Synaptic Transmission

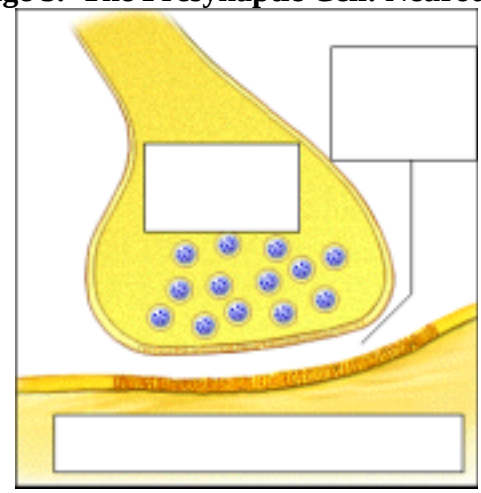
Page 1. Introduction

- Synaptic transmission involves the release of neurotransmitter from the presynaptic cell, diffusion of neurotransmitter across the synaptic cleft, and binding of the neurotransmitter to receptors on the postsynaptic cell.
- It ends when the neurotransmitter dissociates from the receptor and is removed from the synaptic cleft.

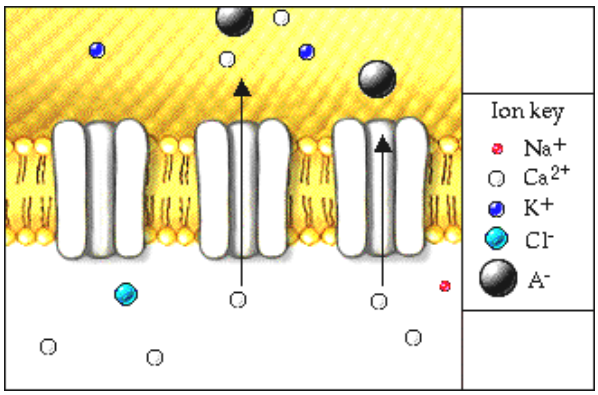
Page 2. Goals

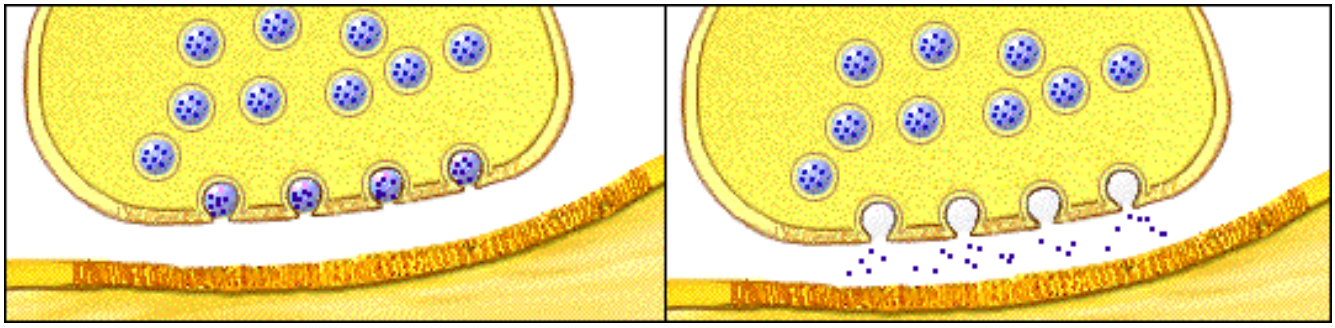
- To understand the detailed mechanism of neurotransmitter release, diffusion, and binding to the postsynaptic receptor.
- To learn that the action of the neurotransmitter depends on the type of receptor on the postsynaptic cell.
- To review the location and function of neurotransmitters.

