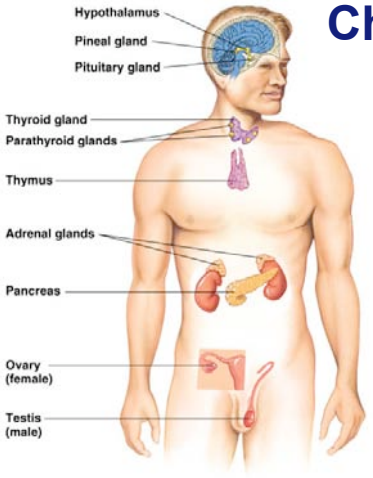


Chapter 45.

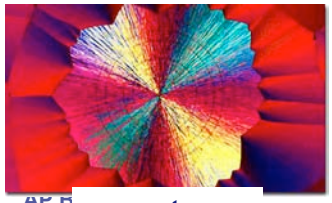


Endocrine System Hormones

2004-2005

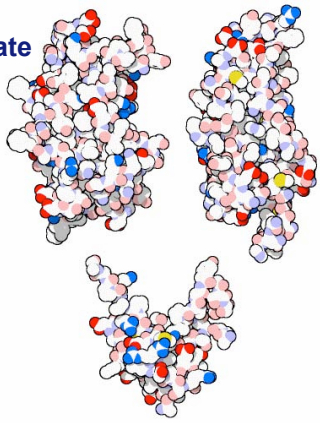
Regulation

- Why are hormones needed?
  - homeostasis
    - animals = fine-tuned, complex, multi-functioning systems
    - communication needed to coordinate whole body functions
      - metabolic rate
      - growth
      - maturation
      - reproduction



progesterone

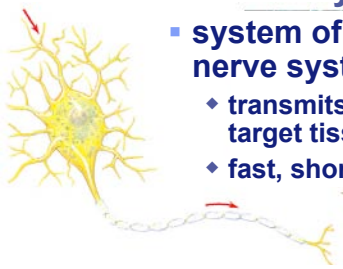
estradiol

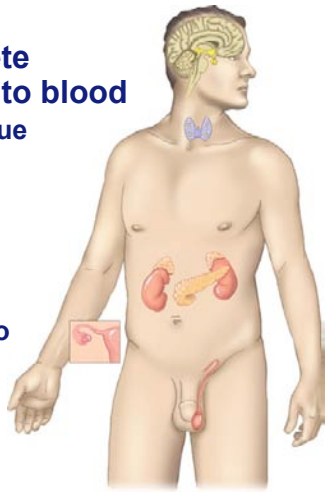


growth hormones

Regulation & Communication

- **Animals rely on 2 systems for regulation**
  - **endocrine system**
    - **ductless gland which secrete chemical signals directly into blood**
      - **chemical travels to target tissue**
      - **slow, long-lasting response**
  - **nervous system**
    - **system of neurons, central nerve system**
      - **transmits "electrical" signal to target tissue**
      - **fast, short-lasting response**

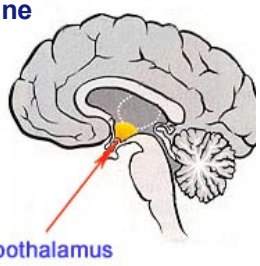


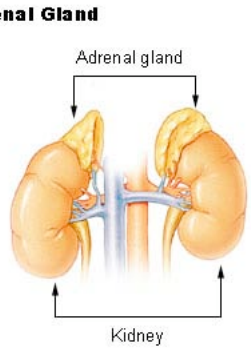


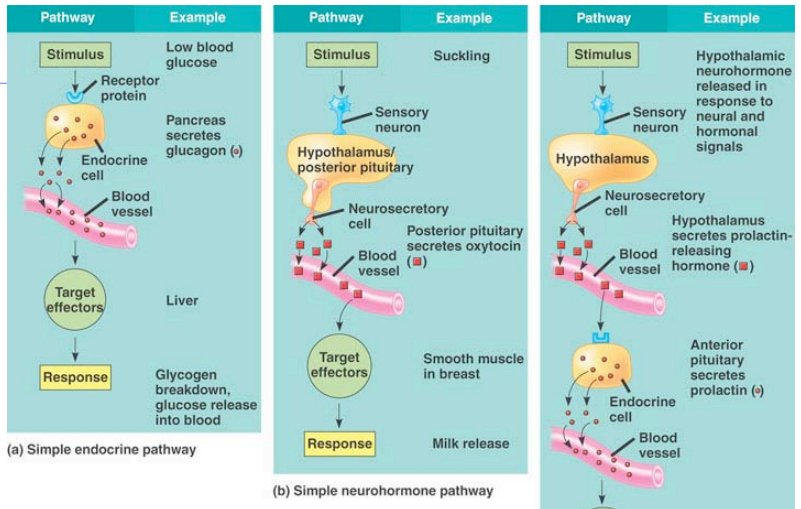
Hormones coordinate slower but longer–acting responses to stimuli such as stress, dehydration, and low blood glucose levels. Hormones also regulate long–term developmental processes by informing different parts of the body how fast to grow or when to develop the characteristics that distinguish male from female or juvenile from adult. Hormone–secreting organs, called endocrine glands, are referred to as ductless glands because they secrete their chemical messengers directly into extracellular fluid. From there, the chemicals diffuse into the circulation.

