ELEMENTARY SCIENCE MADE EASY™

Activity-Based Curriculum That Meets Your Classroom Needs

Brain & Body Communication

DEVELOPED BY: SCIENCE DELIVERED!

Overview Sheet

NGSS: GRADE 4

DCI Standard 4-LSI-2

INTRODUCTION

This unit teaches students how humans and animals gather, process, and respond to information in the environment. This sounds a little complicated, but essentially the unit explores the interaction between the senses, the brain, and the body. It is aligned with the Next Generation Science Standards (NGSS). We align to Disciplinary Core Ideas (DCI), Crosscutting Concepts (CCC), and Scientific Practices.

This unit includes reading lessons with assessments and corresponding hands-on, but simple, science activities. It also includes a fun poem and an introductory demo that will amaze your students! For you, the teacher, we include science background, NGSS-alignment teacher keys, and suggested scripts to use at your discretion.

Ideally, this unit will supplement your regular science curriculum. This unit is a great place to begin for those just getting started with activity-based science.

Remember SOME is always better that NONE. If you are new to activity-based science and only have the time, energy, or bandwidth to do a piece of this unit, do that piece! Over time your knowledge base and skill-set will grow. We want to help and support you wherever you are in your science instruction journey.

MATERIALS INCLUDED IN THIS UNIT

BEFORE YOU BEGIN

2 NGSS Standard Alignment

4 Science Background for Teachers: Overview

6 Science Background for Teachers: The Nitty Gritty

11 Resources & Photo Credits

DAY 1 IN THE CLASSROOM

12 Perceiving is Believing - Demo Teacher's Background & Scripts

16 Perceiving is Believing - Printouts for Demo

DAY 2 IN THE CLASSROOM

20 Reading and Assessment & Teacher's Keys: Animal Eyes

DAY 3 IN THE CLASSROOM

28 Activity and Assessment & Teacher Key: The Eyes See

DAY 4 IN THE CLASSROOM

37 Reading Assessment and Teacher's Keys: Tasting With Feet?

41 Activity: The Nose Tastes?

DAY 5 IN THE CLASSROOM

43 Reading Assessment and Teacher's Keys: The Star Nosed Mole (Touch)

DAY 6 IN THE CLASSROOM

48 Activity, Data Collection Sheets and Assessment and Teacher's Keys: How Sensitive is Your Skin?

DAY 7 IN THE CLASSROOM

55 Poem and Teacher's Key: Brain and Body Communication, In Rhyme

59 End Assessment and Teacher's Key: Drawing Information Pathways

NGSS Standards Alignment

INTRODUCTION

The Elementary Science Made Easy unit on Brain & Body Communication is shaped around the NGSS DCI 4th grade standard:

> ***4-LS1-2. From Molecules to Organisms: Structures and Processes***
>
> *Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.*
> *[Clarification Statement: Emphasis is on systems of information transfer.]*
> *[Assessment Boundary: Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.]*

In other words, students should:

- Understand that animals/people receive information about the world through their senses.
- Understand that information collected through the senses is processed in the brain.
- Understand that animals/people will respond to information from the environment in different ways.
- Be able to create a model to demonstrate they understand the ideas in the three bullet points above.
- The assessment boundary suggests the lessons should focus on general principles and not details about, say, cellular mechanisms.

Q: What does the clarification statement mean by "information transfer"?

A: There is a TON of information in the environment around us at any moment. Our bodies must "transfer" this information from our senses, to our brains, and back to our bodies for us to act appropriately and survive in our environment. Please see the Science Background section for examples.

CROSSCUTTING CONCEPTS

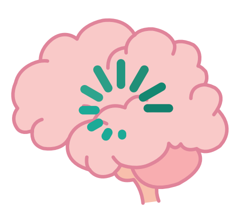
- Patterns
- Cause and Effect
- Scale, Proportion and Quantity
- Systems and System Models
- Energy and Matter
- Structure and Function
- Stability and Change

How to Talk About Crosscutting Concepts

Many crosscutting concepts can be explored in this unit. We focus here on "Patterns," "Cause and Effect," and "Systems and System Models".

Patterns

- A pattern is an occurance or trait that happens in a reoccurring or predictable way.
- Patterns are VERY important to our brain and its ability to process information. The brain is encountering new environments, objects and people every day and has to be able to respond appropriately to these new things.
- For example, everyone smiles, but everyone's smile looks just a little bit different. When we meet a stranger, the brain needs to be able to recognize that an upturned mouth is a smile, and that a smile is friendly.
- Brains of non-human animals also rely heavily on patterns, just like human brains do.
- For example, frogs have a varied diet and eat things like flies, mosquitos, moths and worms, often anything that crosses their path! Frogs need to be able to recognize certain patterns to identify their food. A frog wants to eat small insects or worms vs. trying to eat a big animal, like a snake (the frog might end up being eaten if it tries to eat a snake). Being able to identify small insects and worms is one example of pattern recognition that the brain can do.
- Our examples of patterns may seem incredibly obvious – of course humans can recognize smiles and of course frogs don't try to eat large snakes. But many patterns do indeed seem obvious to us!
- Part of science education is learning to think more deeply about "obvious" things.



NGSS Standards Alignment *continued*

Cause and Effect

• Cause and Effect is built into the standard in this unit. Meaning, an important piece of the standard is understanding the *effect* on behavior that certain sensory inputs have. (A sensory input is a sound, smell, flavor etc.)

• For example, a *cause* might be that a mosquito bites you, the *effect* is you move your arm to swat away the mosquito. Your brain was essential to this process.

• Another example might be that you see your brother (cause 1) and since you love your brother (cause 2), your brain decides it wants to hug your brother. Your brain then tells your limbs and body to move in such a way as to hug your brother (effect).

System and System Models

• "A system is an organized group of related objects or components" – National Science Teacher's Association.

• Your sensory organs, brain, and body can be considered related components in one system. Inputs come into your sensory organs, your sensory organs talk to your brain, and your brain talks to your muscles to create behavior.

When discussing CCC and this unit, note that sensory inputs can also create changes in a person's or animal's internal state. For example, a person might hear something that upsets them, and a flood of hormones and chemical changes in the brain might make them feel upset, but they might not have a specific behavior associated with the initial sensory input.

SCIENTIFIC PRACTICES

- Asking questions
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (science) and designing solutions (engineering)
- Engaging in argument from evidence
- Obtaining evaluating and communicating information

How to Integrate Scientific Practices

Many scientific practices can be explored in this unit. We focus here on "Constructing Explanations" and "Analyzing and Interpreting Data".

Constructing Explanations

When studying bodies, students have a wealth of information to work with! Have students "construct an explanation" for the "information pathway" that occurrs in their bodies to "explain" how their bodies work and interact with the environment. For example: Maybe a student was home in their room and smelled baking cookies. Their nose is the sense organ which collected smell information from the environment and sent that information to their brain. Their brain processed this information, "figured out" that the smell was something desirable, and then instructed their bodies to go downstairs, pick up, and eat a cookie.

For another example: ask the class to stand up. Students will stand up. Ask them to "construct an explanation" of the information pathway that occurred to make them stand up. The answers would look something like (a kid version of) this: "My ears heard sounds from the environment and sent the sound information to my brain. My brain figured out that the teachers asked us to "stand up". My brain sent signals to my body to move in a certain way to make me stand up."

Analyzing and Interpreting Data

The NGSS states (among other things) that in grades 3-5, teachers should be "... introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations."

In our Touch Sensitivity Activity, students collect and record data over multiple trials, satisfying this part of the standard. You may choose to take the activity further and graph the data.

In this unit, students also "analyze and interpret data to make sense of phenomena" in ways both quantitative and anecdotal.

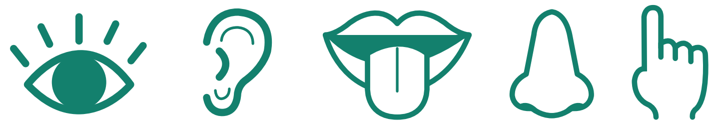
Science Background for Teachers

OVERVIEW: BRAIN & BODY CONNECTION

The current NGSS standard asks us to describe how animals:

1. Receive different types of information through their senses
2. Process the information in the brain and
3. Respond to that information in different ways.

Essentially, this standard is asking us to understand how our brain and body work together to allow us to navigate our environment. For example, how do our eyes, brain, and body work together to avoid getting stung by a bee? How does our nose work together with our brain and body to determine the source of the smell of



freshly baked cookies? How do our ears, brain and body work to respond car honking at us? These are the types of question we will answer in this unit.

