# Unit 23 · Endocrinology

STUDY NOTES

### WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Human Biology (Units 17–24 together): 16 of 75 marks; 4 MCQs (knowledge, understanding, application, higher ability), 1 short question (4 marks: knowledge 1, application 2, higher ability 1) and 1 long question (8 marks: understanding 2, application 2, higher ability 4)
- **The paper:** Botany 37 + Zoology 38; each part: MCQs × 1 (5 Botany, 6 Zoology) · 4 short × 4 · 2 long × 8; one OR in each short and long group; 3 hours; 1 mark per expected point
- **CDC's model paper:** MCQ on the corpus luteum (with Unit 24)
- **Our model papers:** Paper 1's short OR question ($T_3$ and $T_4$; how iodine lack swells the thyroid; why goiter was common in the hills, iodized salt); Paper 2 MCQ (six hours' walk, no food: glucagon from alpha cells); Paper 3 MCQ (oxytocin) and long question (how the anterior pituitary controls other glands and the hypothalamus controls it; two patients with much urine: diabetes mellitus and diabetes insipidus, and why)
- **MCQ (1 mark)**
  - thyroid endocrine; secretin found by Bayliss and Starling
  - many hormones are proteins, like enzymes
  - pituitary below the hypothalamus; posterior lobe releases oxytocin, ADH
  - ADH: water balance; TSH → $T_3$, $T_4$
  - swollen thyroid: blood test for $T_3$, $T_4$, TSH
  - calcitonin lowers blood calcium; Graves': too much thyroid
  - adrenaline not from the cortex; cortisol: metabolism, stress
  - aldosterone: $Na^+$ and $K^+$; Addison's: lack of aldosterone and cortisol
- **Short and long (in parts)**
  - exocrine vs endocrine; enzymes vs hormones
  - the posterior pituitary (store and release)
  - hypo- and hyperthyroidism
  - the pancreas (heterocrine, in the duodenum's curve)
  - parathyroids and calcium; gonads; adrenal medulla; pineal
  - label the endocrine glands (A–H), the pituitary (a–c)
  - hypothalamus (long); pituitary, master gland (long); thyroid and BMR (long); adrenal (long)

## Key terms

**Gland**: cell(s), usually epithelial, making and releasing a useful substance.

**Exocrine** (ducted): through a **duct**; acts near by.

**Endocrine** (ductless): **straight into the blood**; acts far away.

**Heterocrine** (mixed): both; **pancreas**, **testes**, **ovaries**.

**Hormone** (Starling, 1905; *hormao*, I set in motion): chemical messenger in the blood to **target cells** with a **receptor**.

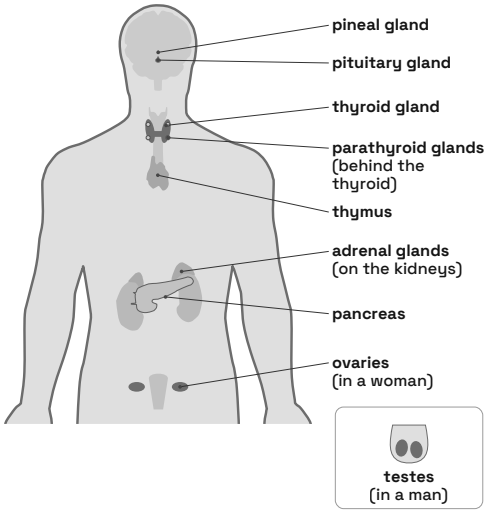
**Endocrinology**: study of endocrine glands and hormones.

**Hyper-** / **hyposecretion**: too much / too little.

**Tropic hormone**: makes another endocrine gland work.

**Negative feedback**: the final hormone slows the hypothalamus and pituitary.

**Portal vein**: from one capillary net to another without the heart.




The main endocrine glands.

