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9.01 Introduction to Neuroscience
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Ch. 5-6 Review Questions

- All the following statements about chemical synapses using ligand-gated ion channels are true EXCEPT:
 - Most neurotransmitters are stored in synaptic vesicles
 - The postsynaptic response to a neurotransmitter generally takes about 1 sec
 - The synaptic cleft is generally about 50 nm between pre- and post-synaptic cells
 - Proteins and carbohydrates hold the two sides of the synapse together
- Which of the following is NOT a criterion for classifying a molecule as a neurotransmitter?
 - Synthesized and packed in the neuron
 - Released by stimulation of the presynaptic cell
 - Produces an EPSP in the postsynaptic cell
 - Mechanisms are present to remove the chemical from the system
- If a neuron uses dopamine as its neurotransmitter, it will contain all of the following EXCEPT:
 - Epinephrine
 - Tyrosine hydroxylase
 - L-dopa
 - Tyrosine
 - Dopa decarboxylase
- Dales' Principle states that:
 - Each axon on a neuron contacts a dendrite on only one other neuron
 - Each neuron uses only one second messenger
 - Each neuron generates either EPSPs or IPSPs, but not both
 - Each neuron uses only one neurotransmitter
- All the following statements about Ca^{++} are true EXCEPT:
 - Ca^{++} enters the presynaptic terminal when it is depolarized
 - Ca^{++} enters the presynaptic terminal at active zones
 - Ca^{++} enters vesicles after entering the presynaptic terminal
 - Ca^{++} binds to synaptotagmin, affecting the shape of SNAREs
- All the following statements about peptide neurotransmitters are true EXCEPT:
 - They are synthesized in the soma
 - They are synthesized as long chains that are later cut into the functional peptide transmitter
 - They are stored in dense-core vesicles
 - Secretory granules containing peptide transmitters pinch off from the Golgi apparatus
 - They are released at active zones
- The famous frog heart experiment of Otto Loewi demonstrated that
 - Neurons use electrical synapses to excite muscle.
 - Peptides are only synthesized in neurons of the peripheral nervous system
 - The Neuron Doctrine was wrong
 - Neurons release chemicals as messengers.
 - Frog legs are much tastier than frog hearts.
- The very next step after neurotransmitter binds to a G-protein coupled receptor is
 - GTP binds to the Alpha subunit of a G-protein
 - Effector enzyme begins to synthesis second messenger
 - Phosphorylation of protein
 - Opening of an ion channel

9. The larger the length constant
- The more effective a dendrite is at conducting electrical signals farther away from the point of origin
 - The more time it takes an action potential to be generated
 - The greater the distance between synapses
 - The larger the cell body of the neuron
10. Neurotransmitter is removed from the synapse by all of the following ways EXCEPT
- Enzymes in the cleft break the neurotransmitter down
 - Receptors in the postsynaptic membrane bind the neurotransmitter & transport it into the postsynaptic cell
 - The neurotransmitter diffuses out of the synaptic cleft
 - Transporter proteins in the presynaptic terminal result in reuptake of the neurotransmitter
11. All of the following are true about responses that use G-protein coupled receptors compared to ion channel receptors EXCEPT
- The response is longer lasting.
 - The response is amplified.
 - The response is faster.
 - In the nervous system, more synapses use g-protein coupled receptors than ion channel receptors.
12. Gap Junctions:
- transform electrical signals into chemical signals
 - are more common in neurons than glial cells
 - let electrical signals pass through, but block the flow of ions
 - all of the above
 - none of the above
13. If a neuron did not have vesicular transporters, synaptic vesicles could not be loaded and therefore
- the neuron could NOT fire action potentials or release neurotransmitters
 - the neuron could fire action potentials, but NOT release neurotransmitters
 - the neuron could NOT fire action potentials, but could still release neurotransmitters
 - the neuron would still be able to fire action potentials and release neurotransmitters
14. All of the following are criteria for classifying a molecule as a neurotransmitter EXCEPT:
- It is synthesized and stored in neurons
 - It is released when the presynaptic cell is stimulated
 - It is the only molecule released at the synapse
 - It always evokes the same post-synaptic response
 - It is degraded or removed from the synapse
15. Feedback inhibition in the synthesis of the neurotransmitter norepinephrine:
- opposes the action of end product inhibition
 - modulates the activity of the rate limiting enzyme, tyrosine hydroxylase
 - is higher if the neuron is more active
 - blocks the production of epinephrine from norepinephrine
 - is an exception to Dale's principle
16. Which permeability changes ALL lead to membrane depolarization?
- Na⁺ permeability up, K⁺ permeability down, Cl⁻ permeability down, Ca⁺⁺ permeability up
 - Na⁺ permeability up, K⁺ permeability down, Cl⁻ permeability up, Ca⁺⁺ permeability down
 - Na⁺ permeability up, K⁺ permeability up, Cl⁻ permeability down, Ca⁺⁺ permeability up
 - Na⁺ permeability up, K⁺ permeability up, Cl⁻ permeability up, Ca⁺⁺ permeability down
 - Na⁺ permeability down, K⁺ permeability up, Cl⁻ permeability down, Ca⁺⁺ permeability up

