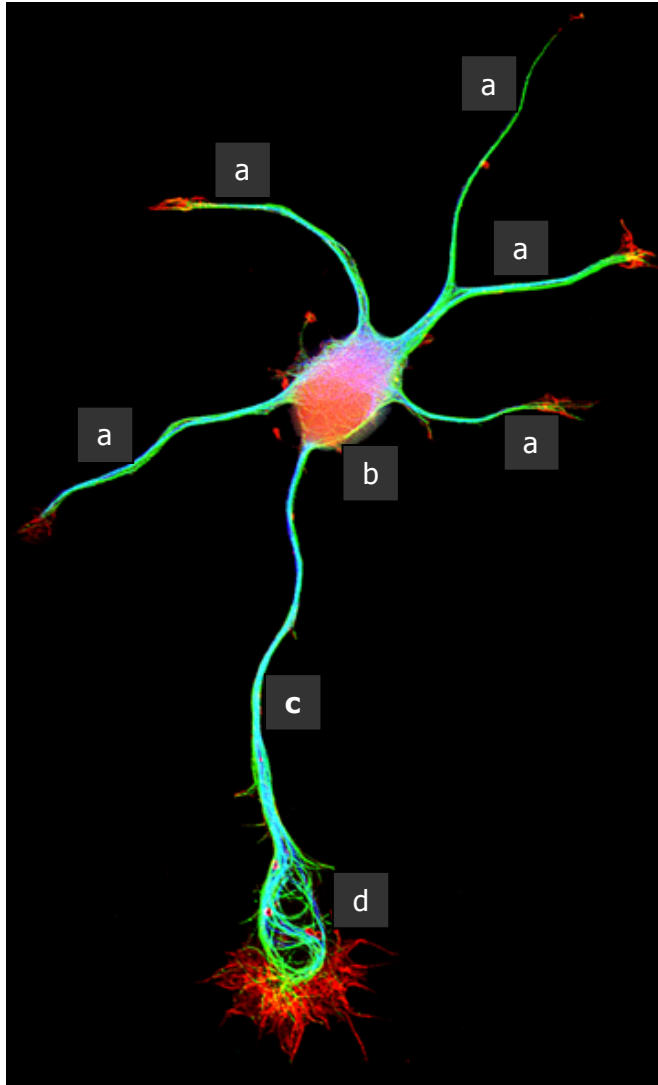


How Neurons Communicate (the Neuron Game)

Background Information

Neurons are cells in your nervous system. This is what a real neuron looks like¹:



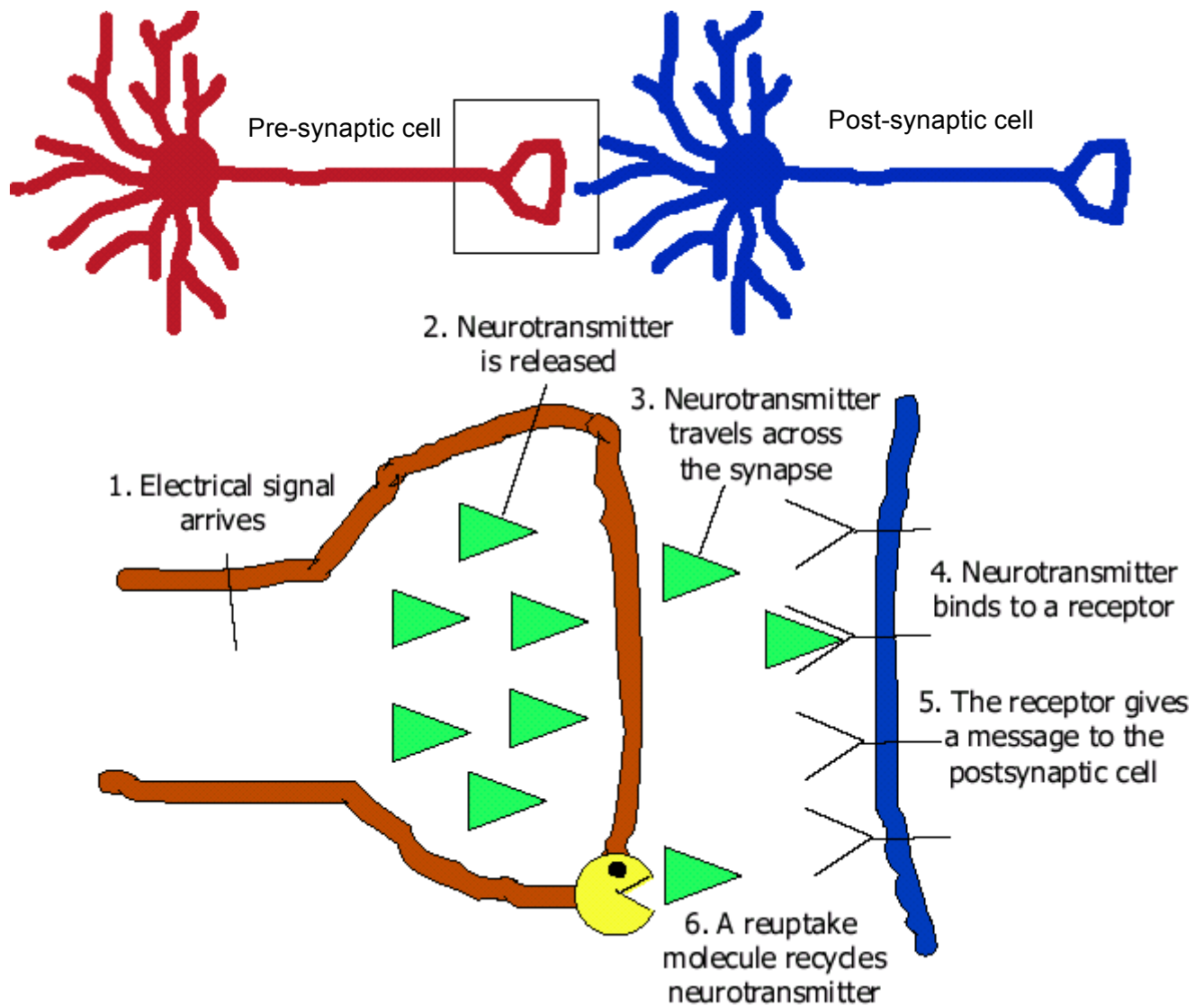
- a) **Dendrites:** collects input signals from many neurons using receptors (more on receptors later). They have many branches and sometimes even spines along each branch so that there is a lot of area for other neurons to contact its surface.
- b) **Cell Body:** decides whether or not to continue passing along the signal the neuron received. The decision depends on the cell's "**threshold**". For example, imagine you (the cell body) are standing at center court in a basketball game. All the fans (input signals) are screaming at you but you can't hear what they are saying since everyone is talking at once with different messages. Suddenly, some fans start screaming in unison "DEFENCE... stomp stomp... DEFENCE... stomp stomp". More and more fans pick up the chant until you can now understand what they are saying. It took exactly 500 people to shout in unison before you got the message. The number of simultaneous inputs needed to get the message is your threshold.
- c) **Axon:** transmits messages long distances using an electrical signal (like a wire). The cell uses an electrical signal because it is fast and because

the message stays exactly the same (is accurate) from beginning to end. Like a wire, the axon is typically insulated to further increase speed and prevent the message from changing as it travels.

- d) **Synaptic terminal:** sends a chemical message to the next neuron. The cell uses a chemical message here, not an electrical signal because a chemical message can be easily modified when necessary. In upcoming activities, you will see some of the many ways neurons modify signals and how different drugs can modify signals as well.

¹ A developing cortical neuron with fluorescently labeled microtubules and actin filaments. From Katherine Kalil. www.anatomy.wisc.edu/faculty_kalil.html

How neurons communicate can best be understood by looking more closely at a synaptic terminal where one neuron connects to a neighboring neuron.



