MEDICAL EDUCATION RESOURCE

Suprarenal Gland and Chromaffin System

? Suprarenal Gland and Chromaffin System

Introduction

- The **suprarenal glands** (adrenal glands) are **paired endocrine organs** lying on the **superior poles of the kidneys**.
- They are **retroperitoneal** and surrounded by **perinephric fat** within the **renal fascia**, separated from the kidneys by a thin fibrous septum.
- Each gland weighs about **4–5 g** and is **golden-yellow** in color due to lipid content.

Right Suprarenal Gland

- **Shape:** Triangular or pyramidal.
- **Position:** Lies on the **upper pole of right kidney**, behind the inferior vena cava.
- **Relations:**
  - *Anterior:* Right lobe of liver, inferior vena cava.
  - *Posterior:* Diaphragm.
  - *Medial:* Inferior vena cava.

- **Hilum:** On anterior surface where veins emerge.

Left Suprarenal Gland

- **Shape:** Crescentic or semilunar.
- **Position:** Lies on the **upper medial border of the left kidney**.
- **Relations:**
  - *Anterior:* Stomach (through omental bursa), pancreas, spleen.
  - *Posterior:* Diaphragm.
  - *Medial:* Aorta.

Capsules

- **True capsule:** Condensation of connective tissue of gland.
- **False capsule:** Formed by renal fascia enclosing perinephric fat.

Structure

Each gland has two parts:

1. **Cortex (outer yellow layer)**
   - Derived from **mesoderm**.
   - Secretes **steroid hormones**.

- Divided into three zones:
  - **Zona glomerulosa:** Mineralocorticoids (aldosterone).
  - **Zona fasciculata:** Glucocorticoids (cortisol).
  - **Zona reticularis:** Sex steroids (androgens).

2. **Medulla (inner dark brown core)**
   - Derived from **neural crest cells**.
   - Contains **chromaffin cells** (modified post-ganglionic sympathetic neurons).
   - Secretes **catecholamines — adrenaline and noradrenaline**.
   - Under **sympathetic control**, not pituitary.

Functions

PART	HORMONES	MAIN FUNCTION
Cortex	Aldosterone	Sodium and water retention, ? BP
Cortex	Cortisol	Glucose metabolism, stress response, anti-inflammatory
Cortex	Androgens	Secondary sexual characters
Medulla	Adrenaline/Noradrenaline	“Fight-or-flight” response — ? heart rate, BP, blood glucose

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Arterial Supply

Each gland receives **three main arteries**:

1. **Superior suprarenal arteries** ? from *inferior phrenic artery*
2. **Middle suprarenal artery** ? from *abdominal aorta*
3. **Inferior suprarenal artery** ? from *renal artery*

These form a **subcapsular arterial plexus**, which supplies both cortex and medulla.

Venous Drainage

- **Single suprarenal vein** from each gland:
    - **Right suprarenal vein ?** directly into *inferior vena cava*
    - **Left suprarenal vein ?** drains into *left renal vein*
- Venous blood from cortex flows through medulla before exiting, bathing medullary cells with cortical hormones (important for adrenaline synthesis).

Lymphatic Drainage

- To **lateral aortic (para-aortic)** and **renal lymph nodes**.

Nerve Supply

- **Preganglionic sympathetic fibers (T10–L1)** via splanchnic nerves.
- The **medullary chromaffin cells** act as modified sympathetic ganglion cells.

- Cortex has **no direct nerve supply**, controlled hormonally by **pituitary ACTH**.

Embryological Derivation

- **Cortex:** Mesodermal coelomic epithelium.
- **Medulla:** Neural crest (ectodermal).
- Thus, the gland is a **composite organ of dual origin**.

Chromaffin System

- Includes **suprarenal medulla, paraganglia, and sympathetic ganglia** that contain chromaffin cells.
- **Chromaffin reaction:** Cells stain brown with chromic salts (due to oxidation of catecholamines).
- **Extra-adrenal chromaffin bodies:** Organ of Zuckerkandl (near aortic bifurcation), carotid body, sympathetic chain.

Clinical Anatomy

- **Addison’s disease:** Hypofunction of cortex ? low BP, pigmentation, weakness.
- **Cushing’s syndrome:** Excess cortisol ? moon face, obesity, hypertension.
- **Conn’s syndrome:** Aldosterone excess ? hypertension, hypokalemia.
- **Pheochromocytoma:** Tumor of medulla ? episodic hypertension, sweating, palpitations.

