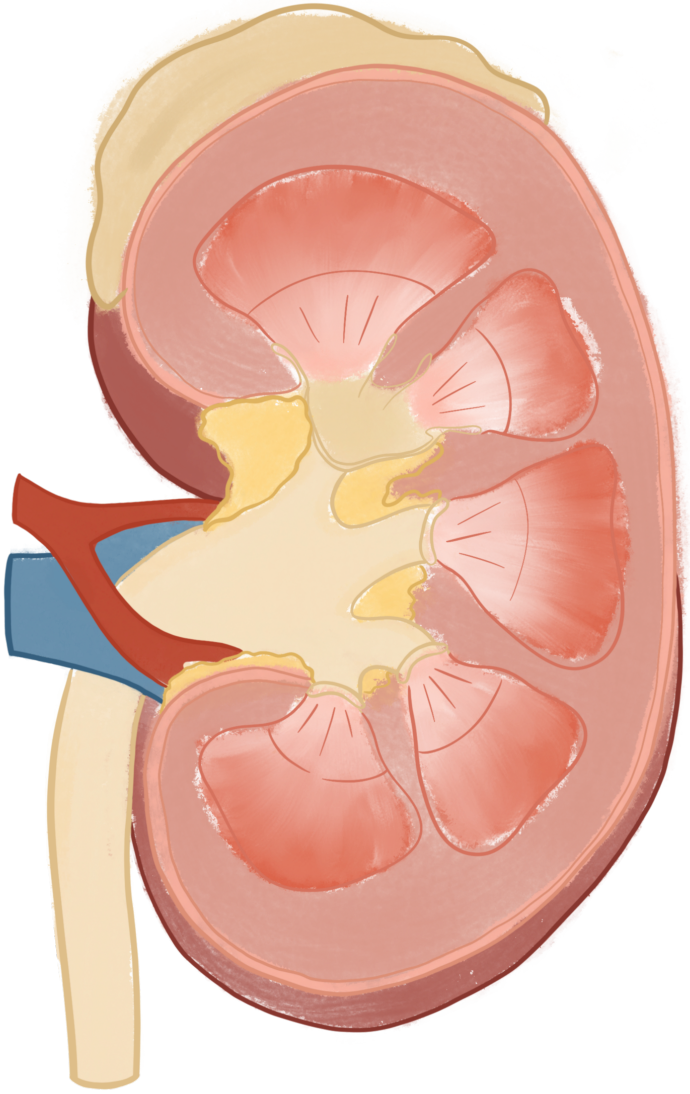


RENAL PHYSIOLOGY

ANSWER KEY

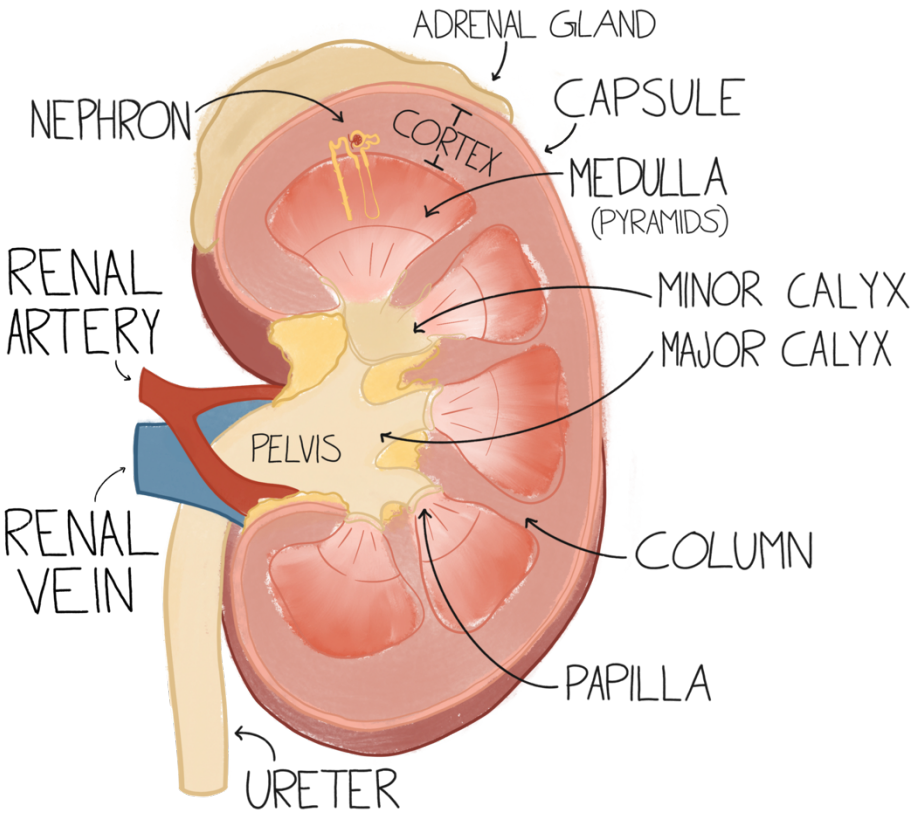
Amalie Misund • Ane Mari Hole • Ida Marie Lisle