Page 3. The Presynaptic Cell: Neurotransmitter Release

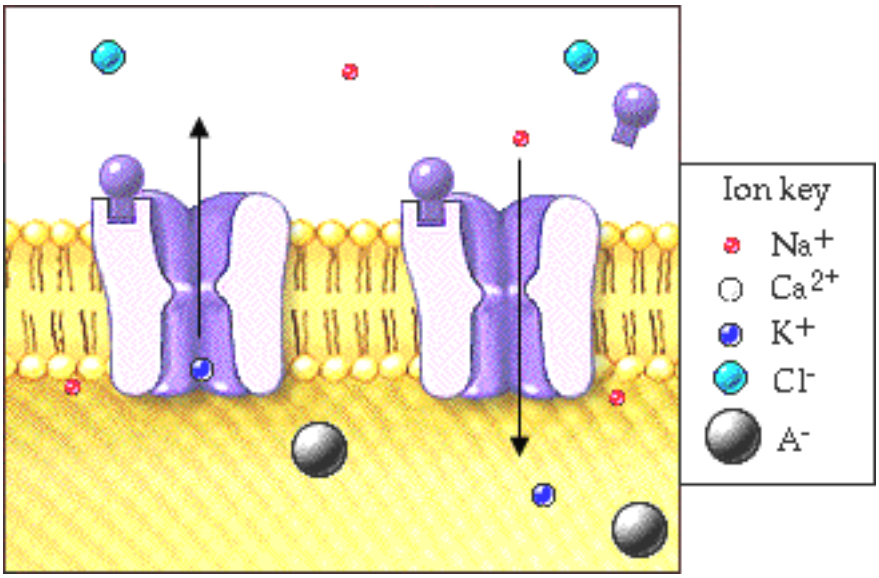


- We have examined the events of synaptic transmission. Now let's look at the details.
- An action potential in the axon terminal causes voltage-gated calcium channels to open and calcium to enter the terminal.
- The presence of calcium inside the cell causes the synaptic vesicles to fuse with the membrane.
- Each vesicle releases a fixed amount of neurotransmitter into the synaptic cleft.
- Neurotransmitter diffuses across the synaptic cleft.





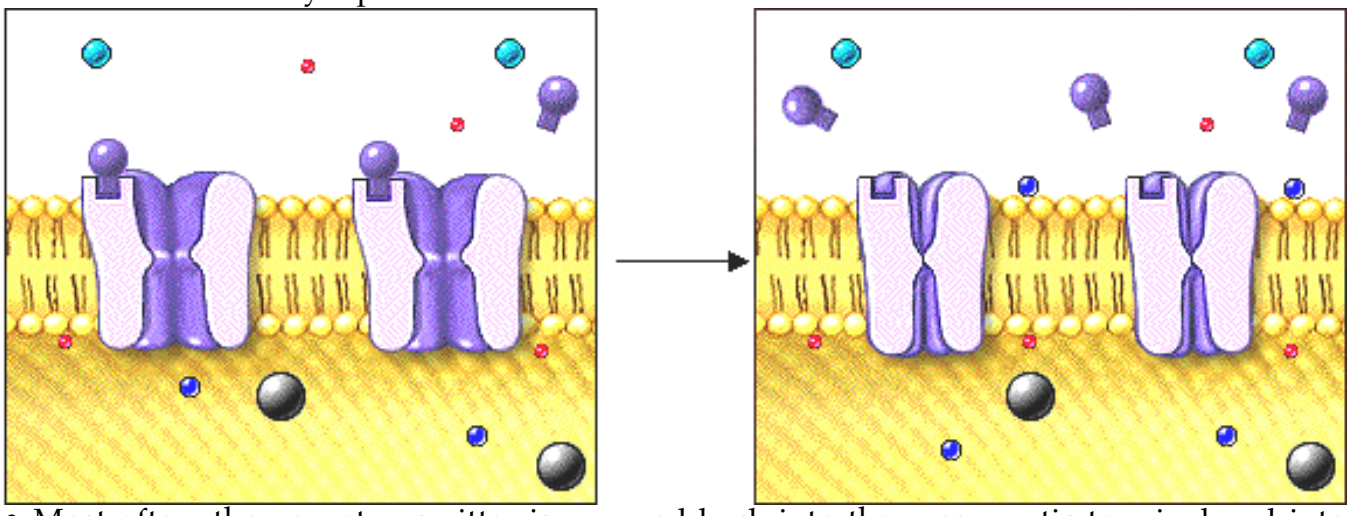
Page 4. The Postsynaptic Cell: Receptor Binding



- Neurotransmitter binds to a receptor on the postsynaptic neuron where it can act directly or indirectly.
- Chemically-gated ion channels remain open as long as the neurotransmitter is bound to the receptor, and are not sensitive to changes in the membrane potential.
- Synaptic current, or ion movement through chemically-gated channels, may depolarize or hyperpolarize the neuron. The example below illustrates depolarization of the postsynaptic neuron.

