Neuroscience Day

Activity Booklet

Code of Conduct

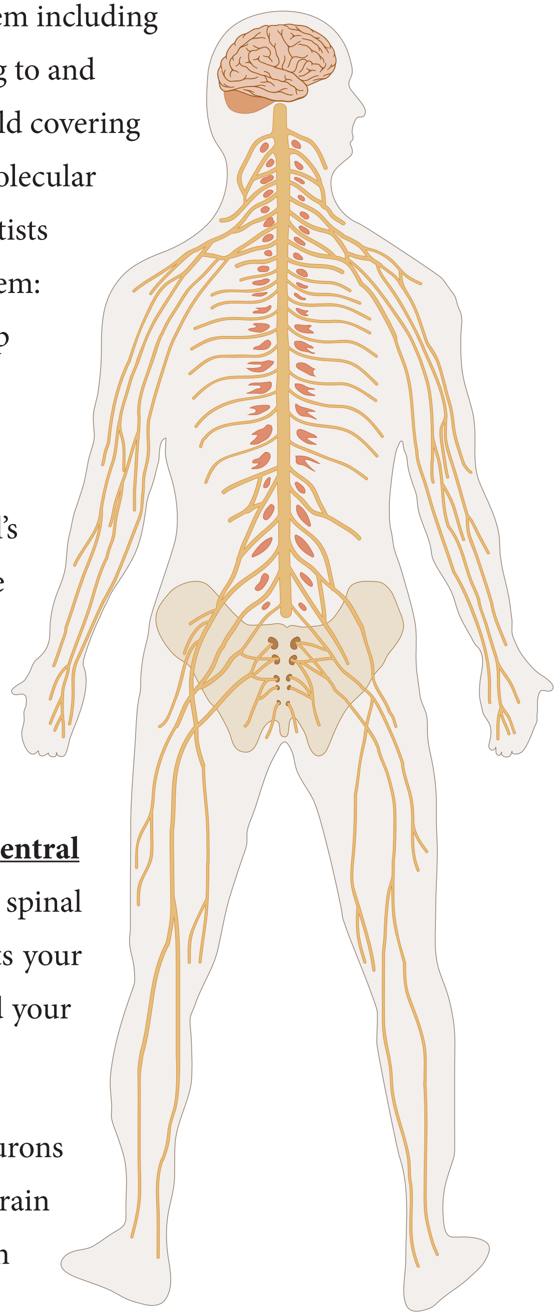
By participating in Neuroscience Day, I agree to

1. Speak, listen, and act courteously.
2. Follow the directions of all staff members at all times.
3. Respect property and the property of others.
4. Wear proper safety equipment and clothing.

Contents

Introduction to Neuroscience

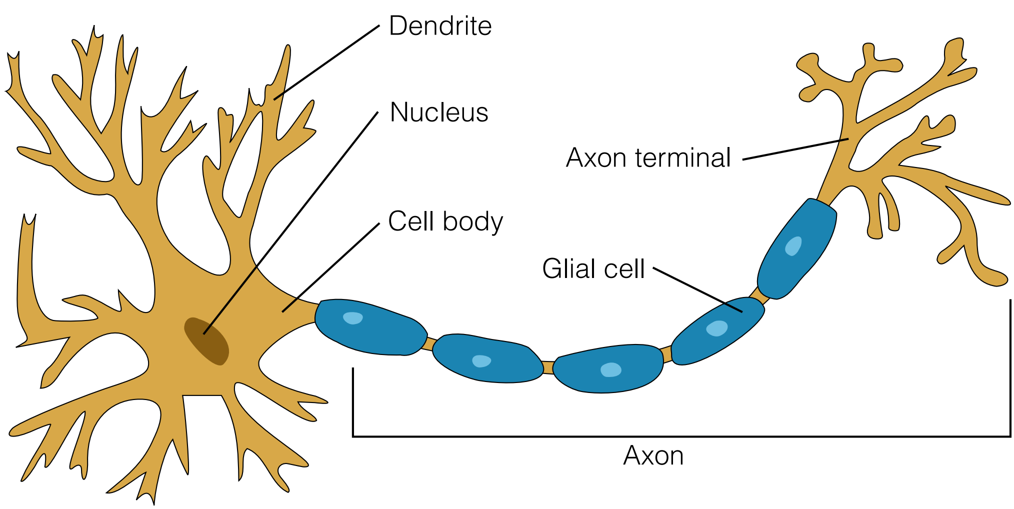
Neuroscience is the study of the nervous system including the brain, spinal cord, and all the nerves going to and from the brain and spinal cord. It is a large field covering several different topics from psychology to molecular biology and even bioengineering. Neuroscientists study the multiple aspects of the nervous system: its function as a whole, cell types that make up the nervous system, proteins within the cells, and molecules that affect the cells.



The nervous system is the part of an animal's body that coordinates the actions of the animal and transmits signals between different parts of its body. In most types of animals the nervous system consists of two main parts: the **peripheral nervous system**, which consists mainly of nerves, and the **central nervous system**, which contains the brain and spinal cord. The peripheral nervous system connects your brain to your senses, like sight and smell, and your muscles to help you move.

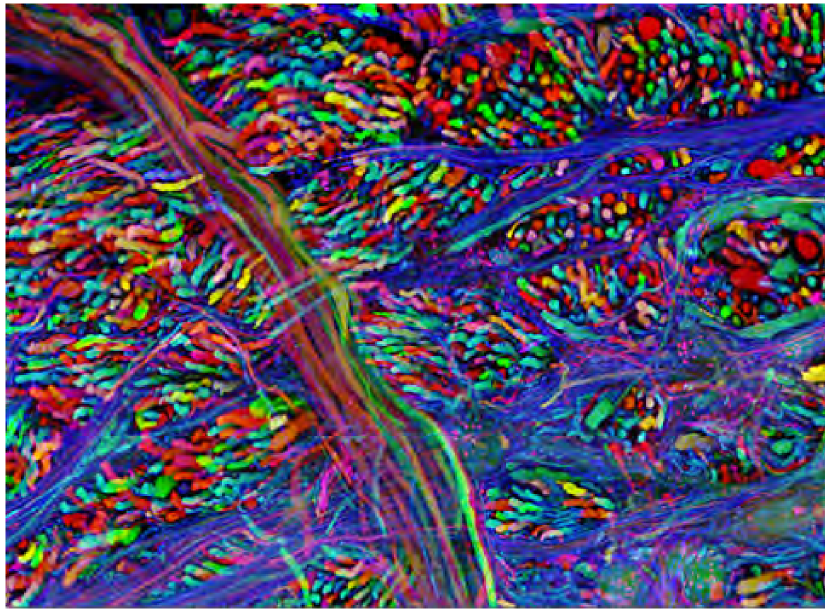
The brain contains two main types of cells: neurons and glia. The **neurons** are the cells of the brain that communicate to one another. A neuron has a central part called the **cell body** with several receiving branches called **dendrites**. Neurons also have very long branches called **axons**, which send signals and information to the dendrites of one or more other neurons.

Glia are very important cells in the brain because, unlike neurons, they are able to divide and replace themselves if they die. The glia support and protect the neurons and have several functions: providing energy from the bloodstream to neurons, forming a barrier around the brain to protect the neurons from harmful toxins, helping conduct impulses through neurons at high speeds, and attacking viruses or invasive molecules that enter the brain. Together the glial cells do a great job of protecting the neurons from harm.



The Plastic Brain

How do we learn and remember how to do things like walk, ride a bike, and chew gum? These tasks involve an important type of memory called procedural memory. This memory is different and mostly becomes habit-like, unlike explicit memory that is used when you answer questions like: What color was your first bike? or What is your favorite flavor of gum?

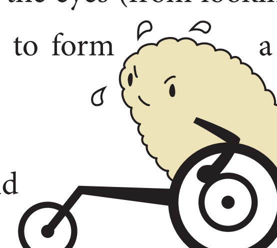

Livet, J, et al. Nature 450, 56-62 (2007). doi:10.1038/nature06293.

This image of neurons in the cerebellum is produced by a scientific imaging technique called Brainbow. Learn more about it on page 13!

The mirror tracing and bean bag toss activities test our existing procedural memories and require us to learn new procedural memories. When you are doing things that are familiar to you, like tracing a shape (page 6) or throwing bean bags (page 5), these types of tasks can be simple. When the task is changed and no longer familiar to you, such as tracing the image reflected in a mirror or putting on prism goggles, the tasks become more difficult.

However, our brains readily learn and adjust to new information by changing the neuron and glial structure, function, or both, a process called **neural plasticity**. In science, "plastic" means moldable or changeable in structure. With practice over time, our brain adapts by incorporating the new information. The more times we try the tasks the better we get because our brain adopts new ways for us to complete the task successfully. Therefore, by adjusting muscle patterns to adapt to the change in input from the eyes (from looking through the goggles or the mirror), your brain has allowed you to form a new procedural memory.

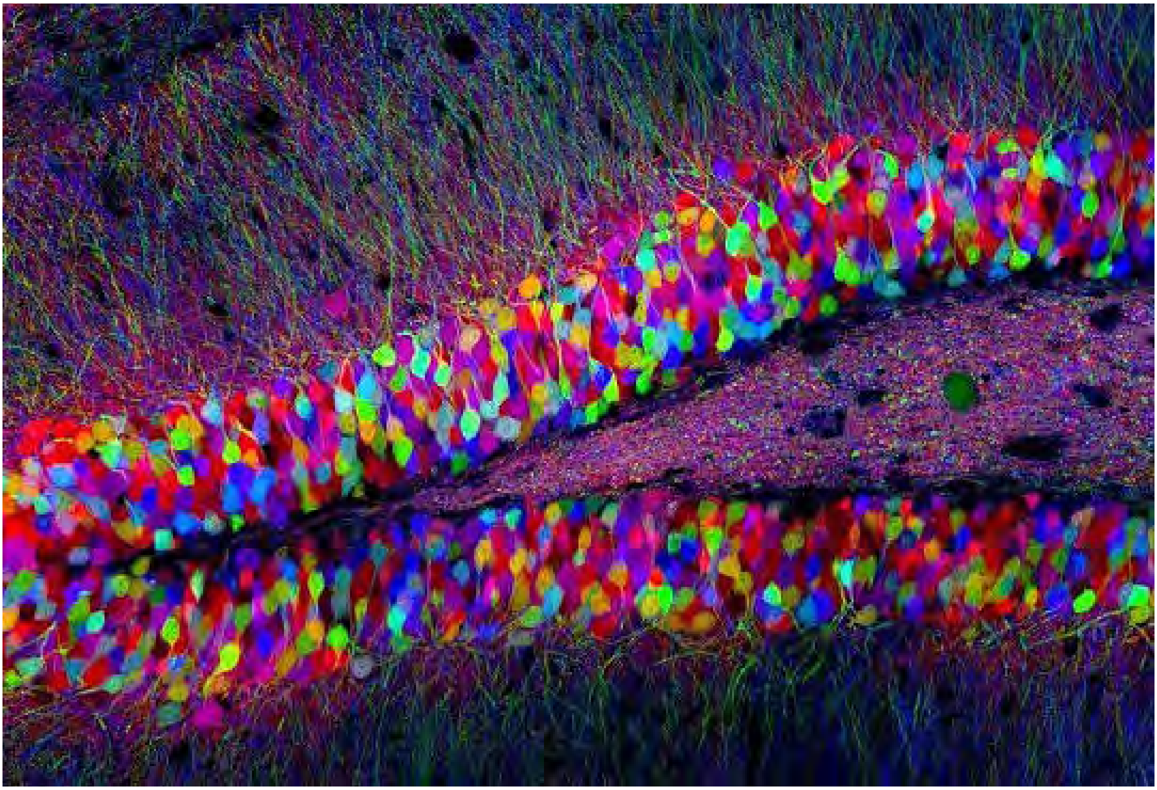
Today you will learn more about the nervous system, brain, and neurons. Enjoy yourself and teach your brain new things!



Bean Bag Toss

Directions

1. Stand at the marked spot and toss the bean bags into the box one by one. On the image to the right, draw where they landed in GRAY pencil.
2. Put on a pair of goggles and toss the bean bags into the box one by one. On the same image to the right, draw where they landed in RED pencil.
3. Do the same with the same pair of goggles. Draw where the bean bags landed in BLUE pencil.
4. Do this again with the same or a different pair of goggles. Draw where the bean bags landed in GREEN pencil.

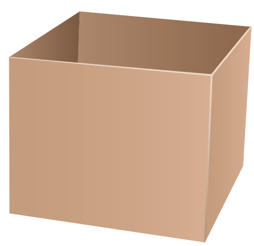


Livet, J, et al. Nature 450, 56-62 (2007). doi:10.1038/nature06293.

This image of neurons is produced by a technique called Brainbow. Learn more about it on page 13!

Draw where your beanbags landed:

1. Trial 1 (no goggles) – GRAY
2. Trial 2 (goggles) – RED
3. Trial 3 (goggles) – BLUE
4. Trial 4 (goggles) – GREEN



How can tracing shapes reveal how your brain is **plastic**? Read about it on page 2!

Mirror Tracing

Directions

Person 1: Hold the folder so that Person 3 cannot see the paper or their hand as they draw.

Person 2: Time each of Person 3's trials and make sure they write it down in their book.

