**ADRENAL GLAND AND IT’S FUNCTION**

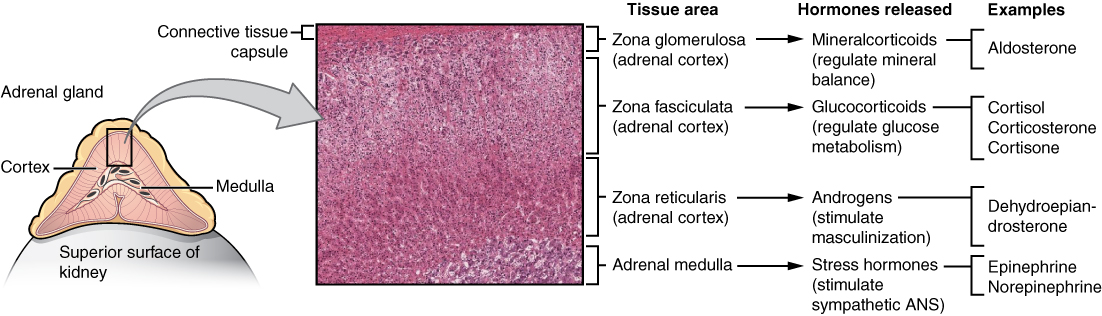
### Learning Objectives

By the end of this section, you will be able to:

* Describe the location and structure of the adrenal glands
* Identify the hormones produced by the adrenal cortex and adrenal medulla, and summarize their target cells and effects

The **adrenal glands** (also known as **suprarenal glands**) are [endocrine glands](https://en.m.wikipedia.org/wiki/Endocrine_gland) that produce a variety of hormones including [adrenaline](https://en.m.wikipedia.org/wiki/Adrenaline) and the steroids [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone) and [cortisol](https://en.m.wikipedia.org/wiki/Cortisol).[[1]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Columbia2015-1)[[2]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-dictionary-2) They are found above the [kidneys](https://en.m.wikipedia.org/wiki/Kidneys). Each gland has an outer [cortex](https://en.m.wikipedia.org/wiki/Adrenal_cortex) which produces [steroid hormones](https://en.m.wikipedia.org/wiki/Steroid_hormone) and an inner [medulla](https://en.m.wikipedia.org/wiki/Adrenal_medulla). The [adrenal cortex](https://en.m.wikipedia.org/wiki/Adrenal_cortex) itself is divided into three zones: the [zona glomerulosa](https://en.m.wikipedia.org/wiki/Zona_glomerulosa), the [zona fasciculata](https://en.m.wikipedia.org/wiki/Zona_fasciculata) and the [zona reticularis](https://en.m.wikipedia.org/wiki/Zona_reticularis).[[3]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-ross-3)

The **adrenal glands** are wedges of glandular and neuroendocrine tissue adhering to the top of the kidneys by a fibrous capsule ([Figure 1](https://opentextbc.ca/anatomyandphysiology/chapter/17-6-the-adrenal-glands/#fig-ch18_06_01)). The adrenal glands have a rich blood supply and experience one of the highest rates of blood flow in the body. They are served by several arteries branching off the aorta, including the suprarenal and renal arteries. Blood flows to each adrenal gland at the adrenal cortex and then drains into the adrenal medulla. Adrenal hormones are released into the circulation via the left and right suprarenal veins.

Figure 1. Adrenal Glands. Both adrenal glands sit atop the kidneys and are composed of an outer cortex and an inner medulla, all surrounded by a connective tissue capsule. The cortex can be subdivided into additional zones, all of which produce different types of hormones. LM × 204. (Micrograph provided by the Regents of University of Michigan Medical School © 2012)

|  |  |
| --- | --- |
| ***Adrenal gland*** | |
| The adrenal glands lie above the kidneys. | |
| [Endocrine system](https://en.m.wikipedia.org/wiki/Endocrine_system) | |
| **Details** | |
| [**Precursor**](https://en.m.wikipedia.org/wiki/Embryology) | [Mesoderm](https://en.m.wikipedia.org/wiki/Mesoderm) and [neural crest](https://en.m.wikipedia.org/wiki/Neural_crest) |
| [**System**](https://en.m.wikipedia.org/wiki/Organ_system) | [Endocrine system](https://en.m.wikipedia.org/wiki/Endocrine_system) |
| [**Artery**](https://en.m.wikipedia.org/wiki/Artery) | [Superior](https://en.m.wikipedia.org/wiki/Superior_suprarenal_artery), [middle](https://en.m.wikipedia.org/wiki/Middle_suprarenal_artery) and [inferior suprarenal arteries](https://en.m.wikipedia.org/wiki/Inferior_suprarenal_artery) |
| [**Vein**](https://en.m.wikipedia.org/wiki/Vein) | [Suprarenal veins](https://en.m.wikipedia.org/wiki/Suprarenal_veins) |
| [**Nerve**](https://en.m.wikipedia.org/wiki/Nerve) | [Celiac](https://en.m.wikipedia.org/wiki/Celiac_plexus) and [renal plexus](https://en.m.wikipedia.org/wiki/Renal_plexus) |
| [**Lymph**](https://en.m.wikipedia.org/wiki/Lymph) | [Lumbar lymph nodes](https://en.m.wikipedia.org/wiki/Lumbar_lymph_nodes) |
| **Identifiers** | |
| [**Latin**](https://en.m.wikipedia.org/wiki/Latin) | *Glandula suprarenalis* |
| [**MeSH**](https://en.m.wikipedia.org/wiki/Medical_Subject_Headings) | [D000311](https://meshb.nlm.nih.gov/record/ui?ui=D000311) |
| [**TA**](https://en.m.wikipedia.org/wiki/Terminologia_Anatomica) | [A11.5.00.001](http://www.unifr.ch/ifaa/Public/EntryPage/TA98%20Tree/Entity%20TA98%20EN/11.5.00.001%20Entity%20TA98%20EN.htm) |
| [**FMA**](https://en.m.wikipedia.org/wiki/Foundational_Model_of_Anatomy) | [9604](https://bioportal.bioontology.org/ontologies/FMA/?p=classes&conceptid=http%3A%2F%2Fpurl.org%2Fsig%2Font%2Ffma%2Ffma9604) |
| [***Anatomical terminology***](https://en.m.wikipedia.org/wiki/Anatomical_terminology)  [[edit on Wikidata](https://www.wikidata.org/wiki/Q712294)] | |