How To Think About The Brain

It's mind-bending to think about, but it is important for students to understand that our brain (and nervous system) controls all of us and creates EVERYTHING we perceive. We say "we see with our eyes," but in a way, we see with our eyes AND our brain. Without a functioning brain, we wouldn't see a thing. (Indeed, brain damage can actually cause blindness, even if our eyes function perfectly.)

Processing Information

Students should understand that animals "... process information in their brain..." What does this mean?

One part of the brain's *processing* job is *identification.* For example, the eyes don't "know" what they are seeing, they simply send light information to the brain. It is the brain that *identifies* the objects that you see, the sounds you hear etc..

Another part of the brain's *processing* job is *comparing* and *integrating* information. You have inputs coming in from all your senses at once and the brain compares these inputs to see what matches up. (Do you smell a delicious buttery smell and see a cookie? You brain determines the cookies must be freshly made).

The brain also *processes* information by deciding what is important to pay *attention* to, and what can be ignored.

Perception

The brain is needed to perceive information from ALL our senses. When you stub your toe, you feel pain "in your toe." But, as mentioned above, one could argue that you are actually feeling that pain in your brain. Your toe might be injured but the PERCEPTION of pain comes from your brain. This is why injuries to the spinal cord can eliminate feeling in our legs or arms.

Because our brain creates all of our perceptions, in order to feel or perceive anything in any part of our body, that part of our body needs to be able to "talk" to our brain. (When the spinal cord is severed, the body can no longer communicate with the brain, so we can no longer feel or perceive our body below the injury.)

All About Senses

Science Background for Teachers: Overview *continued*

"Information Transfer"

The NGSS "clarification statement" for the 4-LS1-2 standard states "Emphasis is on systems of information transfer".

So what is information transfer? Information transfer refers to how information about the world gets transmitted to our brain. For example, the smell of a hot dog is "information" about our world – it tells us someone is cooking a hot dog nearby! How does this information get "transferred" to us so we can perceive and react to it?

First, tiny molecules from the hot dog float through the air and attach to receptors in our nose. Next, the receptors in our nose deliver the smell information to our brain through nerves. The brain then "identifies" the smell (as it is your brain, not your nose, that "knows" the smell is from a hot dog). Finally, the brain sends signals to your body to react to the smell. Maybe you look around to figure out who is grilling a hot dog, or maybe you move away from the smell because you don't like hot dogs!

Our Slice Of The World

Our sense organs (eyes, ears etc.) capture a slice of information about the world around us, but they don't capture ALL the information around us. What you experience and perceive is only a slice of the world. For example, if you damage your ears, you will no longer be able to perceive as much sound information as you could before the injury. For another example, humans cannot see UV light or radio waves; they also cannot hear sounds at certain high frequencies that dogs and other animals can hear. It's important to remember that our personal perceptions do not reflect the entirety of the world around us.

Important Vocabulary

Brain: An organ in your body that is the center of your nervous system. The brain collects information from the outside world, directs motor function (i.e. movement), and mediates thinking, planning, and reasoning, among other functions.

Nervous System: A term that refers to the brain, spinal cord, and nerves.

Neurons: Brain cells. (Although we do not discuss neurons in this unit, it's an important term to be aware of when teaching about the brain.)

Information Transfer: The process where information (sounds, sights, smells, "tastes", etc) travels from the environment to your sense organs (eyes, ears, etc.) and then to your brain.

Sensory Input: Information about the outside world that is transferred to your brain through the senses. Anything you see, hear, taste, smell, or feel counts as sensory input.

Sense Organ: Any body organ that captures information from your environment. Typically, these are your eyes, ears, nose, mouth/tongue, and skin.

Sensory Receptor: A small structure embedded in a sense organ that responds to information in the environment. To elaborate, your nose contains cartilage and muscle but neither of these items help you smell! It's the smell receptors inside your nostril that collect smell information from the environment.

Science Background for Teachers: The Nitty Gritty *continued*

BRAIN AND BODY COMMUNICATION: THE NITTY GRITTY

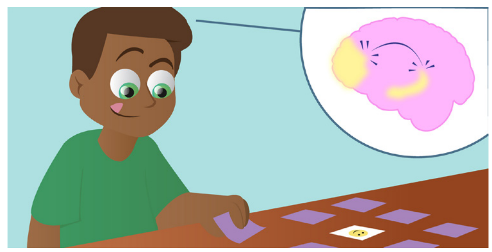
How To Think About This Material

In this and other units, we take items you may already know and frame them in a new way to get you and your students to think about a subject from a deeper perspective. In this unit, we use familiar facts to describe general principles about how your body and brain work together.

For example, you already know that a spinal cord injury can cause a loss of feeling and use of your arms and legs. You might not have considered that this means the brain is, in fact, in charge of perceiving all the information from your body. Meaning, if you injure your leg, it is, in a sense, your brain, not your leg, that is "feeling" the pain. Yes, the leg is the source of the pain signals, but without your brain you will not perceive, or feel, those pain signals. What is essential to understand is that our brain (and nervous

Please note that this section deals with the physical and physiological aspects of the brain and does not comment on spiritual or philosophical questions.

system) controls all of us and IS all of us (on a physical/physiological level). To reiterate, when you stub your toe, you feel pain "in your toe". But in a sense, you are really feeling that pain in your brain. Your toe might be injured but the PERCEPTION of pain is in your brain.



A boy playing a matching game must use his brain and body to take in, process, and react to information in his environment.

Some Examples of How Your Brain Processes Information

Earlier, we wrote that some of the ways your brain processes information is through *identifying* inputs, *integrating* information and determining what to pay *attention* to.

Identification
One example of identification would simply be recognizing that an object in front of you is a dog. When you see a dog, you immediately know what a dog is, because you've seen thousands of dogs before. This may seem so obvious as to be trivial, but identification can be quite difficult at times. For example, imagine you are in the wilderness trying to spot predators before they spot you! Humans are also less adept at identification by our other, non-visual senses. Was that small itch on your arm from a stray hair, or a bug? Was that growl from your dog or the neighbor's dog? The brain cannot always identify objects without visual confirmation.

Integration
Integration refers to your brain's ability to take information from multiple sources and make sense of it. For example, if you hear an angry dog bark and at the same time you see an angry dog running towards you, your brain will integrate, or put together, the visual and sound information and come to the understanding that the sound of the bark and image of the dog are related.

Attention
Your brain also processes information by choosing what to pay attention to and what to ignore. If the brain sees an angry dog but hears church bells, the brain will understand these two items are NOT related and likely decide to pay attention to the angry dog. If you have a mild blister on your toe while the angry dog is chasing you, you are likely going to ignore the weak pain signals coming from the blister. Indeed you might "not even feel" the pain.

Past Experiences
Much of the brain's response to inputs is going to depend on previous experiences. If you were bitten by a dog, and found experience traumatic, the sound of any dog bark may evoke fear. For another person, the sound of a dog's bark may evoke positive feelings.

The brain processes the information coming in to give you the best possible understanding of your environment.

The Brain and Information Transfer

"Information transfer" refers to the process of how information about our environment (sights, sounds etc.) is collected by parts of our body (eyes, ears, etc.) and transferred to our brain.

Science Background for Teachers: The Nitty Gritty *continued*

For example, if a person sees a bee, the person probably wants to avoid touching said bee! What is the transfer of information that occurs when we see and avoid a bee?

First, our eyes "collect" visual information about the bee. What is this visual information? Our eyes see a small, moving, oval object that has black and yellow stripes. This visual information is sent from our eyes to the brain.

Remember, our eyes are only sending information about light signals, or visual inputs, to the brain. Meaning, the eye is NOT telling the brain it sees "a bee", the eye is telling the brain it sees some yellow and black stripes moving around. Our eyes don't "know" anything about bees so they can't tell the brain they see a bee. Our eyes only "know" about things like shapes, luminance, and colors.

The eyes are saying to the brain: "Hey brain, there is small, moving, circular, kind of fuzzy object in front of us. It has black and yellow stripes. Does this mean anything you?"

The brain gets this information and says, "Hey, yea, hold on a small fraction of a second, let me search my networks-" [a very small fraction of a second goes by as the brain searches...] "Here it is, yes, I'm familiar with this fuzzy circular black and yellow object– it's a bee!"

The brain knows from prior experience that bees can sting. So once the brain identifies the bee, the brain creates a danger signal. Then the brain sends signals to the body telling the body to move in such a way as to avoid the bee.

Above, we described one instance where information was transferred from the outside world to the brain. We also described how the brain commands the body to respond to information in the environment.

A summary of the flow of information from the environment to the body for the above example is as follows:

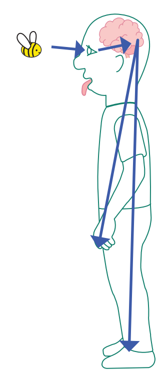
Step 1: Light signals* --> Eyes : Light reflects off a bee and into the eye.