## Hormones

- first hormone: **secretin** (Bayliss and Starling, 1902)

| Kind | Made from | Examples |
|---|---|---|
| **steroid** | **cholesterol** | testosterone, estrogen, progesterone, aldosterone, cortisol |
| **amino acid derivative** | **tyrosine** | **thyroxine**, $T_3$, **adrenaline**, noradrenaline |
| **peptide** | short chains | oxytocin, ADH, MSH, ACTH, parathormone, calcitonin |
| **protein** | long chains | insulin, glucagon, GH, prolactin |
| **glycoprotein** | protein + sugar | TSH, FSH, LH; erythropoietin; inhibin |
| **eicosanoid** | arachidonic acid | prostaglandins |

- peptides, proteins, glycoproteins = **proteinaceous**
- properties:
  - **tiny amounts** (billionths of a gram per liter)
  - mostly **small**, pass capillary walls
  - into **blood**, act **far away**
  - steroid, thyroid hormones carried bound to plasma proteins
  - **not catalysts**: messengers to receptors
  - **broken down** (liver) or excreted → must keep being made
  - **prohormones** (proinsulin → insulin)
  - **non-antigenic**
- control: metabolism · homeostasis · growth, repair · sex, reproduction · other glands · adaptation to stress, cold, hunger, danger

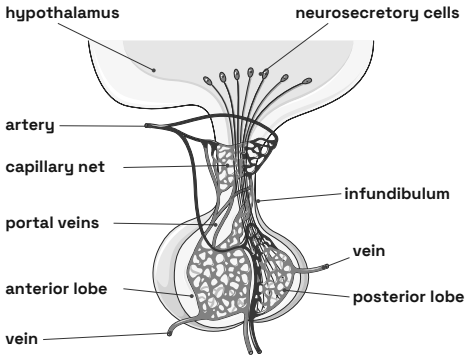
| | Hormones | Enzymes |
|---|---|---|
| made by | endocrine glands | exocrine glands, all cells |
| act | far, via blood | near, or inside the cell |
| size | mostly small | large |
| nature | steroids, proteins, peptides, amino acid derivatives | nearly all proteins |
| after acting | broken down | reused |
| speed | seconds to days | very fast |
| effect | speed up or slow down | speed up |

## Hypothalamus

- floor of the **diencephalon**, almond-sized, above the pituitary; **ectoderm**
- nervous and endocrine meet: **supreme commander** of endocrine regulation
- **anterior (supra-optic) region**: **supra-optic**, **paraventricular** nuclei
  - **CRH** → ACTH · **TRH** → TSH · **GnRH** → FSH, LH
  - **oxytocin**, **ADH**
  - **somatostatin** (stops GH, TSH)
  - cools (sweating); **circadian rhythm**
- **middle (tuberal) region**: **ventromedial** (appetite, "full") · **arcuate** (**GHRH**)
- **posterior (mammillary) region**: posterior nucleus (warms: **shivering**) · **mammillary nuclei** (memory)
- releasing, inhibiting hormones → anterior pituitary by the **hypophyseal portal system**; oxytocin, ADH down **nerve fibers** → posterior pituitary

## Pituitary (hypophysis)

- below the hypothalamus on the **infundibulum**; in the **sella turcica** of the **sphenoid**; pea-sized, ~1.3 cm, 0.5 g
- **master gland**, but run by the hypothalamus: **hypothalamo-hypophyseal axis**
- lobes: **anterior** (pars distalis, largest) · **middle** (pars intermedia, tiny in adults) · **posterior** (pars nervosa)
- **adenohypophysis** (anterior + middle; ~75%) from **Rathke's pouch** (roof of the mouth)
- **neurohypophysis** (posterior; ~25%) from the floor of the brain

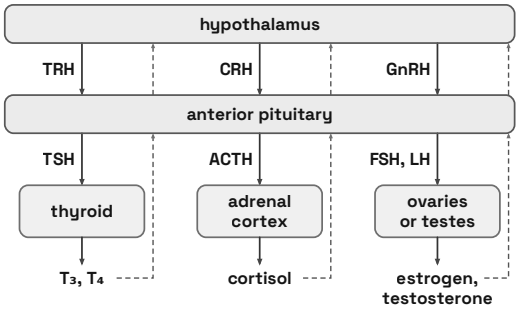



The pituitary and the hypothalamus, cut front to back.

