Spring Brain Conference

Neuroscience Teaching Team

Brain Anatomy
SBC OUTREACH PROGRAM
Demo Outlines

The Neuroscience Teaching Team program is comprised of three demonstration modules based on demos used by the Young Scientist Program at Washington University in St. Louis. Usually they are done in a single class that is split into three rotating groups (~5-8 students in each), with 15-20 minutes per station. The three components are designed to give a basic understanding of how the brain is organized and how it helps us interact with our environment.

Below are detailed descriptions of the three demos: Brain Anatomy, Visual Motor Adaptation, & Proprioception: The 6th sense, but feel free to add/skip/rearrange things as you like. Evaluation forms that can be given to students are also included at the end.

BRAIN ANATOMY - In this module, students will be given an overview of brain anatomy.

I. What is the brain made out of? (cells, tissues, 3 lbs.)
II. What is the main kind of cell? (neuron)
   a. Point out dendrites, axons, cell body, etc. with help of pictures.
   b. How many neurons are in the brain? (100 billion, 30,000 could fit on a pinhead)
III. How do neurons talk to each other?
   a. How information gets from head to toe (pictures)
      i. different speeds in different types of neurons (0.5 m/s - 120 m/s or 268 mph)
   b. Axons / dendrites, axons can be really long, run from toe to spinal ccrd...
   c. Synapses (pictures)
   d. Nervous System
      i. CNS = Brain + Spinal Cord (inside the skeleton)
      ii. PNS = nerves to rest of body (outside the skeleton)
      iii. Sensory nerves = info from body to brain
      iv. Motor nerves = info from brain to body
IV. What does the brain look like?
   a. Is it one big mush or divided into different segments?
   b. Take out model brain, ask students what they notice about it
   c. Which end is front / back? (hold it up to someone’s head, show where eyes would be)
   d. Point out how wrinkly it is. Why? (takes up less space when folded up)
   e. Different regions for different functions
      i. Point out various functional regions
      ii. Right versus left hemispheres
      iii. 4 lobes (frontal, parietal, occipital, temporal)
      iv. Where do they think the part of brain that processes visual information would be? (optic nerve, optic chiasm, visual cortex…)
      v. Cerebellum, involved in movement and coordinating movement
      vi. any other regions… (hippocampus – forming memories, thalamus – gating movements)
V. Spinal cord
   a. Main pathway connecting brain and PNS
VI. Nervous system injury
   a. Stroke can damage different parts of the brain
   b. Spinal cord injury, paralysis
   c. fMRI to visualize brain activity
   d. fMRI images from injured/diseased brains
The adult human brain weighs about 1300-1400 g (about 3 lbs.). A newborn human brain weighs between 350 and 400 g. For comparison:

elephant brain = 6,000 g
chimpanzee brain = 420 g
rhesus monkey brain = 95 g
beagle dog brain = 72 g
cat brain = 30 g
rat brain = 2 g

It is estimated that there are 100 billion (100,000,000,000) neurons in the human brain. To get an idea of how many 100 billion is, think of this:

Assume that you were going to count all 100 billion cells at a rate of 1 cell per second. How long would it take you to count all 100 billion cells? My calculations say it would take about 3,171 years!!! Do the math yourself. (Here is a hint on the math: there are 60 seconds in a minute; 60 minutes in an hour; 24 hours in a day; 365 days in a year). By the way, my calculations did NOT take "leap years" into account. Actually, it would probably take a lot longer than 3,171 years since it takes more than 1 second to say the large numbers.

Here is another way to think of 100 billion:

Assume the cell body of one neuron is 10 microns wide (this is just an assumption since neurons come in many different sizes. However, 10 microns is small; smaller than the period at the end of this sentence). Ok...if you were able to line up all 100 billion neurons in a straight line, how long would your line be? Check my math!!

1 neuron = 10 microns wide
10 neurons = 100 microns wide
100 neurons = 1000 microns wide = 1 mm wide
1,000 neurons = 10 mm wide = 1 cm wide
100,000 neurons = 100 cm wide = 1 m wide
100,000,000 neurons = 1000 m = 1 km
10,000,000,000 neurons = 100 km
100,000,000,000 neurons = 1000 km (about 600 miles)
While all the neurons lined up side by side would stretch 1000 km, the line would be only 10 microns wide...invisible to the naked eye!!!

To get an idea of how small a neuron is, let's do some more math:

The dot on top of this "i" is about 0.5 mm (500 microns or 0.02 in) in diameter. Therefore, if you assume a neuron is 10 microns in diameter, you could squeeze in 50 neurons side-by-side across the dot. However, you could squeeze in only 5 large (100 micron diameter) neurons.

If you assume the average person is 150 pounds and the average brain weighs 3 lbs. then the brain is 2% of the total body weight.

The average spinal cord is 45 cm long in men and 43 cm long in women. The spinal cord weighs about 35 g.

Information travels at different speeds within different types of neurons. Transmission can be as slow as 0.5 meters/sec or as fast as 120 meters/sec. Traveling at 120 meters/sec is the same as going 268 miles/hr!!!
A Neuron has three main parts. The cell body, or soma, is a neuron’s main cellular space. The soma houses the nucleus, in which the neuron’s main genetic information can be found. The axon sends messages to other neurons. The dendrites receive messages from other neurons.
Neurons: Building Blocks

- Building blocks of the brain
- 100 billion neurons
- 30,000 on a pinhead

from the collection of Frank Sharp, M.D.