Neurosecretory cells

- Overlap between endocrine & nervous system regulation
  - specialized nerve cells which release hormones into blood
    - hypothalamus
    - adrenal gland
      - epinephrine



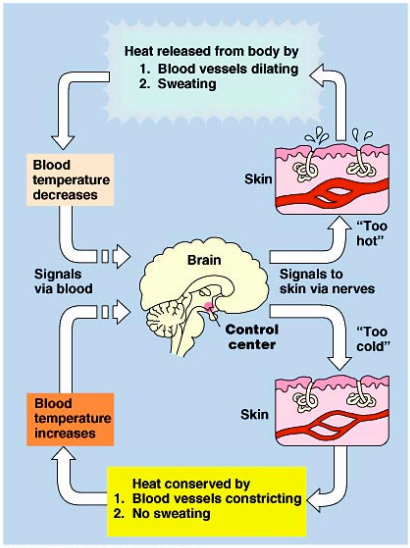




- **Receptor detects change in internal or external stimulus & informs control center**
- **Control center sends out signal**
  - **hormone or neurohormone**

Homeostasis

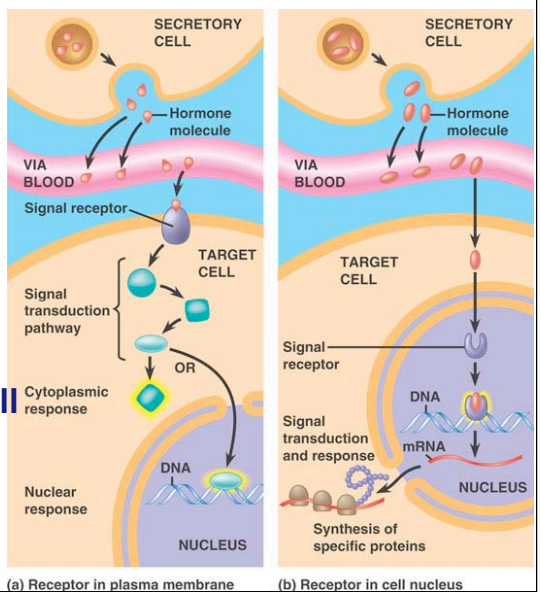
- **Negative feedback**
  - stimulus triggers control mechanism that counteracts further change
    - body temperature
    - sugar metabolism
- **Positive feedback**
  - stimulus triggers control mechanism that amplifies effect
    - lactation



(b) Control of body temperature

Modes of hormone action on target cells

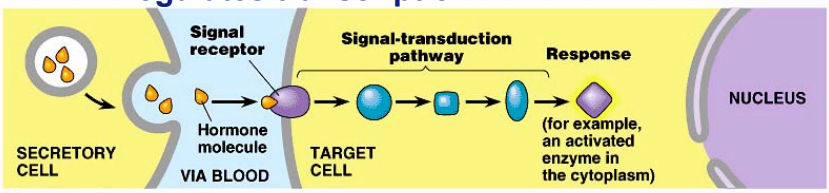
- Hormone binds to cell membrane
  - protein hormones
  - signal transduction
- Hormone enters cell & binds to receptors within cell
  - lipid hormones
    - steroids



(a) Receptor in plasma membrane (b) Receptor in cell nucleus

Protein hormones

- Communication from the outside
  - hormone binds to cell membrane receptor
  - triggers multi-step signal-transduction pathway
    - initiates cellular response
      - activation of enzyme, change in uptake or secretion of specific molecules, rearrangement of cytoskeleton
    - regulates transcription



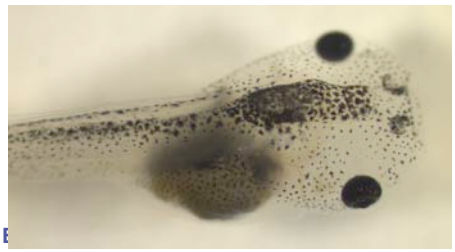
AP B

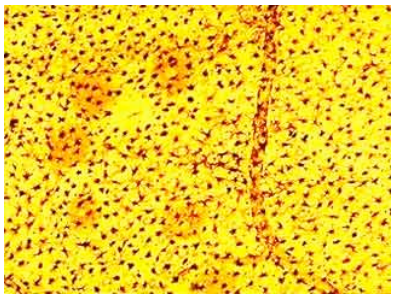
(a) Receptor in plasma membrane

Triggering internal cellular activity

Melanocyte stimulating hormone (MSH)

Cell-surface receptors respond to changing light trigger movement of melanocytes in frog skin helping to camouflage the frog



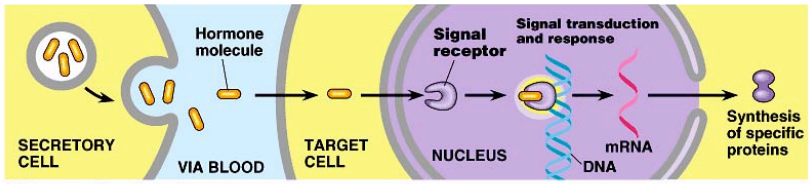


AP

Another demonstration of the role of cell–surface receptors involves changes in a frog's skin color, an adaptation that helps camouflage the frog in changing light. Skin cells called melanocytes contain the dark brown pigment melanin in cytoplasmic organelles called melanosomes. The frog's skin appears light when melanosomes cluster tightly around the cell nuclei and darker when melanosomes spread throughout the cytoplasm. A peptide hormone called melanocyte–stimulating hormone controls the arrangement of melanosomes and thus the frog's skin color. Adding melanocyte–stimulating hormone to the interstitial fluid surrounding the pigment–containing cells causes the melanosomes to disperse. However, direct microinjection of melanocyte–stimulating hormone into individual melanocytes does not induce melanosome dispersion—evidence that interaction between the hormone and a surface receptor is required for hormone action.