Page 5. Termination of Synaptic Transmission

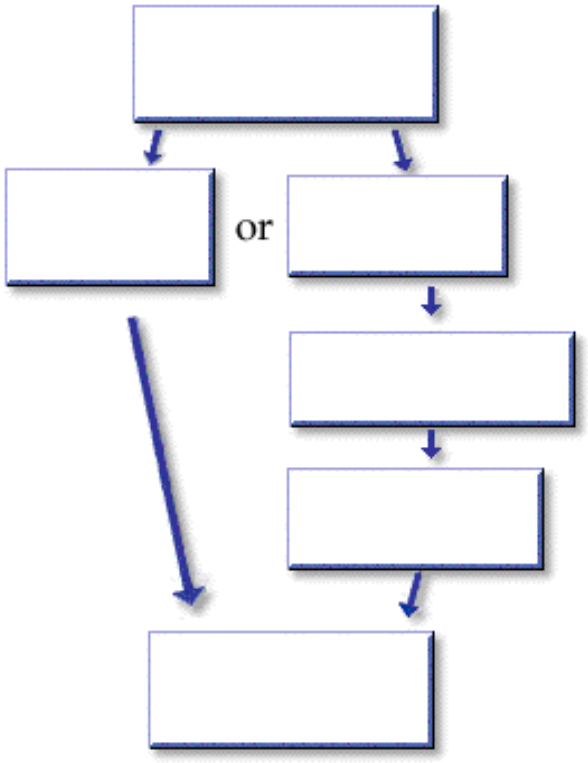
- Synaptic transmission ends when the neurotransmitter dissociates from the receptor and is removed from the synaptic cleft.



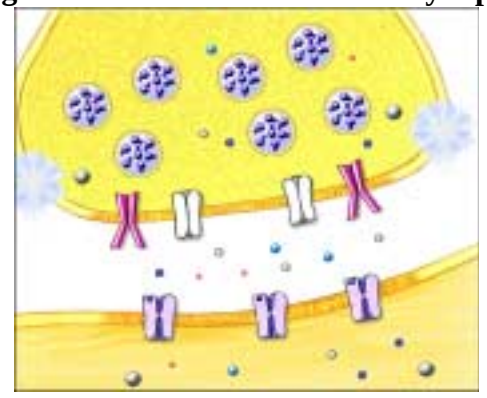
- Most often, the neurotransmitter is pumped back into the presynaptic terminal and into nearby glial cells.
- Here we illustrate the neurotransmitter glutamate being pumped back into the presynaptic terminal.
- In some cases, the neurotransmitter is broken down by enzymes, and the breakdown products are pumped away.
- The neurotransmitter acetylcholine is an example of this process.
- When breakdown products are transported into the presynaptic terminal, they are used to resynthesize neurotransmitter.

- The neurotransmitter, which has been returned to the terminal, is repackaged into vesicles for storage and subsequent release.
- The mechanism by which neurotransmitter is returned to the terminal is specific for each neurotransmitter and can be selectively affected by drugs.

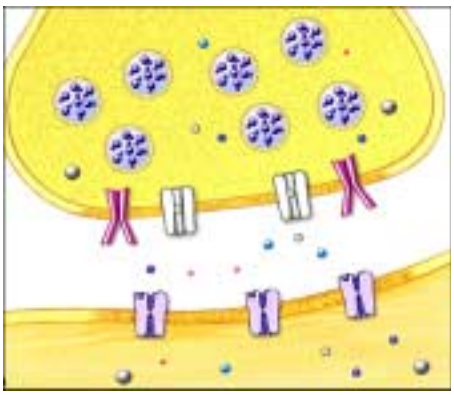
- Fill out this chart:



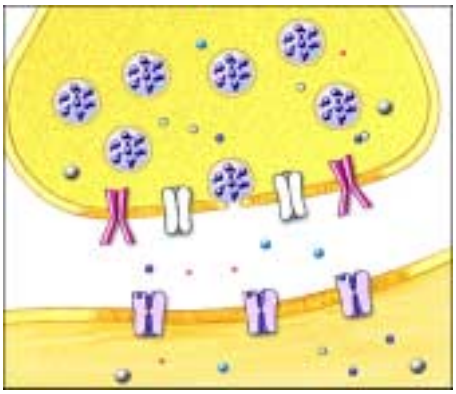
Page 6. Review of the Events of Synaptic Transmission



