Animal control systems: Hormones

Hormones are substances produced in one region of the body that have effects in some other region: ***chemical messengers***

Examples:

- **Endocrine** hormones: produced in specialized endocrine ('ductless') glands, distributed in blood
- **Neurotransmitters, neurohormones:** released from nerve cells directly onto other cells (neurotransmitters) or into blood (neurohormones)
- **"local messengers:"** not produced in specialized glands; tend to have local effects on nearby cells -- **paracrine signaling** (histamines, prostaglandins, nitrous oxide, cytokines, etc.)

Animal control systems: Hormones

Hormones work to regulate functions ***within*** individuals.

A special category of chemical messengers mediates many interactions ***between*** individuals: **Pheromones**

- chemicals produced by one individual that change the behavior or physiology of other individuals

Pheromones are extremely common in all sorts of animals:

- species recognition
- group recognition
- social interactions (aggression, cooperation, status, alarm, etc.)
- territory marking
- navigation
- reproduction (gender recognition, sex attractants, receptivity indication, fertility control, etc.)
- parent-offspring interactions

Human pheromones probably unimportant -- only one or two conclusively demonstrated (control timing of female reproductive cycles). ***NO*** proven sex attractants, social indicators, etc.

Animal control systems: Hormones

Hormones are substances produced in one region of the body that have effects in some other region

The other basic control mechanism is the ***nervous system*** (a lot of overlap, such as neurohormones)

Comparison between hormonal control and neuronal control:

	hormonal	**neuronal**
Speed:	slow (seconds or more)	fast (fractions of seconds)
Duration:	long-lasting	very brief (milliseconds)
Specificity of target cells:	signal 'broadcast' widely; only target cells have the correct receptors (like cell phone)	signal sent ***only*** to the intended target cells via wire-like axons (like desk telephone)

General categories of hormone function

- **Homeostatic regulation,** especially of blood-born substances (***aldosterone, vasopressin, insulin, glucagon***)
- **Emergency responses** ("fight or flight"), often in concert with the nervous system to prepare the body for emergencies (***epinephrine***)
- **Development, growth, maturation** (***growth hormones*** in vertebrates; ***molting hormones*** in arthropods)
- **Reproduction,** including maturation and functioning of gonads, other reproductive organs, secondary sexual characteristics, and reproductive and parental behavior (***testosterone, estrogens, progesterone, prolactin, oxytocin…***)
- **Biological rhythms**, including circadian, monthly, or annual rhythms. These rhythms are often mediated by hormone activity (***melatonin, etc.***)

Hormone chemistry

Hormone chemical structure must be complex enough to be clearly unique. Three basic chemical classes:

- **proteins or short polypeptides:** 5-100 amino acids (e.g. insulin, growth hormone, vasopressin, endorphins) or **glycoproteins** (FSH, lutenizing hormone). A small number of amino acid substitutions can produce hormones with very different effects (e.g., oxytocin and vasopressin).
- **modified amino acids:** ***Amine*** hormones, such as catecholamines (epinephrine, norepinephrine), histamine, melatonin, serotonin, thyroid hormone (contains iodine)
- **lipid-derived hormones:** ***steroids:*** corticosteroids involved in homeostasis and stress responses (aldosterone, corticosterone, cortisol) and sex hormones that affect primary and secondary sexual characteristics (testosterone, estrogens; often chemically similar). ***Prostaglandins*** are chemically different but also lipid based.

Hormone evolution

Although many hormone types are **shared** among vertebrates (i.e. most or all have insulin, vasopressin, growth hormone, etc.), and to a large degree they are **interchangeable** (e.g., can use pig insulin to treat human diabetics), hormones have clearly evolved:

- most easily seen in peptide hormones; usually there are amino acid substitutions between taxa (most often in regions of the peptide chain away from active site).
  - degree of difference between hormones closely reflects the phylogenetic tree derived from other data: sequences are most similar in closely-related species.
- ***functions*** of hormones have also evolved (they ***can*** do different things in different species -- most likely in distantly related lineages).
  - **melatonin** governs *biological rhythms* in mammals; *pigmentation* in frogs
  - **prolactin** and **oxytocin** control *milk production* in mammals; *parental and social behavior* in birds

