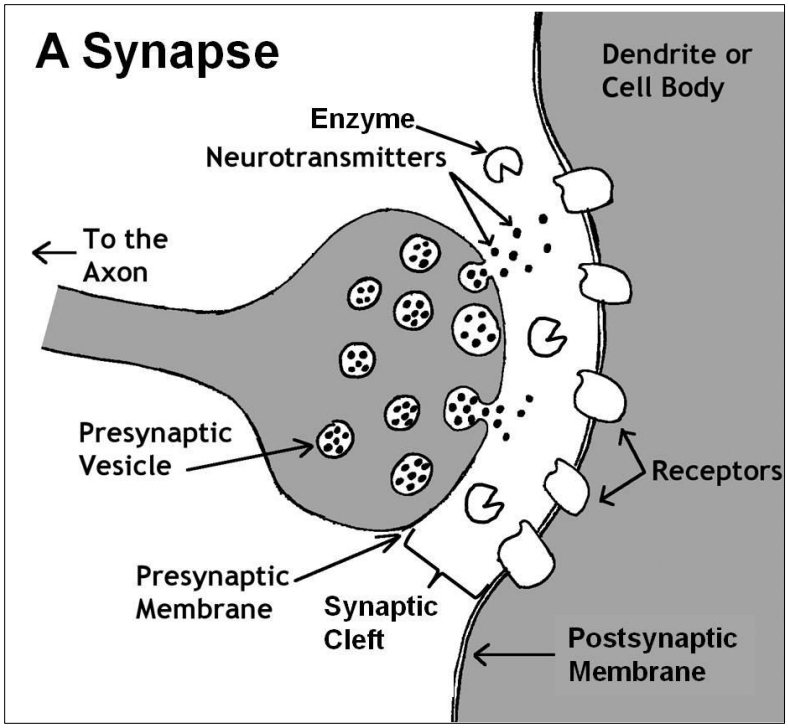
Chemical Transmission Between Nerve Cells



Some nerve cells transmit an impulse by directly sharing the action potential if the two cell membranes are touching (at an **electrical synapse**). However, most nerve cells do not actually touch other cells. The location of communication between a nerve cell and another cell where impulses are passed without touching is called a **chemical synapse**. The tiny space between the two cells is called the **synaptic cleft**. Nerve impulses are transmitted across this gap by changing the action potential into a chemical signal that moves across the cleft.

When the action potential arrives at the synaptic terminal, calcium gated ion channels open and calcium ions (Ca^{2+}) enter. The increased calcium concentration causes **presynaptic vesicles** to fuse with the presynaptic membrane and release molecules called **neurotransmitters**. Neurotransmitters are created by the nerve cells and stored in the vesicles until needed. The neurotransmitters diffuse across the synaptic cleft and bind to **receptor** molecules on the **postsynaptic membrane**, triggering a reaction in the second cell that can start a new action potential. These neurotransmitters are only temporarily bound.

The neurotransmitters may be removed from the receptors in one of three ways: they may be broken down by specialized enzymes in the synaptic cleft, reabsorbed by the synaptic (axon) terminal and recycled, or they may simply diffuse away. If the neurotransmitters were not removed, the receptors would never cease triggering.

Example: Transmission to Muscle Cells

The synapses that connect nerves to muscles are called **neuromuscular junctions**. Most neuromuscular junctions use the same neurotransmitter, acetylcholine, which is broken down by the enzyme acetylcholinesterase. A signal from a nerve to a muscle is transmitted in 4 stages:

Authored by Amanda Richer

1. A nerve impulse travelling down the axon causes calcium to move into the cell through channels in the presynaptic membrane.
2. Acetylcholine is released from the presynaptic vesicles fused to the presynaptic membrane and diffuses across the synaptic cleft.
3. The receptors in the muscle cell detect the acetylcholine, which open sodium ion channels that allow sodium into the cell, creating an action potential in the muscle.
4. Acetylcholine in the synaptic cleft is broken down by acetylcholinesterase, and some parts of the molecules are taken back into the nerve cell to be recycled.

Acetylcholinesterase is a very fast acting enzyme: it clears all of the acetylcholine from the synaptic cleft quickly enough to allow up to 1000 separate impulses per second to be transmitted!

ADVANTAGES OF CHEMICAL TRANSMISSION

There are pros and cons for both chemical and electrical transmission. Electrical transmission is essentially instantaneous, as there is no need to wait for exocytosis or diffusion of neurotransmitters in the synapse (i.e. milliseconds). Electrical synapses can also transmit information bidirectionally, while chemical synapses are unidirectional. Electrical synapses can be found in organisms that use escape behaviours because the escape response needs to be as quick as possible. However, chemical synapses have one major advantage over electrical transmission. In electrical transmission, the signal in the postsynaptic cell is always similar to the presynaptic cell; in chemical transmission, the presynaptic signal does not have to be the same as the postsynaptic signal. Therefore, an additional level of regulation for the nervous system is achieved because the presynaptic signal can either activate or inhibit the postsynaptic cell.

Some chemical synapses use neurotransmitters that cause the postsynaptic membrane to depolarize and create an action potential (**excitatory synapses**), while others use neurotransmitters that make the postsynaptic membrane harder to depolarize (**inhibitory synapses**). A single nerve cell can have both types of synapses, and the effects of one type of synapse can add to or subtract from the effects of another. The type of neuron that receives many of these types of connections from other neurons is called an **integrator**.

EFFECT OF DRUGS ON CHEMICAL SYNAPSES

Some types of drugs act by interfering with neurotransmitters in one of several ways:

- Increasing or decreasing the amount of neurotransmitter that is released
- Completely blocking the release of neurotransmitters
- Blocking the receptors on the postsynaptic membrane
- Degrading the neurotransmitters inside the presynaptic vesicles
- Interfering with the enzymes that break down the neurotransmitter

QUESTIONS

1. Which part of the neuron secretes neurotransmitters? Receives?

2. How is it possible that an integrator neuron could receive two signals from other cells, but not start an action potential?

3. Which does not belong:

a. Synaptic vesicle
b. Receptor
c. Acetylcholinesterase
d. Axon hillock

4. Curare, a poison many South American tribes use on hunting darts, works by blocking acetylcholine receptors. Why is curare an effective poison?

5. Sarin, a nerve gas used in chemical warfare, prevents acetylcholinesterase from working. How would its effects be different from curare? (Question 4)

6. Clinical depression has been linked to a lack of the neurotransmitter serotonin in the body. For a patient suffering from depression, would you recommend a drug that interferes with the re-absorption of serotonin into cells, or a drug that blocks serotonin receptors?

ANSWERS

1. The synaptic terminals secrete neurotransmitters while dendrites receive neurotransmitters.

2. If one signal was excitatory, and the other was inhibitory, the two signals would cancel each other out, and no action potential would be generated.

3. All except answer d are found at synapses. The axon hillock is located between the cell body and axon. It is where the action potential starts.

4. Blocking acetylcholine would prevent impulses from being transmitted to muscle cells from neurons, and the victim would 'relax to death', no longer moving or breathing.

5. Blocking acetylcholinesterase would prevent the breakdown and removal of acetylcholine from the neuromuscular junctions. This would result in the muscles being constantly stimulated and tense without rest. This type of paralysis is opposite to curare, where the muscles cannot be stimulated.

6. Blocking the receptors would prevent what serotonin the patient has from being effective. Slowing the re-absorption of serotonin would be a better choice, since it would allow the serotonin to be in the synaptic cleft for longer and stimulate the receiving nerve cell for longer.