

INTRODUCTION

C: Use a very light color for C and a darker one for D (actually located on posterior surface of thyroid). (1) After coloring endocrine glands and tissues, color the scheme at lower left.

ENDOCRINE GLANDS

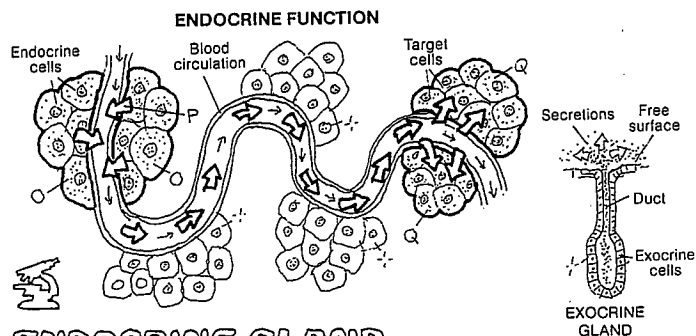
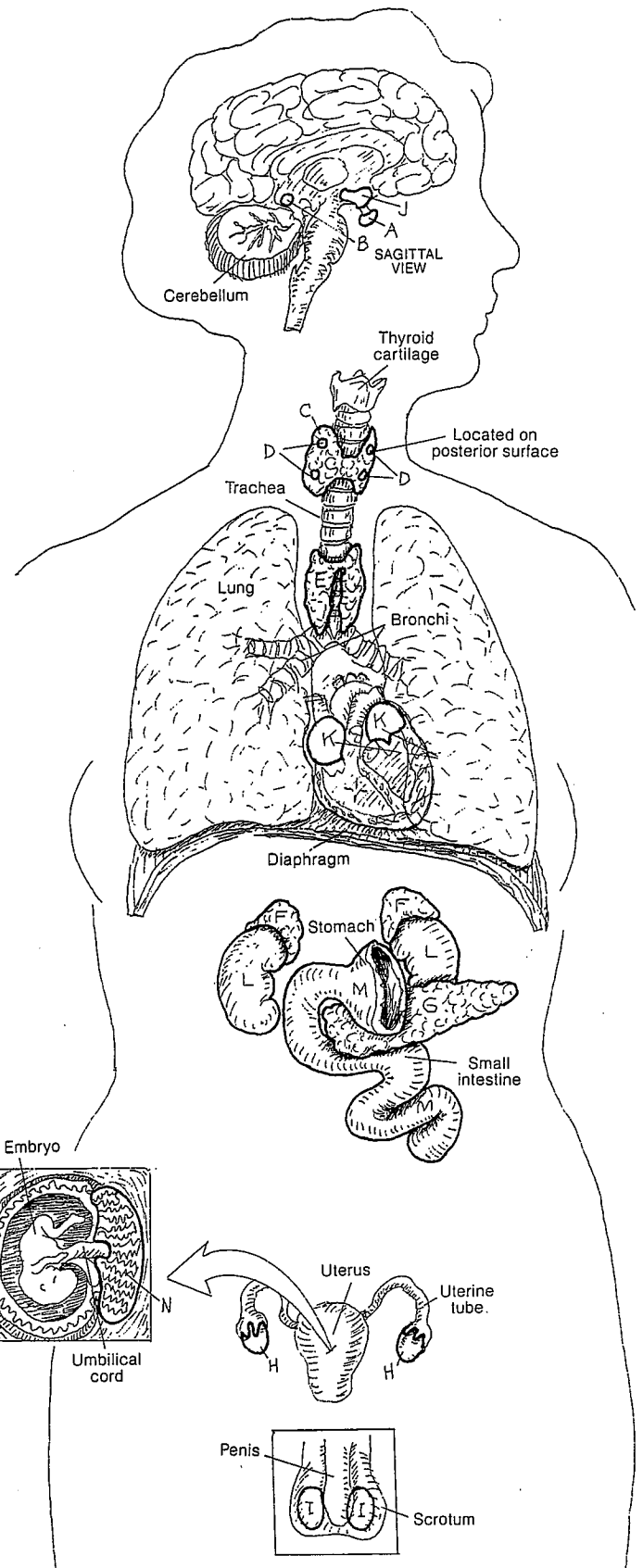
- HYPHYPHYSIS (PITUITARY) **A**
- PINEAL **B**
- THYROID **C**
- PARATHYROID (4) **D**
- THYMUS **E**
- ADRENAL (SUPRARENAL) (2) **F**
- PANCREAS **G**
- OVARY (2) **H**
- TESTIS (2) **I**

ENDOCRINE TISSUES

- HYPOTHALAMUS **J**
- HEART (ATRIA) **K**
- KIDNEY (2) **L**
- GASTROINTESTINAL TRACT **M**
- PLACENTA **N**

Endocrine glands and tissues are discrete masses of secretory cells and their supporting tissues in close proximity to blood capillaries, into which the cells secrete their hormones. The glands and tissues are ductless. Hormones are chemical agents usually effective among cells (target organs) located some distance from their source. Hormonal secretion results in negative or positive feedback control mechanisms. In the broader scope, hormonal activity results in growth, reproduction, and related activity as well as metabolic stability in the internal environment. Stability of the internal environment is called homeostasis.

