A 33-year-old woman presents to her physician with complaints of severe thirst and frequent urination. Laboratory tests show:

Serum glucose: 96 mg/dL
Serum osmolality: 300 mOsm/kg
Urine osmolality: 190 mOsm/kg
Urine specific gravity: 1.001

When she is deprived of fluids, her urine osmolality fails to increase. However, in response to exogenous ADH (vasopressin), urine osmolality increases by >50%.

An abnormality is most likely present at which of the following locations?

- **A.** Collecting ducts of the nephron
- **B.** Lateral nucleus
- **C.** Posterior nucleus
- **D.** Supraoptic nucleus
- **E.** Ventromedial nucleus

The correct answer is D. 70% chose this.

This patient has signs and symptoms of diabetes insipidus (DI), which include severe thirst, polyuria, polydipsia, low urine osmolality despite increased plasma osmolality, and a low urine specific gravity. This condition can be caused by a deficiency of ADH as seen in **neuro**genic (central) DI or by insensitivity of the kidneys to ADH as seen in **nephro**genic DI. A dose of subcutaneous vasopressin will cause urine osmolality to increase in neurogenic (central) but not nephrogenic DI. Therefore this patient likely has neurogenic DI. Diminished or absent ADH can be the result of a defect in one or more sites involving the hypothalamic osmoreceptors, supraoptic or para-ventricular nuclei, or the supraopticohypophyseal tract. Of the possible choices, supraoptic nucleus of the hypothalamus is the most likely answer.

Supraoptic nucleus Specific gravity Polyuria Polydipsia Hypothalamus Diabetes insipidus Plasma osmolality Vasopressin Osmolality Urine Osmoreceptor Diabetes mellitus Kidney Urine osmolality Blood plasma Nervous system Nephrotoxicity

A is not correct. 8% chose this.

ADH acts at the collecting ducts to increase the osmolality of urine. In the stem, ADH was given and an increase in urine osmolality was seen, suggesting that the defect was in ADH production and not in ADH sensitivity.

Osmolality Urine Collecting duct system Urine osmolality Vasopressin

B is not correct. 4% chose this.

The lateral nucleus of the hypothalamus is thought to be the "hunger center" of the brain. Damage to this area leads to anorexia and starvation, and, actually, decreased water intake.

Hypothalamus Anorexia nervosa Cell nucleus Anorexia (symptom) Human brain

C is not correct. 10% chose this.

The posterior hypothalamus functions to conserve heat. Bilateral lesions to this area lead to poikilothermia, in which the body temperature varies with the environment. This area is not involved in ADH production or regulation of thirst or water balance.

Hypothalamus Poikilotherm Thermoregulation

E is not correct. 8% chose this.

An important function of the ventromedial nucleus is control of eating. Bilateral lesions of the ventromedial nucleus in animals and probably humans result in overeating and extreme obesity as well as a chronically irritable mood and increased aggressive behavior (termed hypothalamic rage). This area is not involved in ADH production or regulation of thirst.

Ventromedial nucleus of the hypothalamus Vasopressin Hypothalamus Obesity Cell nucleus

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E is not correct. 8% chose this.

An important function of the ventromedial nucleus is control of eating. Bilateral lesions of the ventromedial nucleus in animals and probably humans result in overeating and extreme obesity as well as a chronically irritable mood and increased aggressive behavior (termed hypothalamic rage). This area is not involved in ADH production or regulation of thirst.

Ventromedial nucleus of the hypothalamus Vasopressin Hypothalamus Obesity Cell nucleus

Bottom Line:

If the urine is not concentrated in response to water deprivation, the patient has DI. If this abnormality is corrected with ADH administration, the patient must lack ADH (central DI). If the patient does not respond to vasopressin, the abnormality is in the end organ (nephrogenic DI). The supraoptic nucleus is responsible for ADH production.

Supraoptic nucleus Vasopressin Urine Cell nucleus

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FA17 p 334.1

Diabetes insipidus Characterized by intense thirst and polyuria with inability to concentrate urine due to lack of ADH (central) or failure of response to circulating ADH (nephrogenic).