The adrenal cortex produces three main types of [steroid hormones](https://en.m.wikipedia.org/wiki/Steroid_hormone): [mineralocorticoids](https://en.m.wikipedia.org/wiki/Mineralocorticoid), [glucocorticoids](https://en.m.wikipedia.org/wiki/Glucocorticoid), and [androgens](https://en.m.wikipedia.org/wiki/Androgen). Mineralocorticoids (such as [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone)) produced in the zona glomerulosa help in the regulation of blood pressure and [electrolyte balance](https://en.m.wikipedia.org/wiki/Osmoregulation). The glucocorticoids [cortisol](https://en.m.wikipedia.org/wiki/Cortisol) and [cortisone](https://en.m.wikipedia.org/wiki/Cortisone) are synthesized in the zona fasciculata; their functions include the regulation of [metabolism](https://en.m.wikipedia.org/wiki/Metabolism) and [immune system](https://en.m.wikipedia.org/wiki/Immune_system) suppression. The innermost layer of the cortex, the zona reticularis, produces androgens that are converted to fully functional sex hormones in the [gonads](https://en.m.wikipedia.org/wiki/Gonad) and other target organs.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4) The production of steroid hormones is called [steroidogenesis](https://en.m.wikipedia.org/wiki/Steroid#Steroidogenesis), and involves a number of reactions and processes that take place in cortical cells.[[5]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-miller_auchus-5) The medulla produces the [catecholamine](https://en.m.wikipedia.org/wiki/Catecholamine) which function to produce a [rapid response](https://en.m.wikipedia.org/wiki/Fight-or-flight_response_(in_humans)) throughout the body in [stress](https://en.m.wikipedia.org/wiki/Stress_(biology)) situations.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)

A number of [endocrine diseases](https://en.m.wikipedia.org/wiki/Endocrine_disease) involve dysfunctions of the adrenal gland. Overproduction of cortisol leads to [Cushing's syndrome](https://en.m.wikipedia.org/wiki/Cushing%27s_syndrome), whereas insufficient production is associated with [Addison's disease](https://en.m.wikipedia.org/wiki/Addison%27s_disease). [Congenital adrenal hyperplasia](https://en.m.wikipedia.org/wiki/Congenital_adrenal_hyperplasia) is a genetic disease produced by dysregulation of endocrine control mechanisms.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)[[6]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-harrison's-6) A variety of [tumors](https://en.m.wikipedia.org/wiki/Neoplasm" \o "Neoplasm) can arise from adrenal tissue and are commonly found in [medical imaging](https://en.m.wikipedia.org/wiki/Medical_imaging) when searching for other diseases.[[7]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-nieman-7)

## Structure[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=1)

The adrenal glands are located on both sides of the body in the [retroperitoneum](https://en.m.wikipedia.org/wiki/Retroperitoneum" \o "Retroperitoneum), above and slightly [medial](https://en.m.wikipedia.org/wiki/Anatomical_terms_of_location#medial_and_lateral) to the [kidneys](https://en.m.wikipedia.org/wiki/Kidney). In humans, the right adrenal gland is pyramidal in shape, whereas the left is semilunar or crescent shaped and somewhat larger.[[8]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Thomas2013-8) The adrenal glands measure approximately 3 cm in width, 5.0 cm in length, and up to 1.0 cm in thickness.[[9]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-9) Their combined weight in an adult human ranges from 7 to 10 grams.[[10]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-10) The glands are yellowish in colour.[[8]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Thomas2013-8)

The adrenal glands are surrounded by a [fatty capsule](https://en.m.wikipedia.org/wiki/Adipose_capsule_of_kidney) and lie within the [renal fascia](https://en.m.wikipedia.org/wiki/Renal_fascia), which also surrounds the kidneys. A weak [septum](https://en.m.wikipedia.org/wiki/Septum) (wall) of [connective tissue](https://en.m.wikipedia.org/wiki/Connective_tissue) separates the glands from the kidneys.[[11]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Moore-11) The adrenal glands are directly below the [diaphragm](https://en.m.wikipedia.org/wiki/Thoracic_diaphragm), and are attached to the [crura of the diaphragm](https://en.m.wikipedia.org/wiki/Crura_of_the_diaphragm" \o "Crura of the diaphragm) by the renal fascia.[[11]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Moore-11)

Each adrenal gland has two distinct parts, each with a unique function, the outer [adrenal cortex](https://en.m.wikipedia.org/wiki/Adrenal_cortex) and the inner [medulla](https://en.m.wikipedia.org/wiki/Adrenal_medulla), both of which produce hormones.[[12]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kay2015-12)

### Adrenal Cortex[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=2)

Main article: [Adrenal cortex](https://en.m.wikipedia.org/wiki/Adrenal_cortex)

[](https://en.m.wikipedia.org/wiki/File:Adrenal_cortex_labelled.jpg)

Section of human adrenal gland [under the microscope](https://en.m.wikipedia.org/wiki/Histology), showing its different layers. From the surface to the center: zona glomerulosa, zona fasciculata, zona reticularis, medulla. In the medulla, the central adrenomedullary vein is visible.

The adrenal cortex is the outermost layer of the adrenal gland. Within the cortex are three layers, called "zones". When [viewed under a microscope](https://en.m.wikipedia.org/wiki/Histology) each layer has a distinct appearance, and each has a different function.[[13]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-whitehead-13) The [adrenal cortex](https://en.m.wikipedia.org/wiki/Adrenal_cortex) is devoted to production of [hormones](https://en.m.wikipedia.org/wiki/Hormone), namely [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone), [cortisol](https://en.m.wikipedia.org/wiki/Cortisol), and [androgens](https://en.m.wikipedia.org/wiki/Androgen).[[14]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-safeuses-14)

#### Zona glomerulosa[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=3)

The outermost zone of the adrenal cortex is the [zona glomerulosa](https://en.m.wikipedia.org/wiki/Zona_glomerulosa). It lies immediately under the fibrous capsule of the gland. Cells in this layer form oval groups, separated by [thin strands](https://en.m.wikipedia.org/wiki/Trabeculae) of connective tissue from the fibrous capsule of the gland and carry wide [capillaries](https://en.m.wikipedia.org/wiki/Capillary).[[15]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-wheater-15)

