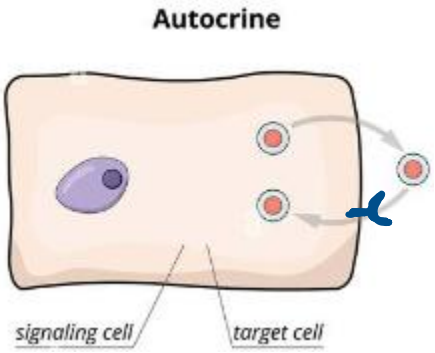
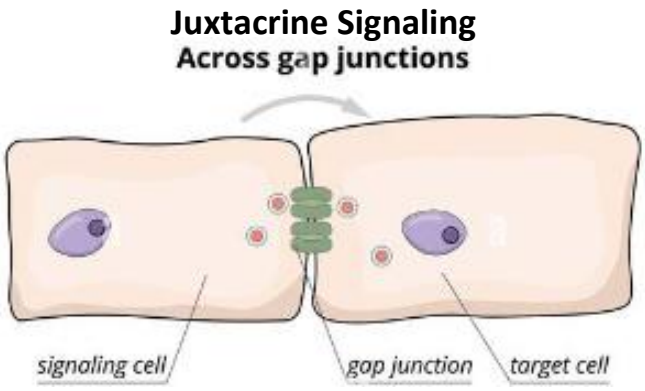
CONCEPT: ENDOCRINE SYSTEM

- Chemical signals allow cells to communicate with each other
- ***Pheromones*** – chemical signals released to the environment to communicate with other organisms
- ***Autocrine signaling*** – self-signaling, cell secretes chemical signal that stimulates receptors on its own membrane
  - □ Cytokines are released by T cells, and act as an autocrine signal
- ***Juxtacrine signaling*** – cells release signals to neighboring cells with which they have physical contact

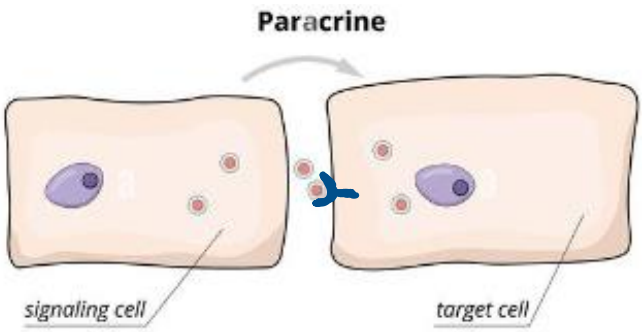
EXAMPLE:

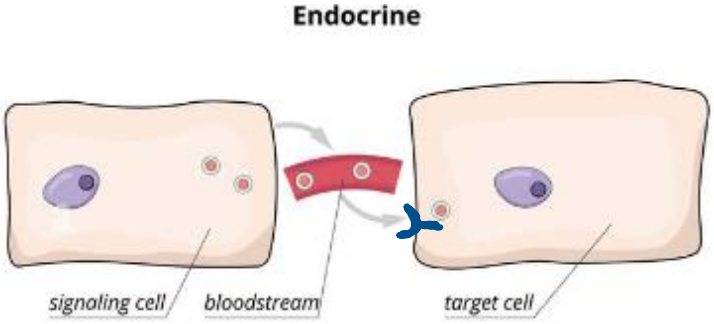




- ***Paracrine signaling*** – cell releases chemical signal to communicate with neighboring and nearby cells
  - □ Local regulators – can act as autocrine of paracrine signals
    - Nitric oxide (NO) – acts as hormone causing vasodilation, also acts as a neurotransmitter
  - □ Prostaglandins promote inflammatory response through paracrine signals
  - □ Insulin, glucagon, somatostatin have paracrine effects on the pancreas
- ***Endocrine signaling*** – hormones are released into the bloodstream to signal distant cells

EXAMPLE:

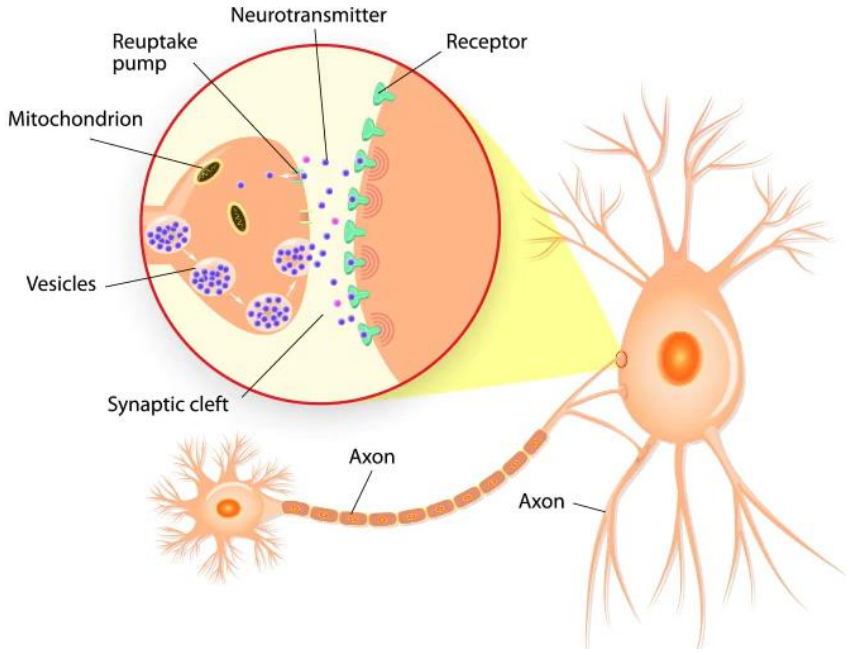




CONCEPT: ENDOCRINE SYSTEM

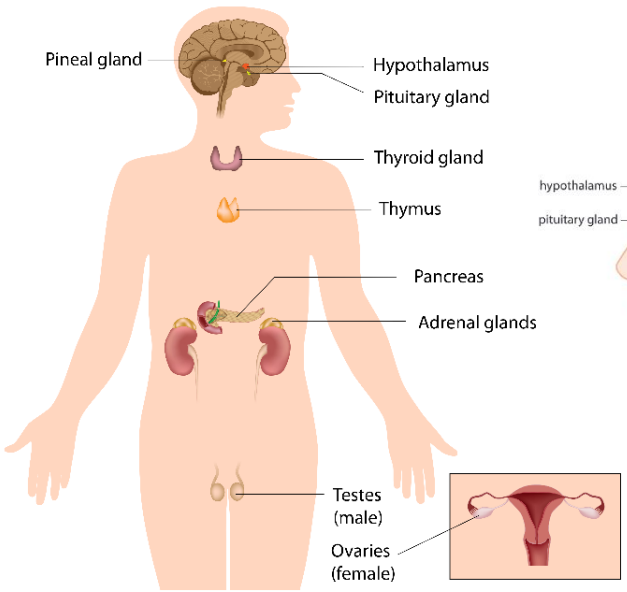
- ***Synaptic signaling*** – neurons carry electric signals that are translated into chemical signals, and released to other cells
    - □ ***Neurotransmitters*** – chemicals that traverse the synapses between neurons to carry signals between cells

