

GUYTON AND HALL PHYSIOLOGY REVIEW

THIRD EDITION

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ELSEVIER

UNIT V

blue: Filteration and reabsorbtion

Yellow: Urine concentration and osmolarity

Pink: K+ regulation and acid-base balance

Mid material

Final material

The Body Fluids and Kidneys

1. Which of the following solutions, when infused intravenously, would result in an increase in extracellular fluid volume, a decrease in intracellular fluid volume, and an increase in total body water after osmotic equilibrium?
   A) 1 Liter of 0.9% sodium chloride (NaCl) solution
   B) 1 Liter of 0.45% NaCl solution
   C) 1 Liter of 3% NaCl solution
   D) 1 Liter of 5% dextrose solution
   E) 1 Liter of pure water

2. Partial obstruction of a major vein draining a tissue would tend to __________ lymph flow rate, __________ interstitial fluid hydrostatic pressure, and __________ interstitial fluid protein concentration in the tissue drained by that vein.
   A) Increase, increase, increase
   B) Increase, increase, decrease
   C) Increase, decrease, decrease
   D) Decrease, decrease, decrease
   E) Decrease, increase, increase
   F) Decrease, increase, decrease

3. A 36-year-old woman reports headaches and frequent urination. Laboratory values reveal the following information.

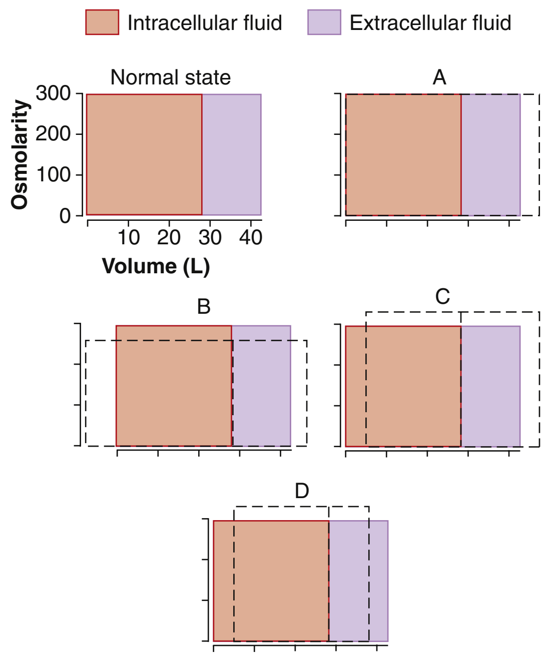
   Urine specific gravity = 1.003
   Urine protein = negative
   Plasma sodium (Na^+) = 165 mmol/L
   Plasma potassium (K^+) = 4.4 mmol/L
   Plasma creatinine = 1.4 mg/dl
   Blood pressure = 88/40 mm Hg
   Heart rate = 115 beats/min

   What is the most likely cause of her elevated plasma Na^+ concentration?

   A) Primary aldosteronism
   B) Diabetes mellitus
   C) Diabetes insipidus
   D) Simple dehydration due to insufficient water intake and heavy exercise
   E) Bartter's syndrome
   F) Liddle's syndrome

4. After receiving a kidney transplant, a patient has severe hypertension (170/110 mm Hg). A renal arteriogram indicates severe renal artery stenosis in his single remaining kidney, with a reduction in glomerular filtration rate (GFR) to 25% of normal. Which of the following changes, compared with normal, would be expected in this patient, assuming steady-state conditions?
   A) A large increase in plasma sodium concentration
   B) A reduction in urinary sodium excretion to 25% of normal
   C) A reduction in urinary creatinine excretion to 25% of normal
   D) An increase in serum creatinine to about four times normal
   E) Normal renal blood flow in the stenotic kidney due to autoregulation

Questions 5–7



The figure above represents various states of abnormal hydration. In each diagram, the normal state (orange and lavender) is superimposed on the abnormal state (dashed lines) to illustrate the shifts in the volume (width of rectangles) and total osmolarity (height of rectangles) of the extracellular and intracellular fluid compartments. Use this figure to answer Questions 5–7.

5. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volume and osmolarity after the infusion of 1% dextrose?
   A) A
   B) B
   C) C
   D) D

6. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volume and osmolarity in a patient with the syndrome of inappropriate antidiuretic hormone (ADH; i.e., excessive secretion of ADH)?
   A) A
   B) B
   C) C
   D) D

7. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volumes and osmolarities after the infusion of 3% NaCl?
   A) A
   B) B
   C) C
   D) D

8. Which of the following tends to decrease potassium secretion by the cortical collecting tubule?
   A) Increased plasma potassium concentration
   B) A diuretic that decreases proximal tubule sodium reabsorption
   C) A diuretic that inhibits the action of aldosterone (e.g., spironolactone)
   D) Acute alkalosis
   E) High sodium intake

9. Because the usual rate of phosphate filtration exceeds the transport maximum for phosphate reabsorption, which statement is true?
   A) All the phosphate that is filtered is reabsorbed
   B) More phosphate is reabsorbed than is filtered
   C) Phosphate in the tubules can contribute significantly to titratable acid in the urine
   D) The "threshold" for phosphate is usually not exceeded
   E) Parathyroid hormone must be secreted for phosphate reabsorption to occur

Questions 10 and 11

Use the following clinical laboratory test results to answer Questions 10 and 11.

Urine flow rate = 1 ml/min
Urine inulin concentration = 100 mg/ml
Plasma inulin concentration = 2 mg/ml
Urine urea concentration = 50 mg/ml
Plasma urea concentration = 2.5 mg/ml

10. What is the GFR?
   A) 25 ml/min
   B) 50 ml/min
   C) 100 ml/min
   D) 125 ml/min
   E) None of the above

11. What is the net urea reabsorption rate?
   A) 0 mg/min
   B) 25 mg/min
   C) 50 mg/min
   D) 75 mg/min
   E) 100 mg/min

12. If a patient has a creatinine clearance of 90 ml/min, a urine flow rate of 1 ml/min, a plasma K^+ concentration of 4 mEq/L, and a urine K^+ concentration of 60 mEq/L, what is the approximate rate of K^+ excretion?
   A) 0.06 mEq/min
   B) 0.30 mEq/min
   C) 0.36 mEq/min
   D) 3.6 mEq/min
   E) 60 mEq/min

13. Given the following measurements, calculate the filtration fraction:

   Glomerular capillary hydrostatic pressure (P_G) = 70 mm Hg
   Bowman's space hydrostatic pressure (P_B) = 20 mm Hg
   Colloid osmotic pressure in the glomerular capillaries (π_G) = 35 mm Hg
   Glomerular capillary filtration coefficient (K_f) = 10 ml/min/mm Hg
   Renal plasma flow = 428 ml/min

   A) 0.16
   B) 0.20
   C) 0.25
   D) 0.30
   E) 0.35
   F) 0.40

14. In normal kidneys, which of the following is true of the osmolarity of renal tubular fluid that flows through the early distal tubule in the region of the macula densa?
   A) Usually isotonic compared with plasma
   B) Usually hypotonic compared with plasma
   C) Usually hypertonic compared with plasma
   D) Hypertonic, compared with plasma, in antidiuresis

15. Which of the following changes would be expected in a patient with diabetes insipidus due to a lack of ADH secretion?

	Plasma Osmolarity Concentration	Plasma Sodium Concentration	Plasma Renin	Urine Volume
A)	↔	↔	↓	↑
B)	↔	↔	↑	↑
C)	↑	↑	↑	↑
D)	↑	↑	↔	↔
E)	↓	↓	↓	↔

16. A 26-year-old woman recently decided to adopt a healthier diet and eat more fruits and vegetables. As a result, her potassium intake increased from 80 to 160 mmol/day. Which of the following conditions would you expect to find 2 weeks after she increased her potassium intake, compared with before the increase?

	Potassium Excretion Rate	Sodium Excretion Rate	Plasma Aldosterone Concentration	Plasma Potassium Concentration
A)	↔	↔	↑	Large increase (>1 mmol/L)
B)	↔	↓	↑	Small increase (<1 mmol/L)
C)	↑2×	↔	↑	Small increase (<1 mmol/L)
D)	↑2×	↑	↓	Large increase (>1 mmol/L)
E)	↑2×	↑	↔	Large increase (>1 mmol/L)

17. When the dietary intake of K^+ increases, body K^+ balance is maintained by an increase in K^+ excretion primarily by which of the following?
    A) Decreased glomerular filtration of K^+
    B) Decreased reabsorption of K^+ by the proximal tubule
    C) Decreased reabsorption of K^+ by the thick ascending limb of the loop of Henle
    D) Increased K^+ secretion by the late distal and collecting tubules
    E) Shift of K^+ into the intracellular compartment

18. Which of the following would cause the greatest decrease in GFR in a person with otherwise normal kidneys?
    A) Decrease in renal arterial pressure from 100 to 80 mm Hg in a normal kidney
    B) 50% increase in glomerular capillary filtration coefficient
    C) 50% increase in proximal tubular sodium reabsorption
    D) 50% decrease in afferent arteriolar resistance
    E) 50% decrease in efferent arteriolar resistance
    F) 5 mm Hg decrease in Bowman's capsule pressure

19. An 8-year-old boy is brought to your office with extreme swelling of the abdomen. His parents indicate that he had a very sore throat a "month or so" ago and that he has been "swelling up" since that time. He appears to be edematous, and when you check his urine, you find that large amounts of protein are being excreted. Your diagnosis is nephrotic syndrome subsequent to glomerulonephritis. Which of the following changes would you expect to find, compared with normal?

	Thoracic Lymph Flow	Interstitial Fluid Protein Concentration	Interstitial Fluid Hydrostatic Pressure	Plasma Renin Concentration
A)	↑	↓	↑	↑
B)	↑	↓	↑	↔
C)	↑	↓	↔	↑
D)	↓	↑	↔	↔
E)	↓	↓	↓	↓

20. A patient with severe hypertension (blood pressure 185/110 mm Hg) is referred to you. A renal magnetic resonance imaging scan shows a tumor in the kidney, and laboratory findings include a very high plasma renin activity of 12 ng angiotensin I/ml/h (normal = 1). The diagnosis is a renin-secreting tumor. Which of the following changes would you expect to find in this patient, under steady-state conditions, compared with normal?

	Plasma Aldosterone Concentration	Sodium Excretion Rate	Plasma Potassium Concentration	Renal Blood Flow
A)	↔	↓	↓	↑
B)	↔	↔	↓	↑
C)	↑	↔	↓	↓
D)	↑	↓	↔	↓
E)	↑	↓	↓	↔

21. The clinical laboratory returned the following values for arterial blood taken from a patient: plasma pH = 7.28, plasma HCO_3^- = 32 mEq/L, and plasma partial pressure of carbon dioxide (P_{CO_2}) = 70 mm Hg. What is this patient's acid-base disorder?
    A) Acute respiratory acidosis without renal compensation
    B) Respiratory acidosis with partial renal compensation
    C) Acute metabolic acidosis without respiratory compensation
    D) Metabolic acidosis with partial respiratory compensation

22. The following laboratory values were obtained in a 58-year-old man:

    Urine volume = 4320 milliliters of urine collected during the preceding 24 hours
    Plasma creatinine = 3 mg/100 ml
    Urine creatinine = 50 mg/100 ml
    Plasma potassium = 4.0 mmol/L
    Urine potassium = 30 mmol/L

What is his approximate GFR, assuming that he collected all of his urine in the 24-hour period?

A) 20 ml/min
B) 30 ml/min
C) 40 ml/min
D) 50 ml/min
E) 60 ml/min
F) 80 ml/min
G) 100 ml/min

Questions 23 and 24

23. A 65-year-old man had a heart attack and experiences cardiopulmonary arrest while being transported to the emergency department. Use the following laboratory values obtained from arterial blood to answer Questions 23 and 24.

Plasma pH = 7.12
Plasma P_{CO_2} = 60 mm Hg
Plasma HCO_3^- concentration = 19 mEq/L

Which of the following options best describes his acid-base disorder?

A) Respiratory acidosis with partial renal compensation
B) Metabolic acidosis with partial respiratory compensation
C) Mixed acidosis: combined metabolic and respiratory acidosis
D) Mixed alkalosis: combined respiratory and metabolic alkalosis

24. In this patient, which of the following laboratory results would be expected, compared with normal?

A) Increased renal excretion of bicarbonate (HCO_3^-)
B) Decreased urinary titratable acid
C) Increased urine pH
D) Increased renal excretion of ammonia (NH_4^+)

25. What would cause the greatest degree of hyperkalemia?

A) Increase in potassium intake from 60 to 180 mmol/day in a person with normal kidneys and a normal aldosterone system
B) Chronic treatment with a diuretic that inhibits the action of aldosterone
C) Decrease in sodium intake from 200 to 100 mmol/day
D) Chronic treatment with a diuretic that inhibits loop of Henle Na^+-$2Cl^-$-K^+ co-transport
E) Chronic treatment with a diuretic that inhibits sodium reabsorption in the collecting ducts

26. Which of the following changes would be expected in a patient with Liddle's syndrome (i.e., excessive activity of amiloride-sensitive sodium channel in the collecting tubule) under steady-state conditions, assuming that the intake of electrolytes remained constant?

	Plasma Renin Concentration	Blood Pressure	Sodium Excretion Concentration	Plasma Aldosterone
A)	↔	↑	↓	↔
B)	↑	↑	↔	↑
C)	↑	↑	↓	↓
D)	↓	↑	↔	↓
E)	↓	↑	↓	↓
F)	↓	↓	↑	↑

27. A patient is referred for treatment of hypertension. After testing, you discover that he has a very high level of plasma aldosterone, and your diagnosis is Conn's syndrome. Assuming no change in electrolyte intake, which of the following changes would you expect to find, compared with normal?

	Plasma pH	Plasma K^+ Concentration	Urine K^+ Excretion	Urine Na^+ Excretion	Plasma Renin Concentration
A)	↑	↓	↔	↔	↓
B)	↓	↓	↔	↔	↓
C)	↑	↓	↑	↓	↓
D)	↑	↑	↔	↓	↑
E)	↑	↑	↑	↑	↑

28. A patient with renal disease had a plasma creatinine of 2 mg/dl during an examination 6 months ago. You note that his blood pressure has increased about 30 mm Hg since his previous visit, and laboratory tests indicate that his plasma creatinine is now 4 mg/dl. Which of the following changes, compared with his previous visit, would you expect to find, assuming steady-state conditions and no changes in electrolyte intake or metabolism?

	Sodium Excretion Rate	Creatinine Excretion Rate	Creatinine Clearance	Filtered Load of Creatinine
A)	↔	↔	↓ by 50%	↓
B)	↔	↔	↓ by 50%	↔
C)	↔	↔	↓ by 75%	↓
D)	↓	↓	↔	↔
E)	↓	↓	↓ by 50%	↓

29. Which change tends to increase GFR?

A) Increased afferent arteriolar resistance
B) Decreased efferent arteriolar resistance
C) Increased glomerular capillary filtration coefficient
D) Increased Bowman's capsule hydrostatic pressure
E) Decreased glomerular capillary hydrostatic pressure

30. Which of the following changes, compared with normal, would you expect to find 3 weeks after a patient ingested a toxin that caused sustained impairment of proximal tubular NaCl reabsorption? Assume that there has been no change in diet or ingestion of electrolytes.