Step 2: Eyes --> Brain : "There is a small moving, circular object that has black and yellow stripes."

Step 3: [Within brain] : "Small moving circular objects with black and yellow stripes are bees! Bees are dangerous, they can sting. We need to move our body to avoid hitting the bee."

Step 4: Brain --> Body : "Back away from the bee!"

*(*We say "light signals" here because everything we see is coming into our eyes via light signals.)*



THE SENSES

The way our brain receives information about the world is through the senses and sense organs. Here we go through the five basic senses and describe how the sense organs communicate with the brain.

Eyes

Eyes transfer visual information (which is light information) from the outside world to the brain. Everything we see is through light. Light reflects off objects and into our eyes, and this is how we see! (See 4th grade NGSS standard 4-PS4-2.)

For example, if you see a blue cup, you are seeing blue light that bounced off the cup and into your eyes. When you see green leaves, you are seeing green light that bounced off the leaves and into your eyes.

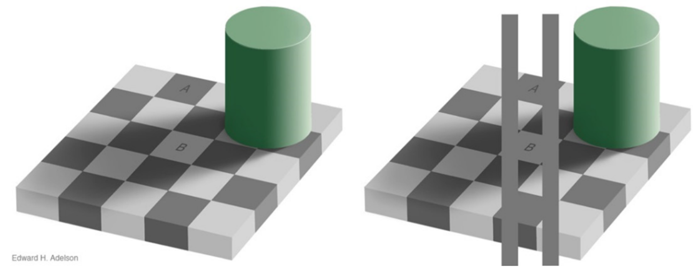
Light enters the eye through the pupil and travels to the back of the eye, called the retina. The retina is actually made out of layers of brain cells (neurons). One might even say the eye has its own mini-brain! The retina processes the light information a bit (for example, it compares colors and luminance) and then sends the light information to the brain.

The brain takes the light information and makes sense of it. Your eyes "know" if something is green, or round, or shiny, or bright but it is your BRAIN that knows if you are seeing a ball, or a plant, or the face of your child.

We tend to think of our visual perception as accurate, and it is, more or less. However, our perception is influenced by many factors and just because we perceive something to be a certain way, it does not necessarily mean we are correct. An extreme example of inaccurate perception would be visual hallucinations caused by drugs or mental illness.

Science Background for Teachers: The Nitty Gritty *continued*

People who understand HOW our eyes and brain process light can create optical illusions. Optical illusions make us perceive things that aren't quite accurate. In the checkerboard drawing [RIGHT], square A and square B are the same color. The second part of the image provides proof of this. However, our brain is telling us that A and B are completely different shades of gray. This is because the illusion has taken advantage of the way our brain sees light, shadow, and contrast to "trick" us into seeing something inaccurately. What we perceive is not a "pure" version of the world around us, but one that has been edited by our eyes and brain.



A & B are the same color

Hearing

Sounds are created by vibrations that enter our ears and push tiny little sensors called "hair cells" inside our ears. Hair cells have bitty little parts that stick up out of the cell and are physically pushed by sound! Hair cells are delicate and easily damaged, which is why many people suffer hearing loss over time.

Having two ears allows us to identify the location of sounds. (However, we are not nearly as good at this task as many animals.)

How do we identify the location of a sound? First, understand that sounds travel through the air as waves. This means that a sound coming from your right side will hit the right ear slightly before it hits the left ear. The sound will also be slightly louder in your right ear than in your left ear.

Each ear sends a signal to your brain about the timing and loudness of a sound. Based on the *differences* in these signals that each ear receives, the brain can calculate the source of the sound. In the case above, because the sound reached the right ear first and was louder in the right ear, the brain would determine that the sound came from the right side.

Taste and Smell

Taste and smell are categorized as separate senses but are quite similar.

Smell

For smell, tiny molecules of matter attach to receptors in your nose; the activated receptors talk to your brain so your brain can identify a smell.

Here we will answer an occasionally asked question: "Do you actually have poop in your nose when you smell poop?" The answer is ... yes and no. The poop smell is from gas molecules that came off of the poop, but it's not like you have chunks of poop or even poop bacteria in your nose.

Taste

Taste receptors are very similar to smell receptors. In some animals it's difficult to even say if a sense is a taste or smell. (Do butterflies "taste" or "smell" with their feet?)

Molecules from food attach to taste receptors, located in taste buds, which then send signals to the brain about the taste and flavor of the food.

Importantly, you taste with both your mouth AND nose. If you plug your nose, you will notice the flavor of food is dampened quite a bit! But how is it possible to taste with your nose if the food is in your mouth and not your nose?

The answer is that tiny molecules of the food you are eating get pushed up into your nose as you chew (remember the mouth and nose are connected). Those molecules bind to smell receptors, which then send flavor information to your brain. When you plug your nose, or have a cold, those smell receptors are blocked and the food will taste very bland.

Touch

There are many different types of touch. Please note that our lab activity focuses on pressure. But in addition to pressure, our skin also mediates pain and temperature.

You might wonder if pressure and pain are different degrees of the same sensation. For example, is pain simply "harder" pressure? The answer, neurologically, is no. Think about how anesthetics are able to block pain but leave pressure intact. In childbirth, epidurals remove the pain sensation, but leave women able to still feel pressure. This is because pain and pressure are mediated by different nerves. Likewise, different nerves also mediate temperature.

Science Background for Teachers: The Nitty Gritty *continued*

SCIENTIFIC PRACTICES

Repeated Trials

The touch activity in this unit has students performing *repeated trials.* A scientific trial can be defined as "one of a number of repetitions in an experiment." To help students define this word, we often tell them that each time they try the experiment, it's one trial (this is an imperfect definition but helps with understanding).

For example, if a scientist were testing how fast a frog can catch a bug, they might put the frog in a container with a video camera. Then they would introduce a fly and time how long it takes for the frog to eat it. The first fly-eating episode would be one trial. The scientist would then give the frog a second fly and again time how long it takes the frog to eat it. That would be the second trial. The scientist then might wait for the frog to get hungry again, and do more trials at a later time. (The scientists would also use multiple frogs, pay attention to the time of day, how hungry each frog is, etc.).
Scientists NEED to do repeated trials to ensure their data and experiments are accurate. With only a single trial in an experiment, any number of things could make the data incorrect.

In human drug studies, scientists are essentially doing repeated trials by testing the new drug on a large number of people. For example, if there is a new cancer drug, and you give it to only 5 people, it would be very difficult to say if the drug helped those people, because any observed changes in the illness could be due to chance (i.e. the change might have happened even without the drug). That is why drug studies need to include hundreds or thousands of people.

RELATING THE BRAIN, SENSES, AND BODY TO REAL LIFE

Hallucinations

A great way to get students to understand that the brain controls perception is through discussing hallucinations. Diseases like schizophrenia, or ingestion of certain drugs, can cause hallucinations. The hallucinations affect any sense, meaning people can see, hear, feel, smell, or taste things that aren't really there.

As always with sensitive topics, be wary that these issues will be very personal for some students. Some students will have parents with mental illness or who struggle with addiction, so make sure to talk about the issues with sensitivity and compassion!

Phantom Limb Syndrome

Phantom Limb Syndrome is a prime example of how our perception is controlled by our brain. People who lose limbs often report being able to still feel the limb. For example, one patient reports feeling like his toes are painfully crossed over each other, despite the fact that he no longer has these toes. (See Video in **Resources.**)

The exact basis for phantom limb is not understood, but it **is** understood that sensations persist in the missing limb because, ultimately, all your physical sensations are "felt," or perceived, in your brain. This man's foot no longer exists, but something was still (incorrectly) giving his brain pain and discomfort signals about his toes and foot. His perception of his own body is inaccurate.

Aids for our Senses

Sometimes our sense organs start to fail. In this case, for some senses, we use external aids to help the information transfer from the environment to our brain. For example, if our eyes cannot properly focus light, we wear glasses. If our ears become damaged, we can wear a hearing aid. There are even now glasses to improve some types of color blindness!

Unfortunately, there are no aids to correct for loss of smell, taste or touch sensation.

Color Blindness

A great way to understand how our perception shows us just a slice of the world is through understanding color blindness. (This is another area to teach with sensitivity.) "Color blind" people can see color, but they cannot see the full range of colors most people see. Most common is Red-Green color blindness where reds and greens look like shades of brown and yellow.

Some people can make it to adulthood before realizing they are color blind. After all, a person only knows their own perception, and might not realize they are missing out on a range of colors.