This layer is the main site for production of [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone), a [mineralocorticoid](https://en.m.wikipedia.org/wiki/Mineralocorticoid), by the action of the enzyme [aldosterone synthase](https://en.m.wikipedia.org/wiki/Aldosterone_synthase).[[16]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-pmid1775135-16)[[17]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-pmid8333830-17) Aldosterone plays an important role in the long-term [regulation of blood pressure](https://en.m.wikipedia.org/wiki/Regulation_of_blood_pressure).[[18]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-marieb-18)

#### Zona fasciculata[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=4)

The [zona fasciculata](https://en.m.wikipedia.org/wiki/Zona_fasciculata) is situated between the zona glomerulosa and zona reticularis. Cells in this layer are responsible for producing [glucocorticoids](https://en.m.wikipedia.org/wiki/Glucocorticoid) such as [cortisol](https://en.m.wikipedia.org/wiki/Cortisol).[[19]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kaplan.Physio-19) It is the largest of the three layers, accounting for nearly 80% of the volume of the cortex.[[3]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-ross-3) In the zona fasciculata, cells are arranged in columns radially oriented towards the medulla. Cells contain numerous lipid droplets, abundant [mitochondria](https://en.m.wikipedia.org/wiki/Mitochondrion) and a complex [smooth endoplasmic reticulum](https://en.m.wikipedia.org/wiki/Endoplasmic_reticulum#smooth_endoplasmic_reticulum).[[15]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-wheater-15)

#### Zona reticularis[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=5)

The innermost cortical layer, the [zona reticularis](https://en.m.wikipedia.org/wiki/Zona_reticularis), lies directly adjacent to the medulla. It produces [androgens](https://en.m.wikipedia.org/wiki/Androgen), mainly [dehydroepiandrosterone](https://en.m.wikipedia.org/wiki/Dehydroepiandrosterone" \o "Dehydroepiandrosterone) (DHEA), [DHEA sulfate](https://en.m.wikipedia.org/wiki/DHEA_sulfate) (DHEA-S), and [androstenedione](https://en.m.wikipedia.org/wiki/Androstenedione) (the precursor to [testosterone](https://en.m.wikipedia.org/wiki/Testosterone)) in humans.[[19]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kaplan.Physio-19) Its small cells form irregular cords and clusters, separated by capillaries and connective tissue. The cells contain relatively small quantities of cytoplasm and lipid droplets, and sometimes display brown [lipofuscin](https://en.m.wikipedia.org/wiki/Lipofuscin" \o "Lipofuscin) pigment.[[15]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-wheater-15)

### Medulla[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=6)

Main article: [Adrenal medulla](https://en.m.wikipedia.org/wiki/Adrenal_medulla)

The [adrenal medulla](https://en.m.wikipedia.org/wiki/Adrenal_medulla) is at the centre of each adrenal gland, and is surrounded by the adrenal cortex. The [chromaffin cells](https://en.m.wikipedia.org/wiki/Chromaffin_cell" \o "Chromaffin cell) of the medulla are the body's main source of the [catecholamines](https://en.m.wikipedia.org/wiki/Catecholamine" \o "Catecholamine) adrenaline and noradrenaline, released by the medulla. Approximately 20% noradrenaline (norepinephrine) and 80% adrenaline (epinephrine) are secreted here.[[19]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kaplan.Physio-19)

The adrenal medulla is driven by the [sympathetic nervous system](https://en.m.wikipedia.org/wiki/Sympathetic_nervous_system) via [preganglionic fibers](https://en.m.wikipedia.org/wiki/Preganglionic_fiber) originating in the [thoracic spinal cord](https://en.m.wikipedia.org/wiki/Thoracic_spinal_cord), from vertebrae T5–T11.[[20]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-essentialneuroscience-20) Because it is innervated by [preganglionic nerve fibers](https://en.m.wikipedia.org/wiki/Preganglionic_nerve_fibers), the adrenal medulla can be considered as a specialized [sympathetic ganglion](https://en.m.wikipedia.org/wiki/Sympathetic_ganglion).[[20]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-essentialneuroscience-20) Unlike other sympathetic ganglia, however, the adrenal medulla lacks distinct synapses and releases its secretions directly into the blood.

### Blood supply[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=7)

The adrenal glands have one of the greatest blood supply rates per gram of tissue of any organ: up to 60 [small arteries](https://en.m.wikipedia.org/wiki/Arteriole) may enter each gland.[[21]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-isbn960-399-074-4-21) Three arteries usually supply each adrenal gland:[[8]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Thomas2013-8)

* The [superior suprarenal artery](https://en.m.wikipedia.org/wiki/Superior_suprarenal_artery), a branch of the [inferior phrenic artery](https://en.m.wikipedia.org/wiki/Inferior_phrenic_arteries)
* The [middle suprarenal artery](https://en.m.wikipedia.org/wiki/Middle_suprarenal_artery), a direct branch of the [abdominal aorta](https://en.m.wikipedia.org/wiki/Abdominal_aorta)
* The [inferior suprarenal artery](https://en.m.wikipedia.org/wiki/Inferior_suprarenal_artery), a branch of the [renal artery](https://en.m.wikipedia.org/wiki/Renal_artery)

These blood vessels supply a network of small arteries within the capsule of the adrenal glands. Thin strands of the capsule enter the glands, carrying blood to them.[[8]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Thomas2013-8)

[Venous blood](https://en.m.wikipedia.org/wiki/Vein) is drained from the glands by the [suprarenal veins](https://en.m.wikipedia.org/wiki/Suprarenal_veins), usually one for each gland:[[8]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Thomas2013-8)

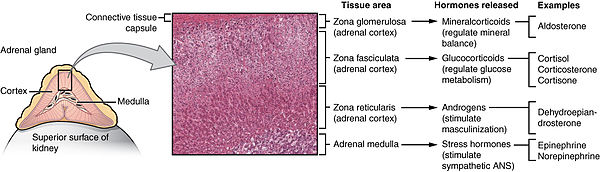
* The [right suprarenal vein](https://en.m.wikipedia.org/wiki/Right_suprarenal_vein) drains into the [inferior vena cava](https://en.m.wikipedia.org/wiki/Inferior_vena_cava)
* The [left suprarenal vein](https://en.m.wikipedia.org/wiki/Left_suprarenal_vein) drains into the left [renal vein](https://en.m.wikipedia.org/wiki/Renal_vein) or the left [inferior phrenic vein](https://en.m.wikipedia.org/wiki/Inferior_phrenic_vein).