	Central DI	Nephrogenic DI
ETIOLOGY	Pituitary tumor, autoimmune, trauma, surgery, ischemic encephalopathy, idiopathic	Hereditary (ADH receptor mutation), 2° to hypercalcemia, hypokalemia, lithium, demeclocycline (ADH antagonist)
FINDINGS	↓ ADH Urine specific gravity < 1.006	Normal or ↑ ADH levels Urine specific gravity < 1.006

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$Na^+ \geq 145$, or urine osmolality does not rise despite a rising plasma osmolality.

FA17 p 317.3

Antidiuretic hormone

SOURCE	Synthesized in hypothalamus (supraoptic nuclei), stored and secreted by posterior pituitary.	
FUNCTION	Regulates serum osmolarity (V_2-receptors) and blood pressure (V_1-receptors). Primary function is serum osmolarity regulation (ADH ↓ serum osmolarity, ↑ urine osmolarity) via regulation of aquaporin channel insertion in principal cells of renal collecting duct.	ADH level is ↓ in central diabetes insipidus (DI), normal or ↑ in nephrogenic DI. Nephrogenic DI can be caused by mutation in V_2-receptor. Desmopressin acetate (ADH analog) is a treatment for central DI and nocturnal enuresis.
REGULATION	Osmoreceptors in hypothalamus (1°); hypovolemia.	

FA17 p 466.2

Hypothalamus

Maintains homeostasis by regulating Thirst and water balance, controlling Adenohypophysis (anterior pituitary) and Neurohypophysis (posterior pituitary) release of hormones produced in the hyopthalamus, and regulating Hunger, Autonomic nervous system, Temperature, and Sexual urges (TAN HATS).

Inputs (areas not protected by blood-brain barrier): OVLT (senses change in osmolarity), area

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IGF-1 is a polypeptide that acts as the major mediator of somatic growth in response to growth hormone secretion. Growth-hormone dependent IGF-1 production occurs almost exclusively in the liver.

At which of the following sites does hepatically produced IGF-1 first enter the systemic circulation?

- **A.** Hepatic artery
- **B.** Hepatic vein
- **C.** Inferior vena cava
- **D.** Portal vein

The correct answer is B. 66% chose this.

IGFs/somatomedins (polypeptides) are produced by the liver in response to growth hormone and are secreted into the systemic circulation. Therefore, this question is really asking about the anatomy of hepatic venous drainage. Drainage of the liver into the systemic circulation proceeds through the hepatic vein and then into the inferior vena cava.

Hepatic vein Inferior vena cava Circulatory system Peptide Growth hormone Hormone Liver Anatomy Venae cavae Vein

A is not correct. 8% chose this.

The hepatic artery carries oxygen-rich blood to the liver and does not carry blood to the systemic circulation.

Common hepatic artery Circulatory system Liver

C is not correct. 12% chose this.

Although blood from the liver eventually enters the inferior vena cava, it first proceeds through the hepatic vein, which then drains into the IVC. Answer choice B is a better choice because the question asks where hepatically produced substances would initially enter the systemic circulation. Careful reading of all answer choices to select the best answer is essential to USMLE success.

Hepatic vein Inferior vena cava Circulatory system Liver Venae cavae United States Medical Licensing Examination

D is not correct. 14% chose this.

The portal vein delivers blood from the gastrointestinal tract to the liver and does not deliver hepatic outflow to the systemic circulation.

Human gastrointestinal tract Circulatory system Gastrointestinal tract Liver

Bottom Line:

IGFs/somatomedins (polypeptides) are produced by the liver in response to growth hormone and are secreted into the systemic circulation via the hepatic vein and, ultimately, the inferior vena cava.

