## Endocrine System

- Overall functions

– Regulate organic metabolism & $H_2O$ & electrolyte balance

– Induce adaptive changes to help body cope with stressful situations

– Promote smooth, sequential growth & development

– Control reproduction

– Regulate red blood cell production

– Along with autonomic nervous system, control & integrate both circulation & digestion/absorption of food

TABLE 2.1 Vertebrate hypothalamic and pituitary hormones

| Source of Hormone | | | Major Physiological Roles[a] |
|---|---|---|---|
| **Hypothalamus** | | | |
| Gonadotropin-releasing hormone | GnRH | ↑ | FSH and LH secretion |
| Thyrotropin-releasing hormone | TRH | ↑ | TSH secretion |
| Corticotropin-releasing hormone | CRH | ↑ | ACTH secretion |
| Dopamine | DA | ↓ | Prolactin secretion |
| Melanocyte-stimulating hormone (MSH) release inhibiting factor | MIF[b] | ↓ | MSH secretion |
| Somatostatin | SST | ↓ | GH secretion |
| Growth hormone-releasing hormone | GHRH | ↑ | GH secretion |
| **Pituitary gland** | | | |
| *Posterior lobe (pars nervosa):*[c] | | | |
| Oxytocin | OT | ↑ | Milk secretion; uterine contraction |
| Vasopressin (arginine vasopressin) (antidiuretic hormone) | AVP ADH | ↑ | Renal water absorption; vasoconstriction |
| Melanin-concentrating hormone | MCH | ↑ | Melanosome aggregation (teleost fishes) |
| *Intermediate lobe (pars intermedia):* | | | |
| Melanocyte-stimulating hormone | MSH | ↑ | Integumental melanogenesis; melanosome dispersion |
| *Anterior lobe (pars distalis):* | | | |
| Follicle-stimulating hormone (follitropin) | FSH | ↑ | Female: ovarian follicle growth; estradiol synthesis |
| | | ↑ | Male: spermatogenesis |
| Luteinizing hormone (lutropin) | LH | ↑ | Female: ovulation; ovarian estradiol and progesterone synthesis |
| | | ↑ | Male: testicular androgen synthesis |
| Prolactin | PRL | ↑ | Milk synthesis; corpus luteum progesterone synthesis in some species |
| Thyrotropin (thyroid-stimulating hormone) | TSH | ↑ | Thyroid hormone ($T_4$ and $T_3$) synthesis and secretion |
| Adrenocorticotropin (adrenal cortical stimulating hormone) | ACTH | ↑ | Adrenal steroidogenesis |
| Growth hormone | GH | ↑ | Hepatic somatomedin (IGF-I, II) biosynthesis |

[a]The effect of each hormone on either an increased or stimulated (↑) or a decreased or inhibited (↓) physiological response is indicated.
[b]There is some evidence for putative PRL- and MSH-releasing factors.
[c]See Chap. 7 for other vertebrate neurohypophysial hormones.

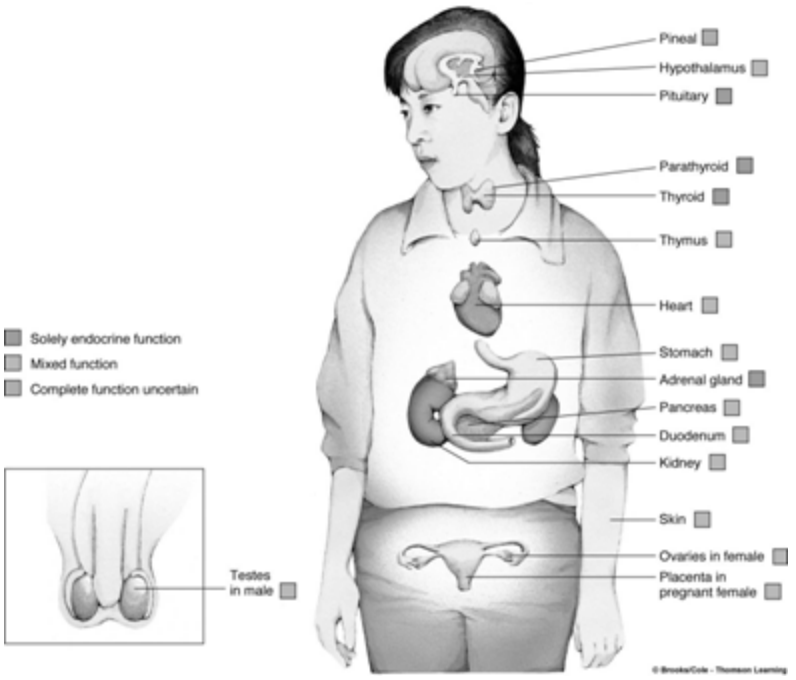
TABLE 2.2 Some other vertebrate hormones