The central adrenomedullary vein, in the adrenal medulla, is an unusual type of blood vessel. Its structure is different from the other veins in that the [smooth muscle](https://en.m.wikipedia.org/wiki/Smooth_muscle) in its [tunica media](https://en.m.wikipedia.org/wiki/Tunica_media) (the middle layer of the vessel) is arranged in conspicuous, longitudinally oriented bundles.[[3]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-ross-3)

### Variability[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=8)

The adrenal glands may not develop at all, or may be fused in the midline behind the [aorta](https://en.m.wikipedia.org/wiki/Aorta).[[12]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kay2015-12) These are associated with other [congenital abnormalities](https://en.m.wikipedia.org/wiki/Congenital_abnormality), such as failure of the kidneys to develop, or fused kidneys.[[12]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kay2015-12) The gland may develop with a partial or complete absence of the cortex, or may develop in an unusual location.[[12]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kay2015-12)

## Function[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=9)

[](https://en.m.wikipedia.org/wiki/File:1818_The_Adrenal_Glands.jpg)

Different hormones are produced in different zones of the cortex and medulla of the gland. Light microscopy at magnification × 204.[[22]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-22)

The adrenal gland secretes a number of different hormones which are metabolised by [enzymes](https://en.m.wikipedia.org/wiki/Enzyme) either within the gland or in other parts of the body. These hormones are involved in a number of essential biological functions.[[23]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-DAVIDSONS2010-23)

### Corticosteroids[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=10)

[Corticosteroids](https://en.m.wikipedia.org/wiki/Corticosteroid) are a group of steroid hormones produced from the cortex of the adrenal gland, from which they are named.[[24]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-24) Corticosteroids are named according to their actions:

* Mineralocorticoids such as [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone) regulate salt ("mineral") balance and blood volume.[[25]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Marieb-25)
* Glucocorticoids such as [cortisol](https://en.m.wikipedia.org/wiki/Cortisol) influence metabolism rates of proteins, fats and sugars ("glucose").[[26]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-26)

**Mineralocorticoids**

The adrenal gland produces [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone), a [mineralocorticoid](https://en.m.wikipedia.org/wiki/Mineralocorticoid), which is important in the regulation of salt ("mineral") balance and [blood volume](https://en.m.wikipedia.org/wiki/Blood_volume). In the kidneys, aldosterone acts on the [distal convoluted tubules](https://en.m.wikipedia.org/wiki/Distal_convoluted_tubule) and the [collecting ducts](https://en.m.wikipedia.org/wiki/Collecting_duct_system) by increasing the reabsorption of [sodium](https://en.m.wikipedia.org/wiki/Sodium_in_biology) and the excretion of both potassium and hydrogen ions.[[18]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-marieb-18) Aldosterone is responsible for the reabsorption of about 2% of filtered [glomerular filtration rates](https://en.m.wikipedia.org/wiki/Glomerular_filtration_rate).[[27]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-27) Sodium retention is also a response of the distal colon and sweat glands to aldosterone receptor stimulation. [Angiotensin II](https://en.m.wikipedia.org/wiki/Angiotensin_II) and extracellular [potassium](https://en.m.wikipedia.org/wiki/Potassium) are the two main regulators of aldosterone production.[[19]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-Kaplan.Physio-19) The amount of sodium present in the body affects the extracellular volume, which in turn influences [blood pressure](https://en.m.wikipedia.org/wiki/Blood_pressure). Therefore, the effects of aldosterone in sodium retention are important for the regulation of blood pressure.[[28]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-boron-28)

**Glucocorticoids**

[Cortisol](https://en.m.wikipedia.org/wiki/Cortisol) is the main [glucocorticoid](https://en.m.wikipedia.org/wiki/Glucocorticoid) in humans. In species that do not create cortisol, this role is played by [corticosterone](https://en.m.wikipedia.org/wiki/Corticosterone" \o "Corticosterone) instead. Glucocorticoids have many effects on [metabolism](https://en.m.wikipedia.org/wiki/Metabolism). As their name suggests, they increase the circulating level of [glucose](https://en.m.wikipedia.org/wiki/Glucose). This is the result of an increase in the mobilization of [amino acids](https://en.m.wikipedia.org/wiki/Amino_acids) from protein and the stimulation of [synthesis of glucose](https://en.m.wikipedia.org/wiki/Gluconeogenesis) from these amino acids in the liver. In addition, they increase the levels of [free fatty acids](https://en.m.wikipedia.org/wiki/Free_fatty_acids), which cells can use as an alternative to glucose to obtain energy. Glucocorticoids also have effects unrelated to the regulation of blood sugar levels, including the suppression of the immune system and a potent [anti-inflammatory](https://en.m.wikipedia.org/wiki/Anti-inflammatory) effect. Cortisol reduces the capacity of [osteoblasts](https://en.m.wikipedia.org/wiki/Osteoblast) to produce new bone tissue and decreases the absorption of calcium in the [gastrointestinal tract](https://en.m.wikipedia.org/wiki/Human_gastrointestinal_tract).[[28]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-boron-28)

The adrenal gland secretes a basal level of cortisol but can also produce bursts of the hormone in response to [adrenocorticotropic hormone](https://en.m.wikipedia.org/wiki/Adrenocorticotropic_hormone) (ACTH) from the [anterior pituitary](https://en.m.wikipedia.org/wiki/Anterior_pituitary). Cortisol is not evenly released during the day – its concentrations in the blood are highest in the early morning and lowest in the evening as a result of the [circadian rhythm](https://en.m.wikipedia.org/wiki/Circadian_rhythm) of ACTH secretion.[[28]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-boron-28) [Cortisone](https://en.m.wikipedia.org/wiki/Cortisone) is an inactive product of the action of the enzyme [11β-HSD](https://en.m.wikipedia.org/wiki/11-Beta_hydroxysteroid_dehydrogenase) on cortisol. The reaction catalyzed by 11β-HSD is reversible, which means that it can turn administered cortisone into cortisol, the biologically active hormone.[[28]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-boron-28)

**Formation**

[](https://en.m.wikipedia.org/wiki/File:Adrenal_Steroids_Pathways.svg)