	Glomerular Filtration Rate	Afferent Arteriolar Resistance	Sodium Excretion
A)	↔	↔	↑
B)	↔	↔	↑
C)	↓	↑	↑
D)	↓	↑	↔
E)	↑	↓	↔

31. What is the net renal tubular reabsorption rate of potassium in the patient described in Question 5?
   A) 0.020 mmol/min
   B) 0.040 mmol/min
   C) 0.090 mmol/min
   D) 0.110 mmol/min
   E) 0.200 mmol/min
   F) Potassium is not reabsorbed in this example

32. The maximum clearance rate possible for a substance that is totally cleared from the plasma is equal to which of the following?
   A) GFR
   B) Filtered load of that substance
   C) Urinary excretion rate of that substance
   D) Renal plasma flow
   E) Filtration fraction

33. A patient has the following laboratory values: arterial pH = 7.13, plasma HCO_3^- = 15 mEq/L, plasma chloride concentration = 118 mEq/L, arterial P_{CO_2} = 28 mm Hg, and plasma Na^+ concentration = 141 mEq/L. What is the most likely cause of his acidosis?
   A) Salicylic acid poisoning
   B) Diabetes mellitus
   C) Diarrhea
   D) Emphysema

34. The GFR of a 26-year-old man with glomerulonephritis decreases by 50% and remains at that level. For which substance would you expect to find the greatest increase in plasma concentration?
   A) Creatinine
   B) K^+
   C) Glucose
   D) Na^+
   E) Phosphate
   F) H^+

Questions 35 and 36

Assume the following initial conditions: intracellular fluid volume = 40% of body weight before fluid administration, extracellular fluid volume = 20% of body weight before fluid administration, molecular weight of NaCl = 58.5 g/mol, and no excretion of water or electrolytes.

35. A male patient appears to be dehydrated, and after obtaining a plasma sample, you find that he has hyponatremia, with a plasma sodium concentration of 130 mmol/L and a plasma osmolarity of 260 mOsm/L. You decide to administer 2 L of 3% sodium chloride (NaCl). His body weight was 60 kilograms before the fluid is administered. What is his approximate plasma osmolarity after administration of the NaCl solution and after osmotic equilibrium? Assume the initial conditions previously described.
   A) 273 mOsm/L
   B) 286 mOsm/L
   C) 300 mOsm/L
   D) 310 mOsm/L
   E) 326 mOsm/L

36. What is the approximate extracellular fluid volume in this patient after administration of the NaCl solution and after osmotic equilibrium?
   A) 15.1 Liters
   B) 17.2 Liters
   C) 19.1 Liters
   D) 19.8 Liters
   E) 21.2 Liters

37. Which changes would you expect to find after administering a vasodilator drug that caused a 50% decrease in afferent arteriolar resistance and no change in arterial pressure?
   A) Decreased renal blood flow, decreased GFR, and decreased peritubular capillary hydrostatic pressure
   B) Decreased renal blood flow, decreased GFR, and increased peritubular capillary hydrostatic pressure
   C) Increased renal blood flow, increased GFR, and increased peritubular capillary hydrostatic pressure
   D) Increased renal blood flow, increased GFR, and no change in peritubular capillary hydrostatic pressure
   E) Increased renal blood flow, increased GFR, and decreased peritubular capillary hydrostatic pressure

38. If the average hydrostatic pressure in the glomerular capillaries is 50 mm Hg, the hydrostatic pressure in the Bowman's space is 12 mm Hg, the average colloid osmotic pressure in the glomerular capillaries is 30 mm Hg, and there is no protein in the glomerular ultrafiltrate, what is the net pressure driving glomerular filtration?
   A) 8 mm Hg
   B) 32 mm Hg
   C) 48 mm Hg
   D) 60 mm Hg
   E) 92 mm Hg

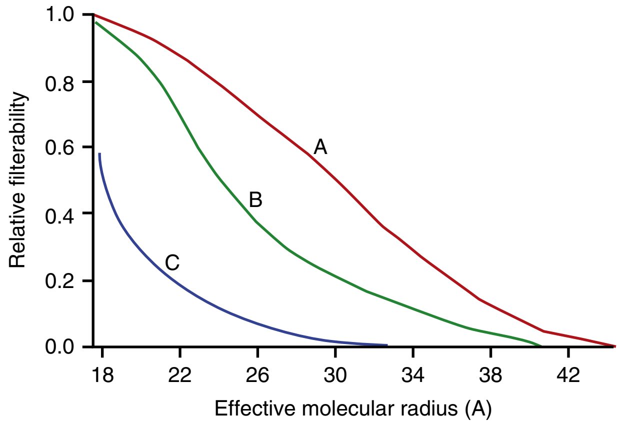
UNIT V

39. In a patient who has chronic, uncontrolled diabetes mellitus, which set of conditions would you expect to find, compared with normal?

	Titratable Acid Excretion	NH^+ Excretion	HCO_3^- Excretion	Plasma P_{CO_2}
A)	↔	↑	↓	↔
B)	↓	↑	↔	↓
C)	↑	↑	↔	↑
D)	↑	↑	↓	↓
E)	↓	↓	↓	↓
F)	↔	↑	↓	↔

40. Intravenous infusion of 1 liter of 0.45% NaCl solution (molecular weight of NaCl = 58.5) would cause which of the following changes, after osmotic equilibrium?

	Intracellular Fluid Volume	Intracellular Fluid Osmolarity	Extracellular Fluid Volume	Extracellular Fluid Osmolarity
A)	↑	↑	↑	↑
B)	↑	↓	↑	↓
C)	↔	↑	↑	↑
D)	↓	↑	↑	↑
E)	↓	↓	↓	↓



41. Lines A, B, and C on the figure above show the relative filterability by the glomerular capillaries of dextran molecules as a function of their molecular radius and electrical charges. Which lines on the graph best describe the electrical charges of the dextrans?

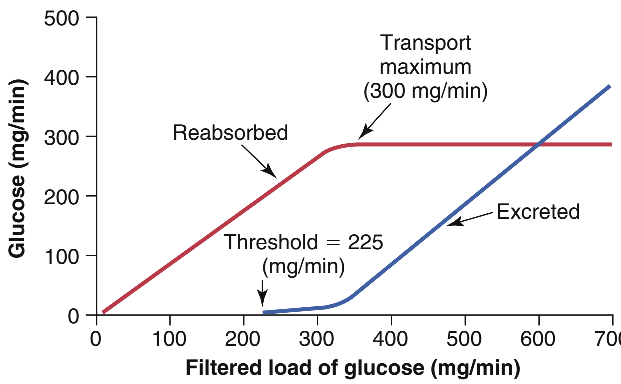
A) A = polycationic; B = neutral; C= polyanionic
B) A = polycationic; B = polyanionic; C = neutral
C) A = polyanionic; B = neutral; C = polycationic
D) A = polyanionic; B = polycationic; C = polycationic
E) A = neutral; B = polycationic; C = polyanionic
F) A = neutral; B = polyanionic; C = polycationic

42. If distal tubule fluid creatinine concentration is 5 mg/100 ml and plasma creatinine concentration is 1.0 mg/100 ml, what is the approximate percentage of the water filtered by the glomerular capillaries that remains in the distal tubule?

A) 5%
B) 10%
C) 20%
D) 50%
E) 80%
F) 95%

43. Which change tends to increase peritubular capillary fluid reabsorption?

A) Increased blood pressure
B) Decreased filtration fraction
C) Increased efferent arteriolar resistance
D) Decreased angiotensin II
E) Increased renal blood flow



44. A 32-year-old man reports frequent urination. He is overweight (280 pounds [127 kilograms], 5 feet 10 inches [178 cm] tall). After measuring the 24-hour creatinine clearance, you estimate his GFR to be 150 ml/min. His plasma glucose level is 300 mg/dl. Assuming that his renal transport maximum for glucose is normal, as shown in the figure above, what would be this patient's approximate rate of urinary glucose excretion?

A) 0 mg/min
B) 100 mg/min
C) 150 mg/min
D) 225 mg/min
E) 300 mg/min
F) Information provided is inadequate to estimate the glucose excretion rate

45. An adrenal tumor that causes excess aldosterone secretion would tend to __________ plasma K^+ concentration, __________ plasma pH, __________ renin secretion, and __________ blood pressure.

A) Decrease, decrease, decrease, decrease
B) Decrease, increase, decrease, increase
C) Decrease, decrease, decrease, increase
D) Decrease, increase, increase, increase
E) Increase, increase, decrease, increase
F) Increase, decrease, decrease, increase

46. Which of the following tends to increase potassium secretion by the cortical collecting tubule?
 A) A diuretic that inhibits the action of aldosterone (e.g., spironolactone)
 B) A diuretic that decreases loop of Henle sodium reabsorption (e.g., furosemide)
 C) Decreased plasma potassium concentration
 D) Acute metabolic acidosis
 E) Low sodium intake

47. A diabetic patient has chronic renal disease and is referred to your nephrology clinic. According to his family physician, his creatinine clearance has decreased from 100 ml/min to 40 ml/min during the past 4 years. His glucose level has not been well controlled, and his plasma pH is 7.14. Which changes, compared with before the development of renal disease, would you expect to find, assuming steady-state conditions and no change in electrolyte intake?

	Sodium Excretion Rate	Creatinine Excretion Rate	Plasma Creatinine Concentration	Plasma HCO_3^- Concentration	NH_4^+ Excretion Rate
A)	↓	↓	↑	↑	↑
B)	↔	↔	↑	↓	↑
C)	↔	↔	↑	↓	↔
D)	↔	↓	↑	↓	↔
E)	↓	↓	↓	↓	↑
F)	↓	↓	↓	↓	↓

48. A 62-year-old woman has previously had a unilateral nephrectomy after diagnosis of renal carcinoma. Her GFR (estimated from creatinine clearance) is 50 ml/min, her urine flow rate is 2.0 ml/min, and her plasma glucose concentration is 200 mg/100 ml. If she has a kidney transport maximum for glucose of 150 mg/min, what would be her approximate rate of glucose excretion?
 A) 0 mg/min
 B) 50 mg/min
 C) 100 mg/min
 D) 150 mg/min
 E) 200 mg/min
 F) 300 mg/min
 G) Glucose excretion rate cannot be estimated from these data

49. A 20-year-old woman comes to your office because of rapid weight gain and marked fluid retention. Her blood pressure is 105/65 mm Hg, her plasma protein concentration is 3.6 g/dl (normal = 7.0), and she has no detectable protein in her urine. Which changes would you expect to find, compared with normal?

	Thoracic Lymph Flow	Interstitial Fluid Protein Concentration	Capillary Filtration	Interstitial Fluid Pressure
A)	↓	↓	↓	↓
B)	↓	↑	↔	↔
C)	↑	↓	↑	↑
D)	↑	↓	↑	↔
E)	↑	↑	↑	↑

50. A 48-year-old woman reports severe polyuria (producing about 0.5 liter of urine each hour) and polydipsia (drinking two to three glasses of water every hour). Her urine contains no glucose, and she is placed on overnight water restriction for further evaluation. The next morning, she is weak and confused, her sodium concentration is 160 mEq/L, and her urine osmolarity is 80 mOsm/L. Which of the following is the most likely diagnosis?
 A) Diabetes mellitus
 B) Diabetes insipidus
 C) Primary aldosteronism
 D) Renin-secreting tumor
 E) Syndrome of inappropriate ADH

51. Which substance is filtered most readily by the glomerular capillaries?
 A) Albumin in plasma
 B) Neutral dextran with a molecular weight of 25,000
 C) Polycationic dextran with a molecular weight of 25,000
 D) Polyanionic dextran with a molecular weight of 25,000
 E) Red blood cells

52. A 22-year-old woman runs a 10-kilometer race on a hot day and becomes dehydrated. Assuming that her ADH levels are very high and that her kidneys are functioning normally, in which part of the renal tubule is the most water reabsorbed?
 A) Proximal tubule
 B) Loop of Henle
 C) Distal tubule
 D) Cortical collecting tubule
 E) Medullary collecting duct

53. Furosemide (Lasix) is a diuretic that also produces natriuresis. Which of the following is an undesirable side effect of furosemide due to its site of action on the renal tubule?
   A) Edema
   B) Hyperkalemia
   C) Hypercalcemia
   D) Decreased ability to concentrate the urine
   E) Heart failure

54. A female patient has unexplained severe hypernatremia (plasma Na^+ = 167 mmol/L) and reports frequent urination and large urine volumes. A urine specimen reveals that the Na^+ concentration is 15 mmol/L (very low) and the osmolarity is 155 mOsm/L (very low). Laboratory tests reveal the following data: plasma renin activity = 3 ng angiotensin I/ml/h (normal = 1.0), plasma ADH = 30 pg/ml (normal = 3 pg/ml), and plasma aldosterone = 20 ng/dl (normal = 6 ng/dl). Which of the following is the most likely reason for her hypernatremia?
   A) Simple dehydration due to decreased water intake
   B) Nephrogenic diabetes insipidus
   C) Central diabetes insipidus
   D) Syndrome of inappropriate ADH
   E) Primary aldosteronism
   F) Renin-secreting tumor

55. Which change would you expect to find in a dehydrated person deprived of water for 24 hours?
   A) Decreased plasma renin activity
   B) Decreased plasma antidiuretic hormone concentration
   C) Increased plasma atrial natriuretic peptide concentration
   D) Increased water permeability of the collecting duct

56. Juvenile (type 1) diabetes mellitus is often diagnosed because of polyuria (high urine flow) and polydipsia (frequent drinking) that occur because of which of the following?
   A) Increased delivery of glucose to the collecting duct interferes with the action of antidiuretic hormone
   B) Increased glomerular filtration of glucose increases Na^+ reabsorption via the sodium-glucose co-transporter
   C) When the filtered load of glucose exceeds the renal threshold, a rising glucose concentration in the proximal tubule decreases the osmotic driving force for water reabsorption
   D) High plasma glucose concentration decreases thirst
   E) High plasma glucose concentration stimulates ADH release from the posterior pituitary

57. Which of the following would cause the most serious hypokalemia?
   A) A decrease in potassium intake from 150 mEq/day to 60 mEq/day
   B) An increase in sodium intake from 100 to 200 mEq/day
   C) Excessive aldosterone secretion plus high sodium intake
   D) Excessive aldosterone secretion plus low sodium intake
   E) A patient with Addison's disease
   F) Treatment with a β-adrenergic blocker
   G) Treatment with spironolactone

58. A 26-year-old woman reports that she has had a severe migraine and has taken six times more than the recommended dose of aspirin for the past 3 days to relieve her headaches. Her plasma pH is 7.24. Which of the following would you expect to find (compared with normal)?

	Plasma HCO_3^- Concentration	Plasma P_{CO_2}	Urine HCO_3^- Excretion	Urine NH_4^+ Excretion	Plasma Anion Gap
A)	↑	↓	↑	↑	↑
B)	↑	↑	↑	↓	↑
C)	↓	↓	↓	↓	↓
D)	↓	↓	↓	↑	↑
E)	↓	↓	↓	↑	↓
F)	↓	↔	↓	↓	↔

59. Under conditions of normal renal function, what is true of the concentration of urea in tubular fluid at the end of the proximal tubule?
   A) It is higher than the concentration of urea in tubular fluid at the tip of the loop of Henle
   B) It is higher than the concentration of urea in the plasma
   C) It is higher than the concentration of urea in the final urine in antidiuresis
   D) It is lower than plasma urea concentration because of active urea reabsorption along the proximal tubule

60. You begin treating a hypertensive patient with a powerful loop diuretic (e.g., furosemide). Which changes would you expect to find, compared with pretreatment values, when he returns for a follow-up examination 2 weeks later?