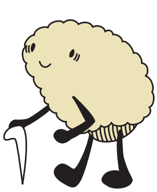
Person 3:

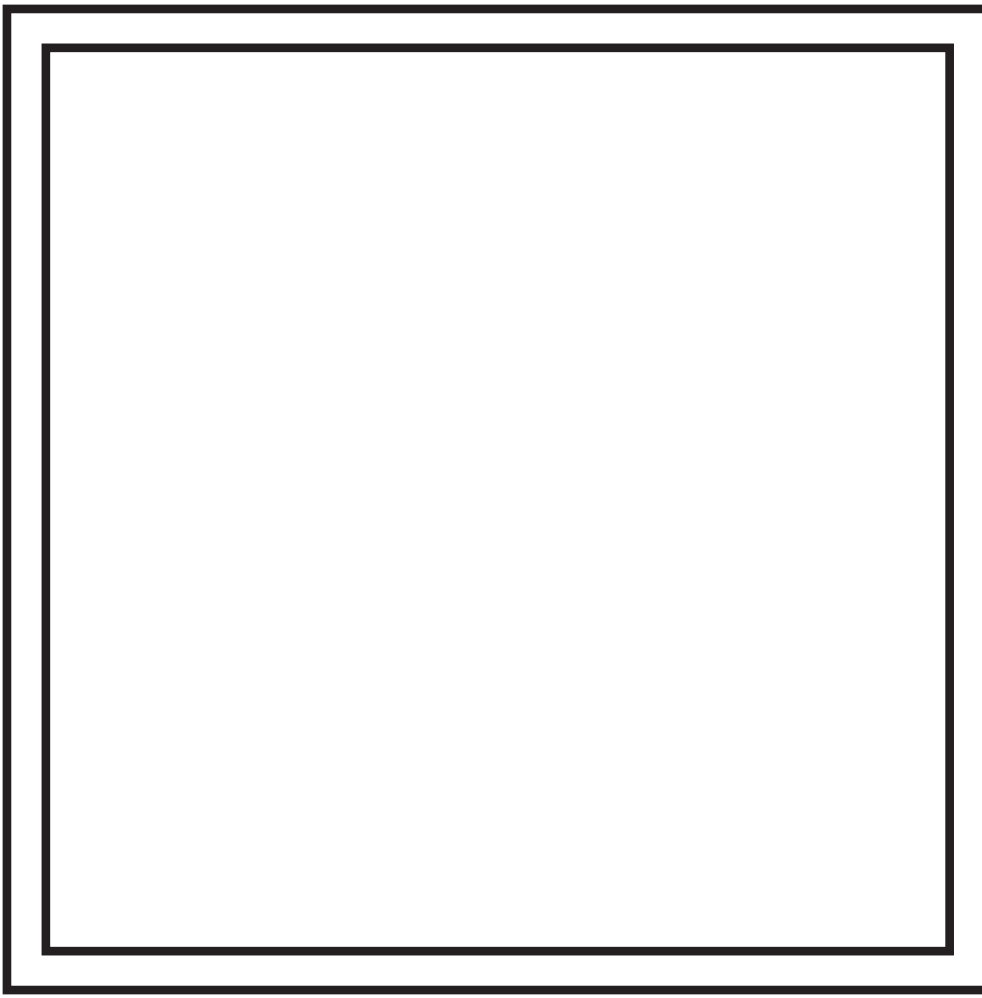
1. Using a GRAY pencil, trace the shape while staying within the two lines as fast as you can. Record the time.
2. Now position the page so that you can see the reflection in the mirror. Using a RED pencil, trace the shape again, but this time **only** look at it through the mirror. Record the time.
3. Repeat tracing the shape in the mirror with the BLUE and GREEN pencil, recording your times for each trial.
4. Try another shape beginning again with Step 1. Record the times for each trial.

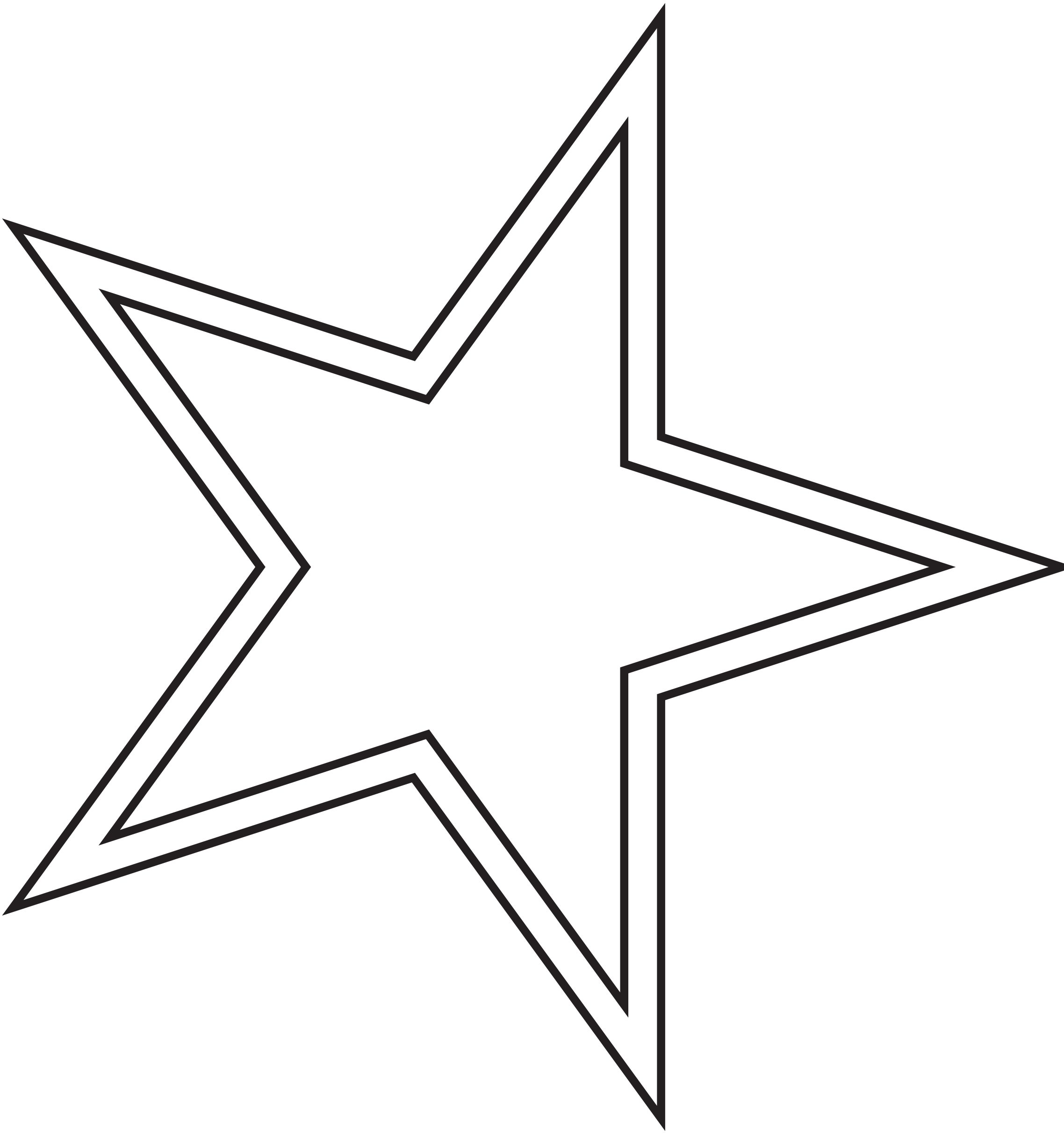
Shape	Time to complete			
	Gray pencil (no mirror)	Red pencil (mirror)	Blue pencil (mirror)	Green pencil (mirror)
Square				
Circle				
5-pointed star				
6-pointed star				
Advanced				

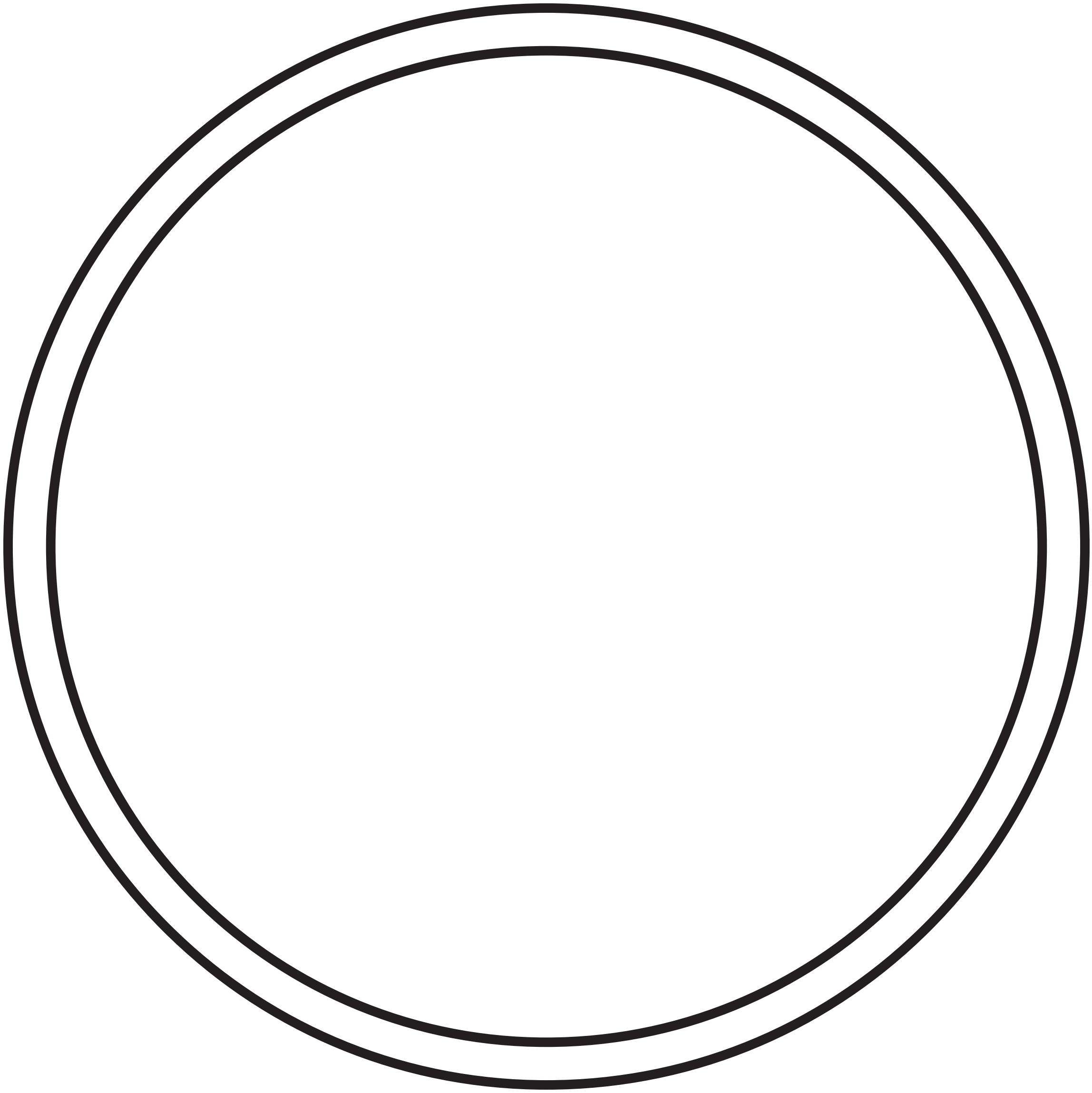
Questions

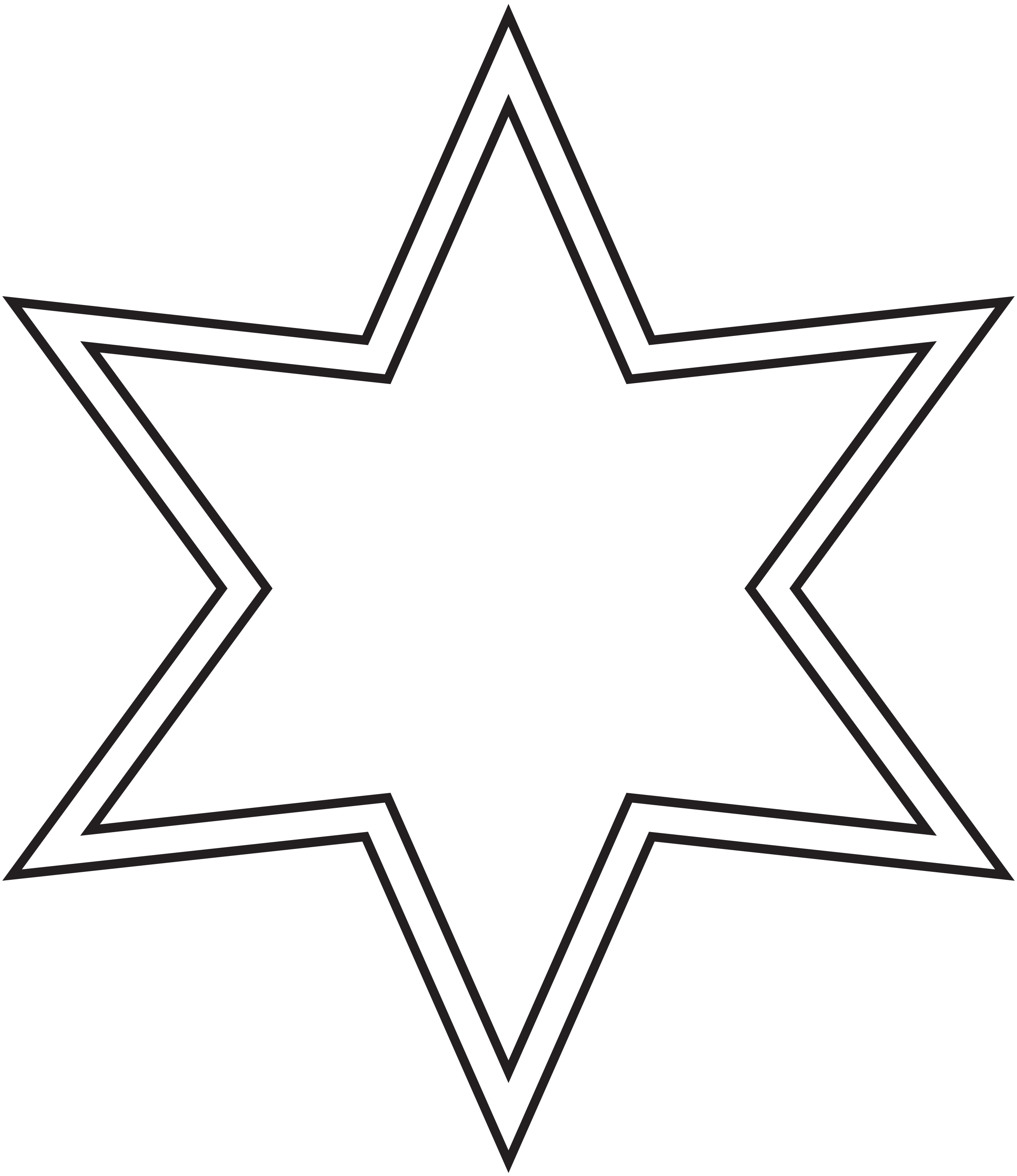
1. What do you notice is happening to the amount of time you take to do this and your accuracy level?