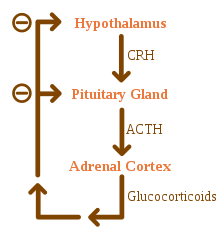
Steroidogenesis in the adrenal glands – different steps occur in different layers of the gland

All [corticosteroid](https://en.m.wikipedia.org/wiki/Corticosteroid) hormones share [cholesterol](https://en.m.wikipedia.org/wiki/Cholesterol) as a common precursor. Therefore, the first step in [steroidogenesis](https://en.m.wikipedia.org/wiki/Steroid#Steroidogenesis) is cholesterol uptake or synthesis. Cells that produce steroid hormones can acquire cholesterol through two paths. The main source is through dietary cholesterol transported via the blood as [cholesterol esters](https://en.m.wikipedia.org/wiki/Cholesterol_esters) within [low density lipoproteins](https://en.m.wikipedia.org/wiki/Low_density_lipoprotein) (LDL). LDL enters the cells through [receptor-mediated endocytosis](https://en.m.wikipedia.org/wiki/Receptor-mediated_endocytosis). The other source of cholesterol is synthesis in the cell's [endoplasmic reticulum](https://en.m.wikipedia.org/wiki/Endoplasmic_reticulum). Synthesis can compensate when LDL levels are abnormally low.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4) In the [lysosome](https://en.m.wikipedia.org/wiki/Lysosome), cholesterol esters are converted to free cholesterol, which is then used for steroidogenesis or stored in the cell.[[29]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-miller_bose-29)

The initial part of conversion of cholesterol into steroid hormones involves a number of enzymes of the [cytochrome P450](https://en.m.wikipedia.org/wiki/Cytochrome_P450) family that are located in the inner membrane of [mitochondria](https://en.m.wikipedia.org/wiki/Mitochondrion). Transport of cholesterol from the outer to the inner membrane is facilitated by [steroidogenic acute regulatory protein](https://en.m.wikipedia.org/wiki/Steroidogenic_acute_regulatory_protein) and is the rate-limiting step of steroid synthesis.[[29]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-miller_bose-29)

The layers of the adrenal gland differ by function, with each layer having distinct enzymes that produce different hormones from a common precursor.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4) The first enzymatic step in the production of all steroid hormones is cleavage of the cholesterol side chain, a reaction that forms [pregnenolone](https://en.m.wikipedia.org/wiki/Pregnenolone" \o "Pregnenolone) as a product and is catalyzed by the enzyme [P450scc](https://en.m.wikipedia.org/wiki/P450scc), also known as *cholesterol desmolase*. After the production of pregnenolone, specific enzymes of each cortical layer further modify it. Enzymes involved in this process include both mitochondrial and [microsomal](https://en.m.wikipedia.org/wiki/Microsome) P450s and [hydroxysteroid dehydrogenases](https://en.m.wikipedia.org/wiki/Hydroxysteroid_dehydrogenase" \o "Hydroxysteroid dehydrogenase). Usually a number of intermediate steps in which pregnenolone is modified several times are required to form the functional hormones.[[5]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-miller_auchus-5) Enzymes that catalyze reactions in these metabolic pathways are involved in a number of endocrine diseases. For example, the most common form of [congenital adrenal hyperplasia](https://en.m.wikipedia.org/wiki/Congenital_adrenal_hyperplasia) develops as a result of deficiency of [21-hydroxylase](https://en.m.wikipedia.org/wiki/21-hydroxylase), an enzyme involved in an intermediate step of cortisol production.[[30]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-charmandari-30)

**Regulation**

[](https://en.m.wikipedia.org/wiki/File:ACTH_Negative_Feedback.svg)

Negative feedback in the [HPA axis](https://en.m.wikipedia.org/wiki/HPA_axis)

Glucocorticoids are under the regulatory influence of the [hypothalamus-pituitary-adrenal (HPA) axis](https://en.m.wikipedia.org/wiki/HPA_axis). Glucocorticoid synthesis is stimulated by [adrenocorticotropic hormone](https://en.m.wikipedia.org/wiki/Adrenocorticotropic_hormone) (ACTH), a hormone released into the bloodstream by the [anterior pituitary](https://en.m.wikipedia.org/wiki/Anterior_pituitary). In turn, production of ACTH is stimulated by the presence of [corticotropin-releasing hormone](https://en.m.wikipedia.org/wiki/Corticotropin-releasing_hormone" \o "Corticotropin-releasing hormone) (CRH), which is released by neurons of the [hypothalamus](https://en.m.wikipedia.org/wiki/Hypothalamus). ACTH acts on the adrenal cells first by increasing the levels of StAR within the cells, and then of all steroidogenic P450 enzymes. The HPA axis is an example of a negative feedback system, in which cortisol itself acts as a direct inhibitor of both CRH and ACTH synthesis. The HPA axis also interacts with the immune system through increased secretion of ACTH at the presence of certain molecules of the [inflammatory response](https://en.m.wikipedia.org/wiki/Inflammatory_response).[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)

Mineralocorticoid secretion is regulated mainly by the [renin–angiotensin–aldosterone system](https://en.m.wikipedia.org/wiki/Renin%E2%80%93angiotensin%E2%80%93aldosterone_system) (RAAS), the concentration of [potassium](https://en.m.wikipedia.org/wiki/Potassium), and to a lesser extent the concentration of ACTH.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4) Sensors of blood pressure in the [juxtaglomerular apparatus](https://en.m.wikipedia.org/wiki/Juxtaglomerular_apparatus) of the kidneys release the enzyme [renin](https://en.m.wikipedia.org/wiki/Renin) into the blood, which starts a cascade of reactions that lead to formation of [angiotensin II](https://en.m.wikipedia.org/wiki/Angiotensin_II). [Angiotensin receptors](https://en.m.wikipedia.org/wiki/Angiotensin_receptor) in cells of the zona glomerulosa recognize the substance, and upon binding they stimulate the release of [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone).[[31]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-crowley-31)