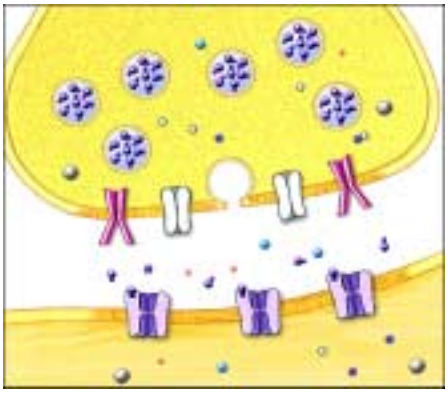
- An action potential occurs in the presynaptic terminal.



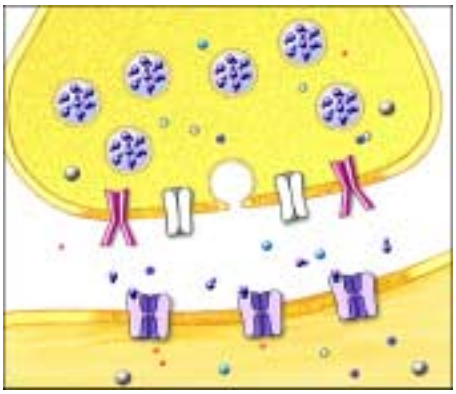
- The voltage-gated calcium channels open and calcium diffuses into the axon terminal



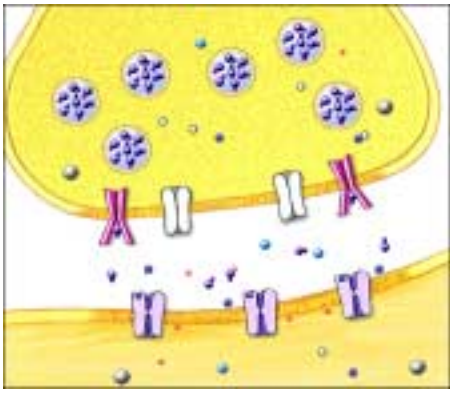
- The synaptic vesicles fuse with the presynaptic cell membrane and open.



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



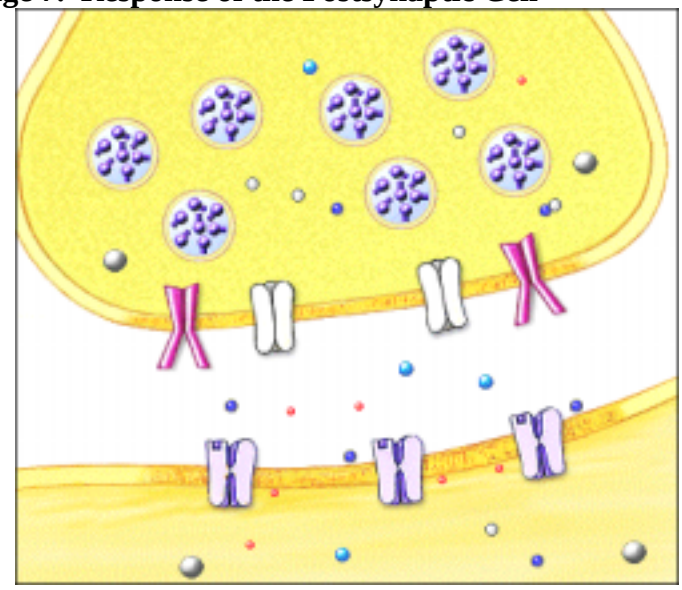
- Current flows across the postsynaptic cell membrane.



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

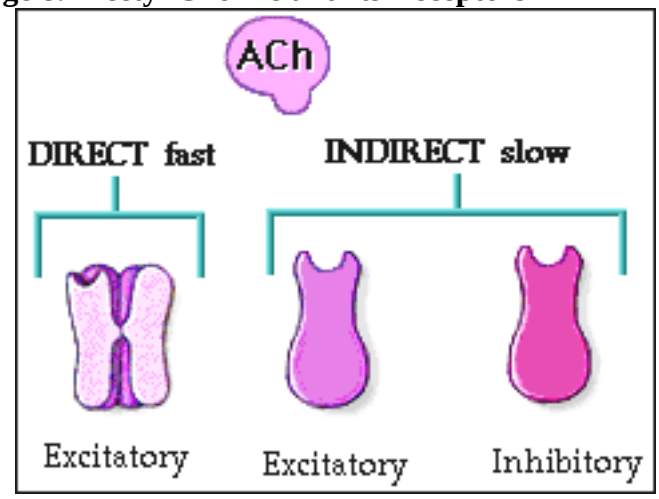
* Now is a good time to go to quiz question 1:
  - Click the Quiz button on the left side of the screen.
  - Work through quiz question 1.
  - When you are done return to "Page 7. Response of the Postsynaptic Cell."