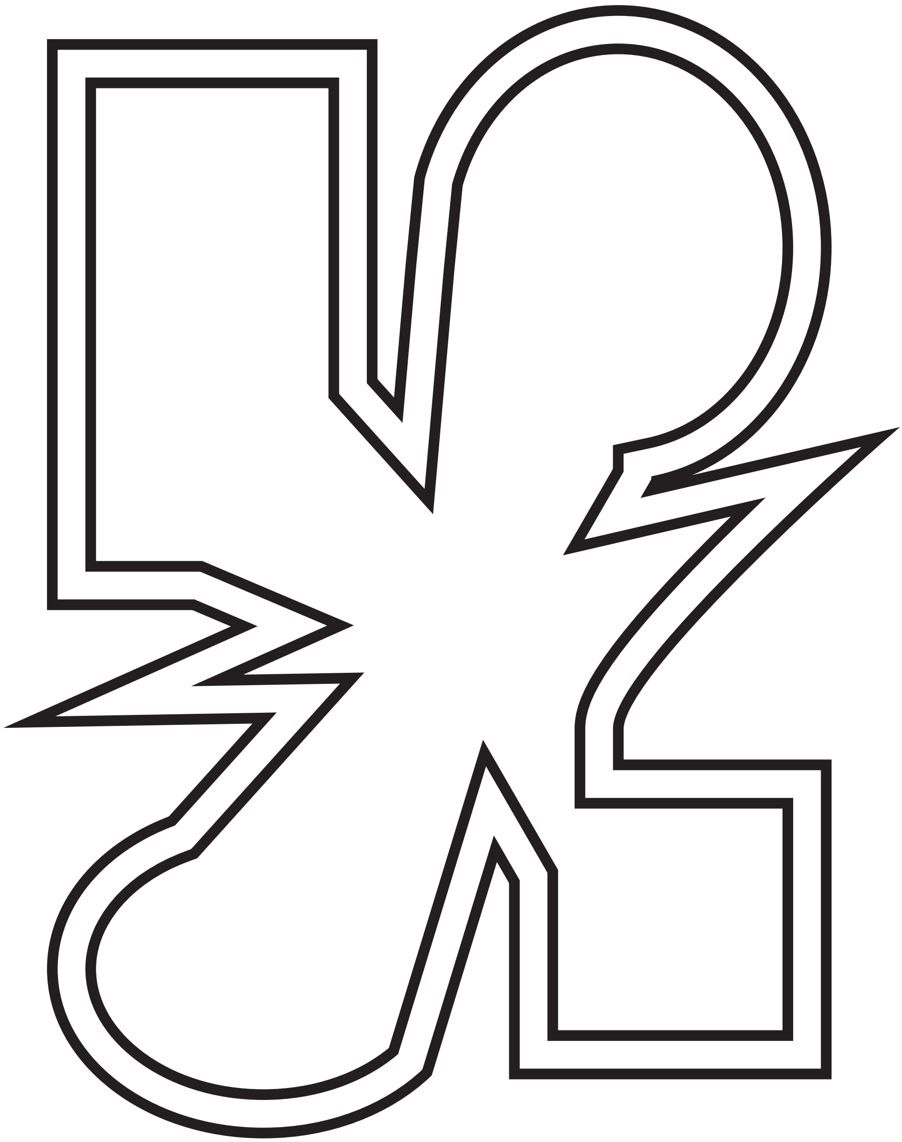












Paint Chip Sorting

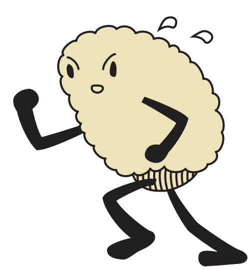
Directions

1. Each group member will take turns sorting paint chips into color categories.
2. Sort chips as fast as possible! You only get 1:30 minutes.
3. After time is up, count the number of paint chips that were divided into each color category and record that number in the data table below.
4. Mix up the paint chips, and then the next group member can do the activity.
5. Discuss and answer the questions under the data table once all group members have taken their turns.

Group member:	Red	Orange	Yellow	Green	Blue	Purple	Brown
1							
2							
3							
4							

Questions

1. Did every group member get the same results?

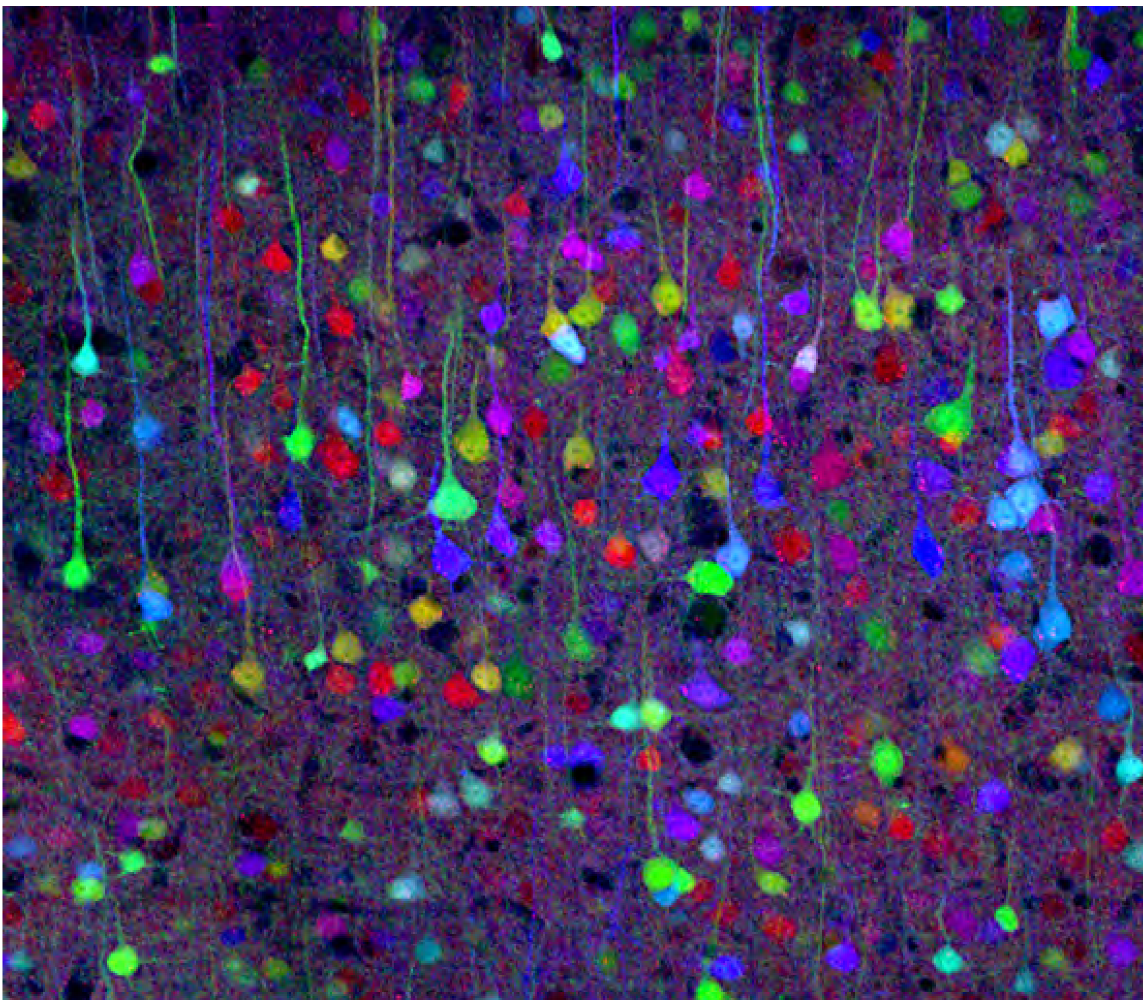


2. What reasons can you give for your results?
3. Which colors did everyone sort into the same category? On which colors did people disagree?

Brainbow

Brainbow (from “brain rainbow”) is an imaging technique in which neuroscientists make individual neurons in the brain fluoresce (glow) different colors.

The technique was developed by scientists at the Harvard Medical School. The images of mice brains in this booklet first appeared in the scientific journal Nature in November 2007 and have won many scientific and photography awards. You can find these images and more online at http://cbs.fas.harvard.edu/science/connectome-project/brainbow.



Livet, J, et al. Nature 450, 56-62 (2007). doi:10.1038/nature06293.

Candy Sorting

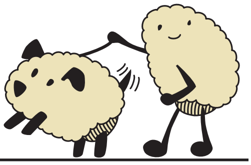
Predictions

1. What color do you predict the red candies will look like under **white** light? Why?

2. What color do you predict the red candies will look like under **red** light? Why?

3. What color do you predict the red candies will look like under the **green** light? Why?

4. What color do you predict the red candies will look like under the **blue** light? Why?



Directions

1. The first person pours out the candies in Cup #1 onto the paper plate under the light.
2. Another person starts the timer as the first member removes all the RED candies and places them back into the cup (do not look at the candies in the cup yet).
3. Stop the timer when they are done.
4. Pour out the removed candies and use a white light to check the color of the candies.
5. Record the time, # red removed, # total removed, and total red (including ones that were missed) in the table.
6. Calculate your selection and completion accuracy using the equations below.
7. Repeat steps 1-6 for each group member, using a different cup each time.
8. Rotate to different colored lamps and repeat the activity.

Selection Accuracy % = "# of red removed" / "total removed" X 100

Completion Accuracy % = "# of red removed"/ "total red" X 100

Data for WHITE light

Cup	# RED removed	# TOTAL removed	# TOTAL red	Time (s)	Selection accuracy %	Completion accuracy %
1						
2						
3						
4						

Data for RED light

Cup	# RED removed	# TOTAL removed	# TOTAL red	Time (s)	Selection accuracy %	Completion accuracy %
1						
2						
3						
4						

Data for GREEN light

Cup	# RED removed	# TOTAL removed	# TOTAL red	Time (s)	Selection accuracy %	Completion accuracy %
1						
2						
3						
4						

Data for BLUE light

Cup	# RED removed	# TOTAL removed	# TOTAL red	Time (s)	Selection accuracy %	Completion accuracy %
1						
2						
3						
4						

Questions

1. With which color light did you do best?

2. What evidence can you provide for your response?

3. With which color light did you do worst?

4. What evidence can you provide for your response?

5. Does the environment affect perception? Give evidence using data from your data tables, and explain your reasoning for why the data supports your answer.

The Stroop Effect

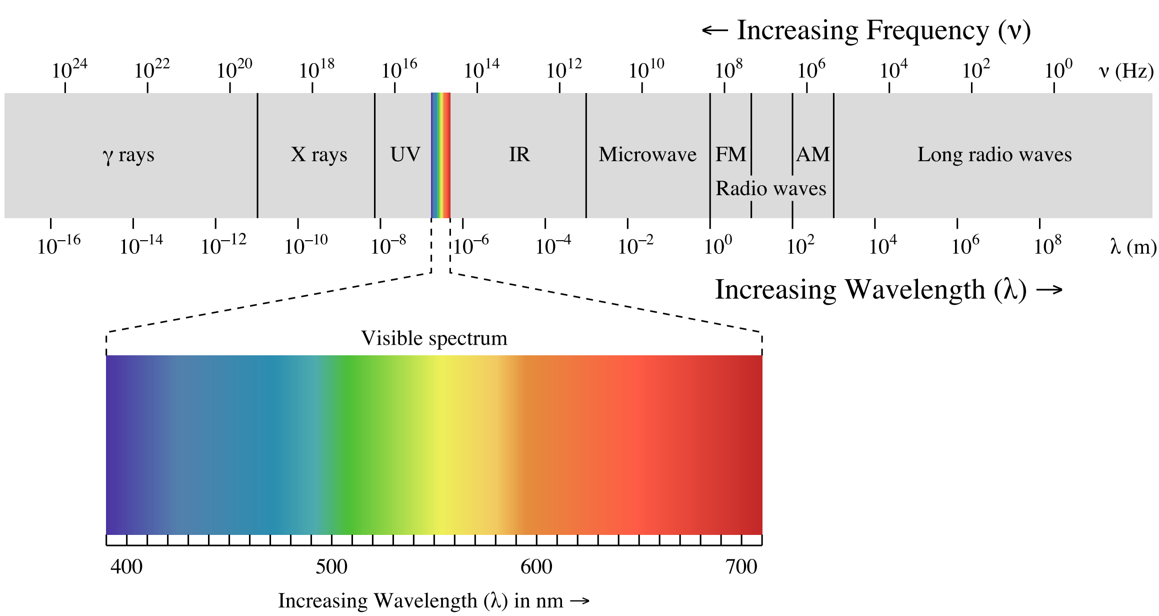
The famous "Stroop Effect" is named after J. Ridley Stroop who discovered this strange phenomenon in the 1930s. Here is your job: name the colors of the following words. Do NOT read the words—rather, say the color of the words. For example, if the word "BLUE" is printed in a red color, you should say "RED". Say the colors as fast as you can. It is not as easy as you might think! Have a friend check your answers (page 54) as you read out loud.

