

HORMONES AND BEHAVIOR

1. **The Neuroendocrine System**: Sum of the glands, hormones, and target tissues/organs involved in the control of bodily functions (including behavior)

Glands: Specific cell masses in various parts of the body which produce and secrete a variety of chemicals.

Two types:

Exocrine glands : secrete their chemicals into “ducts”, which are carried to the surface of the body (ex., sweat and tear glands)

Endocrine glands : ductless glands that secrete “hormones” into the general circulation (ex., pituitary and gonadal glands)

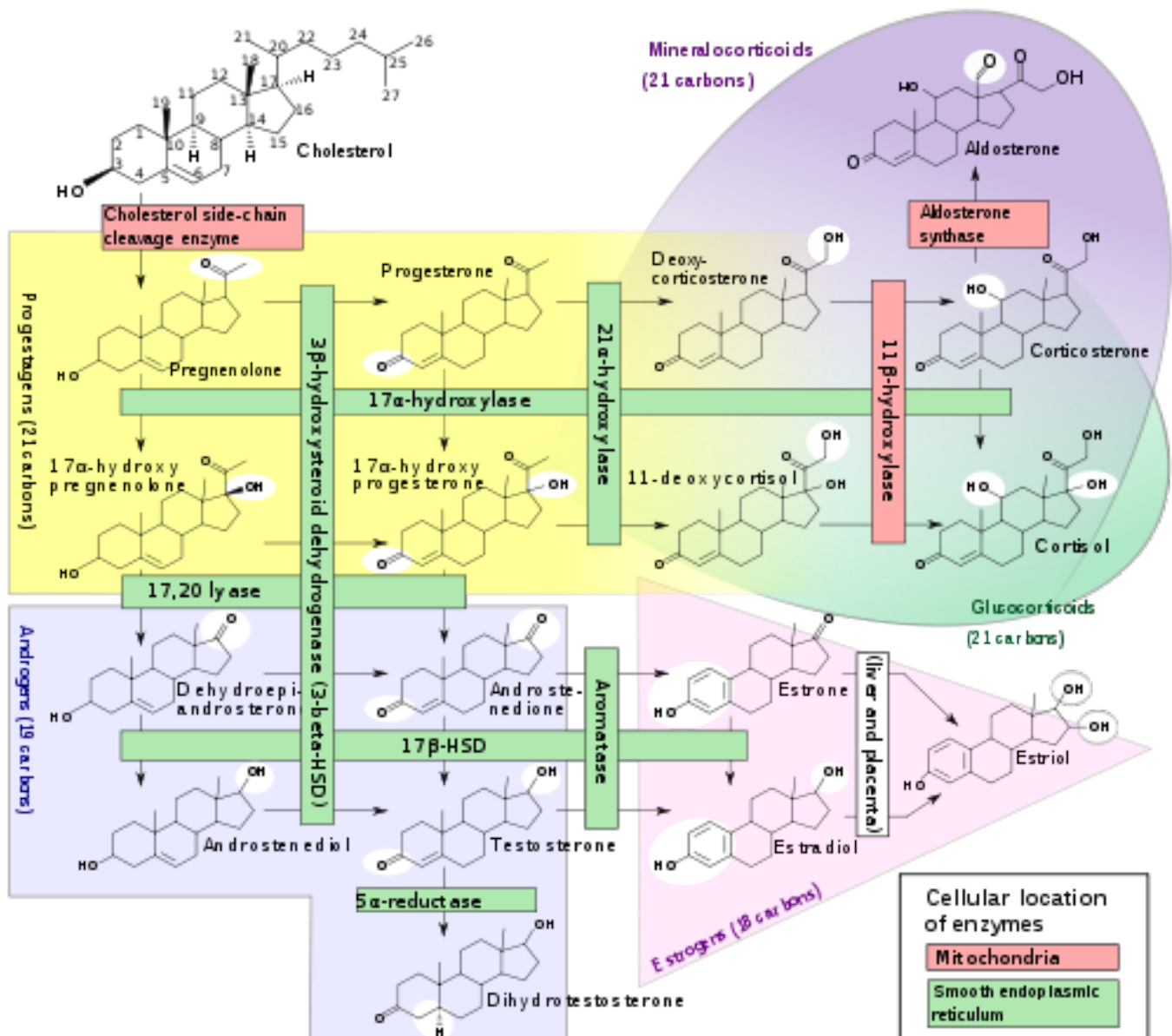
Hormones: Chemicals released by the endocrine glands into the general circulation (blood)

I. Amino acid derivatives (ex., adrenaline)

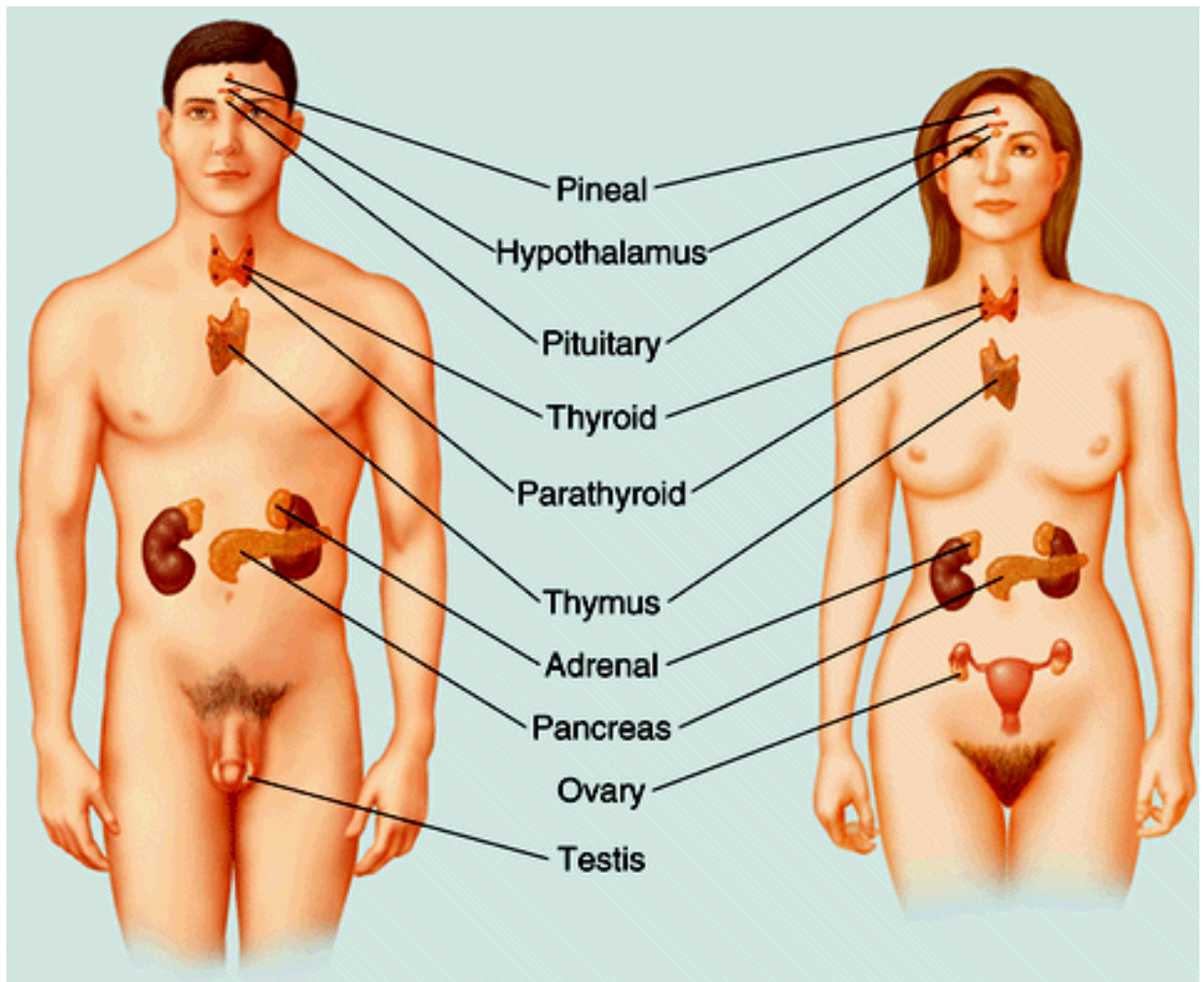
II. Short peptides and proteins (ACTH)