The classical endocrine glands listed and shown here are presented in the following plates, with the exception of the pineal gland (see Plate 75) and the thymus (see Plate 124). Also listed here are just a few of the myriad tissues/cells that secrete chemical agents influential in cellular activities. The role of the hypothalamus can be colored in Plates 152 and 153. The atria of the heart secrete atrial natriuretic peptide (ANP) during periods of weak myocardial contraction, resulting in increased excretion of sodium and water. The juxtaglomerular cells of the kidney (Plate 150) secrete renin, an enzyme that converts angiotensinogen to angiotensin I and indirectly induces increased blood pressure and conservation of body fluids, such as during hemorrhage. Numerous endocrine factors secreted by cells of the gastrointestinal tract influence intestinal motility and enzyme secretion. The placenta secretes, among many hormones, human chorionic gonadotropin, which contributes to the support of embryonic growth during the first 90 days post-fertilization by stimulating the growth of the corpus luteum (Plates 161, 163, 165, 166).



ENDOCRINE GLAND.
HORMONAL SECRETION **P**
TARGET ORGAN **Q**

PITUITARY GLAND & HYPOTHALAMUS

CN: Use red for H, blue for K, purple for I, and a very light color for J.
(1) Begin with the enlarged view of the hypophysis and hypothalamus.

PITUITARY GLAND (HYPOPHYSIS)

- ADENOHYPHYSIS**
 - PARS TUBERALIS_A
 - PARS DISTALIS (ANT. LOBE)_B
 - PARS INTERMEDIUS_C
- NEUROHYPHYSIS**
 - MEDIAN EMINENCE_D
 - INFUNDIBULAR STEM_E
 - PARS NERVOSA (POST. LOBE)_F

HYPOTHALAMUS

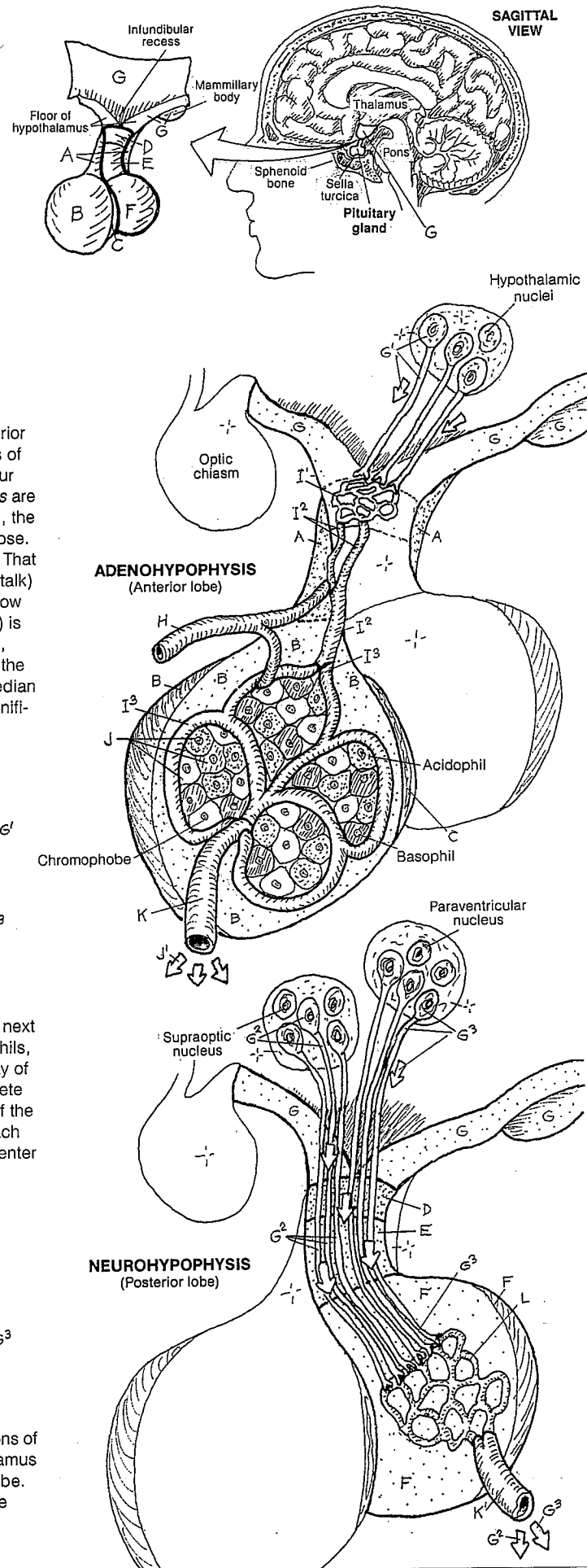
The pituitary gland (hypophysis) essentially consists of an anterior and a posterior lobe. It is suspended from the hypothalamus of the brain and fits into a recess of the sphenoid bone called the sella turcica. The pituitary is about the size of four peas (thank you, Dr. Marian Diamond). The three parts of the *adenohypophysis* are derived from an upward extension of the developing roof of the mouth; indeed, the gland was once thought to form mucus ("pituita") that was secreted into the nose. The posterior lobe is a downward migration from the floor of the hypothalamus. That floor, inferior to the third ventricle, consists of the hollow infundibulum (stem, stalk) surrounded by the *median eminence*. The lowest part of the infundibulum (below the median eminence, still part of the hypothalamic floor, but no longer hollow) is continuous with the posterior lobe. The three (infundibulum, median eminence, and posterior lobe) are often considered as the "*neurohypophysis*." Note how the pars tuberalis of the adenohypophysis embraces the *infundibular stem* and median eminence. The pars intermedius is rudimentary and appears to secrete no significant levels of hormone.