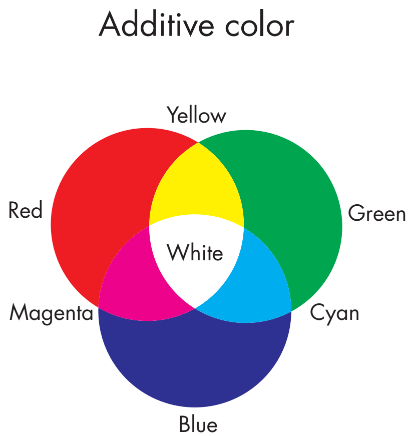
BLUE	ORANGE	TAN
GREEN	GRAY	GREEN
YELLOW	PINK	RED
PURPLE	PURPLE	ORANGE
BROWN	YELLOW	BLUE
WHITE	BROWN	WHITE
RED	BLUE	PINK

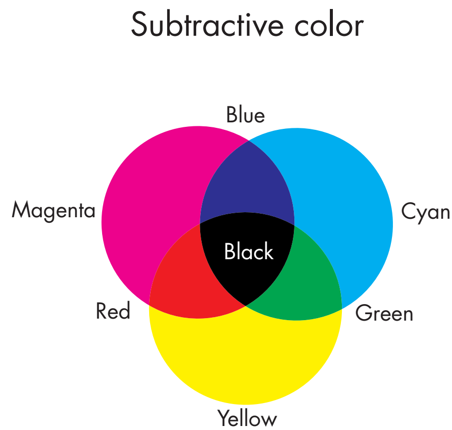
How do we perceive color?

Color is not a physical entity. While light is a physical entity, color is a perception. The human brain perceives color after processing information about combinations of wavelengths of light. The image below shows the range of wavelengths of light that the human eye can detect. This range is known as the human visible spectrum.

Note that the human visual spectrum is only a small part of the electromagnetic spectrum. You may be familiar with other categories of electromagnetic radiation including radio waves, microwaves, infrared waves, ultraviolet (UV) radiation, x-rays, and gamma rays.



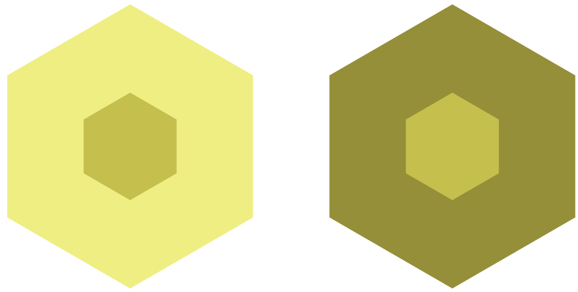




Not What You Learn in Art Class

What color do you see if red light and green light are mixed? You are mistaken if a muddy brown color is what you picture! A combination of red and green light makes yellow light. Mixing light results in colors that are different than what you get when you mix paint. The difference relates to how light gets to the eye. When light is mixed, additional wavelengths of light reach the eye. When paint is mixed, some wavelengths of light are absorbed by the paint, subtracting them out from the light that is reflected to the eye.

The light-sensing cells in the eye that detect color are called cone cells. Cone cells come in three varieties: red-sensitive, green-sensitive and blue-sensitive. The human eye perceives yellow when the red-sensitive cones and green-sensitive cones are both activated. The perception of most colors requires activation of more than one variety of cone cells. When the green-sensitive and blue-sensitive cones are both activated, the brain perceives cyan. When the blue-sensitive and red-sensitive cones are both activated, the brain perceives magenta. Detecting different colors of light occurs through an **additive** process. On the other hand, paint derives its color by absorbing light, leaving the remaining light for detection by the eyes. Thus, the perception of paint colors occurs through a **subtractive** process.



The Mystery Behind White Light

White light is composed of all the colors of the human visible spectrum. White paint looks white in sunlight because it absorbs none and reflects all the colors of light. Under blue light, it appears blue. Under green light, it appears green. Under yellow light it appears yellow, and so forth. Under white light, a yellow object appears yellow because red and green wavelengths of light are reflected into the eye, activating the red-sensitive and green-sensitive cone cells simultaneously. On the other hand, at the same time, the "blue" wavelengths of the human visible spectrum are absorbed by the yellow object. Therefore blue-sensitive cone cells are not activated.

Is it This Simple?

Many people assume that color is a defining property of objects and that it is based only on specific wavelengths of reflected light. However, color sensation is created in the brain. Imagine if the colors we perceive depended only on the wavelength of reflected light. In that case, the color of your t-shirt would appear to change dramatically with variations in lighting throughout the day or in shadows. Instead, patterns of activity in your brain lead to a perception of the color of your t-shirt that is relatively stable regardless of changes in the environment. This does not mean that environment, context, or experience has no role in perception of colors.

The Case of the Unbelievable Rubik's Cube

The famous Rubik's Cube Color Illusion (below) is a great example to show how experience and context play a role in our perception of colors. Does the center square on the top look the same as the center square on the left side? The "brown" square on the top of the Rubik's cube is actually identical in color to the "orange" square in the middle of the cube's side within the shadow.

Role of experience: Our experience tells us that when one side is darker, that face of the cube is in a shadow, and our vision system tries to compensate for it.

Role of context: A color looks lighter if the surrounding area is darker; a color looks darker if the surrounding area is lighter. This simple rule is also called the **simultaneous contrast**, which is illustrated on page 20--the blue in the center of each square is exactly the same. In the Rubik's cube, we perceive the top square as "brown." However, it is actually the same orange color as the one in shadow. The square only looks darker in the bright context.

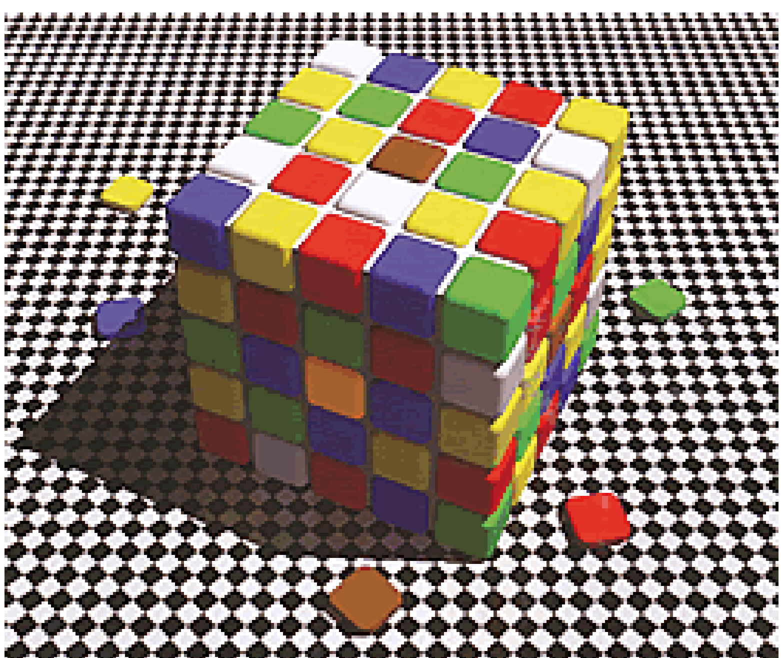


Image from Action Optical Illusions by Al Seckel.

Cow Eye vs. Human Eye

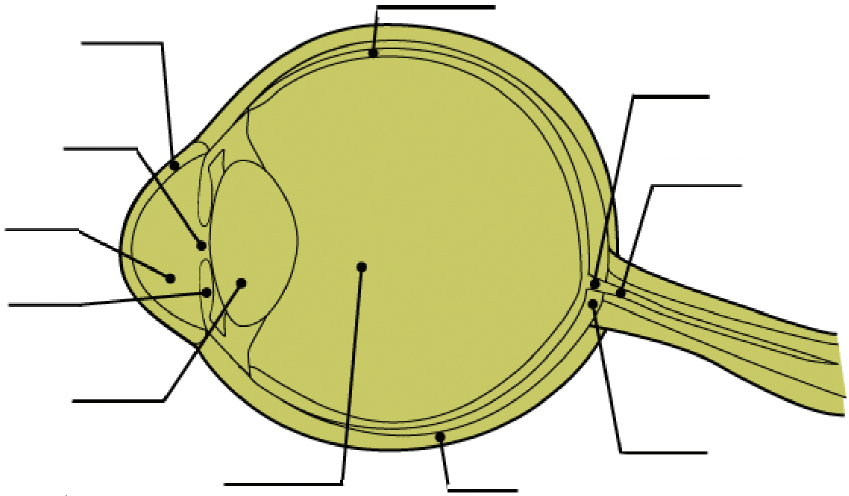


Image adapted from The Exploratorium, http://www.exploratorium.edu/

Cow eye: Label the parts

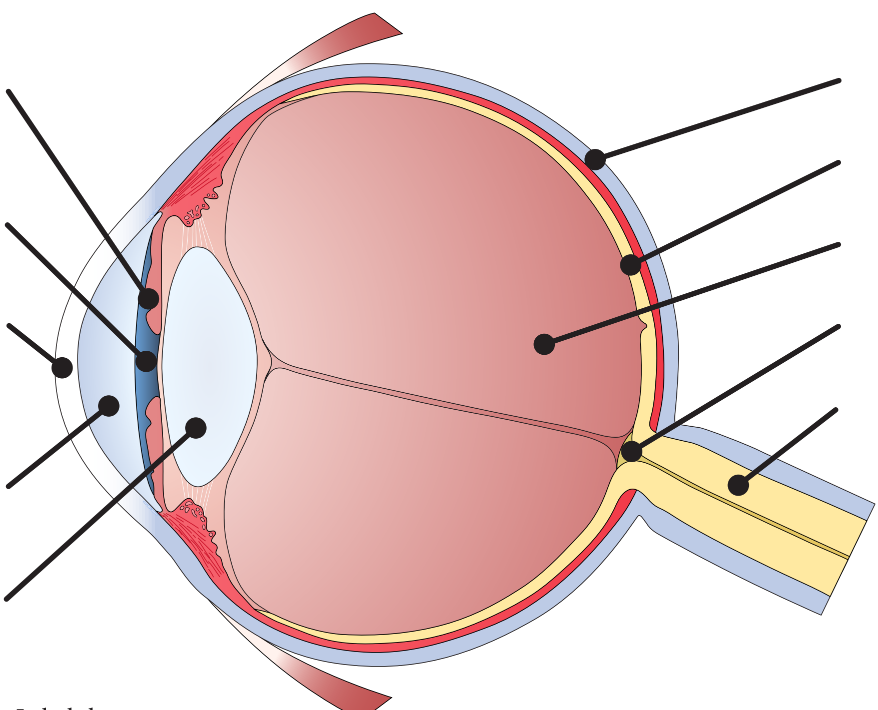


Illustration from iStock, by David Gunn.

Human eye: Label the parts

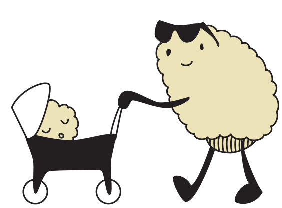
Label the following parts on the human eye model on page 22:

A. **<u>Aqueous humor</u>**: This thick fluid fills the space behind the cornea and is constantly replenished.
B. **<u>Blind spot</u>**: There are no light-sensitive cells on this part of the retina.
C. **<u>Cornea</u>**: The only transparent part of the eye's exterior, allowing light to enter the lens.
D. **<u>Iris</u>**: This circular structure changes shape to control the amount of light entering the eye.
E. **<u>Lens</u>**: This transparent sphere can change its shape to focus of light entering the eye.
F. **<u>Optic nerve</u>**: This is the primary connection between the eye and the brain.
G. **<u>Pupil</u>**: This hole appears black and light passes through it into the eye.
H. **<u>Retina</u>**: Using rod and cone cells, this layer of the eye converts light into nerve impulses.
I. **<u>Sclera</u>**: This protective layer of connective tissue forms the outermost layer of the eye.
J. **<u>Tapetum</u>**: This colorful, shiny material reflects light back into the retina.
K. **<u>Vitreous humor</u>**: This gel-like substance helps maintain the round shape of the eye.

Questions

1. How is the pupil of the cow eye different than the pupil of the human eye?

2. The cow eye has a tapetum. Explain why you think human eyes do not have this structure.



Sheep Brain Dissection

The Lobes of the Brain

Most functions of the cerebral cortex are distributed among multiple brain regions. However, some sensory functions are associated primarily with portions of one lobe.

The **occipital lobe** processes visual information (sight). Damage to this lobe can result in visual impairments in vision and visual hallucinations.

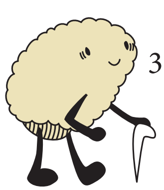
The **temporal lobe** seems to have a multitude of functions. Notably, damage to the temporal lobe can result in a loss of recognition of words and faces as well as the inability to categorize words or pictures, depending on which side is damaged. Memory processing for events is also affected by temporal lobe damage, as is hearing, language, and taste!

Patients with damage to the **frontal lobe** have significant changes to their personality and social behavior in addition to flexible thinking such as planning and organizing activities. A famous example is Phineas Gage, a railroad worker who suffered from an injury to his left frontal lobe when a large iron rod went through his skull in 1845.

The **parietal lobe** takes the sensory information from a single perception and then integrates these perceptions into a complex network that creates the world around us. Patients with damage to the parietal lobe can have difficulties in determining spatial relationships.