Page 7. Response of the Postsynaptic Cell

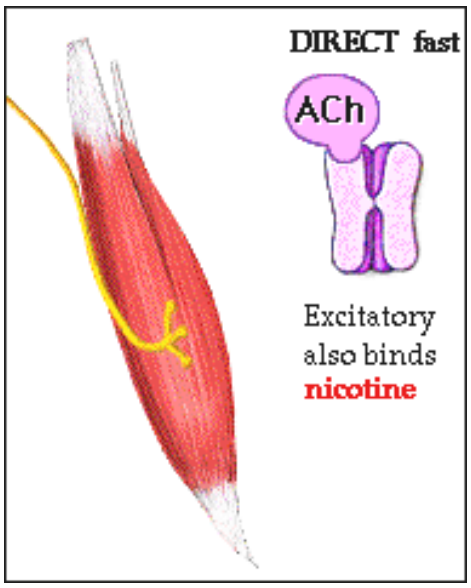


- We have examined the mechanism of synaptic transmission.
- Now let's look at the consequences of synaptic activity on the postsynaptic cell.
- The action of the postsynaptic cell depends on which neurotransmitter is involved, and the specific receptor found on that cell.

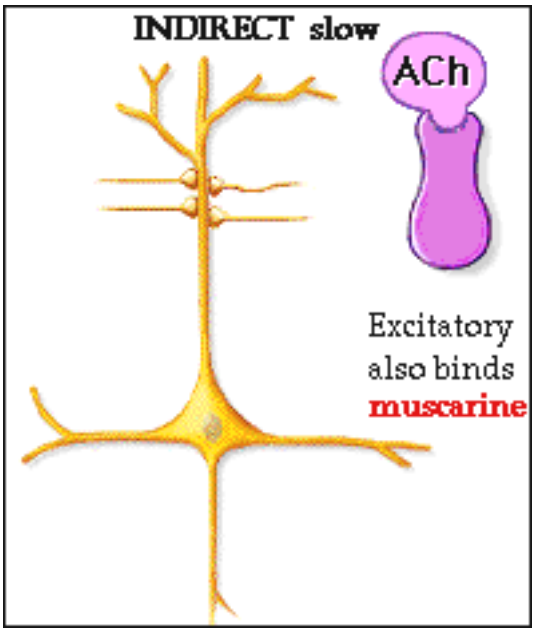
Page 8. Acetyl Choline and its Receptors



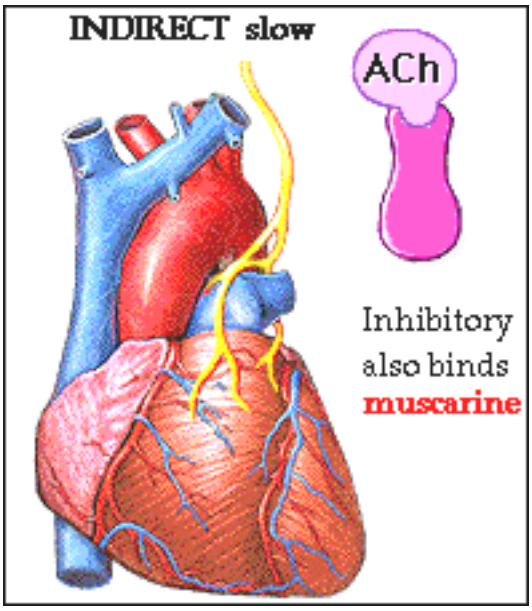
- There are multiple receptors for each neurotransmitter.
- Each such receptor activates a different ion channel, causing a different effect in the postsynaptic cell.
- There are two groups of receptors, called cholinergic receptors, which bind acetylcholine.
- One group also binds the chemical nicotine; the other group also binds the chemical muscarine.