- adenohypophysis cells: **acidophils** (somatotrophs: GH; lactotrophs: prolactin) · **basophils** (thyrotrophs, corticotrophs, gonadotrophs) · **chromophobes**
- neurohypophysis: **axons** of hypothalamic neurosecretory cells, **pituicytes**; oxytocin, ADH stored in **Herring bodies**; **makes nothing**, stores and releases

**Adenohypophysis hormones** (mostly **tropic**; GH, prolactin act directly)

1. **TSH** (thyrotropin) → thyroid: $T_3$, $T_4$
2. **ACTH** → adrenal cortex: glucocorticoids, sex corticoids
3. **FSH**: follicles grow, ripen, make **estrogen**; men: **seminiferous tubules**, sperm
4. **LH**: **ovulation**, **corpus luteum** (progesterone); men: **Leydig cells** → **testosterone** (ICSH)
5. **prolactin** (PRL, LTH): breasts grow, **make milk**; too much: galactorrhea, amenorrhea, infertility; men: gynecomastia
6. **MSH**: fish, amphibians darken skin (**melanophores**); humans: small amounts by skin and brain (tanning, appetite)
7. **GH** (somatotropin): growth of **bones**, muscles; raises blood sugar, burns fat, builds protein; mostly in deep sleep




Three chains of command, with negative feedback.

- thyroid removed → no feedback → **TSH rises**

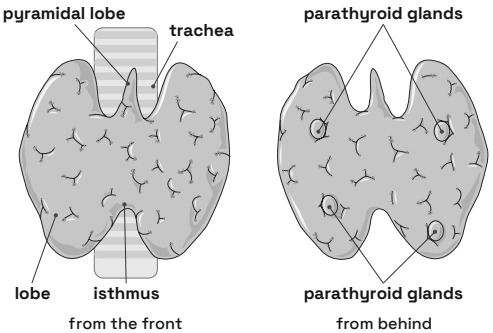
| GH | In childhood | In adults |
|---|---|---|
| too little | **pituitary dwarfism** (ateliosis): short, well-proportioned, **normal intelligence**; GH injections | **Simmonds' disease** (all anterior hormones fail): thin, weak, early aging, sex organs waste |
| too much | **gigantism**: very tall, long limbs | **acromegaly**: bones thicken; hands, feet, jaw, nose, brow large; pituitary tumor |

**Neurohypophysis hormones** (9-amino-acid peptides)

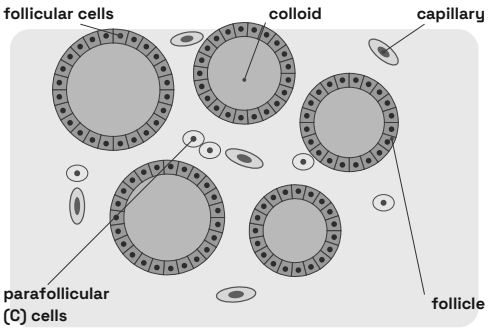
- **oxytocin** (Pitocin, "birth" or "love" hormone): **uterus contracts** in labor; **milk ejection** (let-down) on suckling; closeness, touch; helps sperm in ejaculation
- **ADH** (vasopressin, Pitressin): **collecting ducts** (and last DCT) let water through → small, concentrated urine; set by hypothalamic **osmoreceptors**; large amounts narrow arteries, raise BP
  - too little: **diabetes insipidus**: 5–20 L dilute urine a day, thirst, **no sugar**
  - too much: little urine (**antidiuresis**), blood diluted
- prolactin **makes** milk; oxytocin **lets it out**

## Thyroid

- **largest** endocrine gland; neck below the larynx, round the **trachea**, C5–T1
- H or butterfly: two **lobes** + **isthmus**; 20–25 g, lobes ~5 cm; rich blood; **capsule**; from **endoderm** (pharynx floor)
- **follicles**: one layer of **cuboidal** follicular cells round **colloid** (**thyroglobulin**; 2–3 months' store)
- **parafollicular (C) cells** between follicles: **calcitonin**




The thyroid from the front and behind (parathyroids behind).




Thyroid follicles.