1. Damage to which lobe(s) may interfere with parking the car?

2. Damage to which lobe(s) may interfere with learning and remembering new words?



3. Damage to which lobe(s) may interfere with the ability to solve problems?

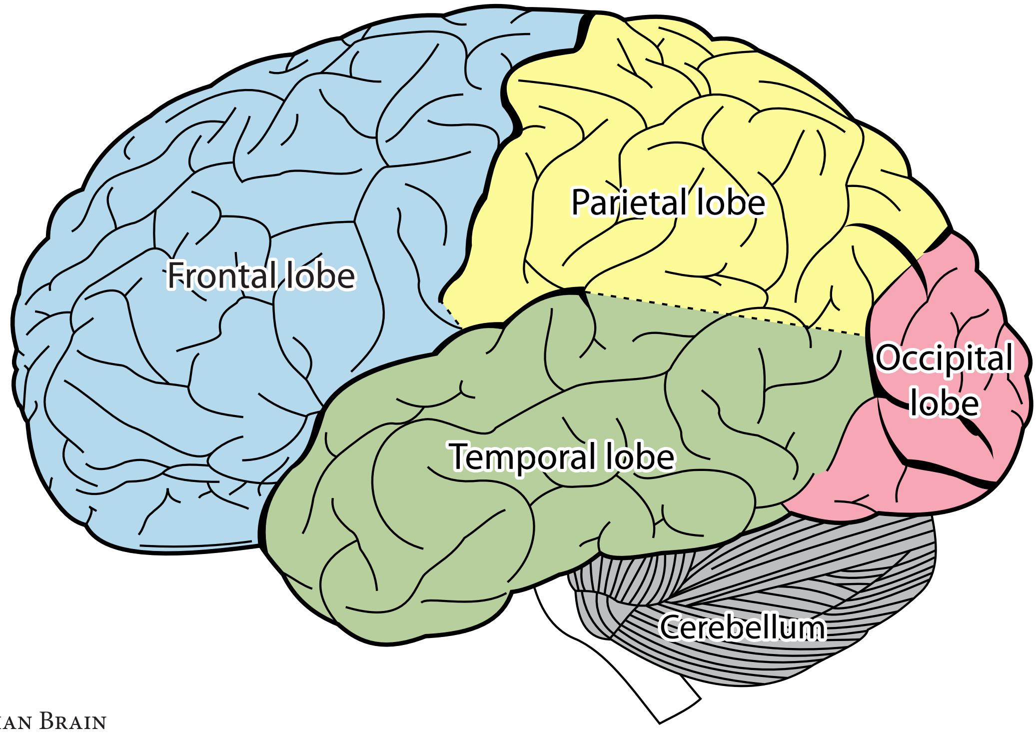
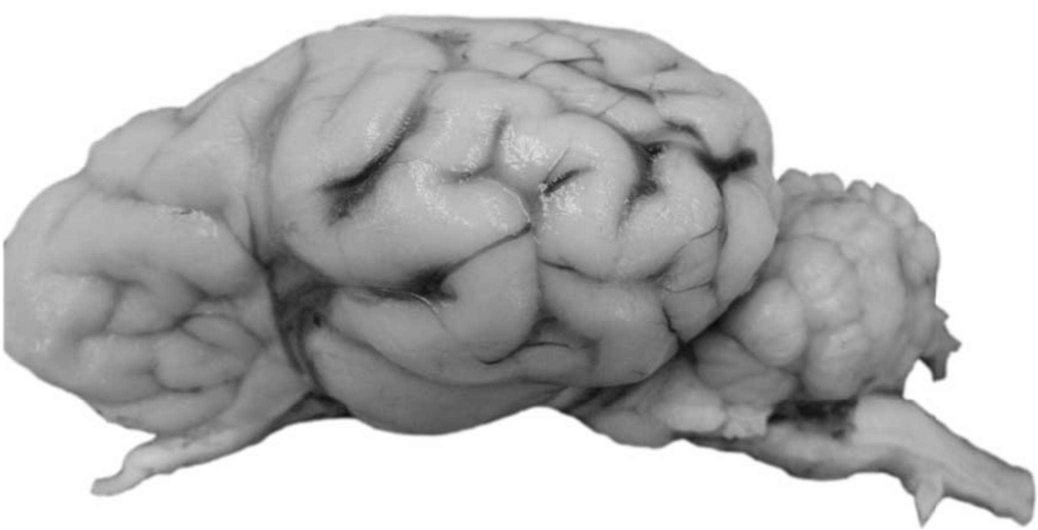


Image adapted from Wikimedia Commons. Public Domain..

HUMAN BRAIN

Using the human brain above as a reference, label the four lobes and cerebellum on the sheep brain below:



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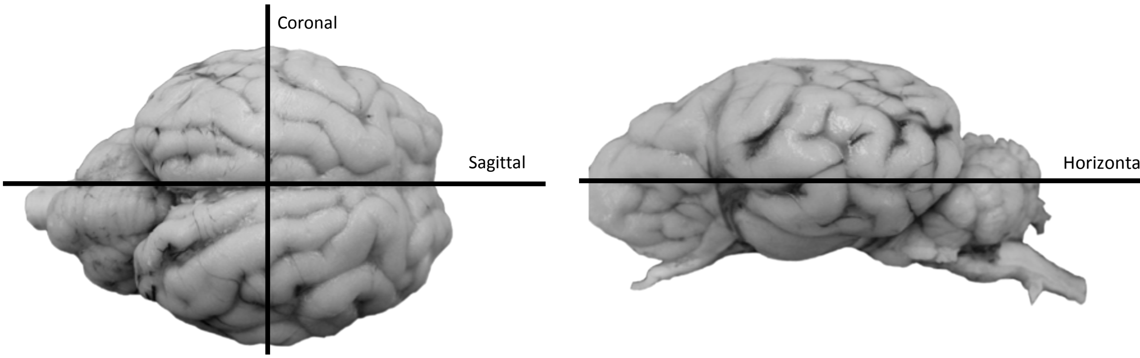
SHEEP BRAIN

The three most common ways to slice the brain are **coronal**, **sagittal**, and **horizontal**. Below is an example of these slices on a sheep brain.



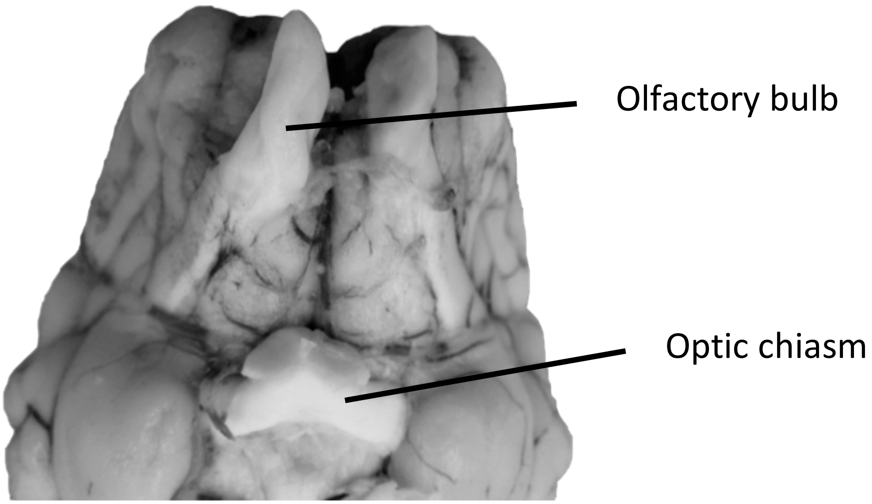
- The **coronal plane** divides the brain from front to back, like slicing a loaf of bread.
- The **sagittal plane** divides the brain from left to right.
- The **horizontal plane** divides the top and the bottom of the brain.

One clinical imaging technique used to visualize the brain is Magnetic Resonance Imaging (MRI). Images like those below are produced by this technique and are the equivalent to looking at thin slices of the brain.

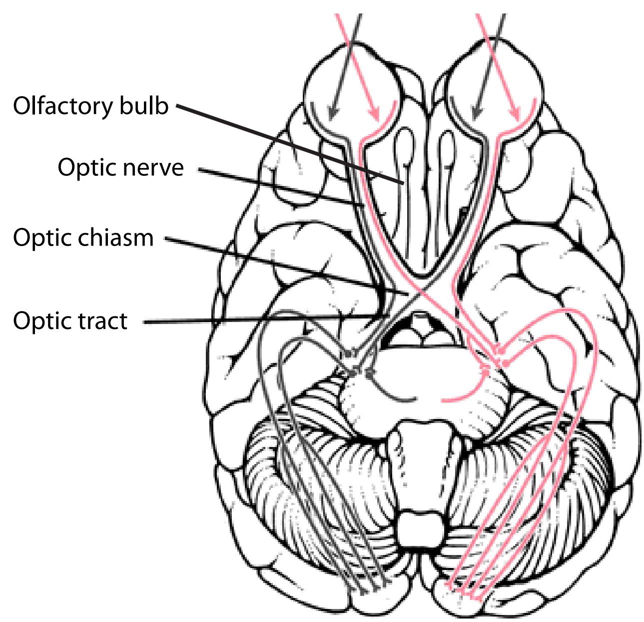
1. Label each image below as from a coronal, horizontal, or sagittal plane:

Sight and Smell

These are the structures used for processing visual and olfactory (smell) signals. Did you will notice the prominent **olfactory bulbs** on the bottom of the frontal cortex? Take a look at this image of the sheep brain and note about how big the olfactory bulbs are in comparison to the rest of the brain:



There are two optic nerves that bring visual information from the eye to the brain. These pathways cross at the **optic chiasm**. The optic chiasm is an "X"-shaped structure where the two optic nerves partially cross. As shown on the diagram of the human brain, information from the right visual fields of both eyes being processed by the left hemisphere of the brain, and vice versa.



Thalamus and Hypothalamus

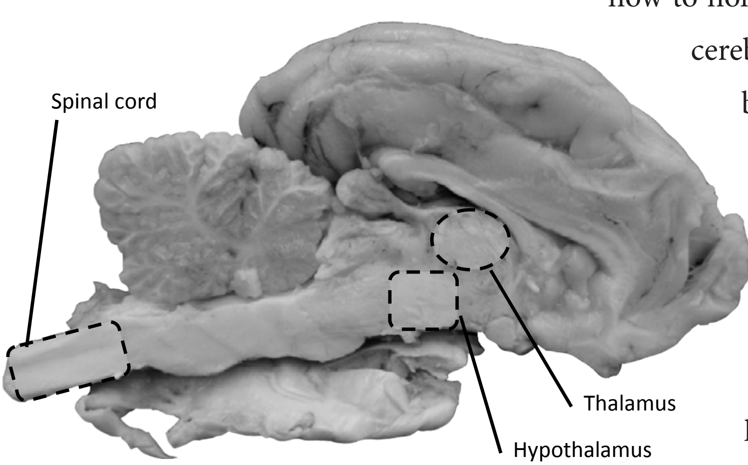
During your dissection you were also directed to the thalamus, and the hypothalamus. The **thalamus** integrates and processes information, then relays it to appropriate regions for even more processing. The **hypothalamus** ("hypo" means below, so below the thalamus) in involved in many functions from biological timekeeping to regulation of body temperature.

The hypothalamus comprises a collection of cells that are involved in a variety of functions. It links the nervous system to the endocrine system and keeps many of the body's processes at a set point within narrow parameters. These functions include circadian rhythms (keeping "biological time") and sleep, feeding and drinking, and body temperature.

A stroke that affects the hypothalamus can cause it to malfunction, which leads to an imbalance of hormones which can cause extra sensations of reward when eating, encouraging overeating.

Multiple memory systems in the brain

How do we remember to ride a bike? Or where we live? Is this information processed in the same brain areas? It turns out that different types of memory are managed by different regions of the brain. For example, procedural memories, which allow us to remember how to hold a pencil, are processed in the cerebellum and other parts of the brain. The hippocampus is important for memories, such as facts that you might need to know for the test. Each of these regions is responsible for helping us perform our daily tasks.



Questions

Answer the following questions based on the information on pages 27 and 28.

Cross-eyed cats

Some Siamese cats have a genetic mutation where the wiring of the optic chiasm is disrupted. This causes a decrease in the crossing of the nerves. Interestingly, these cats are able to function normally but have to alter their behavior to do this.

1. Why do you think the cats have to cross their eyes to correct this problem?

Mystery weight gain

A patient has recently suffered from a stroke and is concerned about her recent weight gain. She exercises everyday and eats a healthy diet but still seems to gain weight.

2. Which area of the brain might be malfunctioning and why?

Memory

Research has shown that jugglers, who need particularly attuned motor memory, and London cab drivers, who must memorize extensive street maps, each have a particular region of their brain that is enlarged.

3. Which region of the brain do you think is enlarged in the jugglers?

4. Which region of the brain do you think is enlarged in the London cab drivers?

Comparative Neuroanatomy

Comparing the brains of different animal species

Different animals depend on different types of behavior for their survival. Since many behaviors are produced by the brain, some differences in behavior are mirrored by differences in brain structures of various animals.

Human vs. Sheep Brain

Using the dissection guide and the brain models, draw a picture of a sheep brain and a human brain. The pictures don't have to be perfect, but add as much detail as you can. Drawing will help you look more closely and observe how the brains are similar and different.

The sheep brain has large, noticeable olfactory bulbs, whereas the olfactory bulbs of the human brain are relatively small and hard to find (see images on page 27).