III. Steroids (lipid soluble - synthesized from cholesterol)

- ex., cortisol, estrogen, testosterone)



Endocrine glands & some of their hormones



Examples of hormones released by the different glands:

Pineal: Melatonin

Hypothalamus: Corticotropin-releasing hormone (CRH)

Pituitary: Luteinizing hormone (LH)

Thyroid: Thyroxin hormone (T3, T4)

Thymus: Lymphokines (involved in immunity – IL-1)

Adrenals: Cortisol, adrenaline

Pancreas: Insulin

Testes: Testosterone, estradiol

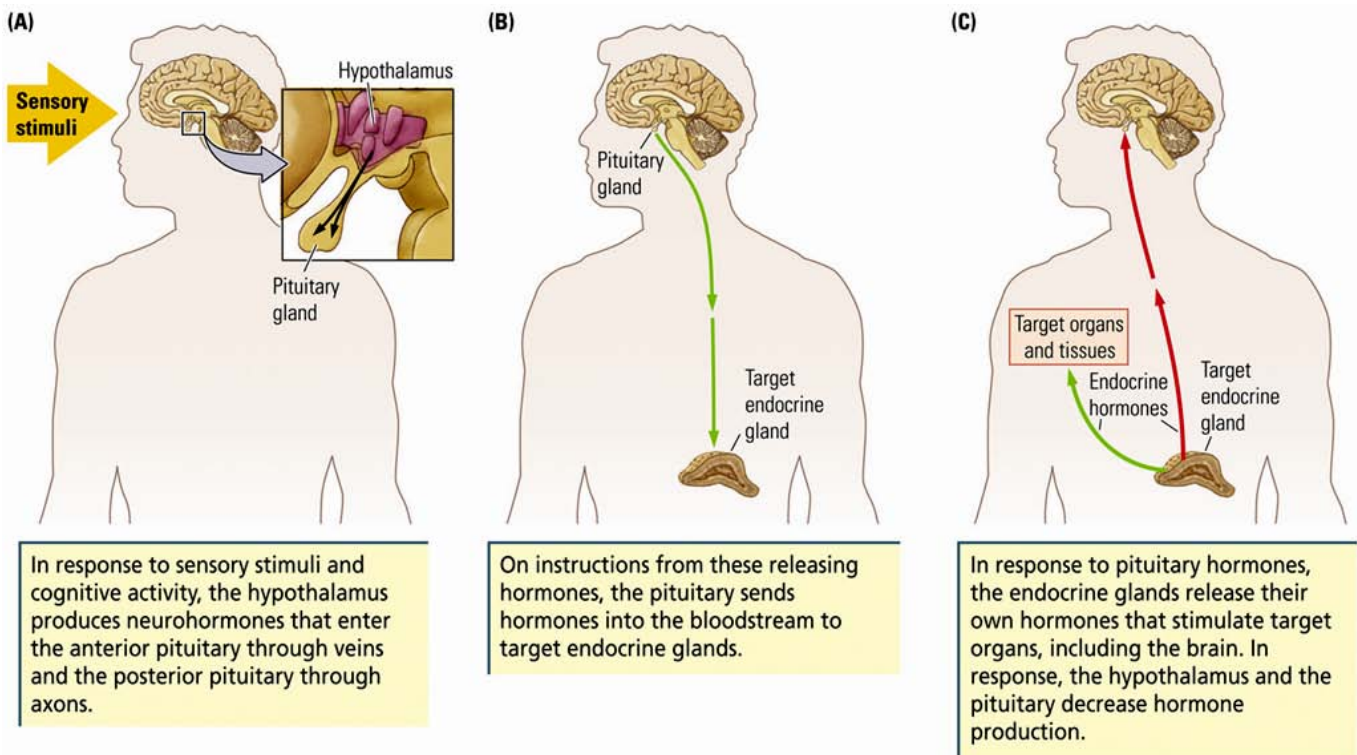
Ovaries: Testosterone, estradiol

Hierarchical control of hormones

The brain (hypothalamus) ultimately controls many of the hormones found in the body.

