The Synapse
Neuroscience Teaching Team

Module Overview
In this demonstration, students will learn about how neurons communicate with each other through synaptic activity and how synaptic activity can be altered through drug use and in disease.

Materials
Materials are per 3-5 students/demonstration.
Eight (8) Ping pong balls
Four (4) Velcro pads
One (1) Game board

Introduction
The brain is made up of nerve cells. Show images/models of the brain, neuron, and parts of the neuron. There are ~100 billion neurons in the brain.

How do neurons communicate with each other (*baseline synaptic activity*)?

- What is a synapse?
- What are neurotransmitters ("signaling molecules")?
    - There are different types of neurotransmitters (NT) in the brain that do different things. Some NT are excitatory (increase excitation in a post-synaptic cell) and others are inhibitory (reduce excitation in a post-synaptic cell).
- What are receptors?

Examples in which the communication between brain cells is altered or abnormal:

- Drugs
    - Initial drug exposure/acclimation: increase NT release, increase activation of post-synaptic cell [*Note: depending on the age group and allotted time for this demonstration, you can explain excitatory and inhibitory NTs in the context of stimulants/depressants*].
    - Tolerance: post-synaptic cell wants to bring activity back to normal, so it removes some receptors. Now, it takes more drugs to elicit the same response that occurred after the initial use (*"homeostasis": back to normal*).
    - Withdrawal: once the drug is removed, there are fewer receptors and fewer NTs being released, so the post-synaptic cell has much less activity. Symptoms of withdrawal are usually opposite of the drug-induced symptoms (e.g. amphetamines cause hyperactivity/alertness, so amphetamine withdrawal could cause sleepiness).
- Disease/Neurological disorders
    - Schizophrenia: increased activity of dopamine
        - About 1% (1 out of every 100 people) of the population is affected
        - Increased dopamine transmission can cause symptoms like hallucinations, disorganized speech, and delusions.

- ■ Treatment: blocking dopamine (and some serotonin) receptors
- ○ Epilepsy: increased glutamate activity
    - ■ Occurs in about 1 in every 100-200 people
    - ■ Overactivation of neurons (by increased glutamate (i.e., increased excitation) or decreased GABA (i.e., decreased inhibition) causes seizures
    - ■ Treatment: blocking glutamate receptors, or increasing GABA
- ○ Parkinson's Disease: loss of dopamine neurons
    - ■ Affects at least 500,000 people in the US (50,000 new cases reported annually)
    - ■ Reduced dopamine can cause symptoms like resting tremor, difficulty/slow movements, and inability to move/speak.
    - ■ Treatment: increase dopamine (in this case, there can also be tolerance/withdrawal)
- ○ *Note: depending on the age group, it may be interesting to explain how increased usage of anti-schizophrenia drugs produce parkinsonian symptoms because of decreased dopamine at the synapse, and how anti-parkinson drugs can produce schizophrenia-like symptoms because of increased dopamine at the synapse.*

Methods/Protocol
Each state (i.e., normal synaptic activity, and synaptic activity in the presence of drugs, tolerance, and withdrawal) will be allotted ~4 minutes for explanation (see Introduction above) and 15-seconds of game time. The main instructor will announce the time schedule as the game proceeds.

<u>Rules of the game:</u> Students must use fingers to flick a ping-pong ball (NT/signaling molecule) across the game board (synapse) and have it attach to a receptor on the other side of the game board. The game board should be propped up so that balls roll back down if they do not attach to a receptor. Once a ball is attached to a receptor, it stays there until the game is over. If a ball gets stuck but is not physically Velcro-ed to a receptor, push it back down to the bottom. After the 15-seconds is over, the score (# of NTs attached to receptors) should be reported.

1. Introduce students of the concept of neurotransmitters binding to receptors and producing a response inside the cell as a result (see Introduction above). In this demonstration the ping pong balls represent neurotransmitters, and the Velcro pads are receptors. *[Note: It is very important that the students make the connection that the more NTs they get stuck to the receptors, the more neuron #2 responds (i.e., producing pleasure, pain, thought, etc.)].*

2. Ask students to get into groups of 3-5 and stand at the short edge of a table. Give each pair of students 8 ping pong balls and 4 Velcro pads. The following step details how many of each they will need in each "phase" of the lab. The students will use varying numbers of each to model how the brain adapts to chronic drug use.

3. Students will take turns flicking the ping pong balls onto the receptors on the other side of the table. The round ends after 15-seconds. Count how many balls are attached to a

receptor. Between each round, explain to students what each scenario represents in the brain and how these phases actually occur.

Synapse Conditions:

4. Normal Synapse (4 NTs, 4 receptors - *homeostasis*)
5. Drugs (8 NTs, 4 receptors)
   - Adding more NTs (balls) mimics the brain's response to drugs. Therefore, neuron #2 gets more excited. For example, use of amphetamines (stimulants) causes increased synaptic activity of the neurochemicals dopamine and norepinephrine. Some examples of amphetamines are diet pills, Ritalin, and cocaine. The use of some depressants causes increased synaptic activity of inhibitory NTs (which has an end effect of reduced excitation, or inhibition). [*Note: this might be confusing since the end result of increased neurotransmission is reduced excitation, or inhibition*]. Some examples of depressants include alcohol and tranquilizers.
6. Tolerance (8 balls, 2 receptors)
   - The brain adapts to the high level of drug-induced signals by reducing the number of receptors (to try and bring it back to 'normal'). It then takes more drug (hence more NTs) to get the same response from neuron #2.
7. Withdrawal (2 balls, 2 receptors)
   - When a person stops taking the drug, the synapse is starved of activity (less NTs). The result is the opposite of when you are taking the drug (e.g. amphetamine withdrawal symptoms include sleepiness, depression, and sickness).

Discussion Questions

1. Based on what you learned in this demonstration, describe the parts of a neuron and how each part helps neurons communicate with each other.
2. Can you think of other things besides drugs that change the communication between neurons? Is it a good thing or a bad thing that neurons can change their communication?