Lipid hormones

- **Communication from the inside**
  - hormone enters through cell membrane
    - steroids hormones / sex hormones
  - binds to receptor in cytoplasm or nucleus
  - receptor triggers transduction of signal directly
  - regulates transcription
    - change in gene expression



AP Bi

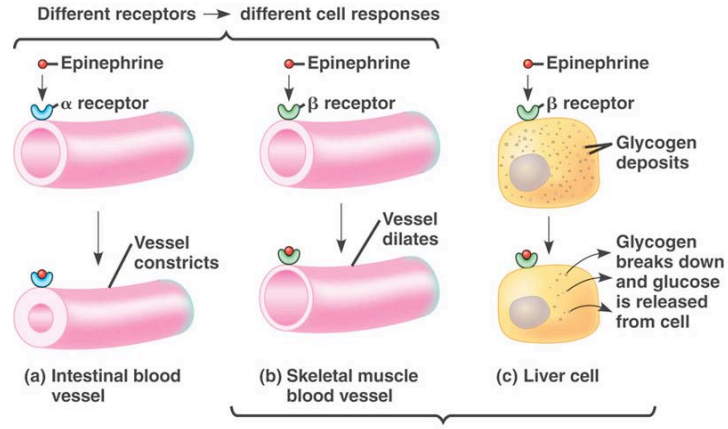
(b) Receptor in cell nucleus

Intracellular receptors usually perform the entire task of transducing a signal within a target cell. The chemical signal activates the receptor, which then directly triggers the cell's response. In almost all cases, the intracellular receptor activated by a lipid–soluble hormone is a transcription factor, and the response is a change in gene expression.

Most intracellular receptors are already located in the nucleus when they bind hormone molecules, which have diffused in from the bloodstream. The resulting hormone–receptor complexes bind, in turn, to specific sites in the cell's DNA and stimulate the transcription of specific genes. Some steroid hormone receptors, however, are trapped in the cytoplasm when no hormone is present. Binding of a steroid hormone to its cytoplasmic receptor forms a hormone–receptor complex that can move into the nucleus and stimulate transcription of specific genes. In both cases, mRNA produced in response to hormone stimulation is translated into new protein in the cytoplasm. For example, estrogen induces cells in the reproductive system of a female bird to synthesize large amounts of ovalbumin, the main protein of egg white.

Cell specific response

- **Interaction of hormones & receptors based on chemical properties**



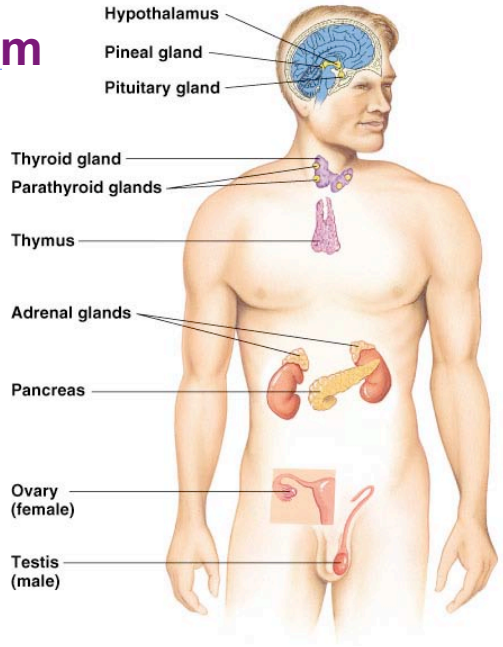
AP Biolog 005

One chemical signal, different effects. Epinephrine, the primary "fight–or–flight" hormone, produces different responses in different target cells. Responses of target cells may differ if they have different receptors for a hormone [compare (a) with (b)]. Target cells with the same receptor exhibit different responses if they have different signal transduction pathways and/or effector proteins [compare (b) with (c)].

As with hormones that bind to cell–surface receptors, hormones that bind to intracellular receptors may exert different effects on different target cells. The estrogen that stimulates a bird's reproductive system to make ovalbumin causes the bird's liver to make other proteins. The same hormone also may have different effects in different species. For instance, thyroxine produced by the thyroid gland regulates metabolism in humans and other vertebrates. But in frogs, thyroxine has additional effects: it triggers the metamorphosis of a tadpole into an adult, stimulating resorption of the tadpole's tail and other changes.

Endocrine system

- Ductless glands release hormones into blood



Duct glands = exocrine (tears, salivary)

Table 45.1 Major Vertebrate Endocrine Glands and Some of Their Hormones (Hypothalamus – Parathyroid glands)

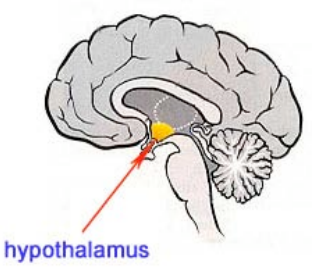
Gland		Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus		Hormones released by the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Pituitary gland Posterior pituitary (releases hormones made by hypothalamus)		Oxytocin	Peptide	Stimulates contraction of uterus and mammary gland cells	Nervous system
		Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance
Anterior pituitary		Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
		Prolactin (PRL)	Protein	Stimulates milk production and secretion	Hypothalamic hormones
		Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates production of ova and sperm	Hypothalamic hormones
		Luteinizing hormone (LH)	Glycoprotein	Stimulates ovaries and testes	Hypothalamic hormones
		Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid gland	Thyroxine in blood; hypothalamic hormones
		Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Glucocorticoids; hypothalamic hormones
Thyroid gland		Triiodothyronine (T_3) and thyroxine (T_4)	Amine	Stimulate and maintain metabolic processes	TSH
		Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands		Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood

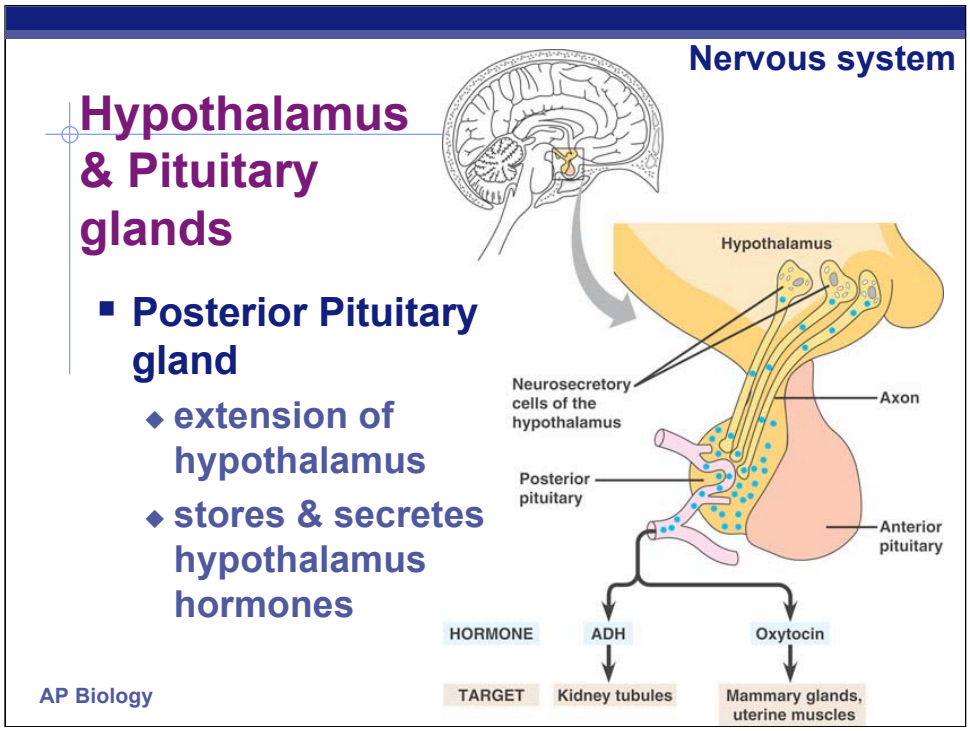
Table 45.1 Major Vertebrate Endocrine Glands and Some of Their Hormones (Pancreas – Thymus)

Gland		Hormone	Chemical Class	Representative Actions	Regulated By
Pancreas		Insulin	Protein	Lowers blood glucose level	Glucose in blood
		Glucagon	Protein	Raises blood glucose level	Glucose in blood
Adrenal glands					
Adrenal medulla		Epinephrine and norepinephrine	Amine	Raise blood glucose level; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex		Glucocorticoids	Steroid	Raise blood glucose level	ACTH
		Mineralocorticoids	Steroid	Promote reabsorption of Na^+ and excretion of K^+ in kidneys	K^+ in blood
Gonads					
Testes		Androgens	Steroid	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries		Estrogens	Steroid	Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics	FSH and LH
		Progesterone	Steroid	Promotes uterine lining growth	FSH and LH
Pineal gland		Melatonin	Amine	Involved in biological rhythms	Light/dark cycles
Thymus		Thymosin	Peptide	Stimulates T lymphocytes	Not known

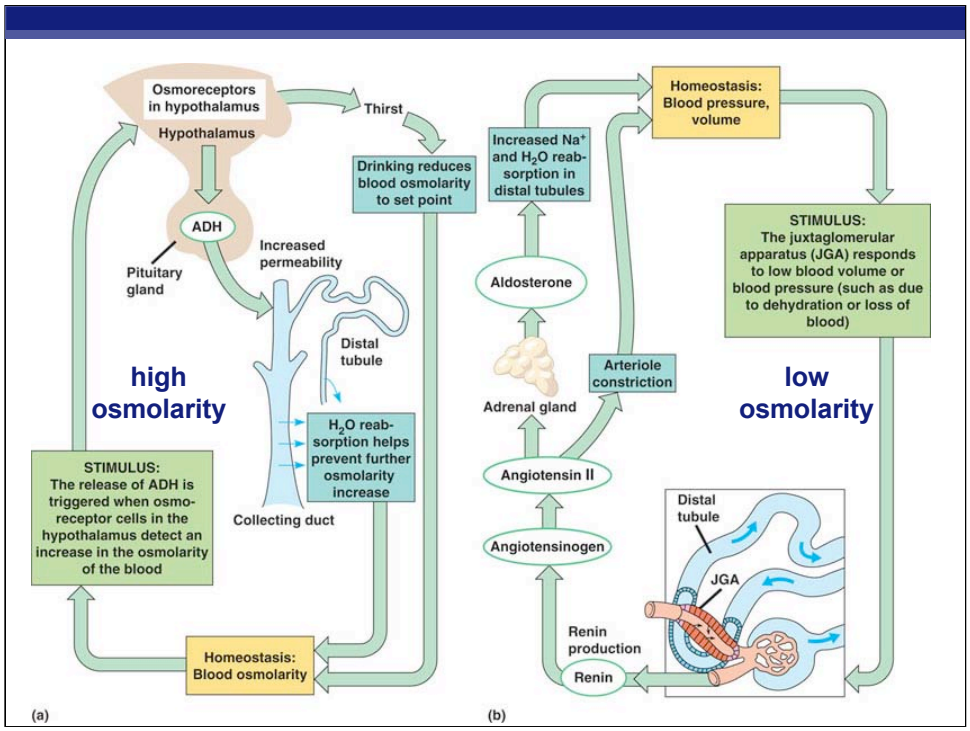
Endocrine & Nervous system links

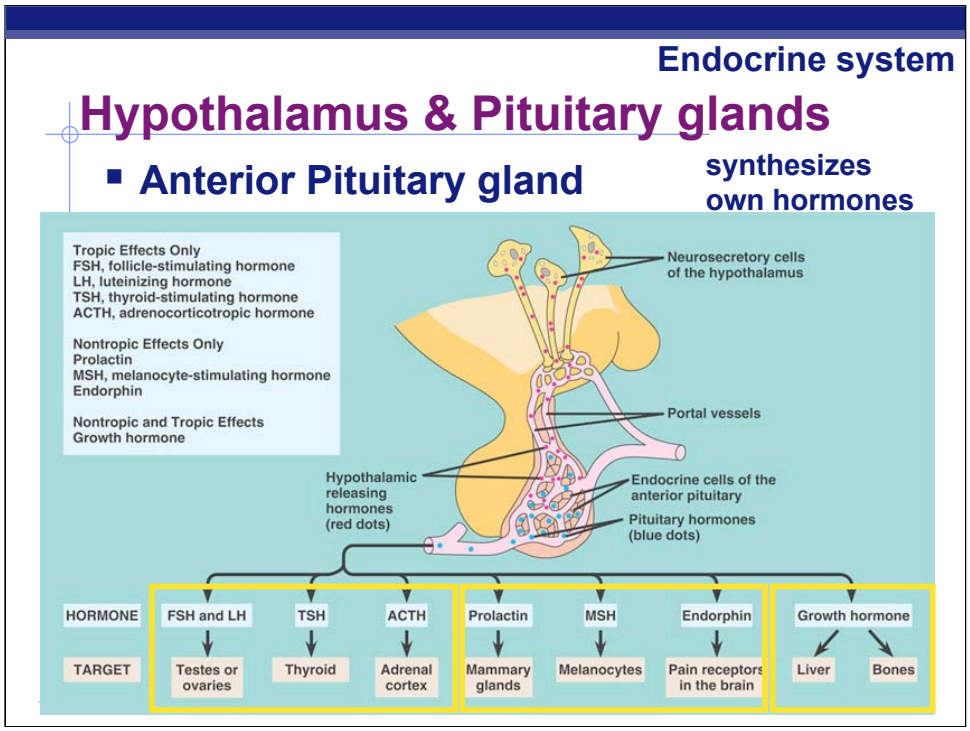
- Hypothalamus = “master control center”
  - nervous system
  - receives information from nerves around body about internal conditions
  - regulates release of hormones from pituitary
- Pituitary gland = “master gland”
  - endocrine system
  - secretes broad range of hormones regulating other glands



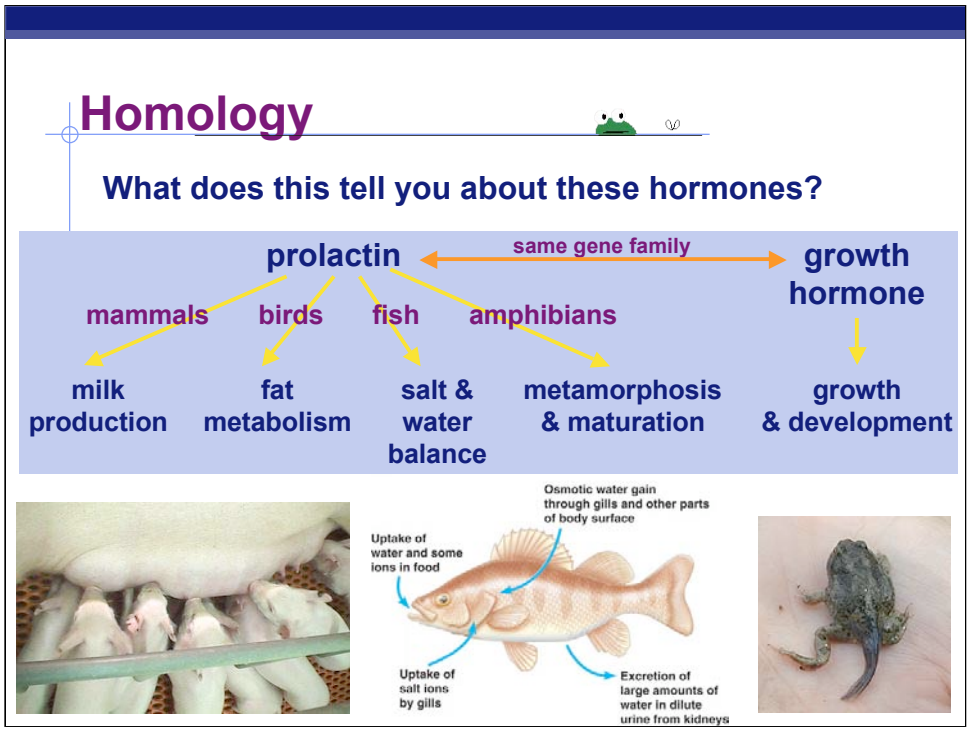


Production and release of posterior pituitary hormones. The posterior pituitary gland is an extension of the hypothalamus. Certain neurosecretory cells in the hypothalamus make antidiuretic hormone (ADH) and oxytocin, which are transported to the posterior pituitary where they are stored. Nervous signals from the brain trigger release of these neurohormones.


Osmoreceptors in hypothalamus
Hypothalamus
Thirst
Drinking reduces blood osmolarity to set point
ADH
Pituitary gland
Increased permeability
Distal tubule
high osmolarity
H2O reab-sorption helps prevent further osmolarity increase
Collecting duct
STIMULUS: The release of ADH is triggered when osmo-receptor cells in the hypothalamus detect an increase in the osmolarity of the blood
Homeostasis: Blood osmolarity
(a)
Homeostasis: Blood pressure, volume
Increased Na+ and H2O reab-sorption in distal tubules
Aldosterone
Adrenal gland
Arteriole constriction
STIMULUS: The juxtaglomerular apparatus (JGA) responds to low blood volume or blood pressure (such as due to dehydration or loss of blood)
low osmolarity
Angiotensin II
Angiotensinogen
Distal tubule
JGA
Renin production
Renin
(b)

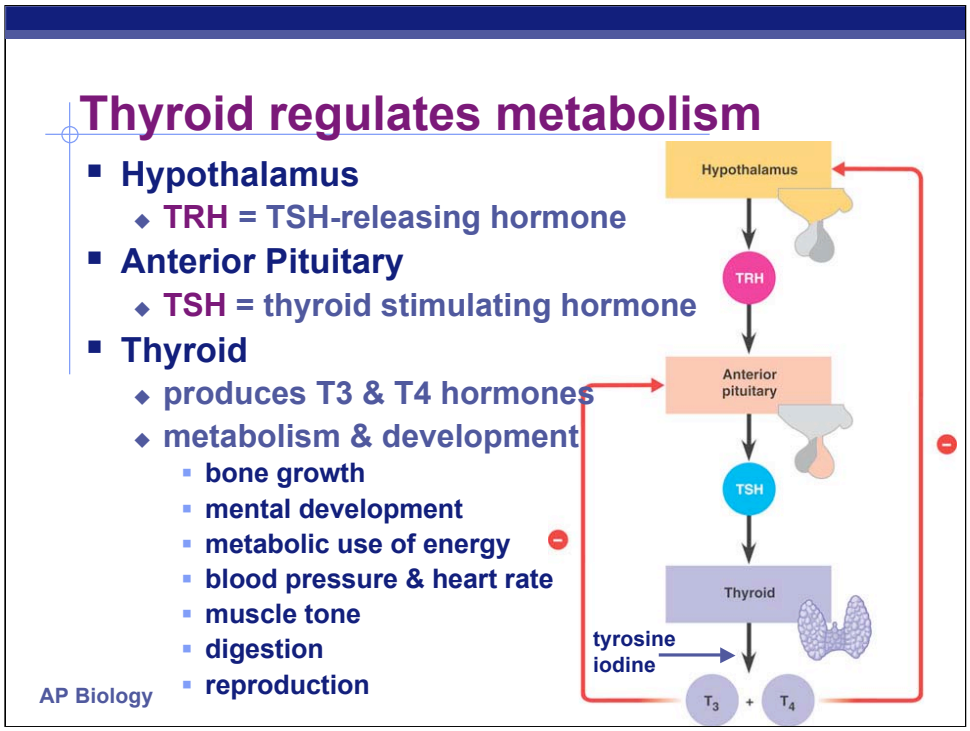


Production and release of anterior pituitary hormones. The release of hormones synthesized in the anterior pituitary gland is controlled by hypothalamic tropic hormones. The hypothalamic releasing and inhibiting hormones are secreted by neurosecretory cells into a capillary network within the hypothalamus. These capillaries drain into portal vessels that connect with a second capillary network in the anterior pituitary. Each hormone made in the anterior pituitary is secreted in response to a specific releasing hormone.



The most remarkable characteristic of prolactin (PRL) is the great diversity of effects it produces in different vertebrate species. For example, prolactin stimulates mammary gland growth and milk synthesis in mammals; regulates fat metabolism and reproduction in birds; delays metamorphosis in amphibians, where it may also function as a larval growth hormone; and regulates salt and water balance in freshwater fishes. This list suggests that prolactin is an ancient hormone whose functions have diversified during the evolution of the various vertebrate groups.

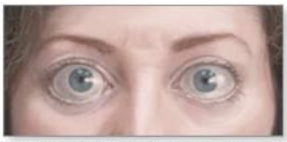
Growth hormone (GH) is so similar structurally to prolactin that scientists hypothesize that the genes directing their production evolved from the same ancestral gene.



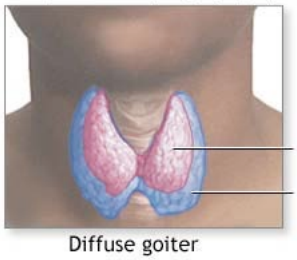
The thyroid gland produces two very similar hormones derived from the amino acid tyrosine: triiodothyronine (T3), which contains three iodine atoms, and tetraiodothyronine, or thyroxine (T4), which contains four iodine atoms. In mammals, the thyroid secretes mainly T4, but target cells convert most of it to T3 by removing one iodine atom. Although both hormones are bound by the same receptor protein located in the cell nucleus, the receptor has greater affinity for T3 than for T4. Thus, it is mostly T3 that brings about responses in target cells.

Diseases of the thyroid

- **Hyperthyroid**
  - **Graves disease**
- **Hypothyroid**
  - **Cretinism**



Exophthalmos (bulging eyes)



Diffuse goiter

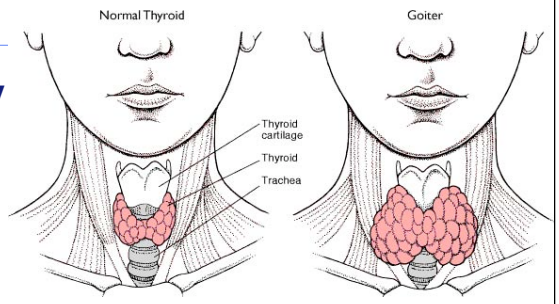
Graves' disease is a common cause of hyperthyroidism, an over-production of thyroid hormone, which causes enlargement of the thyroid and other symptoms such as exophthalmos, heat intolerance and anxiety

AP Biology

The thyroid gland also has important homeostatic functions. In adult mammals, for instance, thyroid hormones help maintain normal blood pressure, heart rate, muscle tone, digestion, and reproductive functions. Throughout the body, T3 and T4are important in bioenergetics, generally increasing the rate of oxygen consumption and cellular metabolism. Too much or too little of these hormones in the blood can result in serious metabolic disorders. In humans, excessive secretion of thyroid hormones, known as hyperthyroidism, can lead to high body temperature, profuse sweating, weight loss, irritability, and high blood pressure. The most common form of hyperthyroidism is Graves' disease; protruding eyes, caused by fluid accumulation behind the eyes, are a typical symptom