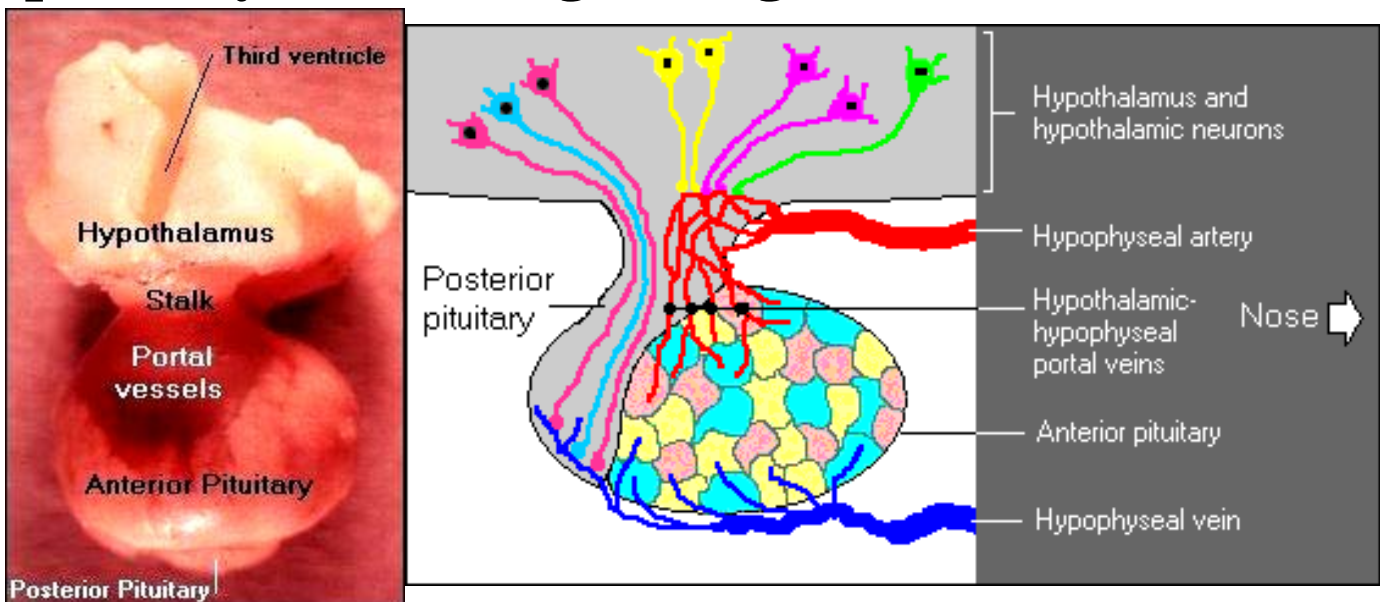
This is usually regulated through “multi-step” signaling mechanisms (pituitary gland) all the way to the various glands in the body that synthesize hormones.

In turn, many hormones reach back to the brain and influence various cognitive and behavioral functions.



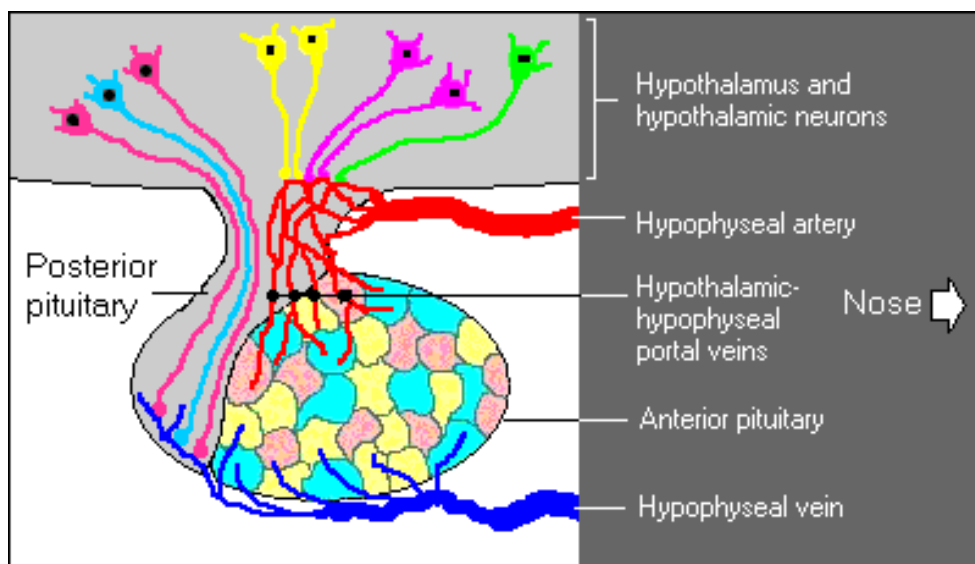
Neural control of the ANTERIOR pituitary gland

- neurons of several hypothalamic nuclei (see yellow, pink and green neurons below) produce and release hormones (“releasing hormones”) from their axons in the median eminence;
- the median eminence is highly vascularised by the hypophyseal artery, which transport the released hormones into the anterior pituitary via portal veins;
- anterior pituitary cells respond to hypothalamic hormones by producing and releasing their hormones into the hypophyseal vein, which bring hormones into the general blood circulation (goes everywhere in the body).
- Ex., Gonadotropin-releasing hormone (GnRH) from the hypothalamus produces the release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) from the anterior pituitary, which target the gonads.



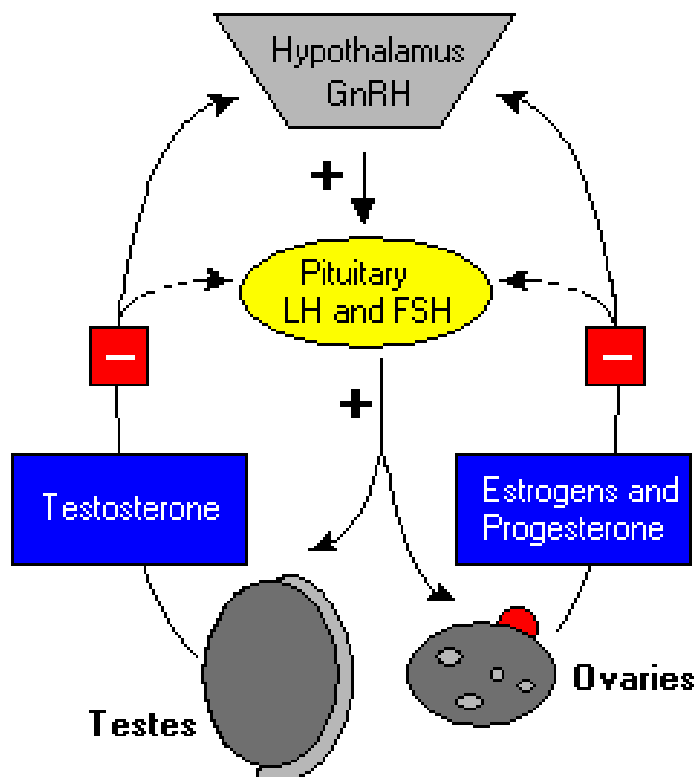
Neural control of the POSTERIOR pituitary gland

- neurons from different hypothalamic nuclei also control the posterior pituitary gland;
- hormone containing neurons of the hypothalamus (see blue and red neurons below) release their hormones directly in the posterior pituitary gland;
- the released hormones then enter the hypophyseal vein and reach the general blood circulation.
- **Example:** oxytocin is released from neurons of the supraoptic nucleus of the hypothalamus directly into the posterior pituitary and is involved in uterine contraction during child birth and milk ejection during suckling.



