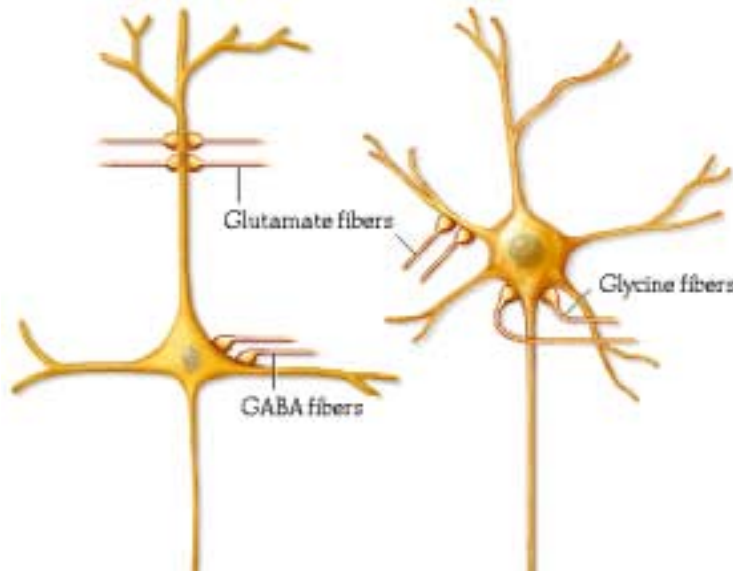


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- Sympathetic postganglionic neurons release norepinephrine.
- They are adrenergic.
- Parasympathetic postganglionic neurons release acetylcholine.
- They are cholinergic.
- Both acetylcholine and norepinephrine act indirectly on the effector organs of the autonomic nervous system.
- Their action is slow, sometimes excitatory, sometimes inhibitory, depending on which receptor is found on the effector organ.

Page 12. Excitatory and Inhibitory Neurotransmitters in the CNS



- Glutamate is the most common and most potent excitatory neurotransmitter in the central nervous system.
- Glutamate acts directly on ion channels that permit passage of both sodium and potassium, producing fast excitatory postsynaptic potentials.
- The major inhibitory neurotransmitters in the central nervous system are GABA and glycine.
- Like GABA, glycine binds to receptors which directly open chloride channels, producing fast inhibitory postsynaptic potentials.

Page 13. Fast Versus Slow Synaptic Action: Directly-acting Neurotransmitters

- The rapid signaling of directly-acting neurotransmitters is important for sensory-motor coordination, communication, and many other higher functions.

Sensory - Motor
Coordination

- Rapid synaptic signaling is essential for coordinating sensory input with motor output, especially during athletic performances.

Communication

- Rapid synaptic signaling is essential for speech and other forms of communication.

Higher Functions

- Playing music requires rapid synaptic signaling.

Page 14. Fast Versus Slow Synaptic Action: Indirectly-acting Neurotransmitters



- All of the neurotransmitters at effector organs of the peripheral autonomic nervous system act indirectly.
- Norepinephrine, acetylcholine, and serotonin, another central nervous system neurotransmitter, all produce state changes in the central nervous system. One important example is the change from the sleep state, to wakefulness, to attentive arousal.
- Theories of learning and memory often invoke the action of indirect neurotransmitters to explain changes in synaptic activity. Indirect neurotransmitters can modulate neurons, ultimately changing their channel functions, and producing a new and different output.

Page 15: Summary

- Neurotransmitter is released from vesicles in the presynaptic cell and binds to receptors of the postsynaptic cell.
- Neurotransmission ends when the neurotransmitter dissociates from its receptor.
- The effect of the neurotransmitter on the postsynaptic cell depends on the receptor, not the neurotransmitter molecule.
- Acetylcholine and norepinephrine are the most important neurotransmitters in the peripheral nervous
- Glutamate, GABA, and glycine are the most important neurotransmitters in the central nervous system.
- Fast and slow synaptic activities serve different functions.

* Now is a good time to go to quiz questions 2-9:

- Click the Quiz button at the bottom of the screen.
- Work through quiz questions 2-9.