### Catecholamines[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=11)

Primarily referred to in the United States as [epinephrine](https://en.m.wikipedia.org/wiki/Epinephrine) and [norepinephrine](https://en.m.wikipedia.org/wiki/Norepinephrine), [adrenaline](https://en.m.wikipedia.org/wiki/Adrenaline) and [noradrenaline](https://en.m.wikipedia.org/wiki/Noradrenaline) are [catecholamines](https://en.m.wikipedia.org/wiki/Catecholamine), water-soluble [compounds](https://en.m.wikipedia.org/wiki/Organic_compound) that have a structure made of a [catechol](https://en.m.wikipedia.org/wiki/Catechol) group and an [amine group](https://en.m.wikipedia.org/wiki/Amine_group). The adrenal glands are responsible for most of the adrenaline that circulates in the body, but only for a small amount of circulating noradrenaline.[[23]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-DAVIDSONS2010-23) These hormones are released by the adrenal medulla, which contains a dense network of blood vessels. Adrenaline and noradrenaline act at [adrenoreceptors](https://en.m.wikipedia.org/wiki/Adrenoreceptor" \o "Adrenoreceptor) throughout the body, with effects that include an increase in blood pressure and heart rate.[[23]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-DAVIDSONS2010-23) actions of adrenaline and noradrenaline are responsible for the [fight or flight response](https://en.m.wikipedia.org/wiki/Fight_or_flight_response), characterised by a quickening of breathing and heart rate, an increase in blood pressure, and constriction of blood vessels in many parts of the body.[[32]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-gleitman-32)

**Formation**

Catecholamines are produced in chromaffin cells in the medulla of the adrenal gland, from [tyrosine](https://en.m.wikipedia.org/wiki/Tyrosine), a non-essential amino acid derived from food or produced from [phenylalanine](https://en.m.wikipedia.org/wiki/Phenylalanine) in the liver. The enzyme [tyrosine hydroxylase](https://en.m.wikipedia.org/wiki/Tyrosine_hydroxylase) converts tyrosine to [L-DOPA](https://en.m.wikipedia.org/wiki/L-DOPA) in the first step of catecholamine synthesis. L-DOPA is then converted to [dopamine](https://en.m.wikipedia.org/wiki/Dopamine) before it can be turned into noradrenaline. In the [cytosol](https://en.m.wikipedia.org/wiki/Cytosol), noradrenaline is converted to epinephrine by the enzyme [phenylethanolamine N-methyltransferase](https://en.m.wikipedia.org/wiki/Phenylethanolamine_N-methyltransferase" \o "Phenylethanolamine N-methyltransferase) (PNMT) and stored in granules. Glucocorticoids produced in the adrenal cortex stimulate the synthesis of catecholamines by increasing the levels of tyrosine hydroxylase and PNMT.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)[[13]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-whitehead-13)

Catecholamine release is stimulated by the activation of the [sympathetic nervous system](https://en.m.wikipedia.org/wiki/Sympathetic_nervous_system). [Splanchnic nerves](https://en.m.wikipedia.org/wiki/Splanchnic_nerves) of the [sympathetic nervous system](https://en.m.wikipedia.org/wiki/Sympathetic_nervous_system) innervate the medulla of the adrenal gland. When activated, it evokes the release of catecholamines from the storage granules by stimulating the opening of [calcium channels](https://en.m.wikipedia.org/wiki/Calcium_channel) in the cell membrane.[[33]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-garcia-33)

### Androgens[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=12)

Cells in [zona reticularis](https://en.m.wikipedia.org/wiki/Zona_reticularis) of the adrenal glands produce male sex hormones, or [androgens](https://en.m.wikipedia.org/wiki/Androgen), the most important of which is [DHEA](https://en.m.wikipedia.org/wiki/Dehydroepiandrosterone). In general, these hormones do not have an overall effect in the male body, and are converted to more potent androgens such as [testosterone](https://en.m.wikipedia.org/wiki/Testosterone) and [DHT](https://en.m.wikipedia.org/wiki/Dihydrotestosterone) or to [estrogens](https://en.m.wikipedia.org/wiki/Estrogen" \o "Estrogen) (female sex hormones) in the [gonads](https://en.m.wikipedia.org/wiki/Gonad), acting in this way as a [metabolic intermediate](https://en.m.wikipedia.org/wiki/Metabolic_intermediate).[[34]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-guyton-34)

## Gene and protein expression[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=13)

Further information: [Bioinformatics § Gene and protein expression](https://en.m.wikipedia.org/wiki/Bioinformatics#Gene_and_protein_expression)

The [human genome](https://en.m.wikipedia.org/wiki/Human_genome) includes approximately 20,000 protein coding genes and 70% of these [genes are expressed](https://en.m.wikipedia.org/wiki/Gene_expression) in the normal, adult adrenal glands.[[35]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-35)[[36]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-36) Only some 250 genes are more specifically expressed in the adrenal glands compared to other organs and tissues. The adrenal gland specific genes with highest level of expression include members of the [cytochrome P450](https://en.m.wikipedia.org/wiki/Cytochrome_P450) superfamily of enzymes. Corresponding proteins are expressed in the different compartments of the adrenal gland, such as [CYP11A1](https://en.m.wikipedia.org/wiki/CYP11A1), [HSD3B2](https://en.m.wikipedia.org/wiki/HSD3B2) and [FDX1](https://en.m.wikipedia.org/wiki/FDX1) involved in [steroid hormone](https://en.m.wikipedia.org/wiki/Steroid_hormone) synthesis and expressed in cortical cell layers, and [PNMT](https://en.m.wikipedia.org/wiki/Phenylethanolamine_N-methyltransferase) and [DBH](https://en.m.wikipedia.org/wiki/Dopamine_beta-hydroxylase) involved in [noradrenalin](https://en.m.wikipedia.org/wiki/Noradrenalin) and [adrenalin](https://en.m.wikipedia.org/wiki/Epinephrine) synthesis and expressed in the medulla.[[37]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-37)

The normal function of the adrenal gland may be impaired by conditions such as infections, tumors, genetic disorders and [autoimmune diseases](https://en.m.wikipedia.org/wiki/Autoimmune_disease), or as a [side effect](https://en.m.wikipedia.org/wiki/Side_effect) of medical therapy. These disorders affect the gland either directly (as with infections or autoimmune diseases) or as a result of the dysregulation of hormone production (as in some types of [Cushing's syndrome](https://en.m.wikipedia.org/wiki/Cushing%27s_syndrome)) leading to an excess or insufficiency of adrenal hormones and the related symptoms.