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- **Adrenal hemorrhage (Waterhouse-Friderichsen):** Seen in meningococcal septicemia ? shock.
- **Congenital adrenal hyperplasia:** Genetic enzyme defect ? androgen excess, ambiguous genitalia.

? Venous Drainage

- Each gland has **a single large central vein**, which drains blood from both cortex and medulla.
- **Right suprarenal vein** ? short, opens **directly into inferior vena cava**.
- **Left suprarenal vein** ? long, joins **left renal vein**.
- The **medullary veins** receive blood from the cortical sinusoids, so medullary cells are exposed to high steroid concentrations — aiding conversion of noradrenaline to adrenaline.

? Lymphatic Drainage

- Lymphatics from both glands drain into **lateral aortic (para-aortic)** and **renal lymph nodes**.
- No lymphatics from medulla directly reach cisterna chyli.

? Nerve Supply

- Supplied by **preganglionic sympathetic fibers** from **T10–L1 spinal segments**.
- **Cortex:** Has no direct nerve supply; regulated hormonally by **pituitary ACTH**.
- **Medulla:** Supplied by **greater and lesser splanchnic nerves**; chromaffin cells act as **modified sympathetic neurons**, secreting adrenaline and noradrenaline directly into blood.

? Clinical Anatomy

1. **Addison’s Disease:**
    - Hypofunction of cortex ? ?cortisol & aldosterone.
    - Symptoms: Weakness, hypotension, pigmentation, salt loss.
2. **Cushing’s Syndrome:**
    - Hypersecretion of cortisol (often due to pituitary adenoma).
    - Features: Moon face, truncal obesity, hypertension, striae.
3. **Conn’s Syndrome:**
    - Hypersecretion of aldosterone.
    - Features: Hypertension, hypokalemia, muscle weakness.
4. **Pheochromocytoma:**

- Tumor of medulla (chromaffin cells).
- Causes episodic hypertension, palpitations, sweating, headache.

5. **Waterhouse–Friderichsen Syndrome:**
   - Bilateral adrenal hemorrhage in meningococcal septicemia.
   - Leads to acute adrenal insufficiency and shock.
6. **Congenital Adrenal Hyperplasia:**
   - Genetic enzyme deficiency (21-hydroxylase).
   - Excess androgens ? ambiguous genitalia in females.
7. **Adrenal Crisis:**
   - Acute insufficiency due to sudden withdrawal of steroids or infection.

? Histology

- **Cortex:**
  - **Zona glomerulosa:** Arched clusters of small columnar cells secreting aldosterone.
  - **Zona fasciculata:** Long cords of lipid-laden cells (spongiocytes) secreting cortisol.
  - **Zona reticularis:** Network of darkly stained cells secreting sex steroids.
- **Medulla:**

- Chromaffin cells arranged in cords around veins.
- Contain secretory granules rich in catecholamines.
- Stain brown with chromic salts (chromaffin reaction).
- Surrounded by sympathetic ganglion cells and venous sinusoids.

? Development

- **Cortex:** From **mesoderm of posterior abdominal wall**.
  - *Fetal cortex* forms early, later replaced by *definitive cortex*.
- **Medulla:** From **neural crest cells**, migrating inward to form chromaffin tissue.
- By birth:
  - Gland relatively large due to prominent fetal cortex.
  - After birth, gland shrinks as fetal cortex regresses.

?? Molecular Regulation

- **Steroidogenic Factor-1 (SF-1):** Controls adrenal cortex development and steroidogenesis.
- **DAX-1 and WT-1 genes:** Regulate cortical differentiation.

- **BMP and ACTH:** Promote cortex proliferation.
- **Phox2B and Mash1:** Control chromaffin cell differentiation in medulla.

???? Dissection Points

- The gland lies in **perinephric fat** at upper pole of kidney.
- Carefully dissect the renal fascia to expose it.
- Note that the **right gland** is smaller and pyramidal, **left gland** larger and semilunar.
- Trace its veins to IVC (right) and left renal vein (left).
- Identify three arteries entering at multiple points on the surface.

? Chromaffin System

- Comprises **chromaffin cells** found in adrenal medulla and in extra-adrenal sites (paraganglia).
- These cells secrete **catecholamines (adrenaline, noradrenaline)** under sympathetic stimulation.
- **Chromaffin reaction:** Cells stain brown due to oxidation of catecholamines with chromic salts.
- **Extra-adrenal chromaffin bodies include:**

- *Organ of Zuckerkandl* (near aortic bifurcation)
- *Carotid body*
- *Aortic and sympathetic paraganglia*

- These structures help regulate **vascular tone** in fetal life and early infancy.