- **TSH** → **$T_3$** (triiodothyronine) and **$T_4$** (thyroxine): **iodine** + **tyrosine** on thyroglobulin; $T_4$ four I, $T_3$ three; most released is $T_4$, **$T_3$ active** ($T_4$ loses one I in the tissues)
- functions: **BMR**, heat (calorigenic) · carbohydrate, protein, fat metabolism · **growth**, **brain** and bones before birth and in childhood · heart, nerves, muscles, kidney tubules · amphibian **metamorphosis**

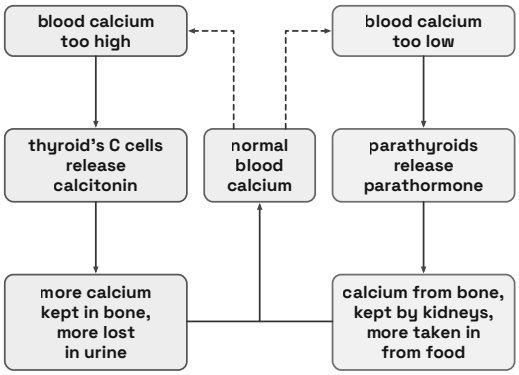
| Too little (hypothyroidism) | Signs |
|---|---|
| **cretinism** (from birth) | stunted (short limbs), **intellectual disability**, undeveloped sex organs, thick tongue, slow pulse, low BP, BMR, temperature; newborn test + thyroxine → normal |
| **myxedema** (adults) | puffy face, hands; dry pale skin; slow thinking, speech; tired; weight gain; cold; low BMR |
| **simple goiter** | **iodine** lacking → too little hormone → pituitary keeps sending **TSH** → thyroid cells multiply, swell |
| **Hashimoto's disease** (1912) | **autoimmune** destruction; commonest cause where iodine is enough |

- hills: rain and snow wash iodine out of the soil → goiter (over half in some hill districts, 1960s); salt **iodized** since **1973**
- too much: **Graves' disease** (exophthalmic goiter; Basedow's, Parry's): **autoimmune**, antibodies switch on the TSH receptor; **bulging eyes**, weight loss despite eating, restless, sleepless, sweating, **palpitations**, high BMR, temperature, trembling
- **calcitonin**: **lowers** blood calcium: slows osteoclasts (calcium stays in bone), kidneys reabsorb less; small effect in humans
- swollen thyroid tested by blood **$T_3$**, **$T_4$**, **TSH**

## Parathyroids

- **four**, two on the **back** of each thyroid lobe; 4–6 mm, 30–50 mg; **endoderm** (pharynx); amphibians to mammals, not fishes
- **chief cells** (make PTH) · **oxyphil cells** (job unknown)
- **parathormone** (PTH, **Collip's hormone**, 1925) **raises** blood calcium:
  1. **bone**: osteoclasts dissolve it
  2. **kidneys**: more $Ca^{2+}$ reabsorbed, more phosphate out
  3. active **vitamin D** → **intestine** absorbs more

- calcium for muscle contraction, **clotting**, nerve impulses, bones, teeth
- **calcitonin** and **PTH**: **antagonistic**

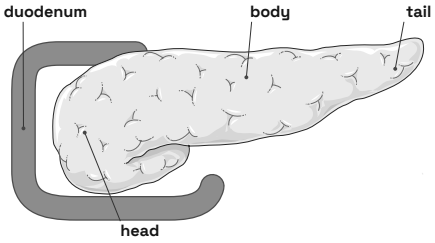



Calcium kept steady by two opposite hormones.

- **too little PTH**: $Ca^{2+}$ falls, phosphate rises → tingling, cramps, **tetany**, convulsions
- **too much PTH** (tumor): **hypercalcemia**, **hypercalciuria**; weak, painful bones (**osteoporosis**, cysts); **kidney stones**

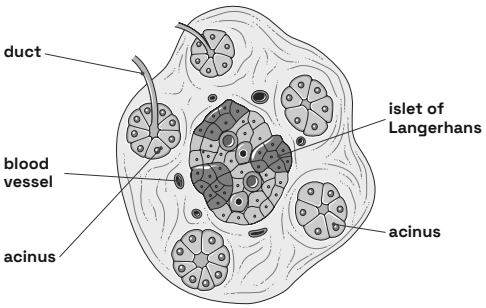
## Pancreas

- soft, lobed; ~15 cm, 60–100 g; **behind the stomach**; **head** in the duodenum's C, **body**, **tail** to the spleen; **endoderm**; **heterocrine**
- **98–99%** exocrine: **acini** → pancreatic juice
- **islets of Langerhans** (Paul Langerhans, 1869): **1–2 million**, ~1–2%; capillaries, autonomic nerves