- ADENOHYPHYSIS**
 - HYPOTHAL. SECR. NEURON / HORMONE_G
 - SUP. HYPOPHYSEAL ARTERY_H
 - HYPOPHYSEAL PORTAL SYSTEM_I
 - CAPILLARY_{I¹} / PORTAL VEIN_{I²} / SINUSOID_{I³}
 - SECRETORY CELL_J / HORMONES_J
 - INF. HYPOPHYSEAL VEIN_K

The pars distalis contains a variety of cells that secrete several hormones (see next plate). There are three types that can be differentiated by staining: the acidophils, basophils (both chromophilic cells), and chromophobes. The secretory activity of these cells is stimulated by neurons of the hypothalamus. These neurons secrete releasing hormones into the vascular *hypophyseal portal system* at the level of the median eminence (next plate). Capillaries there drain into portal veins that reach the *sinusoids* of the pars distalis. Secretions from the cells of the pars distalis enter the sinusoids, which are drained by the *inferior hypophyseal vein*.

- NEUROHYPHYSIS**
 - HYPOTHAL. SECRETORY NEURONS_{G²}
 - SUPRAOPTIC NUCL. / HORMONE_{G²}
 - PARAVENTRIC. NUCL. / HORMONE_{G³}
 - CAPILLARY PLEXUS_L
 - HYPOPHYSEAL VEIN_{K¹}

The pars nervosa of the neurohypophysis has no secretory cells of its own. Axons of secretory neurons in the *supraoptic* and *paraventricular nuclei* of the hypothalamus extend down through the infundibulum to *capillary networks* in the posterior lobe. There these axon terminals release oxytocin and antidiuretic hormones into the circulation (see next plate).



PITUITARY GLAND & TARGET ORGANS

CN: Use the color from the previous plate for hypothalamic hormones (A) and secretions (A¹). Color the major headings distributed throughout the illustration. (1) Begin with the arrows and circles representing those hormones and secretions, including the penetration of the cells of the anterior lobe. (2) Color the pituitary hormones. (3) Color the arrows representing the target organ hormones performing their feedback function.

PITUITARY GLAND HORMONES / SOURCE CELL

PARS DISTALIS

- FOLLICLE-STIM. H. (FSH)_B / BASOPHIL_C
- LUTEINIZING H. (LH)_D / BASOPHIL_C
- THYROID STIM. H. (TSH)_E / BASOPHIL_C
- ADRENOCORTICOTROPIC H. (ACTH)_F / BASOPHIL_C
- GROWTH H. (GH)_G / ACIDOPHIL_H
- PROLACTIN_I / ACIDOPHIL_H