### Corticosteroid overproduction[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=19)

#### Cushing's syndrome[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=20)

[Cushing's syndrome](https://en.m.wikipedia.org/wiki/Cushing%27s_syndrome) is the manifestation of glucocorticoid excess. It can be the result of a prolonged treatment with glucocorticoids or be caused by an underlying disease which produces alterations in the [HPA axis](https://en.m.wikipedia.org/wiki/HPA_axis) or the production of cortisol. Causes can be further classified into [ACTH](https://en.m.wikipedia.org/wiki/Adrenocorticotropic_hormone)-dependent or ACTH-independent. The most common cause of [endogenous](https://en.m.wikipedia.org/wiki/Endogeny) Cushing's syndrome is a [pituitary adenoma](https://en.m.wikipedia.org/wiki/Pituitary_adenoma) which causes an excessive production of ACTH. The disease produces a wide variety of signs and symptoms which include obesity, diabetes, increased blood pressure, excessive body hair ([hirsutism](https://en.m.wikipedia.org/wiki/Hirsutism)), [osteoporosis](https://en.m.wikipedia.org/wiki/Osteoporosis), depression, and most distinctively, [stretch marks](https://en.m.wikipedia.org/wiki/Striae) in the skin, caused by its progressive thinning.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)[[6]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-harrison's-6)

#### Primary aldosteronism[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=21)

When the zona glomerulosa produces excess [aldosterone](https://en.m.wikipedia.org/wiki/Aldosterone), the result is [primary aldosteronism](https://en.m.wikipedia.org/wiki/Primary_aldosteronism). Causes for this condition are bilateral [hyperplasia](https://en.m.wikipedia.org/wiki/Hyperplasia) (excessive tissue growth) of the glands, or aldosterone-producing [adenomas](https://en.m.wikipedia.org/wiki/Adenoma) (a condition called [Conn's syndrome](https://en.m.wikipedia.org/wiki/Conn%27s_syndrome)). Primary aldosteronism produces hypertension and [electrolyte](https://en.m.wikipedia.org/wiki/Electrolyte) imbalance, increasing [potassium](https://en.m.wikipedia.org/wiki/Potassium) depletion and sodium retention.[[6]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-harrison's-6)

### Adrenal insufficiency[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=22)

Adrenal insufficiency (the deficiency of [glucocorticoids](https://en.m.wikipedia.org/wiki/Glucocorticoid)) occurs in about 5 in 10,000 in the general population.[[6]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-harrison's-6) Diseases classified as *primary adrenal insufficiency* (including [Addison's disease](https://en.m.wikipedia.org/wiki/Addison%27s_disease) and genetic causes) directly affect the adrenal cortex. If a problem that affects the [hypothalamic-pituitary-adrenal axis](https://en.m.wikipedia.org/wiki/Hypothalamic-pituitary-adrenal_axis) arises outside the gland, it is a *secondary adrenal insufficiency*.

#### Addison's disease[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=23)

[](https://en.m.wikipedia.org/wiki/File:T._Addison;_On...supra-renal_capsules_Wellcome_L0018484.jpg)

Characteristic skin [hyperpigmentation](https://en.m.wikipedia.org/wiki/Hyperpigmentation) in [Addison's disease](https://en.m.wikipedia.org/wiki/Addison%27s_disease)

Addison's disease refers to primary hypoadrenalism, which is a deficiency in glucocorticoid and mineralocorticoid production by the adrenal gland. In the Western world, Addison's disease is most commonly an [autoimmune](https://en.m.wikipedia.org/wiki/Autoimmunity) condition, in which the body produces [antibodies](https://en.m.wikipedia.org/wiki/Antibody) against cells of the adrenal cortex. Worldwide, the disease is more frequently caused by infection, especially from [tuberculosis](https://en.m.wikipedia.org/wiki/Tuberculosis). A distinctive feature of Addison's disease is [hyperpigmentation](https://en.m.wikipedia.org/wiki/Hyperpigmentation) of the skin, which presents with other nonspecific symptoms such as fatigue.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)

A complication seen in untreated Addison's disease and other types of primary adrenal insufficiency is the [adrenal crisis](https://en.m.wikipedia.org/wiki/Adrenal_crisis), a [medical emergency](https://en.m.wikipedia.org/wiki/Medical_emergency) in which low glucocorticoid and mineralocorticoid levels result in [hypovolemic shock](https://en.m.wikipedia.org/wiki/Hypovolemic_shock) and symptoms such as vomiting and fever. An adrenal crisis can progressively lead to [stupor](https://en.m.wikipedia.org/wiki/Stupor) and [coma](https://en.m.wikipedia.org/wiki/Coma).[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4) The management of adrenal crises includes the application of [hydrocortisone](https://en.m.wikipedia.org/wiki/Hydrocortisone) injections.[[46]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-46)

#### Secondary adrenal insufficiency[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=24)

In secondary adrenal insufficiency, a dysfunction of the [hypothalamic-pituitary-adrenal axis](https://en.m.wikipedia.org/wiki/Hypothalamic-pituitary-adrenal_axis) leads to decreased stimulation of the adrenal cortex. Apart from suppression of the axis by glucocorticoid therapy, the most common cause of secondary adrenal insufficiency are tumors that affect the production of [adrenocorticotropic hormone](https://en.m.wikipedia.org/wiki/Adrenocorticotropic_hormone) (ACTH) by the [pituitary gland](https://en.m.wikipedia.org/wiki/Pituitary_gland).[[6]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-harrison's-6) This type of adrenal insufficiency usually does not affect the production of [mineralocorticoids](https://en.m.wikipedia.org/wiki/Mineralocorticoid), which are under regulation of the [renin–angiotensin system](https://en.m.wikipedia.org/wiki/Renin%E2%80%93angiotensin_system) instead.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)