Table of Contents

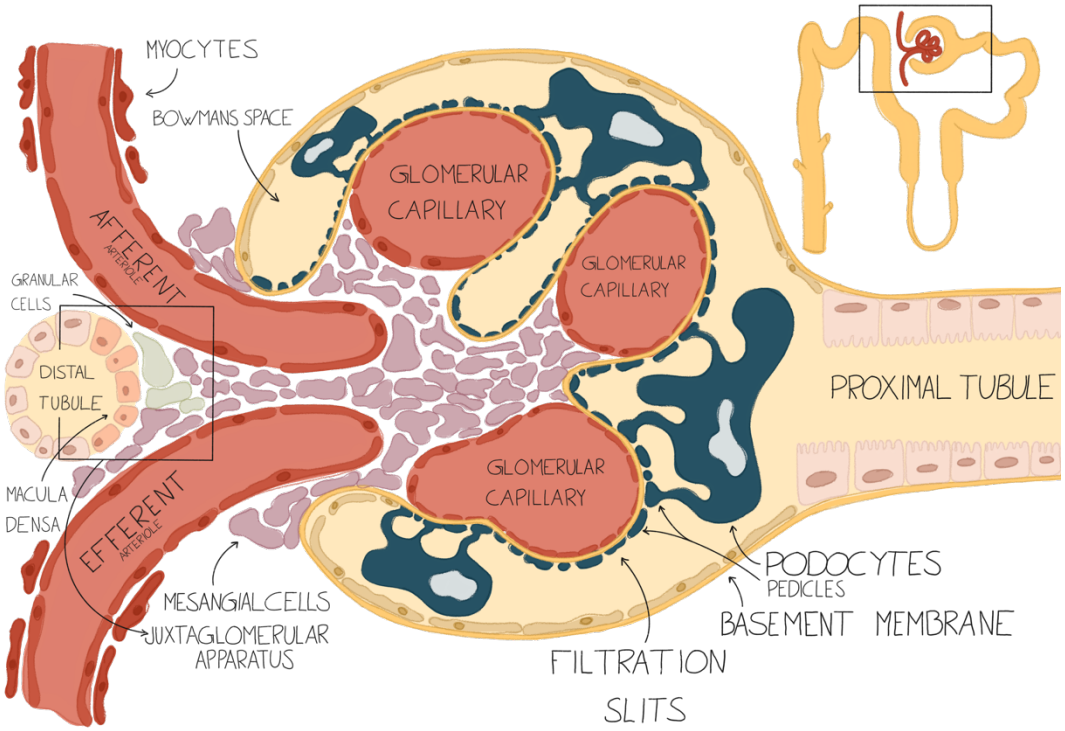
Section 1 – Anatomy of the Kidney

1) Fill in the blank spaces:

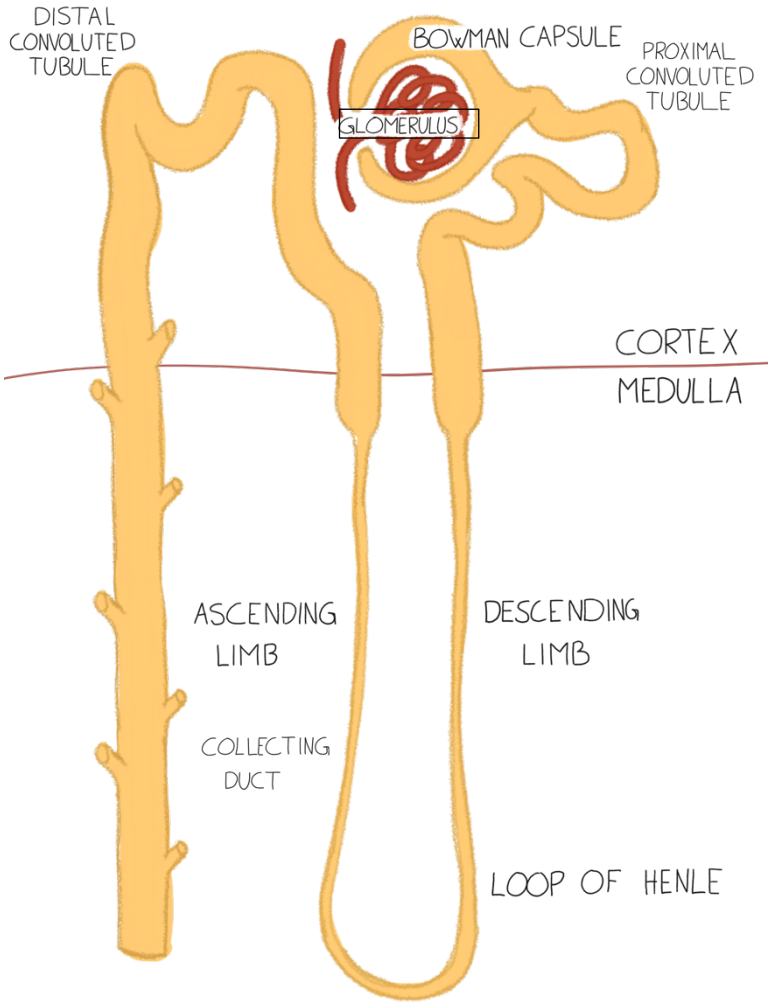
a)



b)



c)


DISTAL CONVOLUTED TUBULE
BOWMAN CAPSULE
PROXIMAL CONVOLUTED TUBULE
GLOMERULUS
CORTEX
MEDULLA
ASCENDING LIMB
DESCENDING LIMB
COLLECTING DUCT
LOOP OF HENLE

Section 2 – Body Fluids

1) What is the 60 – 40 – 20 rule?

a) A rule that tells you that 60% of body water is located inside the cells, 40% is extracellular and 20% is plasma

b) A rule that tells you that 60% of our body weight is water, 40% of that is intracellular, while 20% is extracellular fluid (ECF)

c) A rule that describes the relationship between ions in the ECF: 60% Na^+, 40% Cl^- and 20% HCO_3^-

d) A rule that tells you the relative amounts of plasma components: 60% is water, 40% is red blood cells and 20% is electrolytes

2) Why will women generally have lower total body water than men?

Women will have lower levels of total body water than men, because they generally have higher amounts of adipose tissue.

3) Write how many % of the blood volume plasma and red blood cells take up:

a) Plasma **55** %

b) Red blood cells **45** %

4) Which ions are more prominent in the intracellular fluid?

a) K^+, Mg^{2+} and proteins and organic phosphates

b) Mg^{2+}, Cl^- and HCO_3^-

c) Proteins and organic phosphates and Na^+

d) Na^+, Cl^- and HCO_3^-

e) HCO_3^-, proteins and organic phosphates and Cl^-

5) Which electrolytes are more prominent in the extracellular fluid?