Notes

Synaptic transmission

- depolarization from action potential reaches terminal
- voltage-gated calcium channels open; calcium influx because of [] gradient and charge difference
- change in calcium concentration affects conformation of SNARES → exocytosis begins
- vesicles spill open and a quantal amount of neurotransmitter is released
- neurotransmitter release happens quickly, suggesting that the vesicles involved are those already “docked” at active zones (the sites of neurotransmitter release)
- vesicle membrane is later recovered by endocytosis
- neurotransmitter traverses synaptic cleft and binds to one of two kinds of receptors

Postsynaptic receptors

- transmitter-gated ion channels (neurotransmitter binds to channel, channel opens)
- G-protein coupled receptors (see explanation of G-proteins below)
 - shortcut (effector protein = ion channel; α subunits bind to ion channels, open/close them)
 - second messenger cascade (effector protein = enzyme that synthesizes second messengers)
 - example: G-protein activates adenylyl cyclase which converts ATP to cAMP which activates protein kinase A which phosphorylates the K⁺ channel closing it
 - second messenger cascade can greatly amplify the original chemical signal

transmitter-gated ion channels = FASTEST response/change for postsynaptic neuron

G-protein shortcut = MODERATE

G-protein second messenger cascade = SLOW

G-proteins

- contain three subunits (α , β , and γ) that floats along the inside of the cell membrane
- the α subunit has a GDP attached
- if the G-protein bumps into a receptor and the receptor has a transmitter molecule bound to it, then the G-protein activates
- the α subunit trades the GDP for the energy-rich GTP
- the α subunit with the GTP splits off from the β and γ subunits; both G_{α} -GTP and $G_{\beta\gamma}$ can influence and activate effector proteins
- eventually, the GTP becomes GDP, terminating the action of the G-protein
- the two parts come back together

Dendritic length constant

- index for how far depolarization can spread down a dendrite; the higher the length constant, the more likely an EPSP generated at a distant synapse will depolarize the membrane at axon hillock
- what affects the length constant?
 - internal resistance (width of dendrite)
 - membrane resistance (number of open channels)
- bringing back the garden hose analogy: water flows farther down a wide hose with few leaks; current flows farther down a wide dendrite with few open channels

Answers to Review Questions

- 1) B
- 2) C
- 3) A
- 4) D
- 5) D
- 6) E
- 7) D
- 8) A

- 9) A
- 10) B
- 11) C
- 12) E
- 13) B
- 14) C
- 15) B
- 16) A

Explanations, Additional Info for Select Questions

Question 2

See page 135. Your book also lists another criterion for classifying a molecule as a neurotransmitter. When experimentally applied, the molecule must produce a response in the postsynaptic cell that mimics the response produced by the release of the molecule by the presynaptic cell.

Question 3

Read pages 141-152 for information on neurotransmitter chemistry. Here are specifics about the catecholamine neurotransmitters (DA, NE, epinephrine) and pathway:

- tyrosine is converted to dopa in the *cytosol* by the action of enzyme tyrosine hydroxylase (TH)
- dopa is converted to dopamine (DA) in the *cytosol* by the action of enzyme dopa decarboxylase
- dopamine is converted to norepinephrine (NE or noradrenaline) in *vesicles* by the action of enzyme dopamine β-hydroxylase (DBH)
- norepinephrine is converted to epinephrine (or adrenaline) in *cytosol* by the action of enzyme phenolamine N-methyltransferase (PNMT)

The entire pathway does not occur in all neurons, i.e. a dopaminergic neuron will not convert DA to NE. Interesting note: enzyme DBH is located only in vesicles, which is why the conversion to NE occurs in vesicles. For a neuron that releases epinephrine, DA is transported into vesicles and converted to NE; the vesicles let out NE so that it can be converted into epinephrine, which is then transported back into vesicles to await an action potential.

Question 4

Page 142. Many neurons violate Dale's Principle, namely peptide-containing neurons.

Question 6

Peptide neurotransmitters are one type. The other two: amino acids and amines. Peptide neurotransmitters are packed into secretory granules by the Golgi apparatus. Amino acid and amine neurotransmitters are packed into vesicles by protein transporters embedded in vesicle membrane. Secretory granules are larger than other vesicles; they appear dark in electron microscopy.

Question 7

Page 103. Inspired by a dream, Otto Loewi isolated a frog heart with the vagal innervation nerve intact. When the nerve was stimulated by electricity, the heart slowed. When Loewi applied to the nerve the solution that the heart was bathed in, he got the same result. This suggests that neurons release chemicals as messengers.

Question 12

Gap junctions (pages 103-5) are located at electrical synapses, a narrow gap spanned by connexin proteins (six connexin proteins form a connexon). The channel allows ions to pass directly from one cell to another. Electrical synapses are bidirectional. The cells connected by them are referred to as "electrically coupled." Transmission across gap junctions is fast and fail-safe.