Mechanisms of hormone function

Hormonal function involves **reception, signal transduction,** and **response.**

Reception requires binding of hormone molecule to a **receptor protein**

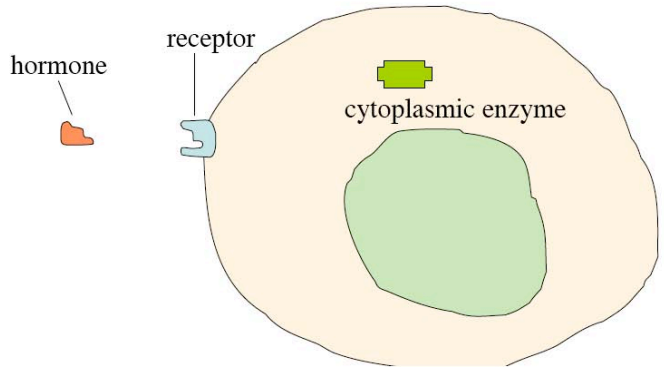
- like enzymes binding substrates
- **receptors** can be on cell surface or in the cytoplasm or nucleus
- different receptors for the same hormone may produce different responses, as for **epinephrine**:
  - causes dilation of blood vessels with beta (β) receptors
  - causes contraction of blood vessels with alpha (α) receptors
  - causes glycogen breakdown in liver cells with β receptors

Signal transduction pathways 'carry' message to effectors that produce the **response.**

Mechanisms of hormone function

Hormones influence their target cells in two general ways (same as for plant hormones):

- change the activity of **existing** proteins, transporters, etc:



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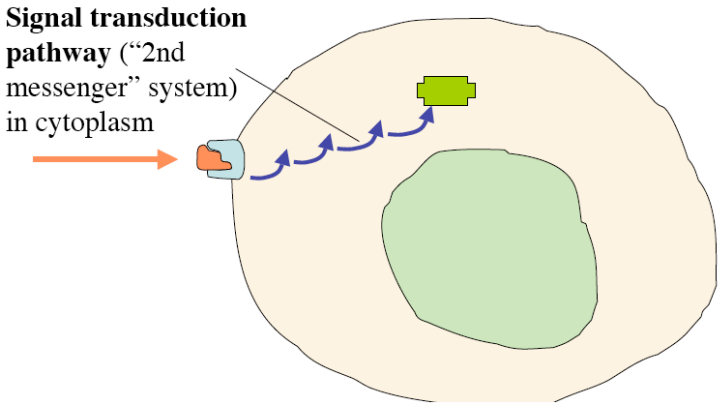

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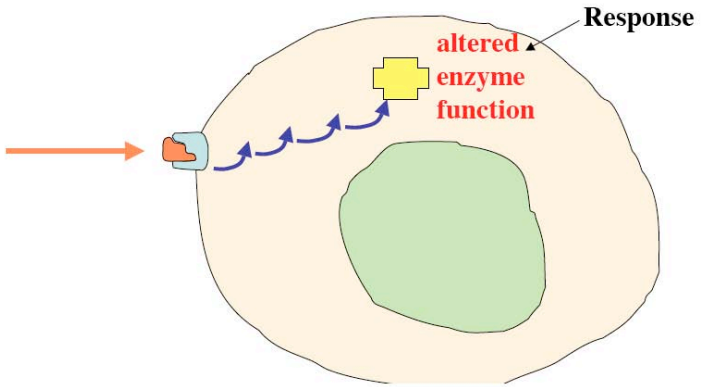