Here is an online quote, from a color blind internet user with the moniker "SpeedRacer05". This person could not distinguish red blood from motor oil, he thought peanut butter was red, and he "knows" (from being told) the top of the stoplight is red, but to him it looks yellow. (Edited for clarity.)
"We are taught that blood is red, everyone knows that. When I see blood coming out from an injury, [my] mind tells [me] it's red and

Science Background for Teachers: The Nitty Gritty *continued*

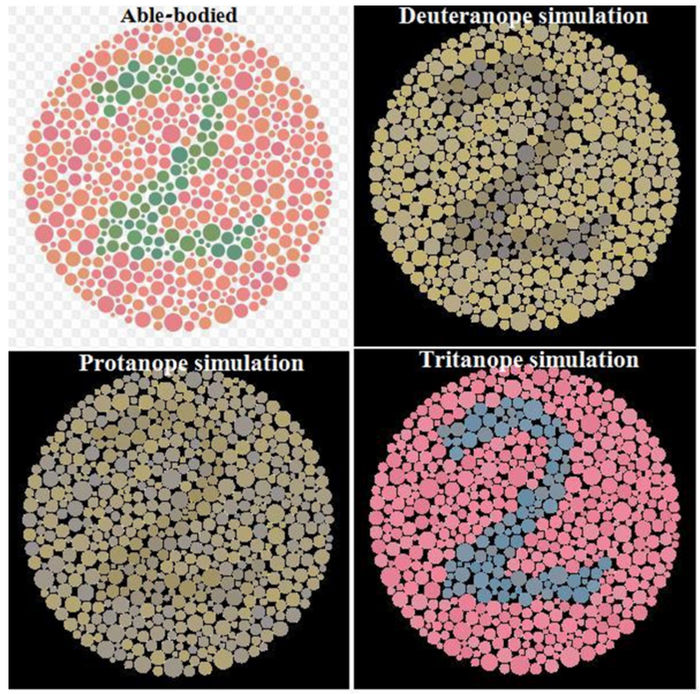
[I] see red. However I found out when working on my car, not too long ago, that to me blood actually looks just like motor oil. I had unknowingly cut my hand and I kept seeing oil on my hand and wiping it off. I couldn't figure out where the oil was coming from and it was starting to [anger me]. Finally in my rage, I scrubbed the oil on my hand really hard with the rag which opened up the cut pretty badly. It was one of those surreal moments in life, like when I found out peanut butter isn't red. It just shows how your mind can play tricks on you because of what you know to be true. Like knowing a red light is red, even when it looks yellow."

https://gizmodo.com/5983288/this-is-what-its-like-to-be-color-blind, . Comment posted 2/11/13. Retrieved 7/18/18

[RIGHT]
The top, left image shows the number "2" made with circles of slightly different shades of green, surrounded by circles of shades of pink and orange. People with color-blindness will not see these same colors, although in some types of color blindness they will be able to see the "2".

The top-right image shows what a person with moderate "red-green" color blindness would see when looking at the top left image. The circles now appear shades of a brownish-green. The bottom images show what people with more extreme (bottom-left) and less severe (bottom-right) color blindness would see.

Note: This image needs to be viewed in color.



Correcting Misconceptions

- Many people believe the little visible bumps on our tongue are taste receptors. These are actually not taste receptors but called papillae. The taste buds are in the grooves between the papillae.

- Many people were taught that the tongue is mapped into different sections and which respond best to salt, sweet, bitter, and sour flavors (and umami, the taste of fat). While different taste receptors respond to these different categories, these receptors are intermingled all over your tongue.

- Insects do NOT see hundreds of tiny images. Their eyes are made from multiple lenses, but their brain almost certainly combines these images into one, just like our brain combines the images from our two eyes into one internal picture. (See very awesome link in **Resources.**)

- The myth that we only use 10% of our brains is just that – a complete and total myth. It's unclear the exact origins for this myth but it is *totally, completely* and *utterly* wrong. We use all of our brain.

- It **is** true that we have some redundant aspects of our brain, so if you get "minor" brain damage, like a minor concussion, you often can continue to function with only relatively minor issues.

Science Background for Teachers *continued*

RESOURCES

Articles

Phantom Limb Syndrome (with video) https://www.livescience.com/33763-phantom-limb-sensation.html

Animal Perception; How do we see vs. how other animals see. This webpage shows that different animals perception of the world around us is different, even if we are looking at the same thing? What are our eyes equipped to see? GO HERE IT'S AMAZING! Natural History Museum, how do animals see the world? http://www.nhm.ac.uk/discover/how-do-other-animals-see-the-world.html

Article about starfish vision: https://news.nationalgeographic.com/news/2014/01/140107-starfish-sea-star-eyes-coral-reef-ocean-animal-science/

Why spiders have 8 eyes: https://www.livescience.com/24054-why-spiders-have-eight-eyes.html

How a proboscis works (text only): https://www.sciencedaily.com/releases/2009/11/091122161748.htm

Article on star-nose Moles, NYT 2005: https://www.nytimes.com/2005/02/08/science/underground-gourmet-mole-sets-a-speed-record.html

Pictures of anatomy, NYT 2005: https://archive.nytimes.com/www.nytimes.com/imagepages/2005/02/07/science/20050208_MOLE_GRAPHIC.html

Star nose mole smells in stereo

http://phenomena.nationalgeographic.com/2013/02/05/stereo-mole-noses/

Berkeley review of star-nose mole

http://berkeleysciencereview.com/learning-about-touch-sensation-from-an-unlikely-creature-the-star-nosed-mole/

Video

What it's like to be color blind: https://www.youtube.com/watch?v=FKSOe5NK_qQ

Video (normal speed) of mole eating a worm: https://www.youtube.com/watch?v=W-56nE20vrl

Go to this link to see the "underside" of the star-nose Mole at work. Researcher Ken Catania videoed the mole from underneath a glass sheet! https://as.vanderbilt.edu//catanialab/research/star-nosed-mole/

PHOTO CREDITS

NGSS Standard Alignment

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Checkerboard Illusion

Checkerboard Illusion (8, 13, 14, 16): copyright: 1995 Edward Adelson Retrieved from: http://persci.mit.edu/gallery/checkershadow in July 2018

Shadow Pictures, ground and leaf (14): by Olivia Mullins. Copyright Science Delivered, 2018. Attribution-NonCommercial-ShareAlike CC BY-NC-SA

Eye Placement in Predators and Prey

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The Eyes See

Student, EJ, doing various activities (29, 31, 32, 34, 35): By Allyson Murphy. Copyright Science Delivered, 2018. Attribution-NonCommercial-ShareAlike CC BY-NC-SA

Tasting with Feet?

Swallowtail Butterfly (37,39): By © 2010 Jee & Rani Nature Photography (License: CC BY-SA 4.0), CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=18406234

Small tortoiseshell butterfly (37, 39): By pamsai, 200K views, thank you - Nectar!, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=67303078

The Star-Nose Mole

Mole in dirt (43, 45): PLoS One. 2013; 8(1): e55001. Published online 2013 Jan 30. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0055001 © 2013 Gerhold et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License

How Sensitive is Your Skin?

Toothpicks (48): by Olivia Mullins. Copyright Science Delivered, 2018. Attribution-NonCommercial-ShareAlike CC BY-NC-SA

Forearm, fingertips, being pricked (48,50). By Allyson Murphy. Copyright Science Delivered, 2018. Attribution-NonCommercial-ShareAlike CC BY-NC-SA

Brain & Body Communication: In Rhyme

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Drawing Information Pathways

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TEACHER DEMONSTRATION

Perceiving is Believing: Checkerboard Ilusion

Note: There is no studnet worksheet with this activity.

LEVEL 2

OVERVIEW

The instructors will how the class this optical illusion, using a document camera (if available).

Why It's Easy for You

- This is a demo using two pieces of paper.
- Requires less than 5 minutes of prep (printing 2 pages and cutting 2 shapes out of a piece of paper).

OPTIONS

1. You may choose to print (and laminate) multiple copies of the checkerboard illusion and "blocking" page and hand them out to the students to explore in pairs or groups.

2. Pass out only the checkerboard illusion to students and have them cut out squares 'A' and 'B' to prove to themselves that these two squares are the exact same color.

3. Print and laminate 1+ set(s) of the illusion and blocking page and make it into a science station.

Conditions and Challenges

- The explanation of what is happening in this activity can be hard to grasp, but we provide helpful explanations and scripts! We recommend doing this activity.

LEARNING OBJECTIVES

Students understand:

1. That our brain is ultimately responsible for our perceptions in the world.

2. That our brain makes its perceptions of the world based on sensory input, but the brain can be tricked.

3. Although our brain can be tricked, most of the time our body and brain work together to give us an accurate view of the world around us.