1. Why do you think sheep might have larger olfactory bulbs?

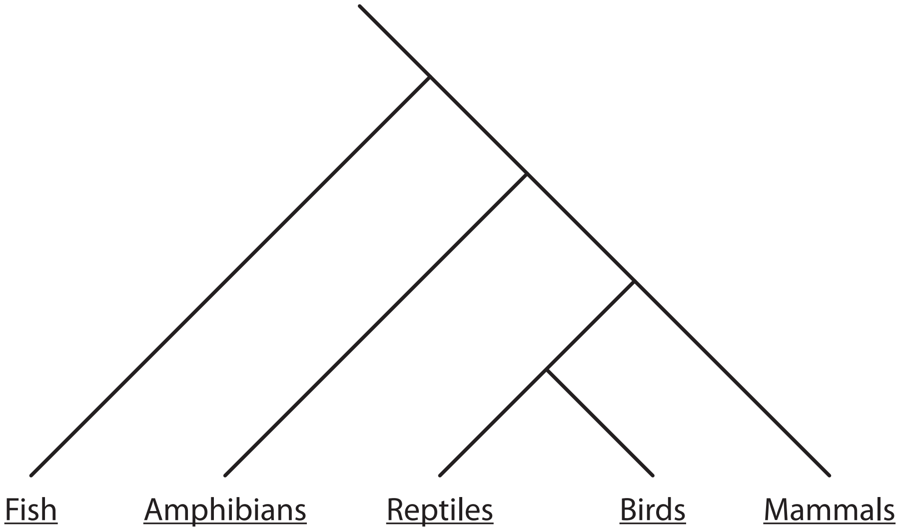
The outside of the brain has "wrinkles" made up of furrows or **sulci** and ridges or **gyri**. Sulci and gyri increase the total surface area of the brain, allowing more complicated brain processes to occur. The human brain is characterized by many sulci and gyri, but other species have fewer. The sheep brain, for example, has fewer than the human brain, and the rat and mouse brains are almost entirely smooth.

2. What behaviors do humans, but not sheep, perform that you think might be associated with more sulci and gyri?

3. What are some other differences you notice between the human and sheep brains?

HUMAN BRAIN: Draw or record observations here

SHEEP BRAIN: Draw or record observations here

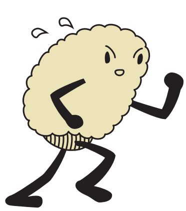


This evolutionary tree diagram is a representation of the most recent common ancestors (nodes) between different lineages (branches) of animals. Animal groups that have a more recent common ancestor are more closely related to each other than other groups. For example, birds and reptiles are more closely related to each other than either is related to mammals.

Fish, Amphibian, Reptile, and Bird Brains

The brains in this display are arranged in order of relatedness of these animals to each other over evolutionary time (see diagram above). Make a list, or draw pictures, of the differences and similarities you notice between these brains on page 33.

1. Do the brains of more or less related species look more similar or different to you? Explain why you think this might be.

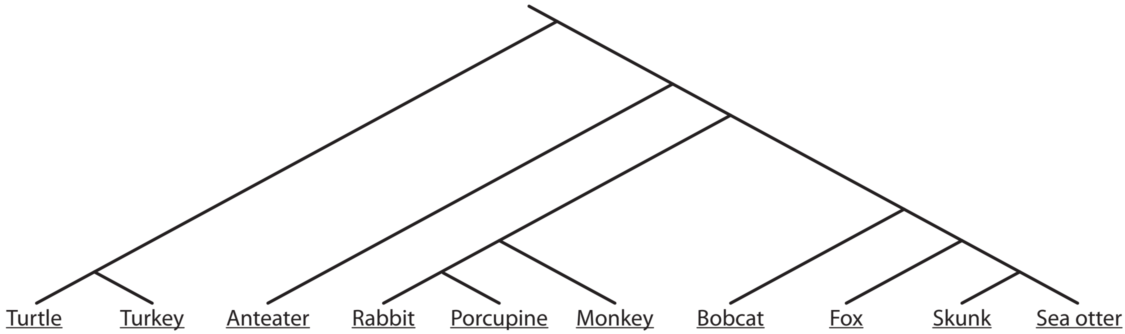


Fish brain

Amphibian brain

Reptile brain

Bird brain



This evolutionary tree diagram is a representation of the most recent common ancestors (nodes) between different lineages (branches) of the animal skulls we have today.

Animal Skulls

Choose two skulls and draw or write your observations in the boxes on page 35. Can you identify or label holes in the skull that allow the nervous system to connect to the brain (e.g. **brainstem**, **optic nerve**, **olfactory nerve**)?

1. How are the turtle and turkey skulls different from the rest? Why do you think this is the case?

2. Of the mammals, list an example of a **carnivore**, **herbivore**, and **omnivore** below and explain how you can tell.

Type	Example(s)	Evidence
Carnivore		
Herbivore		
Omnivore		

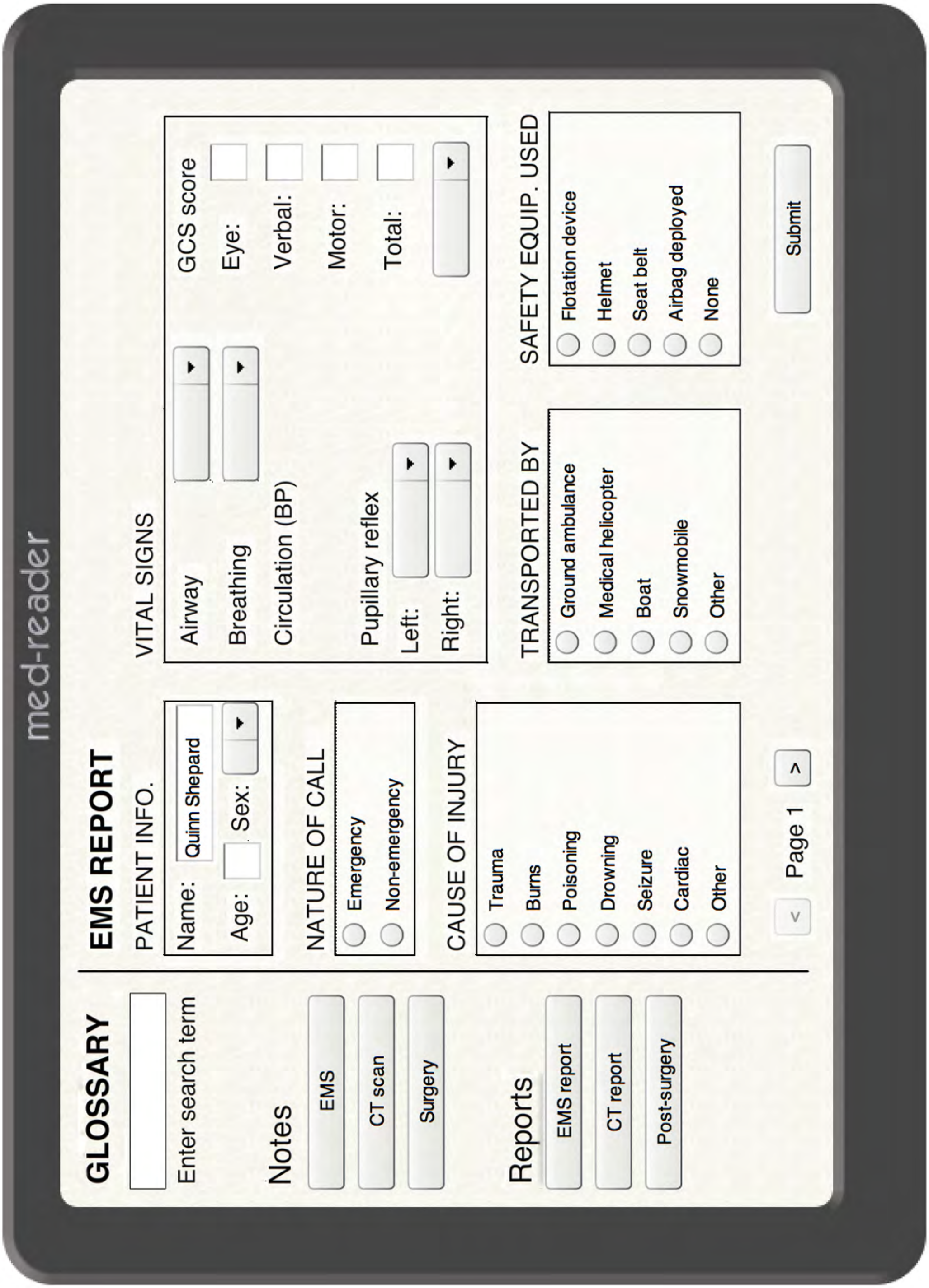
Drawing or observations of a skull that belongs to a ___________________________

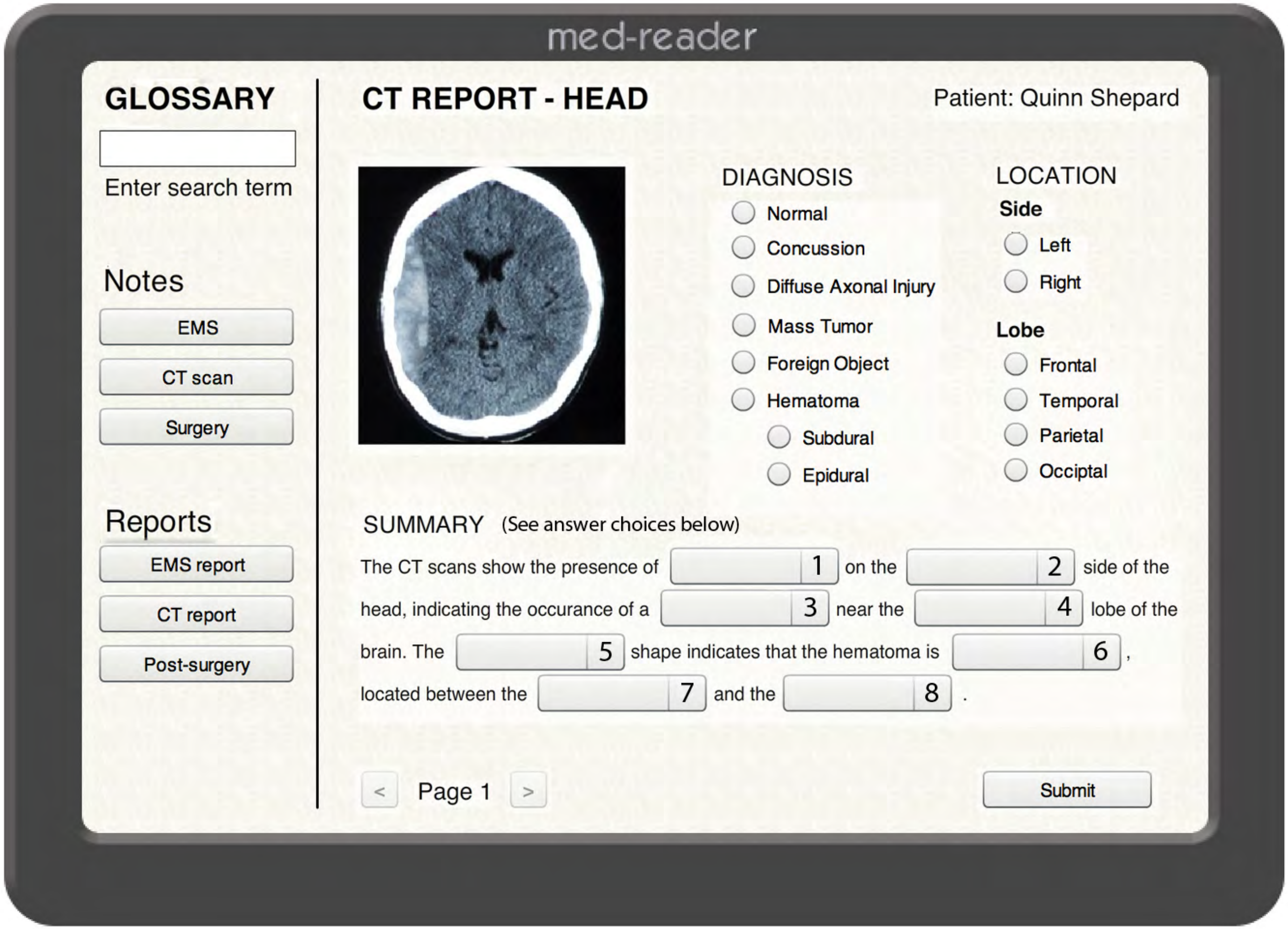
Drawing or observations of a skull that belongs to a ___________________________

The Golden Hour Game

Today you will play a computer game called The Golden Hour, which was designed by Project NEURON for students like you to learn about traumatic brain injury. You get to take on the role of an advanced medical student and make important decisions regarding your patient's treatment. Are you up to the challenge?