	Urine Sodium Excretion	Extracellular Fluid Volume	Blood Pressure	Plasma Potassium Concentration
A)	↑	↓	↓	↓
B)	↑	↓	↔	↔
C)	↔	↓	↓	↓
D)	↔	↓	↔	↔
E)	↑	↔	↓	↑

61. Which change, compared with normal, would be expected to occur, under steady-state conditions, in a patient whose severe renal disease has reduced the number of functional nephrons to 25% of normal?
    A) Increased GFR of the surviving nephrons
    B) Decreased urinary creatinine excretion rate
    C) Decreased urine flow rate in the surviving nephrons
    D) Decreased urinary excretion of sodium
    E) Increased urine-concentrating ability

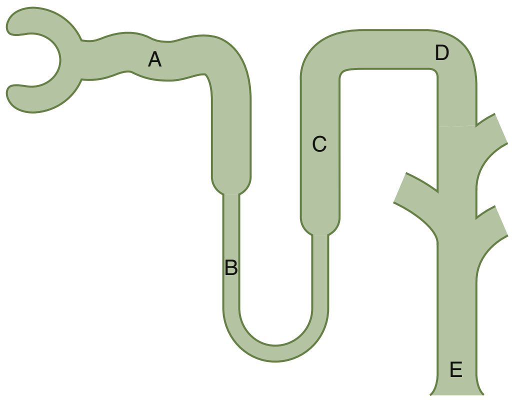
62. Which of the following would likely lead to hyponatremia?
    A) Excessive ADH secretion
    B) Restriction of fluid intake
    C) Excess aldosterone secretion
    D) Administration of 2 liters of 3% NaCl solution
    E) Administration of 2 liters of 0.9% NaCl solution

63. Assuming steady-state conditions and that water and electrolyte intake remained constant, a 75% loss of nephrons and a 75% decrease in GFR due to chronic kidney disease would cause all of the following changes *except* what?
    A) A large increase in plasma sodium concentration
    B) An increase in plasma creatinine to four times normal
    C) An increase in average volume excreted per remaining nephron to four times normal
    D) A significant increase in plasma phosphate concentration
    E) Reduced ability of the kidney to maximally concentrate the urine

64. Which statement is correct?
    A) Urea reabsorption in the medullary collecting tubule is less than in the distal convoluted tubule during antidiuresis
    B) Urea concentration in the interstitial fluid of the renal cortex is greater than in the interstitial fluid of the renal medulla during antidiuresis
    C) The thick ascending limb of the loop of Henle reabsorbs more urea than the inner medullary collecting tubule during antidiuresis
    D) Urea reabsorption in the proximal tubule is greater than in the cortical collecting tubule

65. A patient's urine is collected for 2 hours, and the total volume is 600 milliliters during this time. Her urine osmolarity is 150 mOsm/L, and her plasma osmolarity is 300 mOsm/L. What is her "free water clearance"?
    A) +5.0 ml/min
    B) +2.5 ml/min
    C) 0.0 ml/min
    D) −2.5 ml/min
    E) −5.0 ml/min

Questions 66–69



For Questions 66–69, choose the appropriate nephron site in the above figure.

66. In a patient with severe central diabetes insipidus caused by a lack of ADH secretion, which part of the tubule would have the lowest tubular fluid osmolarity?
    A) A
    B) B
    C) C
    D) D
    E) E

67. In a person on a very low potassium diet, which part of the nephron would be expected to reabsorb the most potassium?
    A) A
    B) B
    C) C
    D) D
    E) E

68. Which part of the nephron normally reabsorbs the most water?
    A) A
    B) B
    C) C
    D) D
    E) E

69. In a normally functioning kidney, which part of the tubule has the lowest permeability to water during antidiuresis?
    A) A
    B) B
    C) C
    D) D
    E) E

70. Which substances are best suited to measure interstitial fluid volume?
 A) Inulin and heavy water
 B) Inulin and ^{22}Na
 C) Heavy water and ^{125}I-albumin
 D) Inulin and ^{125}I-albumin
 E) ^{51}Cr red blood cells and ^{125}I-albumin

71. Long-term administration of furosemide (Lasix) would do what?
 A) Inhibit the Na^+-Cl^- co-transporter in the renal distal tubules
 B) Inhibit the Na^+-Cl^--K^+ co-transporter in the renal tubules
 C) Tend to reduce renal concentrating ability
 D) Tend to cause hyperkalemia
 E) A and C
 F) B and C
 G) B, C, and D

72. A patient with normal lungs who has uncontrolled type 1 diabetes and a plasma glucose concentration of 400 mg/100 ml (normal ~100 mg/100 ml) would be expected to have which set of blood values?

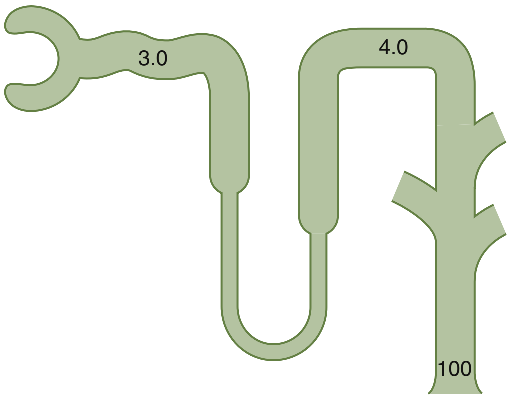
	pH	HCO_3^- (mmol/L)	P_{CO_2} (mm Hg)	Na^+ (mmol/L)	Cl^- (mmol/L)
A)	7.66	22	20	143	111
B)	7.52	38	48	146	100
C)	7.29	14	30	143	117
D)	7.25	12	28	142	102
E)	7.07	14	50	144	102

73. Which of the following would be expected to cause a decrease in extracellular fluid potassium concentration (hypokalemia) at least in part by stimulating potassium uptake into the cells?
 A) α-adrenergic blockade
 B) Insulin deficiency
 C) Strenuous exercise
 D) Aldosterone deficiency (Addison's disease)
 E) Metabolic alkalosis

74. If a person has a kidney transport maximum for glucose of 350 mg/min, a GFR of 100 ml/min, a plasma glucose level of 150 mg/dl, a urine flow rate of 2 ml/min, and no detectable glucose in the urine, what would be the approximate rate of glucose reabsorption, assuming normal kidneys?
 A) Glucose reabsorption cannot be estimated from these data
 B) 0 mg/min
 C) 50 mg/min
 D) 150 mg/min
 E) 350 mg/min

75. Which diuretic inhibits Na^+-$2Cl^-$-K^+ co-transport in the loop of Henle as its primary action?
 A) Thiazide diuretic
 B) Furosemide
 C) Carbonic anhydrase inhibitor
 D) Osmotic diuretic
 E) Amiloride
 F) Spironolactone

76. A selective decrease in *efferent* arteriolar resistance would __________ glomerular hydrostatic pressure, __________ GFR, and __________ renal blood flow.
 A) Increase, increase, increase
 B) Increase, decrease, increase
 C) Increase, decrease, decrease
 D) Decrease, increase, decrease
 E) Decrease, decrease, increase
 F) Decrease, increase, increase



77. The above figure shows the concentration of inulin at different points along the renal tubule, expressed as the tubular fluid/plasma ratio of inulin concentration. If inulin is not reabsorbed, what is the approximate percentage of the filtered water that has been reabsorbed prior to the distal convoluted tubule?
 A) 25%
 B) 33%
 C) 66%
 D) 75%
 E) 99%
 F) 100%

78. A patient with renal tubular acidosis would be expected to have which set of blood values?

	pH	HCO_3^- (mmol/L)	P_{CO_2} (mm Hg)	Na^+ (mmol/L)	Cl^- (mmol/L)
A)	7.66	22	20	143	111
B)	7.52	38	48	146	100
C)	7.07	14	50	144	102
D)	7.25	12	28	142	102
E)	7.29	14	30	143	117

79. A patient reports that he is always thirsty, and his breath has an acetone smell. You suspect that he has diabetes mellitus, and that diagnosis is confirmed by a urine sample that tests positive for glucose and a blood sample that shows a fasting blood glucose concentration of 400 mg/dl. Compared with normal, you would expect to find which changes in his urine?

	Urine pH	NH_4^+ Excretion	Urine volume (ml/24 h)	Renal HCO_3^- Production
A)	↓	↓	↓	↓
B)	↓	↑	↓	↓
C)	↑	↓	↓	↓
D)	↓	↑	↑	↑
E)	↑	↑	↑	↑

Questions 80–82

A person with normal body fluid volumes weighs 60 kg and has an extracellular fluid volume of approximately 12.8 L, a blood volume of 4.3 L, and a hematocrit of 0.4; 57% of his body weight is water. Use this information to answer Questions 80–82.

80. What is the approximate intracellular fluid volume?
   - A) 17.1 liters
   - B) 19.6 liters
   - C) 21.4 liters
   - D) 23.5 liters
   - E) 25.6 liters

81. What is the approximate plasma volume?
   - A) 2.0 liters
   - B) 2.3 liters
   - C) 2.6 liters
   - D) 3.0 liters
   - E) 3.3 liters

82. What is the approximate interstitial fluid volume?
   - A) 6.4 liters
   - B) 8.4 liters
   - C) 10.2 liters
   - D) 11.3 liters
   - E) 12.0 liters

83. Which nephron segment is the primary site of magnesium reabsorption under normal conditions?
   - A) Proximal tubule
   - B) Descending limb of the loop of Henle
   - C) Ascending limb of the loop of Henle
   - D) Distal convoluted tubule
   - E) Collecting ducts

84. The principal cells in the cortical collecting tubules
   - A) Are the main site of action of the thiazide diuretics
   - B) Have sodium-chloride-potassium co-transporters
   - C) Are highly permeable to urea during antidiuresis
   - D) Are an important site of action of amiloride
   - E) Are the main site of action of furosemide

85. A patient has a GFR of 100 ml/min, her urine flow rate is 2.0 ml/min, and her plasma glucose concentration is 200 mg/100 ml. If the kidney transport maximum for glucose is 250 mg/min, what would be her approximate rate of glucose excretion?
   - A) 0 mg/min
   - B) 50 mg/min
   - C) 100 mg/min
   - D) 150 mg/min
   - E) 200 mg/min
   - F) 300 mg/min
   - G) Glucose excretion rate cannot be estimated from these data

86. Which changes would you expect to find in a newly diagnosed 10-year-old patient with type 1 diabetes and uncontrolled hyperglycemia (plasma glucose = 300 mg/dl)?

	Thirst (Water Intake)	Urine Volume	Glomerular Filtration Rate	Afferent Arteriolar Resistance
A)	↑	↓	↑	↓
B)	↑	↑	↓	↑
C)	↑	↑	↑	↓
D)	↓	↑	↑	↑
E)	↓	↓	↓	↓

Questions 87 and 88

To evaluate kidney function in a 45-year-old woman with type 2 diabetes, you ask her to collect her urine for a 24-hour period. She collects 3600 milliliters of urine in that period. The clinical laboratory returns the following results after analyzing the patient's urine and plasma samples: plasma creatinine = 4 mg/dl, urine creatinine = 32 mg/dl, plasma potassium = 5 mmol/L, and urine potassium = 10 mmol/L.

87. What is this patient's approximate GFR, assuming that she collected all her urine in the 24-hour period?
   - A) 10 ml/min
   - B) 20 ml/min
   - C) 30 ml/min
   - D) 40 ml/min
   - E) 80 ml/min

88. What is the net renal tubular reabsorption rate of potassium in this patient?
   - A) 1.050 mmol/min
   - B) 0.100 mmol/min
   - C) 0.037 mmol/min
   - D) 0.075 mmol/min
   - E) Potassium is not reabsorbed in this example

Questions 89–93

Match each of the patients described in Questions 89–93 with the correct set of blood values in the following table (the same values may be used for more than one patient).

	pH	HCO_3^- (mEq/L)	P_{CO_2} (mm Hg)	Na^+ (mEq/L)	Cl^- (mEq/L)
A)	7.66	22	20	143	111
B)	7.28	30	65	142	102
C)	7.24	12	29	144	102
D)	7.29	14	30	143	117
E)	7.52	38	48	146	100
F)	7.07	14	50	144	102

89. A patient with severe diarrhea

90. A patient with primary aldosteronism

91. A patient with proximal renal tubular acidosis

92. A patient with diabetic ketoacidosis and emphysema

93. A patient treated chronically with a carbonic anhydrase inhibitor

94. Which change would you expect to find in a patient who developed acute renal failure after ingesting poisonous mushrooms that caused renal tubular necrosis?
   A) Increased plasma bicarbonate concentration
   B) Metabolic acidosis
   C) Decreased plasma potassium concentration
   D) Decreased blood urea nitrogen concentration
   E) Decreased hydrostatic pressure in Bowman's capsule

95. The type A intercalated cells in the collecting tubules
   A) Are highly permeable to urea during antidiuresis
   B) Secrete K^+
   C) Secrete H^+
   D) Are the main site of action of furosemide
   E) Are the main site of action of thiazide diuretics

96. Which of the following would be the most likely cause of hypernatremia associated with a small volume of highly concentrated urine (osmolarity = 1400 mOsm/L) in a person with normal kidneys?
   A) Primary aldosteronism
   B) Diabetes mellitus
   C) Diabetes insipidus
   D) Dehydration due to insufficient water intake and heavy exercise
   E) Bartter's syndrome
   F) Liddle's syndrome

97. The most serious hypokalemia would occur in which condition?
   A) Decrease in potassium intake from 150 to 60 mEq/day
   B) Increase in sodium intake from 100 to 200 mEq/day
   C) Fourfold increase in aldosterone secretion plus high sodium intake
   D) Fourfold increase in aldosterone secretion plus low sodium intake
   E) Addison's disease

98. Which of the following has similar values for both intracellular and interstitial body fluids?
   A) Potassium ion concentration
   B) Colloid osmotic pressure
   C) Sodium ion concentration
   D) Chloride ion concentration
   E) Total osmolarity

99. Which of the following is true of the tubular fluid that passes through the lumen of the early distal tubule in the region of the macula densa?
   A) It is usually isotonic
   B) It is usually hypotonic
   C) It is usually hypertonic
   D) It is hypertonic in antidiuresis
   E) It is hypertonic when the filtration rate of its own nephron decreases to 50% below normal

100. In a person with normal kidneys and normal lungs who has chronic metabolic acidosis, you would expect to find all of the following, compared with normal, *except*:
   A) Increased renal excretion of NH_4Cl
   B) Decreased urine pH
   C) Decreased urine HCO_3^- excretion
   D) Increased plasma HCO_3^- concentration
   E) Decreased plasma P_{CO_2}

101. In a patient with very high levels of aldosterone and otherwise normal kidney function, approximately what percentage of the filtered load of sodium would be reabsorbed by the distal convoluted tubule and collecting duct?
   A) >66%
   B) 40% to 60%
   C) 20% to 40%
   D) 10% to 20%
   E) <10%

Questions 102–104

The following test results were obtained: urine flow rate = 2.0 ml/min; urine inulin concentration = 60 mg/ml; plasma inulin concentration = 2 mg/ml; urine potassium concentration = 20 µmol/ml; plasma potassium concentration = 4.0 µmol/ml; urine osmolarity = 150 mOsm/L; and plasma osmolarity = 300 mOsm/L.

102. What is the approximate GFR?
   A) 20 ml/min
   B) 25 ml/min
   C) 30 ml/min
   D) 60 ml/min
   E) 75 ml/min
   F) 150 ml/min

103. What is the net potassium reabsorption rate?
   A) 0 µmol/min
   B) 20 µmol/min
   C) 60 µmol/min
   D) 200 µmol/min
   E) 240 µmol/min
   F) 300 µmol/min
   G) Potassium is not reabsorbed in this case

104. What is the free water clearance rate?
   A) +1.0 ml/min
   B) +1.5 ml/min
   C) +2.0 ml/min
   D) −1.0 ml/min
   E) −1.5 ml/min
   F) −2.0 ml/min

105. Assume that you have a patient who needs fluid therapy and you decide to administer by intravenous infusion 2.0 liters of 0.45% NaCl solution (molecular weight NaCl = 58.5). After osmotic equilibrium, which changes would you expect, compared with before infusion of the NaCl?

	Intracellular Volume	Intracellular Osmolarity	Extracellular Volume	Extracellular Osmolarity
A)	↑	↑	↑	↑
B)	↑	↓	↑	↓
C)	↔	↑	↑	↑
D)	↓	↑	↑	↑
E)	↓	↓	↓	↓

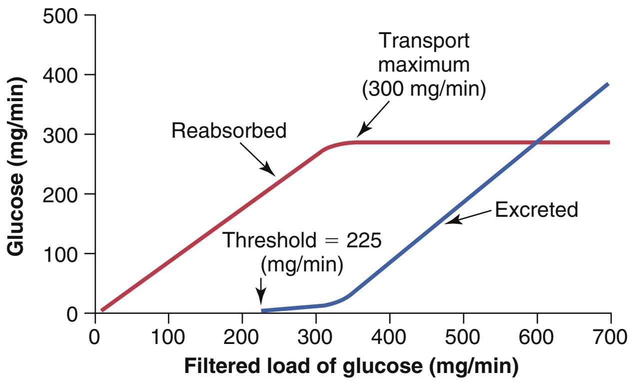
106. If the renal clearance of substance X is 300 ml/min and the glomerular filtration rate is 100 ml/min, it is most likely that substance X is
   A) Filtered freely but not secreted or reabsorbed
   B) Bound to plasma proteins
   C) Secreted
   D) Reabsorbed
   E) Bound to tubular proteins
   F) Clearance of a substance cannot be greater than the GFR

107. Which change tends to increase urinary calcium (Ca^{++}) excretion?
   A) Extracellular fluid volume expansion
   B) Increased plasma parathyroid hormone concentration
   C) Decreased blood pressure
   D) Increased plasma phosphate concentration
   E) Metabolic alkalosis

108. Which change would you expect to find in a patient consuming a high-sodium diet (200 mEq/day) compared with the same patient on a normal-sodium diet (100 mEq/day), assuming steady-state conditions?
   A) Increased plasma aldosterone concentration
   B) Increased urinary potassium excretion
   C) Decreased plasma renin activity
   D) Decreased plasma atrial natriuretic peptide
   E) An increase in plasma sodium concentration of at least 5 mmol/L

109. What would tend to decrease GFR by more than 10% in a normal kidney?
   A) Decrease in renal arterial pressure from 100 to 85 mm Hg
   B) 50% decrease in afferent arteriolar resistance
   C) 50% decrease in efferent arteriolar resistance
   D) 50% increase in the glomerular capillary filtration coefficient
   E) Decrease in plasma colloid osmotic pressure from 28 to 20 mm Hg

110. Acute metabolic acidosis tends to _____ intracellular K^+ concentration and _____ K^+ secretion by the cortical collecting tubules.
   A) Increase, increase
   B) Increase, decrease
   C) Decrease, increase
   D) Decrease, decrease
   E) Cause no change in, increase
   F) Cause no change in, cause no change in



111. A 55-year-old overweight male patient reports frequent urination, and his blood pressure is 165/98 mm Hg. Based on 24-hour creatinine clearance, you estimate his GFR to be 150 ml/min. His plasma glucose is 400 mg/100 ml. Assuming that his renal transport maximum for glucose is normal, as shown in the above figure, what would be the approximate rate of urinary glucose excretion for this patient?

A) 0 mg/min
B) 100 mg/min
C) 150 mg/min
D) 225 mg/min
E) 300 mg/min
F) The information provided is inadequate to estimate the glucose excretion rate

112. Which statement is true?

A) ADH increases water reabsorption from the ascending loop of Henle
B) Water reabsorption from the descending loop of Henle is normally less than that from the ascending loop of Henle
C) Sodium reabsorption from the ascending loop of Henle is normally less than that from the descending loop of Henle
D) Osmolarity of fluid in the early distal tubule would be less than 300 mOsm/L in a dehydrated person with normal kidneys and increased ADH levels
E) ADH decreases the urea permeability in the medullary collecting tubules

113. You have been monitoring a patient with type 2 diabetes and chronic renal disease whose GFR has decreased from 80 ml/min to 40 ml/min during the past 4 years. Which of the following changes in sodium and creatinine (Cr) would you expect to find compared with 4 years ago, before the decline in GFR, assuming steady-state conditions and no change in electrolyte intake or protein metabolism?

	Sodium Excretion Rate	Cr Excretion Rate	Cr Clearance	Filtered Load Cr	Plasma Cr Concentration
A)	↓	↓	↔	↔	↑
B)	↓	↓	↓	↓	↑
C)	↔	↔	↓	↓	↑
D)	↔	↔	↓	↓	↔
E)	↔	↔	↓	↔	↑
F)	↔	↔	↔	↔	↑

114. In a person on a high-potassium (200 mmol/day) diet, which part of the nephron would be expected to secrete the most potassium?

A) Proximal tubule
B) Descending loop of Henle
C) Ascending loop of Henle
D) Early distal tubule
E) Collecting tubules

115. Which of the following would you expect to find in a patient who has chronic diabetic ketoacidosis?

A) Decreased renal HCO_3^- excretion, increased NH_4^+ excretion, increased plasma anion gap
B) Increased respiration rate, decreased arterial P_{CO_2}, decreased plasma anion gap
C) Increased NH_4^+ excretion, increased plasma anion gap, increased urine pH
D) Increased renal HCO_3^- production, increased NH_4^+ excretion, decreased plasma anion gap
E) Decreased urine pH, decreased renal HCO_3^- excretion, increased arterial P_{CO_2}

116. A patient has a creatinine clearance of 100 ml/min, a plasma K^+ concentration of 4.0 mmol/L, a urine flow rate of 2.0 ml/min, and a urine K^+ concentration of 60 mmol/L. What is his approximate rate of potassium excretion?

A) 0.12 mmol/min
B) 0.16 mmol/min
C) 0.32 mmol/min
D) 8.0 mmol/min
E) 120 mmol/min
F) 400 mmol/min

117. Using the indicator dilution method to assess body fluid volumes in a 40-year-old man weighing 70 kg, the inulin space is calculated to be 16 liters and ^{125}I-albumin space is 4 liters. If 60% of his total body weight is water, what is his approximate interstitial fluid volume?

A) 4 liters
B) 12 liters
C) 16 liters
D) 26 liters
E) 38 liters
F) 42 liters

118. What would tend to decrease plasma potassium concentration by causing a shift of potassium from the extracellular fluid into the cells?
    A) Strenuous exercise
    B) Aldosterone deficiency
    C) Acidosis
    D) β-adrenergic blockade
    E) Insulin excess

119. A 26-year-old construction worker is brought to the emergency department with a change in mental status after working a 10-hour shift on a hot summer day (average outside temperature was 97°F [36°C]). The man had been sweating profusely during the day but did not drink fluids. He has a fever of 102°F [39°C], a heart rate of 140 beats/min, and a blood pressure of 100/55 mm Hg in the supine position. Upon examination, he has no perspiration, appears to have dry mucous membranes, and is poorly oriented to person, place, and time. Assuming that his kidneys were normal yesterday, which set of hormone levels describes his condition, compared with normal?
    A) High ADH, high renin, low angiotensin II, low aldosterone
    B) Low ADH, low renin, low angiotensin II, low aldosterone
    C) High ADH, low renin, high angiotensin II, low aldosterone
    D) High ADH, high renin, high angiotensin II, high aldosterone
    E) Low ADH, high renin, low angiotensin II, high aldosterone

120. A 23-year-old man runs a 10-kilometer race in July and loses 2 liters of fluid by sweating. He also drinks 2 liters of water during the race. Which changes would you expect, compared with normal, after he absorbs the water and assuming osmotic equilibrium and no excretion of water or electrolytes?

	Intracellular Volume	Intracellular Osmolarity	Extracellular Volume	Extracellular Osmolarity
A)	↓	↑	↓	↑
B)	↓	↓	↓	↓
C)	↔	↓	↔	↓
D)	↔	↑	↓	↑
E)	↑	↓	↓	↓
F)	↑	↓	↑	↓

121. Which change would tend to increase Ca^{2+} reabsorption in the renal tubule?
    A) Extracellular fluid volume expansion
    B) Increased plasma parathyroid hormone concentration
    C) Increased blood pressure
    D) Decreased plasma phosphate concentration
    E) Metabolic acidosis

122. A patient has the following laboratory values: arterial pH = 7.04, plasma HCO_3^- = 13 mEq/L, plasma chloride concentration = 120 mEq/L, arterial P_{CO_2} = 30 mm Hg, and plasma sodium = 141 mEq/L. What is the most likely cause of his acidosis?
    A) Emphysema
    B) Methanol poisoning
    C) Salicylic acid poisoning
    D) Diarrhea
    E) Diabetes mellitus

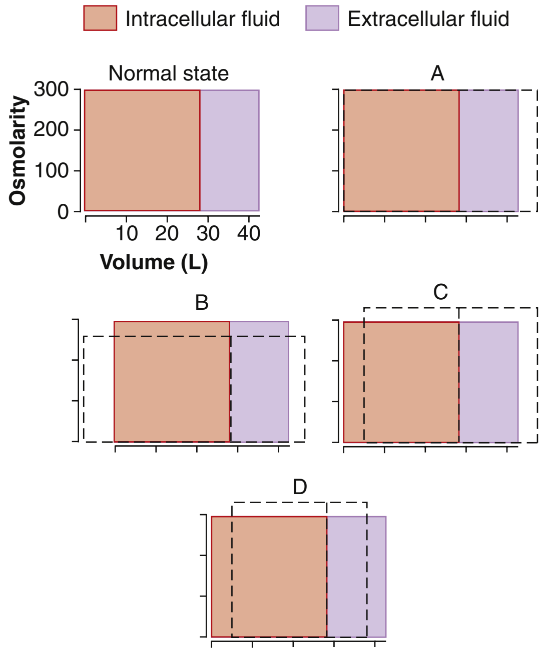
123. A young man is found comatose, having taken an unknown number of sleeping pills an unknown time before. An arterial blood sample yields the following values: pH = 7.02, HCO_3^- = 14 mEq/L, and P_{CO_2} = 68 mm Hg. Which of the following describes this patient's acid-base status most accurately?
    A) Uncompensated metabolic acidosis
    B) Uncompensated respiratory acidosis
    C) Simultaneous respiratory and metabolic acidosis
    D) Respiratory acidosis with partial renal compensation
    E) Respiratory acidosis with complete renal compensation

124. If the GFR suddenly decreases from 150 ml/min to 75 ml/min and tubular fluid reabsorption simultaneously decreases from 149 ml/min to 75 ml/min, which change will occur (assuming that the changes in GFR and tubular fluid reabsorption are maintained)?
    A) Urine flow rate will decrease to 0
    B) Urine flow rate will decrease by 50%
    C) Urine flow rate will not change
    D) Urine flow rate will increase by 50%

125. In a person with chronic respiratory acidosis who has partial renal compensation, you would expect to find which changes, compared with normal: ______ urinary excretion of NH_4^+; ______ plasma HCO_3^- concentration; and _____ urine pH.
    A) Increased, increased, decreased
    B) Increased, decreased, decreased
    C) No change in, increased, decreased
    D) No change in, no change in, decreased
    E) Increased, no change in, increased

126. At which renal tubular sites would the concentration of creatinine be expected to be highest in a normally hydrated person?
    A) The concentration would be the same in all renal tubular segments because creatinine is neither secreted nor reabsorbed
    B) Glomerular filtrate
    C) End of the proximal tubule
    D) End of the loop of Henle
    E) Distal tubule
    F) Collecting duct

Questions 127 and 128



The figure above represents various states of abnormal hydration. In each diagram, the normal state (orange and lavender) is superimposed on the abnormal state (dashed lines) to illustrate the shifts in the volume (width of rectangles) and total osmolarity (height of rectangles) of the extracellular fluid and intracellular fluid compartments.

127. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volume and osmolarity after infusion of 2 liters of 3.0% dextrose?
   A) A
   B) B
   C) C
   D) D

128. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volume and osmolarity in a patient with severe "central" diabetes insipidus?
   A) A
   B) B
   C) C
   D) D

129. Increases in both renal blood flow and GFR are caused by which mechanism?
   A) Dilation of the afferent arterioles
   B) Increased glomerular capillary filtration coefficient
   C) Increased plasma colloid osmotic pressure
   D) Dilation of the efferent arterioles

130. If the cortical collecting tubule tubular fluid inulin concentration is 40 mg/100 ml and plasma concentration of inulin is 2.0 mg/100 ml, what is the approximate percentage of the filtered water that remains in the tubule at that point?
   A) 0%
   B) 2%
   C) 5%
   D) 10%
   E) 20%
   F) 100%

131. A 55-year-old male patient with hypertension has had his blood pressure reasonably well controlled by administration of a thiazide diuretic. At his last visit (6 months ago), his blood pressure was 130/75 mm Hg and his serum creatinine was 1 mg/100 ml. He has been exercising regularly for the past 2 years but recently has reported knee pain and began taking large amounts of a nonsteroidal anti-inflammatory drug. When he arrives at your office, his blood pressure is 155/85 mm Hg and his serum creatinine is 2.5 mg/100 ml. What best explains his increased serum creatinine level?
   A) Increased efferent arteriolar resistance that reduced GFR
   B) Increased afferent arteriolar resistance that reduced GFR
   C) Increased glomerular capillary filtration coefficient that reduced GFR
   D) Increased angiotensin II formation that decreased GFR
   E) Increased muscle mass due to the exercise

132. An elderly patient reports muscle weakness and lethargy. A urine specimen reveals a Na^+ concentration of 600 mmol/L and an osmolarity of 1200 mOsm/L. Additional laboratory tests provide the following information: plasma Na^+ concentration = 167 mmol/L, plasma renin activity = 4 ng angiotensin I/ml/h (normal = 1), plasma ADH = 60 pg/ml (normal = 3 pg/ml), and plasma aldosterone = 15 ng/dl (normal = 6 ng/dl). What is the most likely reason for this patient's hypernatremia?
   A) Dehydration caused by decreased fluid intake
   B) Syndrome of inappropriate ADH
   C) Nephrogenic diabetes insipidus
   D) Primary aldosteronism
   E) Renin-secreting tumor

ANSWERS

1. **C)** A 3% NaCl solution is hypertonic, and when infused intravenously, it would increase extracellular fluid volume and osmolarity, thereby causing water to flow out of the cell. This action would decrease intracellular fluid volume and further increase extracellular fluid volume. The 0.9% NaCl solution and 5% dextrose solution are isotonic and therefore would not reduce intracellular fluid volume. Pure water and the 0.45% NaCl solution are hypotonic, and when infused, they would increase both intracellular and extracellular fluid volumes.
   TMP13 pp. 311-314

2. **B)** Partial obstruction of a major vein draining a tissue would increase capillary hydrostatic pressure in the tissue, which, in turn, would raise capillary fluid filtration and cause increases interstitial fluid volume, interstitial fluid hydrostatic pressure, and lymph flow. The increased lymph flow would "wash out" proteins from the interstitial fluid, decreasing interstitial fluid protein concentration.
   TMP 13 p. 317

3. **C)** The hypernatremia (plasma Na^+ = 165 mmol/L) associated with a low blood pressure (88/44 mm Hg) suggests dehydration. The frequent urination and low urine specific gravity (1.003, which implies a urine osmolarity of about 100-120 mOsm/L) despite hypernatremia and dehydration suggests diabetes insipidus due to either insufficient secretion of ADH (central diabetes insipidus) or failure of the kidneys to respond to ADH (nephrogenic diabetes insipidus).
   TMP 13 pp. 315-316, 378-379, 438-439

4. **D)** A severe renal artery stenosis that reduces GFR to 25% of normal would also decrease renal blood flow but would cause only a transient decrease in urinary creatinine excretion. The transient decrease in creatinine excretion would increase serum creatinine (to about four times normal), which would restore the filtered creatinine load to normal and therefore return urinary creatinine excretion to normal levels under steady-state conditions. Urinary sodium secretion would also decrease transiently but would be restored to normal so that intake and excretion of sodium are balanced. Plasma sodium concentration would not change significantly because it is carefully regulated by the ADH–thirst mechanism.
   TMP13 pp. 366, 435-436

5. **B)** A 1% solution of dextrose is hypotonic, and when infused, it would increase both intracellular and extracellular fluid volumes while decreasing the osmolarity of these compartments.
   TMP13 pp. 311-313

6. **B)** Excessive secretion of ADH would increase renal tubular reabsorption of water, thereby increasing extracellular fluid volume and reducing extracellular fluid osmolarity. The reduced osmolarity, in turn, would cause water to flow into the cells and raise intracellular fluid volume. In the steady state, both extracellular and intracellular fluid volumes would increase, and osmolarity of both compartments would decrease.
   TMP13 pp. 314, 381-382

7. **C)** A 3% solution of NaCl is hypertonic, and when infused into the extracellular fluid, it would raise osmolarity, thereby causing water to flow out of the cells into the extracellular fluid until osmotic equilibrium is achieved. In the steady state, extracellular fluid volume would increase, intracellular fluid volume would decrease, and osmolarity of both compartments would increase.
   TMP13 pp. 311-312

8. **C)** Aldosterone stimulates potassium secretion by the principal cells of the collecting tubules. Therefore, blockade of the action of aldosterone with spironolactone would inhibit potassium secretion. Other factors that stimulate potassium secretion by the cortical collecting tubule include increased potassium concentration, increased cortical collecting tubule flow rate (as would occur with high sodium intake or a diuretic that reduces proximal tubular sodium reabsorption), and acute alkalosis.
   TMP13 pp. 392-396

9. **C)** Phosphate excretion by the kidneys is controlled by an overflow mechanism. When the transport maximum for reabsorbing phosphate is exceeded, the remaining phosphate in the renal tubules is excreted in the urine and can be used to buffer hydrogen ions and form titratable acid. Phosphate normally begins to spill into the urine when the concentration of extracellular fluid rises above a threshold of 0.8 mmol/L, which is usually exceeded.
   TMP13 pp. 397-398

10. **B)** GFR is equal to inulin clearance, which is calculated as the urine inulin concentration (100 mg/ml) × urine flow rate (1 ml/min)/plasma inulin concentration (2 mg/ml), which is equal to 50 ml/min.
    TMP13 p. 365

11. D) The net urea reabsorption rate is equal to the filtered load of urea (GFR [50 ml/min] × plasma urea concentration [2.5 mg/ml]) − urinary excretion rate of urea (urine urea concentration [50 mg/ml] × urine flow rate [1 ml/min]). Therefore, net urea reabsorption = (50 ml/min × 2.5 mg/ml) − (50 mg/ml × 1 ml/min) = 75 mg/min.
TMP13 p. 365

12. A) K^+ excretion rate = urine K^+ concentration (60 mEq/L) × urine flow rate (0.001 L/min) = 0.06 mEq/min.
TMP13 p. 365

13. E) Filtration fraction (FF) = GFR ÷ Renal plasma flow (RPF).

$GFR = K_f \times (P_G - P_B - \pi_G) = 10 \times (70 - 20 - 35) = 150$ ml/min

FF = 150 ml/min ÷ 428 ml/min = 0.35
TMP13 pp. 337-338

14. B) As water flows up the ascending limb of the loop of Henle, solutes are reabsorbed, but this segment is relatively impermeable to water; progressive dilution of the tubular fluid occurs so that the osmolarity decreases to approximately 100 mOsm/L by the time the fluid reaches the early distal tubule. Even during maximal antidiuresis, this portion of the renal tubule is relatively impermeable to water and is therefore called the diluting segment of the renal tubule.
TMP13 pp. 378-379

15. C) In the absence of ADH secretion, a marked increase in urine volume occurs because the late distal and collecting tubules are relatively impermeable to water. As a result of increased urine volume, there is dehydration and increased plasma osmolarity and high plasma sodium concentration. The resulting decrease in extracellular fluid volume stimulates renin secretion, resulting in an increase in plasma renin concentration.
TMP13 p. 380

16. C) When potassium intake is doubled (from 80 to 160 mmol/day), potassium excretion also approximately doubles within a few days, and the plasma potassium concentration increases only slightly. Increased potassium excretion is achieved largely by increased secretion of potassium in the cortical collecting tubule. Increased aldosterone concentration plays a significant role in increasing potassium secretion and in maintaining a relatively constant plasma potassium concentration during increases in potassium intake. Sodium excretion does not change markedly during chronic increases in potassium intake.
TMP13 pp. 392-396

17. D) Most of the daily variation in potassium excretion is caused by changes in potassium secretion in the late distal tubules and collecting tubules. Therefore, when the dietary intake of potassium increases, the total body balance of potassium is maintained primarily by an increase in potassium secretion in these tubular segments. Increased potassium intake has little effect on GFR or on reabsorption of potassium in the proximal tubule and loop of Henle. Although high potassium intake may cause a slight shift of potassium into the intracellular compartment, a balance between intake and output must be achieved by increasing the excretion of potassium during high potassium intake.
TMP13 pp. 390-391

18. E) A 50% decrease in efferent arteriolar resistance would cause a substantial decrease in GFR. A decrease in renal arterial pressure from 100 to 80 mm Hg in a normal kidney would cause only a slight reduction in GFR in a normal kidney because of autoregulation. All of the other changes would tend to increase GFR.
TMP13 pp. 337-339

19. A) The patient described has protein in the urine (proteinuria) and reduced plasma protein concentration as a result of glomerulonephritis caused by an untreated streptococcal infection ("strep throat"). The reduced plasma protein concentration, in turn, decreased the plasma colloid osmotic pressure and resulted in leakage from the plasma to the interstitium. The extracellular fluid edema raised interstitial fluid pressure and interstitial fluid volume, causing increased lymph flow and decreased interstitial fluid protein concentration. Increasing lymph flow causes a "washout" of the interstitial fluid protein as a safety factor against edema. The decreased blood volume would tend to lower blood pressure and stimulate the secretion of renin by the kidneys, raising the plasma renin concentration.
TMP13 pp. 317-320

20. C) In a patient with a very high rate of renin secretion, there would also be increased formation of angiotensin II, which in turn would stimulate aldosterone secretion. The increased levels of angiotensin II and aldosterone would cause a transient decrease in sodium excretion, which would cause expansion of the extracellular fluid volume and increased arterial pressure. The increased arterial pressure, as well as other compensations, would return sodium excretion to normal so that intake and output are balanced. Therefore, under steady-state conditions, sodium excretion would be normal and equal to sodium intake. The increased aldosterone concentration would cause hypokalemia (decreased plasma potassium concentration), whereas the high level of angiotensin II would cause renal vasoconstriction and decreased renal blood flow.
TMP13 pp. 399-401

21. B) This patient has respiratory acidosis because the plasma pH is lower than the normal level of 7.4 and the plasma P_{CO_2} is higher than the normal level of 40 mm Hg (see table below). The elevation in plasma bicarbonate concentration above normal (~24 mEq/L) is due to partial renal compensation for the respiratory acidosis. Therefore, this patient has respiratory acidosis with partial renal compensation.

TMP12 pp. 421-422

Characteristics of Primary Acid-Base Disturbances

	pH	H^+	P_{CO_2}	HCO_3^-
Normal	7.4	40 mEq/L	40 mm Hg	24 mEq/L
Respiratory acidosis	↓	↑	↑↑	↑
Respiratory alkalosis	↑	↓	↓↓	↓
Metabolic acidosis	↓	↑	↓	↓↓
Metabolic alkalosis	↑	↓	↑	↑↑

The primary event is indicated by the double arrows (↑↑ or ↓↓). Note that respiratory acid-base disorders are initiated by an increase or decrease in P_{CO_2}, whereas metabolic disorders are initiated by an increase or decrease in HCO_3^-.

22. D) GFR is approximately equal to creatinine clearance, which is calculated as the urine creatinine concentration (50 mg/100 ml) × urine flow rate (3 ml/min)/plasma creatinine concentration (3 mg/100 ml), which is equal to 50 ml/min. Urine flow rate = 4320 ml/24 h = 4320 ml/1440 min = 3 ml/min.

TMP12, pp. 366-367

this answer is for Q 24

23. D) An important compensation for respiratory acidosis is increased renal production of NH_4^+ and increased NH_4^+ excretion. In acidosis, urinary excretion of HCO_3^- would be reduced, as would urine pH, and urinary titratable acid would be slightly increased as a compensatory response to the acidosis.

TMP13 pp. 418-419

this answer is for Q 23

24. C) Because the patient has a low plasma pH (normal = 7.4), he has acidosis. The fact that his plasma bicarbonate concentration is also low (normal = 24 mEq/L) indicates that he has metabolic acidosis. However, he also appears to have respiratory acidosis because his plasma P_{CO_2} is high (normal = 40 mm Hg). The rise in P_{CO_2} is due to his impaired breathing as a result of cardiopulmonary arrest. Therefore, the patient has a mixed acidosis with combined metabolic and respiratory acidosis.

TMP13 pp. 422-426

25. B) Inhibition of aldosterone causes hyperkalemia by two mechanisms: (1) shifting potassium out of the cells into the extracellular fluid, and (2) decreasing cortical collecting tubular secretion of potassium. Increasing potassium intake from 60 to 180 mmol/day would cause only a very small increase in plasma potassium concentration in a person with normal kidneys and normal aldosterone feedback mechanisms (see TMP13 **Figs. 30-7 and 30-8**). A reduction in sodium intake also has very little effect on plasma potassium concentration. Chronic treatment with a diuretic that inhibits loop of Henle Na^+-$2Cl^-$-K^+ co-transport would tend to cause potassium loss in the urine and hypokalemia. However, chronic treatment with a diuretic that inhibits sodium reabsorption in the collecting ducts, such as amiloride, would have little effect on plasma potassium concentration.

TMP13 pp. 393-394

26. D) Excessive activity of the amiloride-sensitive sodium channel in the collecting tubules would cause a transient decrease in sodium excretion and expansion of extracellular fluid volume, which in turn would increase arterial pressure and decrease renin secretion, leading to decreased aldosterone secretion. Under steady-state conditions, sodium excretion would return to normal so that intake and renal excretion of sodium are balanced. One of the mechanisms that re-establishes this balance between intake and output of sodium is the rise in arterial pressure that induces a "pressure natriuresis."

TMP13 pp. 399-401, 439-440

27. A) Primary excessive secretion of aldosterone (Conn's syndrome) would be associated with marked hypokalemia and metabolic alkalosis (increased plasma pH). Because aldosterone stimulates sodium reabsorption and potassium secretion by the cortical collecting tubule, there could be a transient decrease in sodium excretion and an increase in potassium excretion, but under steady-state conditions, both urinary sodium and potassium excretion would return to normal to match the intake of these electrolytes. However, the sodium retention and the hypertension associated with aldosterone excess would tend to reduce renin secretion.

TMP13 pp. 392, 404

28. B) A doubling of plasma creatinine implies that the creatinine clearance and GFR have been reduced by approximately 50%. Although the reduction in creatinine clearance would initially cause a transient decrease in filtered load of creatinine, creatinine excretion rate, and sodium excretion rate, the plasma concentration of creatinine would increase until the filtered load of creatinine and the creatinine excretion rate returned to normal. However, creatinine clearance would remain reduced because creatinine clearance is

the urinary excretion rate of creatinine divided by the plasma creatinine concentration. Urinary sodium excretion would also return to normal and would equal the sodium intake, under steady-state conditions, as a result of compensatory mechanisms that reduce renal tubular reabsorption of sodium.
TMP13 pp. 366, 435-436

29. C) The glomerular capillary filtration coefficient is the product of the hydraulic conductivity and surface area of the glomerular capillaries. Therefore, increasing the glomerular capillary filtration coefficient tends to increase GFR. Increased afferent arteriolar resistance, decreased efferent arteriolar resistance, increased Bowman's capsule hydrostatic pressure, and decreased glomerular hydrostatic pressure tend to decrease GFR.
TMP13 pp. 337-340

30. D) Impairment of proximal tubular NaCl reabsorption would increase NaCl delivery to the macula densa, which in turn would cause a tubuloglomerular feedback–mediated increase in afferent arteriolar resistance. The increased afferent arteriolar resistance would decrease the GFR. Initially there would be a transient increase in sodium excretion, but after 3 weeks, steady-state conditions would be achieved. Sodium excretion would equal sodium intake, and no significant change would occur in urinary sodium excretion.
TMP13 pp. 343-345

31. D) The net potassium reabsorption rate is equal to the filtered load of urea (GFR [50 ml/min] × plasma potassium concentration [4 mmol/L]) − urinary excretion rate of potassium (urine potassium concentration [30 mmol/L] × urine flow rate [3 ml/min]). Therefore, net potassium reabsorption = (0.050 L/min × 4 mmol/L) − (30 mmol/L × 0.003 L/min) = 0.110 mmol/min. In this example the flow terms for GFR and urine flow rate are converted to L/min because the concentrations of potassium are in mmol/L.
TMP13 pp. 365-367

32. D) If a substance is completely cleared from the plasma, the clearance rate of that substance would equal the total renal plasma flow. In other words, the total amount of substance delivered to the kidneys in the blood (renal plasma flow × concentration of substance in the blood) would equal the amount of that substance excreted in the urine. Complete renal clearance of a substance would require both glomerular filtration and tubular secretion of that substance.
TMP13 pp. 365-368

33. C) The patient has a lower than normal pH and is therefore acidotic. Because the plasma bicarbonate concentration is also lower than normal, the patient has metabolic acidosis with respiratory compensation (i.e., P_{CO_2} is lower than normal). The plasma anion gap (Na^+-Cl^--HCO_3^- = 10 mEq/L) is in the normal range, suggesting that the metabolic acidosis is not caused by excess nonvolatile acids such as salicylic acid or ketoacids caused by diabetes mellitus. Therefore, the most likely cause of the metabolic acidosis is diarrhea, which would cause a loss of HCO_3^- in the feces and would be associated with a normal anion gap and a hyperchloremic (increased chloride concentration) metabolic acidosis.
TMP13 pp. 422, 426

34. A) A 50% reduction of GFR would approximately double the plasma creatinine concentration because creatinine is not reabsorbed or secreted and its excretion depends largely on glomerular filtration. Therefore, when GFR decreases, the plasma concentration of creatinine increases until the renal excretion of creatinine returns to normal. Plasma concentrations of glucose, potassium, sodium, and hydrogen ions are closely regulated by multiple mechanisms that keep them relatively constant even when GFR falls to very low levels. Plasma phosphate concentration is also maintained near normal until GFR falls to below 20% to 30% of normal.
TMP13 pp. 366, 435-436

35. C) Calculation of fluid shifts and osmolarities after infusion of hypertonic saline solution is discussed in Chapter 25 of TMP13 (pp. 312-314). The tables shown above represent the initial conditions and the final conditions after infusion of 2 liters of 3% NaCl and osmotic equilibrium. Three percent NaCl is equal to 30 grams of NaCl/L, or 0.513 mol/L (513 mmol/L). Because NaCl has two osmotically active particles per mole, the net effect is to add a total of 2052 millimoles in 2 liters of solution. As an approximation, one can assume that cell membranes are impermeable to the NaCl and that the NaCl infused remains in the extracellular fluid compartment.
TMP13 pp. 311-314

36. B) Extracellular fluid volume is calculated by dividing the total milliosmoles in the extracellular compartment (5172 mOsm) by the concentration after osmotic equilibrium (300 mOsm/L) to give 17.2 liters.
TMP13 pp. 311-314

37. C) A 50% reduction in afferent arteriolar resistance with no change in arterial pressure would increase renal blood flow and glomerular hydrostatic pressure, thereby increasing GFR. At the same time, the reduction in afferent arteriolar resistance would raise peritubular capillary hydrostatic pressure.
TMP13 pp. 338-340

38. A) The net filtration pressure at the glomerular capillaries is equal to the sum of the forces favoring filtration (glomerular capillary hydrostatic pressure) minus the forces that oppose filtration (hydrostatic pressure in Bowman's space and glomerular colloid osmotic pressure). Therefore, the net pressure driving glomerular filtration is 50 − 12 − 30 = 8 mm Hg.
TMP13 p. 337

39. D) Uncontrolled diabetes mellitus results in increased blood acetoacetic acid levels, which in turn cause metabolic acidosis and decreased plasma HCO_3^- and pH. The acidosis causes several compensatory responses, including increased respiratory rate, which reduces plasma P_{CO_2}; increased renal NH^+ production, which leads to increased NH^+ excretion; and increased phosphate buffering of hydrogen ions secreted by the renal tubules, which increases titratable acid excretion.

TMP13 p. 422

40. B) Infusion of a hypotonic solution of NaCl would initially increase extracellular fluid volume and decrease extracellular fluid osmolarity. The reduction in extracellular fluid osmolarity would cause osmotic flow of fluid into the cells, thereby increasing intracellular fluid volume and decreasing intracellular fluid osmolarity after osmotic equilibrium.

TMP13 pp. 312-314

41. A) For any given molecular radius, positively charged molecules (cations) are filtered more readily than negatively charged molecules (anions) because negative charges on the proteins of the basement membrane and podocytes of the glomerular capillaries tend to repel large negatively changed molecules (e.g., polycationic dextrans, curve C). Large positively charged molecules (curve A) are filtered more readily.

TMP 13 p. 336

42. C) Because water is reabsorbed by the renal tubules whereas creatinine is not reabsorbed, the concentration of creatinine in the renal tubular fluid will increase as fluid flows from the proximal to the distal tubule. An increase in the concentration from 1.0 mg/100 ml in the proximal tubule to 5.0 mg/100 ml in the distal tubule means that only about one fifth (20%) of the water that was in the proximal tubules remains in the distal tubule.

TMP 13 p. 354

43. C) Peritubular capillary fluid reabsorption is determined by the balance of hydrostatic and colloid osmotic forces in the peritubular capillaries. Increased efferent arteriolar resistance reduces peritubular capillary hydrostatic pressure and therefore increases the net force favoring fluid reabsorption. Increased blood pressure tends to raise peritubular capillary hydrostatic pressure and reduce fluid reabsorption. Decreased filtration fraction increases the peritubular capillary colloid osmotic pressure and tends to reduce peritubular capillary reabsorption. Decreased angiotensin II causes vasodilatation of efferent arterioles, raising peritubular capillary hydrostatic pressure, decreasing reabsorption, and decreasing tubular transport of water and electrolytes. Increased renal blood flow also tends to raise peritubular capillary hydrostatic pressure and decrease fluid reabsorption.

TMP13 pp. 360-362

44. C) The filtered load of glucose in this example is determined as follows: GFR (150 ml/min) × plasma glucose (300 mg/dl) = 450 mg/min. The transport maximum for glucose in this example is 300 mg/min. Therefore, the maximum rate of glucose reabsorption is 300 mg/min. The urinary glucose excretion is equal to the filtered load (450 mg/min) minus the tubular reabsorption of glucose (300 mg/min), or 150 mg/min.

TMP13 pp. 350-351, 365

45. B) Excess aldosterone increases sodium reabsorption and potassium secretion by the principal cells of the collecting tubules, causing sodium retention, increased blood pressure, and decreased renin secretion while increasing excretion of potassium and tending to decrease plasma potassium concentration. Excess aldosterone also causes a shift of potassium from the extracellular fluid into the cells, further reducing plasma potassium concentration. Aldosterone excess also stimulates hydrogen ion secretion and bicarbonate reabsorption by the intercalated cells and tends to increase plasma pH (alkalosis). Therefore the classic manifestations of excess aldosterone secretion are hypokalemia, hypertension, alkalosis, and low renin levels.

TMP 13 pp. 356-357, 390

46. B) Potassium secretion by the cortical collecting ducts is stimulated by (1) aldosterone, (2) increased plasma potassium concentration, (3) increased flow rate in the cortical collecting tubules, and (4) alkalosis. Therefore, a diuretic that inhibits aldosterone, decreased plasma potassium concentration, acute acidosis, and low sodium intake would all tend to decrease potassium secretion by the cortical collecting tubules. A diuretic that decreases loop of Henle sodium reabsorption, however, would tend to increase the flow rate in the cortical collecting tubule and therefore stimulate potassium secretion.

TMP13 pp. 392, 396

47. B) This patient with diabetes mellitus and chronic renal disease has a reduction in creatinine clearance to 40% of normal, implying a marked reduction in GFR. He also has acidosis, as evidenced by a plasma pH of 7.14. The decrease in creatinine clearance would cause only a transient reduction in sodium excretion and creatinine excretion rate. As the plasma creatinine concentration increased, the urinary creatinine excretion rate would return to normal, despite the sustained decrease in creatinine clearance (creatinine excretion rate/plasma concentration of creatinine). Diabetes is associated with increased production of acetoacetic acid, which would cause metabolic acidosis and decreased plasma HCO_3^- concentration, as well as a compensatory increase in renal NH_4^+ production and increased NH_4^+ excretion rate.

TMP13 pp. 422, 435-436

48. A) The filtration rate of glucose in this example is GFR (50 ml/min) × plasma glucose concentration (200 mg/100 ml, or 2 mg/ml) = 100 mg/min. Because the transport maximum for glucose in this example is 150 mg/min, all of the filtered glucose would be reabsorbed and the renal excretion rate for glucose would be zero.

TMP 13 pp. 350-351

49. C) A reduction in plasma protein concentration to 3.6 g/dl would increase the capillary filtration rate, thereby raising interstitial fluid volume and interstitial fluid hydrostatic pressure. The increased interstitial fluid pressure would, in turn, increase the lymph flow rate and reduce the interstitial fluid protein concentration ("washout" of interstitial fluid protein).

TMP13 pp. 316-318

50. B) The most likely diagnosis for this patient is diabetes insipidus, which can account for the polyuria and the fact that her urine osmolarity is very low (80 mOsm/L) despite overnight water restriction. In many patients with diabetes insipidus, the plasma sodium concentration can be maintained relatively close to normal by increasing fluid intake (polydipsia). When water intake is restricted, however, the high urine flow rate leads to rapid depletion of extracellular fluid volume and severe hypernatremia, as occurred in this patient. The fact that she has no glucose in her urine rules out diabetes mellitus. Neither primary aldosteronism nor a renin-secreting tumor would lead to an inability to concentrate the urine after overnight water restriction. Syndrome of inappropriate ADH would cause excessive fluid retention and increased urine osmolarity.

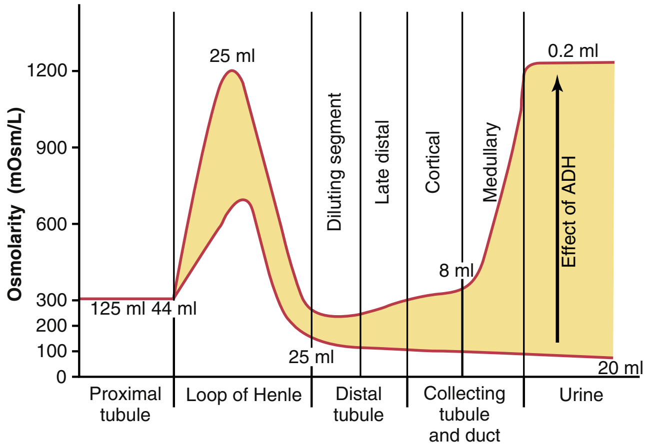
TMP13 pp. 380-381, 385

51. C) The filterability of solutes in the plasma is inversely related to the size of the solute (molecular weight). Also, positively charged molecules are filtered more readily than are neutral molecules or negatively charged molecules of equal molecular weight. Therefore, the positively charged polycationic dextran with a molecular weight of 25,000 would be the most readily filtered substance of the choices provided. Red blood cells are not filtered at all by the glomerular capillaries under normal conditions.

TMP13 pp. 336-337

52. A) In normally functioning kidneys, approximately two thirds of the water filtered by the glomerular capillaries is reabsorbed in the proximal tubule. Although dehydration increases ADH levels and water reabsorption by the distal tubules, collecting tubules, and collecting ducts, and this action contributes importantly to decreased water excretion in dehydration, the total amount of water that remains in these tubular segments is small compared with the amount of water in the proximal tubules (see the figure below).

TMP 13 pp. 378-379



53. D) Furosemide (Lasix) inhibits the Na^+-$2Cl^-$-K^+ co-transporter in the ascending limb of the loop of Henle. This action not only causes marked natriuresis and diuresis but also reduces the urine-concentrating ability. Furosemide does not cause edema; in fact, it is often used to treat severe edema and heart failure. Furosemide also increases the renal excretion of potassium and calcium and therefore tends to cause hypokalemia and hypocalcemia rather than increasing the plasma concentrations of potassium and calcium.

TMP13 pp. 355, 394-397, 427-428

54. B) Hypernatremia can be caused by excessive sodium retention or water loss. The fact that the patient has large volumes of dilute urine suggests excessive urinary water excretion. Of the two possible disturbances listed that could cause excessive urinary water excretion (nephrogenic diabetes insipidus and central diabetes insipidus), nephrogenic diabetes insipidus is the most likely cause. Central diabetes insipidus (decreased ADH secretion) is not the correct answer because plasma ADH levels are markedly elevated. Simple dehydration due to decreased water intake is unlikely because the patient is excreting large volumes of dilute urine.

TMP13 pp. 314-315, 380-381

55. D) Dehydration due to water deprivation decreases extracellular fluid volume, which in turn increases renin secretion and decreases plasma atrial natriuretic peptide. Dehydration also increases the plasma sodium concentration, which stimulates the secretion of ADH. The increased ADH increases water permeability in the collecting ducts. The ascending limb of the loop of Henle is relatively impermeable to water, and this low permeability is not altered by water deprivation or increased levels of ADH.

TMP13 pp. 375-376

56. C) High urine flow occurs in type 1 diabetes because the filtered load of glucose exceeds the renal threshold, resulting in an increase in glucose concentration in the tubule, which decreases the osmotic driving force for water reabsorption. Increased urine flow reduces extracellular fluid volume and stimulates the release of ADH.
TMP13 pp. 350-351, 381-382

57. C) Excess aldosterone and a high-salt diet could cause serious hypokalemia because aldosterone stimulates potassium secretion by the renal tubules (and therefore tends to increase potassium excretion), as well as causing a shift of potassium from the extracellular fluid into the cells. A high-salt diet would exacerbate the hypokalemia because this would increase collecting tubular flow rate, which would tend to further increase renal potassium secretion. Treatment with spironolactone or a β-adrenergic blocker or Addison's disease (adrenal insufficiency) would tend to increase plasma potassium concentration. Changes in sodium and potassium intakes over the ranges indicated would have minimal effects on plasma potassium concentration.
TMP 13 pp. 390-395

58. D) Ingestion of excess aspirin (acetylsalicylic acid) would tend to cause metabolic acidosis, which would lead to decreases in plasma HCO_3^-, decreased P_{CO_2} (due to respiratory compensation), decreased urine HCO_3^- excretion and increased NH_4^+ excretion (renal compensation), and increased anion gap due to increased unmeasured anions.
TMP 13 pp. 424-426

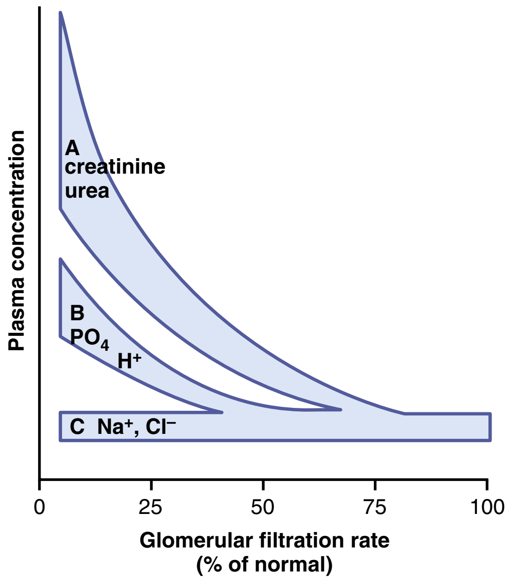
59. B) Approximately 30% to 40% of the filtered urea is reabsorbed in the proximal tubule. However, the tubular fluid urea concentration increases because urea is not nearly as permeant as water in this nephron segment. Urea concentration increases further in the tip of the loop of Henle because water is reabsorbed in the descending limb of the loop of Henle. Under conditions of antidiuresis, urea is further concentrated as water is reabsorbed and as fluid flows along the collecting ducts. Therefore, the final urine concentration of urea is substantially greater than the concentration in the proximal tubule or in the plasma.
TMP13 pp. 376-377

60. C) Diuretics that inhibit loop of Henle sodium reabsorption are used to treat conditions associated with excessive fluid volume (e.g., hypertension and heart failure). These diuretics initially cause an increase in sodium excretion that reduces extracellular fluid volume and blood pressure, but under steady-state conditions, the urinary sodium excretion returns to normal, due in part to the fall in blood pressure. One of the important adverse effects of loop diuretics is hypokalemia that is caused by the inhibition of Na^+-$2Cl^-$-K^+ co-transport in the loop of Henle and by the increased tubular flow rate in the cortical collecting tubules, which stimulates potassium secretion.
TMP13 pp. 394-395, 427-428

61. A) A reduction in the number of functional nephrons to 25% of normal would cause a compensatory increase in GFR and urine flow rate of the surviving nephrons and decreased urine concentrating ability. Under steady-state conditions, the urinary creatinine excretion rate and sodium excretion rate would be maintained at normal levels. (For further information, see TMP13, **Table 32-6.**)
TMP13 pp. 435-436

62. A) Excessive secretion of ADH increases water reabsorption by the renal collecting tubules, which reduces extracellular fluid sodium concentration (hyponatremia). Restriction of fluid intake, excessive aldosterone secretion, or administration of hypertonic 3% NaCl solution would all cause increased plasma sodium concentration (hypernatremia), whereas administration of 0.9% NaCl (an isotonic solution) would cause no major changes in plasma osmolarity.
TMP13 pp. 312-314

63. A) A 75% loss of nephrons would *not* cause a large increase in plasma sodium concentration because tubular reabsorption of sodium is reduced in proportion to the reduction in filtered load of sodium cause by nephron loss, and because the ADH–thirst mechanisms help maintain extracellular sodium concentration at a fairly constant level. Plasma creatinine is inversely related to GFR and would increase to approximately four times normal as GFR is reduced to one fourth normal. If fluid intake remains constant, the average volume excreted by the surviving nephrons would need to increase to four times normal to maintain fluid balance, and this high flow rate in the nephrons would reduce urine-concentrating ability. Plasma phosphate concentration is maintained at a nearly normal level until GFR falls below about 30% of normal, and then the plasma concentration rises progressively as GFR decreases further (see figure below).
TMP 13 pp. 435-436



64. D) Approximately 40% to 50% of the filtered urea is reabsorbed in the proximal tubule. The distal convoluted tubule and the cortical collecting tubules are relatively impermeable to urea, even under conditions of antidiuresis; therefore, little urea reabsorption takes place in these segments. Likewise, very little urea reabsorption takes place in the thick ascending limb of the loop of Henle. Under conditions of antidiuresis, the concentration of urea in the renal medullary interstitial fluid is markedly increased because of reabsorption of urea from the collecting ducts, which contributes to the hyperosmotic renal medulla.
TMP13 pp. 376-377

65. B) Free water clearance is calculated as urine flow rate (600 ml/2 h, or 5 ml/min) – osmolar clearance (urine osmolarity × urine flow rate/plasma osmolarity). Therefore, free water clearance is equal to +2.5 ml/min.
TMP13 p. 380

66. E) In the absence of ADH, the late distal tubule and collecting tubules are not permeable to water (see above). Therefore, the tubular fluid, which is already dilute when it leaves the loop of Henle (about 100 mOsm/L), becomes further diluted as it flows through the late distal tubule and collecting tubules as electrolytes are reabsorbed. Therefore, the final urine osmolarity in the complete absence of ADH is less than 100 mOsm/L.
TMP13 p. 378, Fig. 29-8

67. A) About 65% of the filtered potassium is reabsorbed in the proximal tubule, and another 20% to 30% is reabsorbed in the loop of Henle. Although most of the daily variation in potassium excretion is caused by changes in potassium secretion in the distal and collecting tubules, only a small percentage of the filtered potassium load can be reabsorbed in these nephron segments. (For further information, see TMP13, **Fig. 30-2.**)
TMP13 pp. 390-391

68. A) The proximal tubule normally absorbs approximately 65% of the filtered water, with much smaller percentages being reabsorbed in the descending loop of Henle and in the distal and collecting tubules. The ascending limb of the loop of Henle is relatively impermeable to water and therefore reabsorbs very little water.
TMP13 pp. 353, 378-379

69. C) The thick ascending limb of the loop of Henle is relatively impermeable to water even under conditions of maximal antidiuresis. The proximal tubule and descending limb of the loop of Henle are highly permeable to water under normal conditions, as well as during antidiuresis. Water permeability of the late distal and collecting tubules increases markedly during antidiuresis because of the effects of increased levels of ADH.
TMP13 pp. 378-379

70. D) Interstitial fluid volume is equal to extracellular fluid volume minus plasma volume. Extracellular fluid volume can be estimated from the distribution of inulin or ^{22}Na, whereas plasma volume can be estimated from ^{125}I-albumin distribution. Therefore, interstitial fluid volume is calculated from the difference between the inulin distribution space and the ^{125}I-albumin distribution space.
TMP13 pp. 309-310, Table 25-3

71. F) Furosemide (Lasix) is a "loop" diuretic that inhibits the Na^+-Cl^--K^+ co-transporter in the thick ascending loop of Henle, thus reducing urine-concentrating ability, increasing renal excretion of Na^+, Cl^-, and K^+, and tending to cause hypokalemia.
TMP 13 pp. 427-428

72. D) Uncontrolled type 1 diabetes would tend to cause metabolic acidosis (decreases in plasma pH and HCO_3^-) due to increased metabolisms of fat and production of acetoacetic acid, which, in turn, would be associated with increased anion gap. The normal respiratory compensation would decrease plasma P_{CO_2}.
TMP 13 p. 426

73. E) Metabolic alkalosis is associated with hypokalemia due to a shift of potassium from the extracellular fluid into the cells (see table below). β-adrenergic blockade, insulin deficiency, strenuous exercise, and aldosterone deficiency all cause hyperkalemia due to a shift of potassium out of the cells into the extracellular fluid.
TMP13 pp. 389-390, Table 30-1

Factors That Can Alter Potassium Distribution Between the Intracellular and Extracellular Fluid

Factors That Shift K^+ Into Cells (Decrease Extracellular K^+)	Factors That Shift K^+ Out of Cells (Increase Extracellular K^+)
Insulin	Insulin deficiency (diabetes mellitus)
Aldosterone	Aldosterone deficiency (Addison's disease)
β-Adrenergic stimulation	β-Adrenergic blockade
Alkalosis	Acidosis
	Cell lysis
	Strenuous exercise
	Increased extracellular fluid osmolarity

74. D) In this example, the filtered load of glucose is equal to GFR (100 ml/min) × plasma glucose (150 mg/dl), or 150 mg/min. If there is no detectable glucose in the urine, the reabsorption rate is equal to the filtered load of glucose, or 150 mg/min.
TMP13 p. 365

75. B) Furosemide is a powerful inhibitor of the Na^+-$2Cl^-$-K^+ co-transporter in the loop of Henle. Thiazide diuretics primarily inhibit NaCl reabsorption into the distal tubule, whereas carbonic anhydrase inhibitors decrease bicarbonate reabsorption in the tubules. Amiloride inhibits sodium channel activity, whereas spironolactone inhibits the action of mineralocorticoids in the renal tubules. Osmotic diuretics inhibit water and solute reabsorption by increasing osmolarity of the tubular fluid.
TMP13 p. 428

76. E) Decreased efferent arteriolar resistance would increase renal blood flow while reducing glomerular hydrostatic pressure, which, in turn, would tend to decrease the GFR.
TMP 13 pp. 338-339

77. D) The tubular fluid–plasma ratio of inulin concentration is 4 in the early distal tubule, as shown in the figure. Because inulin is not reabsorbed from the tubule, this means that water reabsorption must have concentrated the inulin to four times the level in the plasma that was filtered. Therefore, the amount of water remaining in the tubule is only one fourth of what was filtered, indicating that 75% of the water has been reabsorbed prior to the distal convoluted tubule.
TMP13 p. 359

78. E) Renal tubular acidosis results from a defect of renal secretion or H^+, a defect in reabsorption of HCO_3^-, or both. This defect causes metabolic acidosis associated with decreases in plasma pH and HCO_3^- and a normal anion gap associated with hyperchloremia (increased plasma chloride concentration). Plasma P_{CO_2} is reduced because of respiratory compensation for the acidosis.
TMP 13 p. 423

79. D) The patient has classic symptoms of diabetes mellitus: increased thirst, breath smelling of acetone (due to increased acetoacetic acids in the blood), high fasting blood glucose concentration, and glucose in the urine. The acetoacetic acids in the blood cause metabolic acidosis that leads to a compensatory decrease in renal HCO_3^- excretion, decreased urine pH, and increased renal production of ammonium and HCO_3^-. The high level of blood glucose increases the filtered load of glucose, which exceeds the transport maximum for glucose, causing an osmotic diuresis (increased urine volume) due to the unreabsorbed glucose in the renal tubules acts as an osmotic diuretic.
TMP13 pp. 350-351, 422

80. C) Intracellular fluid volume is calculated as the difference between total body fluid (0.57 × 60 kilograms = 34.2 kilograms, or approximately 34.2 liters) and extracellular fluid volume (12.8 liters), which equals 21.4 liters.
TMP13 pp. 309-310

81. C) Plasma volume is calculated as blood volume (4.3 liters) × (1.0 − hematocrit), which is 4.3 × 0.6 = 2.58 liters (rounded up to 2.6).
TMP13 pp. 309-310

82. C) Interstitial fluid volume is calculated as the difference between extracellular fluid volume (12.8 liters) and plasma volume (2.6 liters), which is equal to 10.2 liters.
TMP13 pp. 309-310

83. C) The primary site of reabsorption of magnesium is in the loop of Henle, where about 65% of the filtered load of magnesium is reabsorbed. The proximal tubule normally reabsorbs only about 25% of filtered magnesium, and the distal and collecting tubules reabsorb less than 5%.
TMP13 p. 398

84. D) The principal cells of the collecting tubules are an important site of action of amiloride, which blocks entry of sodium into sodium channels. Thiazide diuretics inhibit Na^+-Cl^- co-transport in the early distal tubule. The collecting tubule cells are not very permeable to urea. Furosemide inhibits the Na^+-Cl^--K^+ co-transporter in the thick ascending loop of Henle.
TMP 13 pp. 358, 377, 428

85. A) The filtration rate of glucose in this example is GFR (100 ml/min) × plasma glucose concentration (200 mg/100 ml, or 2 mg/ml) = 100 mg/min. Because the transport maximum for glucose in this example is 250 mg/min, all of the filtered glucose would be reabsorbed and the renal excretion rate for glucose would be zero.
TMP 13 pp. 350-351

86. C) A plasma glucose concentration of 300 mg/dl would increase the filtered load of glucose above the renal tubular transport maximum and therefore increase urinary glucose excretion. The unreabsorbed glucose in the renal tubules would also cause an osmotic diuresis, increased urine volume, and decreased extracellular fluid volume, which would stimulate thirst. Increased glucose also causes vasodilatation of afferent arterioles, which increases GFR.
TMP13 pp. 345-346, 351, 384-385

87. B) GFR is approximately equal to the clearance of creatinine. Creatinine clearance = urine creatinine concentration (32 mg/dl) × urine flow rate (3600 ml/24 h, or 2.5 ml/min) ÷ plasma creatinine concentration (4 mg/dL) = 20 ml/min.
TMP13 pp. 365-366

88. D) The net renal tubular reabsorption rate is the difference between the filtered load of potassium (GFR × plasma potassium concentration) and the urinary excretion of potassium (urine potassium concentration × urine flow rate). Therefore, the net tubular reabsorption of potassium is 0.075 mmol/min.
TMP13 pp. 365-366

89. D) Severe diarrhea would result in loss of HCO_3^- in the stool, thereby causing metabolic acidosis that is characterized by low plasma HCO_3^- and low pH. Respiratory compensation would reduce P_{CO_2}. The plasma anion gap would be normal, and the plasma chloride concentration would be elevated (hyperchloremic metabolic acidosis) in metabolic acidosis caused by HCO_3^- loss in the stool.

TMP13 pp. 421-426

90. E) Primary excessive secretion of aldosterone causes metabolic alkalosis due to increased secretion of hydrogen ions and HCO_3^- reabsorption by the intercalated cells of the collecting tubules. Therefore, the metabolic alkalosis would be associated with increases in plasma pH and HCO_3^-, with a compensatory reduction in respiration rate and increased P_{CO_2}. The plasma anion gap would be normal, with a slight reduction in plasma chloride concentration.

TMP13 pp. 424-426

91. D) Proximal tubular acidosis results from a defect of renal secretion of hydrogen ions, reabsorption of bicarbonate, or both. This defect leads to increased renal excretion of HCO_3^- and metabolic acidosis characterized by low plasma HCO_3^- concentration, low plasma pH, a compensatory increase in respiration rate and low P_{CO_2}, and a normal anion gap with an increased plasma chloride concentration.

TMP13 pp. 421-426

92. F) A patient with diabetic ketoacidosis and emphysema would be expected to have metabolic acidosis (due to excess ketoacids in the blood caused by diabetes), as well as increased plasma P_{CO_2} due to impaired pulmonary function. Therefore, the patient would be expected to have decreased plasma pH, decreased HCO_3^-, increased P_{CO_2}, and an increased anion gap (Na^+-Cl^--HCO_3^- > 10-12 mEq/L) due to the addition of ketoacids to the blood.

TMP13 pp. 422-426

93. D) Secretion of hydrogen ions and reabsorption of HCO_3^- depend critically on the presence of carbonic anhydrase in the renal tubules. After inhibition of carbonic anhydrase, renal tubular secretion of hydrogen ions and reabsorption of HCO_3^- would decrease, leading to increased renal excretion of HCO_3^-, reduced plasma HCO_3^- concentration, and metabolic acidosis. The metabolic acidosis, in turn, would stimulate the respiration rate, leading to decreased P_{CO_2}. The plasma anion gap would be within the normal range.

TMP13 pp. 416-417, 425-426

94. B) Acute renal failure caused by tubular necrosis would cause the rapid development of metabolic acidosis due to the kidneys' failure to rid the body of the acid waste products of metabolism. The metabolic acidosis would lead to decreased plasma HCO_3^- concentration. Acute renal failure would also lead to a rapid increase in blood urea nitrogen concentration and a significant increase in plasma potassium concentration due to the kidneys' failure to excrete electrolytes or nitrogenous waste products. Necrosis of the renal epithelial cells causes them to slough away from the basement membrane and plug up the renal tubules, thereby increasing hydrostatic pressure in Bowman's capsule and decreasing GFR.

TMP13 pp. 431, 438

95. C) The type A intercalated cells of the collecting tubules are important sites for H^+ secretion and K^+ *reabsorption*, but the collecting tubules are not highly permeable to urea. Furosemide acts mainly in the thick ascending loop of Henle, and thiazide diuretics act mainly in the early distal tubule.

TMP13 pp. 356-357

96. D) Dehydration due to insufficient water intake and heavy exercise would increase plasma sodium concentration, which would then stimulate release of ADH. This would increase water reabsorption in the distal and collecting tubules/ducts, causing a small volume of highly concentrated urine. Primary aldosteronism would be associated with sodium and water retention but normal renal excretion (equal to intake) of sodium and water after a few days. Uncontrolled diabetes mellitus is typically associated with large volumes of urine due to the osmotic diuresis associated with the hyperglycemia. Diabetes insipidus is associated with large volumes of dilute urine. Bartter's syndrome is defective Na^+-Cl^--K^+ co-transport in the thick ascending loop of Henle and is associated with increased urine volume. Liddle's syndrome is caused by increased sodium reabsorption and, like primary aldosteronism, is associated with sodium and water retention but normal renal excretion (equal to intake) of sodium and water after a few days.

TMP13 pp. 439-440

97. C) A large increase in aldosterone secretion combined with a high sodium intake would cause severe hypokalemia. Aldosterone stimulates potassium secretion and causes a shift of potassium from the extracellular fluid into the cells, and a high sodium intake increases the collecting tubular flow rate, which also enhances potassium secretion. In normal persons, potassium intake can be reduced to as low as one fourth of normal with only a mild decrease in plasma potassium concentration (for further information, see TMP13, **Fig. 30-8**). A low sodium intake would tend to oppose aldosterone's hypokalemic effect because a low sodium intake would reduce the collecting tubular flow rate and thus tend to reduce potassium secretion. Patients with Addison's disease have a deficiency of aldosterone secretion and therefore tend to have hyperkalemia.