Materials

- Printed Checkerboard illusion *(note, this will work in black and white as well as color printing)*
- Printed "Blocking Pheet"
- Document camera (if available)

INSTRUCTIONS

Prep for demo

1. Print the "Checkerboard Illusion" and "Blocking Page"

2. Cut the outlined shapes out of the "Blocking Page"

3. (Optional) Laminate pages (make sure to laminate after cutting out the shapes.)

4. Explore illusion so you are familiar with it before presenting it to the class.

Perceiving is Believing: Checkerboard Illusion *continued*

INSTRUCTIONS

Demonstration

1. Place the Checkerboard image under the document camera (or hold it in front of students if you don't have the camera).

2. Ask students if they would believe you if you told them that 'Square A' and 'Square B' were actually the same color.

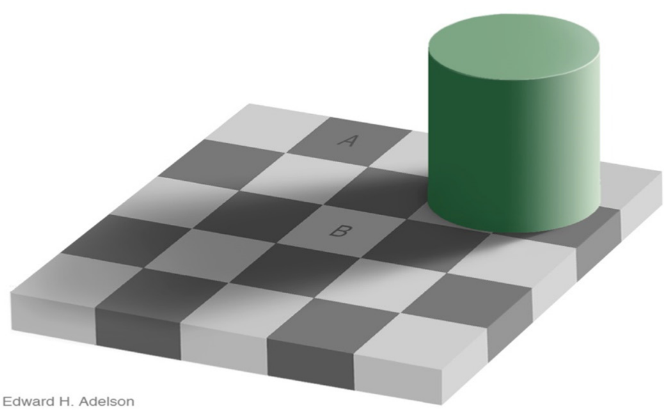
3. Allow students to answer and discuss.

4. Place the "Blocking Page" over the illusion so that only squares 'A' and 'B' are visible. They should look identical in color.

5. Allow students time to react to the illusion! Remove the blocking paper, put it back. Allow students time to take in what they are seeing.

6. Give students an explanation of what occurred. Use scripts below and information in the Teacher's Background as a guide.

Scripts: Mix and Match to Explain Demo



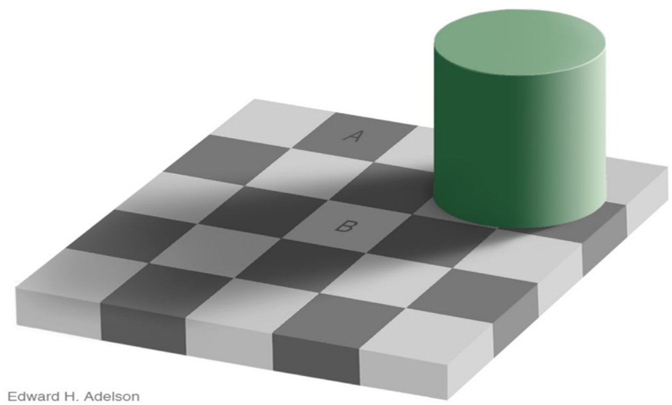
Edward H. Adelson

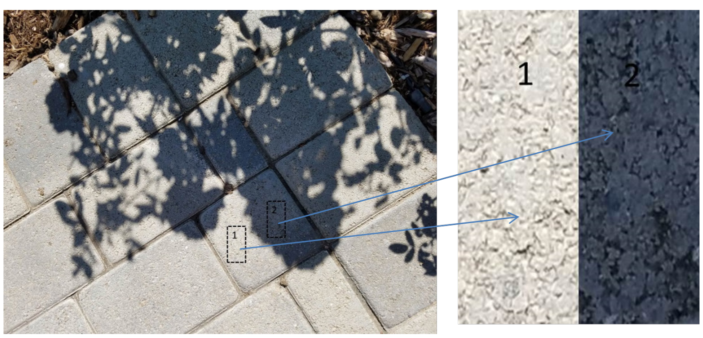
Script A

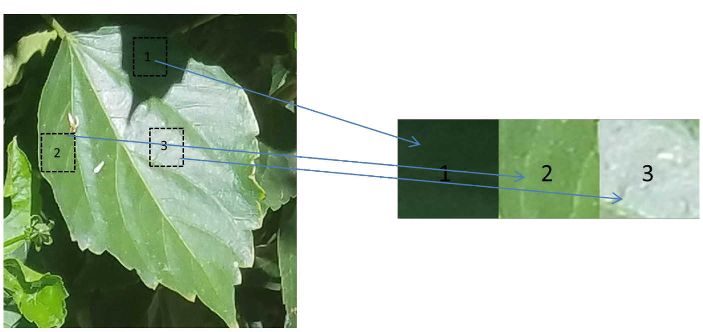
"When you look at this illusion, square 'A' and 'B' look like completely different colors. But I proved to you that 'A' and 'B' are actually the *exact* same color. How can this be? Well, what we are going to learn is that our brain actually controls our *perception* of the world. Our *perception* refers to everything we experience; it's what we see, hear, smell, taste, and feel! Usually our perception of the world is very accurate. For example, when we see a leaf in front of us, there is usually a leaf in front of us. If we feel something touch our arm, usually something has touched our arm!

But sometimes our perception is *not* accurate. Sometimes we perceive things that aren't really there, or that are different from what our brain is telling us. This checkerboard illusion is an example of a time when our perception does not match reality."

Perceiving is Believing: Checkerboard Illusion *continued*







Script B

"The Checkerboard Illusion tricks our brain in many ways. One is the use of shadow. In real life, objects can look very different depending on how much light is on them. Our brain needs to be able to understand that a shadow, say, on the ground does not mean that the actual color of the ground has suddenly changed!

Make a shadow on your desk using your hand. Do you think the table has a hand-shaped stain on it? No! Your brain knows it's a shadow and understands the color of the actual desk did not suddenly change.

In this optical illusion, we have a *picture* of a shadow, but not an *actual* shadow. However, the brain is treating the picture of the shadow like it would an actual, real-life shadow. This makes the brain change its perception of the colors in the drawing. It perceives that the lighter square in the "shadow" is the same color as the light squares at the edge of the checkerboard.

One final note is that the brain also uses contrast in its perceptions. Square 'A' is surrounded by lighter squares, which makes square 'A' look darker. Square 'B' is surrounded by darker squares, which makes square 'B' look lighter."

Note for script 'B': In the images on the left we show examples of how drastically shadows and changing light levels alter the color information that comes to our eyes. The first image shows a shadow of flowers on a stone walkway. The second image is of a leaf on a sunny day with part of the leaf covered in a shadow.

The part of the image in each box is blown up to allow you to more easily compare the different colors reflecting off the objects at any given time.

Our brains need to be able to compensate for all this different information coming in, and so our brains evolved to actually change the way we see in order to compensate for shadows and changing light levels.

(Note: the images on the left look best when viewed in color)