? Facts to Remember

- Each suprarenal gland is a **retroperitoneal endocrine organ** lying on the upper pole of the kidney.
- **Right gland** ? smaller, pyramidal; **Left gland** ? larger, crescentic.
- Both glands are enclosed within the **renal fascia**, separated from the kidney by a fibrous septum.
- **Cortex** (mesodermal) and **medulla** (neural crest) have **dual embryological origin**.
- The **cortex** secretes **steroid hormones**:
  - Zona glomerulosa ? aldosterone
  - Zona fasciculata ? cortisol
  - Zona reticularis ? androgens
- The **medulla** secretes **catecholamines** (adrenaline and noradrenaline).

- The **cortex** is controlled by **pituitary ACTH**; the **medulla** by **sympathetic preganglionic fibers**.
- Each gland receives **three arteries** — superior (from inferior phrenic), middle (from aorta), inferior (from renal artery).
- Each gland has **a single vein** —
    - Right ? inferior vena cava
    - Left ? left renal vein
- Venous blood from cortex flows through the medulla ? provides steroids necessary for **adrenaline synthesis**.
- Lymph drains to **lateral aortic and renal lymph nodes**.
- **Chromaffin cells** are modified sympathetic neurons showing brown color with chromic salts.
- **Organ of Zuckerkandl** (near aortic bifurcation) is the largest extra-adrenal chromaffin body.
- The glands are **essential for life** — total removal leads to death unless hormone replacement is given.
- Tumors of medulla ? **pheochromocytoma**, producing paroxysmal hypertension.
- Overactivity of cortex ? **Cushing's or Conn's syndrome**; underactivity ? **Addison's disease**.

?? Clinicoanatomical Problems

1. **Addison’s Disease (Adrenal Insufficiency)**
    - Destruction or atrophy of adrenal cortex.
    - Features: Hypotension, fatigue, skin pigmentation, salt loss, and weight loss.
2. **Cushing’s Syndrome**
    - Overproduction of cortisol due to adrenal or pituitary tumor.
    - Features: Moon face, truncal obesity, hypertension, osteoporosis, diabetes.
3. **Conn’s Syndrome (Primary Hyperaldosteronism)**
    - Excess aldosterone secretion.
    - Features: Hypertension, hypokalemia, muscle weakness, metabolic alkalosis.
4. **Pheochromocytoma**
    - Tumor of adrenal medulla.
    - Secretes excess catecholamines ? paroxysmal hypertension, sweating, tachycardia, headache.
5. **Waterhouse–Friderichsen Syndrome**
    - Acute adrenal hemorrhage secondary to meningococcal septicemia.
    - Leads to circulatory collapse and death if untreated.

6. **Congenital Adrenal Hyperplasia (CAH)**
    - Enzyme deficiency (most commonly 21-hydroxylase).
    - Leads to androgen excess ? virilization of females, salt loss.
7. **Adrenal Crisis**
    - Acute failure of adrenals due to stress, infection, or sudden steroid withdrawal.
    - Manifests as hypotension, hypoglycemia, and shock.
8. **Adrenal Incidentaloma**
    - Benign adrenal mass discovered incidentally on imaging; may secrete hormones.
9. **Ectopic Adrenal Tissue**
    - Small accessory adrenal rests found along the gonadal descent path.
10. **Adrenal Cysts or Hemorrhage in Newborn**

- Due to birth trauma or hypoxia; may mimic abdominal tumor.

11. **Adrenal Metastasis**

- Common secondary site for carcinoma (especially lung and breast).

12. **Addisonian Crisis**

- Acute adrenal insufficiency precipitated by stress in a chronically deficient patient.

13. **Chromaffinoma (Extra-Adrenal Pheochromocytoma)**

- Arises from paraganglia (e.g., organ of Zuckerkandl).

14. **ACTH-Dependent Cushing’s Disease**

- Pituitary overproduction of ACTH causing bilateral cortical hyperplasia.

15. **Adrenogenital Syndrome**

- Congenital enzyme defect ? excessive androgen secretion ? precocious puberty in boys, masculinization in girls.

16. **Adrenal Calcification**

- Seen in tuberculosis and old hemorrhage.

17. **Hyperpigmentation in Addison’s Disease**

- Due to increased ACTH stimulating melanocytes.

18. **Adrenalectomy Considerations**

- Bilateral removal requires lifelong hormone replacement; right gland more difficult to remove due to short vein.