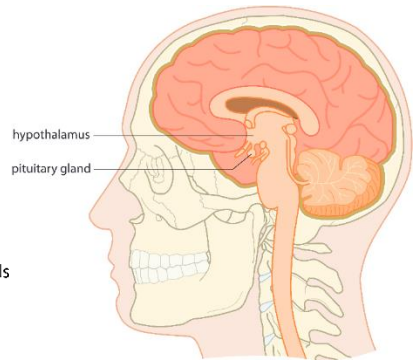
EXAMPLE:

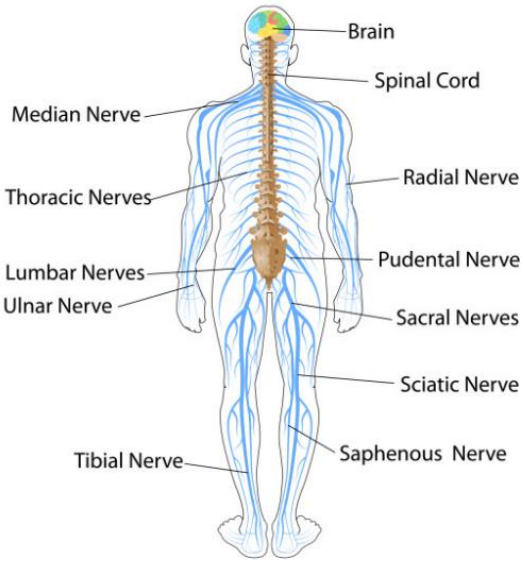


- ***Neuroendocrine signaling*** – neuronal signals cause hormone secretion, connects nervous and endocrine systems
    - □ ***Neurohormones*** – hormone produced by neuroendocrine cells
- Nervous system and endocrine system are tightly integrated
    - □ Hypothalamus interacts with the pituitary gland to send endocrine signals via stimulation of the nervous system

EXAMPLE:



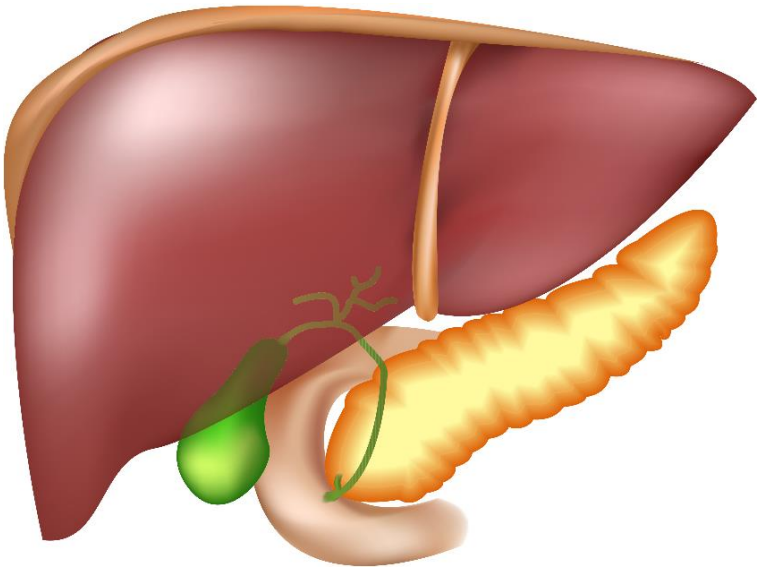


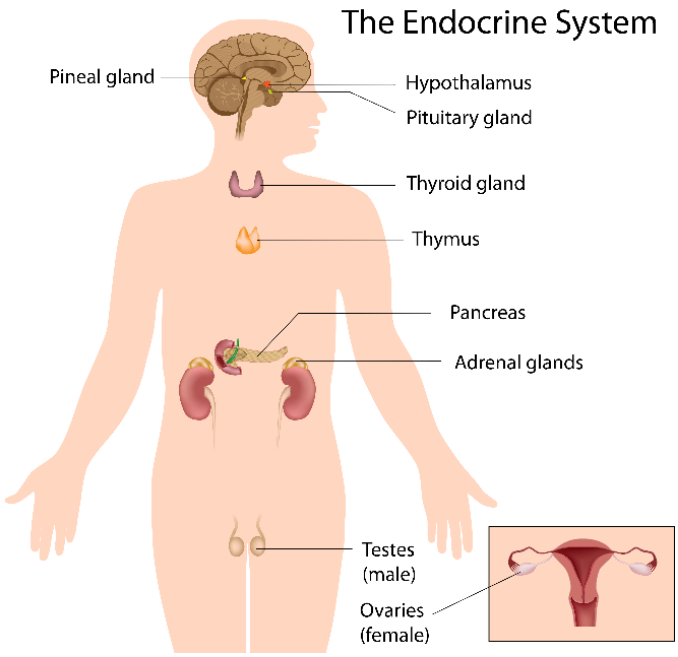


CONCEPT: ENDOCRINE SYSTEM

- ***Endocrine system*** – chemical signaling system made up of glands that secrete hormones into the bloodstream
  - □ ***Glands*** – organs that synthesize and secrete substances into the body
    - ***Endocrine glands*** – synthesize hormones and secrete them into the bloodstream
    - ***Exocrine glands*** – secrete substances into ducts to be delivered to target sites
  - □ ***Hormone*** – signaling molecule produced in glands and secreted into the blood stream
  - □ Endocrine system plays an important role in development, growth, and reproduction
  - □ Certain responses to the environment are mediated by the endocrine system
  - □ Maintenance of many homeostatic systems involves endocrine signaling

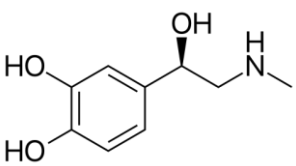
EXAMPLE:

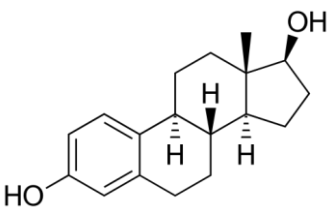


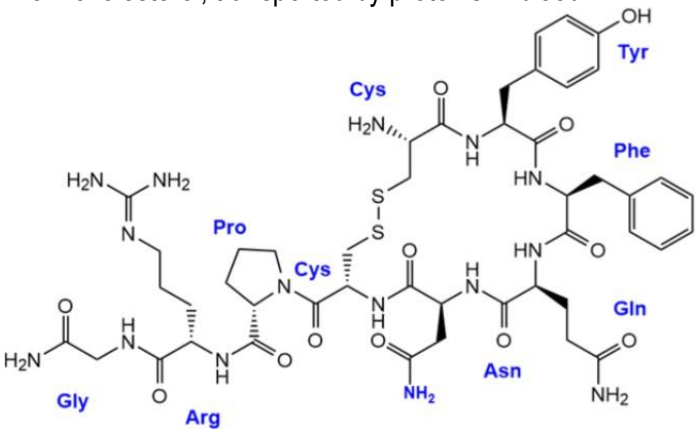


- There are 3 classes of hormone structure:
  - □ ***Polypeptide hormones*** – larger, polar hormones that cannot cross the cell membrane, but are water soluble
  - □ ***Amine hormones*** (amino acid derived hormones) – synthesized from amino acid tyrosine, tend to be fairly polar
    - Catecholamines (epinephrine, norepinephrine, and dopamine) and thyroid hormones
  - □ ***Steroid hormones*** – lipid-soluble hormones derived from cholesterol, transported by proteins in blood
- Direct hormones – act directly on tissues
- Tropic hormones – stimulate a gland to secrete hormones

EXAMPLE:



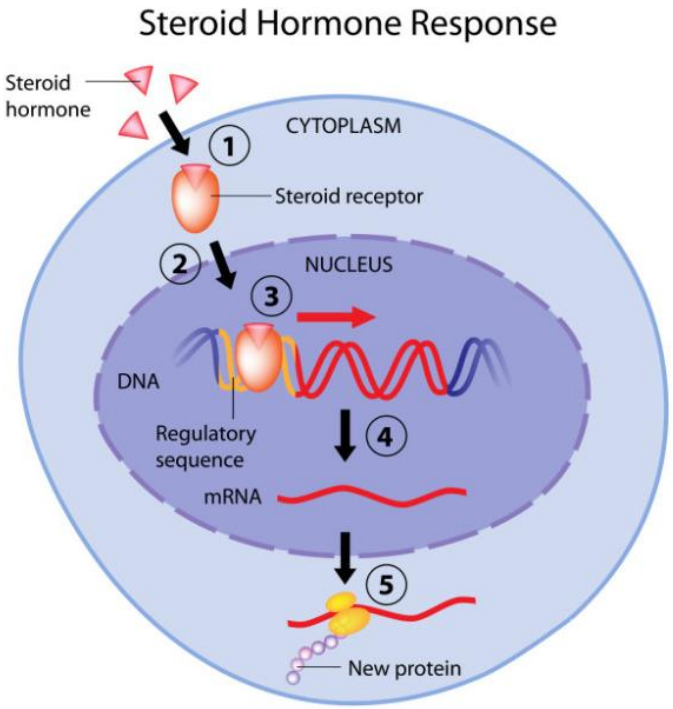




CONCEPT: ENDOCRINE SYSTEM

- Steroid hormones can readily cross the cell membrane, and have intracellular receptors
  - □ Intracellular receptors – receptors found inside of cells
  - □ Tend to modify gene expression by acting as transcription factors, or by activating transcription factors
  - □ ***Hormone-response elements*** – upstream area to coding sequence that hormone-receptor complex activates
  - □ Thyroid hormones act like steroid hormones, and are nonpolar

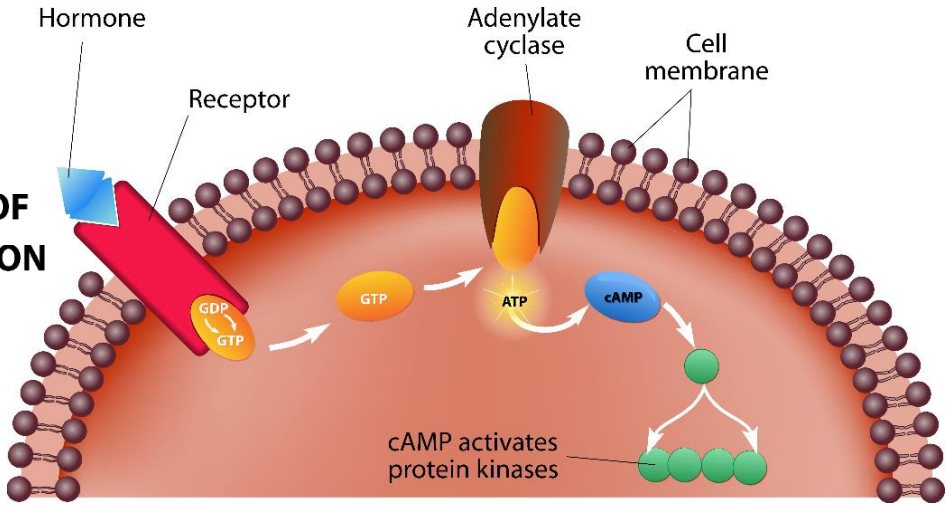
EXAMPLE:



- Water-soluble hormones bind to cell-surface receptors because they can't cross the membrane
  - □ Activate signal transduction pathway to communicate the hormone signal within the cell
    - Often use G protein-coupled receptors and second messengers to transduce signals
  - □ ***Second messenger*** – nonprotein intracellular signaling molecule
    - ***Cyclic AMP*** (***cAMP***) – common second messenger derived from ATP, produced by adenylyl cyclase
  - □ Signal transduction cascade involves the activation/inactivation of a series of molecules, and signal amplification

EXAMPLE:

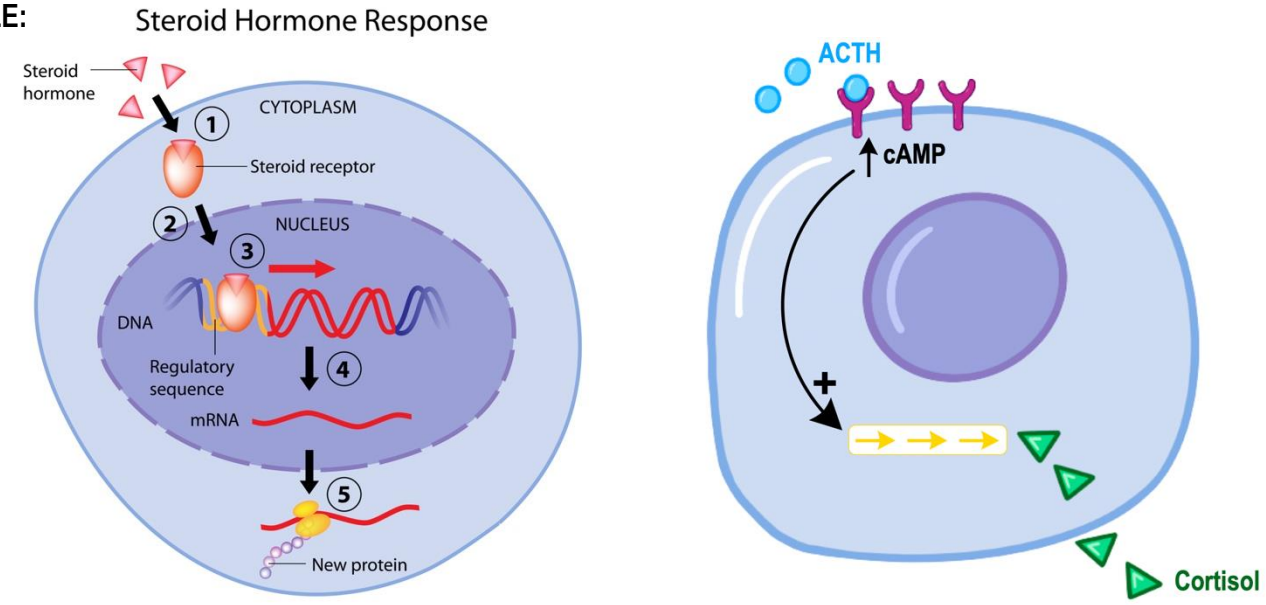
MECHANISMS OF HORMONE ACTION



CONCEPT: ENDOCRINE SYSTEM

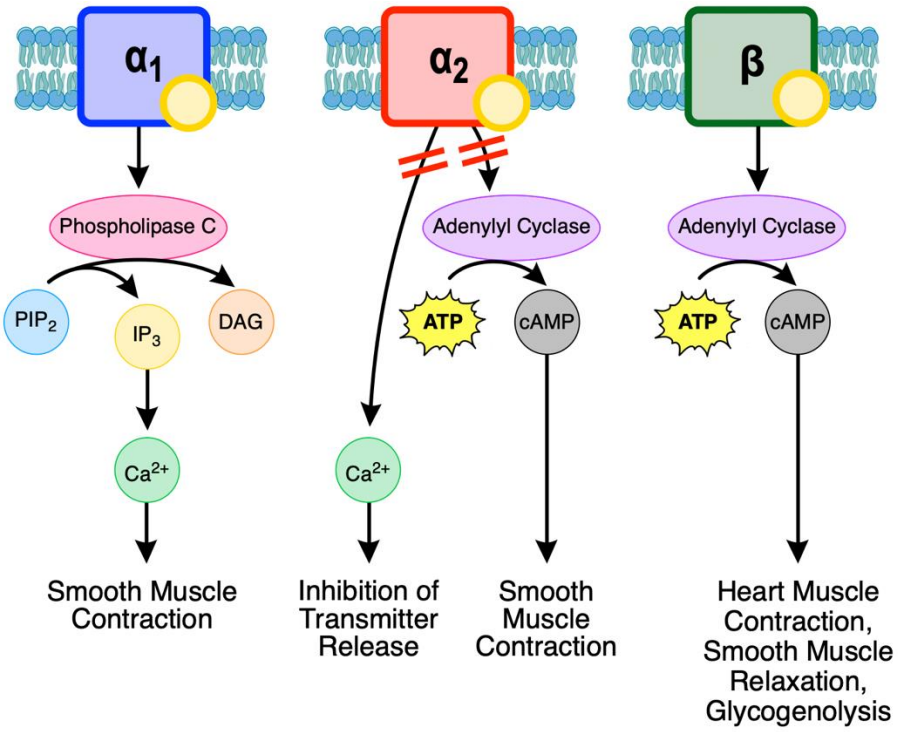
- Steroid hormones take longer to exert their effects, but they are longer lasting
- Water soluble hormones exert their effects more quickly, but they have a shorter duration

EXAMPLE:



- Effect of a hormone depends on the presence of specific receptors
  - □ Many hormones have a diverse array of effects due to the presence of different receptors in different tissues
  - □ Epinephrine increases blood flow to muscles, but decreases blood flow to digestive system

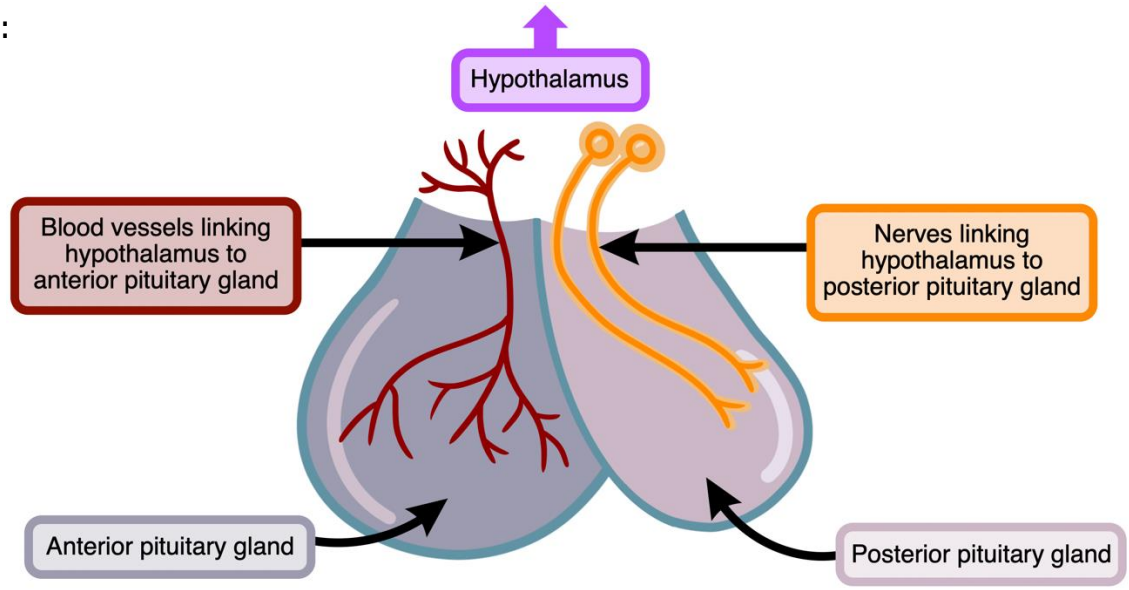
EXAMPLE:



CONCEPT: ENDOCRINE SYSTEM

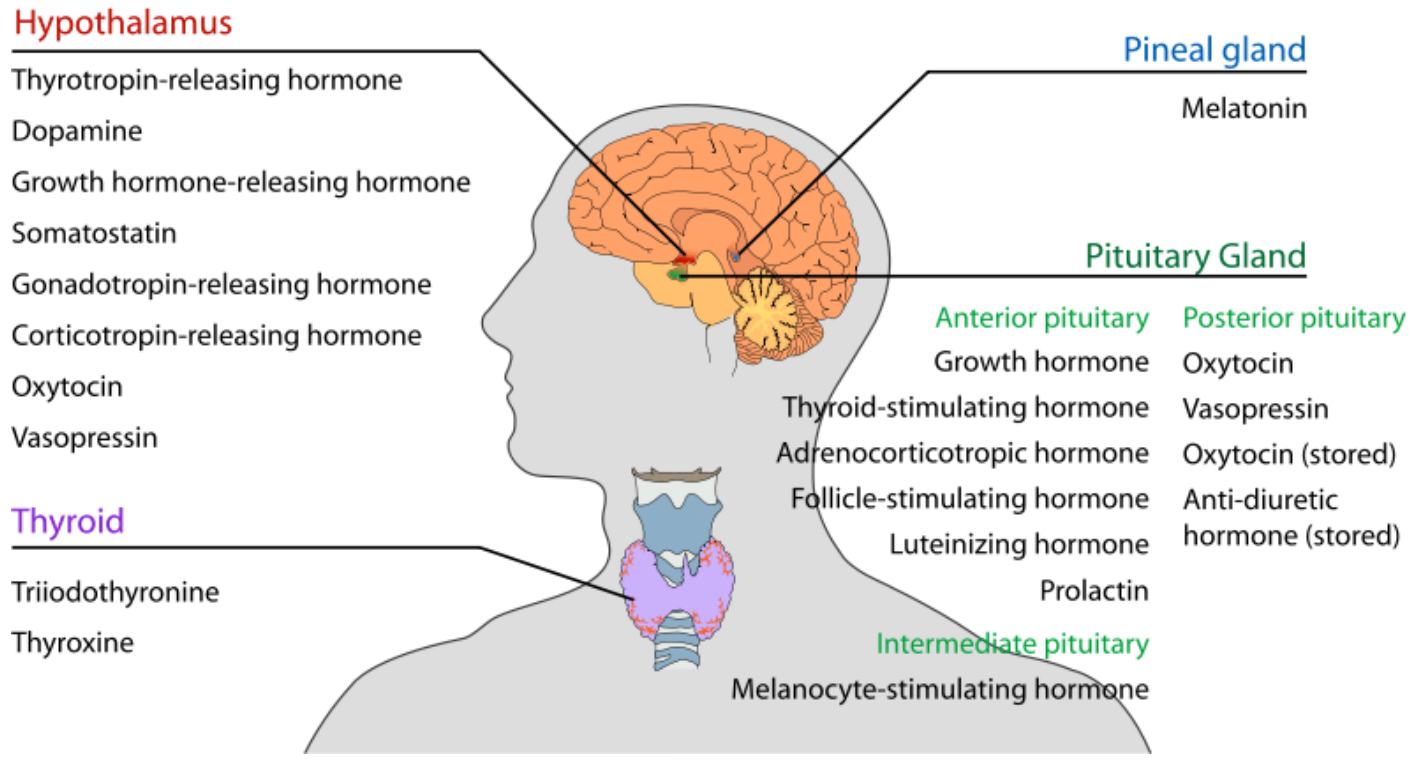
- ***Hypothalamus*** – brain structure that bridges the nervous and endocrine system, interacts with pituitary gland
  - □ Acts as a homeostatic center for many regulatory systems like body temperature and blood pressure
  - □ Secretes tropic peptide hormones to anterior pituitary, and releases neurohormones in posterior pituitary
- ***Pituitary gland*** – small endocrine gland under the hypothalamus with two lobes

EXAMPLE:



- ***Pineal gland*** – endocrine gland in the brain that produces melatonin, a hormone involved in circadian rhythms

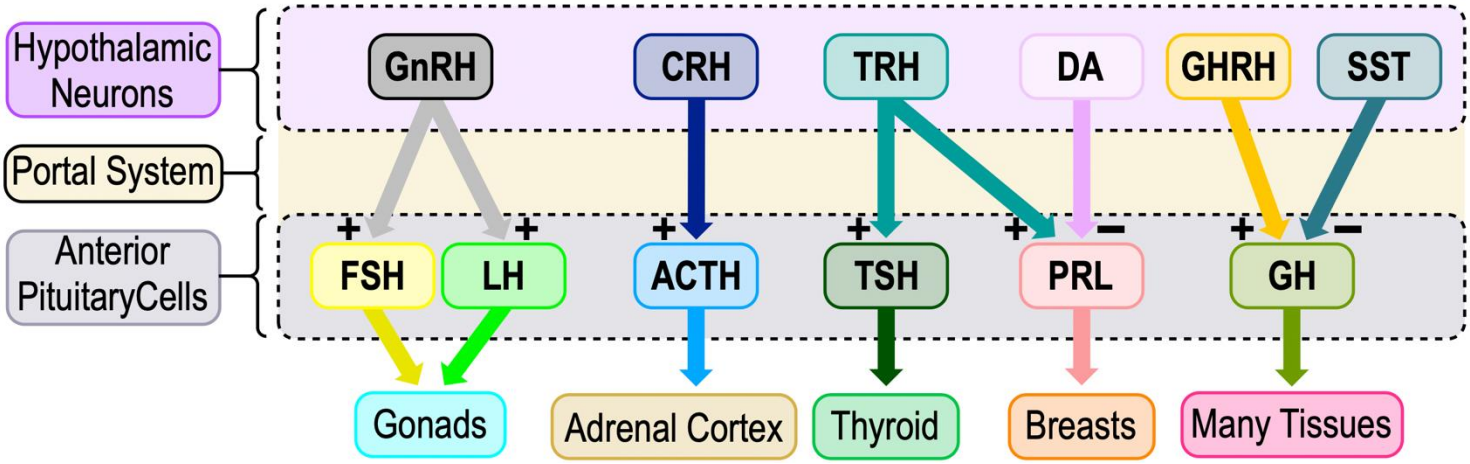
EXAMPLE:



CONCEPT: ENDOCRINE SYSTEM

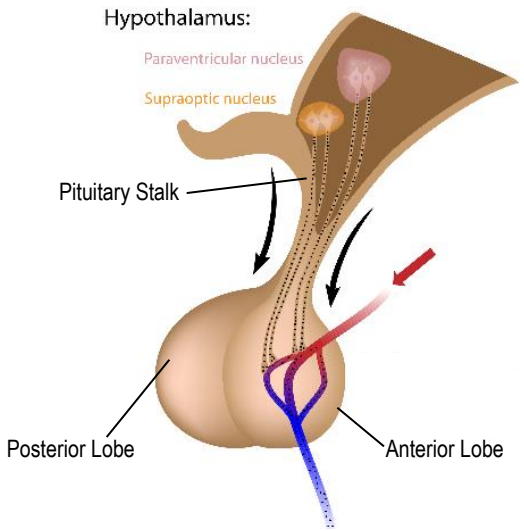
- ***Anterior pituitary*** – secretes tropic and direct hormones, linked to hypothalamus by blood vessels
  - □ Hypothalamus secretes hormones into its capillaries connected to capillaries in the anterior pituitary
  - □ ***Follicle stimulating hormone*** (***FSH***) – stimulates follicle maturation and spermatogenesis
  - □ ***Luteinizing hormone*** (***LH***) – stimulates ovulation and testosterone synthesis
  - □ ***Adrenocorticotropic hormone*** (***ACTH***) – stimulates adrenal cortex to secrete glucocorticoids, like cortisol
  - □ ***Thyroid stimulating hormone*** (***TSH***) – stimulates thyroid to secrete thyroid hormones
  - □ ***Prolactin*** – stimulates milk production and secretion in mammary glands
  - □ ***Growth hormone*** (***GH***) – stimulates growth

EXAMPLE:



- ***Posterior pituitary*** – secretes direct hormones, linked to hypothalamus by neuron axons
  - □ Hypothalamus produces neurohormones and stores them in neurons that connect to posterior pituitary
  - □ Hypothalamic axons synapse on capillaries in the posterior pituitary where they release neurohormones
  - □ ***Oxytocin*** – stimulates lactations, labor contractions, and plays an important role in social bonding
  - □ ***Antidiuretic hormone*** (***ADH*** or ***vasopressin***) – increases water reabsorption by kidneys

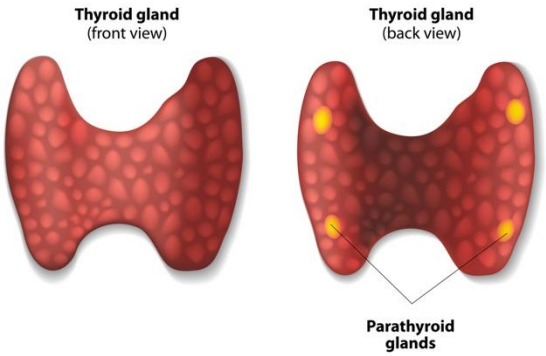
EXAMPLE:

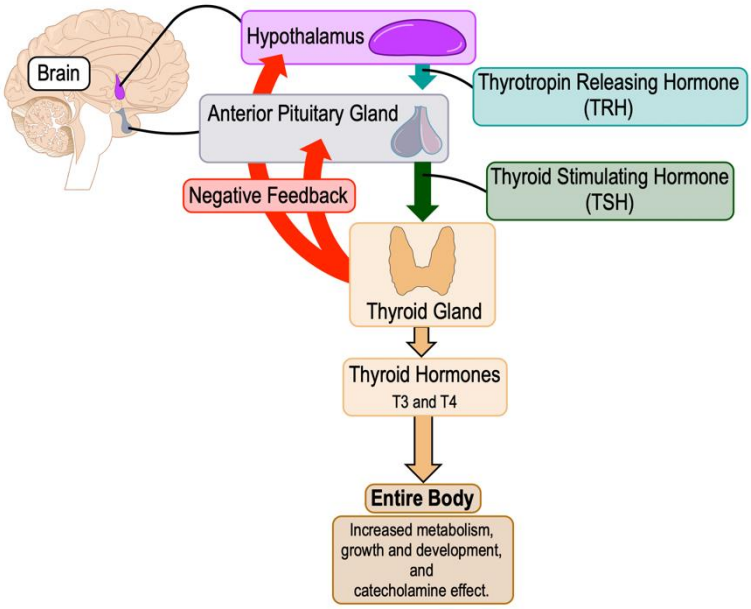


CONCEPT: ENDOCRINE SYSTEM

- ***Thyroid gland*** – endocrine gland involved in regulation of metabolic rate and calcium homeostasis
  - □ Thyroid hormones are synthesized from tyrosine and iodine, although act like steroid hormones
    - ***Triiodothyronine*** (T_3) – thyroid hormone containing 3 iodine atoms
    - ***Thyroxine*** (T_4) – thyroid hormone containing 4 iodine atoms
  - □ Thyroid hormones have a wide range of effects, but generally affect metabolic + heart rate, and heat production
  - □ Thyroid hormones block TRH from hypothalamus and TSH release from anterior pituitary

EXAMPLE:

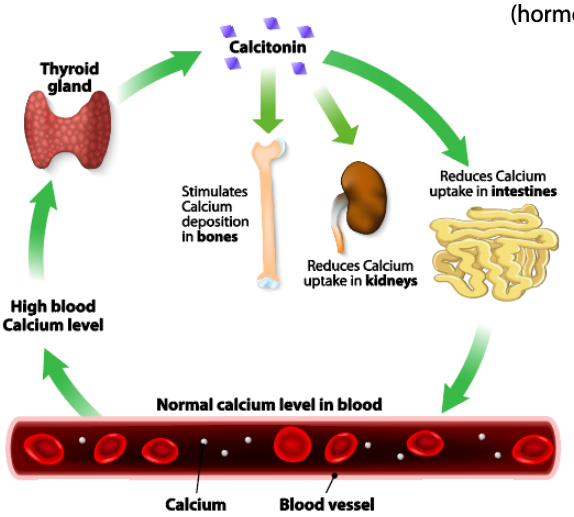


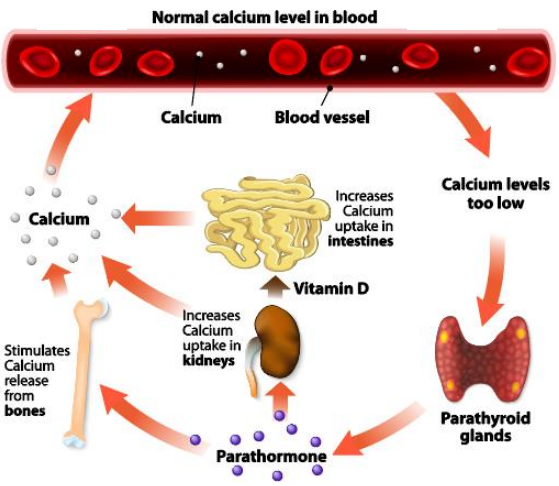


  - □ ***Calcitonin*** – peptide hormone involved in calcium homeostasis, along with parathyroid hormone
    - Secreted in response to high levels of calcium in the blood, reduces calcium concentration in blood
    - Increases calcium storage in bone and excretion in kidneys, decreases absorption in gut
- ***Parathyroid gland*** – endocrine gland on the back of the thyroid gland that secretes parathyroid hormone
  - □ ***Parathyroid hormone*** – peptide hormone secreted in response to low calcium levels in the blood
    - Increase bone reabsorption, decreases Ca^{2+} excretion in kidneys, and increases Ca^{2+} absorption in gut

EXAMPLE:

CALCITONIN and PARATHORMONE
(hormonal regulation of blood calcium levels)

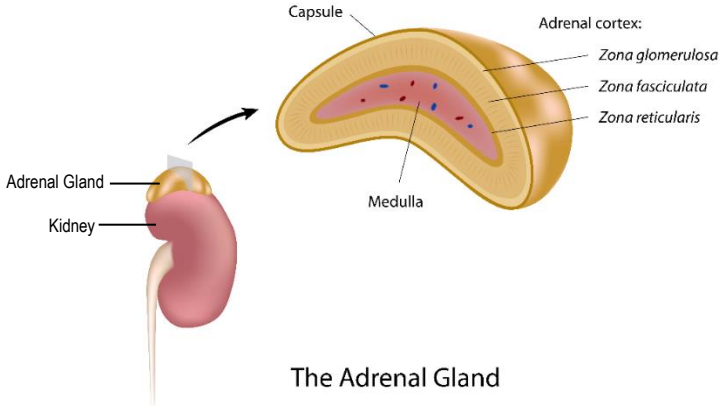




CONCEPT: ENDOCRINE SYSTEM

- ***Erythropoietin*** – hormone secreted by kidneys to stimulate erythrocyte production in bone marrow
- ***Adrenal glands*** – endocrine and neuroendocrine glands that sit atop the kidneys
    - □ ***Adrenal cortex*** – outer gland that secretes mineralocorticoids and glucocorticoids
        - Receives hormonal signals from hypothalamus
        - ***Glucocorticoids*** – steroid hormones involved in glucose metabolism, like cortisol
        - ***Cortisol*** – steroid hormone involved in long-term stress and fight-or-flight response
        - ***Mineralocorticoids*** – steroid hormones that regulate water and electrolyte balance, like aldosterone
    - □ ***Adrenal medulla*** – inner gland that secretes epinephrine and norepinephrine in response to synaptic signals
        - ***Epinephrine*** (***adrenaline***) – amine hormone and neurotransmitter involved in stress response

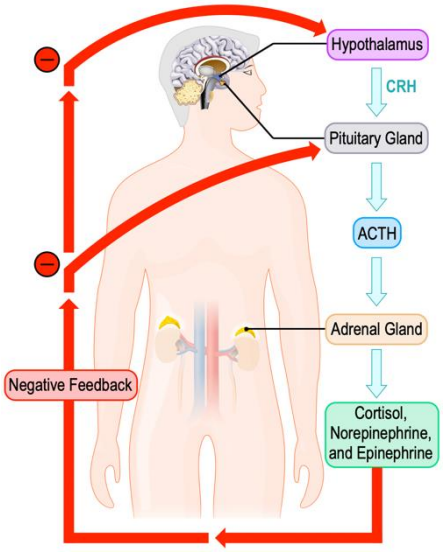
EXAMPLE:



The Adrenal Gland

- ***Fight-or-flight response*** – short-term stress response triggered by sympathetic nervous system
    - □ Hypothalamus triggers synaptic and endocrine signal in response to perceived threat
    - □ Adrenal medulla secretes epinephrine and norepinephrine and adrenal cortex secretes cortisol
    - □ Leads to many changes like increased metabolic rate, breathing rate, blood pressure, and blood glucose levels
- ***Hypothalamic-pituitary-adrenal*** (***HPA***) ***axis*** – negative feedback loop that controls stress levels
    - □ Hypothalamus secretes CRH → anterior pituitary secretes ACTH → adrenal cortex secretes cortisol
    - □ Cushing's disease – caused by increased ACTH secretion, results in persistent stress response