The pancreas in the curve of the duodenum.

| Cell | Share | Hormone |
|---|---|---|
| $\beta$ | ~60% | **insulin** |
| $\alpha$ | ~25% | **glucagon** |
| $\delta$ | ~10% | **somatostatin** |
| **PP (F)** | few | pancreatic polypeptide (holds back pancreatic juice) |




An islet of Langerhans among the acini.

**Insulin**: only hormone that **lowers blood sugar**

1. cells **take up glucose**
2. liver, muscle store **glycogen** (glycogenesis)
3. extra glucose → **fat**
4. builds protein, fat; with GH, growth

- **diabetes mellitus**: too little insulin or cells don't respond → **hyperglycemia** → **glycosuria** (water follows) → much urine, thirst, hunger, tired, weight loss
  - **type 1**: immune system destroyed $\beta$ cells (childhood); insulin for life
  - **type 2**: **insulin resistance**; age, overweight, no exercise; diet, exercise, tablets
- too much insulin: **hypoglycemia** (shaking, sweating, confusion, fits); diabetic overdose or missed meal; **insulinoma**

**Glucagon** (blood sugar **falls**, between meals): mainly the **liver**

1. **glycogenolysis**: glycogen → glucose
2. **gluconeogenesis**: new glucose from amino acids

- insulin and glucagon **antagonists**: fasting glucose ~70–100 mg/100 mL

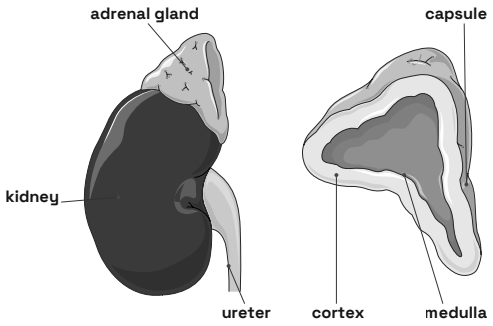
**Somatostatin**: $\delta$ cells hold back insulin, glucagon (and gut); hypothalamic somatostatin holds back GH

**Much urine, two causes (paper question)**

- **diabetes mellitus**: glucose left in the tubule holds water (osmosis); urine **sweet**
- **diabetes insipidus**: no **ADH** → collecting ducts waterproof; urine **dilute, no sugar**

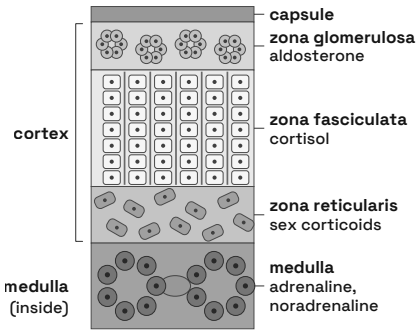
## Adrenal glands

- caps **on the kidneys** (supra-renal): right triangular, left half-moon; ~5 cm, 4–5 g; rich blood; capsule
- **cortex** (~80–90%; **mesoderm**; fat, **cholesterol**) and **medulla** (**ectoderm**, neural crest): two glands in one




An adrenal gland on a kidney, and cut lengthwise.

| Zone | Where | Makes | Controlled by |
|---|---|---|---|
| **glomerulosa** | outer, thin | **mineralocorticoids** (aldosterone) | blood salt (renin–angiotensin), $K^+$ |
| **fasciculata** | middle, thickest | **glucocorticoids** (cortisol) | **ACTH** |
| **reticularis** | inner | **sex corticoids** (weak androgens) | **ACTH** |




The layers of the adrenal gland.

