

Marcello Cherchi's chart of

Hormones in endocrine physiology

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(Please let me know of any errors! mchercl@uic.edu)

BL BERNE, Robert M. and Matthew N. LEVY, *Principles of Physiology*. St. Louis: The C.V. Mosby Company, 1990.

CO COSTANZO, Linda S., *Physiology*, 2nd ed. Baltimore: Williams & Wilkins, 1998.

GG Dr. Geula Gibori's lectures.

Steroid hormones: cortisol, aldosterone, androgens, estrogens, progestins (BL 482). These are all derivatives of cholesterol (CO 243).

Adrenal hormones				
Hormone	Site of synthesis	Stimuli for secretion; mechanisms	Targets and effects	Factors inhibiting secretion
Epinephrine and Norepinephrine	Chromaffin cells of adrenal medulla (BL 480, 572).	<ul style="list-style-type: none">◆ Neurons in hypothalamus cause the sympathetic nervous system, which stimulates the adrenal medulla (BL 480, 573).◆ Low glucose (BL 480).◆ Granule exocytosis is stimulated by Ca^{2+} (BL 482).◆ Adrenocorticotropin (ACTH, released from anterior pituitary, BL 560) whose secretion is in turn stimulated by corticotropin releasing hormone (CRH) from the hypothalamus (BL 561).	<ul style="list-style-type: none">◆ Has many effects (BL 563-4).◆ Stimulates conversion of protein to glucose (BL 564).◆ Inhibits effects of insulin (BL 565).◆ Signals liver to release stored glucose (BL 480).◆ Signals non-hepatic tissues to reduce glucose utilization (BL 480).◆ Important in the stress response (BL 562, 578).◆ Stimulates α_1, α_2, β_1, β_2 receptors (BL 575-6) with many effects.◆ Brings about whole-body fuel mobilization (BL 575).	

Cortisol (a glucocorticoid)	Zona fasciculata of adrenal cortex (BL 559).	<ul style="list-style-type: none"> ◆ Neurons in hypothalamus signal the adrenal cortex (BL 480). ◆ Low glucose (BL 480). ◆ ACTH (CO 258). 	<ul style="list-style-type: none"> ◆ Causes liver to augment glucose synthesis (BL 480). ◆ Inhibits insulin-stimulated utilization of glucose by tissues other than the brain (BL 480; CO 261). ◆ Release of glucagon (GG). ◆ Breakdown of protein (CO 261), especially in muscle (GG). ◆ Inhibits CRH secretion from hypothalamus (CO 259). ◆ Inhibits ACTH secretion from anterior pituitary (CO 259). ◆ Important in response to stress (CO 260). ◆ Inhibits production of IL-2 and thereby depresses the immune system (CO 261). 	
Aldosterone (a mineralocorticoid)	Zona glomerulosa of adrenal cortex (BL 559).	<ul style="list-style-type: none"> ◆ High angiotensin II. ◆ High plasma K⁺ ◆ β adrenergic stimulation (BL 568). ◆ High ACTH (BL 569; CO 258). 	<ul style="list-style-type: none"> ◆ Targets kidney (BL 569). ◆ Sustain extracellular fluid volume by conserving Na⁺ (BL 567) and promoting its reabsorption (CO 260-1). ◆ Prevent overload of K⁺ by accelerating excretion (BL 567; CO 261). 	Low plasma K ⁺ (BL 569).
Androgens (dehydroepiandrosterone and androstenedione)	Zona reticularis of adrenal cortex (CO 257).	<ul style="list-style-type: none"> ◆ ACTH (CO 258). 		

Hormones of the pancreatic islets

Hormone	Site of synthesis	Stimuli for secretion; mechanisms	Targets and effects	Factors inhibiting secretion
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Insulin	β cells of pancreas (BL 504).	<ul style="list-style-type: none"> ◆ High glucose (BL 505-6; CO 266). ◆ Second messenger is Ca^{2+} (BL 505) and cAMP (GG). ◆ GI hormones (GG). ◆ Amino acids (GG). ◆ Glucocorticoids (GG). ◆ Growth hormone (GG). ◆ Parasympathetic stimulation (ACh) (GG). 	<ul style="list-style-type: none"> ◆ Facilitates storage of substrates and inhibits their release (BL 507). ◆ Decreases blood glucose concentration by: <ol style="list-style-type: none"> (1) Increasing glucose uptake by cells (CO 267). (2) Promoting formation of glycogen in muscle and liver (CO 267). (3) Inhibiting gluconeogenesis (CO 267). (4) Inhibiting glucagon synthesis (GG). ◆ Stimulates fat deposition (CO 267). 	<ul style="list-style-type: none"> ◆ Epinephrine from adrenal medulla (GG). ◆ Norepinephrine from sympathetic stimulation (GG). ◆ Somatostatin (CO 268).
Glucagon	α cells of pancreas (BL 504).	<ul style="list-style-type: none"> ◆ Low glucose (BL 511; CO 265). 	<ul style="list-style-type: none"> ◆ Stimulates liver to release stored glucose (BL 479). ◆ Stimulates gluconeogenesis (CO 266). ◆ Stimulates glycogenolysis and β oxidation in the liver (BL 512-13; CO 265). 	<ul style="list-style-type: none"> ◆ High glucose (BL 511). ◆ Somatostatin (CO 268).
Somatostatin	<ul style="list-style-type: none"> ◆ δ cells of pancreas (BL 513). ◆ Hypothalamus (GG). 	<ul style="list-style-type: none"> ◆ Glucose, free fatty acids, glucagon, CCK, VIP (BL 513). 	<ul style="list-style-type: none"> ◆ Decreases the rate of digestion and absorption of nutrients (BL 513). ◆ Inhibits secretion of insulin and glucagon (BL 513; CO 268). ◆ Inhibits release of growth hormone (BL 540). 	Probably inhibited by insulin (BL 513).

Hormones involved in regulation of mineral metabolism

Hormone	Site of synthesis	Stimuli for secretion; mechanisms	Targets and effects	Factors inhibiting secretion
Vitamin D	Absorbed in gut. Converted to active form either in skin (via UV light) or in liver and kidney (BL 520).		Vitamin D helps increase plasma Ca^{2+} levels by the following mechanisms: <ul style="list-style-type: none"> ◆ Increases Ca^{2+} and PO_4^{3-} absorption from intestinal lumen (BL 521; CO 273). ◆ Increases renal Ca^{2+} and PO_4^{3-} reabsorption (CO 273). ◆ Increases bone resorption (osteoclastic activity) (BL 521). ◆ Stimulates parathyroid to secrete PTH (GG). 	

Parathyroid hormone (PTH)	Chief cells of parathyroid glands (BL 522).	<ul style="list-style-type: none"> ◆ Low plasma Ca^{2+} (BL 522; CO 270). ◆ Vitamin D (GG). ◆ Second messenger is cAMP (CO 270). 	<p>Acts on kidney, bone, GI tract (BL 523) to bring about the following:</p> <ul style="list-style-type: none"> ◆ Increases plasma Ca^{2+} by stimulating entry of Ca^{2+} into plasma from bone, tubular urine, and intestinal tract (BL 522). ◆ Decreases plasma PO_4^{3-} (BL 523) by inhibiting renal phosphate reabsorption (CO 270). ◆ Increases renal Ca^{2+} reabsorption (CO 270). ◆ Increases intestinal Ca^{2+} reabsorption (CO 270). ◆ Increases bone resorption (CO 270). 	High plasma Ca^{2+} (BL 522).
Calcitonin (CT)	C cells (parafollicular cells) in thyroid gland (BL 525; CO 273).	Second messenger is cAMP (BL 526).	<ul style="list-style-type: none"> ◆ Lowers plasma Ca^{2+} (BL 526). ◆ Inhibits bone resorption (CO 273). 	

Hormones of the hypothalamus and pituitary gland (hypophysis)

Hormone	Site of synthesis	Stimuli for secretion; mechanisms	Targets and effects	Factors inhibiting secretion
Antidiuretic hormone (ADH) or Arginine vasopressin (AVP)	Synthesized in neurons of the supraoptic nuclei (CO 252) whose cell bodies lie in the hypothalamus, then transported to the terminal swellings (of those neurons) in the posterior pituitary (neurohypophysis) (BL 529).	<ul style="list-style-type: none"> ◆ Increase in plasma osmolality (BL 534). ◆ Hypovolemia (BL 534). 	<p>Causes retention of free water by kidney, resulting in (BL 534-6):</p> <ul style="list-style-type: none"> ◆ Increase in urine osmolality. ◆ Decrease in plasma osmolality. ◆ Increases H_2O permeability of the principal cells of the late distal tubule and collecting duct (CO 252). ◆ Causes constriction of vascular smooth muscle (CO 252). 	

Oxytocin (OCT) or Milk letdown factor	Synthesized in neurons of the paraventricular nuclei (CO 252) whose cell bodies lie in the hypothalamus, then transported to the terminal swellings (of those neurons) in the posterior pituitary (neurohypophysis) (BL 536-7).	<ul style="list-style-type: none"> ◆ Suckling (CO 252). ◆ Dilation of the cervix and orgasm (CO 252). 	<ul style="list-style-type: none"> ◆ Causes contraction of myoepithelial cells in breast (BL 537; CO 253). ◆ Causes contraction of uterus (BL 537; 253). 	
Somatotropin or Growth hormone (GH)	Somatotrophs in anterior pituitary (adenohypophysis) (BL 537-8).	<ul style="list-style-type: none"> ◆ Synthesis is upregulated by thyroid hormone, cortisol, GHRH (BL 538-40). ◆ Release is stimulated by GHRH (BL 540; CO 249). ◆ Secretion is increased by sleep, stress, hormones related to puberty, starvation, exercise, and hypoglycemia (CO 248). ◆ Second messenger is cAMP (BL 540). 	<ul style="list-style-type: none"> ◆ Targets cells throughout the body (BL 540-1). ◆ Stimulates postnatal growth and development (BL 538). ◆ Reduces glucose uptake into cells (diabetogenic) (CO 249). ◆ Increases lipolysis (CO 249). ◆ Increases protein synthesis in muscle (CO 249). 	<ul style="list-style-type: none"> ◆ Somatostatin (BL 540; CO 249). ◆ Growth hormone inhibits its own secretion by stimulating the secretion of somatostatin from the hypothalamus (CO 249).
Growth hormone releasing hormone (GHRH)			<ul style="list-style-type: none"> ◆ Stimulates synthesis and secretion of growth hormone (CO 249). 	GHRH inhibits its own secretion from the hypothalamus (negative feedback) (CO 249).
Prolactin (PRL)	Mammotrophs in maternal pituitary (BL 543).	<p>Synthesis and release is stimulated by:</p> <ul style="list-style-type: none"> ◆ Thyrotropin releasing hormone (TRH) (BL 543). ◆ High estrogen levels (BL 612). 	<ul style="list-style-type: none"> ◆ Stimulates breast development and milk production (BL 543; CO 250). ◆ Inhibits ovulation (CO 250). ◆ Inhibits spermatogenesis by decreasing GnRH (CO 250). 	<ul style="list-style-type: none"> ◆ Dopamine (BL 543; CO 250). ◆ Prolactin inhibits its own secretion by stimulating the hypothalamic release of dopamine (CO 250).

Thyroid hormones				
Hormone	Site of synthesis	Stimuli for secretion; mechanisms	Targets and effects	Factors inhibiting secretion
Thyrotropin releasing hormone (TRH)	Synthesized in hypothalamus, stored in median eminence, reaches target cells via pituitary portal vein (BL 549; CO 255).		<ul style="list-style-type: none"> ◆ Targets thyrotroph cells (BL 551). ◆ Causes release of TSH from anterior pituitary (CO 255). ◆ Prolonged TRH exposure also upregulates TSH synthesis (BL 551). 	
Thyrotropin or Thyroid stimulating hormone (TSH)	Anterior pituitary (adenohypophysis).	<ul style="list-style-type: none"> ◆ TSH (CO 255). ◆ Second messengers are phosphatidylinositol and cAMP (BL 552). 	<ul style="list-style-type: none"> ◆ Targets follicular cells of thyroid gland (BL 551). ◆ Has many effects (see diagram in BL 551). 	<ul style="list-style-type: none"> ◆ High levels of T₄ (BL 552). ◆ High levels of dopamine and somatostatin from hypothalamus (BL 552).
Thyroid hormone T ₄ (“thyroxine”) is a prohormone T ₃ (“triiodothyronine”) is biologically active (BL 546)			<ul style="list-style-type: none"> ◆ In circulation, 75% of T₃ and T₄ is bound to TBG (thyroxine binding protein) (BL 553). ◆ Stimulates transcription of many things (BL 553). ◆ Increases whole body rate of O₂ consumption and heat production (BL 555; CO 256). ◆ Increases cardiac output (BL 555; CO 256). ◆ Downregulates activity of sympathetic nervous system (BL 555). ◆ Potentiates effects of various hormones on the GI tract (BL 555; CO 256). ◆ Stimulates linear growth, development, and bone maturation (BL 556; CO 255-6). ◆ Required for normal neurological development and functioning (BL 556; CO 256). ◆ Contributes to reproductive function in both genders (BL 556). 	

Reproductive hormones				
Hormone	Site of synthesis	Stimuli for secretion; mechanisms	Targets and effects	Factors inhibiting secretion
Gonadotropin-releasing hormone (GnRH) or Lutenizing hormone-releasing hormone (LHRH)	Synthesized by hypothalamic neurons in the arcuate and preoptic areas, and transported along axons to neuron termini in the median eminence. From there it is released into pituitary portal veins (BL 581).		Stimulates release of LH and FSH by gonadotroph cells in anterior pituitary (BL 581; CO 276).	
Follicle stimulating hormone (FSH)	Anterior pituitary (CO 275).	GnRH (BL 581; CO 276).	<ul style="list-style-type: none"> ◆ Stimulates granulosa cells (in female) and Sertoli cells (in male) to secrete estrogens (BL 582, 595). ◆ Maintains spermatogenesis (CO 275, 276). ◆ Stimulates steroidogenesis, follicular development, ovulation, lutenization (CO 276). ◆ Stimulates secretion of inhibin and other proteins (BL 582). ◆ Second messenger is cAMP (BL 582). 	In the male, inhibin (synthesized by Sertoli cells) inhibits the secretion of FSH (CO 275).
Lutenizing hormone (LH)	Anterior pituitary (CO 276).	<ul style="list-style-type: none"> ◆ GnRH (BL 581). ◆ Second messenger is cAMP (BL 582). ◆ The surge of LH before ovulation is the result of positive feedback of estrogen on the anterior pituitary; LH then acts on the ovaries and causes further secretion of estrogen. This is one of the few examples of positive feedback regulation in hormone secretion (CO 243). 	<ul style="list-style-type: none"> ◆ Stimulates theca cells (in female) and Leydig cells (in male) to synthesize and secrete androgens and estrogens (BL 582). ◆ Stimulates granulosa cells in female (BL 582). 	

Antimüllerian hormone (AMH)	Sertoli cells of testis (BL 587).		<ul style="list-style-type: none"> ◆ Causes atrophy of müllerian ducts (BL 587). ◆ Stimulates descent of testes into inguinal area (BL 587). 	
Testosterone (the inactive form) and Dihydrotestosterone (DHT) (the active form)	Leydig cells of testes (BL 595; CO 274).	LH and ACTH increase testosterone synthesis (CO 274, 275).	<ul style="list-style-type: none"> ◆ Accessory sex organs (e.g. prostate) convert testosterone to dihydrotestosterone (CO 275). ◆ Circulates mostly bound to sex steroid-binding globulin (SSBG). The rest is bound to albumin (BL 595). ◆ Inhibits secretion of LH (CO 275). ◆ Causes pubertal changes (CO 276). 	
Estrogens (estradiol, estrone, estriol)	Initially synthesized by corpus luteum, but gradually the placenta takes over this function (BL 611).		<ul style="list-style-type: none"> ◆ Stimulates continuous growth of uterine muscles necessary for labor (BL 611). ◆ Induces softening of pelvic ligaments (BL 611). ◆ Augments ductal system in breast (BL 611; 277). ◆ Causes maturation and maintenance of fallopian tubes, uterus, cervix, vagina (CO 277). ◆ Upregulates receptors for estrogen, LH, progesterone (CO 277). ◆ Causes proliferation and development of ovarian granulosa cells (CO 277). ◆ Maintains pregnancy (CO 277). 	
Estradiol			Causes somatic changes that result in female adult appearance (BL 607).	
Relaxin	Corpus luteum and decidua (BL 612).	HCG (BL 612).	<ul style="list-style-type: none"> ◆ Relaxes pelvic outlet (BL 612). ◆ Inhibits uterine muscle contractions (BL 612). ◆ Softens cervix (BL 612). 	
Progesterone			<ul style="list-style-type: none"> ◆ Has negative feedback effects on FSH and LH secretion during luteal phase (CO 278). ◆ Maintains pregnancy (CO 278). ◆ Stimulates breast development (CO 278). 	

Hormones secreted by the placenta				
Hormone	Site of synthesis	Stimuli for secretion; mechanisms	Targets and effects	Factors inhibiting secretion

Human chorionic gonadotropin (HCG)	Placental syncytiotrophoblast cells (BL 611).	GnRH from adjacent placental cells (BL 611).	Maintains corpus luteum (BL 611).	
Progesterone	Placenta (BL 611).		<ul style="list-style-type: none"> ◆ Required for implantation, early sustenance of embryo, maintaining uterine lining BL 611. ◆ Stimulates mammary gland development and lactation capacity (BL 611). ◆ Inhibits uterine contractions (BL 611, 614). 	
Human chorionic somatomammotropin (HCS) or Human placental lactogen	Placental trophoblasts (BL 611).		<ul style="list-style-type: none"> ◆ Directs maternal metabolism to maintain flow of nutrients to fetus (BL 611). ◆ Stimulates lipolysis, raises maternal free fatty acid and glucose levels (BL 611). 	