#### Congenital adrenal hyperplasia[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=25)

[Congenital adrenal hyperplasia](https://en.m.wikipedia.org/wiki/Congenital_adrenal_hyperplasia) is a [congenital disease](https://en.m.wikipedia.org/wiki/Congenital_disease) in which [mutations](https://en.m.wikipedia.org/wiki/Mutation) of enzymes that produce steroid hormones result in a glucocorticoid deficiency and malfunction of the negative feedback loop of the [HPA axis](https://en.m.wikipedia.org/wiki/HPA_axis). In the HPA axis, cortisol (a glucocorticoid) inhibits the release of [CRH](https://en.m.wikipedia.org/wiki/Corticotropin-releasing_hormone) and [ACTH](https://en.m.wikipedia.org/wiki/Adrenocorticotropic_hormone), hormones that in turn stimulate corticosteroid synthesis. As cortisol cannot be synthesized, these hormones are released in high quantities and stimulate production of other adrenal steroids instead. The most common form of congenital adrenal hyperplasia is due to [21-hydroxylase](https://en.m.wikipedia.org/wiki/21-hydroxylase) deficiency. 21-hydroxylase is necessary for production of both mineralocorticoids and glucocorticoids, but not [androgens](https://en.m.wikipedia.org/wiki/Androgen). Therefore, ACTH stimulation of the adrenal cortex induces the release of excessive amounts of [adrenal androgens](https://en.m.wikipedia.org/wiki/Adrenal_androgen), which can lead to the development of ambiguous [genitalia](https://en.m.wikipedia.org/wiki/Genitalia) and [secondary sex characteristics](https://en.m.wikipedia.org/wiki/Secondary_sex_characteristic).[[30]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-charmandari-30)

### Adrenal tumors[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=26)

Main article: [Adrenal tumor](https://en.m.wikipedia.org/wiki/Adrenal_tumor)

Adrenal tumors are commonly found as [incidentalomas](https://en.m.wikipedia.org/wiki/Incidentaloma" \o "Incidentaloma), unexpected [asymptomatic](https://en.m.wikipedia.org/wiki/Asymptomatic) tumors [found](https://en.m.wikipedia.org/wiki/Incidental_findings) during [medical imaging](https://en.m.wikipedia.org/wiki/Medical_imaging). They are seen in around 3.4% of [CT scans](https://en.m.wikipedia.org/wiki/X-ray_computed_tomography),[[7]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-nieman-7) and in most cases they are benign [adenomas](https://en.m.wikipedia.org/wiki/Adrenocortical_adenoma).[[47]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-mantero-47) [Adrenal carcinomas](https://en.m.wikipedia.org/wiki/Adrenal_carcinoma) are very rare, with an [incidence](https://en.m.wikipedia.org/wiki/Incidence_(epidemiology)) of 1 case per million per year.[[4]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-williams-4)

[Pheochromocytomas](https://en.m.wikipedia.org/wiki/Pheochromocytomas) are tumors of the adrenal medulla that arise from [chromaffin cells](https://en.m.wikipedia.org/wiki/Chromaffin_cell" \o "Chromaffin cell). They can produce a variety of nonspecific symptoms, which include headaches, sweating, anxiety and [palpitations](https://en.m.wikipedia.org/wiki/Palpitation). Common signs include [hypertension](https://en.m.wikipedia.org/wiki/Hypertension) and [tachycardia](https://en.m.wikipedia.org/wiki/Tachycardia). Surgery, especially adrenal [laparoscopy](https://en.m.wikipedia.org/wiki/Laparoscopy), is the most common treatment for small pheochromocytomas.[[48]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-martucci-48)

## History[Edit](https://en.m.wikipedia.org/w/index.php?title=Adrenal_gland&action=edit&section=27)

[Bartolomeo Eustachi](https://en.m.wikipedia.org/wiki/Bartolomeo_Eustachi), an Italian anatomist, is credited with the first description of the adrenal glands in 1563–4.[[49]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-schmidt-49)[[50]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-OHARE2012-50) However, these publications were part of the [papal library](https://en.m.wikipedia.org/wiki/Papal_library) and did not receive public attention, which was first received with [Caspar Bartholin the Elder](https://en.m.wikipedia.org/wiki/Caspar_Bartholin_the_Elder)'s illustrations in 1611.[[50]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-OHARE2012-50)

The adrenal glands are named for their location relative to the kidneys. The term "adrenal" comes from *ad-* (Latin, "near") and *renes* (Latin, "kidney").[[51]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-51) Similarly, "suprarenal", as termed by [Jean Riolan the Younger](https://en.m.wikipedia.org/wiki/Jean_Riolan_the_Younger) in 1629, is derived from the [Latin](https://en.m.wikipedia.org/wiki/Latin) [*supra*](https://en.wiktionary.org/wiki/supra-) ([Latin](https://en.m.wikipedia.org/wiki/Latin_language): *"above"*) and *[renes](https://en.wiktionary.org/wiki/renes" \o "wikt:renes)* ([Latin](https://en.m.wikipedia.org/wiki/Latin_language): *kidney*). The suprarenal nature of the glands was not truly accepted until the 19th century, as anatomists clarified the ductless nature of the glands and their likely secretory role – prior to this, there was some debate as to whether the glands were indeed suprarenal or part of the kidney.[[50]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-OHARE2012-50)

One of the most recognized works on the adrenal glands came in 1855 with the publication of *On the Constitutional and Local Effects of Disease of the Suprarenal Capsule*, by the English physician [Thomas Addison](https://en.m.wikipedia.org/wiki/Thomas_Addison). In his monography, Addison described what the French physician [George Trousseau](https://en.m.wikipedia.org/wiki/Georges_Phillipe_Trousseau) would later name [Addison's disease](https://en.m.wikipedia.org/wiki/Addison%27s_disease), an eponym still used today for a condition of [adrenal insufficiency](https://en.m.wikipedia.org/wiki/Adrenal_insufficiency) and its related clinical manifestations.[[52]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-pearce-52) In 1894, English physiologists [George Oliver](https://en.m.wikipedia.org/wiki/George_Oliver_(physician)) and [Edward Schafer](https://en.m.wikipedia.org/wiki/Edward_Albert_Sharpey-Schafer) studied the action of adrenal extracts and observed their [pressor](https://en.m.wikipedia.org/wiki/Antihypotensive_agent" \o "Antihypotensive agent) effects. In the following decades several physicians experimented with extracts from the adrenal cortex to treat Addison's disease.[[49]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-schmidt-49) [Edward Calvin Kendall](https://en.m.wikipedia.org/wiki/Edward_Calvin_Kendall), [Philip Hench](https://en.m.wikipedia.org/wiki/Philip_Hench) and [Tadeusz Reichstein](https://en.m.wikipedia.org/wiki/Tadeusz_Reichstein) were then awarded the 1950 [Nobel Prize in Physiology or Medicine](https://en.m.wikipedia.org/wiki/Nobel_Prize_in_Physiology_or_Medicine) for their discoveries on the structure and effects of the adrenal hormones.[[53]](https://en.m.wikipedia.org/wiki/Adrenal_gland#cite_note-nobel-1950-53)