Example: Release of GONADAL HORMONES

- Neurons of different hypothalamic nuclei produce and release gonadotropin-releasing hormone (GnRH) in the anterior pituitary gland;
- GnRH induces the production and release of follicle-stimulating and luteinizing hormones – (FSH & LH) from anterior pituitary cells, which reach the general circulation;
- FSH and LH eventually reach the gonads, inducing the production and release of estrogens, progesterone, and androgens (testosterone) from cells in the gonads.



Regulation of Hormone Levels

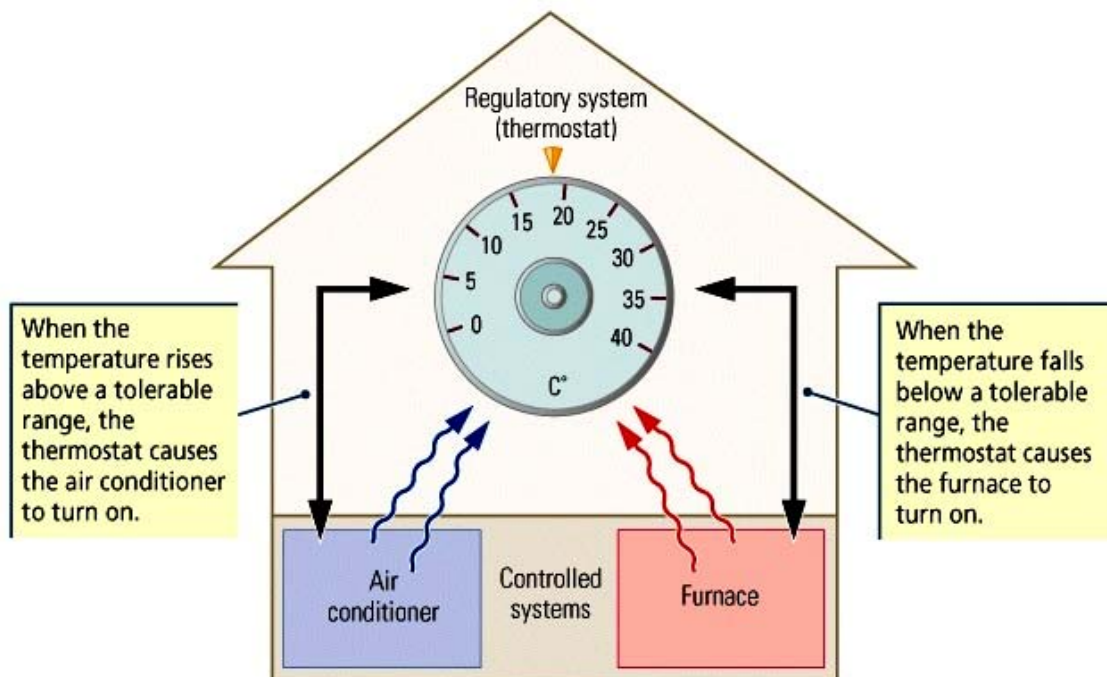
- Concept of Homeostasis: a state of internal metabolic balance, which keeps body functions within a narrow range.
- this is achieved via 1. Feedback loops; 2. Neural controls; and 3. Experience or learning.

1. Feedback in the Neuroendocrine System:

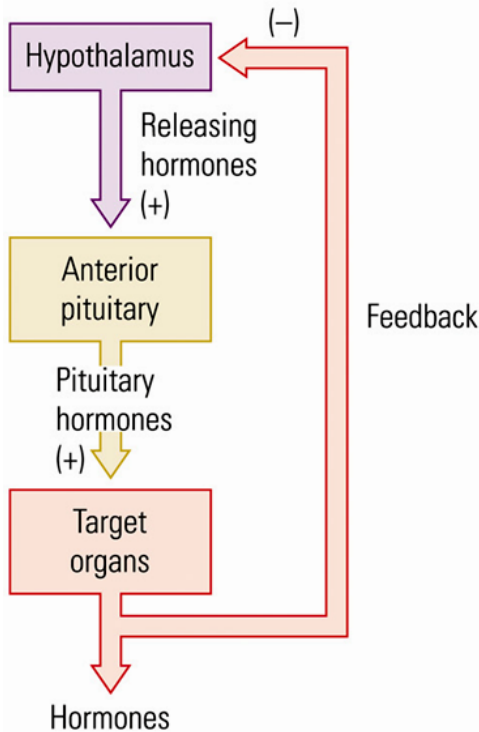
Most of the feedback in the neuroendocrine system is inhibitory (negative feedback)

Negative feedback: A signal in one direction that results in a compensatory effect in the other direction ;

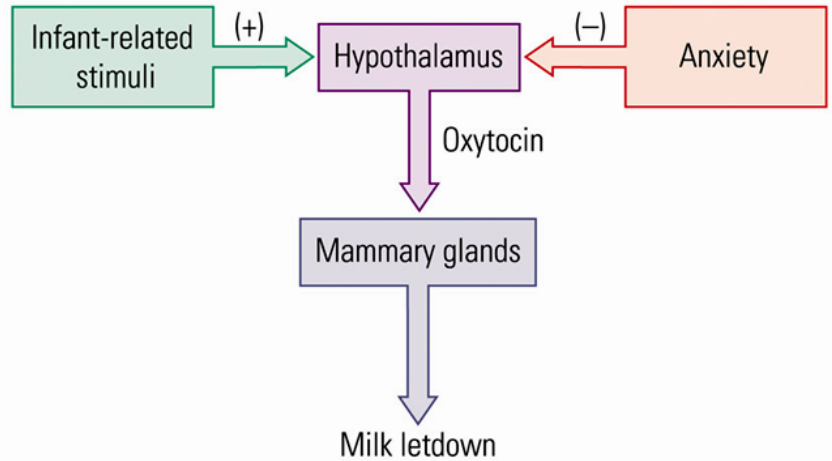
Example of negative feedback: heating system in your house or apartment



(A) Feedback loops



(B) Milk-letdown response



2. Neural control:

Neurons from other brain regions send their axons to hypothalamic nuclei and can regulate the activity of hypothalamic releasing-hormone neurons (see (B) above);

- this can increase or decrease hormone release and overall levels in bloodstream.