Hepatic vein Inferior vena cava Circulatory system Hormone Liver Peptide Venae cavae Growth hormone

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The portal vein delivers blood from the gastrointestinal tract to the liver and does not deliver hepatic outflow to the systemic circulation.
Human gastrointestinal tract Circulatory system Gastrointestinal tract Liver

Bottom Line:

IGFs/somatomedins (polypeptides) are produced by the liver in response to growth hormone and are secreted into the systemic circulation via the hepatic vein and, ultimately, the inferior vena cava.
Hepatic vein Inferior vena cava Circulatory system Hormone Liver Peptide Venae cavae Growth hormone

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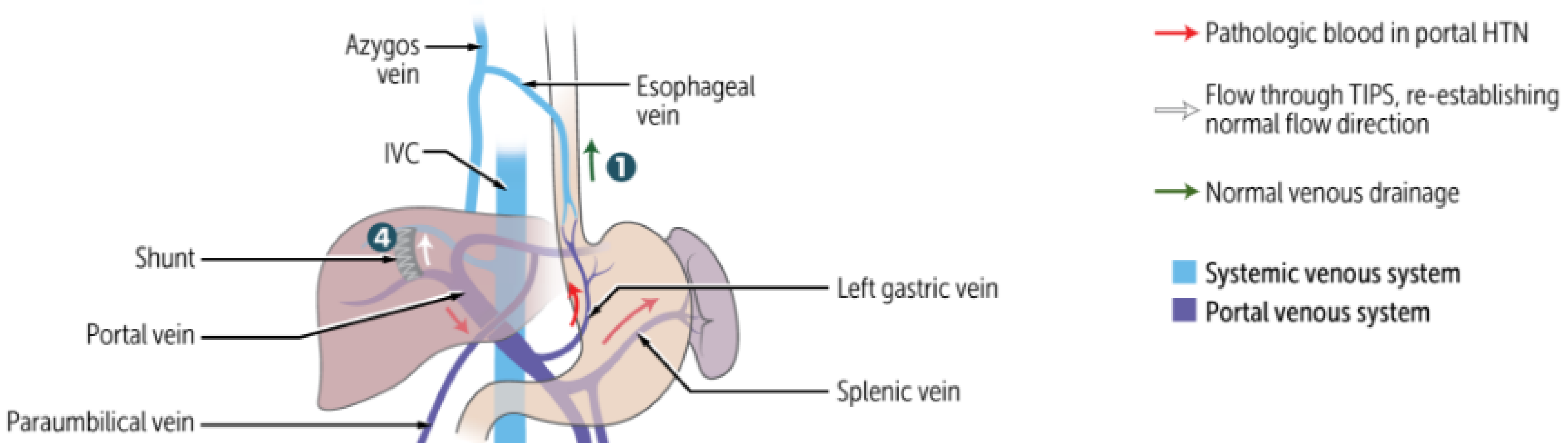
FA17 p 350.1

Portosystemic anastomoses



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A 25-year-old man with no significant medical history comes to the emergency department after experiencing tremors. On questioning, he admits to a recent history of sweating, nausea, vomiting, and lightheadedness. On physical examination he is visibly anxious. Laboratory studies show a blood glucose level of 50 mg/dL. CT of the abdomen shows a mass in an abdominal organ.

Surgical resection of this mass will necessitate ligation of branches from which of the following vascular structures?

- **A.** The gastroduodenal and inferior mesenteric arteries
- **B.** The proper hepatic and inferior mesenteric arteries
- **C.** The proper hepatic and superior mesenteric arteries
- **D.** The gastroduodenal and superior mesenteric arteries
- **E.** The left gastric and inferior mesenteric arteries
- **F.** The left gastric and superior mesenteric arteries

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The correct answer is D. 58% chose this.

This patient has a mass in the head of the pancreas, an organ that is both an exocrine and endocrine gland and is both secondarily retroperitoneal and peritoneal. As an exocrine gland it produces bicarbonates and digestive enzymes, and as an endocrine gland it produces hormones such as glucagon, insulin, and somatostatin. This patient's symptoms and low blood glucose level suggest that there is an abundance of insulin production, such as in a tumor. Sweating, lightheadedness, nausea, and vomiting, like this patient experienced, are classic features of hypoglycemia. The CT findings support a mass, which likely is the source. Treatment involves resection of the mass and ligation of its blood supply in the case of a tumor. As shown in the illustration, the head of the pancreas and the duodenum share a dual blood supply from the gastroduodenal artery, which is a branch of the common hepatic artery. The common hepatic artery is a branch of the celiac trunk. This artery supplies the anterior and posterior superior pancreaticoduodenal arteries, as well as the superior mesenteric artery, which supplies the anterior and posterior inferior pancreaticoduodenal arteries. Therefore, to resect any portion of the duodenum or the head of the pancreas, branches from both the gastroduodenal and superior mesenteric arteries must be ligated.