a) K^+, Mg^{2+} and proteins and organic phosphates

b) Mg^{2+}, Cl^- and HCO_3^-

c) Proteins and organic phosphates and Na^+

d) Na^+, Cl^- and HCO_3^-

e) HCO_3^-, proteins and organic phosphates and Cl^-

6) Which type of fluid can be considered an ultrafiltrate?

a) The blood inside capillaries

b) Intracellular fluid

c) Interstitial fluid

d) Urine

7) What characteristic is mainly considered when identifying the appropriate marker to measure body fluid volume?

a) Charge

b) Size

c) Type of molecule (e.g.: Proteins, ions, sugars etc)

8) What is the normal osmolarity of body fluids?

a) 250 mOsm/L

b) 260 mOsm/L

c) 270 mOsm/L

d) 280 mOsm/L

e) 290 mOsm/L

9) Fill in arrows indicating the correct change in the parameters

a) Volume contraction

	Example	ECF volume	ICF volume	Osmolarity	Hematocrit	[Plasma protein]
Hyperosmotic	Sweating[1], fever, DI[2]	↓	↓	↑	–	↑
Isosmotic	Diarrhea, burn wounds	↓	–	–	↑	↑
Hyposmotic	Adrenal insufficiency[3]	↓	↑	↓	↑	↑

b) Volume expansion

	Example	ECF volume	ICF volume	Osmolarity	Hematocrit	[Plasma protein]
Hyperosmotic	↑ NaCl intake	↑	↓	↑	↓	↓
Isosmotic	Isotonic NaCl infusion	↑	–	–	↓	↓
Hyposmotic	SIADH[1]	↑	↑	↓	–	↓

10) Why does hematocrit stay constant in hyperosmotic volume contraction and hypoosmotic volume expansion?

In hyperosmotic volume contraction, when the concentration of red blood cells (RBCs) decreases, water also moves out of the RBCs. The decreased RBC volume works against the increased concentration of RBCs, which leaves the hematocrit unchanged.
The opposite occurs in hypoosmotic volume expansion: The increased ECF volume causes a decreased [RBC], but water will move into the cells, which will increase the RBC volume. This will leave the hematocrit unchanged.

Section 4 – Glomerular Filtration

1) What is the order of the layers in the glomerular filtration barrier?

1: **Fenestrated capillaries**

2: **Basement membrane**

3: **Podocytes**

2) What is the main purpose of negative charge in the glomerular filtration barrier?

a) Repels ions like Na^+ and HCO_3^-

b) Repelling the plasma proteins that are small enough to pass through the basement membrane

c) It has no effect

d) It attracts the solutes like Cl^- and urea

e) b and d

3) Which of the starling forces favors glomerular filtration? Choose the answers you think are correct.

☑ **Water permeability of the glomerular capillaries**

☑ **The hydrostatic pressure in the glomerular capillaries**

☐ The hydrostatic pressure in the Bowman space

☐ Oncotic pressure in the glomerular capillaries

4) How does angiotensin II protect the kidneys in major hemorrhage?

When the pressure in the glomerular capillaries is low, the GFR will be reduced and kidney function can be lost. Angiotensin II prevents this from happening by always causing more constriction of the efferent arteriole than the afferent arteriole, maintaining sufficient hydrostatic pressure.

5) What happens to the GFR (increased or decreased) when:

a) Afferent arteriole constricts ↓

b) Afferent arteriole dilates ↑

c) Efferent arteriole constricts ↑

d) Efferent arteriole dilates ↓

6) How will renal blood flow be affected (increased or decreased) by secretion of these substances? Fill in the empty boxes.

Endogenous substances affecting RBF	RBF
Circulating catecholamines[1]	↓
Angiotensin II (AT-II)	↑/↓
Atrial natriuretic peptide[3]	↑
Prostaglandins	↑
Dopamine	↑

7) Why should we never give NSAIDs with ACE inhibitors?

a) They both increased blood pressure and the patient can go into hypertensive emergency

b) NSAIDs will counteract the effect of ACE inhibitors

c) They both decrease GFR, which can precipitate acute kindey injury

d) They both increase permeability of the glomerular basement membrane which can lead to proteinuria

8) What are the characteristics of and ideal glomerular marker? Can you give an example of an ideal glomerular marker? Why do we not routinely use this marker?