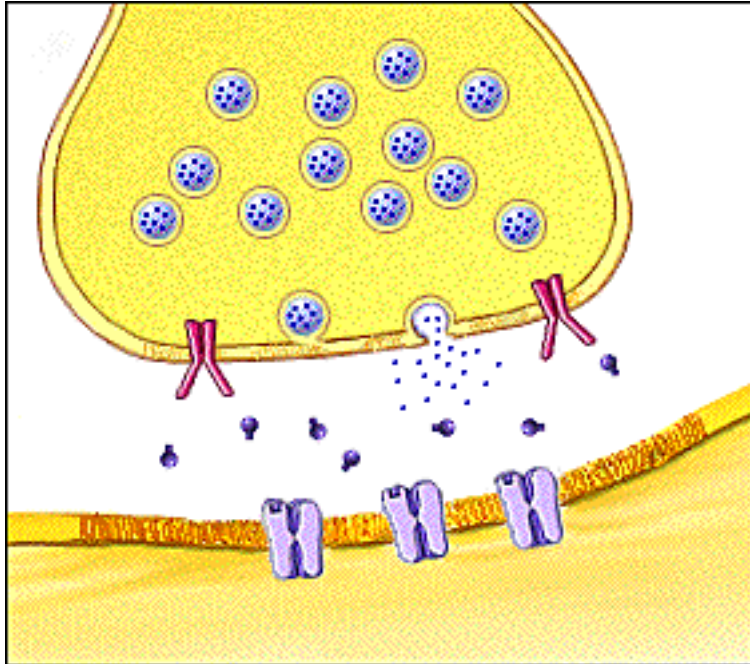
Notes on Quiz Questions:

Quiz Question #1: Chemical Synapse

- This question asks you to the sequence of events in synaptic transmission.

Quiz Question #2: Synaptic Transmission

- This question asks you to determine all the different ways that drugs can act to inhibit synaptic transmission.
- Record your answers below:



Quiz Question #3: Neurotransmitter/GABA

- This question asks you to determine how some drugs act on the CNS.

Quiz Question #4: Neurotransmitter/ACh

- This question asks you to determine where acetyl choline would act to stimulate receptors.

Quiz Question #5: Cholinergic Blockers

- This question asks you to determine what would happen if you got bitten by a snake.

Quiz Question #6: nACh/mACh Receptors

- This question asks you to determine how to treat a patient with Myasthenia gravis.

Quiz Question #7: Peripheral Nervous System

- This question asks you to determine recreate a picture in the program.

Quiz Question #8: NE Receptors

- This question asks you to determine the functions of alpha and beta receptors.

Quiz Question #9: Indirectly Acting Neurotransmitters

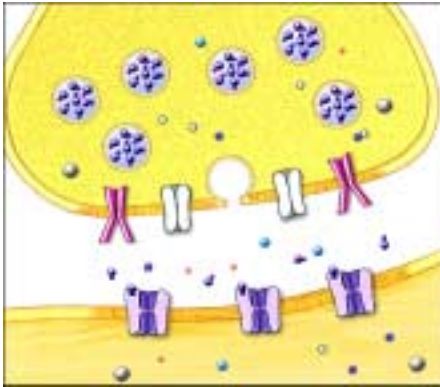
- This question asks you to predict which behaviors are due to indirectly acting neurons.

Study Questions on Synaptic Transmission:

1. (Page 3.) Label the diagram on page 3.
2. (Page 3, 4.) Put these statements into the correct order for synaptic transmission:
 - a. Neurotransmitter diffuses across the synaptic cleft.
 - b. The presence of calcium inside the cell causes the synaptic vesicles to fuse with the membrane.
 - c. Most often, the neurotransmitter is pumped back into the presynaptic terminal and into nearby glial cells.
 - d. An action potential in the axon terminal causes voltage-gated calcium channels to open and calcium to enter the terminal.
 - e. Each vesicle releases a fixed amount of neurotransmitter into the synaptic cleft.
 - f. Neurotransmitter binds to a receptor on the postsynaptic neuron where it can act.
3. (Page 4.) Neurotransmitter binds to a receptor on the _____ where it can act directly or indirectly.
 - a. postsynaptic neuron
 - b. presynaptic neuron
4. (Page 4.) Chemically-gated ion channels remain open as long as the _____ is bound to the receptor, and are not sensitive to changes in the membrane potential.
 - a. synapse
 - b. neurotransmitter
 - c. ion
5. (Page 4.) Synaptic current, or ion movement through chemically-gated channels, may _____ or _____ the neuron.
 - a. excite or inhibit
 - b. depolarize, hyperpolarize
6. (Page 5.) Synaptic transmission ends when the _____ dissociates from the receptor and is removed from the synaptic cleft.
 - a. synapse
 - b. neurotransmitter
 - c. ion
7. (Page 5.) Most often, the neurotransmitter is pumped back into the _____ and into nearby glial cells.
 - a. postsynaptic neuron
 - b. presynaptic neuron
8. (Page 5.) In some cases, the neurotransmitter is broken down by enzymes, and the breakdown products are pumped away. The neurotransmitter _____ is an example of this process.
 - a. acetyl choline
 - b. GABA
 - c. norepinephrine
 - d. glycine
9. (Page 5.) When breakdown products are transported into the _____, they are used to resynthesize neurotransmitter.
 - a. presynaptic terminal
 - b. postsynaptic terminal
10. (Page 5.) Fill out the chart on page 5.

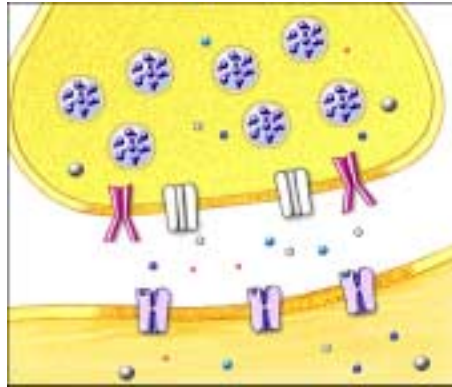
11. (Page 6.) Put these pictures in order:

a.



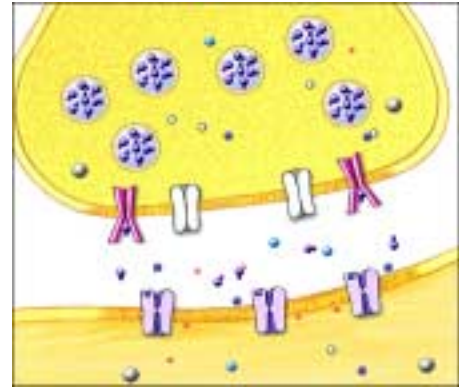
• Neurotransmitter diffuses across the synaptic cleft and binds to the postsynaptic receptor .

b.



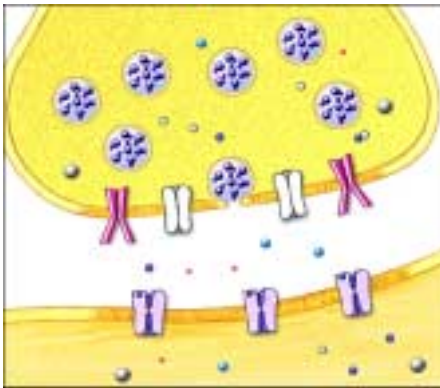
• The voltage-gated calcium channels open and calcium diffuses into the axon terminal .

c.



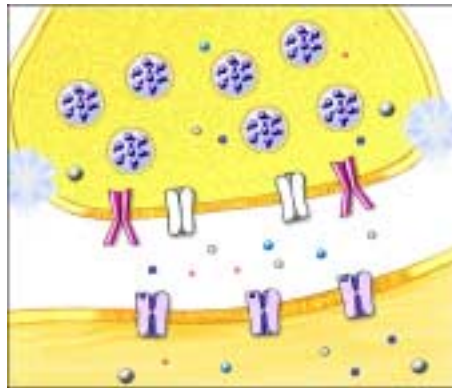
• Neurotransmitter dissociates from the receptor and is pumped back into the axon terminal.

d.