PARS NERVOSA

- OXYTOCIN_J
- ANTIDIURETIC H. (ADH)_K

TARGET ORGAN HORMONES

- ESTROGEN_N
- PROGESTERONE_O
- TESTOSTERONE_P
- THYROXINE_Q
- ADRENAL CORTICAL H._R

HYPOTHALAMIC HORMONES

PITUITARY GLAND HORMONES

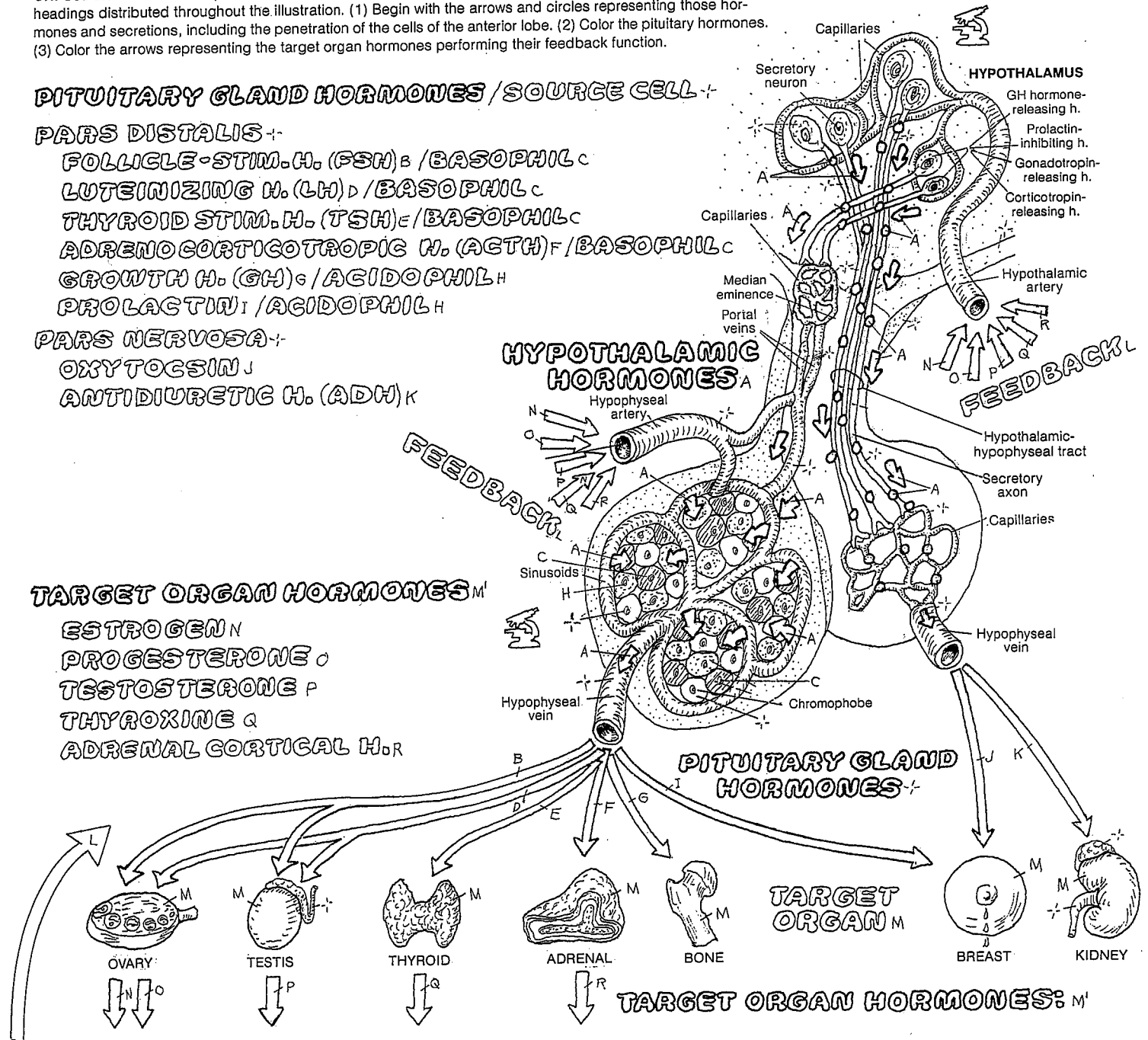
TARGET ORGAN

TARGET ORGAN HORMONES: M'

STRUCTURAL/FUNCTIONAL EFFECT/FEEDBACK

Hypothalamic releasing or inhibiting hormones act on the anterior lobe of the pituitary. These hormones stimulate/inhibit the target cells in the anterior lobe to increase/decrease their secretion of hormone. Inhibition of pituitary hormone secretion is most often controlled by negative feedback. For example, the hypothalamus is sensitive to the concentration of estrogen in the hypothalamic circulation (via the hypothalamic artery). As estrogen levels diminish, certain hypothalamic nuclei sense this and increase their secretion of gonadotropic-releasing hormone (GRH). GRH is released from secretory nerve endings into the hypophyseal portal system in the median eminence. GRH reaches the sinusoids of the anterior lobe and stimulates certain basophils there to secrete follicle-stimulating hormone. FSH is released into the circulation and has a stimulatory influence on the growth of ovarian follicles (as well as spermatogenesis in the male). Significantly increased levels of estrogen are sensed by the hypothalamus (feedback), and the hypothalamus turns off its secretion of GRH (negative feedback).

LH stimulates testosterone secretion, ovulation, development of the corpus luteum, and estrogen/progesterone secretion (Plate 163). TSH induces secretion of the thyroid hormone thyroxine (Plate 154). ACTH stimulates the release of adrenal cortical hormones (e.g., cortisol); it also has melanocyte-stimulating properties, dispersing pigment in the skin (Plate 155). GH stimulates body growth, especially bone. Prolactin mediates milk secretion (Plate 164) and is inhibited by prolactin-inhibiting hormone in the hypothalamus. Oxytocin and antidiuretic hormone (ADH, vasopressin) are products of secretory neurons in the supraoptic and paraventricular nuclei of the hypothalamus; the secretory material is transported down long axons (hypothalamo-hypophyseal tract) to capillaries in the posterior lobe, where they are released into the general circulation via the hypophyseal vein. Oxytocin induces ejection of milk (Plate 164) and stimulates uterine contractions. ADH (plate 155) causes retention of body water by the kidneys. Its secretion is induced by osmoreceptors in the hypothalamus. ADH is also a powerful vasoconstrictor.



THYROID & PARATHYROID GLANDS

CN: Use red for H, blue for I, light colors for E, F, G, and the same colors as on Plate 151 for A and D. (1) Color the three upper views simultaneously, taking note of the arteries and veins that penetrate the thyroid. (2) Color the microscopic sections of the hypoactive and hyperactive thyroid follicles; normal tissue lies between the two extremes. (3) Color the diagram of thyroid and parathyroid function.