Characteristics of good glomerular markers:

1. Must be freely filtered
2. Cannot be reabsorbed or secreted
3. Cannot alter GFR when administered

Inulin is the ideal glomerular marker, but we don't use it clinically because we have to infuse it before we can measure it (i.e.: Inconvenient)

9) What does the filtration fraction describe?

Filtration fraction describes how much of the fluid that passes through the glomerular capillaries actually reach the renal tubules.

10) How much plasma is normally filtered into the renal tubules?

a) 10%

b) 20%

c) 30%

d) 40%

e) 50%

Section 5 – Reabsorption and Secretion

1) How can we calculate the reabsorption and secretion rate?

Reabsorption/excretion rate = Filtered load – Excretion rate

2) Which ion is glucose dependent on to be reabsorbed in the tubules?
a) Na^+
b) Mg^{2+}
c) Cl^-
d) HCO_3^-
e) Ca^{2+}

3) What is secondary active transport?

Secondary active transport is when a solute relies on another ion gradient to be transported across a membrane – like the Na^+/Glucose cotransport on the luminal membrane where glucose travels against its gradient with Na^+ by relying on the Na^+ concentration gradient maintained by the Na^+/K^+-ATPase on the basolateral membrane.

4) What is the T_m value in the setting of glucose reabsorption?
a) When the filtered load is at its maximum
b) When excretion of glucose start
c) When all the glucose transporters are saturated
d) The point where the affinity of the glucose transporters to glucose is at their highest

5) Which parts of the nephron are permeable to urea?

PCT, descending limb, thin descending limb and the inner medullary collecting ducts

6) Which hormone stimulates facilitated diffusion of urea at the inner medullary collecting duct?

ADH

7) Which drug is secreted through the transporter responsible for secretion of para-aminohippuric acid?

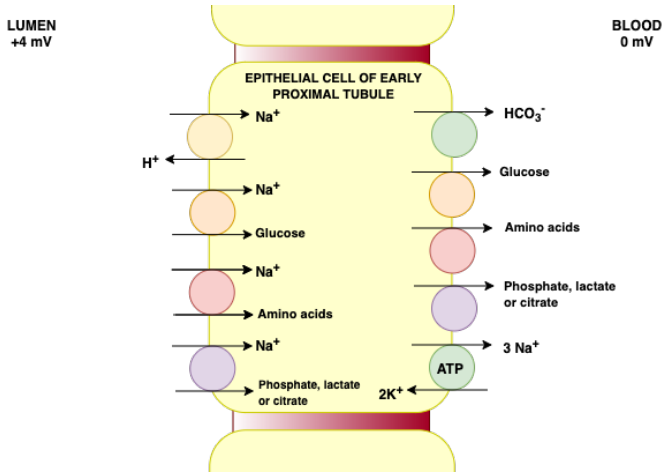
Penicillin

8) Explain why we can use alkalization of urine as a way to treat aspirin overdose.

As we now know, aspirin is an acid, salicylic acid. Alkalizing the urine makes the the salisylic acid stay in its charged form, which makes it unable to diffuse back into the blood and the excretion rate (and clearance) increases.

Section 6 – Sodium Balance

1) Draw in the movement of solutes in the epithelial cell of the early proximal tubule



2) Glomerulotubular balance ensure that the right fraction of filtered load is reabsorbed. Fill in the correct arrows for the mechanism of glomerulotubular balance:

↑ Filtered load: ↑ GFR→ ↑ Filtration fraction→ ↑π_C →↑ Reabsorption

3) Fill in the blanks

Thin descending limb	Thin Ascending limb	Thick Ascending limb
Permeable to water and small solutes (as NaCl and urea)	Permeable to NaCl Impermeable to water	Net reabsorption of Na^+, K^+ and Cl^- Impermeable to water
Passive diffusion of solutes	Passive diffusion of solutes	Active reabsorption by Na^+-K^+-$2Cl^-$ cotransporter.
Water moves out, solutes move in	Solutes moves out, water remains in the lumen	Solute is reabsorbed, water remains in the lumen
Filtrate becomes more *hyper*osmotic as it moves down the thin descending limb	Filtrate becomes *hypo*osmotic as it moves up the thin ascending limb	Tubular fluid become more diluted

4) Aldosterone

a) Increases sodium secretion

b) Increases sodium reabsorption

c) Decreases sodium reabsorption

d) Decrease sodium secretion

5) Name the segment of the nephron, and transporter affected by Thiazide diuretics.