| Source of Hormone | | | Major Physiological Roles* |
|---|---|---|---|
| **Thyroid** | | | |
| Thyroxine | $T_4$ | ↑ | Growth; differentiation; calorigenesis (↑ metabolic rate and oxygen consumption) |
| Triiodothyronine | $T_3$ | | Same as for thyroxine |
| **Adrenal steroidogenic tissue (adrenal cortex)** | | | |
| Cortisol | | ↑ | Carbohydrate metabolism; sympathetic function |
| Corticosterone | | ↑ | Carbohydrate metabolism; sympathetic function |
| Aldosterone | | ↑ | Sodium retention |
| **Adrenal chromaffin tissue (adrenal medulla)** | | | |
| Epinephrine | E | | Multiple ↑ and ↓ effects on nerves, muscles, cellular secretions, and metabolism |
| Norepinephrine | NE | | Generally same physiological roles as epinephrine |
| **Ovary (preluteal follicle)** | | | |
| Estradiol | $E_2$ | ↑ | Female sexual development and behavior |
| **Ovary (corpus luteum)** | | | |
| Progesterone | | ↑ | Uterine and mammary gland growth; maternal behavior |
| Relaxin | | ↑ | Relaxation of pubic symphysis and dilation of uterine cervix |
| **Placenta** | | | |
| Chorionic gonadotropin (choriogonadotropin) | CG | ↑ | Corpus luteum progesterone synthesis |
| Placental lactogen | PL | ↑ | Possibly fetal growth and development, mammary gland development in the mother |
| **Testes (Leydig cells)** | | | |
| Testosterone | | ↑ | Male sexual development and behavior |
| **Testes (Sertoli cells)** | | | |
| Inhibin | | ↓ | Pituitary FSH secretion |
| Anti-Müllerian Hormone | AMH | | Müllerian duct regression (atrophy) |
| **Pineal (epiphysis)** | | ↓ | Gonadal development (antigonadotropic action) |
| Melatonin | | | |
| **Thymus gland** | | | |
| Thymic hormones | | ↑ | Proliferation and differentiation of lymphocytes |
| **Pancreatic islets** | | | |
| Insulin | | ↓ | Blood glucose; ↑ protein, glycogen, and fat synthesis |
| Glucagon | | ↑ | Blood glucose; gluconeogenesis; glycogenolysis |
| Somatostatin | SST | ↓ | Secretion of other pancreatic islet hormones |
| Pancreatic polypeptide | PP | ↑↓ | Secretion of other pancreatic islet hormones |
| **Gastrointestinal (GI) tract** | | | |
| Gastrin | | ↑ | HCL secretion |
| Secretin | | ↑ | Pancreatic acinar cell fluid (bicarbonate) secretion |
| Cholecystokinin | CCK | ↑ | Pancreatic acinar cell enzyme secretion; gall bladder contraction |
| Gastric inhibitory peptide | GIP | ↓ | Gastric acid (HCL) secretion, |
| | | ↑ | Insulin secretion |
| Vasoactive intestinal peptide | VIP | ↑ | Intestinal secretion of electrolytes; smooth muscle relaxation |
| Glucagon-like peptide-1 | GLP-1 | ↑ | Insulin secretion |
| Motilin | | ↑ | Gastric acid secretion; villous motility |
| Neurotensin | NT | | Enteric neurotransmitter |
| Substance P | SP | | Enteric neurotransmitter |
| Gastrin-releasing peptide | GRP | ↑ | Gastrin secretion; gastric acid secretion |
| **Parathyroid glands** | | | |
| Parathormone | PTH | ↑ | Blood calcium ($Ca^{2+}$) |
| | | ↓ | Blood phosphate ($PO_4^{-2}$) |
| **Thyroid parafollicular cells (or ultimobranchial glands)** | | | |
| Calcitonin | CT | ↓ | Blood $Ca^{2+}$ |