- The cholinergic nicotinic receptor, or nACh is the well-known receptor found at the neuromuscular junction.
- At this receptor, acetylcholine acts directly to open an ion channel producing a fast excitatory postsynaptic potential.
- Acetylcholine is excitatory at nicotinic receptors.
- It causes skeletal muscle to contract.

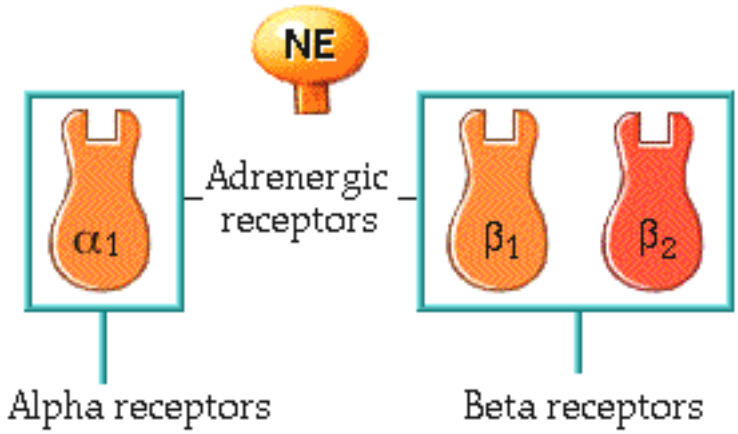


- One type of cholinergic muscarinic receptor, or mACh is found in the central nervous system and on most effector organs of the parasympathetic branch of the nervous system.
- Acetylcholine acts indirectly at these mACh receptors producing a slow excitatory postsynaptic potential.
- Acetylcholine is excitatory at these muscarinic receptors, causing neurons to fire action potentials, and smooth muscle to contract.

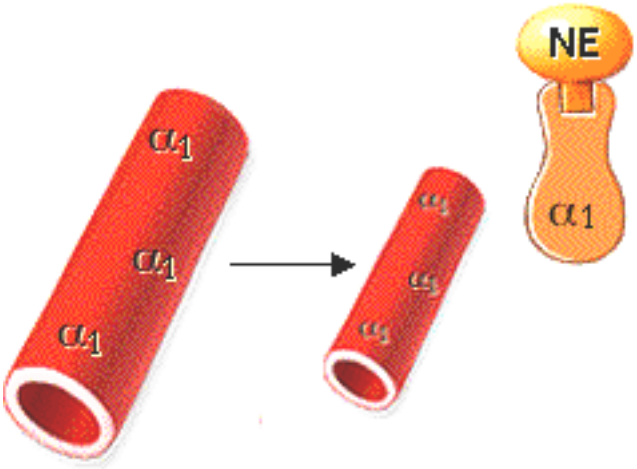


- A second type of mACh receptor is found in the central nervous system, and in the heart.
- Acetylcholine acts indirectly at these receptors, producing a slow inhibition of the postsynaptic cells.
- In the heart, this effect decreases the heart rate.
- Acetylcholine is inhibitory at these muscarinic receptors causing neurons to hyperpolarize, and the heart to slow down.
- The action of acetylcholine may be excitatory or inhibitory. The effect depends on which receptor is present on the postsynaptic cell.

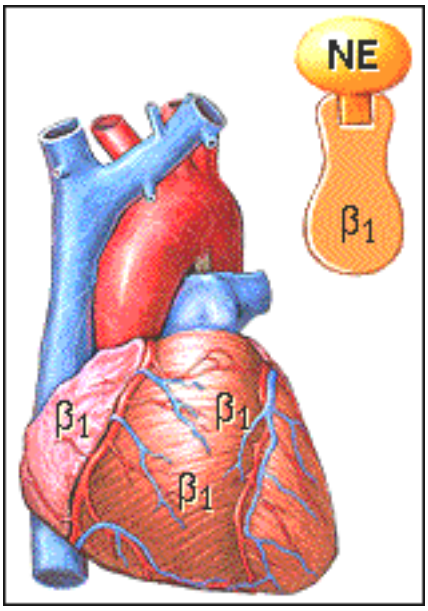
Page 9. Norepinephrine and its Receptors