Early distal tubule – NaCl cotransporter

6) PTH inhibits which transporter in the early proximal tubule?

Na^2 – phosphate cotransporter

7) What is the main function of the late proximal tubule?

Net reabsorption of NaCl

8) Explain the term isosmotic reabsorption

Isosmotic reabsorption means that water and solutes is reabsorbed to the same degree. Taking water and sodium in the proximal tubule – the concentration of sodium in the end of the proximal tubule equal to the concentration at the beginning, even though the amount of sodium present is way less.

Section 7 – Potassium Balance

1) Fill in the table: Factors altering the internal K^+ balance

K+ into cell ⟶ Hypokalemia	K+ out of cell ⟶ Hyperkalemia
- High levels of insulin - Alkalemia – blood ↓ [H^+] - β_2 agonists & α antagonists	- Low levels of insulin - Acidemia – blood ↑ [H^+] - α agonists & β_2 antagonists - Hyperosmolarity - Cell lysis - Exercise

2) In which segments of the nephron is potassium reabsorbed?
a) Proximal tubule, thick ascending limb, collecting duct
b) Proximal tubule, thin descending limb and distal convoluted tubule
c**) Proximal tubule, thick ascending limb late distal tubule and collecting duct**
d) Proximal tubule, thick ascending limb early distal tubule

3) How does K^+ sparing diuretics inhibit K^+ secretion?

K^+ sparing diuretics inhibits the effects of aldosterone on principal cells

4) In which segments of the nephron is potassium secreted?

Late distal convoluted tubule and collecting duct

5) How does acidemia and alkalemia affect K^+ distribution?

See 7.1.1 – Mechanisms that alter the distribution of K^+ - II. Acid-Base abnormalities
Alkalemia – blood [H^+] ↓ → H^+ leaves the cells and K^+ enters the cells → hypokalemia
Alkalemia – blood [H^+] ↓ → H^+ leaves the cells and K^+ enters the cells → hypokalemia

6) Chemotherapy and rhabdomyolysis can cause hyperkalemia, how?

In chemotherapy and rhabdomyolysis we have **cell lysis**, and the K^+ large amount of K^+ from inside the cells is released into the extracellular compartment possibly creating hyperkalemia.

7) What happens with the K^+ excretion in a low K^+ diet?

With low K^+ intake, the amount of K^+ excreted in the urine decreases

8) Which factors alter K^+ secretion?

Dietary intake, Aldosterone levels, acid-base disturbances (with some exceptions), Loop diuretics, Thiazide diuretics, K^+ sparing diuretics and luminal anions.

Section 8 – Phosphate, Calcium and Magnesium Balance

True or false	True	False
Thiazide diuretics and PTH increases Ca^{2+} reabsorption in the early distal convoluted tubule	X	
PTH causes decreased excretion of phosphate		X I**ncreased** excretion
Thiazide diuretics can be used to treat hypercalcemia		X **Loop** diuretics
Calcium reabsorption in the proximal convoluted tubule is coupled to Na^+ reabsorption	**X**	

1) Where can we find most of the phosphate in the body?

Bone matrix

2) Where is most of the phosphate reabsorbed?

Proximal convoluted tubule

3) Where is most of magnesium reabsorbed?

Thick ascending limb

4) By what mechanism can Loop diuretic cause hypomagnesemia?

Loop diuretics inhibit the Na^+-K^+-$2Cl^-$ cotransporter in the thick ascending limb, which causes the lumen-positive potential difference by which magnesium is reabsorbed. As this is where 60% of magnesium should be reabsorbed, this significantly increases the magnesium excretion, which can lead to hypomagnesemia.