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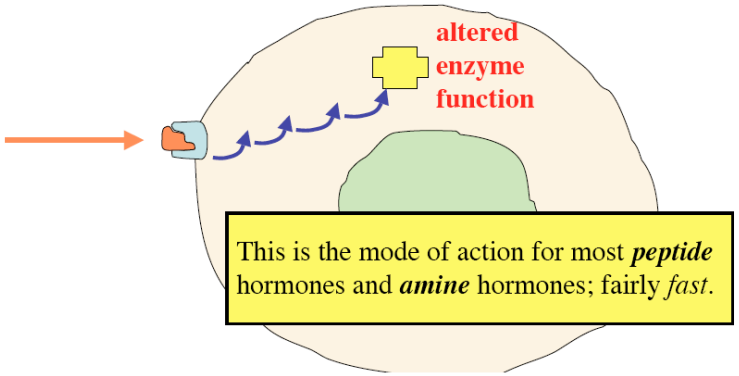

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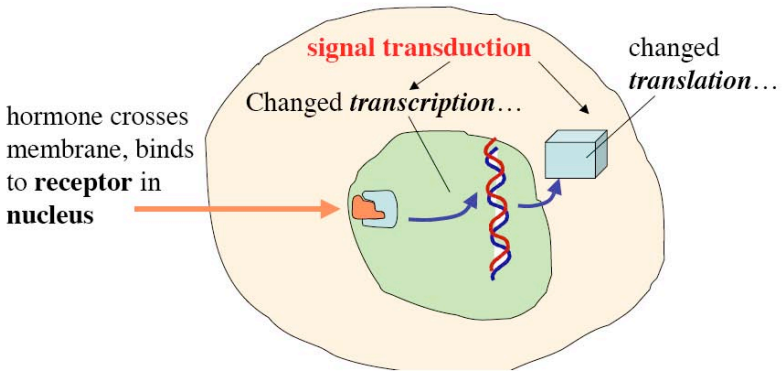

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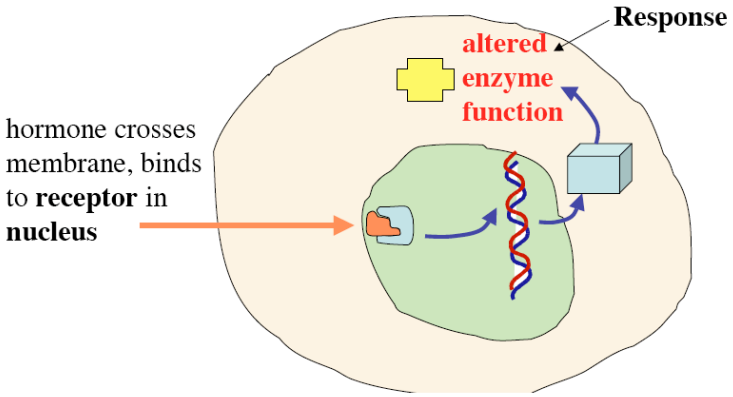

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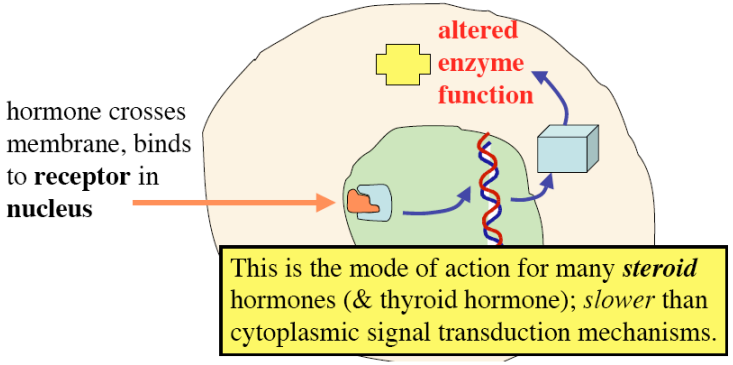


Hormonal control systems: Negative feedback

Most hormones are part of ***homeostasis***: maintenance of constant internal conditions even if environment fluctuates. Nearly all such control is based on ***negative feedback:*** these systems are **self-limiting.**

In many or most regulatory mechanisms mediated by hormones, there are **multiple levels of feedback:**