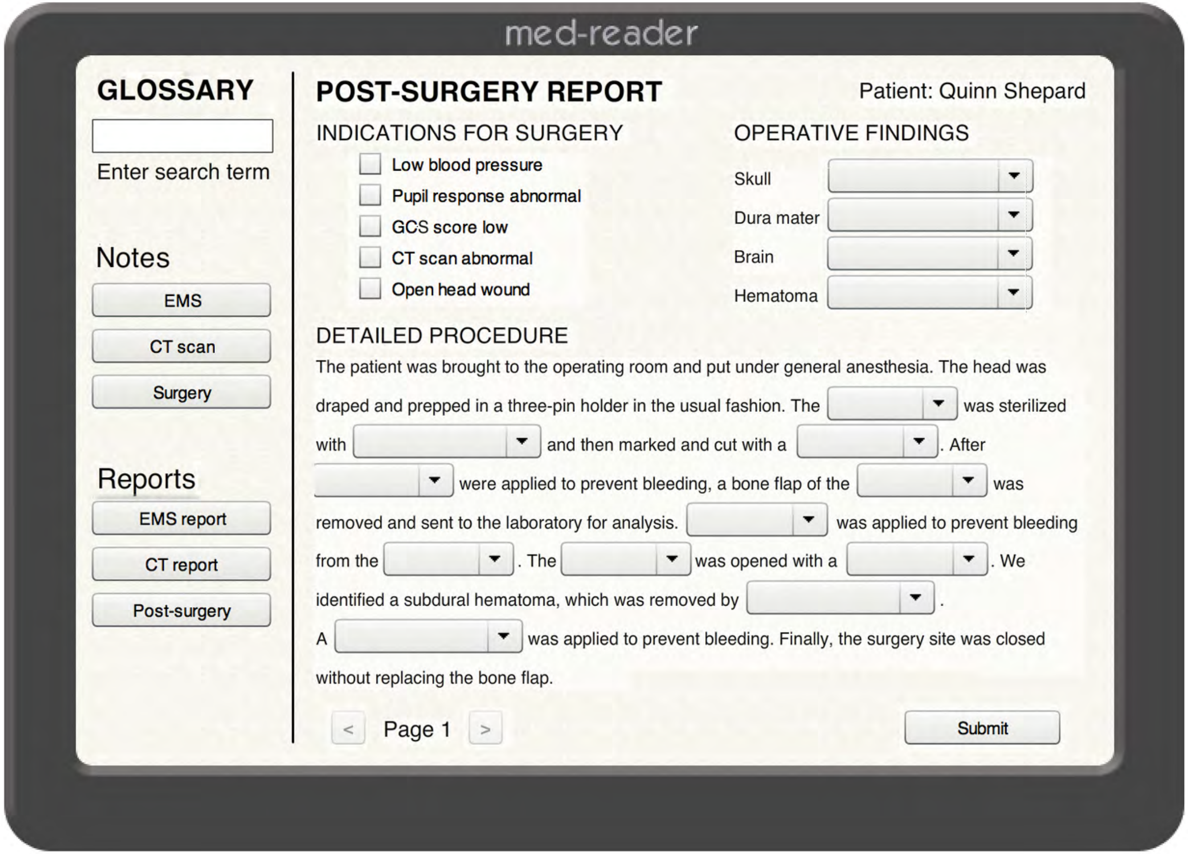
We hope you have fun playing this game today! If you want to play it again, you can find it and other cool science games online at http://neuron.illinois.edu!


med-reader
GLOSSARY
Enter search term
Notes
EMS
CT scan
Surgery
Reports
EMS report
CT report
Post-surgery
EMS REPORT
PATIENT INFO.
Name:
Quinn Shepard
Age:
Sex:
NATURE OF CALL
Emergency
Non-emergency
CAUSE OF INJURY
Trauma
Burns
Poisoning
Drowning
Seizure
Cardiac
Other
Page 1
VITAL SIGNS
Airway
Breathing
Circulation (BP)
Pupillary reflex
Left:
Right:
GCS score
Eye:
Verbal:
Motor:
Total:
TRANSPORTED BY
Ground ambulance
Medical helicopter
Boat
Snowmobile
Other
SAFETY EQUIP. USED
Flotation device
Helmet
Seat belt
Airbag deployed
None
Submit



SUMMARY — Write the correct multiple choice answer on the tablet image above.

#1	#2	#3	#4	#5	#6	#7	#8
A. bone fragments	A. right	A. contusion	A. frontal	A. crescent	A. epidural	A. brain	A. dura mater
B. blood	B. left	B. hematoma	B. parietal	B. convex	B. subdural	B. skull	B. skull
C. fluid		C. mass/tumor	C. occipital			C. skin	C. brainstem
D. tumor			D. temporal				



Operative Findings — Write the correct multiple choice answer on the tablet above.			
Skull	**Dura mater**	**Brain**	**Hematoma**
A. fractured	A. intact	A. appeared normal	A. near occipital lobe
B. appeared normal	B. damaged	B. appeared bruised	B. near temporal lobe
		C. lacerated	C. near frontal lobe

Detailed Procedure — Fill in the blanks on the tablet above with the correct multiple choice options.			
A. bone edge	D. dura scalpel	G. Raney clips	J. skull
B. bone wax	E. iodine and alcohol	H. scalp	K. surgical sponge
C. dura mater	F. irrigation and suction	I. scalpel	

Model Organisms

A **model organism** is a non-human species that is extensively studied to understand particular biological phenomena with the expectation that discoveries made in the organism model will provide insight into the workings of other organisms. This strategy is feasible because all living organisms originated from a common ancestor and share many functions and genetic material. Today you will observe planarians and honey bees as model organisms, but here are some others used in neuroscience research:

Sea slug (*Aplysia caligornica*)

The neurons of this West Coast invertebrate are unusually large—about 1 millimeter long at the most—and visible to the naked eye. The sea slug's brain cells are easily manipulated and there are only about 20,000 of them, compared to the 100 billion of a human brain. The neuroscientist Eric Kandel and his colleagues were awarded with a Nobel Prize in 2000 for work using sea slugs to study how memories are formed at the molecular level.

Fruit fly (*Drosophila melanogaster*)

You may think nothing about this 3-mm long, tiny insect you see around spoiled fruit or the trash, but this model organism has been used for over 100 years to study genetics. Fruit flies are convenient for this use because they have only four chromosomes, including sex chromosomes X and Y. However, these flies are so easy and cheap to breed, raise, and observe that they have been used for many different types of studies. Thomas Hunt Morgan is a famous scientist who received a Nobel Prize in 1933 for his work using fruit flies to study the role of chromosomes in genetics.

Planaria (*Schmidtea mediterranea*)

Planarians are invertebrate flatworms with an amazing ability to **regenerate**. If you cut off a piece of the planarian, an entire new flatworm can be generated! Because the creatures are also easily observable, researchers can observe their response to different types of stimuli (touch, light, and chemical stimuli in particular) and further investigate how their simple nervous system controls these behavioral responses. For these reasons, planarians can be used to study how stem cells regenerate tissue and specifically the genes that control stem cells. These advances can lead to discoveries in how human stem cells can be manipulated in **neurogenesis**, or the creation of new neurons, and used to treat patients with neurodegenerative disorders, such as Alzheimer's and Parkinson's disease, and spinal cord injuries.

Animal Testing

Non-human animals have helped scientists and doctors cure many diseases and save millions of human lives by developing vaccines, surgery and organ transplant techniques, and antibiotics. Today, there are strict US federal policies regarding the treatment of animals in research. Any scientist that receives federal funding must justify research involving animals and show that animals will not be "unnecessarily burdened." This means that the number of animals used in research is minimized, experiments are refined to reduce pain and distress, and computer or *in vitro* (intact or in a natural state) models are preferred.

Planarian Observations

Questions

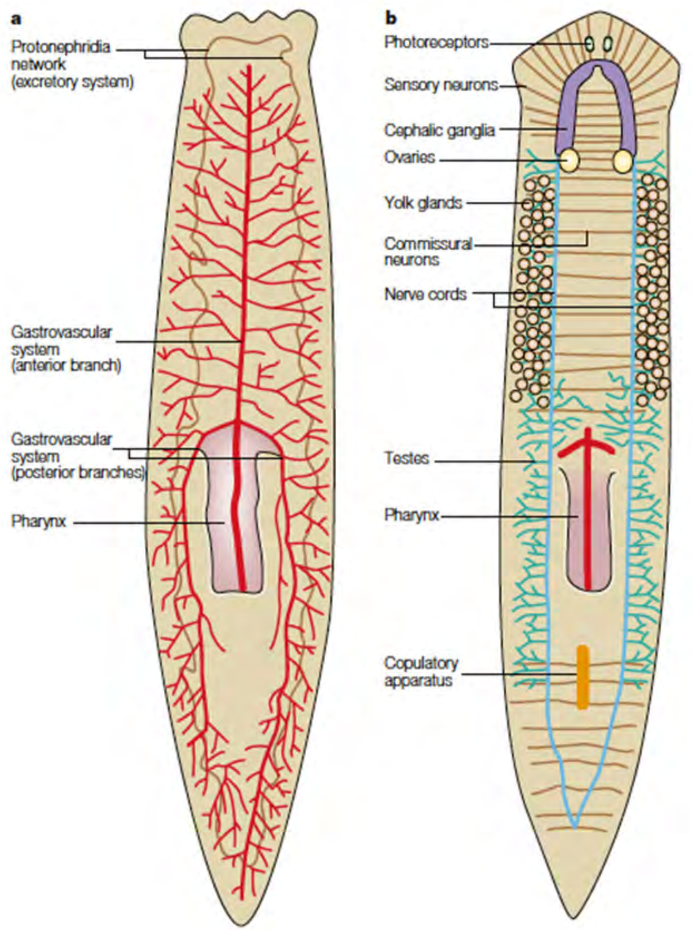
In the spaces below, record your observations. **These observations might be notes, drawings, or both.** Be as complete as possible.

1. Observe the planarians "normal" behavior (before you disturb or affect their environment) for at least five minutes. Draw a planarian in the space on page 43. Label the parts you can see.

2. What happens when you give planarians food? Place some food for the planarian in a petri dish and record your observations.

3. What happens when you shine a light on the planarian? In a darkened area, shine a bright, focused light onto a petri dish containing planarians. The light should not cover the whole dish, but should be a small "spotlight" in the dish.

4. What happens when you touch the planarian gently with a toothpick?



Newmark, P. A. and A. Sánchez Alvarado. 2002. Not your father's planarian: a classic model enters the era of functional genomics. Nature Reviews Genetics 3: 210-219.

Drawing of a planarian

Planarian Experiment

Before you begin

1. How do you think the caffeine will affect the planarians? What do you expect to see?

2. How do you think the sugar will affect the planarians? What do you expect to see?

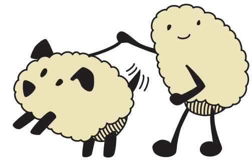
Procedure

3. In a group of three, each student will choose a different solution: caffeine, spring water (control).
4. Pour a small amount of your pre-made solution into three separate Petri dishes for each individual planarian.
5. Place the Petri dishes onto lined graph paper. To measure the activity of the planarians in the different solutions, you will count how many times the planarians cross a line. Decide in your groups how you will count a "line cross" as there may be different ideas on what that means!
6. Place one planarian into each of the three Petri dishes, staggering the time so that each planarian is placed in the new environment ~1.5 minutes apart from one another.
7. After ~4.5 minutes, begin the timer and count how many times the planarian crosses a line for one minute. Record the number of times they cross a line in your data table.
8. Repeat step 5 for the other two planarians.
9. Write or draw any observations about your planarians in your data table as well.
10. Remove the planarians from the different solutions and place into a fresh Spring water container.

	Caffeine solution			Sugar solution			Spring water (control)		
Planarian #	1	2	3	1	2	3	1	2	3
# Line crosses									
Average # line crossing for 3 planarians									
Observations									

Questions

1. Were your predictions correct? How do you explain what happened in your experiment?



Honey Bee Behavior

History of the Honey Bee

Honey bees have been important to humans for thousands of years. Ancient civilizations stole honey, a valuable, energy-rich food source, from wild honey bees. Egyptians, who may have been the first to domesticate honey bees, were keeping bees in man-made hives as early as 2400 BCE, in the same era when the pyramids were built. Our modern society depends on honey bees to produce honey and wax, and to pollinate many important crops, including citrus fruits, apples, nuts, melons, peppers and squash. In the last few hundred years, scientists have become fascinated with a different aspect of honey bees: their complex behavior.

Image from http://cyberbee.net/ © Zach Huang.

Photograph of a worker (left), drone (middle), and queen bee (right). The queen bee is marked with a dot so the beekeeper can easily identify her.

Introduction to the Honey Bee

Honey bees live together in colonies of as many as 80,000 bees. There are three types of bees in the colony: workers, a queen, and drones. Most of the females are **worker bees**, sister or half-sister bees that perform all of the necessary tasks to keep the colony running. These tasks include building new honey comb, caring for baby bees (**larvae**), fighting off predators, and collecting pollen and nectar for food. The mother of all the workers, the **queen bee**, is the only bee in the whole colony that can lay eggs that hatch into more female worker bees or new queens. That is her only task in the colony; worker bees do everything else for her, including grooming her, protecting her, and providing her with food. The queen bee is also mother to a small number of male bees, called drones. **Drones**, like the queen, do not help keep the colony running. They stay in the colony, being fed and cared for by the worker bees, until they are old enough to leave the colony and find young queens with which to mate.

Foraging and Dancing for Food

Another very important behavior for the colony is **foraging**. Older worker bees fly outside the colony to search for important resources—these are the bees you may have seen visiting flowers to collect nectar or pollen. Bees turn **nectar**, the sugary liquid produced by some flowers, into honey that they can eat all winter. Bees eat **pollen** as a food source that contains lots of fat and protein. Foraging bees also collect water to drink, or to cool off the hive when it is very hot outside.


Image from http://cyberbee.net/

The bee performing the waggle dance appears blurry because she is vibrating very fast. Note the other bees watching her.

Forager bees can "talk" with one another about where they have found nectar, pollen or other resources. They do this with something called the waggle dance. A foraging bee that wants to communicate the location of a good flower patch will do a repeating, vibrating dance on the honey comb. The direction she moves as she dances tells the bees watching her the direction of the flower patch, and the amount of time she dances indicates how far to fly. Because bees can communicate this type of information, they can work together to take advantage of good flower patches and quickly bring large amounts of nectar or pollen back to the hive.

Observing the Honey Bee

The first scientists to study honey bees and describe their behaviors started out by making careful observations of bees inside the hive. A good way to do this is with an observation hive, a little hive with honeycomb placed between two glass windows, like a large bee version of an ant farm. You can also learn a little bit more about how bees behave and communicate with each other, by watching them through the windows of the observation hive. We will show some videos of bee behavior in an observation hive.

