Neurons and neurotransmitters

**Why does (nearly) everyone love Prozac?**

**Neurons**
- The brain cells that are responsible for cognition are neurons

**Input / output**
- Electrical signal
  - Established by the relative amount of charged ions inside versus outside the cell membrane
- Inputs change the resting potential of the cell
- Output identifies when the cell potential has increased a lot
  
**Input at dendrites**
- Changes the cell membrane potential
  - which causes further changes in the cell’s chemistry
  - which causes further changes in the membrane potential
- Strong enough input crosses a threshold and the cell fires
  - action potential

**A neuron**
- An action potential generated at the soma travels down the axon to the terminals

**A neuron**
- The action potential then affects the membranes of other cells’ dendrites
Output
- Myelin is like insulation for the cell’s axon
  - It insures that the signal generated by the action potential is strong
  - Jumps electrically rather than the normal chemical exchanges
- In multiple sclerosis the body’s immune system attacks myelin
  - Physical problems (paralysis)
  - Cognitive problems (memory, reasoning, judgement)
  - Cause unknown (300,000 people)

Output
- The output of a neuron is either excitatory or inhibitory on the other neuron it reaches
  - Excitatory: when our neuron sends an output, the receiving neuron is more likely to produce an action potential
  - Inhibitory: when our neuron sends an output, the receiving neuron is less likely to produce an action potential

Networks
- Cognitive behavior is related to groups of neurons working together
  - Include excitation and inhibition
    - More later

Epilepsy
- Disease of central nervous system
  - Causes mostly unknown
  - Seizures
    - Bursts of electrical activity travelling through networks in the brain
    - Brain activity is out of control
    - Epileptic fits
  - Isolated seizures also occur due to high fever, lack of oxygen, or head injury

Epilepsy
- EEG recordings are often used to diagnose epilepsy
- Many different types of epilepsy, with different EEG patterns
  - One theory (but not yet proven) is that epilepsy patients’ inhibitory cells are not working properly
  - Excitatory cells activate everything until they “exhaust” themselves
Epilepsy

- Treatment generally involves drugs, diet, avoiding stress, keeping regular schedule.
- In extreme cases surgery prevents seizures from spreading throughout the brain.

A balanced brain

- The brain is a dynamic system at multiple levels.
- Neurons: balance between "forces" inside and outside of cell membrane allows for action potentials.
- Networks: balance between excitation and inhibition.
- Without these balances you do not think.
- Contrast with ideas about using "more" of your brain.

Neural connections

- Axon → dendrites.

Molecular structure

- Molecules have a particular three-dimensional shape.
- Water, benzene.
- Neurotransmitters are just molecules.
- At least 50 different neurotransmitters: dopamine, norepinephrine, serotonin, acetylcholine, glutamate, gamma-aminobutyric acid (GABA).
- All with different shapes!
Receptor

- Very large molecules called proteins
- Similar to a filter
- Accepts some neurotransmitters
- Rejects others

When it accepts a neurotransmitter, it starts a chain reaction of events
- Physical, chemical, electrical
- Locally changes the cell membrane
  - Depolarization (excitation)
  - Hyperpolarization (inhibition)

Neurotransmitters

- Different neurotransmitters are associated with different properties
- Actually neurotransmitter and receptor pairs
- Neural
- Cognitive
- Behavioral

Tourette’s syndrome

- Inherited (~200,000 in US)
- Behavior
  - Tics
    - Simple: eye blinking, facial grimacing, sniffing
    - Complex: coordinated patterns, sniffing objects, jumping, twisting
- Too much dopamine
- Treated with Haldol (among others)
  - Blocks dopamine
  - http://www.cbsnews.com/video/watch/?id=1033515n

Parkinson’s

- Lack of dopamine
  - Many different causes
  - In extreme cases, patients are “frozen”
- Give patients large doses of L-DOPA
  - A precursor of dopamine
  - Sometimes solves the problem
  - Lots of side effects
- Awakenings, by Oliver Sacks
  - https://www.youtube.com/watch?v=koL0PWCJ4Io

Drugs

- Interact with neurotransmitters in lots of ways, for example
  - Replace: accepted by receptor and with similar effect
  - Production: increase or decrease
  - Reuptake: knock out enzymes that remove neurotransmitter from receptor; neurotransmitter has a bigger effect
  - Blocking: enter receptor but does not trigger reaction, partly closes receptor protein so neurotransmitter cannot enter
Prozac

- Some forms of depression seem to be related to limits in the use of the neurotransmitter serotonin.
- Prozac is a selective serotonin reuptake inhibitor (SSRI).
- It keeps serotonin bound to a receptor for longer than usual, thereby increasing its effect.
- Prozac is one of the most widely prescribed drugs in the world!

Other drugs

- Amphetamines: release of norepinephrin or dopamine
- LSD: resembles serotonin
- Phenothiazine drugs: block dopamine
- Curare: blocks acetylcholine
- Cocaine: prolongs effects of dopamine
- Morphine: resembles a small set of neurotransmitters called endorphin peptides (modulate pain perception)
- Tetrahydrocannabinol (active ingredient in marijuana): binds to some neuroreceptors, but it’s not clear what it does

Conclusions

- Neural action potentials
- Shape of proteins
- Specific use of neurotransmitters for certain behaviors
- Current work on identification of role of neurotransmitters
- Lots of money to be made
- Lots more complicated than what we’ve seen here

Next time

- Neural sensitivity
- Neural codes
- Receptive fields
- CogLab on Blind spot due!
- How do you recognize your grandmother?