Hypoglycemia Exocrine gland Endocrine gland Celiac artery Gastroduodenal artery Common hepatic artery Superior pancreaticoduodenal artery Superior mesenteric artery Glucagon Somatostatin Duodenum Inferior pancreaticoduodenal artery Insulin Pancreas Peritoneum Endocrine system Blood sugar Head of pancreas Retroperitoneal space Bicarbonate Nausea Digestive enzyme Liver Glucose Neoplasm Gland Vomiting Hormone Artery Enzyme Mesentery Perspiration

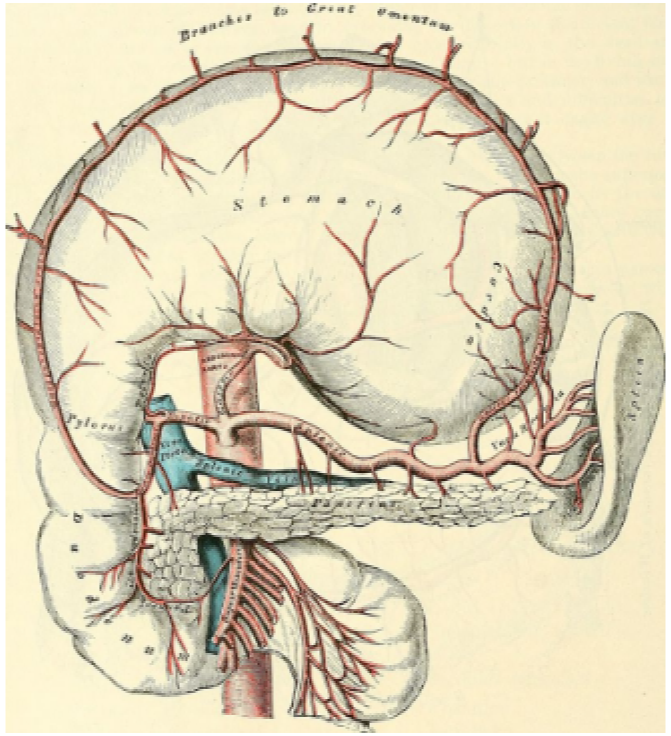

Image courtesy of Wikimedia Commons

A is not correct. 7% chose this.

Although the gastroduodenal artery is an important source of vascular supply to the head of the pancreas, the inferior mesenteric artery does not provide any vascular supply to this structure and thus provides no branches that would need to be ligated to remove the mass described in the question stem.

Inferior mesenteric artery Gastroduodenal artery Pancreas Blood vessel Head of pancreas Mesentery

B is not correct. 4% chose this.

Neither the proper hepatic nor the inferior mesenteric arteries provide any significant arterial supply to the head of the pancreas; thus no branches from

A is not correct. 7% chose this.

Although the gastroduodenal artery is an important source of vascular supply to the head of the pancreas, the inferior mesenteric artery does not provide any vascular supply to this structure and thus provides no branches that would need to be ligated to remove the mass described in the question stem.

Inferior mesenteric artery Gastroduodenal artery Pancreas Blood vessel Head of pancreas Mesentery

B is not correct. 4% chose this.

Neither the proper hepatic nor the inferior mesenteric arteries provide any significant arterial supply to the head of the pancreas; thus no branches from either of these vessels would need to be ligated to complete the resection.

Inferior mesenteric artery Pancreas Mesentery Artery Liver Mesenteric arteries

C is not correct. 12% chose this.

Although the superior mesenteric artery is an important source of vascular supply to the head of the pancreas, the proper hepatic artery does not provide any vascular supply to this structure and therefore provides no branches that would need to be ligated to remove the mass.

Hepatic artery proper Superior mesenteric artery Common hepatic artery Pancreas Liver Blood vessel Head of pancreas Mesentery

E is not correct. 5% chose this.