1. The electrical signal that travels down the axon of the pre-synaptic neuron arrives at the synaptic terminal.
2. Chemicals called neurotransmitters are released out the end of the synaptic terminal into the space between the two cells, the synapse.
3. Neurotransmitter diffuses across the synapse.
4. Neurotransmitter binds to a receptor in a precise lock-and-key fit. Each neurotransmitter has its very own receptor.
5. Once activated by a neurotransmitter molecule, the receptor tells the post-synaptic cell body that a message has arrived (one voice in the basketball stadium).
6. A reuptake molecule sitting on the pre-synaptic cell recycles the neurotransmitter and replenishes the supply of neurotransmitter molecules waiting to be released.

How to play the neuron game

Exercise 1 – Excitatory Neuron:

Setup: Place one molecule of neurotransmitter (candy or beans) in each vesicle of the excitatory neuron.

Play: Roll 2 dice to determine how many molecules of neurotransmitter are released. Move them into the synapse. Place the molecules into the receptors on the post-synaptic cell. If you fill 6 or more receptors on the post-synaptic cell, it fires! Use the reuptake mechanism (little Pac-man) to recycle extra neurotransmitter molecules after each turn. Reset the board and play again!

Record: For each turn, record the number of molecules released, the number of receptors filled, and whether the cell fires.

Exercise 2 - Add Inhibitory Neuron:

Setup: Load the vesicles in the excitatory pre-synaptic neuron and then load each vesicle of the inhibitory pre-synaptic neuron a molecule of a different type of neurotransmitter (different kind of candy or bean).

Play: Roll 2 dice for the excitatory neuron, then roll 1 dice for the inhibitory neuron. Filled inhibitory receptors cancel out filled excitatory neurons. If a total of 6 receptors are activated ($\# \text{ excitatory receptors} - \# \text{ inhibitory receptors}$) then the post-synaptic cell fires.

Exercises 3 & 4 – Variations

Results:

- a) Variation A: Cocaine, amphetamine, Ritalin and certain anti-depressants
New rules: Take out the Pac-man on the excitatory pre-synaptic neuron any excitatory neurotransmitter released remains in the synapse and cannot be reloaded into the vesicles
- b) Variation B: Learning
New rules: The new threshold is 3 or more activated receptors ($\# \text{ excitatory receptors} - \# \text{ inhibitory receptors}$)
- c) Variation C: Parkinson's disease
New rules: Use 1 dice for the excitatory pre-synaptic neuron
- d) Variation D: Opiates (heroin and morphine), LSD and marijuana
New rules: Add 8 pennies to the synapse between the 2 neurons. These pennies mimic excitatory neurotransmitter and fit into round receptors. They cannot be recycled by the Pac-man and remain in the synapse

Resources

The **National Institute on Drug Abuse** has published several drug addiction related lessons with excellent visuals and background information for teachers. For magazine style publications designed for 5th-9th graders, see:

<http://www.nida.nih.gov/MOM/MOMIndex.html>

For a more involved series of lessons and activities designed for 9th graders, see:

<http://science-education.nih.gov/supplements/nih2/addiction/default.htm>

The organization **Neuroscience for Kids** has a great archive of neuroscience activities designed for kids.

<http://faculty.washington.edu/chudler/neurok.html>

PBS had a fabulous series all about the brain called "The Secret Life of the Brain". On the website is one of the best computer animations of neurotransmitters in action showing the effects of cocaine on a hypothetical synapse (click on "episode 3: The Teenage Brain" then look for the link for "additional video clips").

<http://www.pbs.org/wnet/brain/>

The **Society for Neuroscience** has a list of neuroscience resources for teachers including the 3 above, the Exploratorium and a whole lot more.

http://web.sfn.org/Template.cfm?Section=PublicResources&Template=/PublicResources/ResourceLink.cfm&subcat_id=98