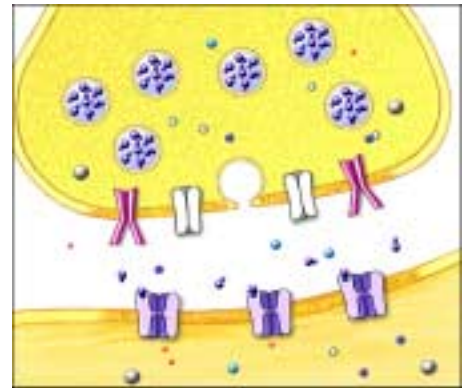
• The synaptic vesicles fuse with the presynaptic cell membrane and open.

e.



• An action potential occurs in the presynaptic terminal.

f.



• Current flows across the postsynaptic cell membrane.

12. (Page 7.) We have examined the mechanism of synaptic transmission. Now let's look at the consequences of synaptic activity on the postsynaptic cell. The action of the _____ depends on which neurotransmitter is involved, and the specific receptor found on that cell.

a. postsynaptic neuron

b. presynaptic neuron

13. (Page 8.) Each such _____ activates a different ion channel, causing a different effect in the postsynaptic cell.

a. synapse b. neurotransmitter c. ion

13. (Page 8.) There are two groups of receptors, called cholinergic receptors, which bind acetylcholine. One group also binds the chemical _____; the other group also binds the chemical _____.

a. nicotine, muscarine b. alpha receptors, beta receptors

14. (Page 8.) The cholinergic _____ receptor, or acetyl choline is the well-known receptor found at the neuromuscular junction.

a. muscarinic b. nicotinic c. alpha d. beta

15. (Page 8.) At this receptor, acetylcholine acts directly to open an ion channel producing a fast excitatory postsynaptic potential. Acetylcholine is excitatory at _____ receptors. It causes skeletal muscle to contract.

a. muscarinic b. nicotinic c. alpha d. beta

16. (Page 8.) One type of cholinergic _____ receptor, or acetyl choline is found in the central nervous system and on most effector organs of the parasympathetic branch of the nervous system.
a. muscarinic b. nicotinic c. alpha receptors d. beta receptors
17. (Page 8.) Acetylcholine acts indirectly at these _____ receptors producing a slow excitatory postsynaptic potential.
a. mACh b. nACh
18. (Page 8.) Acetylcholine is excitatory at these _____ receptors, causing neurons to fire action potentials, and smooth muscle to contract.
a. muscarinic b. nicotinic c. alpha d. beta
19. (Page 8.) A second type of mACh receptor is found in the central nervous system, and in the _____.
a. lungs b. kidney c. heart d. liver
20. (Page 8.) Acetylcholine acts indirectly at these receptors, producing a _____ of the postsynaptic cells. In the heart, this effect _____ the heart rate.
a. fast excitation, increasing b. slow inhibition, decreases
21. (Page 8.) Acetylcholine is inhibitory at these muscarinic receptors causing neurons to _____, and the heart to slow down.
a. hyperpolarize b. depolarize
22. (Page 8.) The action of acetylcholine may be excitatory or inhibitory. The effect depends on which receptor is present on the _____.
a. postsynaptic neuron b. presynaptic neuron
23. (Page 9.) There are two families of receptors for the neurotransmitter norepinephrine, _____ receptors and _____ receptors.
a. muscarinic b. nicotinic c. alpha d. beta e. alpha, beta
24. (Page 9.) These are called _____ receptors, and norepinephrine acts indirectly when binding to them.
a. adrenergic b. cholinergic
25. (Page 9.) Both alpha and beta adrenergic receptors are found in the central nervous system, and more importantly, on effector organs of the _____.
a. sympathetic nervous system b. parasympathetic nervous system
26. (Page 9.) Norepinephrine acts indirectly at alpha-one receptors to produce slow excitation. This causes smooth muscle to contract. Alpha-one receptors are located on _____, which supply the skin, mucosae, and abdominal viscera. Norepinephrine is excitatory at alpha one receptors.
a. heart b. lung c. blood vessels
27. (Page 9.) Norepinephrine also acts indirectly at beta-one receptors in the heart to produce slow excitation. _____ and strength of contraction increase. Norepinephrine is excitatory at beta one receptors.
a. Heart rate b. Lung rate c. Skeletal muscle

28. (Page 9.) Norepinephrine acts indirectly at beta-two receptors, to produce a slow inhibition. This causes smooth muscle to _____. Beta-two receptors are located on the _____ airways, blood vessels that supply _____ muscle and heart, and most other effector organs of the sympathetic system. Norepinephrine is inhibitory at beta-two receptors.