Neither the left gastric nor the inferior mesenteric arteries provide any significant arterial supply to the head of the pancreas; thus no branches from either of these vessels would need to be ligated to complete the resection.

Inferior mesenteric artery Pancreas Mesentery Artery

F is not correct. 14% chose this.

Although the superior mesenteric artery is an important source of vascular supply to the head of the pancreas, the left gastric artery does not provide any vascular supply to this structure and thus provides no branches that would need to be ligated to remove the mass.

Superior mesenteric artery Left gastric artery Pancreas Blood vessel Mesentery Head of pancreas

Bottom Line:

The head of the pancreas and the duodenum share a dual blood supply from the gastroduodenal artery, a branch of the common hepatic artery which comes off of the celiac trunk.

Celiac artery Gastroduodenal artery Common hepatic artery Duodenum Pancreas Head of pancreas Liver

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Although the superior mesenteric artery is an important source of vascular supply to the head of the pancreas, the left gastric artery does not provide any vascular supply to this structure and thus provides no branches that would need to be ligated to remove the mass.

Superior mesenteric artery Left gastric artery Pancreas Blood vessel Mesentery Head of pancreas

Bottom Line:

The head of the pancreas and the duodenum share a dual blood supply from the gastroduodenal artery, a branch of the common hepatic artery which comes off of the celiac trunk.

Celiac artery Gastroduodenal artery Common hepatic artery Duodenum Pancreas Head of pancreas Liver

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FA17 p 349.1

Celiac trunk

Branches of celiac trunk: common hepatic, splenic, and left gastric. These constitute the main blood supply of the stomach.

Strong anastomoses exist between:

- Left and right gastroepiploics
- Left and right gastrics

Posterior duodenal ulcers penetrate gastroduodenal artery causing hemorrhage.

Anterior duodenal ulcers perforate into the anterior abdominal cavity, potentially leading to pneumoperitoneum.

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A 30-year-old woman with no prior medical history is diagnosed with diastolic hypertension. The patient reports having headaches with increased frequency that are accompanied by vision changes. Her blood pressure at examination is 194/112 mm Hg. Laboratory results indicate she is hypokalemic, has decreased renin levels, and has a metabolic alkalosis. CT of the abdomen shows a 4-cm mass located on the right side of the body. In order to immediately relieve the patient's condition surgically, the surgeon must first ligate the primary venous drainage of the mass.

Primary venous drainage flows DIRECTLY into which of the following structures?

A. Abdominal aorta

B. Inferior vena cava

C. Portal vein

D. Right gonadal vein

E. Right renal vein

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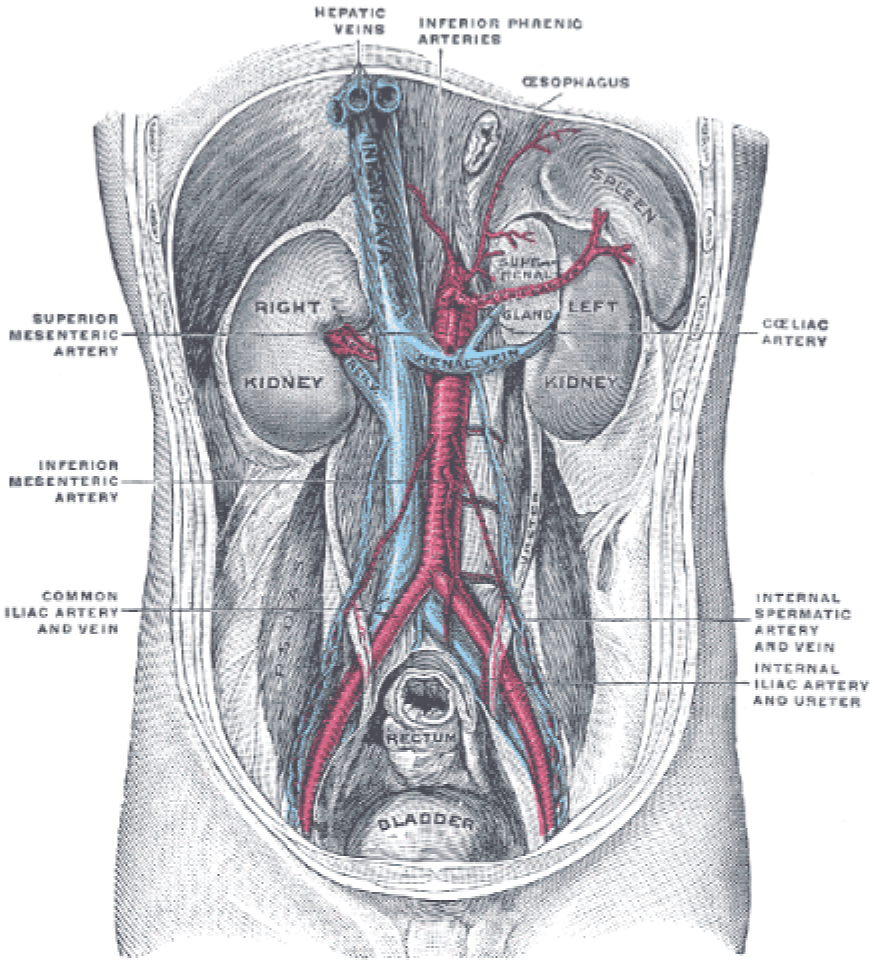
The correct answer is B. 60% chose this.