19. **Functional Zuckerkandl Tumor**

- Extra-adrenal paraganglioma secreting catecholamines.

20. **Steroid Therapy Suppression**

- Long-term exogenous steroids suppress ACTH and cause cortical atrophy ? risk of adrenal crisis if suddenly stopped.

? Frequently Asked Questions – Suprarenal Gland and Chromaffin System

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1. Where are the suprarenal glands located?

They lie **on the upper poles of the kidneys**, behind the peritoneum, enclosed within the **renal fascia**, one on each side of the vertebral column.

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2. What are the shapes of the two glands?

- **Right gland:** Pyramidal or triangular.
- **Left gland:** Crescentic or semilunar.

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3. What are the relations of the right suprarenal gland?

- **Anterior:** Liver and inferior vena cava.
- **Posterior:** Diaphragm.
- **Medial:** Inferior vena cava.

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4. What are the relations of the left suprarenal gland?

- **Anterior:** Stomach, pancreas, spleen (through omental bursa).
- **Posterior:** Diaphragm.
- **Medial:** Aorta.

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5. What are the coverings of the suprarenal gland?

- **True capsule:** Condensed connective tissue.
- **False capsule:** Formed by renal fascia and perinephric fat.

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6. What is the embryological origin of the suprarenal gland?

- **Cortex:** From **mesoderm** (coelomic epithelium).
- **Medulla:** From **neural crest cells**.

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7. What is the dual function of the gland?

It is both an **endocrine organ** and a **modified sympathetic ganglion**.

- Cortex ? secretes steroid hormones.
- Medulla ? secretes catecholamines.

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8. Name the three zones of the adrenal cortex.

1. **Zona glomerulosa** – secretes *aldosterone*.

2. **Zona fasciculata** – secretes *cortisol*.

3. **Zona reticularis** – secretes *androgens*.

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9. What are the functions of the adrenal medulla?

Secretes **adrenaline and noradrenaline**, which increase heart rate, BP, and blood glucose during stress (“fight or flight” response).

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10. What are chromaffin cells?

Modified postganglionic sympathetic neurons present in the **medulla** and **paraganglia**, which secrete catecholamines and stain brown with chromic salts.

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11. What is the chromaffin reaction?

Brown staining of chromaffin cells due to oxidation of catecholamines when treated with chromic salts.

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12. What is the blood supply of suprarenal gland?

Each gland receives **three arteries**:

- Superior suprarenal – from inferior phrenic artery.
- Middle suprarenal – from abdominal aorta.
- Inferior suprarenal – from renal artery.

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13. What is the venous drainage of the glands?

- **Right suprarenal vein ? inferior vena cava**.

- **Left suprarenal vein ? left renal vein**.

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14. What is the lymphatic drainage?

To **lateral aortic (para-aortic)** and **renal lymph nodes**.

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15. What is the nerve supply of the glands?

- **Cortex:** Controlled hormonally by ACTH.
- **Medulla:** Supplied by preganglionic sympathetic fibers (T10–L1) through splanchnic nerves.

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16. What are the hormones secreted by the adrenal cortex?

- **Aldosterone:** Regulates sodium and water balance.
- **Cortisol:** Increases blood glucose, reduces inflammation.
- **Androgens:** Contribute to secondary sexual characters.

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17. What are the hormones secreted by the adrenal medulla?

Adrenaline and noradrenaline, collectively called catecholamines.

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18. How does the adrenal medulla differ from a sympathetic ganglion?

- Medulla secretes hormones directly into blood.
- Sympathetic ganglia transmit impulses via axons.

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19. What are the clinical conditions due to adrenal cortical hyperfunction?

- **Cushing's syndrome** – cortisol excess.
- **Conn's syndrome** – aldosterone excess.
- **Adrenogenital syndrome** – androgen excess.

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20. What are the clinical conditions due to adrenal cortical hypofunction?

- **Addison's disease** – failure of cortex leading to pigmentation, hypotension, and salt loss.

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21. What are the clinical conditions due to adrenal medullary tumor?

- **Pheochromocytoma** – excess catecholamine secretion ? episodic hypertension, tachycardia, sweating, headache.

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22. Why is the right adrenal vein important surgically?

It is very short and opens directly into IVC ? prone to tearing during surgery.

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23. Why is the left gland larger than the right?

Because of its **semilunar shape** and broad contact with stomach and pancreas.

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24. What is the effect of adrenalectomy (removal)?

Bilateral removal causes **death** unless replaced by steroid therapy.