Honey Bee Scavenger Hunt

Look for the following bees and behaviors in the videos and check them off if you can spot them:

- ☐ The queen bee
- ☐ Drone (male) bee
- ☐ Larvae (baby bees)
- ☐ Newly emerged worker bee
- ☐ Nurse bee
- ☐ Bee in retinue (following the queen)
- ☐ Forager bee

Next see if you can spot these behaviors. Check them off as you observe them:

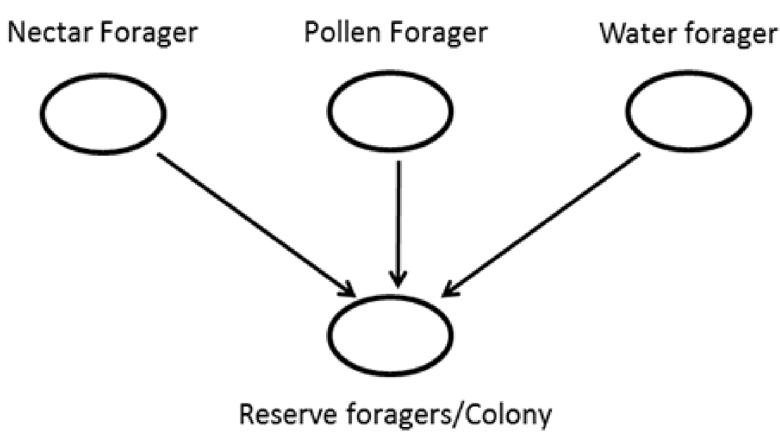
- ☐ **Antennation**: Bees "chatting" with each other by touching antennae, like two dogs sniffing each other after not seeing each other for a while.
- ☐ **Trophallaxis**: One bee regurgitating some nectar into another bee's mouth for her to eat.
- ☐ Attending the queen: A small group of bees will cluster around the queen bee, grooming her and feeding her if necessary.
- ☐ Laying eggs: The queen walks from cell to cell on the honey comb, looking inside each cell to make sure it is empty and then sticking her rear inside to lay an egg.
- ☐ Feeding: worker bees put their heads into cells with nectar or honey for a meal.
- ☐ Caring for young bees: "Nurse" bees put their heads into cells with white larvae to check on them and give them fresh food.
- ☐ **Emergence**: A new adult bee chews open the cap of her pupal cell and crawls out.

Bee & Neuron Networks

Each individual bee in a colony performs just one or a few tasks—this is called **specialization**. If one bee was by herself, she would not be able to survive, but because bees are working together in a large group, they can accomplish much more than if each bee were trying to switch back and forth between many different types of tasks. To work together efficiently, though, bees must communicate with each other about the state of the hive, and the environment outside of it.

In some ways, the organization of neurons in the brain is similar to that of bees in a colony. Neurons are not all the same; individual neurons have different specializations (different functions they perform) that all contribute to the function of the whole brain. Neurons use electrical impulses and neurotransmitters to relay messages. Bees use dance and chemicals to share information.

A group of different types of neurons that are all connected directly to each other within the brain is sometimes called a network. To understand how neurons or bees in a network work together, you will model a network of bees that can work together to collect all the food necessary for the colony. The goal of the colony is to find nectar, pollen, and water. Bees that detect each of these resources will send signals to a bee representing the rest of the colony, to keep track of when all three resources are available.



Directions

For each round, add a checkmark to show who was faster at detecting the presence of all three resources, the bee network or the solitary bee.

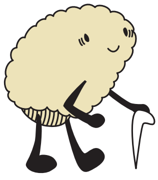
	Who completed the task first?	
Round	Bee network	Solitary bee
1		
2		
3		
4		
5		

Questions

1. Is the bee network better than the solitary bee at this task?

2. If there were plenty of resources available, explain why you think the bee network or the solitary bee would be better at collecting resources.

3. When resources are limited, which do you think would be better at the task and why?



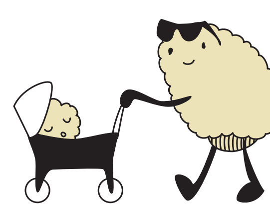
Bee Charades

For this game, you will be acting out what kind of bee you are and what task you are performing in the hive. Pick a bee card and think of a way to act out the behavior on the card. Watch your fellow "bees", and as you spot each type of bee listed below, write the name of the person representing it.

Name	Type of bee	Description
	Queen	Lays eggs, walks around slowly, asks for workers to feed her rather than feeding herself.
	Drone (male)	Doesn't do any work inside the hive; his only job is to go on mating flights with new queens.
	Nurse	Takes care of and feeds larvae (baby bees).
	Comb builder	Produces wax from a special gland, and uses it to construct new honey comb.
	Undertaker	Carries dead bees and other trash out of the colony to keep it clean.
	Guard	Monitors the colony entrance and protects it from intruders, such as strange bees or wasps.
	Forager	Searches outside the colony for nectar, pollen, or water to bring back.

Questions

1. What card did you get? How did you act out your role?



Native Americans in Neuroscience

Biographies adapted from: SACNAS, "Biography Project." http://bio.sacnas.org/biography.

Dr. Jerrel Yakel—Neuroscientist (2002)

My family comes from the La Jolla, Pauma, and Rincon reservations, and my tribes are the Luiseño and La Hoya. I grew up in an urban area of Ventura County in southern California called Camarillo. I am about 3/8 Native American, and what I know about Native American heritage came from my grandparents. The two things I remember most are going to pow wows when I was a kid, and going to the county fair to make and sell fry bread.

I did well in school, and I had a good life growing up. I remember that I was always interested in biology, especially marine biology. Later on I was fascinated by developmental biology—the idea that a single cell could become an entire organism fascinated me. It wasn't until college that I settled on neural biology, which is the study of how brain neurons (cells) work. I didn't realize that I was going to be a neurobiologist until near graduation.

In my final year in college at Oregon State University, there was a professor named Phillip Brownell who taught animal physiology. Professor Brownell was teaching a graduate level neurobiology class that entailed reading significant research papers and discussing them. Normally everything was taught from a text book, but reading actual research papers was great. There was also a serious lab course where we recorded responses from nerve cells. My first electrical recording from a neural cell, from a sea slug (who are close to us in many ways), got me hooked on neurobiology. From that day on, I knew that I wanted to go to graduate school and that I wanted to study the brain.

Today I am a principal investigator at the National Institute of Environmental Health Science. It is part of the US government and the US Department of Health and Human Services. In my lab, my research assistants and I want to see what possible effects the environment may have on nerve cells in the brain.

Dr. Joan Esnayra— Geneticist (2002)

I am a program officer at the National Academies of Science (NAS) in Washington D.C. Abraham Lincoln and Congress started the Academies in 1863 so that the nation would have an organization of scientists and scholars that could advise the country on matters of science and technology policy.

Although I was trained as a geneticist, I work in many different fields of science at NAS. I am very interested in not only science, but also how we apply science to our lives, and the impact that science has on our society and culture.

I have gone in many directions and faced many struggles, but my love of science and my desire for education have always been the forces that have kept me on track. Because I had a difficult home life where there was substance abuse, domestic violence and depression, school was the only place I felt safe and happy. I knew that getting an education was the way for me to improve my life.

When I was in college my grades went up and down like my emotions. I began to think I was stupid. Much later I found out this was a sign of bipolar disorder, a mental illness. When I attended graduate school feelings of insecurity grew, as my illness got worse. I even encountered discrimination about being Native American (Yaqui). Over time, as I began to participate in study groups and classes, I saw that I was just as intelligent as everyone else.

This newfound confidence helped me stand up to people that were discriminating against me for being a disabled Native American woman and for the first time I was able to truly believe that I am a strong person and that I deserve to be treated with respect. Major events like finishing my Ph.D., and working at NAS brought me to the end of one journey and the beginning of the next. Yet there is one thing I will remember every day of my life, and I hope you do too. You are a strong, intelligent person, and you always deserve to be treated with respect.

Answers to the Stroop Effect (page 17): yellow, orange, blue, yellow, red, green, blue, green, yellow, red, blue, orange, yellow, orange, red, blue, orange, green, yellow, red, blue

Glossary

additive light model (18): The process in which colors of light are added together to make white light. Also known as the RGB (red-blue-green) model.

antennation (49): Behavior in which two bees "talk" by touching antennae.

aqueous humor (23): This thick fluid fills the space behind the cornea and is constantly replenished.

axons (1): Long, thin branches of a neuron that send signals to other neurons.

blind spot (23): There are no light-sensitive cells on this part of the retina.

brainstem (34): A large bundle of nerves that connects nerves from the face and spinal cord to the brain.

carnivore (34): A type of animal that only eats other animals.

cell body (1): The central part of the neuron that contains the nucleus. It is also called the soma.

central nervous system (1): Consists of the brain and the spinal cord.

cerebellum: Located between the brainstem and the cerebrum, this part of the brain controls balance and muscle coordination.

cerebrum: The largest portion of the mammalian brain, characterized typically by sulci and gyri.

contusion (36): A "bruise" on the brain.

cornea (23): The only transparent part of the eye's exterior, allowing light to enter the lens.

coronal plane (24): Divides the brain from front to back, like slicing a loaf of bread.

dendrites (1): Branches from the cell body of a neuron that receive signals from other neurons.

drones (46): Male bees that do not help the hive functionally, and who eventually leave to mate with young queens.

dura mater (36): Part of the meninges, this is a thin, tough layer of tissue that surrounds the brain and protects it.

emergence (49): When a bee has transformed from a larva into its adult form and emerges from its pupal cell.

epidural (36): Literally "above the dura," it describes something that is between the dura mater and the skull.

foraging (47): A task performed by older worker bees who collect nectar and pollen.

frontal lobe (24): The lobe of the brain that is associated with some aspects of social behavior, emotion, and personality.

glia (1): These cells support and protect neurons and can regenerate. One type of glial cell wraps around neuronal axons to promote faster signaling.

gyri (30): The ridges on the surface of the brain that give it a wrinkly appearance. See also sulci.

hematoma (36): A pooling of blood within the body which typically occurs as the result of injury.

herbivore (34): A type of animal that only eats plants.

horizontal plane (24): Divides the top and the bottom of the brain.

hypothalamus (28): Part of the brain involved in processes such as regulating body temperature and circadian rhythms such as sleep cycles.

iris (23): This circular structure changes shape to control the amount of light entering the eye.

larvae (46): Baby bees that have not changed into their adult forms.

lens (23): This transparent sphere can change its shape to focus of light entering the eye.

meninges: The thin, protective layers of tissue that surround the brain. Includes the dura mater.

model organism (40): A non-human species that is extensively studied to understand particular biological phenomena

nectar (47): A sugary liquid produced by some plants to encourage animals like bees to spread pollen to other plants. Bees collect nectar to produce honey.

neurogenesis (42): The process by which new neurons are generated from neural stem cells.

neurons (1): The cells of the brain that communicate to one another.

neural plasticity (4): The ability of the brain to adapt to new tasks by changing brain cell structure or function.

occipital lobe (24): The lobe of the brain responsible primarily for vision.

olfactory bulbs (27): Structures in the brain that process olfactory (small) senses.

olfactory nerve (34): The nerve that sends signals from the nose to the olfactory bulb.

omnivore (34): A type of animal that eats both other animals and plants.

optic chiasm (27): An X-shaped structure in the brain where the two optic nerves from the eyes partially cross.

optic nerve (23): The primary connection between the eye and the brain.

parietal lobe (24): The lobe of the brain that helps integrate our senses into our perception of the world around us.

peripheral nervous system (1): Consisting mostly of nerves, this part of the nervous system connects the central nervous system to other parts of the body.

pollen (47): A powder produced by plants and used by bees as a food source of fat and protein.

pupil (23): This hole appears black and light passes through it into the eye.

queen bee (46): A type of bee that lays eggs. There is only one in a colony.

regeneration (42): The ability to recreate lost or damaged tissues, organs and limbs.

retina (23): Using rod and cone cells, this layer of the eye converts light into nerve impulses.

sagittal plane (24): Divides the brain from left to right.

sclera (23): This protective layer of connective tissue forms the outermost layer of the eye.

simultaneous contrast (20): An illusion in which the same color appears lighter when surrounded by dark colors and appears darker when surrounded by light colors.

specialization (50): When individuals in a network or group have different or "special" tasks, as with neurons or honey bees.

subdural (36): Literally "below the dura," it describes something that is between the dura mater and the brain.

subtractive light model (18): The process in which objects (like paint) absorb wavelengths, subtracting colors from the visible spectrum that we perceive.

sulci (30): The furrows on the surface of the brain that give it a wrinkly appearance. See also gyri.

tapetum (23): This colorful, shiny material reflects light back into the retina. It is not present in human eyes.

temporal lobe (24): The lobe of the brain associated with recognition of words and faces, categorizing words or pictures, and some memory processing.

thalamus (28): Part of the brain that integrates information and relays it to appropriate regions for processing.

trophallaxis (49): Behavior in which one bee feeds another by regurgitating (throwing up) food into the other's mouth.

vitreous humor (23): This gel-like substance helps maintain the round shape of the eye.

worker bees (46): Bees that perform all the necessary tasks to keep the colony functional, including building honey comb, caring for other bees, and collecting food.

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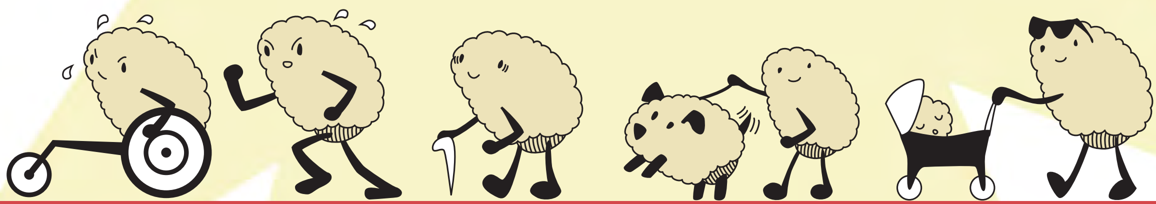

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