This is a case of primary hyperaldosteronism from an adrenal adenoma, also known as Conn syndrome. Primary hyperaldosteronism may come from a secretory adrenal adenoma, or may be seen in settings of bilateral adrenal hyperplasia. In addition to the symptoms seen in this patient, Conn syndrome is associated with failure to suppress aldosterone with salt loading. Pathologic examination would reveal a single, well-circumscribed adenoma with lipid-laden clear cells. In terms of primary venous drainage, the right adrenal gland is drained via the right adrenal vein, which flows directly into the inferior vena cava (IVC). Thus a right-sided hyperfunctioning adrenal adenoma is drained via the right adrenal vein into the IVC. In contrast, the left adrenal gland is drained via the left adrenal vein into the left renal vein, which then flows into the IVC, as can be seen in the illustration. Remember that gonadal vein drainage resembles this pattern, with the right gonadal vein draining directly into the IVC while the left drains into the left renal vein prior to IVC.

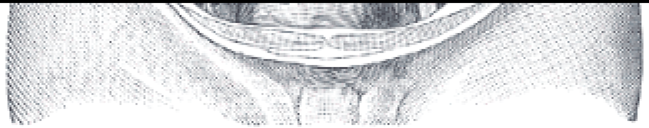
Adrenal gland Renal vein Inferior vena cava Primary aldosteronism Aldosterone

Hyperaldosteronism Adenoma Adrenal adenoma Hyperplasia Kidney



A is not correct. 2% chose this.

The abdominal aorta plays no role in the vascular drainage of any organ but rather provides arterial supply to the abdominal organs, including the kidneys and adrenals glands.



A is not correct. 2% chose this.

The abdominal aorta plays no role in the vascular drainage of any organ but rather provides arterial supply to the abdominal organs, including the kidneys and adrenals glands.

Abdominal aorta Aorta Kidney Adrenal gland Blood vessel

C is not correct. 6% chose this.

The portal vein is superior and anterior to the adrenal and renal vasculature and is not involved in the drainage of either of the adrenal glands. Instead, it drains most of the gastrointestinal tract down to the rectum into the liver.

Human gastrointestinal tract Rectum Gastrointestinal tract Liver Adrenal gland Circulatory system Anterior Kidney

D is not correct. 4% chose this.

The right gonadal vein drains the testes or ovaries directly into the inferior vena cava but does not drain the right adrenal gland in either sex.

Adrenal gland Testicle Ovary Gonadal vein Gland

E is not correct. 28% chose this.

Drainage of the right adrenal gland and hence a right-sided adrenal adenoma does not flow through the right renal vein, but instead the adrenal vein flows directly into the inferior vena cava.

Adrenal gland Inferior vena cava Renal vein Adenoma Venae cavae Adrenal adenoma Gland

Bottom Line:

Primary hyperaldosteronism is caused by increased aldosterone secretion. When secretion is from an adrenal adenoma, this is known as Conn syndrome.