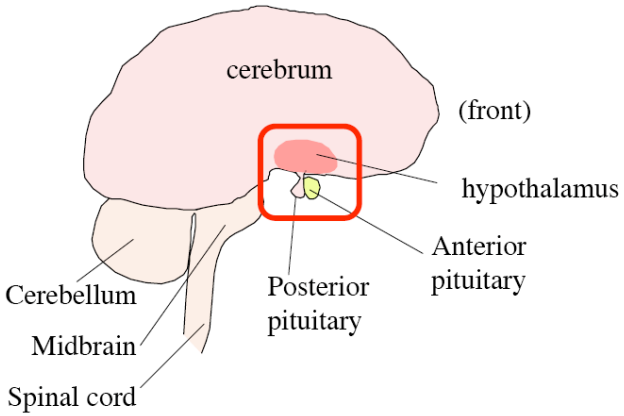
- sensing the status of the parameter of interest -- blood glucose, blood pressure, osmolarity, etc.
- sensing the levels of the hormones themselves.

Some hormones -- at least briefly -- are involved in positive feedback loops in certain 'explosive' responses.

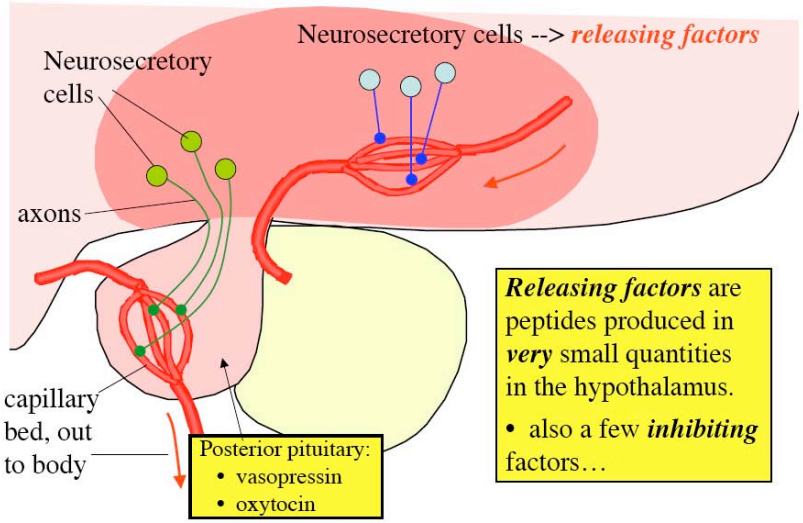
- oxytocin release in response to suckling in mammals (more suckling --> more oxytocin --> more milk release --> more suckling… until baby is satisfied and stops nursing)

Negative feedback in hormonal systems: Endocrine regulation

Most endocrine hormones are regulated through hypothalamus and pituitary gland (**hypothalamic-pituitary axis**)



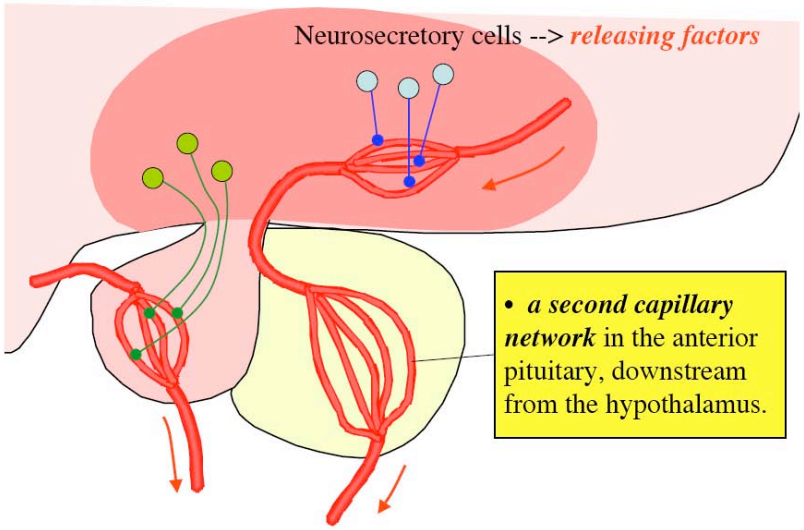
Negative feedback in hormonal systems: Endocrine regulation



Releasing factors are peptides produced in ***very*** small quantities in the hypothalamus.