Perceiving is Believing: Checkerboard Illusion *continued*

Script C

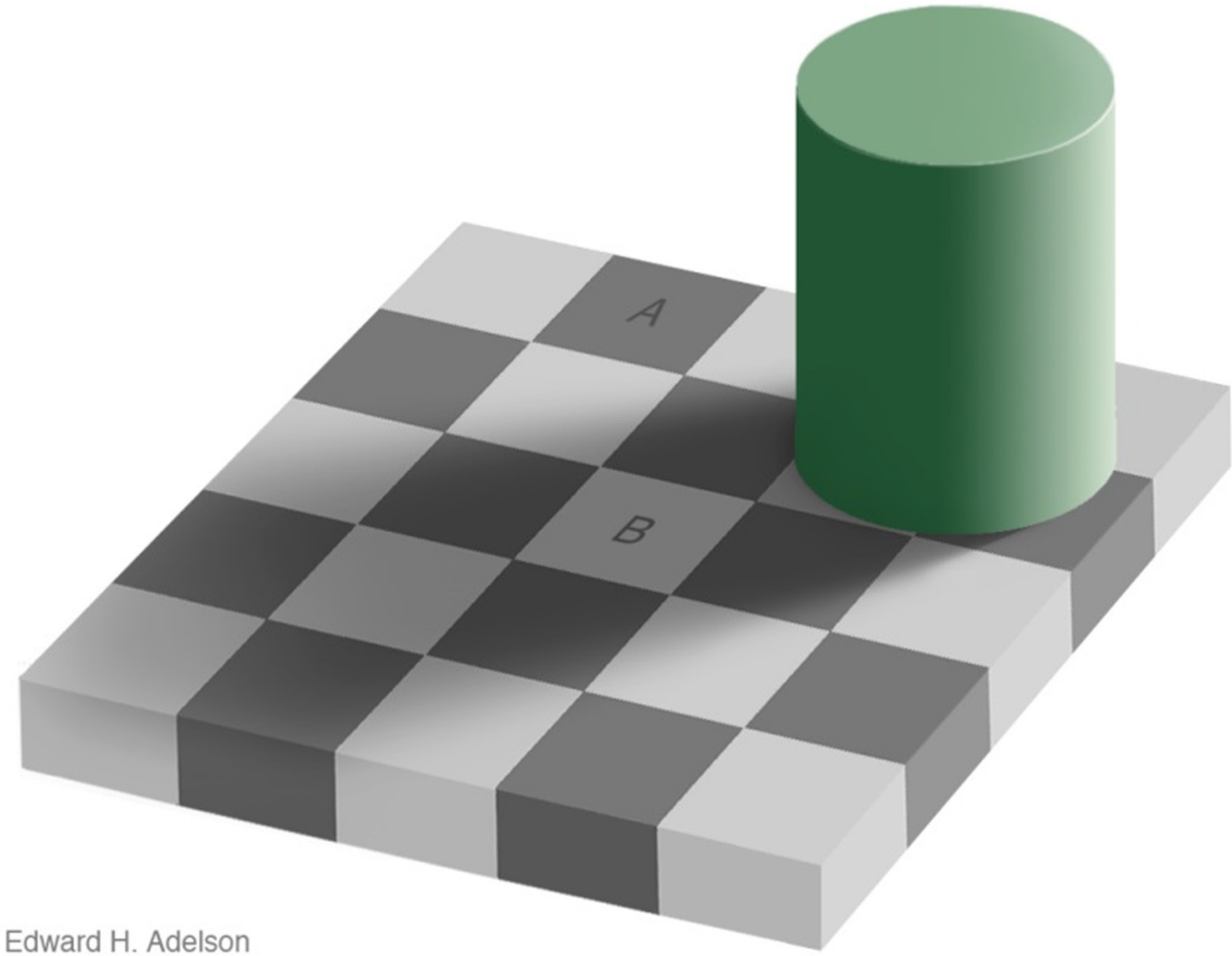
"In the case of the checkerboard illusion, someone created this illusion on purpose to trick your brain and your perception. This person (Edward Adelson, a brain scientist at MIT) understands how the eyes and brain work together to see the world. Because he understands this so well, he is able to create images that trick the brain.

Normally, in your every day life, your brain is very good at figuring out what is actually happening around you. For example, let's say you use your hand to make a hand shaped shadow on your desk. Your brain knows that is a shadow, your brain doesn't think you suddenly have a hand-shaped stain on your desk!"

Script D

"An extreme example of incorrect perception is an hallucination. Hallucinations can happen with brain disorders (like schizophrenia) or in response to taking drugs. People who hallucinate see, hear, taste, smell or feel things that aren't really there. The brain is perceiving things in the environment incorrectly."

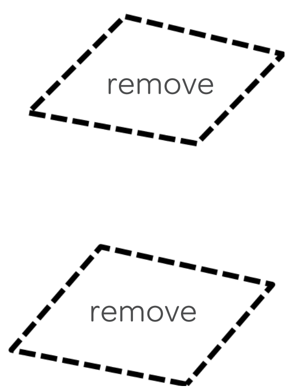
Perceiving is Believing: Checkerboard Illusion *continued*



Perceiving is Believing: Checkerboard Illusion *continued*

Cut along the dotted lines below to remove the two shapes.

Place this pages, with the shapes removed, over the checkerboard image to view squares ‘A’ and ‘B’



Student Handout

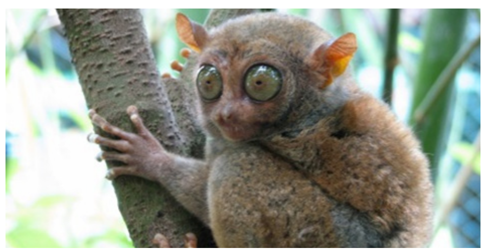
Eye Placement in Predators and Prey

The ability to *see* is important for the survival for millions of different types of animals. Animals come in all different shapes and sizes, but what about animal eyes? Are all animal eyes alike? Are all animal eyes the same shape or color? Are they all in the same place on the body? Take a look at the pictures on this page and you'll see that animal eyes can come in many different shapes, sizes, and numbers!

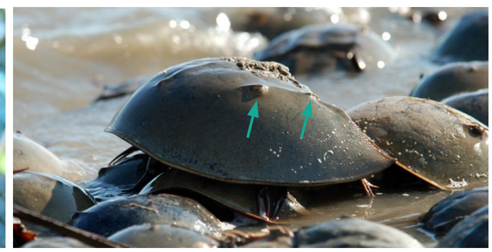
Some animals have eyes that may seem strange to us. Many spiders, like the jumping spider, have eight eyes that go around the front and side of their head. The number and placement of these spiders' eyes helps them see all around their body and detect moving creatures who might be trying to eat them!

Animals called tarsiers have huge eyes that help these nocturnal animals see at night. Horseshoe crabs have multiple eyes on their shells! **Can you think of another animal with interesting eyes?**

Can you find all 8 of the spider's eyes?



Tarsiers have large eyes to help them see at night.



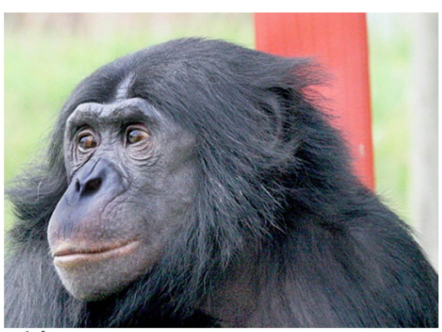
Horseshoe crabs have eyes on their shells.

If you think deeply about the variety of eyes across the animal kingdom, you can start to find certain patterns. For example, most larger animals, like fish and mammals, have only two eyes.

Humans have two eyes which sit in the front of our face, as do chimpanzees, lions, and owls. Can you think of any other animals with eyes at the front of their face?

Animals With Eyes At The Front Of Their Face

Lion



Chimpanzee

Owl

Human

Wolf

Some animals, like deer, zebras, rabbits and many types of fish, have eyes that are placed toward the side of their heads.

Take a break from reading and indicate whether the animals on your worksheet are predator or prey and where their eyes are located. Do you notice any patterns? Do you have any explanations for the patterns you noticed?

Eye Placement In Predators and Prey *continued*

You might have noticed that predator animals tend to have eyes in the front of their face, while prey animals have eyes at the side of their heads. Take a moment to consider why this might be.

We see this pattern of eye placement because forward facing eyes give an animal strong 3D vision (the fancy word for 3D vision is *binocular* vision). Animals that hunt need strong 3D vision to accurately attack prey. Animals that are hunted, in contrast, need to be able to see all around them to best spot predators coming to attack. Having eyes on the side of their head gives prey animals “panoramic” vision. Imagine how much more you could see at once if you had eyes on each side of your head!

Animals With Eyes On The Side Of Their Heads

Zebra

Deer

Rabbit

Clownfish

Some animals that are predators **and** prey have come up with a unique solution to the problem of eye placement; they are able to move their eyes in an extreme way! Animals like chameleons and cuttlefish can move their eyes around so they have great 3D vision when hunting, but panoramic vision at all other times.

It’s important to remember that even when we find robust patterns, the animal world is vast and there will always be animals that don’t fit neatly into any pattern. For example, underwater predators like sharks often have eyes on the side of their head. Insects, which are generally prey, but can be predators too, have a wide variety of eye placements. Crocodiles are predators but have eyes that stick up on top of the head and face to the side. This allows them to hide most of their body in water while looking for prey.

The eyes send visual information to the brain. The brain then generates the image that we perceive. Without our brain, we wouldn’t see anything! You can actually become blind from damage to certain areas of the brain, even if your eyes are still working perfectly.

Answer the questions on your worksheet and then YOU can do a fun activity to discover how your two eyes work together to make images and how important two eyes are for 3D vision.

NAME ______________________ DATE ____________

Student Handout

Eye Placement in Predators & Prey: Finding Patterns

Let's look for patterns. Work with a partner to talk about the animals mentioned in your reading. Determine whether each animal is a predator or prey animal (or both). If the animal hunts, it's a predator, if it's hunted, it's prey. Circle whether each animal has eyes on the front or side of its head.

CIRCLE THE RIGHT ANSWERS:

Predator or Prey?