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25. Why does adrenal medulla depend on cortex for adrenaline synthesis?

Cortisol from the cortex induces the **enzyme phenylethanolamine-N-methyltransferase (PNMT)** needed to convert noradrenaline to adrenaline.

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26. What is the function of aldosterone?

Regulates sodium retention, potassium excretion, and helps maintain blood pressure.

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27. What is the function of cortisol?

Promotes gluconeogenesis, suppresses inflammation, maintains BP and stress response.

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28. What is the Organ of Zuckerkandl?

A large **extra-adrenal chromaffin body** near the aortic bifurcation; active in fetal life.

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29. What is congenital adrenal hyperplasia?

Genetic enzyme deficiency (commonly 21-hydroxylase) causing androgen excess and ambiguous genitalia in females.

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30. What is Waterhouse–Friderichsen syndrome?

Acute adrenal hemorrhage in meningococcal septicemia causing shock and adrenal failure.

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31. Which adrenal vein drains into the renal vein?

Left suprarenal vein.

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32. Which part of the adrenal gland is controlled by ACTH?

The **cortex** (especially zona fasciculata and zona reticularis).

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33. What is the most common site of extra-adrenal pheochromocytoma?

Organ of Zuckerkandl near the aortic bifurcation.

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34. Why is the cortex yellow and the medulla dark brown?

- **Cortex:** Rich in lipid (cholesterol, phospholipids).
- **Medulla:** Rich in chromaffin granules containing catecholamines.

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35. What is the blood supply pattern inside the gland?

Arteries form a **subcapsular plexus** ? capillaries for cortex and medulla ? central vein.

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36. What is the function of the chromaffin reaction?

Used to identify catecholamine-producing cells (diagnostic feature).

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37. What happens in adrenal hypoplasia congenita?

Failure of adrenal cortex development ? adrenal insufficiency in infancy.

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38. What is the effect of stress on adrenal gland?

Stress stimulates ACTH ? increased cortisol and catecholamine secretion (fight or flight).

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39. What is the origin of the adrenal medulla in terms of nervous system?

Derived from **sympathetic neural crest cells**.

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40. Why is the adrenal gland called a ‘life-saving gland’?

Because absence of adrenal cortical hormones leads to **death within days** due to electrolyte imbalance and circulatory collapse.

? Multiple Choice Questions – Suprarenal Gland and Chromaffin System

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1. The suprarenal glands are located:

A. In front of kidneys
B. **On the upper poles of kidneys** ?
C. Behind kidneys
D. Below kidneys

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2. The right suprarenal gland is:

A. Crescentic
B. Oval
C. **Pyramidal** ?
D. Triangular and elongated

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3. The left suprarenal gland is:

A. Pyramidal
B. Conical
C. **Crescentic** ?
D. Oval

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4. The suprarenal glands are covered by:

A. Peritoneum
B. **Renal fascia (Gerota's fascia)** ?
C. Fascia transversalis
D. Parietal peritoneum

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5. The embryological origin of adrenal cortex is:

A. Endoderm
B. Ectoderm
C. **Mesoderm** ?

D. Neural crest

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6. The embryological origin of adrenal medulla is:

A. Mesoderm
B. Endoderm
C. **Neural crest (ectodermal)** ?
D. Mesonephric duct

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7. Which part of adrenal gland secretes steroid hormones?

A. **Cortex** ?
B. Medulla
C. Capsule
D. Both cortex and medulla

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8. Which part secretes adrenaline and noradrenaline?

A. Cortex
B. **Medulla** ?
C. Capsule
D. Both

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9. The hormone aldosterone is secreted by:

A. Zona fasciculata
B. Zona reticularis
C. **Zona glomerulosa** ?
D. Medulla

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10. The hormone cortisol is secreted by:

A. Zona glomerulosa
B. **Zona fasciculata** ?
C. Zona reticularis

D. Medulla

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11. The adrenal cortex is controlled by:

A. Hypothalamus directly
B. **Pituitary ACTH** ?
C. Sympathetic nerves
D. Parasympathetic nerves

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12. The adrenal medulla is controlled by:

A. **Preganglionic sympathetic fibers (T10–L1)** ?
B. ACTH
C. Parasympathetic fibers
D. Somatic nerves

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13. The chromaffin reaction is seen in:

A. Cortical cells
B. **Medullary cells** ?
C. Zona fasciculata
D. Zona reticularis

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14. Which hormone increases blood pressure and heart rate?