TABLE 2.2 Continued

| Source of Hormone | | | Major Physiological Roles |
|---|---|---|---|
| **Skin, liver, kidney** | | | |
| vitamin $D_3$ | ↑ | | Blood $Ca^{2+}$; intestinal $Ca^{2+}$ absorption, renal $Ca^{2+}$ reabsorption |
| **Plasma angiotensinogen** | | | |
| Angiotensin II | All | ↑ | Vasoconstriction; aldosterone secretion; thirst (dipsogenic behavior) |
| **Kidney** | | | |
| Erythropoietin | EP | ↑ | Erythropoiesis |
| **Most all tissues** | | | |
| Prostaglandins (PGs) | $PGE_2$ | ↑ | Second messenger formation |
| | $PGF_{2\alpha}$ | ↑ | Second messenger formation |
| Prostacyclins | $PGI_2$ | ↑ | Second messenger formation |
| Thromboxanes | $TXA_2$ | ↑ | Second messenger formation |
| Leukotrienes | $LTE_4$ | ↑↓ | Second messenger formation |
| **Various tissues** | | | |
| Epidermal growth factor | EGF | ↑ | Epithelial cell proliferation |
| Fibroblast growth factor | FGF | ↑ | Fibroblast proliferation |
| Nerve growth factor | NGF | ↑ | Neurite development |
| Somatomedins | IGF-I, II | ↑ | Cellular growth and proliferation |
| Endorphins (e.g., enkephalins) | | ↑ | Opiate-like activity |
| **Heart** | | | |
| Atrial natriuretic factor (atriopeptin) | ANF | ↓↑ | Renal salt and water diuresis |

*The major effect of each putative chemical messenger on either an increased or stimulated (↑) or a decreased or inhibited (↓) physiological response is indicated.




Endocrine System

- Consists of ductless endocrine glands scattered throughout body
- Glands secrete hormones travel through blood to target cells
  - Target cells have receptors for binding with specific hormone
  - Regulates or directs particular function
- Two hormone categories based on solubility
  1) Hydrophilic
     - Peptide hormones
     - Catecholamines (dopamine, epinephrine, norepinephrine)
  2) Lipophilic
     - Steroid hormones
     - Thyroid hormone

## Classic Categories of Hormones

1) steroids -high affinity receptors in cytosol or within nuclear genome
estrogens/vitamin $D_3$ within nuclear genome

2) polypeptides -high affinity membrane receptors*

3) amino acid-high affinity membrane receptors; nuclear genome
thyroxine or triiodothyronimine within nuclear genome

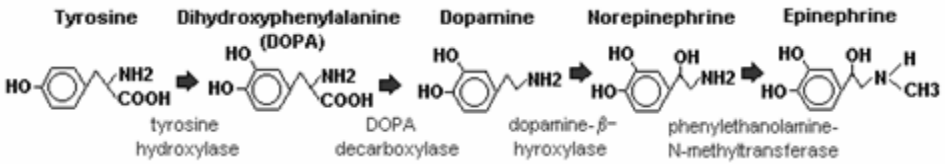
4) fatty acid derived compounds**

***polypeptides-permeability problem: from extracellular space to blood vessel overcome by diffusing through fenestrated (thinning or opening of walls) of capillaries**

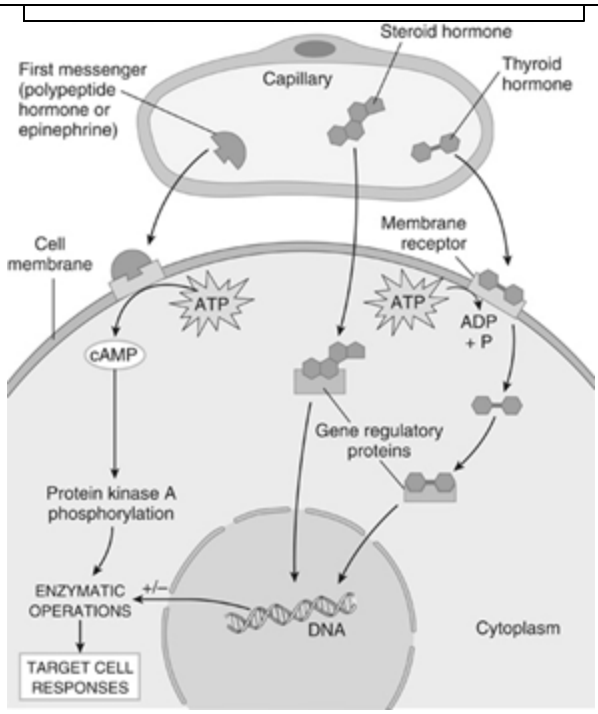
****exclusive products of endocrine glands except #4**

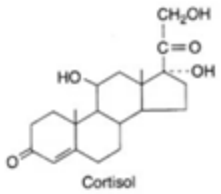
Similarities of classical endocrine hormones & neurotransmitters:
1) epinephrine: hormone of adrenal medulla

2) norepinephrine: major neurotransmitter

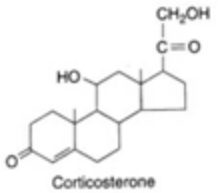



Similarity in chemical structures & overlap in activities

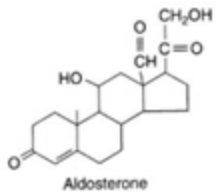


Cortisol

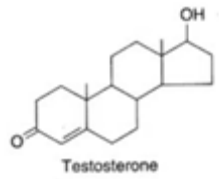


Corticosterone

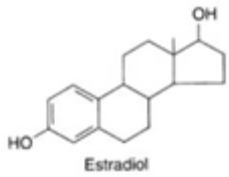


Aldosterone

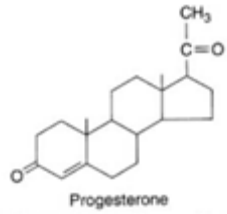
**Figure 2.1** Examples of adrenal steroid hormones.



Testosterone

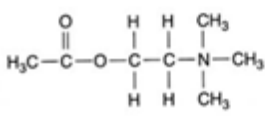


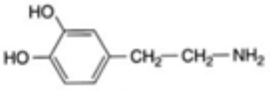
Estradiol



Progesterone

**Figure 2.2** Examples of gonadal steroid hormones.



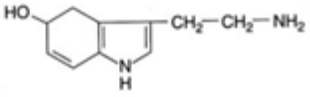
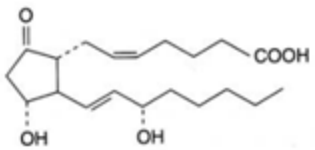




Figure 2.3 Examples of neurotransmitters.



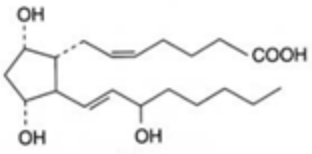




Figure 2.4 Examples of two common prostaglandins.