Goiter

Iodine deficiency & feedback causes thyroid to enlarge



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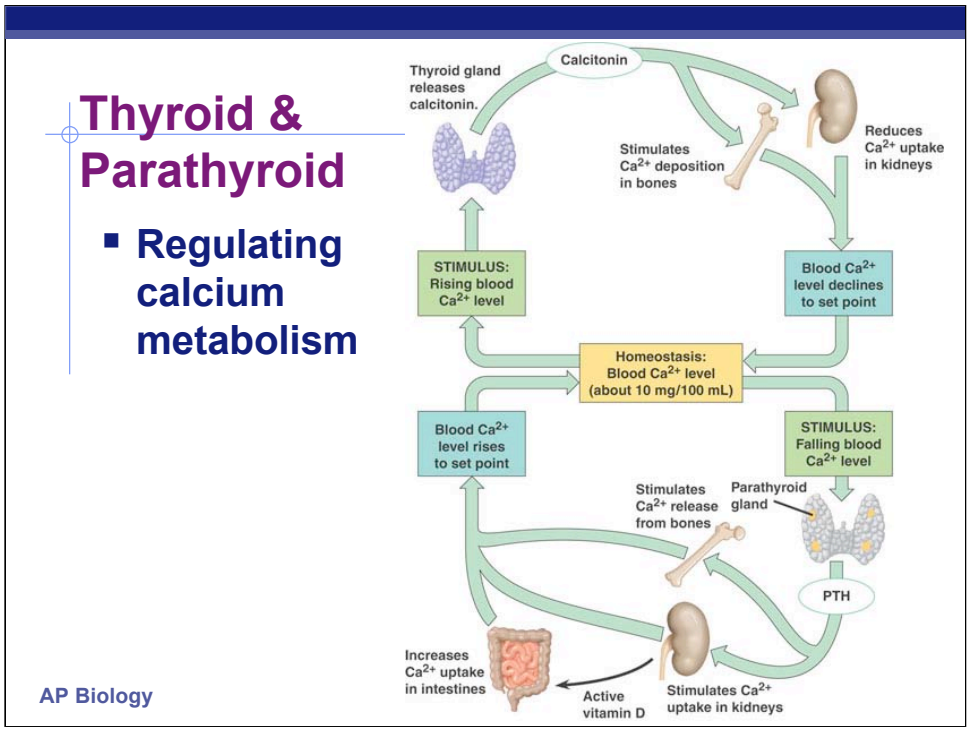
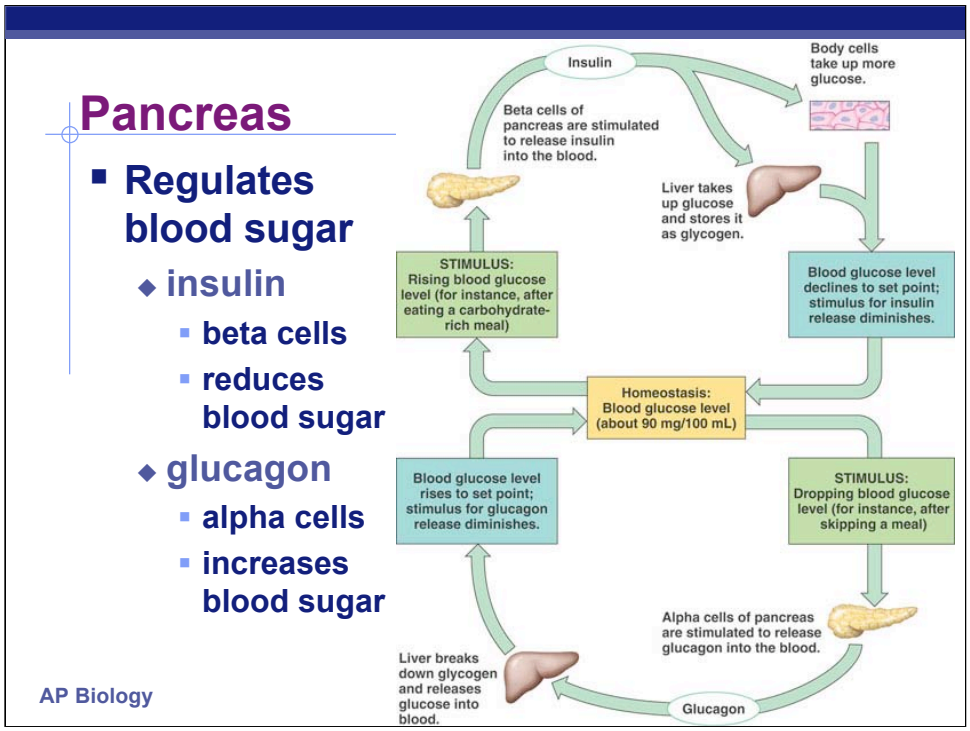


When blood Ca2+ level falls below this set point, parathyroid hormone (PTH) is released. PTH is produced by four small structures, the parathyroid glands, that are embedded in the surface of the thyroid.

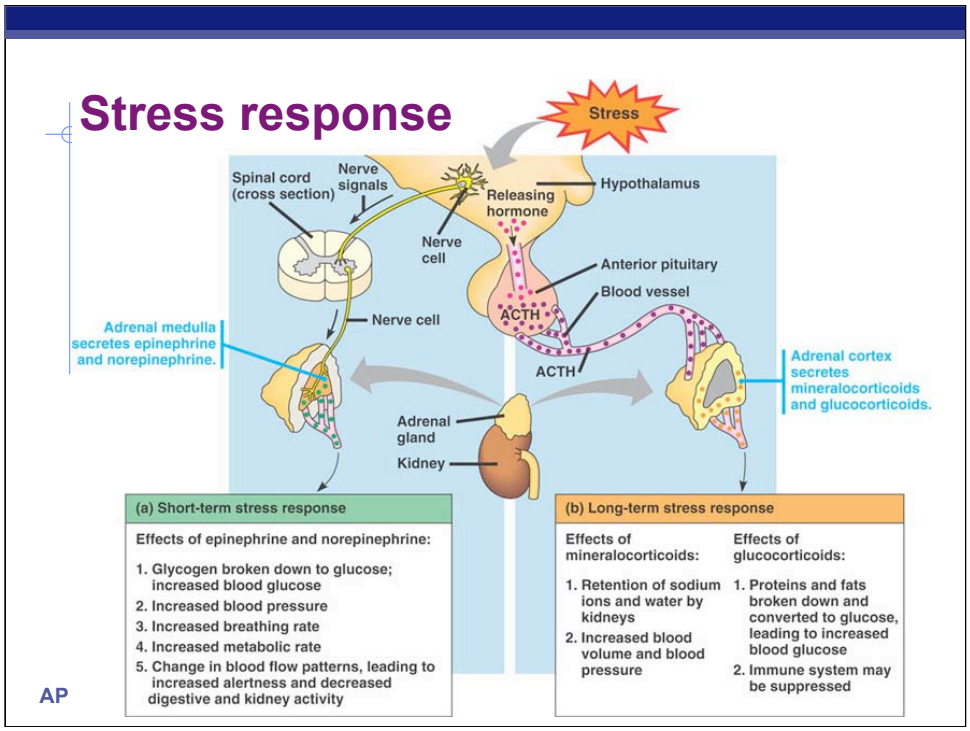
PTH raises the level of blood Ca2+ by direct and indirect effects. In bone, PTH induces specialized cells called osteoclasts to decompose the mineralized matrix of bone and release Ca2+ into the blood. In the kidneys, it directly stimulates reabsorption of Ca2+ through the renal tubules. PTH also has an indirect effect on the kidneys, promoting the conversion of vitamin D to its active hormonal form. An inactive form of vitamin D , a steroid–derived molecule, is obtained from food or synthesized in the skin. Activation of vitamin D begins in the liver and is completed in the kidneys, a process stimulated by PTH. The active form of vitamin D acts directly on the intestines, stimulating the uptake of Ca2+ from food and thus augmenting the effect of PTH.

A rise in blood Ca2+ level above the set point promotes release of calcitonin from the thyroid gland. Calcitonin exerts effects on bone and kidneys opposite to those of PTH and thus lowers the blood Ca2+ level.

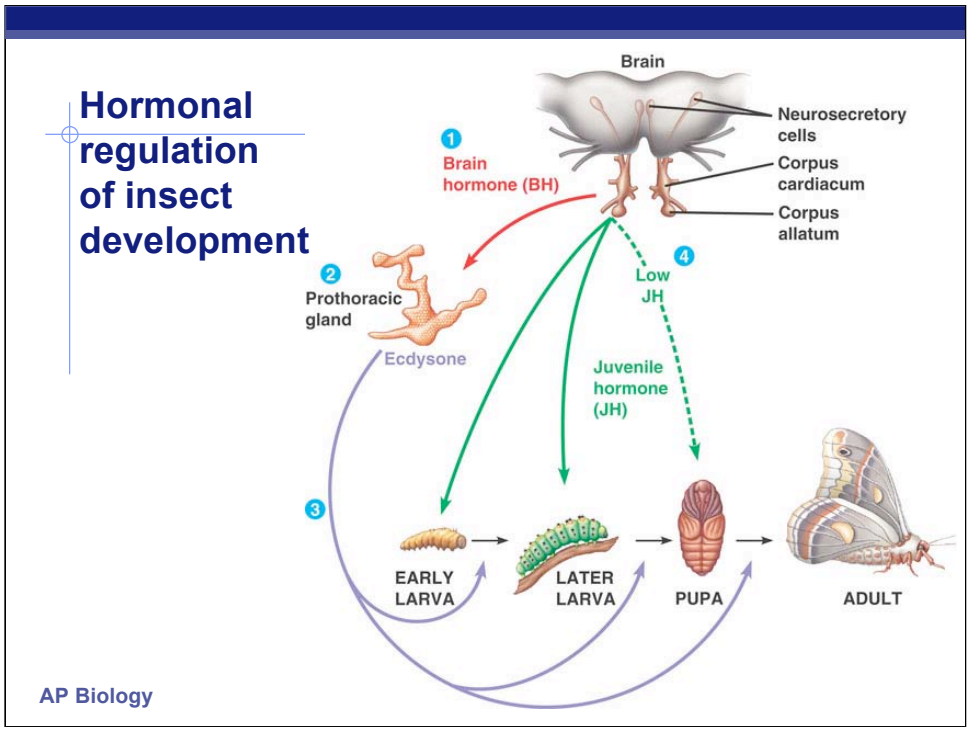


Maintenance of glucose homeostasis by insulin and glucagon. The antagonistic effects of insulin and glucagon help maintain the blood glucose level near its set point. A rise in blood glucose level above the set point promotes insulin release from the pancreas, leading to removal of excess glucose from the blood and its storage as glycogen. A fall in blood glucose level below the set point stimulates the pancreas to secrete glucagon, which acts on the liver to raise the blood glucose level.

Clusters of endocrine cells, the islets of Langerhans , are scattered throughout the exocrine tissue of the pancreas. Each islet has a population of alpha cells, which produce the hormone glucagon , and a population of beta cells, which produce the hormone insulin. Both of these protein hormones, like all endocrine signals, are secreted into the circulatory system.



Stress and the adrenal gland. Stressful stimuli cause the hypothalamus to activate the adrenal medulla via nerve impulses (a) and the adrenal cortex via hormonal signals (b). The adrenal medulla mediates short–term responses to stress by secreting the catecholamine hormones epinephrine and norepinephrine. The adrenal cortex controls more prolonged responses by secreting corticosteroids.



The hormonal regulation of insect development has been studied extensively. Three hormones play major roles in molting and metamorphosis into the adult form.

Brain hormone, produced by neurosecretory cells in the insect brain, stimulates the release of ecdysone from the prothoracic glands, a pair of endocrine glands just behind the head. Ecdysone promotes molting and the development of adult characteristics, as in the change from a caterpillar to a butterfly. Brain hormone and ecdysone are balanced by the third hormone in this system, juvenile hormone. Juvenile hormone is secreted by a pair of small endocrine glands just behind the brain, the corpora allata (singular, corpus allatum), which are somewhat analogous to the anterior pituitary gland in vertebrates. As its name suggests, juvenile hormone promotes the retention of larval (juvenile) characteristics.

In the presence of a relatively high concentration of juvenile hormone, ecdysone can still stimulate molting, but the product is simply a larger larva. Only when the level of juvenile hormone wanes can ecdysone–induced molting produce a developmental stage called a pupa. Within the pupa, metamorphosis replaces larval anatomy with the insect's adult form. Synthetic versions of juvenile hormone are now being used as insecticides to prevent insects from maturing into reproducing adults.