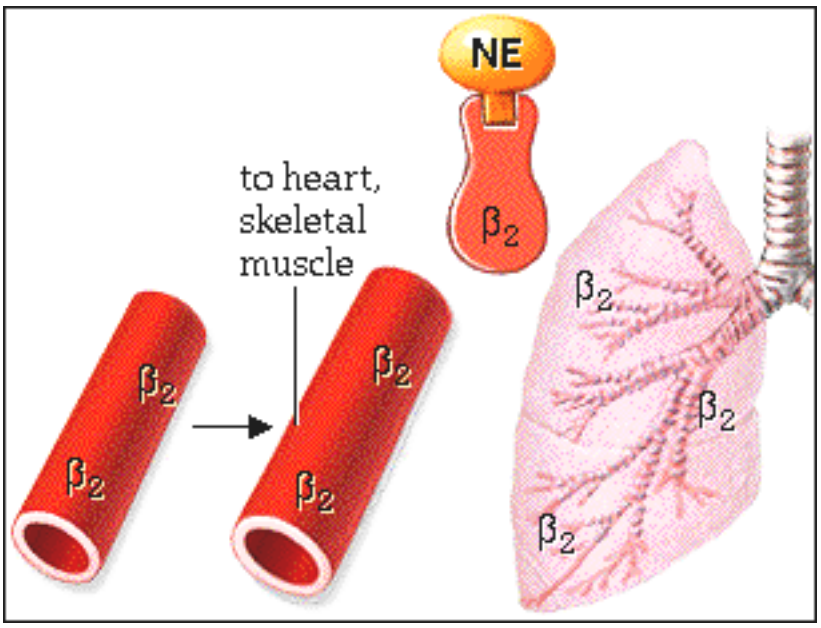
- There are two families of receptors for the neurotransmitter norepinephrine, alpha receptors and beta receptors.
- Each family member is identified by its letter and a number.
- These are called adrenergic receptors, and norepinephrine acts indirectly when binding to them.
- Both alpha and beta adrenergic receptors are found in the central nervous system, and more importantly, on effector organs of the sympathetic nervous system.



- Norepinephrine acts indirectly at alpha-one receptors to produce slow excitation.
- This causes smooth muscle to contract.
- Alpha-one receptors are located on blood vessels, which supply the skin, mucosae, and abdominal viscera.
- Norepinephrine is excitatory at alpha one receptors.

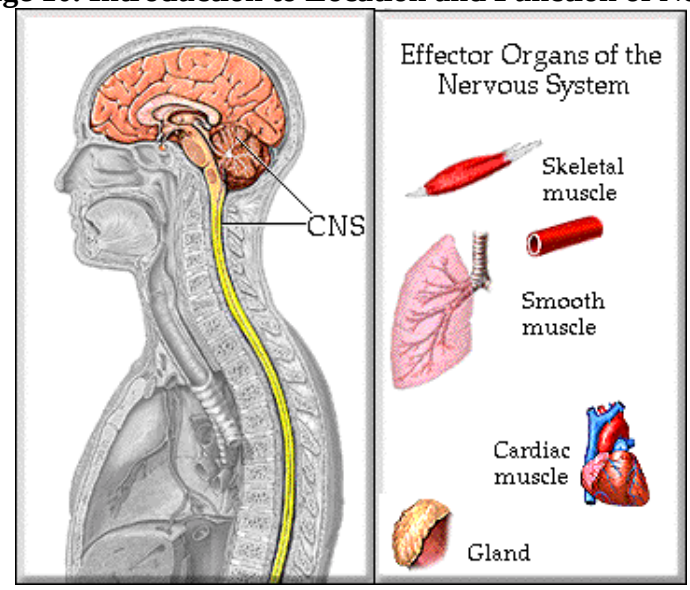


- Norepinephrine also acts indirectly at beta-one receptors in the heart to produce slow excitation.
- Heart rate and strength of contraction increase.
- Norepinephrine is excitatory at beta one receptors.