A. Aldosterone
B. Cortisol
C. **Adrenaline** ?
D. Insulin

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15. Which of the following is NOT secreted by the adrenal cortex?

A. Aldosterone
B. Cortisol
C. **Adrenaline** ?

D. Androgen

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16. The enzyme converting noradrenaline to adrenaline requires:

A. ACTH
B. **Cortisol (PNMT induction)** ?
C. Adrenalinase
D. Dopamine

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17. Which artery supplies the adrenal gland?

A. Superior adrenal artery
B. Middle adrenal artery
C. Inferior adrenal artery
D. **All of the above** ?

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18. The venous drainage of right adrenal gland is into:

A. Renal vein
B. **Inferior vena cava** ?
C. Hepatic vein
D. Azygos vein

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19. The venous drainage of left adrenal gland is into:

A. Inferior vena cava
B. **Left renal vein** ?
C. Left gonadal vein
D. Portal vein

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20. Lymphatic drainage of adrenal gland is to:

A. Internal iliac nodes
B. Inguinal nodes
C. **Lateral aortic (para-aortic) nodes** ?

D. Mesenteric nodes

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21. The main hormone responsible for sodium retention is:

A. Cortisol
B. **Aldosterone** ?
C. Adrenaline
D. Noradrenaline

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22. Cushing’s syndrome is due to:

A. Aldosterone excess
B. **Cortisol excess** ?
C. Catecholamine deficiency
D. Cortisol deficiency

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23. Addison’s disease results from:

A. Excess cortisol
B. Excess aldosterone
C. **Deficiency of adrenal cortical hormones** ?
D. Pheochromocytoma

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24. Conn’s syndrome is due to:

A. Cortisol excess
B. Androgen excess
C. **Aldosterone excess** ?
D. Noradrenaline deficiency

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25. Pheochromocytoma is a tumor of:

A. Cortex
B. Capsule
C. **Medulla** ?

D. Zona fasciculata

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26. Waterhouse–Friderichsen syndrome is due to:

A. Medullary tumor
B. **Adrenal hemorrhage in meningococcal infection** ?
C. Cortical tumor
D. Pituitary hyperplasia

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27. The adrenal glands are essential for life because they secrete:

A. Adrenaline
B. **Cortisol and aldosterone** ?
C. Androgens
D. ACTH

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28. Organ of Zuckerkandl is:

A. Pancreatic structure
B. **Extra-adrenal chromaffin body near aortic bifurcation** ?
C. Adrenal cortex
D. Paraganglion of vagus

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29. The cortical layer richest in lipid is:

A. Zona glomerulosa
B. **Zona fasciculata** ?
C. Zona reticularis
D. Capsule

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30. Which of the following has no direct nerve supply?

A. **Adrenal cortex** ?
B. Medulla
C. Chromaffin tissue

D. Organ of Zuckerkandl

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31. Which artery does NOT supply the adrenal gland?

A. Inferior phrenic
B. Aorta
C. Renal
D. **Gonadal** ?

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32. The right adrenal vein is short because:

A. It drains into hepatic vein
B. **It drains directly into IVC** ?
C. It crosses the aorta
D. It drains into portal vein

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33. Which of the following is a mesodermal derivative?

A. Adrenal medulla
B. Sympathetic ganglion
C. **Adrenal cortex** ?
D. Chromaffin cells

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34. The adrenal medulla corresponds functionally to:

A. Parasympathetic ganglion
B. **Sympathetic ganglion** ?
C. Somatic motor nucleus
D. None

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35. In Addison’s disease, hyperpigmentation occurs due to:

A. Cortisol deficiency
B. **Increased ACTH stimulating melanocytes** ?
C. High aldosterone

D. Catecholamine excess

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36. The enzyme deficiency causing congenital adrenal hyperplasia most often is:

A. 11-?-hydroxylase
B. **21-hydroxylase** ?
C. 17-hydroxylase
D. 3-?-dehydrogenase

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37. Adrenal hypoplasia congenita results in:

A. Cortisol excess
B. **Adrenal insufficiency in infancy** ?
C. Androgen excess
D. None

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38. The adrenal cortex is derived from:

A. Neural crest
B. Endoderm
C. **Mesodermal coelomic epithelium** ?
D. Mesonephric duct

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39. Which structure secretes both epinephrine and norepinephrine?

A. Adrenal cortex
B. **Adrenal medulla** ?
C. Zona fasciculata
D. Sympathetic ganglion

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40. Which hormone increases blood glucose during stress?

A. Aldosterone
B. **Cortisol** ?
C. ADH
D. Insulin