- **aldosterone**: DCT, collecting ducts (sweat, saliva, gut) **keep $Na^+$**, **lose $K^+$**; water follows → blood volume, **blood pressure**; released when $Na^+$ or BP falls, $K^+$ rises
- **glucocorticoids**: **cortisol** (~95%), corticosterone, cortisone:
  1. carbohydrate, protein, fat metabolism
  2. **gluconeogenesis** (amino acids from muscle, glycerol)
  3. **anti-inflammatory** (prednisolone)
  4. **stress hormone**
  5. blood pressure, nervous system
- **sex corticoids**: androgens, some estrogen; women's main androgen source

| Disorder | Cause | Signs |
|---|---|---|
| **Addison's disease** | cortex destroyed (autoimmune; once TB): too little **cortisol**, **aldosterone** | weak, weight loss, vomiting, low BP, low $Na^+$, high $K^+$, dehydration, low sugar, **bronze skin** (ACTH) |
| **Cushing's syndrome** (1912) | too much **cortisol** (tumor, steroid medicines); pituitary ACTH tumor = Cushing's **disease** | **moon face**, trunk fat, shoulder hump, thin limbs, purple stretch marks, slow healing, high sugar, high BP, weak bones |
| **Conn's syndrome** (1955) | too much **aldosterone** | $Na^+$, water kept, $K^+$ lost → **high BP**, weak muscles, polyuria |
| **hypoaldosteronism** | too little aldosterone | $Na^+$, water lost; dehydrated, low BP |
| **adrenal virilism** | too much androgen in a woman | beard (**hirsutism**), deep voice, muscle, periods stop |
| **gynecomastia** | adrenal tumor making estrogen in a man | breasts enlarge, less facial hair |

### Adrenal medulla

- **chromaffin cells** (modified sympathetic neurons): **adrenaline** (~80%) + **noradrenaline** (~20%) = **catecholamines**
- run **directly by sympathetic nerves**, act in seconds: **fight, flight or fright**; **emergency hormones**, **gland of emergency**
- **adrenaline**: anger, fear, cold, pain → heart faster, harder, CO and BP up; skin, gut vessels narrow, **muscle vessels widen**; airways, pupils widen; **glycogenolysis**, fat released; injection for **anaphylaxis**
- **noradrenaline**: narrows nearly all vessels, keeps BP up
- not under the pituitary: adrenal medulla, islets, parathyroids, zona glomerulosa

## Gonads, thymus, pineal

- **ovaries**:
  - **estrogens**: uterus, vagina mature; breasts; wide pelvis; fat on hips, thighs; uterine lining builds; body hair
  - **progesterone** (corpus luteum; placenta): lining ready for and keeps the embryo; second half of the cycle; milk glands in pregnancy
- **testes**: **testosterone** (**Leydig** cells): male organs (before birth, puberty), muscle, bone, hair, broad shoulders, deep voice; sperm
- **thymus**: mediastinum behind the sternum; large at birth, **shrinks after puberty** (fat); **thymosin** → **T lymphocytes** multiply, mature
- **pineal**: 0.1–0.2 g, pine cone, back of the 3rd ventricle; **melatonin** rises in **darkness**: **sleep–wake** (circadian) rhythm; may hold back sex organs before puberty

### COMMON MISTAKES

✗ Hormones are organic catalysts or coenzymes
✓ they are **messengers**; enzymes are the catalysts.

✗ The posterior pituitary makes oxytocin and ADH
✓ the **hypothalamus** makes them; the posterior lobe **stores and releases** them.

✗ Oxytocin makes milk
✓ **prolactin** makes milk; oxytocin lets it **flow out**.

✗ Acromegaly is too much GH in a child
✓ in an **adult**; in a child it is **gigantism**.

✗ A pituitary dwarf is intellectually disabled
✓ normal intelligence; the **cretin**'s brain did not develop.

✗ Diabetes insipidus is a lack of insulin
✓ a lack of **ADH**; urine dilute, **no sugar**.

✗ Goiter always means too much thyroid hormone
✓ simple goiter is the gland straining for lack of **iodine**.

✗ Too little parathormone softens bones
✓ **too much** PTH weakens bones; too little gives **tetany**.

✗ Calcitonin raises blood calcium
✓ it **lowers** it; **parathormone** raises it.

✗ Glucagon lowers blood sugar
✓ **insulin** lowers; **glucagon** raises it.

✗ ACTH controls the adrenal medulla
✓ **sympathetic nerves** do; ACTH acts on the cortex.