THYROID ^A

- THYROID FOLLICLE ⁺
- FOLLICLE CELL ^B
- COLLOID ^C
- THYROXIN ^{A'}

PARATHYROID (4) ^D

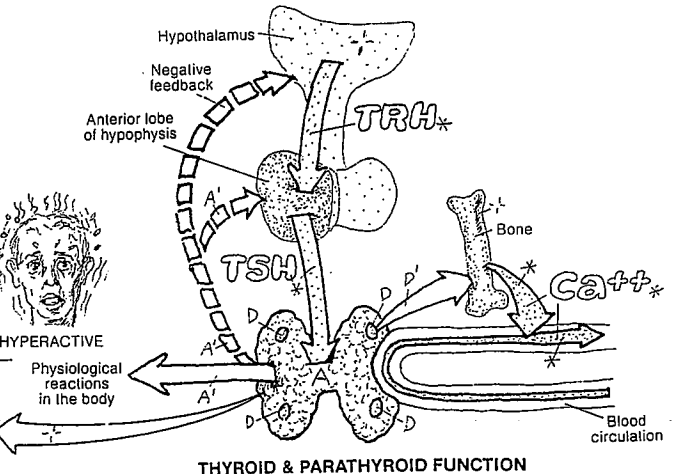
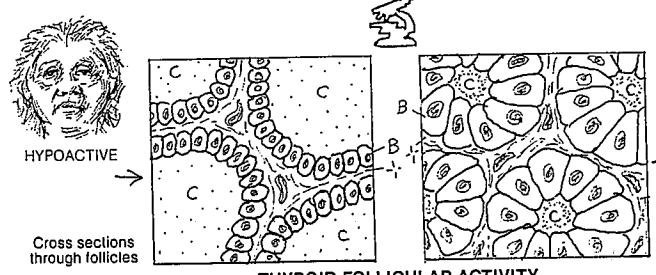
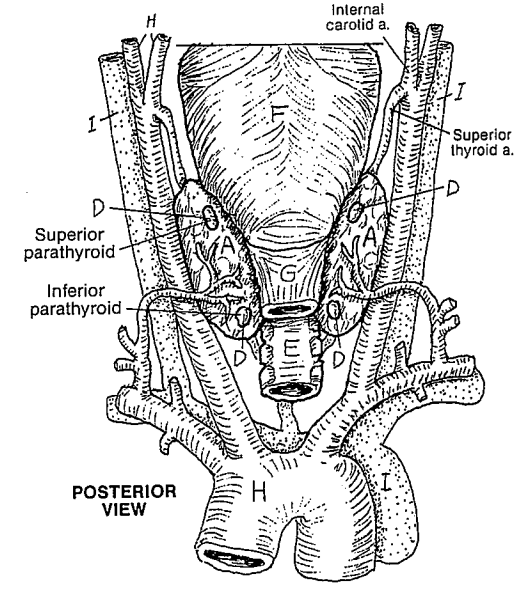
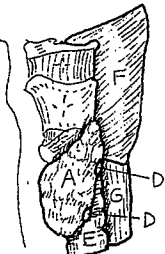
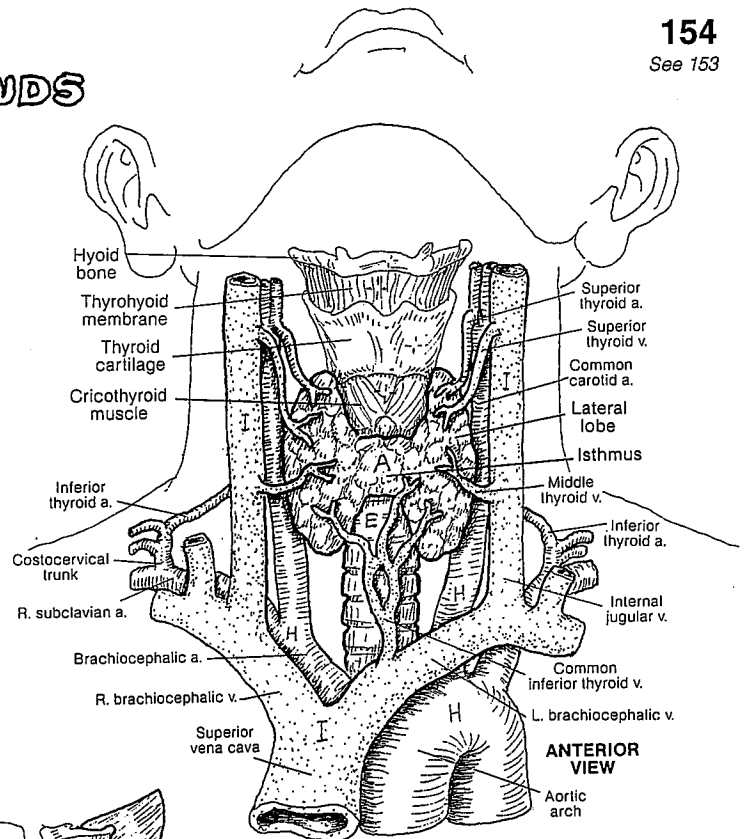
- PARATHORMONE ^{D'}

RELATED STRUCTURES ⁺

- TRACHEA =
- PHARYNX =
- ESOPHAGUS =
- ARTERIES ^H
- VEINS ^I

The thyroid gland, covering the anterior surfaces of the 2nd to 4th *tracheal rings*, is bound by a fibrous capsule whose posterior layer encloses the four *parathyroid glands*. The thyroid gland, composed of right and left lobes connected by an isthmus, consists of clusters of *follicles* (like grapes) supported by loose fibrous tissue rich in blood vessels. A microscopic section through a follicle reveals a single layer of cuboidal epithelial *cells* forming the follicular wall. The follicle contains *colloid*, a glycoprotein (thyroglobulin) produced by the follicle cells. These cells take up thyroglobulin and dismantle it to form a number of hormones, primarily *thyroxin* (T₄, tetraiodothyronine). Thyroxin is then secreted into the adjacent capillaries. Thyroid hormones contain iodine (a reduced form of iodine), which is absorbed by the follicle cells from the blood. Thyroxin formation and secretion is encouraged by thyroid-stimulating hormone (TSH) from the hypophysis. The relationship operates on a negative feedback mechanism: increased secretions of thyroxin inhibit further secretion of TSH. Thyroxin increases oxygen consumption in practically all tissues, and thus maintains the metabolic rate. It is involved at many levels in growth and development. Excessive secretion of thyroxin generally results in weight loss, extreme nervousness, and an elevated basal metabolic rate. Hypothyroidism results in diminished mental activity, voice changes, reduced metabolic activity, and the accumulation of mucus-like material under the skin (myxedema), giving a puffy appearance. Like all endocrine glands, the thyroid is highly vascular. The vessels shown here warrant very careful attention when considering undertaking an emergency tracheostomy or cricothyrotomy. Especially note the inferior thyroid veins on the anterior surface of the trachea. The pattern of these vessels is not always predictable.