5) How does changes in volume affect calcium reabsorption?

Calcium reabsorption in PCT is coupled to sodium reabsorption, and sodium reabsorption is affected by changes in volume.

Volume expansion inhibits Na^+ reabsorption $\rightarrow \downarrow Ca^{2+}$ reabsorption

Volume contraction stimulates Na^+ reabsorption $\rightarrow \uparrow Ca^{2+}$ reabsorption

Section 9 – Water Balance

1) Underline correct word:

1. Ingestion of water **inhibits**/stimulates ADH secretion
2. In the presence of ADH principal cells are impermeable/**permeable** to water
3. Result of the single effect is that osmolarity of the ascending limb **decreases**/increases
4. SIADH is a condition with lack of/**excess** ADH secretion

2) Which two effects of ADH increases the corticopapillary gradient?

Enhancing the single effect of countercurrent multiplication

Enabling urea recycling in the inner medulla

3) What is the major structural difference in production of hypersmotic Vs hyposmotic urine?

In hypersmotic urine production, late distal convoluted tubule and collecting ducts are impermeable to water.

4) If free water clearance is positive, what can that tell us about the ADh levels and the state of the urine?

If free water is positive, ADH levels are low or ineffective (nephrogenic diabetes insipidus) and urine is hyposmotic.

5) Explain the mechanism of countercurrent multiplication
See 9.2.0 – Countecurrent multiplication
Countercurrent multiplication is a sequence of events (single effect, and tubular fluids) that builds a gradient of osmolarity in the loop of Henle.

Section 10 – Renin-Angiotensin-Aldosterone System (RAAS)

1) Angiotensinogen is produced in
a) Liver
b) Kidney
c) Lungs
d) Juxtaglomerular cells

2) Which part of the nephron does aldosterone act on
a) Proximal convoluted tubule
b) Distal convoluted tubule
c) Collecting duct
d) C and d are correct

3) Renin secretion by Juxtaglomerular cells is increased by
a) Increasing mean blood pressure
b) Increasing GFR
c) Increasing sympathetic nerve activity
d) Increasing angiotensin II synthesis

4) ADH will be released from the posterior pituitary when there is a decrease in
a) Plasma Na+ concentration
b) Plasma volume
c) Plasma K+ concentration
d) Plasma pH

5) Which of the following statements about renin is true?
a) Its secretion leads to loss of sodium and water from plasma
b) Its secretion is stimulated by increased mean renal arterial pressure
c) It converts angiotensinogen to angiotensin I
d) It converts angiotensin I to angiotensin II

6) How does aldosterone increase blood pressure?

Aldosterone acts on the principal cells of the distal convoluted tubule and collecting ducts, and causes and increase sodium reabsorption and potassium excretion. This leads to an increase ECF volume and blood volume. Increased blood volume → increased blood pressure.

7) How does ADH increase water reabsorption?

ADH acts on the distal convoluted tubule and collecting duct, and activates aquaporins which facilitates diffusion of water.

8) Why does an increase in peripheral resistance increase the blood pressure?

Mean arterial pressure = Cardiac output x Total peripheral resistance

9) Angiotensin I is converted to Angiotensin II by which enzyme?

Angiotensin Converting Enzyme (ACE)

10) The secretion of renin can be activated through which type of receptor?

β_1 adrenoreceptor

Section 11 – Introduction to Acid-Base Physiology

1) How are volatile acids removed from the circulation?

They are expired by the lungs

2) How are non-volatile (fixed) acids removed from the circulation?