- a. constrict, respiratory, smooth b. constrict, respiratory, heart c. dilate, respiratory, skeletal

29. (Page 10.) We have learned that _____ and _____ are found in the central nervous system and at effector organs of the nervous system.

- a. acetyl choline, norepinephrine b. GABA and glycine

30. (Page 11.) Motor neurons of the somatic nervous system release _____. They are _____. Skeletal muscles bear _____ receptors.
a. norepinephrine, adrenergic, alpha b. acetylcholine, cholinergic, nACh
31. (Page 11.) Thus the action of acetylcholine on skeletal muscle is direct, fast, and _____.
a. inhibitory b. excitatory
32. (Page 11.) The first of two neurons in the sympathetic chain, the preganglionic neuron, is _____.
a. cholinergic b. adrenergic
33. (Page 11.) The first of two neurons in the parasympathetic chain, the preganglionic neuron, is also _____.
a. cholinergic b. adrenergic
34. (Page 11.) The second neuron, or postganglionic neuron, in both the sympathetic and parasympathetic chains, has _____ receptors.
a. mACh b. nACh c. alpha b. beta
35. (Page 11.) Sympathetic postganglionic neurons release _____. They are _____.
a. norepinephrine, adrenergic b. acetyl choline, cholinergic
36. (Page 11.) Parasympathetic postganglionic neurons release _____. They are _____.
a. norepinephrine, adrenergic b. acetyl choline, cholinergic
37. (Page 12.) Glutamate is the most common and most potent excitatory neurotransmitter in the central nervous system. Glutamate acts directly on ion channels that permit passage of both _____ and _____, producing fast excitatory postsynaptic potentials.
a. sodium, potassium b. chloride
38. (Page 12.) The major inhibitory neurotransmitters in the central nervous system are GABA and glycine. Like GABA, glycine binds to receptors which directly open _____ channels, producing fast inhibitory postsynaptic potentials.
a. sodium, potassium b. chloride
39. (Page 13.) Match the following to their proper response.

1.

Sensory - Motor
Coordination

a.

Playing music requires rapid synaptic signaling.

d



2.

Communication

b.

Rapid synaptic signaling is essential for coordinating sensory input with motor output, especially during athletic performances.

e.



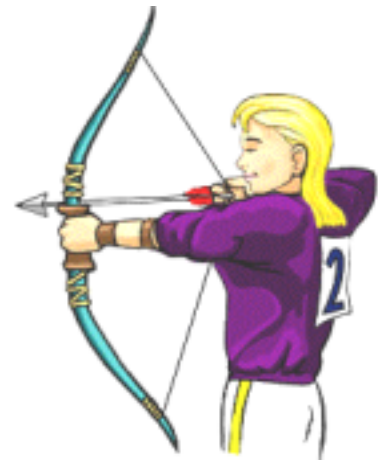
3.

Higher Functions

c.

Rapid synaptic signaling is essential for speech and other forms of communication.

f.



40. (Page 14.) Match the following to their proper response.

1.

Peripheral
Autonomic
Nervous System

a. Norepinephrine, acetylcholine, and serotonin, another central nervous system neurotransmitter, all produce state changes in the central nervous system.

d.

One important example is the change from the sleep state, to wakefulness, to attentive arousal.



2.



b. Theories of learning and memory often invoke the action of indirect neurotransmitters to explain changes in synaptic activity.

Indirect neurotransmitters can modulate neurons, ultimately changing their channel functions, and producing a new and different output.

d.



3.

Learning
and
Memory

c. All of the neurotransmitters at effector organs of the peripheral autonomic nervous system act indirectly.

e.