The parathyroids consist of small buttons of highly vascular tissue containing two cell types, one of which (chief cells) secretes *parathormone*. Parathormone maintains plasma calcium levels by inducing osteoclastic activity (bone breakdown), freeing calcium ions. Normal muscle activity and blood clotting depend on normal calcium levels in the plasma. Reduced parathyroid function lowers calcium levels and below certain levels causes muscle stiffness, cramps, spasms, and convulsions (tetany).



ADRENAL (SUPRARENAL) GLANDS

CN: Use red for F, blue for G, yellow for H, and a very light color for E. (1) In the upper view, only those vessels with subscripts are to be colored. (2) Color the cross section through the adrenal, and related arrows and hormones. (3) Color the various organs associated with the "fight or flight" reaction, noting the listed effects.

ADRENAL GLAND A

CAPSULE A¹

CORTEX: -

ZONA GLOMERULOSA B

ZONA FASCICULATA C

ZONA RETICULARIS D

MEDULLA E

ARTERIES F -

SUPERIOR SUPRARENAL A_D F¹

MIDDLE SUPRARENAL A_B F²

INFERIOR SUPRARENAL A_D F³

VEINS G -

R. & L. SUPRARENAL V_B G²

SUPRARENAL PLEXUS H

GREATER SPLANCHNIC N_B H¹

CELIAC GANGLION H²

PLEXUS H³

MINERALOCORTICOIDS B

(INCLUDING ALDOSTERONE)

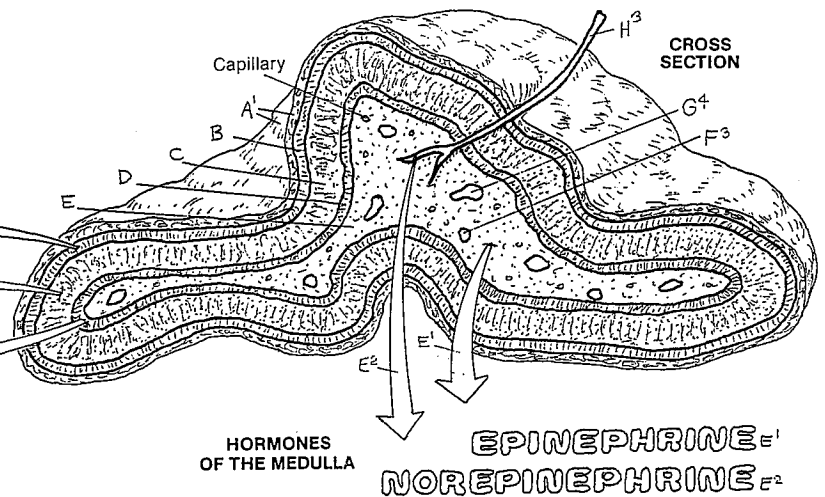
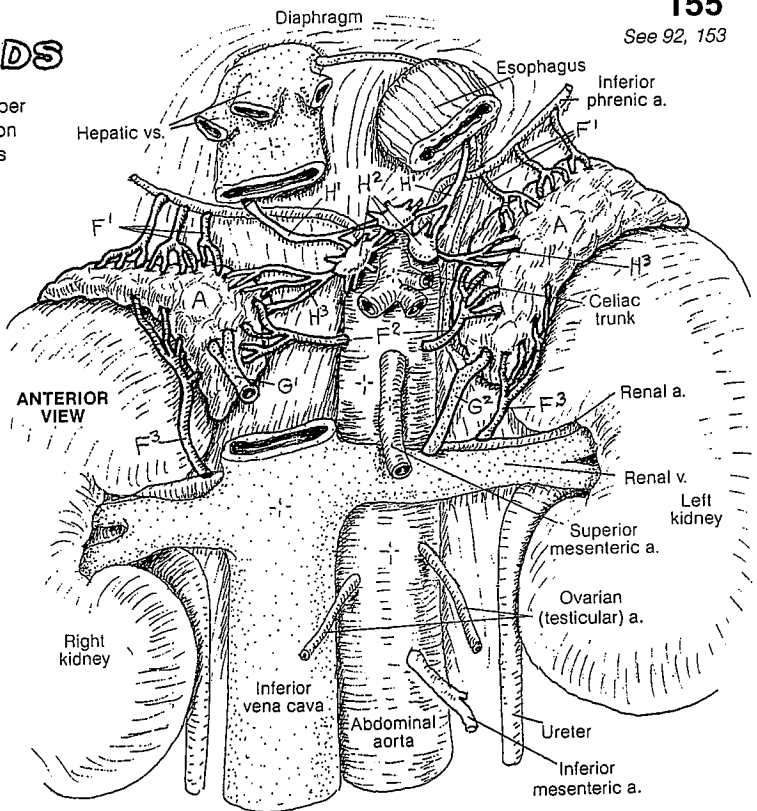
GLUCOCORTICOIDS C

(INCLUDING CORTISOL)

SEX STEROIDS D

(ESTROGENS, PROGESTERONE, ANDROGENS)

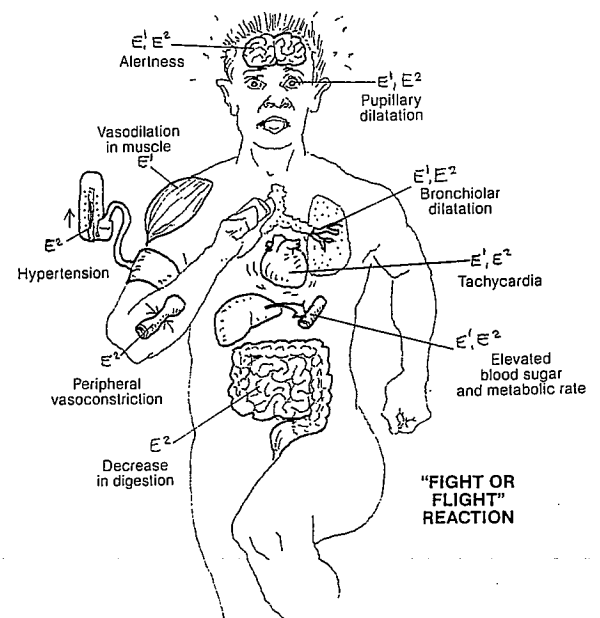
HORMONES OF THE CORTEX



The adrenal (suprarenal) glands lie in the retroperitoneum within the renal fascia on the superior and medial aspects of each kidney (T11-T12 vertebral levels). Like other endocrine glands, the adrenals are abundantly vascularized. The adrenals are two different glands encapsulated as one: the outer *cortex* and the inner *medulla*.

The adrenal cortex is organized into three regions: the outer zona glomerulosa, the middle zona fasciculata, and the inner zona reticularis. When presented with a decrease in fluid volume, as with hemorrhage, the cells of the zona glomerulosa synthesize and secrete hormones called mineralocorticoids. The most well known of these is aldosterone. Mineralocorticoids act primarily on the distal tubules of the kidney, the sweat glands, and the gastrointestinal tract; they encourage the absorption of sodium (and water) and the secretion of potassium. Cells of the zona fasciculata, mediated by ACTH, secrete glucocorticoids. These hormones (primarily cortisol and secondarily corticosterone) stimulate the formation of glucose in the liver. Cells of the zona reticularis secrete the androgen dehydroepiandrosterone (DHEA) in small amounts. DHEA can convert to testosterone. The female sex hormones (estrogen and progesterone) are also secreted in small amounts. These adrenal androgens and estrogens have a limited effect during a lifetime.

The medulla consists of cords of secretory cells supported by reticular fibers, and an abundant collection of capillaries. Fibers of the greater splanchnic nerve pass through the celiac ganglia without synapsing to enter the adrenal gland. These fibers terminate on and stimulate the medullary secretory cells, 80% of which produce and release epinephrine; the rest secrete norepinephrine. These secretory cells are, in fact, modified post-ganglionic neurons. Their secretions elicit the "fight or flight" reaction in response to life-threatening situations, as diagrammatically represented at right.

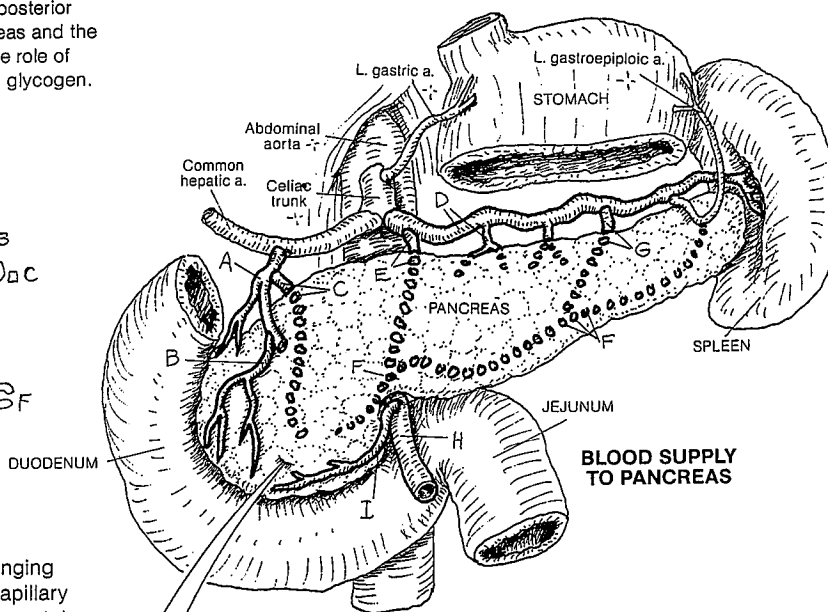


PANCREATIC ISLETS

CN: Use purple for N, and light colors for K and L. (1) In coloring the upper drawing, include the broken lines representing arteries within or on the posterior surface of the pancreas. (2) Color the microscopic section of the pancreas and the enlarged view of an islet. Color the arrows and the diagram reflecting the role of glycogen and insulin receptors in liver cells with respect to glucose and glycogen.

ARTERIES TO THE PANCREAS:

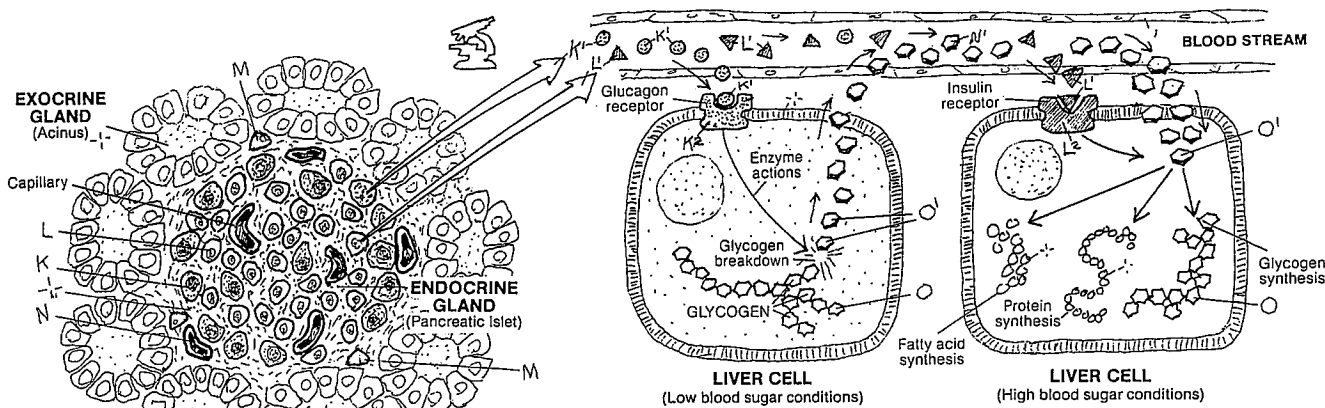
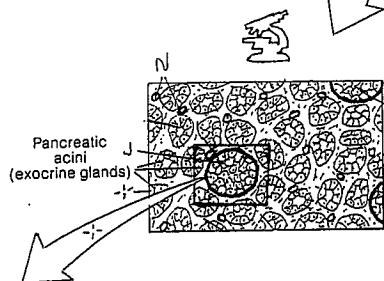
- GASTRODUODENAL & BRS. A
- ANT. PANCREATICO-DUOD. B
- POST. PANCREATICO-DUOD. C
- SPLENIC & BRS. D
- DORSAL PANCREATIC E
- INFERIOR PANCREATIC F
- GREAT PANCREATIC G
- SUPERIOR MESENTERIC H
- INF. PANCREATICO-DUOD. I



The pancreas is supplied by numerous arteries from sources springing from the celiac and superior mesenteric arteries. The extensive capillary networks of the pancreas are drained by tributaries of the hepatic portal vein, which conducts the secreted hormones of the pancreatic islets to the liver and beyond for general circulation.

PANCREATIC ISLET (ENDOCRINE)

- ALPHA CELL K
- GLUCAGON^{K1} / RECEPTOR^{K2}
- BETA CELL L
- INSULIN^{L1} / RECEPTOR^{L2}
- DELTA CELL M
- BLOOD CAPILLARY N
- GLYCOGEN, GLUCOSE, O



The islands (islets) of endocrine tissue (and their capillaries) in the pancreas are surrounded by masses of grape-like clusters/follicles of exocrine gland cells. The secretions of these cells enter ducts that are tributaries of the pancreatic duct(s) opening into the duodenum.

The islets are characterized by three or four different cell types. Alpha (A) cells, generally located in the periphery of the islet, secrete glucagon, a polypeptide hormone that binds to glycogen receptors on liver cell membranes. Glucagon induces the enzymatic breakdown of glycogen to glucose, a process called glycolysis. Glucagon also facilitates the formation of glucose from amino acids in the liver, a process called gluconeogenesis. As a result of these processes, blood glucose levels increase.

Beta (B) cells, constituting 70% of the islet cell population, occupy the central part of the islet and secrete insulin, a polypeptide, primarily in response to increased plasma levels of glucose. Most insulin is taken up by the liver

and kidney, but almost all cells can metabolize insulin. Insulin expedites the removal of glucose from the circulation by increasing the number of proteins that transport glucose across cell membranes (glucose carriers; not shown) in muscle cells, fat cells, leukocytes, and certain other cells (not including liver cells). Insulin increases the synthesis of glycogen from glucose in liver cells. Uptake of insulin is facilitated by insulin receptors (proteins) on the external and internal surfaces of many—but not all—cell membranes. Decreased insulin secretion or decreased numbers or activity of insulin receptors leads to glucose intolerance and/or diabetes mellitus. The effects of insulin activity are far-reaching: mediating electrolyte transport and the storage of nutrients (carbohydrates, proteins, fats), facilitating cellular growth, and enhancing liver, muscle, and adipose tissue metabolism. Delta (D) cells occupy the periphery of the islet and make up about 5% of the islet cell population. They secrete somatostatin and inhibit the Alpha cells' secretion of glucagon and the Beta cells' secretion of insulin.