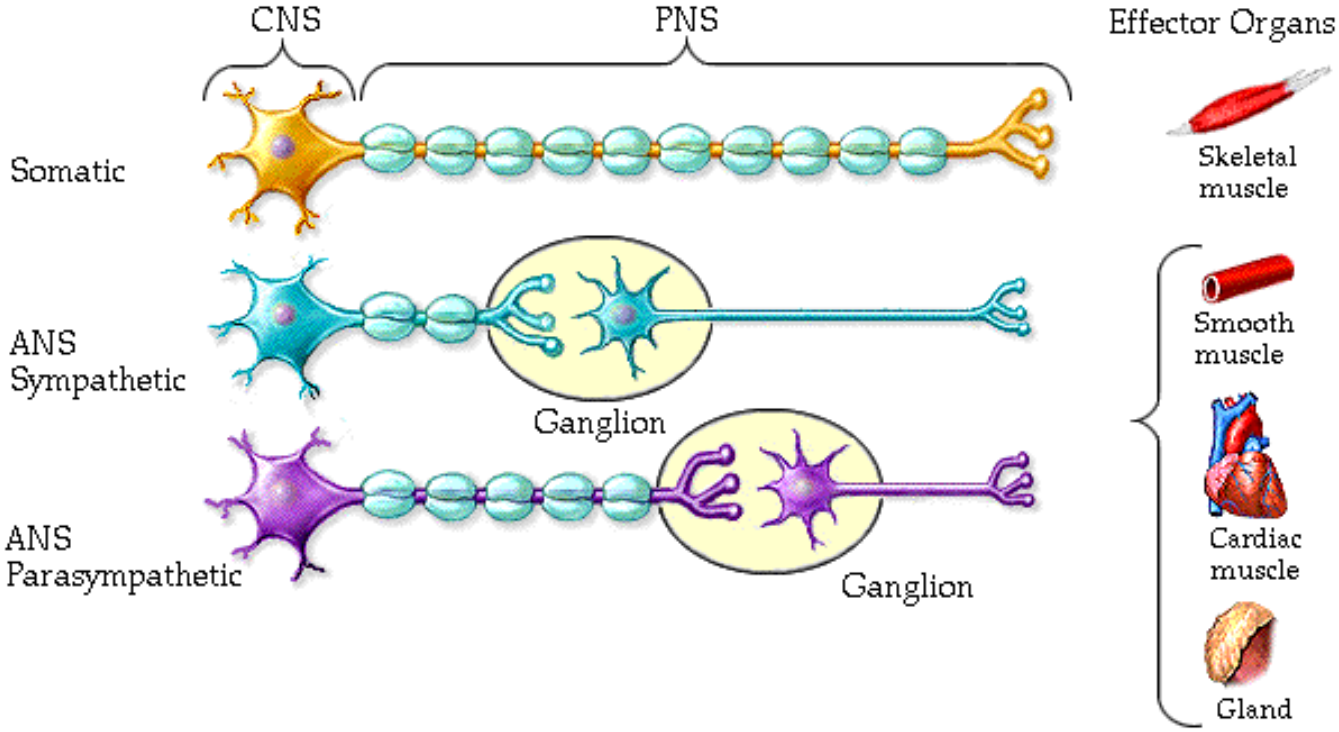
- Norepinephrine acts indirectly at beta-two receptors, to produce a slow inhibition.
- This causes smooth muscle to dilate.
- Beta-two receptors are located on the respiratory airways, blood vessels that supply skeletal muscle and heart, and most other effector organs of the sympathetic system.
- Norepinephrine is inhibitory at beta-two receptors.
- The action of norepinephrine may be excitatory or inhibitory. The effect depends on which receptor is present on the postsynaptic cell.

Page 10. Introduction to Location and Function of Neurotransmitters



- We have learned that acetylcholine and norepinephrine are found in the central nervous system and at effector organs of the nervous system.
- On the next few pages, we will review the location and function of these neurotransmitters in the peripheral nervous system.
- Then we will look into the central nervous system to learn the functions of these and other neurotransmitters.

Page 11. Neurotransmitters in the Peripheral Nervous System



- Motor neurons of the somatic nervous system release acetylcholine.
- They are cholinergic.
- Skeletal muscles bear nACh receptors.
- Thus the action of acetylcholine on skeletal muscle is direct, fast, and excitatory.

- The first of two neurons in the sympathetic chain, the preganglionic neuron, is cholinergic.

- The first of two neurons in the parasympathetic chain, the preganglionic neuron, is also cholinergic.
- The second neuron, or postganglionic neuron, in both the sympathetic and parasympathetic

chains, has nACh receptors.

- Thus the action of acetylcholine on postganglionic neurons is direct, fast, and excitatory.

Continue to Synaptic Transmission Part II
(Separate PDF Document)