Lion:	Predator	Prey
Chimpanzee:	Predator	Prey
Owl:	Predator	Prey
Human:	Predator	Prey
Wolf:	Predator	Prey
Zebra:	Predator	Prey
Deer:	Predator	Prey
Rabbit:	Predator	Prey
Clownfish:	Predator	Prey

Eyes are toward the:

Lion:	Front	Side
Chimpanzee:	Front	Side
Owl:	Front	Side
Human:	Front	Side
Wolf:	Front	Side
Zebra:	Front	Side
Deer:	Front	Side
Rabbit:	Front	Side
Clownfish:	Front	Side

NAME ______________________ DATE ____________

Student Handout

Eye Placement in Predators & Prey: Companion Worksheet

ASSESSMENT

1. Why does it help a prey animal to have eyes on the side of its head?

2. Why does it help a predator to have forward-facing eyes?

3. Will every animal on Earth follow the pattern of eye placement discussed in your reading? Why or why not?

Eye Placement in Predators and Prey
TEACHER KEY

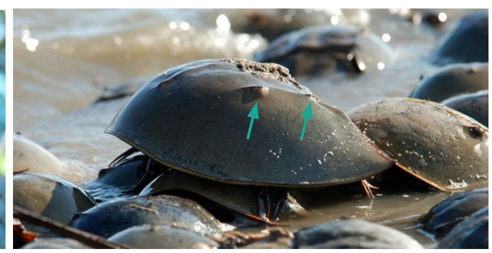
The ability to *see* is important for the survival for millions of different types of animals. Animals come in all different shapes and sizes, but what about animal eyes? Are all animal eyes alike? Are all animal eyes the same shape or color? Are they all in the same place on the body? Take a look at the pictures on this page and you'll see that animal eyes can come in many different shapes, sizes, and numbers!

Some animals have eyes that may seem strange to us. Many spiders, like the jumping spider, have eight eyes that go around the front and side of their head. The number and placement of these spiders' eyes helps them see all around their body and detect moving creatures who might be trying to eat them!

Animals called tarsiers have huge eyes that help these nocturnal animals see at night. Horseshoe crabs have multiple eyes on their shells! **Can you think of another animal with interesting eyes?**

Can you find all 8 of the spider's eyes?

Tarsiers have large eyes to help them see at night.



Horseshoe crabs have eyes on their shells.

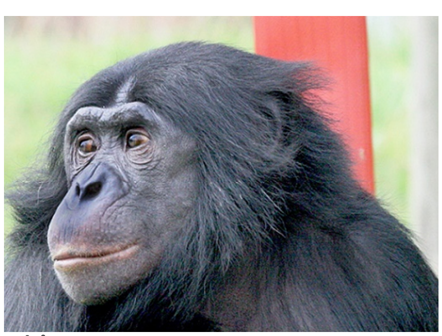
If you think deeply about the variety of eyes across the animal kingdom, you can find certain patterns. For example, most larger animals, like fish and mammals, have only two eyes. *"Patterns" are a crosscutting concept.*

Humans have two eyes which sit in the front of our face, as do chimpanzees, lions, and owls. Can you think of any other animals with eyes at the front of their face?

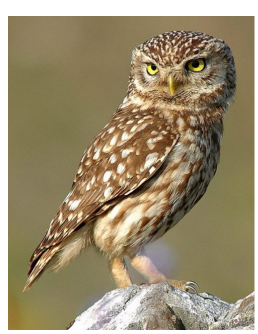
Other animals with eyes toward the front of their face include nearly all primates (monkeys, apes, humans) and big and small cats (tigers, lions, jaguars).

Animals With Eyes At The Front Of Their Face

Lion



Chimpanzee



Owl

Human

Wolf

Eye Placement In Predators and Prey: Teacher Key *continued*

Some animals, like deer, zebras, rabbits and many types of fish, have eyes that are placed toward the side of their heads.

Other animals with eyes on or toward the side of the head are squirrels, rodents (mice, rats, etc), antelope, and more.

Take a break from reading and idicate whether the animals on your worksheet are predator or prey and where their eyes are located. Do you notice any patterns? Do you have any explanations for the patterns you noticed?

We see this pattern of eye placement because forward facing eyes give an animal strong 3D vision (the fancy word for 3D vision is *binocular* vision). Animals that hunt need strong 3D vision to accurately attack prey. Animals that are hunted, in contrast, need to be able to see all around them to best spot predators coming to attack. Having eyes on the side of their head gives prey animals "panoramic" vision. Imagine how much more you could see at once if you had eyes on each side of your head!

3D vision helps the predator know exactly where its prey is. If the predator has poor 3D vision and misjudges distance, it may miss when trying to get its prey, giving the prey time to escape.
Animals with eyes on the side of their heads generally still have some 3D vision, it's just not as robust.

Animals With Eyes On The Side Of Their Heads

Zebra

Deer

Rabbit

Clownfish

Some animals that are predators **and** prey have come up with a unique solution to the problem of eye placement; they are able to move their eyes in an extreme way! Animals like chameleons and cuttlefish can move their eyes around so they have great 3D vision when hunting, but panoramic vision at all other times.

It's important to remember that even when we find robust patterns, the animal world is vast and there will always be animals that don't fit neatly into any pattern. For example, underwater predators like sharks often have eyes on the side of their head. Insects, which are generally prey, but can be predators too, have a wide variety of eye placements.

The eyes send visual information to the brain. The brain then generates the image that we perceive. Without our brain, we wouldn't see anything! You can actually become blind from damage to certain areas of the brain, even if your eyes are still working perfectly.

Eye Placement In Predators and Prey: Teacher Key *continued*

Crocodiles are predators but have eyes that stick up on top of the head and face to the side. This allows them to hide most of their body in water while looking for prey.

Answer the questions on your worksheet and then YOU can do a fun activity to discover how your two eyes work together to make images and how important two eyes are for 3D vision.

Eye Placement in Predators & Prey: Companion Worksheet

Let's look for patterns. Work with a partner to talk about the animals mentioned in your reading. Determine whether each animal is a predator or prey animal (or both). If the animal hunts, it's a predator, if it's hunted, it's prey. Circle whether each animal has eyes on the front or side of its head.

CIRCLE THE RIGHT ANSWERS:

			Eyes are toward the:	
Lion:	**Predator**	Prey	**Front**	Side
Chimpanzee:	**Predator**	Prey	**Front**	Side
Owl:	**Predator**	Prey	**Front**	Side
Human:	**Predator**	Prey	**Front**	Side
Wolf:	Predator	**Prey**	Front	**Side**
Zebra:	Predator	**Prey**	Front	**Side**
Deer:	Predator	**Prey**	Front	**Side**
Rabbit:	Predator	**Prey**	Front	**Side**
Clownfish:	Predator	**Prey**	Front	**Side**

ASSESSMENT

1. Why does it help a prey animal to have eyes on the side of its head?

Eyes at the side of an animal's head give it "panoramic" vision that allows it to see a large percentage of the landscape at once. This helps the animals scan for and detect prey.

2. Why does it help a predator to have forward facing eyes?

Having eyes in the front of the head give predators strong 3D vision. This gives them a better chance to successfully attack their prey. (If the predator did not have good 3D vision it might misjudge the distance when attacking and strike the wrong spot, giving the prey a chance to escape.)

3. Will every animal on Earth follow the "pattern" of eye placement discussed in your reading? Why or why not?

Every animal on Earth will not follow the pattern of eye placement discussed in the story. This is because there is a huge variety of animals which have a huge variety of adaptive traits suited for their particular environment or ecological niche.

Student Activity

The Eyes See

OVERVIEW

This sheet contains three simple activities that help students understand how their eyes and brain work together to give them vision.

LEVEL 2

Why It's Easy for You

- Two of three activities use only the students' body and scrap paper.
- Activities are simple and not messy.
- Each activity can be done in a short period of time at student desks.
- Worksheets are ready-to-print.

LEARNING OBJECTIVES

Students understand:

1. That each of their two eyes send a separate message to their brain.

2. That their brain combines the images from each eye to create a single image.

3. That combining two images from two eyes is what creates 3D vision (binocular vision).

4. That our visual perception of the world is based on the information processed in the brain.

5. That our visual perception usually represents the world accurately, but not always!

Conditions and Challenges

- You need to find ~30 pennies and ~15 items that can blindfold one eye. If it's hard to get enough for the whole class, consider making this activity a station.
- Three activities might need to be broken up over multiple days.

Materials (for all three activties)

- Piece of 8.5x11 scrap paper (one per student).
- Two pennies (one pair of students will share two pennies).
- Something to block one eye (one per pair of students) – this can be a "pirate"-type eye patch, a bandana, a shirt wrapped around one eye, or another creative solution. Or the students can simply close one eye.

NAME DATE

Student Handout

The Eyes See

Do you see the world like a split TV screen? No! You have two eyes, but you only see ONE image. How do your eyes and brain work together to create a single image? Let's explore.

ACTIVITY 1: JUMPING FINGER

Materials: None (only your own body)

EJ winks back and forth with his finger in front of one eye

In this simple activity you will explore the images created by each of your two eyes.