TMP13 pp. 389, 392-395

98. E) Intracellular and extracellular body fluids have the same total osmolarity under steady-state conditions because the cell membrane is highly permeable to water. Therefore, water flows rapidly across the cell membrane until osmotic equilibrium is achieved. The colloid osmotic pressure is determined by the protein concentration, which is considerably higher inside the cell. The cell membrane is also relatively impermeable to potassium, sodium, and chloride, and active transport mechanisms maintain low intracellular concentrations of sodium and chloride and a high intracellular concentration of potassium.
TMP13 pp. 310-312

99. B) Fluid entering the early distal tubule is almost always hypotonic because sodium and other ions are actively transported out of the thick ascending loop of Henle, whereas this portion of the nephron is virtually impermeable to water. For this reason, the thick ascending limb of the loop of Henle and the early part of the distal tubule are often called the diluting segment.
TMP13 pp. 354-355

100. D) Chronic metabolic acidosis is, by definition, associated with decreased HCO_3^-. Decreased excretion of NH_4Cl and HCO_3^- occurs with renal compensation for the acidosis, and respiratory compensation for the acidosis increases the ventilation rate, resulting in decreased plasma P_{CO_2}.
TMP13 pp. 419-420

101. E) Although aldosterone is one of the body's most potent sodium-retaining hormones, it stimulates sodium reabsorption only in the late distal tubule and collecting tubules, which together reabsorb much less than 10% of the filtered load of sodium. Therefore, the maximum percentage of the filtered load of sodium that could be reabsorbed in the distal convoluted tubule and collecting duct, even in the presence of high levels of aldosterone, would be less than 10%.
TMP13 pp. 355, 357-359

102. D) GFR is equal to the clearance of inulin. Inulin clearance = urine inulin concentration (60 mg/ml) × urine flow rate (2 ml/min)/plasma inulin concentration (2 mg/ml) = 60 ml/min.
TMP13 pp. 365-368

103. D) The net renal tubular potassium reabsorption rate is the difference between the filtered load of potassium (GFR × plasma potassium concentration) and the urinary excretion rate of potassium (urine potassium concentration × urine flow rate). Therefore, the net tubular reabsorption rate of potassium is 200 μmol/min.
TMP13 pp. 365-368

104. A) Free water clearance is calculated as urine flow rate (2.0 ml/min) − osmolar clearance (urine osmolarity × urine flow rate/plasma osmolarity). Therefore, free water clearance is equal to +1.0 ml/min.
TMP13 p. 380

105. B) A 0.45% NaCl solution is *hypotonic.* Therefore, administration of 2.0 liters of this solution would reduce intracellular and extracellular fluid osmolarity and cause increases in intracellular and extracellular volumes.
TMP13 pp. 312-313

106. C) If the renal clearance is greater than the GFR, this implies that there must be secretion of that substance into the renal tubules. A substance that is freely filtered and not secreted or reabsorbed would have a renal clearance equal to the GFR.
TMP13 p. 368

107. A) In the proximal tubule, calcium reabsorption usually parallels sodium and water reabsorption. With extracellular volume expansion or increased blood pressure, proximal sodium and water reabsorption is reduced, and a reduction in calcium reabsorption also occurs, causing increased urinary excretion of calcium. Increased parathyroid hormone, increased plasma phosphate concentration, and metabolic alkalosis all tend to decrease the renal excretion of calcium.
TMP13 pp. 396-398

108. C) Increasing sodium intake would decrease renin secretion and plasma renin activity, as well as reduce plasma aldosterone concentration and increase plasma atrial natriuretic peptide because of a modest expansion of extracellular fluid volume. Although a high sodium intake would initially increase distal NaCl delivery, which would tend to increase potassium excretion, the decrease in aldosterone concentration would offset this effect, resulting in no change in potassium excretion under steady-state conditions. Even very large increases in sodium intake cause only minimal changes in plasma sodium concentration as long as the ADH–thirst mechanisms are fully operative.
TMP13 pp. 394-395

109. C) A 50% reduction in efferent arteriolar resistance would cause a large decrease in GFR—greater than 10%. A decrease in renal artery pressure from 100 to 85 mm Hg would cause only a slight decrease in GFR in a normal, autoregulating kidney. A decrease in afferent arteriole resistance, a decrease in plasma colloid osmotic pressure, or an increase in the glomerular capillary filtration coefficient would all tend to increase GFR.
TMP13 pp. 337-340, 343, Figs. 27-7 and 27-9

110. D) Acute metabolic acidosis reduces intracellular potassium concentration, which, in turn, decreases potassium secretion by the principal cells of the collecting tubules. The primary mechanism by which increased hydrogen ion concentration inhibits potassium secretion is by reducing the activity of the sodium-potassium adenosine triphosphatase pump. This action then reduces intracellular potassium concentration, which, in turn, decreases the rate of passive diffusion of potassium across the luminal membrane into the tubule.

TMP13 p. 395

111. E) The kidneys excrete little or no glucose as long as the filtered load of glucose (the product of the GFR and the plasma glucose concentration) does not exceed the tubular transport maximum for glucose. Once the filtered load of glucose rises above the transport maximum, the excess glucose filtered is not reabsorbed and passes into the urine. Therefore, the urinary excretion rate of glucose can be calculated as the filtered load of glucose minus the transport maximum. In this example, the filtered load of glucose is the GFR (150 ml/min) multiplied by the plasma glucose concentration (400 mg/100 ml, or 4 mg/ml), which is equal to 600 mg/min. Because the transport maximum is only 300 mg/min, the rate of glucose excretion would be 600 minus 300 mg/min, or 300 mg/min.

TMP13 pp. 350-351, 365-368

112. D) In a dehydrated person, osmolarity in the early distal tubule is usually less than 300 mOsm/L because the ascending limb of the loop of Henle and the early distal tubule are relatively impermeable to water, even in the presence of ADH. Therefore, the tubular fluid becomes progressively more dilute in these segments compared with plasma. ADH does not influence water reabsorption in the ascending limb of the loop of Henle. The ascending limb, however, reabsorbs sodium to a much greater extent than does the descending limb. Another important action of ADH is to increase the urea permeability in the medullary collecting ducts, which contributes to the hyperosmotic renal medullary interstitium in antidiuresis.

TMP13 pp. 378-379

113. E) A 50% reduction in GFR (from 80 to 40 ml/min) would result in an approximate 50% reduction in creatinine clearance rate because creatinine clearance is approximately equal to the GFR. This reduction would, in turn, lead to doubling of the plasma creatinine concentration. This rise in plasma creatinine concentration results from an initial decrease in creatinine excretion rate, but as the plasma creatinine concentration increases, the filtered load of creatinine (the product of GFR × plasma creatinine concentration) returns to normal and creatinine excretion rate returns to normal under steady-state conditions. Thus, under the steady state conditions, a 50% reduction in GFR is associated with a doubling of plasma creatinine concentration, a 50% decrease in creatinine clearance, and a normal filtered load of creatinine, as well as no change in load of filtered creatinine and no change in the creatinine excretion rate as long as the person's protein metabolism is not altered. Likewise, the sodium excretion rate returns to normal even when the GFR is reduced because of multiple feedback systems that eventually re-establish sodium balance. Under steady-state conditions, sodium excretion must equal sodium intake to maintain life.

TMP13 pp. 366-367, 399

114. E) Most potassium secretion occurs in the collecting tubules. A high-potassium diet stimulates potassium secretion by the collecting tubules through multiple mechanisms, including small increases in extracellular potassium concentration, as well as increased levels of aldosterone.

TMP13 pp. 392-393

115. A) Diabetic ketoacidosis results in a metabolic acidosis that is characterized by a decrease in plasma bicarbonate concentration, increased anion gap (due to the addition of unmeasured anions to the extracellular fluid along with the ketoacids), and a renal compensatory response that includes increased secretion of NH_4^+. There is also an increased respiratory rate with a reduction in arterial P_{CO_2}, as well as decreased urine pH and decreased renal HCO_3^- excretion.

TMP13 pp. 421-426

116. A) Potassium excretion rate is calculated as urine K^+ concentration multiplied by urine flow rate, which in this case = 60 mmol/L × 0.002 L/min = 0.12 mmol/min.

TMP13 pp. 365-368

117. B) Interstitial fluid volume cannot be measured directly, but it can be calculated as the difference between extracellular fluid volume (inulin space = 16 liters) and plasma volume (^{125}I-albumin space = 4 liters). Therefore, interstitial fluid volume is approximately 12 liters.

TMP13 pp. 309-310

118. E) Increased levels of insulin cause a shift of potassium from the extracellular fluid into the cells. All the other conditions have the reverse effect of shifting potassium out of the cells into the extracellular fluid.

TMP13 pp. 389-390

119. D) This patient is severely dehydrated as a result of sweating and lack of adequate fluid intake. The dehydration markedly stimulates the release of ADH and renin secretion, which in turn stimulates the formation of angiotensin II and aldosterone secretion.

TMP13 pp. 363, 382

120. E) After running the race and losing both fluid and electrolytes, this person replaces his fluid volume by drinking 2 liters of water. However, he did not replace the electrolytes. Therefore, he would be expected to experience a decrease in plasma sodium concentration, resulting in a decrease in both intracellular and extracellular fluid osmolarity. The decrease in extracellular fluid osmolarity would lead to an increase in intracellular volume as fluid diffused into the cells from the extracellular compartment. Therefore, after drinking the water and absorbing it, the total body volume would be normal but intracellular volume would be increased and extracellular volume would be reduced.

TMP13 pp. 311-313

121. B) Increased levels of parathyroid hormone stimulate calcium reabsorption in the thick ascending loops of Henle and distal tubules. Extracellular fluid volume expansion, increased blood pressure, decreased plasma phosphate concentration, and metabolic acidosis are all associated with decreased calcium reabsorption by the renal tubules.

TMP13 pp. 396-397

122. D) The patient has metabolic acidosis as evidenced by the reduced plasma HCO_3^- concentration (normal = 24 mEq/L) and decreased arterial P_{CO_2} (normal is approximately 40 mm Hg). Because the plasma anion gap (plasma sodium − HCO_3^- − chloride) is normal (approximately 10 mEq/L), the acidosis is not caused by excess nonvolatile acids caused by salicylic acid poisoning, diabetes, or methanol poisoning. Therefore, the most likely cause of the metabolic acidosis is diarrhea, which leads to loss of bicarbonate in the feces. With emphysema, the acidosis would be associated with the increase in P_{CO_2}.

TMP13 pp. 421-422, 426

123. C) In this example, the acidosis is associated with a reduced plasma bicarbonate concentration, signifying metabolic acidosis. In addition, the patient also has an elevated P_{CO_2}, signifying respiratory acidosis. Therefore, the patient has simultaneous respiratory and metabolic acidosis.

TMP13 pp. 422-426

124. A) Urine flow rate is calculated as the difference between GFR and tubular fluid reabsorption rate. If GFR decreases from 150 to 75 ml/min and tubular fluid reabsorption rate simultaneously decreases from 149 to 75 ml/min, the urine flow rate would be the GFR minus the tubular reabsorption rate, or 75 − 75 ml/min, which would equal 0 ml/min.

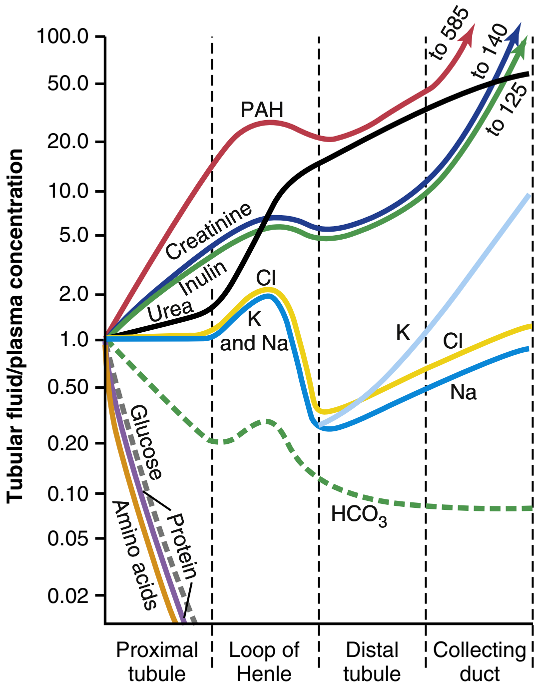
TMP13 pp. 347, 365-366

125. A) Chronic respiratory acidosis is caused by insufficient pulmonary ventilation, resulting in an increase in P_{CO_2}. Acidosis, in turn, stimulates the secretion of hydrogen ions into the tubular fluid and increased renal tubular production of NH_4^+, which further contributes to the excretion of hydrogen ions and the renal production of HCO_3^-, thereby increasing plasma bicarbonate concentration. The increased tubular secretion of hydrogen ions also reduces urine pH.

TMP13 p. 422

126. F) Because creatinine is not reabsorbed significantly in the renal tubules, the concentration of creatinine progressively increases as water is reabsorbed along the renal tubular segments (see figure below). Therefore, in a normally hydrated person, the concentration of creatinine would be greatest in the collecting ducts.

TMP13 p. 359



127. B) Three percent dextrose is a hypotonic solution. Therefore, infusing the 3% dextrose would decrease extracellular fluid osmolarity, which, in turn, would lead to diffusion of water into the cells. Under steady-state conditions, there would be a reduction in intracellular and extracellular osmolarity, as well as an increase in the fluid volume of both compartments.

TMP13 pp. 311-314

128. D) A patient with central diabetes insipidus would have deficient secretion of ADH, resulting in excretion of large volumes of water. This excretion, in turn, would cause dehydration and hypernatremia (increased plasma osmolarity). The hypernatremia would result in decreased intracellular volume. Therefore, the primary loss of water would lead to increases in both extracellular and intracellular fluid osmolarity, as well as decreases in intracellular and extracellular fluid volumes.

TMP13 pp. 313-316

129. A) Dilation of the afferent arterioles leads to an increase in the glomerular hydrostatic pressure and therefore an increase in GFR, as well as an increase in renal blood flow. Increased glomerular capillary filtration coefficient would also raise the GFR but would not be expected to alter renal blood flow. Increased plasma colloid osmotic pressure or dilation of the efferent arterioles would both tend to reduce the GFR. Increased blood viscosity would tend to reduce renal blood flow and GFR.
TMP13 pp. 337-341

130. C) Because inulin is not reabsorbed or secreted by the renal tubules, increasing concentration of inulin in the renal tubules reflects water reabsorption. Thus, an increase of inulin concentration from a level of 2 mg/100 ml in the plasma to 40 mg/100 ml in the cortical collecting tubule implies that there has been a 20-fold increase in concentration of inulin. In other words, only 1/20th (5%) of the water that was filtered into the renal tubule remains in the collecting tubule.
TMP13 p. 359

131. B) Nonsteroidal anti-inflammatory drugs inhibit the synthesis of prostaglandins, which, in turn, causes constriction of afferent arterioles that can reduce the GFR. The decrease in GFR, in turn, leads to an increase in serum creatinine. Increased efferent arteriole resistance and increased glomerular capillary filtration coefficient would both tend to increase rather than reduce GFR. Increasing muscle mass due to exercise would cause very little change in serum creatinine.
TMP13 pp. 337-340, 342

132. A) In this example, the plasma sodium concentration is markedly increased but the urine sodium concentration is relatively normal, and urine osmolarity is almost maximally increased to 1200 mOsm/L. In addition, there are increases in plasma renin, ADH, and aldosterone, which is consistent with dehydration caused by decreased fluid intake. The syndrome of inappropriate ADH would result in a decrease in plasma sodium concentration, as well as suppression of renin and aldosterone secretion. Nephrogenic diabetes insipidus, caused by the kidneys' failure to respond to ADH, would also be associated with dehydration, but urine osmolarity would be reduced rather than increased. Primary aldosteronism would tend to cause sodium and water retention with only a modest change in plasma sodium concentration and a marked reduction in the secretion of renin. Likewise, a renin-secreting tumor would be associated with increases in plasma aldosterone concentration and plasma renin activity but only a modest change in plasma sodium concentration.
TMP13 pp. 380-381, 385-386