They are excreted by the kidneys

3) What is true about venous blood?
a) It contains more CO_2 and will have pH slightly higher than arterial blood
b) It contains less CO_2 and will have pH slightly higher than arterial blood
c) It contains more CO_2 and will have pH slightly lower than arterial blood
d) It contains less CO_2 and will have pH slightly lower than arterial blood

4) Which one is a volatile acid?
a) Methanol
b) CO_2
c) Lactic acid
d) Phospholipids

Section 12 – Buffering

1) Which of these statements is false?
a) If the patient is hypoventilating, bicarbonate must increase to maintain pH
b) Phosphate is the most important extracellular buffer
c) ATP and hemoglobin are examples of intracellular buffers
d) Concentration of bicarbonate is higher than concentration of phosphate in blood

2) How can H^+ enter cells?
a) CO_2 diffuses through the cell membrane, combines with H_2O and generates H^+ inside the cell
b) Co-transport with an organic anion such as lactate
c) In exchange for K^+
d) All the above

3) Which of the statements is true?
a) The concentrations of acid/base are more important than the relationship between them
b) HCO_3^- can be expired by the lungs
c) Phosphate serves as an important buffer in the kidney tubules
d) All the above

Section 13 – Renal Mechanisms in Acid-Base Balance

1) When H^+ is excreted as a titratable acid:
a) It means that it is excreted as NH_4^+
b) It is buffered by phosphate in the tubule

2) Almost all HCO_3^- entering the nephron is reabsorbed in:
a) Thick ascending limb
b) Collecting duct
c) Proximal tubule
d) Distal convoluted tubule

3) Increased HCO_3^- reabsorption is caused by:
a) Decreased pH of blood
b) Increased CO_2 in blood
c) Decreased HCO_3^- in blood
d) All the above

4) Decreased HCO_3^- reabsorption is caused by:
a) Decreased pH of blood
b) Increased ECF volume
c) Decreased CO_2 in blood
d) Activation of RAAS

5) Increased H^+ excretion is caused by all except:
a) Increased pH of blood
b) Decreased pH of blood
c) Increased aldosterone
d) Increased renal catabolism

6) What is false about H^+ excretion as NH_4^+?
a) Some NH_4^+ is reabsorbed from the tubule in thick ascending limb
b) NH_4^+ takes the place of Na^+ on the $Na^+/K^+/2Cl^-$ cotransporter
c) Some NH_4^+ is not reabsorbed in thick ascending limb and follows the tubule to collecting duct
d) NH_3 is excreted in the collecting duct and combines with H^+ to form NH_4^+ in the tubule

7) Diabetic ketoacidosis and chronic renal failure will cause:
a) No change in pH
b) Decreased reabsorption of HCO_3^-
c) Metabolic alkalosis
d) Metabolic acidosis

Section 14 – Acid-Base Disorders

1) A patient with metabolic acidosis will:
a) Hypoventilate
b) Hyperventilate

2) A patient with metabolic alkalosis will:
a) Hypoventilate
b) Hyperventilate

3) Calculating the osmotic gap is important when finding differential diagnosis for:
a) Metabolic acidosis
b) Metabolic alkalosis
c) Respiratory acidosis
d) Respiratory alkalosis

4) Find two correct statements:
a) Acidosis causes hyperkalemia
b) Alkalosis causes hyperkalemia
c) Acidosis causes hypokalemia
d) Alkalosis causes hypokalemia

4) Follow the diagram above on how to interpret ABG results. Establish if the disorder is:

- Acidosis or alkalosis
- Respiratory or metabolic
- Compensated or uncompensated
- Simple or mixed

a) After a panic attack, ABG results are:
pH 7.50
CO_2 29
HCO_3^- 25
Answer: Simple Respiratory alkalosis, uncompensated

b) A patient presents to the ER with confusion, problems with balance and visual disturbances. His respiratory rate is 35. ABG results are:
pH 7.26
CO_2 30
HCO_3^- 15
Answer: Simple Metabolic Acidosis, uncompensated. Potentially caused by methanol poisoning.

c) Patient presents to the GP office due to several days of diarrhea. She seems very unwell. Blood pressure is 86/52, pulse 115 and respiratory rate 23. The doctor sends her to hospital where fluids are started to increase the blood pressure. ABG results are:
pH 7.37
CO_2 31
HCO_3^- 20
Answer: Simple Metabolic acidosis, compensated. Caused by intestinal loss of HCO_3^-.


studyaid