Primary aldosteronism Aldosterone Hyperaldosteronism Adrenal adenoma Adenoma

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Adrenal gland Inferior vena cava Renal vein Adenoma Venae cavae Adrenal adenoma Gland

Bottom Line:

Primary hyperaldosteronism is caused by increased aldosterone secretion. When secretion is from an adrenal adenoma, this is known as Conn syndrome.

Primary aldosteronism Aldosterone Hyperaldosteronism Adrenal adenoma Adenoma

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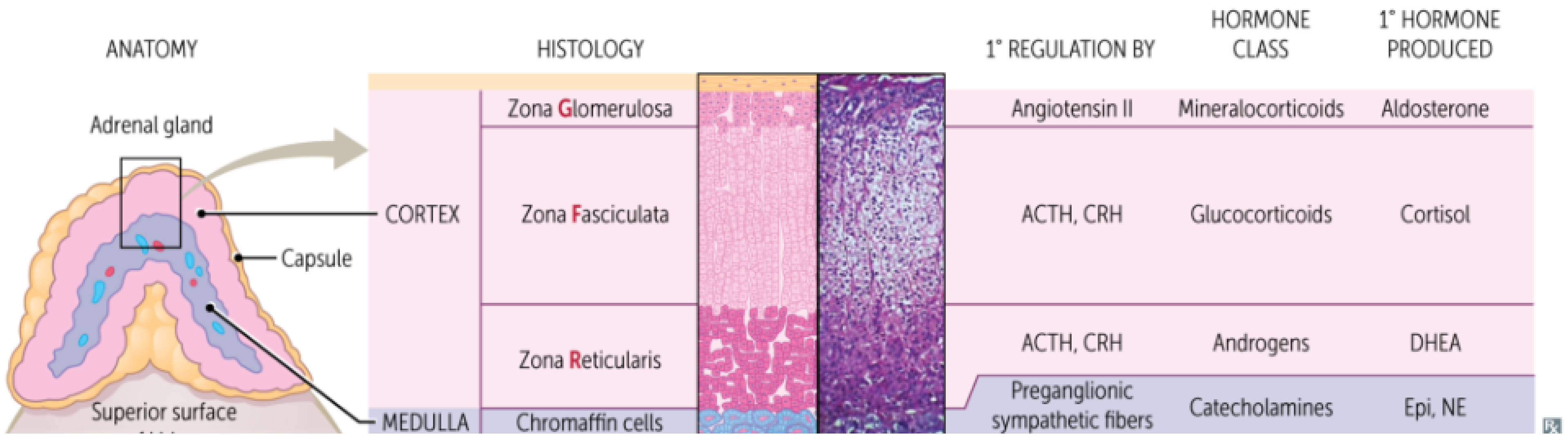
FA17 p 312.2

Adrenal cortex and medulla

Adrenal cortex (derived from mesoderm) and medulla (derived from neural crest).



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GFR corresponds with Salt (mineralocorticoids), Sugar (glucocorticoids), and Sex (androgens).
"The deeper you go, the sweeter it gets."

FA17 p 560.3

Features of renal disorders

CONDITION	BLOOD PRESSURE	PLASMA RENIN	ALDOSTERONE	SERUM Mg^{2+}	URINE Ca^{2+}
Bartter syndrome	—	↑	↑		↑
Gitelman syndrome	—	↑	↑	↓	↓
Liddle syndrome	↑	↓	↓		
SIADH	—/↑	↓	↓		
Primary hyperaldosteronism (Conn syndrome)	↑	↓	↑		
Renin-secreting tumor	↑	↑	↑		

↑ ↓ = 1° disturbance.

FA17 p 324.2

Hyperaldosteronism	Increased secretion of aldosterone from adrenal gland. Clinical features include hypertension, ↓ or normal K^+, metabolic alkalosis. No edema due to aldosterone escape mechanism.
Primary hyperaldosteronism	Seen with adrenal adenoma (Conn syndrome) or bilateral adrenal hyperplasia. ↑ aldosterone, ↓ renin.