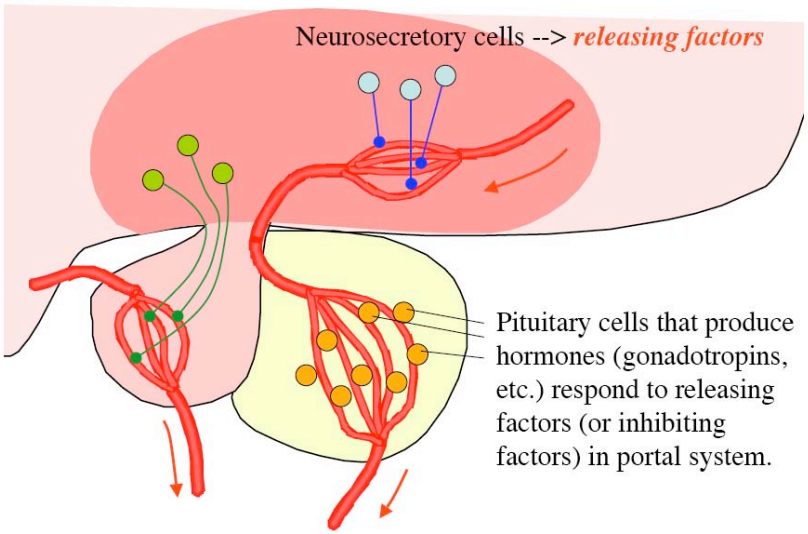
• also a few ***inhibiting*** factors…

Negative feedback in hormonal systems: Endocrine regulation



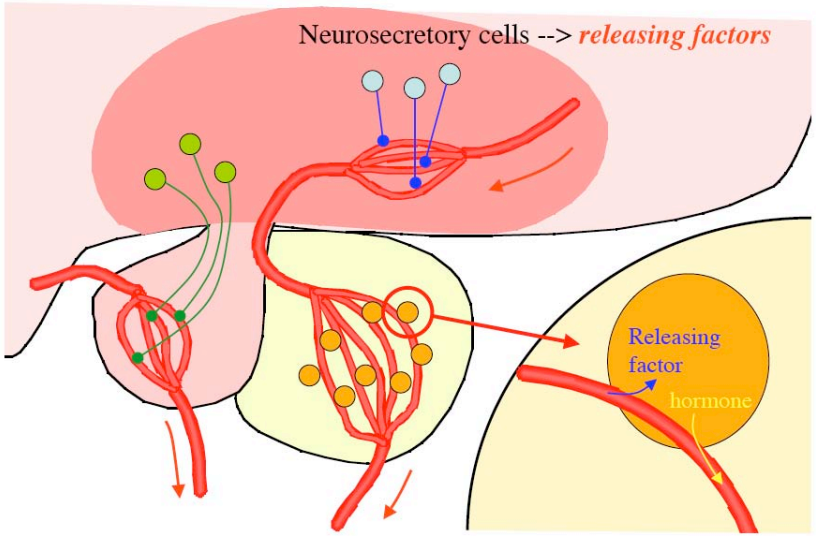
• ***a second capillary network*** in the anterior pituitary, downstream from the hypothalamus.

Negative feedback in hormonal systems: Endocrine regulation



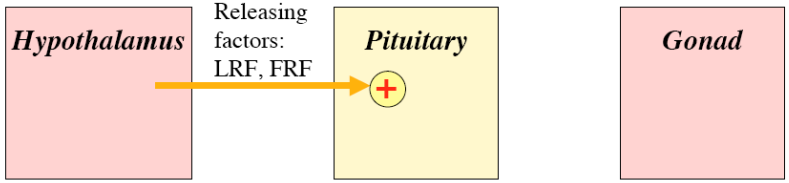
Pituitary cells that produce hormones (gonadotropins, etc.) respond to releasing factors (or inhibiting factors) in portal system.