3. Experience/learning:

Repeated experience (learning) with a specific situation can lead to increased or decreased hormone levels;

- often regulated by brain regions that send axons to hypothalamus.

MOTIVATED BEHAVIORS

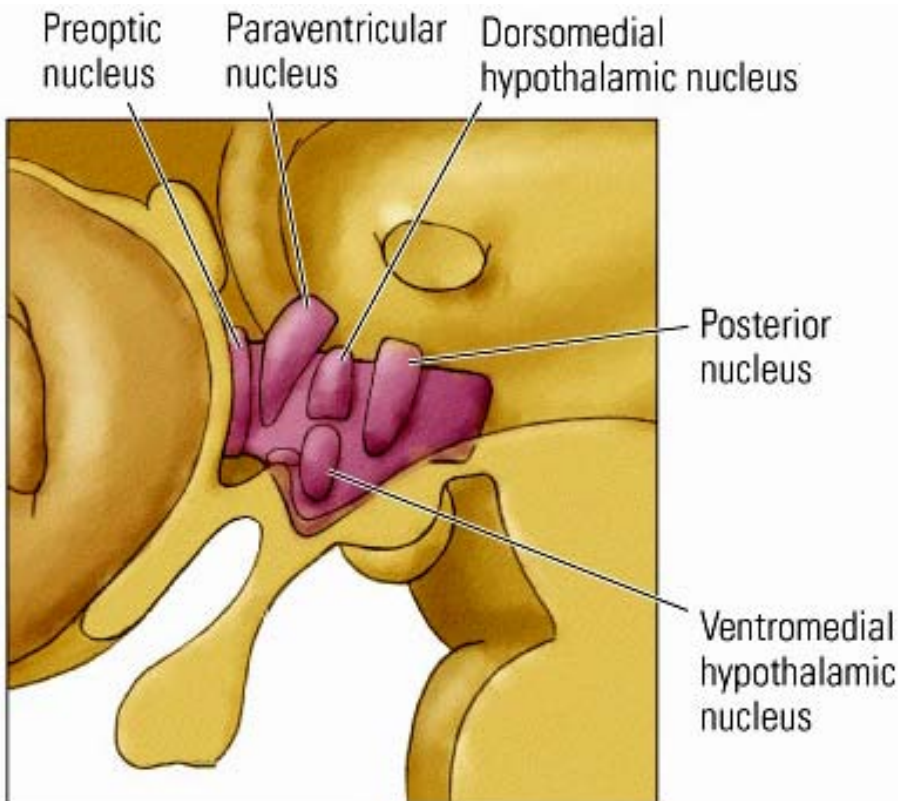
There are 2 general classes of motivated behaviors:

Regulatory Behaviors: behaviors controlled by a homeostatic mechanism

Examples: temperature regulation, eating (energy) and drinking, salt appetite, waste elimination

Non-regulatory Behaviors: behaviors that are not controlled by homeostatic mechanisms - all behaviors excluding those regulated by homeostatic processes

Examples: sexual behavior, parental behavior, aggression, playing sports, watching TV, etc



The hypothalamus is particularly important for the control of regulatory and non-regulatory behaviors

Example of Non-regulatory behavior:

Sexual Behavior

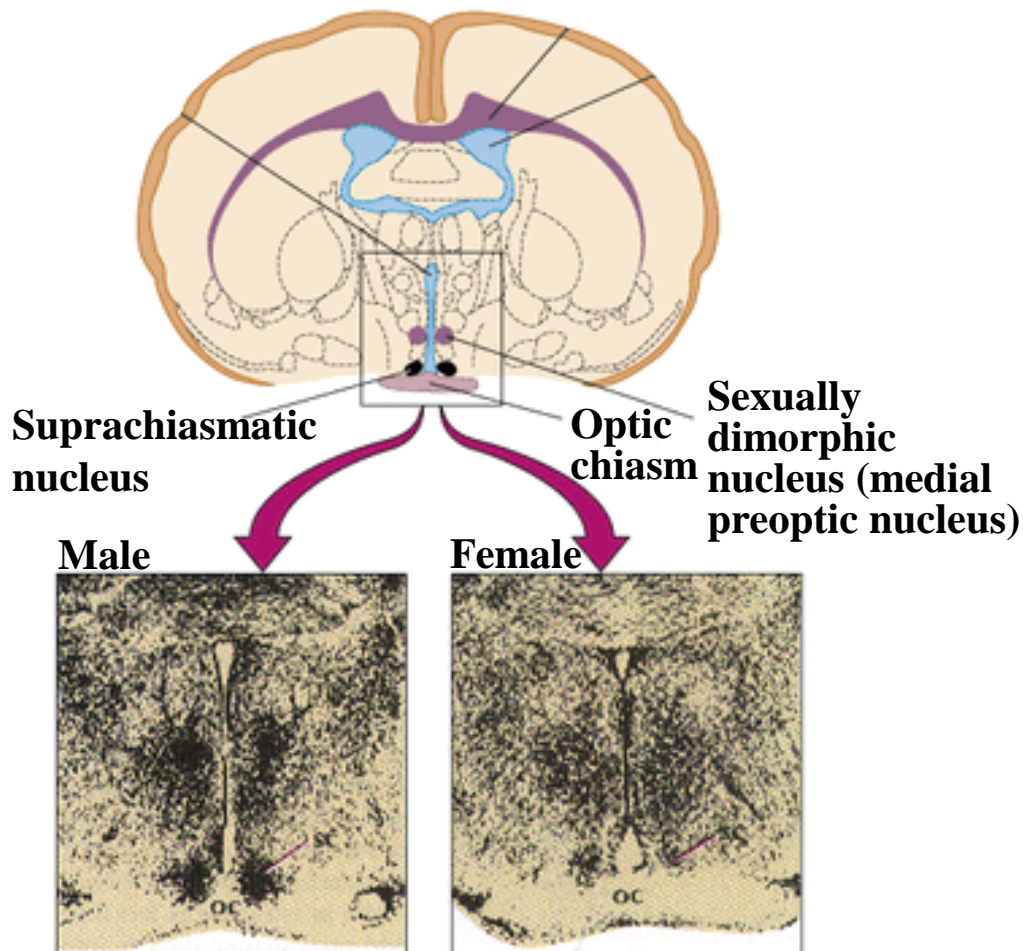
Gonadal (sex) hormones have various actions on the brain and behavior; these actions are both developmental (organizational effects) and in adulthood (activational effects);

1. Organizational effects of sex steroids on the brain and body: Process whereby gonadal hormones act on the brain to produce distinctly female or male brains;

- some brain areas are referred to as sexually dimorphic ;
- the suprachiasmatic and parts of the preoptic nuclei are generally larger in males; additional differences in spinal cord, amygdala, and frontal cortex.