Neurons are the building blocks of your brain. They communicate with each other thousands of times a second.
Red-- MAP2
Green-- SV2

From Ann Marie Craig:

Young neuron cultured from rat hippocampus. Dendrites are labeled with antibodies against MAP2. Synapses are labeled with antibodies against SV2, a protein located on synaptic vesicles. (red) (green)
Figure 1.1  Examples (A–F) of the rich variety of nerve cell morphologies found in the human nervous system. Tracings are from actual nerve cells stained by impregnation with silver salts (the so-called Golgi technique, the method used in the classical studies of Golgi and Cajal). Asterisks indicate that the axon runs on much farther than shown. (Note that some cells, like the retinal bipolar cell, have a very short axon, and that others, like the amacrine cell, have no axon at all.) The drawings are not all at the same scale.

Golgi and Cajal. The joint award indicated some ongoing concern about who was correct, despite Cajal's overwhelming evidence. Any lingering doubt was finally resolved with the advent of electron microscopy in the 1950s. The high-magnification, high-resolution pictures obtained with the electron microscope clearly established that nerve cells are indeed functionally independent units.

The nineteenth-century histological studies of Cajal, Golgi, and a host of successors led to the consensus that the cells of the nervous system can be divided into two broad categories: nerve cells (or neurons), and a variety of supporting cells. Nerve cells are specialized for electrical signaling over long distances, and understanding this process represents one of the more dramatic success stories in modern biology (the subject of Unit I). Supporting cells, in contrast, are not capable of electrical signaling, despite having some other important electrical properties. In the central nervous system (the brain and spinal cord), these supporting cells consist mostly of neuroglial cells. Although the cells of the human nervous system are in many ways similar to those of other organs, they are unusual in their extraordinary numbers (the
The Nervous System

中央神经系统
= 大脑 + 脊髓

周围神经系统
= 从身体到大脑的神经

- 感觉神经
- 运动神经

一起，大脑和脊髓组成中央神经系统。
Figure 1.10 The subdivisions and components of the central nervous system. (A) A lateral view indicating the seven major components of the central nervous system. (Note that the position of the brackets on the left side of the figure refers to the vertebrae, not the spinal segments.) (B) The central nervous system in ventral view, indicating the emergence of the segmental nerves and the cervical and lumbar enlargements. (C) Diagram of several spinal cord segments, showing the relationship of the spinal cord to the bony canal in which it lies.
Figure 5 The main divisions of the brain and lobes of the cerebral cortex are colored and labeled in midsagittal A and lateral B views of the brain from images in Part II (0.6X). The relation of these divisions to the brain stem and cerebrum are summarized in Table 1. The table also indicates the embryonic origins of the different parts of the central nervous system to which many of these divisions correspond.

List for A and B

Cerebellum 4, 14
Corpus callosum, anterior commissure, fornix and septum pellucidum 11
Frontal lobe 10, 19
Hypothalamus, thalamus, habenula and pineal gland (diencephalon) 9
Medulla oblongata (pons, medulla) 6, 16
Midbrain (mesencephalon) 2
Occipital lobe 3, 13
Parietal lobe 1, 12
Pons 7, 17
Spinal cord 5, 15
Temporal lobe 8, 18

The Brain Atlas (2003; Woolsey T)
Caudate nucleus, head
Orbital gyri
Medial rectus muscle
Carotid siphon
Optic tract
Vertebral artery
Ambient cistern
Anterior commissure
Internal capsule, anterior limb
Lateral ventricle, body
Thalamus, Pul
Parieto-occipital sulcus
Dentate nucleus
Cerebellum, horizontal fissure
Middle cerebellar peduncle
Optic tract
Orbital gyri
Parieto-occipital sulcus
Thalamus, pulvinar (Pul)
Vertebral artery

The Brain Atlas (2003; Woolsey T)
Activation during Reading
Spinal cord
  Dorsal roots: sensory info (afferents)
  Ventral roots: motor info (efferents)
Cerebellum: coordination of motor activity, posture, equilibrium; monitors/corrects for errors in ongoing movement

Brainstem: cardiovascular and respiratory control, circadian rhythms, motor control
  Medulla
  Pons
  Midbrain

Frontal lobe: planning responses to stimuli
Temporal lobe: recognizing stimuli; auditory processing
Parietal lobe: attending to stimuli, sensory
Occipital lobe: vision

Corpus callosum: major white matter tract that connects the two hemispheres (comprised of axons from neurons in either hemisphere that contact target neurons in the opposite hemisphere)

Olfactory tracts: smell
Optic tract: axons from eyes; crossing of axons = chiasm
Hippocampus: memory (damaged in Alzheimer’s disease)
Hypothalamus: homeostatic, reproductive functions; visceral function
Thalamus: relay station to cortex from other parts of the brain; especially for sensory processing info

Basal ganglia (caudate, putamen and globus pallidus): organization and guidance/gating of complex motor functions

Amygdala: processing of emotions

Lateral ventricles: fluid-filled (cerebrospinal fluid) spaces
Meninges: three protective tissue layers that surround/support the brain (dura, arachnoid and pia mater)
Levels of Injury and Extent of Paralysis

C4 injury (quadriplegia)

C6 injury (quadriplegia)

T6 injury (paraplegia)

L1 injury (paraplegia)

Cervical (neck)

Thoracic (upper back)

Lumbar (lower back)

Sacral

Coccygeal