Negative feedback in hormonal systems: Endocrine regulation



Negative feedback in hormonal systems: Endocrine regulation

Example: control of sex hormone production



Releasing factors stimulate pituitary…

Negative feedback in hormonal systems: Endocrine regulation

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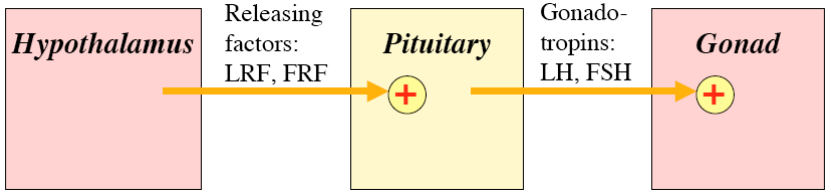
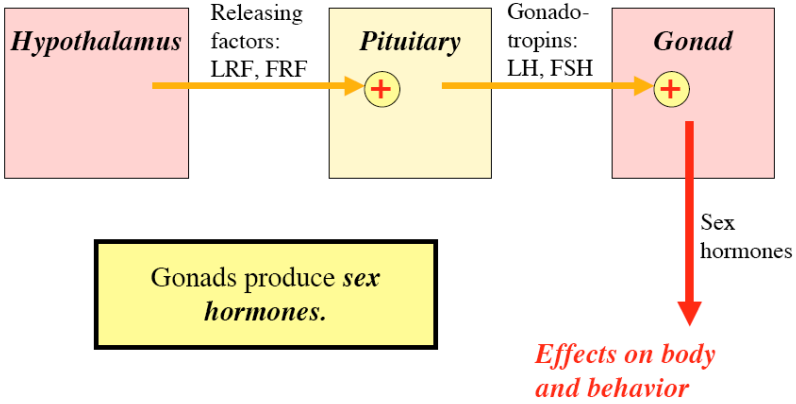


Pituitary ***gonadotropins*** stimulate gonads…

Negative feedback in hormonal systems: Endocrine regulation

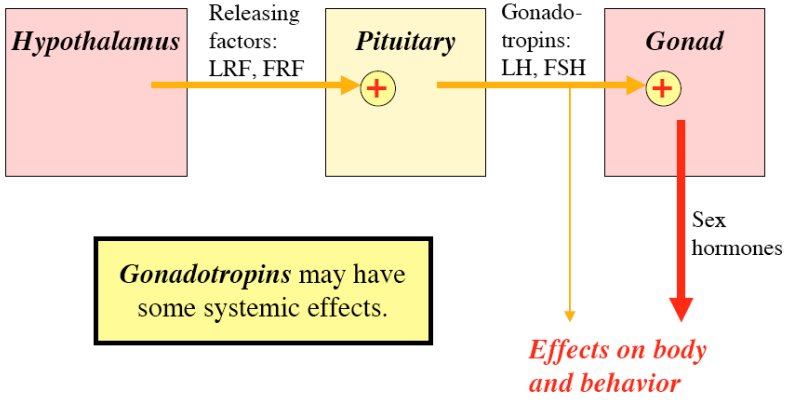
Example: control of sex hormone production



Gonads produce ***sex hormones.***

Negative feedback in hormonal systems: Endocrine regulation

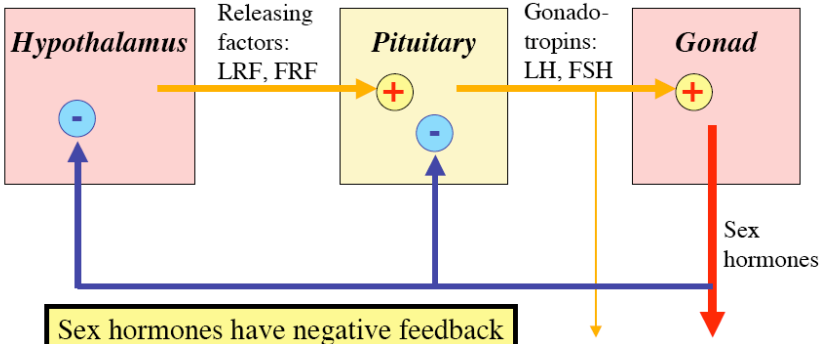
Example: control of sex hormone production



Gonadotropins may have some systemic effects.