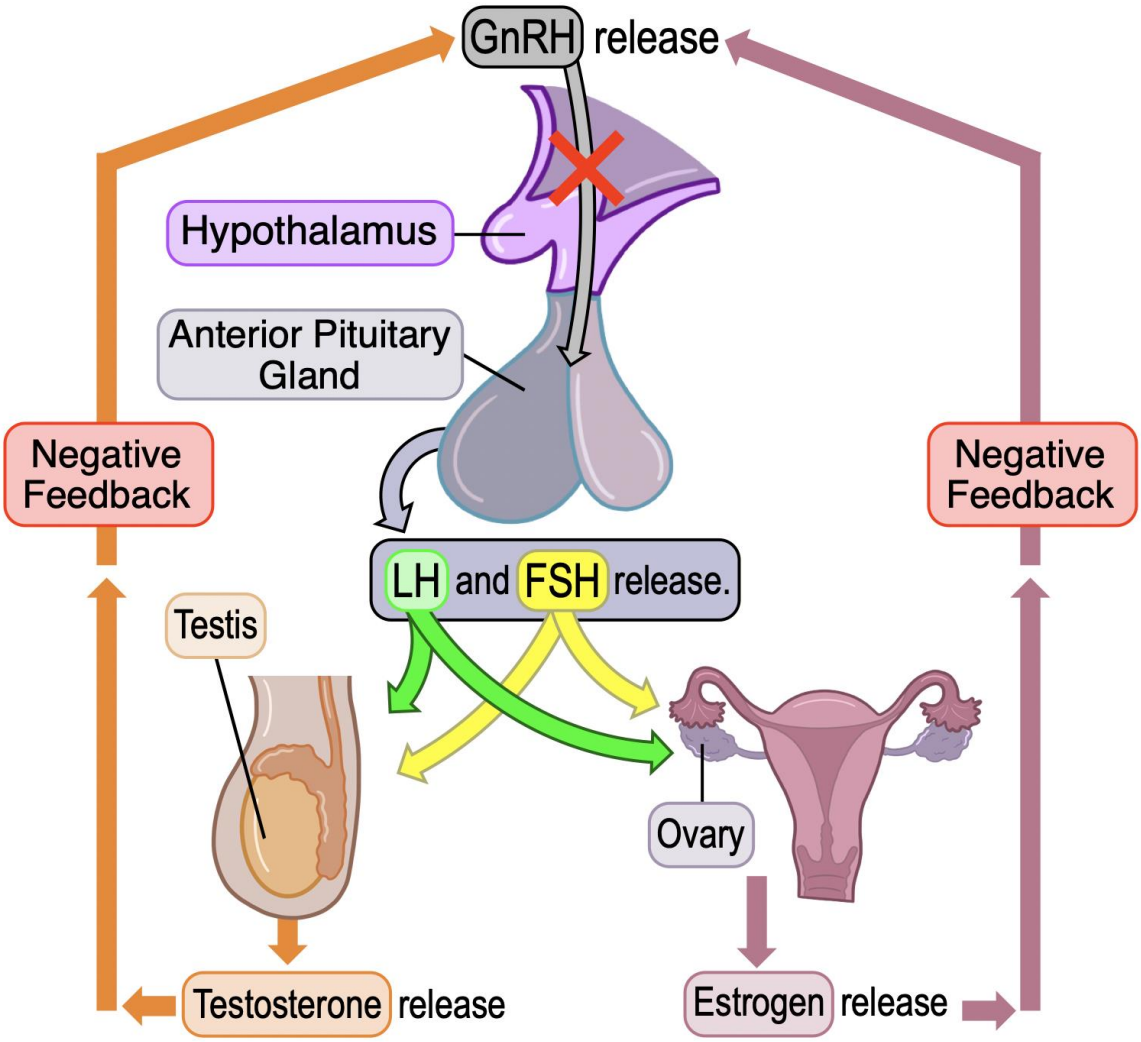
EXAMPLE:



CONCEPT: ENDOCRINE SYSTEM

- ***Gonads*** – endocrine glands that produce gametes, regulated by LH and FSH
- ***Testes*** – male gonads that produce steroid hormones called ***androgens***, male sex hormones
    - □ ***Testosterone*** – main androgen, regulates development and maintenance of male sexual characteristics
    - □ Müllerian inhibitory substance – peptide hormone that prevents female reproductive anatomy development
- ***Ovaries*** – female gonads that produce steroid hormones called ***estrogens***, female sex hormones
    - □ ***Estradiol*** – main estrogen, regulates development and maintenance of female sexual characteristics
    - □ ***Progesterone*** – steroid hormone involved in menstrual cycle and pregnancy
    - □ ***Xenoestrogens*** – foreign substances that bind to estrogen receptors and disrupt endocrine function
- ***Puberty*** – physical changes initiated by hormonal signals that change a child's body to prepare it for sexual reproduction

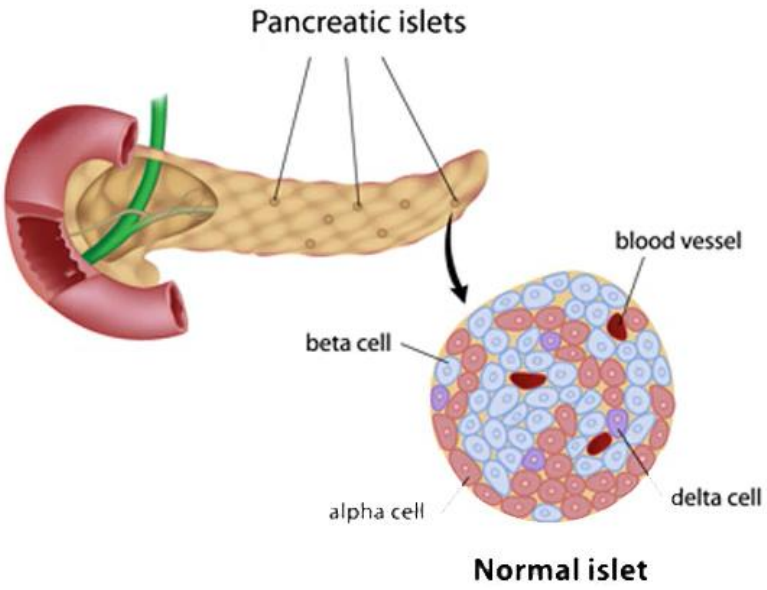
EXAMPLE:

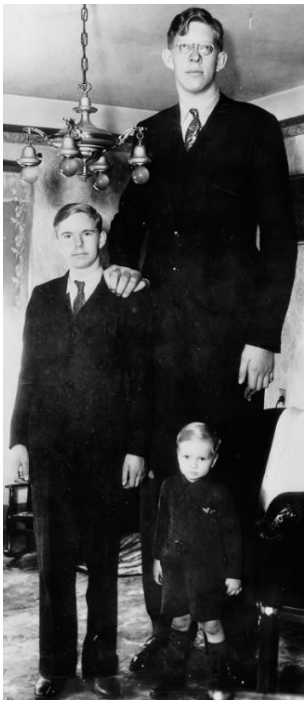


CONCEPT: ENDOCRINE SYSTEM

- ***Growth hormone*** (***GH***) – peptide secreted by AP, has tropic and non-tropic effects that generally increase growth
- ***Pancreas*** – endocrine and exocrine gland, involved in blood sugar homeostasis via insulin and glucagon secretion
  - □ Islets of Langerhans – hormone secreting cells, make peptide hormones insulin, glucagon, and somatostatin
    - □ cells □ glucagon, □ cells □ insulin, and □ cells □somatostatin
  - □ ***Somatostatin*** – peptide hormone that inhibits the effects of growth hormone

EXAMPLE:





- ***Secretin*** – hormone secreted by duodenum to stimulate bicarbonate secretion from pancreas
- Hunger and satiation are controlled by a pair of hormones with antagonistic effects
  - □ ***Leptin*** – hormone produced by adipocytes, has receptors in hypothalamus that inhibit appetite
  - □ ***Ghrelin*** – hormone that works in opposition to leptin, stimulating appetite

EXAMPLE: