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MCB 136 Spring 1999
Exam 1

For questions 1 - 4, indicate whether the statements describe the parasympathetic nervous system, the sympathetic nervous system, both or neither. 1 pt each

P - parasympathetic
S - sympathetic
B - both
N - neither

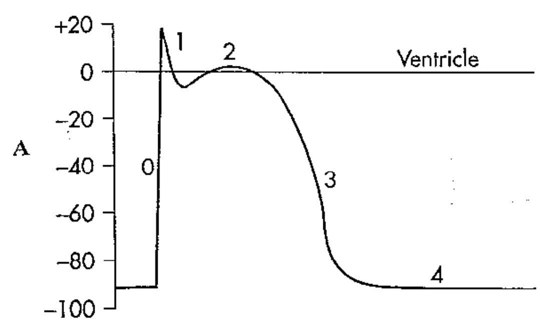
1. ___ Norepinephrine is the neurotransmitter used at the junction between the neuron and the target organ.

2. ___ Acetylcholine binds to a nicotinic receptor.

3. ___ Slows the heart rate.

4. ___ Nerves originate in the lumbar portion of the spinal cord.

Use the diagram below for questions 5 - 8. One answer and 1 pt each.



5. ___ Which one phase coincides most precisely with time of diastolic pressure?

6. ___ Which phase corresponds to the point in the cycle when the membrane is conductive to K^+ and the refractory state has ended?

7. ___ Which phase corresponds to the point in the cycle where the Na^+ conductance is in the inactivated state and Ca^{2+} conductance is activated.

8. ___ Which phase would change its duration the most during sympathetic stimulation?

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For questions 9 - 11, indicate whether the situation described will tend to move fluid into or out of the capillaries.

I - in
O - out

9. ___ Decreased protein concentration in the blood plasma (e.g. starvation).

10. ___ Increased venous pressure (e.g., congestive heart failure).

11. ___ Low blood pressure (e.g., hemorrhage).

MULTIPLE CHOICE. One answer and 1 pt each.

12. Which of the following events causes the myosin head to detach from the actin filament during skeletal muscle contraction?
A. ATP hydrolysis
B. when the myosin head moves, it physically separates from the actin
C. binding of ATP
D. the process is time-dependent
E. phosphorylation of troponin

13. Which of the following is the correct temporal sequence for events at the neuromuscular junction and muscle?
A. Action potential in the motor nerve, release of acetylcholine, release of Ca from sarcoplasmic reticulum (SR), action potential in the T-tubules
B. Action potential in the motor nerve, release of Ca from SR, release of acetylcholine, action potential in the T-tubules
C. Depolarization of muscle end plate, action potential in the muscle membrane, action potential in the T-tubules, Ca release from SR.
D. Release of acetylcholine, depolarization of muscle end plate, action potential in the SR, action potential in T-tubules

14. Which of the following characteristics or components is shared by skeletal and smooth muscle?
A. Thick and thin filaments arranged in sarcomeres
B. Troponin is a regulator
C. Elevation of intracellular Ca^{2+} for excitation-contraction coupling
D. High degree of electrical coupling between cells
E. Spontaneous depolarization of the membrane potential

15. A drug blocks Ca^{2+} channels (ryanodine receptors) in the sarcoplasmic reticulum of cardiac muscle. Which of the following effects would expected?
A. Block the occurrence of action potentials
B. Decrease the rate of rise of the upstroke of the action potential
C. Abolish phase 3 of the rapid cardiac action potential
D. Reduce cardiac contraction
E. Abolish cardiac contraction

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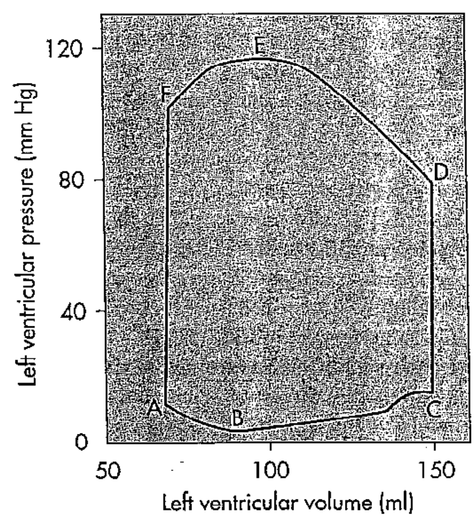
16 and 17. A radiological image of a patient's left renal artery shows narrowing of the artery's radius by 50%.

16. What is the expected change in resistance to blood flow through this artery?
    A. Decrease to 0
    B. Increase by
    C. Decrease by 1/8
    D. Decrease to 1/16
    E. Unchanged

17. If pressure in the aorta and renal artery remained constant, what would happen (compared to the normal condition) to pressure in the region just beyond the narrowing?
    A. Increase to 120 mm Hg
    B. Increase by factor of 2
    C. Decrease by factor of 2
    D. Decrease to 0
    E. Decrease by factor of 16

Questions 18 - 20 refer to the P - V loop shown below:



18. Diastole occurs between
    A. A --> B
    B. C --> D
    C. D --> E
    D. E --> F
    E. F --> C

19. If aortic pressure increased (e.g., hypertension) which part of the graph would increase?
    A. A
    B. B
    C. C
    D. D, E, F

20. If the heart rate is 80 beats/min, then cardiac output is:
    A. 4.8 L/min
    B. 5.0 L/min
    C. 5.6 L/min
    D. 6.0 L/min
    E. 6.4 L/min

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21. The greatest pressure drop in the circulation occurs across the arterioles because
    A. They have the greatest surface area
    B. They have the greatest cross-sectional area
    C. The velocity of blood flow through them is the highest
    D. The velocity of blood flow through them is the lowest
    E. They have the greatest resistance

22. Velocity of blood flow in the circulatory system is in the order
    A. arteries > arterioles > vena cava > capillaries
    B. aorta > arterioles > capillaries > veins
    C. veins > capillaries > aorta > vena cava
    D. vena cava > arterioles > capillaries
    E. capillaries > arterioles > veins > vena cava > aorta

23. The capillaries withstand relatively high internal pressures by
    A. having very slow blood flow rates
    B. contracting in response to increased pulse pressure
    C. having very small cross sectional area (size)
    D. being very thin
    E. having large hydraulic conductivity

MATCHING. One or multiple answers for each number; each letter may be used once, more than once or not at all. 1 pt each

24. aorta
25. arterioles
26. capillaries
27. veins

a. store pressure generated by the heart
b. have walls that are stiff and elastic
c. carry low oxygen blood
d. have endothelial lining
e. act as a volume reservoir
f. blood flows slowest here
g. have lowest blood pressure
h. sites of variable resistance
i. have large compliance

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28. Purkinje fiber
29. SA node
30. gap junctions

a. composed of connective tissue
b. composed of muscle tissue
c. important for electrical continuity of heart
d. generates its own action potentials
e. found in both cardiac and skeletal muscle
f. covers the heart, prevents overfilling

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SHORT ANSWER

31. Compare skeletal muscle and cardiac muscle with regard to the following

A. Quantity of Na^+ and Ca^{2+} that flux across the plasma membrane of the two types of muscle during action potential. Consider the types of channels present, the effects of skeletal vs cardiac muscle anatomy and the effect of increased membrane area on ion flux. 4 pts

B. Difference in duration of absolute refractory period. 3 pts

32. A cell with a membrane potential of -60 mV is found to have internal pH of 7.4 when external pH is 7.4. This internal concentration of H^+ is maintained by secondary active transport, and the cell has H^+ channels.

A. Calculate E_H. Show your reasoning or calculation. 3 pts

B. Determine the direction of passive movement of H^+ through H^+ channels. Show your reasoning or calculation. 3 pts

C. Explain the role of the Na/K-ATPasc in maintaining internal pH. 3 pts

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33. Flux of glucose and Na across the endothelium of capillaries occurs solely by diffusion. If [glucose] = 5 mM in the capillaries and 2 mM in the tissue spaces, while [Na] = 150 mm in both the capillaries and tissue spaces, arrange the following in order of largest to smallest: unidirectional flux of glucose from capillary blood to tissues, net flux of glucose across the capillary wall, unidirectional flux of Na from tissues to blood, and net flux of Na across the capillary wall. Assume D for glucose and Na is the same across the capillary walls and in the solutions. 3 pts.

34. Synaptic delays, i.e., time between arrival of action potential at synapse and release of neurotransmitter, are generally no longer than 10 ms. Calculate the maximum distance between nerves at the synapse to accommodate this delay. Assume diffusion coefficient for neurotransmitter is 10^{-5} cm^2/sec. 3 pts.

35. A hormone caused cAMP concentration in a cell to decrease. List two signaling mechanisms that could have elicited this response. 2 pts.

36. Compare the proposed molecular structures of CFTR (Cl^- channel) of epithelial cells and the Na^+ channel of the heart with regard to:

A. selectivity 2 pts

B. regulation by PKA or voltage 2 pts.

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37. Explain the following effects of epinephrine on the heart.

A. Mention <u>one</u> mechanism that would lead to SA node increasing its rate of generation of action potentials. 2 pts

B. Mention two ways that cell [Ca^{2+}] would increase during systolic contraction of the heart. 4 pts

38. Compare smooth muscle and cardiac muscle with regard to:

A. Sarcomeres and cellular structure 4 pts

B. Regulation of contraction by Ca^{2+} 4 pts

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TRUE OR FALSE? 1 pt each

_____ 39. The adrenal medulla releases increased amounts of epinephrine into the blood during parasympathetic stimulation.

_____ 40. IP_3 receptor, ryanodine receptor (RyR) and "CRAC" are similar in that they all serve as Ca channels.

_____ 41. Treatment of a cell with ouabain, an inhibitor of the Na/K-ATPase, can lead to increased heart contraction.

_____ 42. Na/H exchange, PMCA and SERCA pumps are all examples of secondary active transport mechanisms.

_____ 43. PKA, PKG and PKC all bind ATP and catalyze the phosphorylation of serines and threonines on proteins.

_____ 44. Both the SA and AV nodes are capable of generating their own action potentials without nervous system stimulation; the SA node is the heart's pacemaker because it generates action potentials at a faster rate than the AV node.

_____ 45. A major difference between fast and slow action potentials in the heart is due to the presence of TTX-sensitive Na^+ channels in the former and not in the latter.

_____ 46. The equilibrium potential for an ion is the voltage which balances any concentration difference across the membrane. Active transport is not required to maintain the voltage and concentration difference.

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Useful formulae

$J = -D \cdot A \cdot (c_2 - c_1)/\Delta x$

J in moles/sec, D in cm^2/sec, $(c_2 - c_1)/\Delta x$ in moles/cm^3/cm, A in cm^2

Diffusion coefficient D ~ 10^{-5} cm^2/sec α 1/radius or $1/MW)^{1/3}$

$(\Delta x)^2 = 2\, Dt$

Δx in cm, D in cm^2/sec, t in sec

$J_V = \Delta\pi \cdot L$ or $J_V = \sigma(RT\Delta c \varnothing) \cdot L$

J_V (sometimes Q in syllabus) = volume flow in $cm^3/cm^2 \cdot$ sec or cm/sec and L= hydraulic conductivity in cm/sec·atm; σ is the reflection coefficient, R = 0.082 1-atm/mole°K, T = °K, Δc = moles/1, $\varnothing$ = osmotic coefficient (~0.9 for electrolytes, = 1.0 for non-electrolytes)

RT = 24.5 l-atm per mole at 25°C

Nernst:

$V_{1\text{-}2} = 2.3\, RT/zF\, (\log C_2/C_1) = 60/z\, (\log C_2/C_1)$ in mV

or $V_{io} = 2.3\, RT/zF\, (\log C_o/C_i) = 60/z\, (\log C_o/C_i)$

R = 8.3 joule/mole· deg K, T = 298°K at 25°C and 310°K at 37°C,

F = 96,500 coulombs/mole approximately 10^5 coulombs/mole

z = valence of ion, volts = joule/coulomb

When more than one ion is permeant:

$V_{io} = (g_K E_K + g_{Na} E_{Na} + g_{Cl} E_{Cl} + \ldots) / (g_K + g_{Na} + g_{Cl} + \ldots)$

$I_{ion} = (V_{i\text{-}o} - E_{ion})\, g_{ion}$

I in amperes/cm^2 (A = coulomb/sec) g = conductance in siemens/cm^2 (S/cm^2), V_{io} and E_{ion} in volts

Convert electrical current to moles of ions:

I (A/cm^2 = coulomb/sec/cm^2) x (mole of ions) / F

= I (A/cm^2 = coulomb/sec/cm^2) x (mole of ions) / 10^5 coulombs

Law of Laplace

$\Delta P = T\,(1/r_1 + 1/r_2)$, where r_1 and r_2 are the principal radii of curvature.

For a sperical bubble (soap bubble), $r_1 = r_2$, and $P = T \times 2/r$

For a cylinder, one axis has an infinite radius, i.e., $1/r_2 = 0$, therefore $\Delta P = T/r$

Note: pressure conversion is 1 mm Hg = 1,330 dynes/cm^2