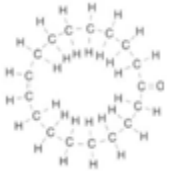
silk worm moths

Figure 2.5 Examples of invertebrate & vertebrate pheromones

sexual attractants

bombykol

male detect female 11 km away



civetone

ketone secreted by perianal glands

African civet: dog-like

**Pheromone: volatile, odorous substances which are released by one animal & detected by another individual of "same species", causing some sort of physiological reaction leading to a relatively specific behavior modification**

**Two classifications**

**1) signaler (releaser): elicits a prompt behavioral reaction**

**e.g. sexual attractant**

**2) primer: elicits a slower effect**

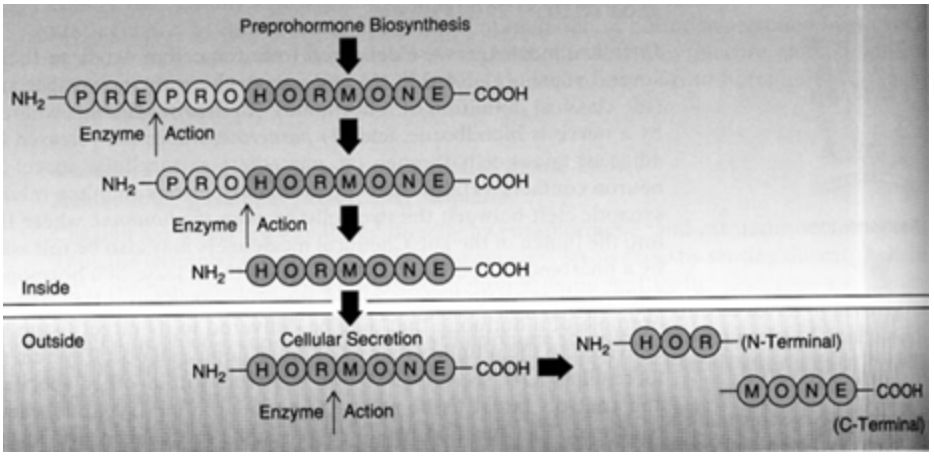
**e.g. alteration of endocrine or reproductive systems**

**Transmission**

**1) aerial: volatile aliphatic substance**

**2) aquatic: hydrophilic substance**

**Figure 2.6 Methods of hormone delivery**
**Modified from [12]**

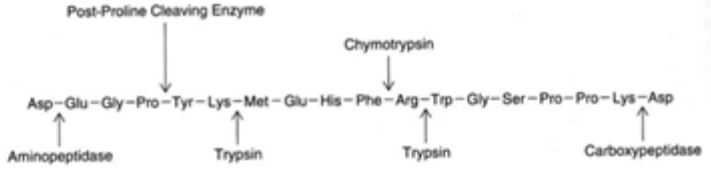




**Figure 2.8** Model of peptide degradation by proteolytic enzymes.

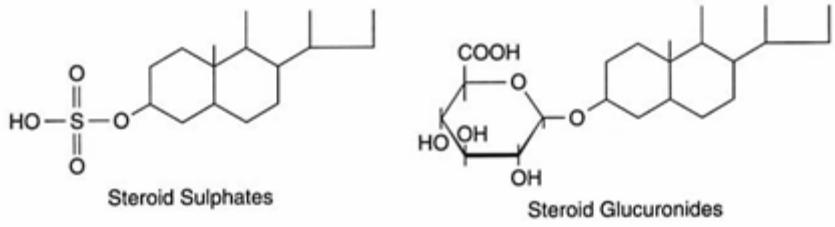



**Figure 2.9 Steroid hormone sulfation and glucuronide formation.**

## Tropic Hormones

- Regulates hormone secretion by another endocrine gland
- Stimulates & maintains their endocrine target tissues
  e.g.
  – Thyroid-stimulating hormone (TSH) secreted from anterior pituitary stimulates thyroid hormone secretion by thyroid gland
  – Maintains structural integrity of thyroid gland