During fetal development, higher testosterone levels produce these changes in the brain, but . . . estradiol masculinizes the brain!

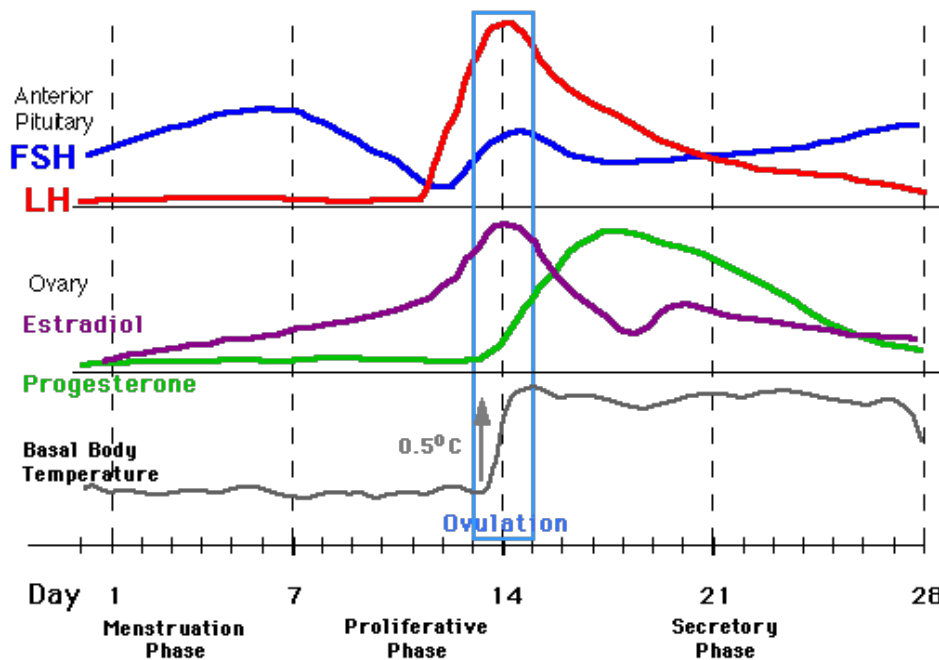
How?



2. Activational effects of gonadal hormones:

Female reproductive cycle: While males have daily fluctuations in sex steroid levels, females display “cycling” gonadal steroid levels, called the *menstrual cycle* in primates (including humans) and *estrous cycle* in other mammals;

- the levels of the different sex steroid hormones change significantly over the cycle period in women (on average, 28 days).

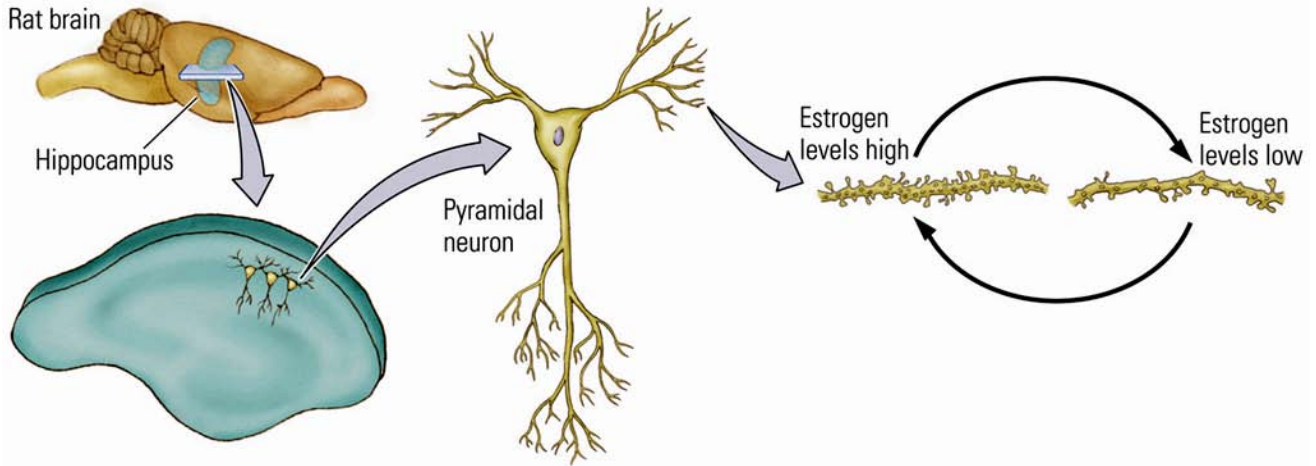


In animals, adult female behavior varies across estrous cycle;

- high estrogen levels are associated with sexual receptivity;
- high estrogen levels are also associated with increased numbers of dendritic spines in the hippocampus (next page).

In adult males, high testosterone levels are associated with increased motivation to seek sexual and copulatory behaviors.

Dendritic remodeling during estrous cycle in female rats



Brain Regions and Sexual Behaviors

Known from animal studies – not clear if this applies to humans!

Ventromedial hypothalamus controls the sexual receptivity posture (mating posture – lordosis) in females;

Preoptic area of the hypothalamus controls copulatory behavior (thrusting) in males, but not sexual motivation;

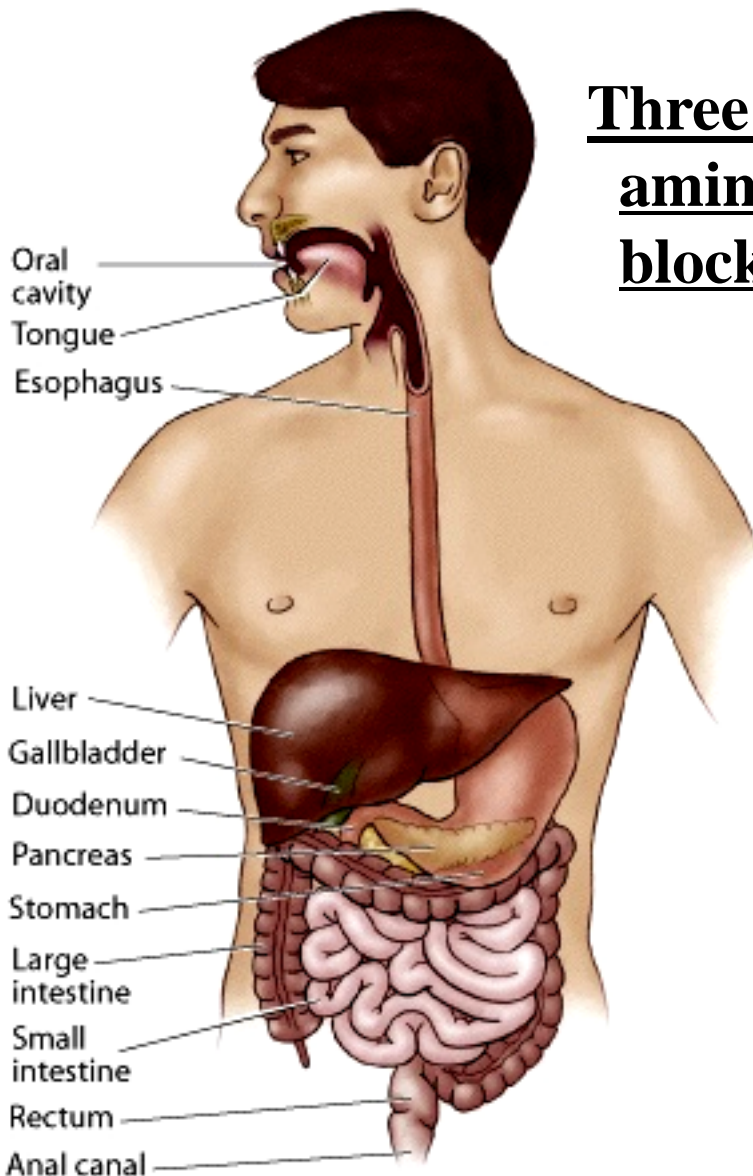
Medial nucleus of the Amygdala in males (and possibly in females) controls sexual motivation (the trap door experiment!!!);

Cortex, especially frontal lobes?

Example of Regulatory Behavior: EATING

Eating is partly controlled by the digestive tract, the hypothalamus, and cognitive factors

- The digestive tract (below): functions as a reservoir where a variety of chemicals and enzymes released (hydrochloric acid, pepsin, etc) help breakdown and absorb essential nutrients and energy molecules.**



Three classes: lipids (fats), amino acids (building blocks of proteins), and glycogens (starches and sugars)

Lipids provide approximately 85% of stored energy, whereas amino acids (14.5%) and glycogens (0.5%) provide the rest

Early work indicating role of ventromedial hypothalamus

EXPERIMENT 11-1

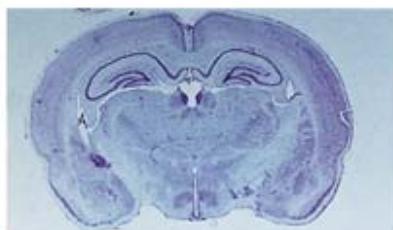
Question: Does the hypothalamus play a role in eating?

Procedure

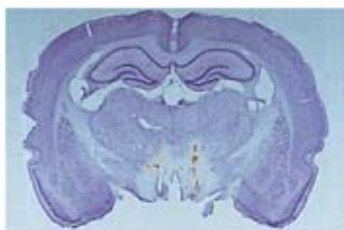


The ventromedial hypothalamus (VMH) of the rat on the right was damaged, and her body weight was monitored for a year. Her sister on the left is normal.

Intact brain of sister rat

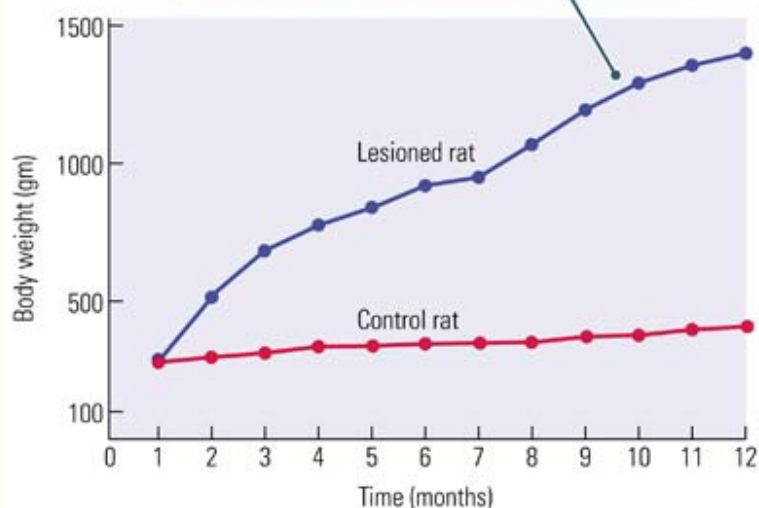


Rat brain with lesion



Results:

The VMH-lesioned rat showed a dramatic increase in food intake and body weight.



Conclusion

The VMH plays a role in controlling the cessation of eating. Damage to the VMH results in prolonged and dramatic weight gain.

Multiple peripheral signals contribute to the Regulation of feeding:

Hunger signals

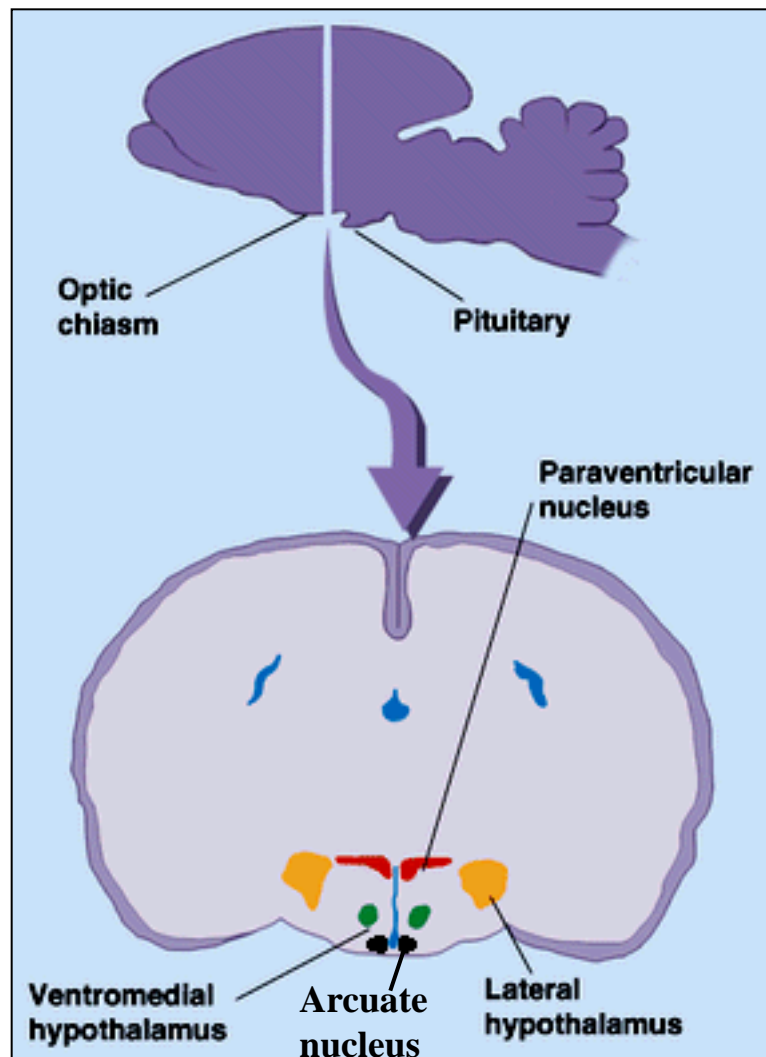
- Sight of food and thinking about food: raises activity of autonomic nervous system, which activates pancreas to release insulin in blood circulation - produces a drop in blood glucose that initiates response in nucleus of the solitary tract (see below)
- Hypoglycemia: a drop in blood glucose levels which is sensed by specialized receptors onto neurons of the area postrema (no blood-brain-barrier), and peripherally in the liver, via the vagus nerve (neurons in the nucleus of the solitary tract in the medulla)
- Lipoprivation: a drop in fatty acid levels (leptin) available to cells, detected in liver and other abdominal organs. Information provided to brain via vagus nerve

Regulation of feeding (continued):

Satiety signals

- Gastric distension: somatosensory receptors located in gastrointestinal tract and enteric nervous system sense stomach distension , and provide this information to nucleus of the solitary tract via the vagus nerve
- Cholecystokinin (CCK): peptide released from gastrointestinal tract and enteric nervous system
- responds to both volume and caloric content of food being absorbed - acts on vagal somatosensory receptors and synergises with gastric distension signals from gastrointestinal tract
- High levels of Insulin (released from β -cells of pancreas) and glucose in blood serve as a satiety signal at the level of the hypothalamus (arcuate nucleus)

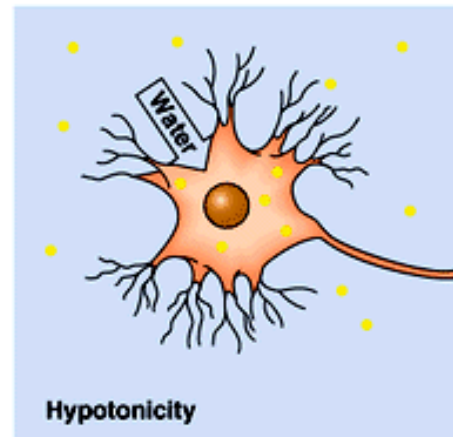
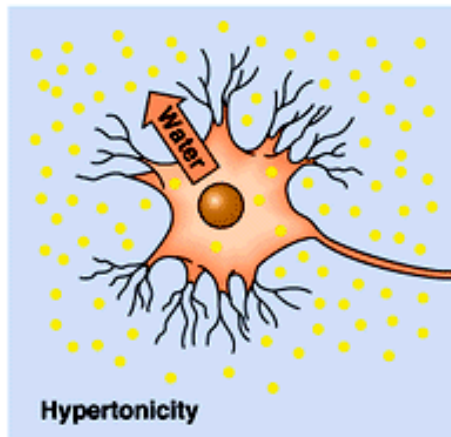
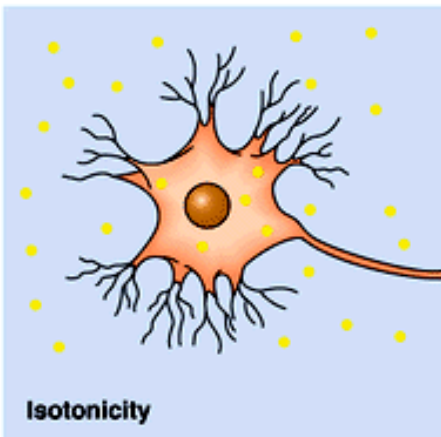
- Some brain control of feeding:** 3 hypothalamic nuclei critically control feeding and metabolism:
- 1. Paraventricular nucleus:** involved in the release of ACTH and thyrotropin from the anterior pituitary (involved in metabolism);
 - 2. Lateral hypothalamus:** coordinates motor responses involved in feeding behaviors;
 - 3. Arcuate nucleus:** receives signals from leptin & insulin, and project to paraventricular nucleus and lateral hypothalamus to • or • feeding.



The Control of Drinking: Water Balance

The human body is made out of approximately 70% water; there is a significant need to keep intracellular and extracellular levels of water at a relatively constant level, via two mechanisms

1. Osmotic thirst (cellular dehydration): increase in concentration of dissolved substances in the blood (hypertonicity) - bar peanuts and chips!!!



Specialized hypothalamic neurons in sense hypertonicity;

- these neurons send axons to paraventricular nucleus neurons that produce vasopressin (antidiuretic hormone - ADH) that, when activated, release vasopressin in posterior pituitary.

2. Hypovolemic thirst: decrease in overall blood volume

- increases water retention via two mechanisms:

a) reduced blood flow in renal system produces release of angiotensin II from kidneys which is sensed by hypothalamic neurons.

- these neurons activates paraventricular ADH neurons to release vasopressin from posterior pituitary.

b) mechanoreceptors (baroreceptors) in wall of large blood vessels and heart signal loss of blood to the hypothalamus via vagus nerve and nucleus of the solitary tract (NTS).

- NTS also projects to paraventricular nucleus and synergizes with effects of angiotensin and activate sympathetic nervous system to help correct the reduction in blood pressure (produces vasoconstriction).

- NTS also projects to lateral hypothalamus to stimulate drinking behaviors.