Negative feedback in hormonal systems: Endocrine regulation

Example: control of sex hormone production



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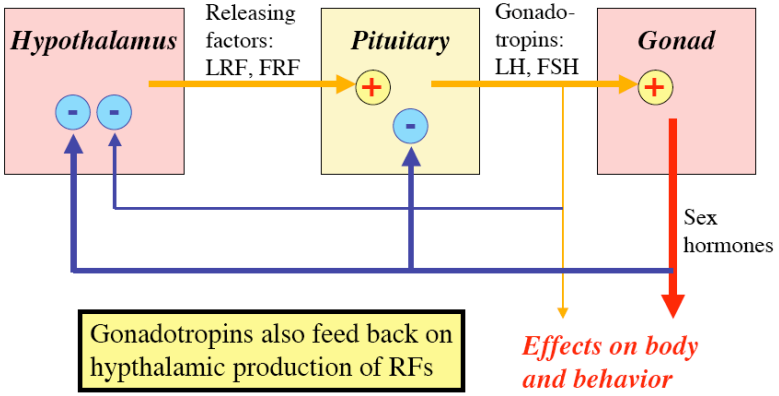

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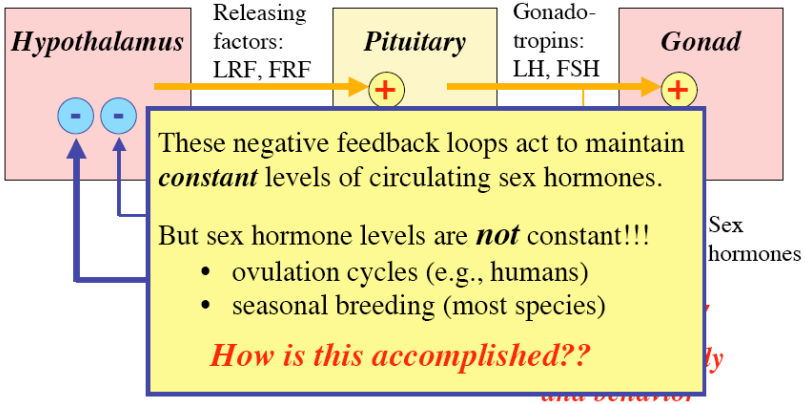

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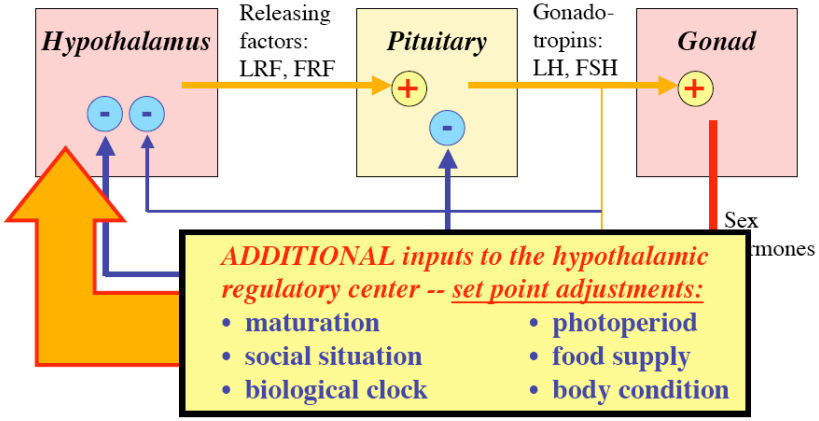

Annual reproductive cycles: ***Adélie penguins***

Spend the winter at sea -- ***completely nonreproductive***

Arrive at colony in October -- ***need to be READY!***

Annual reproductive cycles: ***Adélie penguins***

Under control from pituitary gonadotropins, gonads ***atrophy*** in non-breeding season and ***regrow*** in spring…

- testicle size in **winter**: ~ 0.2 g (**.005%** of body mass)
- as day length increases, so does gonadotropin production….
- testicle size in **spring**: ~ 40 g (**1%** of body mass)…

equal to **0.75 Kg** in man!!