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You may use the following in calculations:

$2.3\,RT \cdot F^{-1} \cdot \log 10 = 60\,mV$ $x^2 = 2Dt$

$\log 3 = 0.48$ $\log 5 = 0.70$ $\log 6 = 0.78$

Put name on every page in case pages become separated.

I. Multiple Choice Circle <u>one</u> of the letters, a - f, below each question. (You may fill in blanks to help formulate answers, but only the a - f answer will count.)

1. During a normal swallowing sequence, the smooth muscle that surrounds the gastroesophageal junction:
   a. remains tonically constricted until the food bolus arrives at this junction
   b. relaxes even before the oncoming wave has arrived
   c. constricts further on the passing bolus and allows a gradual esophageal emptying
   d. is not normally constricted and thus plays no role in the swallowing process

2. The cephalic phase of gastric secretion _____ significantly altered by varied conditions of appetite and _____ blocked by bilateral section of the vagi. (I, is; N, is not)
   a. I,I
   b. I,N
   c. N,I
   d. N,N

3. A major part of gall bladder contractions are due to:
   a. sympathetic stimulation of the viscera
   b. the overfilling of the gall bladder with bile
   c. the ratio of cholesterol, phospholipid and bile salts secreted by the liver
   d. a hormone synthesized by the duodenal mucosa
   e. a pancreatic hormone

4. Digestive breakdown of starch is begun in the _____ (M, mouth; D, duodenum) by action of an enzyme secreted by the _____ (S, salivary glands; L, liver; DM, duodenal mucosa).
   a. M, S
   b. M, L
   c. M, DM
   d. D, S
   e. D, L
   f. D, DM

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5. Bile is synthesized in the _____ (G, gallbladder; P, pancreas; L, liver) and stored _____ (W, as well as; N, but not) concentrated in the _____ (G, gallbladder; P, pancreas; L, liver).
   a. G, W, L c. L, W, G e. P, N, L
   b. P, W, G d. G, N, P f. L, N, G

6. High volume flow from the pancreas is stimulated by _____ (S, secretin; C, cholecystokinin; V, vagal stimulation) to provide a juice that is relatively _____ (H, high; L, low) in HCO_3^- concentration.
   a. S, H c. C, H e. V, H
   b. S, L d. C, L f. V, L

7. Gastric acid is secreted from _____ (C, chief; P, parietal) cells by action of an enzyme that transports H^+ in exchange for _____ (Ca^{++}; K^+; Na^+).
   a. C, Ca^{++} c. C, Na^+ e. P, K^+
   b. C, K^+ d. P, Ca^{++} f. P, Na^+

8. Trypsinogen is produced by the _____ (C, chief cells; D, duodenal mucosa; P, pancreas) and activated by _____ (CP, carboxypeptidase; EK, enterokinase; pH, low pH).
   a. C, CP c. D, CP e. P, CP
   b. C, pH d. D, EK f. P, EK

9. Sodium moves from the intestinal lumen into the epithelial cells by _____ and from the cells into extracellular fluid via _____. (A, active transport; F, facilitated diffusion; S, simple diffusion)
   a. A, S c. F, A e. S, A
   b. A, F d. F, S f. S, F

10. Interstitial fluid has a total osmolarity that is _____ that of most cells and a Na^+ concentration that is _____ that of plasma. (G, greater than; L, less than; S, the same as)
    a. G, L c. G, G e. S, S
    b. G, S d. S, L f. S, G

11. We would expect to find hydrostatic pressure in the afferent arteriole to be _____ that in the efferent arteriole, and the colloid osmotic pressure of the afferent arteriole to be _____ that in the efferent arteriole. (G, greater than; L, less than; S, the same as)
    a. G, L c. L, G e. L, S
    b. G, G d. L, L f. S, G

12. The hormones, aldosterone and natriuretic factor,
    a. are secreted by the adrenal cortex.
    b. are secreted in direct response to an increase in arterial pressure.
    c. cause opposing changes in urinary salt and water output.
    d. can be secreted in response to high doses of ACTH.
    e. are both peptide hormones.
    f. are secreted from granules in right atrial cells.

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13. Autoregulation of renal blood flow _____ (W, will; N, will not) occur in the completely denervated kidney, and is a phenomenon that is of primary importance in regulating _____ (O_2, oxygen requirement of the kidney; GFR, glomerular filtration rate; H, renal hydrogen secretion).
    a. W, O_2 c. W, GFR e. W, H
    b. N, O_2 d. N, GFR f. N, H

14. Quantitatively, the major factor in the increase of renal acid excretion in acidosis is:
    a. increased urine pH d. increased titratable acidity
    b. decreased urine pH e. increased urine-dissolved CO_2
    c. increased ammonium excretion

15. Which of the following absorbs or reabsorbs the largest quantity of water each day?
    a. distal tubules c. large intestine
    b. small intestine d. proximal tubules

16. The lung volume measured from maximum inspiration to maximum expiration is called the _____ (IC, inspiratory capacity; VC, vital capacity) and can be used to directly calculate total lung capacity if we have a measure of _____ (ERV, expiratory reserve volume; RV, residual volume; FRC, functional residual capacity).
    a. VC,ERV c. VC,FRC e. IC,RV
    b. VC,RV d. IC,ERV f. IC,FRC

17. The anatomical dead space is either equal to or _____ (L, less than; G, greater than) the physiological dead space, and will be _____ (I, increased; D, decreased; O, not changed) by increasing the respiratory rate.
    a. L, I c. L, D e. L, O
    b. G, I d. G, D f. G, O

18. A subject is breathing at a rate of 12 breaths/min with a tidal volume of 500 ml and a dead space of 150 ml. For this subject, we would say that the minute volume was _____L/min and the rate of alveolar ventilation was _____L/min.
    a. 6000; 7800 c. 6.0; 7.8 e. 6000; 4.2
    b. 6.0; 4.2 d. 5.0; 4.2 f. 5000; 4200

19. The greatest resistance to air flow occurs in the _____ (A, alveoli; B, bronchioles; U, upper respiratory passageway) and this is likely to be increased by _____ (AS, asthma; EM, emphysema).
    a. A, AS c. B, AS e. U, AS
    b. A, EM d. B, EM f. U, EM

20. In comparison with the systemic circulation, the pulmonary circulation has _____ vascular resistance, _____ hydrostatic pressure, and _____ vascular compliance. (H, higher; L, lower)
    a. H,L,L c. L,H,H e. L,L,H
    b. H,H,L d. L,L,L f. L,H,L

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21. Someone is accidentally exposed to carbon monoxide which combines with half the hemoglobin in the arterial blood. In the arterial blood, we would expect the PO_2 to be _____ and the O_2 content to be _____, while in mixed venous blood we would expect PO_2 to be _____ (H, high; L, low; N, normal)
    a. H, L, N
    b. N, L, L
    c. H, N, L
    d. N, L, N
    e. H, L, L
    f. N, L, H

22. Under normal conditions, oxygen delivery to the body is _____ (D, diffusion-limited; P, perfusion-limited), but this situation can be altered by _____ (HV, hyperventilation; PE, pulmonary edema; CO, carbon monoxide poisoning).
    a. D, HV
    b. D, PE
    c. D, CO
    d. P, HV
    e. P, PE
    f. P, CO

23. All of the following shift the oxygen dissociation curve to the left, **except**
    a. reduction in temperature
    b. reduction in pH
    c. reduction in PCO_2
    d. reduction in 2,3-DPG in the red cell

24. The rate of O_2 moving from the alveoli into the blood would be decreased by _____ surface area of the lung, _____ thickness of the respiratory membrane, and _____ PO_2 difference between lungs and blood. (I, increased; D, decreased)
    a. I,D,D
    b. D,D,I
    c. I,I,D
    d. D,I,I
    e. D,D,D
    f. D,I,D

25. If total ventilation and the rate of O_2 consumption remain constant, which of the following will increase arterial PO_2?
    a. Increase in respiratory frequency.
    b. Increase in FRC.
    c. Increase in tidal volume.

26. In respiratory acidosis blood [HCO_3^-] _____, arterial PCO_2 _____, and renal HCO_3^- reabsorption by the collecting duct _____ (I, increases; D, decreases)
    a. I, I, D
    b. I, D, I
    c. D, I, I
    d. I, I, I
    e. D, D, I
    f. D, I, D

27. Medullary chemoreceptors are exquisitely sensitive to acute alterations of **arterial** _____ (PO_2; pH; PCO_2) and thereby produce a change in _____ (AV, alveolar ventilation; PP, pulmonary perfusion).
    a. PO_2, AV
    b. PO_2, PP
    c. pH, AV
    d. pH, PP
    e. PCO_2, AV
    f. PCO_2, PP

28. Peripheral chemoreceptors respond principally to _____ (PO_2; pH; PCO_2) in _____ (A, arterial; V, venous) blood.
    a. PO_2, A
    b. PO_2, V
    c. pH, A
    d. pH, V
    e. PCO_2, A
    f. PCO_2, V

29. A region of axon cannot be restimulated immediately after an action potential passes, because _____ are still closed and _____ are still open. (FN, fast Na^+ gates; SN, slow Na^+ gates; K, voltage-sensitive K^+ gates)
    a. FN, SN
    b. FN, K
    c. SN, FN
    d. SN, K
    e. K, FN
    f. K, SN

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II. 1. Circle the most appropriate *choice*

a. Increasing the external K^+ concentration around a resting nerve cell will *hyperpolarize*, *depolarize*, *not change* the resting membrane potential.

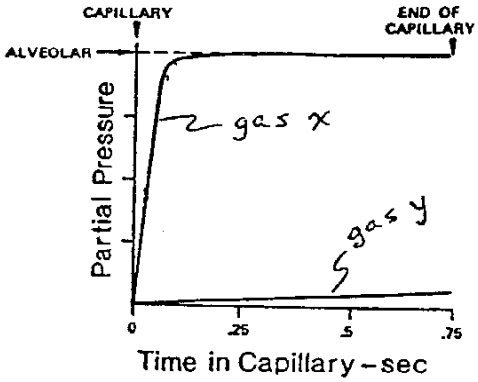
b. After poisoning the Na/K pump in a muscle cell, we measure the resting membrane potential as -65 mV, while $\mathcal{E}_K$ is calculated to be -85 mV. We can predict that the internal K^+ concentration will *increase*, *decrease*, *not change*.

c. In a normal axon, when the Na^+ flowing inward slightly exceeds the K^+ flowing outward, the membrane will *develop an action potential*, *depolarize slightly*, *hyperpolarize*.

d. Conduction velocity in unmyelinated axons *increases*, *decreases*, *doesn't change* with increase in axon diameter.

2. Given the data shown at the right for the movement of two gases, x and y, from alveolar air into pulmonary capillary blood in a resting subject, fill in the following blanks with:

_x_, _y_, or _x and y_



a. Gas(es) _____ is (are) diffusion limited.
b. Exercise would likely lead to an increase in the amount of gas(es) _____ moving into the blood.

3. Fill in the blanks with the most appropriate word or expression:

a) Under resting conditions how long does it take the Hb in a red cell to become saturated with O_2 in a pulmonary capillary? _____.
Does this change in exercise? _____.

b) Following a puncture wound to the right side of the chest, the right lung collapses. This is called a _____, and it is due to the equilibration of _____ pressure with atmospheric pressure.

c) Name two lung volumes that are reduced during exercise.
i) _____ ii) _____
What lung volume increases during exercise? _____

4. The presence of surfactant on the alveolar lining of the lung serves to: (↑, increase; ↓, decrease; 0, not change)

_____ alveolar surface tension
_____ airway resistance in trachea and bronchi
_____ fluid content in the alveoli
_____ pulmonary compliance
_____ work of inspiration

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5. Carbonic anhydrase catalyzes the hydration/dehydration reaction of CO_2 and is an important enzyme for many physiological functions. In cases where carbonic anhydrase is inhibited, there are a number of functional consequences in various tissues. For the processes listed below, indicate whether inhibition of carbonic anhydrase (e.g., by using acetazolamide) will cause an increase (↑), decrease (↓), or no change (0) in the activity.

Renal HCO_3^- excretion _____

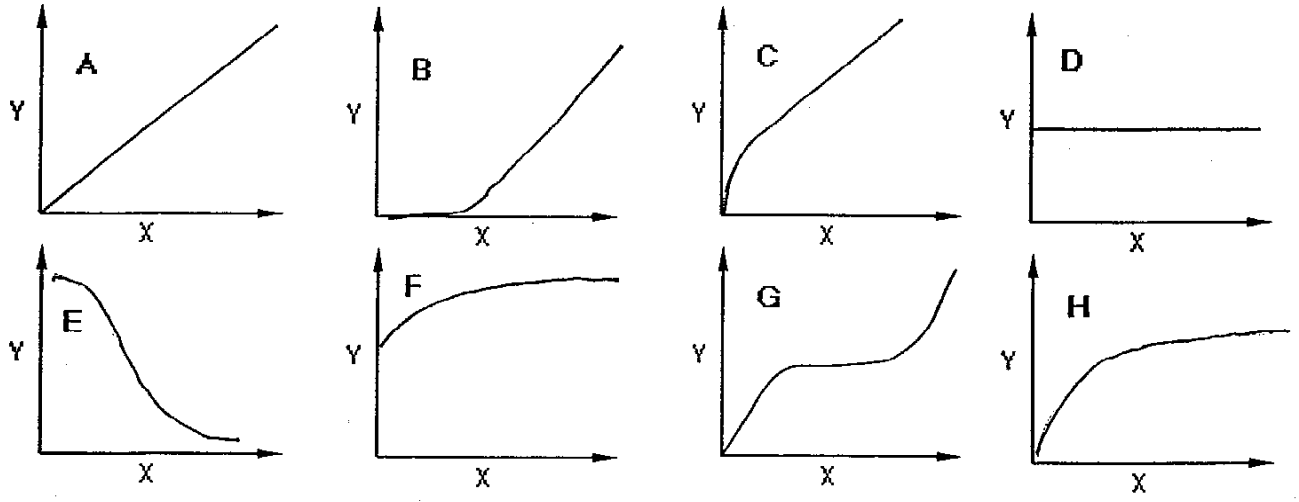
Renal H^+ secretion _____

CO_2 retention in tissues _____

Pancreatic HCO_3^- secretion _____

Gastric H^+ secretion _____

Pulmonary diffusion capacity of CO_2 _____



6. Select the single most appropriate graph, sketched above, for each of the following relationships. (Put one letter, A - H, in each underlined space.) X and Y values increase in the arrow directions.

Y-axis	X-axis
_____ Inulin clearance	Plasma concentration of inulin
_____ Urinary excretion of glucose	Plasma concentration of glucose
_____ Urinary excretion of inulin	Plasma concentration of inulin
_____ GFR	Rate of fluid delivery to macula densa
_____ GFR	Arterial blood pressure
_____ Osmotic pressure of plasma proteins	Distance along glomerular capillary

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7. Given the following data measured on plasma and urine samples from a recently hospitalized patient, and that S_{CO_2} = 0.03 mM per mm Hg and pK = 6.1 for the HCO_3^-/CO_2 system:

Plasma	Urine
$[HCO_3^-]$ = 30 mM	$[HCO_3^-]$ = 0.05 mM
[inulin] = 0.02 mg/ml	[inulin] = 1.3 mg/ml
P_{CO_2} = 60 mm Hg	urine flow rate = 2.0 ml/min

Calculate and show units:

a. Plasma pH

b. Glomerular filtration rate

c. Filtered load of HCO_3^-

d. Rate of HCO_3^- reabsorption by the kidney

e. Name the disturbance in acid-base balance for this patient, and describe one condition that would lead to that disturbance.

8. For a number of substances of similar molecular radii, the concentrations in the glomerular filtrate ([GF]) and in the plasma ([P]) were measured and the following ratios were determined:

Substance	Molecular radius (Å)	[GF]/[P]
neutral dextran	35.5	0.15
cationic dextran	35.5	0.50
serum albumin	35.5	<0.01

a. Explain the difference in [GF]/[P] values for the two dextran molecules.

b. Why did albumin have the lowest [GF]/[P] ratio?

9. It is commonly observed that patients on a nearly Na^+-free diet are able to absorb glucose and amino acids as well as those on a "normal" high-sodium diet. How can this observation be rationalized with the Na^+-gradient hypothesis for intestinal transport of glucose and amino acids?

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10. Indicate your answers to the following with arrows:
(↑) for increase (↓) for decrease (0) no change

a. If production of bile salts by the liver is significantly reduced:

( ) absorption of fats ( ) secretion of CCK

( ) lipid content of the blood ( ) absorption of vitamin A

b. An increase in action potential frequency in gastrointestinal smooth muscle is associated with:

( ) strength of contraction ( ) Ca^{2+} permeability

( ) frequency of slow waves ( ) activation of myosin light chain kinase

11. Correlate each of the numbered events in the electrocardiogram record at the right with one of the most closely associated cardiac events from the following list.

_____ rapid ventricular filling
_____ isovolumetric contraction
_____ closure of pulmonary valve
_____ AV nodal conduction delay
_____ ejection phase of ventricular systole

12. A healthy child performing steady exercise during recess at a school in Denver Colorado (altitude 1000 ft above sea level) has an oxygen consumption rate of 480 ml/min, a systemic O_2 concentration of 180 ml O_2/L blood, and a pulmonary arterial O_2 concentration of 100 ml O_2/L blood.

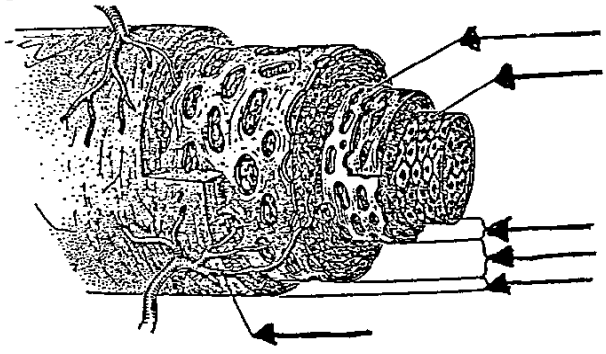
a. What is the child's cardiac output?

b. If the child's heart rate was 120 beats/min., what was the stroke volume?

c. What would you need to measure in order to calculate the ejection fraction?

13. In the spaces provided in the diagram of an artery shown below, locate the following components by their corresponding letter:

a. endothelium
b. vasa vasorum
c. intima
d. internal elastic membrane
e. adventitia
f. media



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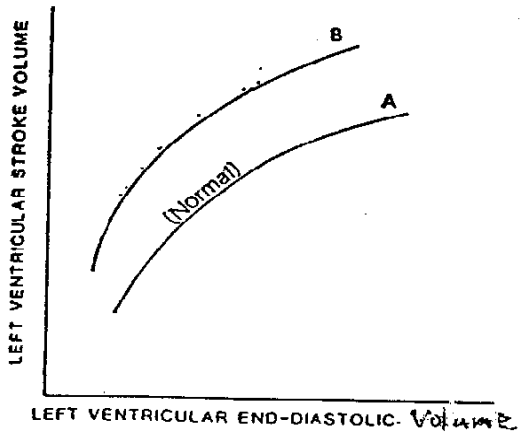
14. Referring to the figure at the right for left ventricular stroke volume vs left ventricular end diastolic volume:
    a. What is responsible (give mechanism) for the increase in stroke volume upon increase of left ventricular end diastolic volume in curve A?



    b. What is responsible (give mechanism) for the shift observed in curve B relative to A?

15. a. Sketch a representative action potential observed in the SA node and indicate where the pacemaker potential (diastolic depolarization) occurs?

    b. Briefly, what is the ionic basis (inward/outward currents) for the pacemaker potential?

    c. How is the pacemaker potential affected by:
    1.) increased sympathetic nervous activity (consider ion currents affected)?

    2.) increased vagal activity (also consider ion currents affected)?

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16. A patient who suffers from low vagal input to the sino-atrial node would have a condition called *bradycardia/tachycardia*, involving a *fast/slow/normal* heart rate and an ECG tracing with a *normal/abnormal* sequence of deflections. (Circle correct three *choices*.)

17. Calculate the time an average O_2 molecule would take to diffuse 0.4 μm from the alveolar surface into a pulmonary capillary. (Use 10^{-5} $cm^2 \cdot sec^{-1}$ for O_2 diffusion coefficient.)

18. Calculate the physiological dead space of a respiratory tract if mixed expired P_{CO_2} = 30 mm Hg and alveolar P_{CO_2} = 40 mm Hg when tidal volume = 400 ml.

19. (Put a membrane characteristic in each blank and circle the direction of change.) Myelination of an axon increases the speed and efficiency of action potential propagation by *increasing/decreasing* the _____ and *increasing/decreasing* the _____ of most of the axon's membrane.

20. Calculate the Na^+ equilibrium potential ($\mathcal{E}_{Na}$) for a nerve cell membrane, given that $g_K = g_{Cl} = 10 \cdot g_{Na}$ and given the following ion concentrations, in mM:

	K^+	Na^+	Cl^-
Intracellular	150	15	20
Extracellular	5	150	120