Directions:

1. Hold a finger a few inches in front of one eye.

2. Stare straight ahead.

3. Close one eye.

4. Continue to stare straight ahead.

5. Open your closed eye and close your open eye. What happens to your finger?

6. Continue to wink back and forth. What happens to your finger as you wink each eye? Discuss with your partner.

All About Senses Worksheet

NAME ______________________ DATE __________

Student Handout

QUESTIONS FROM THE ACTIVITY

1. Describe what happened when you "winked' your eyes back and forth.

2. Does each eye see the exact same image? Or are they slightly different?

3. If each eye sends a separate image to the brain, how is it that you are able to see only ONE picture? How come you don't see two images like a split screen TV? Talk about this as a class.

NAME ______________________ DATE ____________

Student Handout

ACTIVITY 2: HOLE IN HAND

Materials:

• One sheet of paper per student

Directions:

1. Roll your piece of paper up into a tube, like in the picture. The tube should be about an inch wide.

2. Place the tube in your right hand.

3. Put the tube in front of your right eye.

4. Hold up your left hand with your palm facing away from you.

5. Place your left hand next to the tube, about six inches in front of your right eye.

6. Look straight a head, with both eyes open.

7. Do you see a hole in your hand?

Do you think EJ sees a hole in his hand?!

QUESTIONS FROM ACTIVITY

1. Why did it look like your hand had a hole in it?

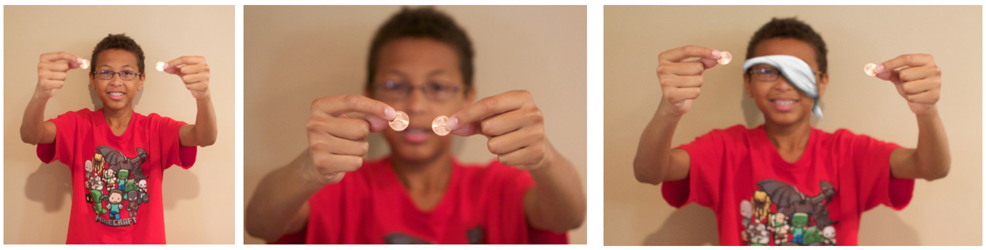
NAME ________________________________ DATE ____________

Student Handout

ACTIVITY 3: THE PENNY CHALLENGE

Materials Per Pair:

- 2 pennies
- One-eye blindfolded (this can be a bandana, a "pirate" eye patch, or a shirt tied around one eye).



Is it easier to match the penny edges together with both eyes open or one eye blocked?

Directions:

1. Hold a penny in each hand using the thumb and index finger.

2. Hold your arms out, slightly wider than shoulder width. Bend your elbows just a tiny, little bit.

3. Make sure the edges of the pennies are facing each other in your hands.

4. Slowly, bring your hands together and try to touch the edges of the pennies together on the first try.

5. Repeat Step 4 several times.

6. How did you do? Was this activity easy, hard, or somewhere in the middle? Discuss with your partner.

7. Place a blindfold on one eye.

8. Repeat steps 1-5.

9. How did you do on this task using only one eye? Was it easier? Harder? Discuss as a class.

QUESTIONS FROM ACTIVITY

1. Most people find this challenge to be difficult with one eye blocked, why is that?

The Eyes See: Activity 1

TEACHER KEY

QUESTIONS FROM THE ACTIVITY

1. Describe what happened when you "winked' your eyes back and forth.

Answers should be along the lines of: My finger "jumped" back and forth as I opened and closed one eye at time. With only my right eye open, the finger was right in the middle of my vision. But with my right eye closed and left eye open, the finger was all the way at the edge of my "visual image"

2. Does each eye see the exact same image? Or are they slightly different?

In general, each eye sees a slightly different image. However, there is a lot of overlap in the images that each eye sees. However, when an object is close to one eye, like a finger a few inches in front of one eye, aspects of each image will be very different. In this activity, the image from one eye had a finger right in the middle of its "visual image", whereas the finger was at the edge of the "visual image" for the other eye.

3. If each eye sends a separate image to the brain, how is it that you are able to see only ONE picture? How come you don't see two images like a split screen TV? Talk about this as a class.

Help guide the class to understand that

1. Each eye sends an image to the brain.

2. The brain combines or "stitches" these two images together to create a single image.

3. The brain is responsible for our visual perception.

4. (Optional) These two pictures stitched together are needed for "3D" vision.

Note: If the kids have ever crossed their eyes, they know they can get double vision – seeing two sets of each item in their visual field. But with eyes in their "normal" place, this is not the case.

The Eyes See: Activity 2

TEACHER KEY

ACTIVITY 2: HOLE IN HAND

Materials:

• One sheet of paper per student

Directions:

1. Roll your piece of paper up into a tube, like in the picture. The tube should be about an inch wide.

2. Place the tube in your right hand.

3. Put the tube in front of your right eye.

4. Hold up your left hand with your palm facing away from you.

5. Place your left hand next to the tube, about six inches in front of your right eye.

6. Look straight a head, with both eyes open.

Do you think EJ sees a hole in his hand?!

7. Do you see a hole in your hand?

Students should see a hole in their hand! Students (and adults) tend to need help getting their body orien-tated the correct way to make this work. Some things to look out for: 1. Make sure the tube is in front of one eye, and the hand in front of the other eye (sometimes students put the tube in front of one eye and the hand off to the side). 2. Make sure the hand is flat and "parallel" to the body (see picture). 3. Make sure the student has both eyes open. 4. Make sure the student is looking straight ahead. Often, students' eyes will dart to one side.

QUESTIONS FROM ACTIVITY

1. Why did it look like your hand had a hole in it?

Each eye sees a different image and sends that information to the brain. The brain takes the images from each eye and combines them to form a SINGLE image. Usually, there is a lot of overlap between the images from each eye. But in this activity we "tricked" the brain. One eye saw a "hole" and the other eye saw a hand. There was no overlap between the two images. The brain combined the two images from each eye to make it look like a hole in the hand!

The Eyes See: Activity 3

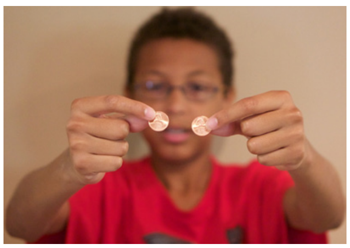
TEACHER KEY

ACTIVITY 3: THE PENNY CHALLENGE

Materials Per Pair:

- 2 pennies
- One-eye blindfolded (this can be a bandana, a "pirate" eye patch, or a shirt tied around one eye).

Students can work in pairs. This allows them to share materials and observe each other.


Is it easier to match the penny edges together with both eyes open or one eye blocked?

Directions:

1. Hold a penny in each hand using the thumb and index finger.

2. Hold your arms out, slightly wider than shoulder width.

3. Bend your elbows just a tiny, little bit.

4. Make sure the edges of the pennies are facing each other in your hands.

5. Slowly, bring your hands together and try to touch the edges of the pennies together on the first try.

6. Repeat Step 5 several times.

Make sure students move the pennies together many times, especially if they say they were able to do the task easily.

7. How did you do? Was this activity easy, hard, or somewhere in the middle? Discuss with your partner.

8. Place a blindfold on one eye.

9. Repeat steps 1-6.

10. How did you do on this task using only one eye? Was it easier? Harder? Discuss as a class.

Activity 3: Teacher Key *continued*

Discuss with students that we need two eyes to see in "3D". Our brain takes the pictures from each eye, and uses this information to figure out how far away things are.

Now, our brain uses plenty of other clues to figure out distance, such as how small things are (things that are far away don't take up much space in our visual field) and "overlap" (things closer to us may partially block things farther away). However, two eyes are needed for true "3D vision". If you only have one eye, the world will appear flat and items will not "pop-out" in space.

Because of the other clues our brain can use to judge distance, we can still get around fairly well in the world with just one eye. However, the penny challenge is moderately difficult, even with two eyes open. So when you now lose your 3D vision by blocking one eye, the task gets very difficult.

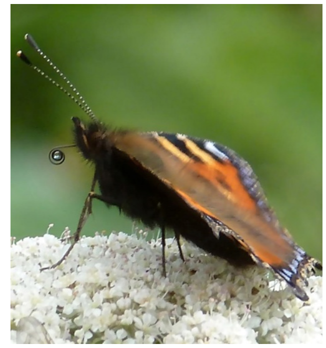
QUESTIONS FROM THE ACTIVITY

1. **Most people find this challenge to be difficult with one eye blocked, why is that?**
   Our brain uses information from each eye to create a 3D image. When we block one eye, things appear flatter. Because this task requires good 3D vision (also called binocular vision or stereopsis) it becomes very challenging without the ability to see things "pop-out" in space!

Student Handout

Tasting With Feet?

In this lesson you are going to read about different aspects of butterflies, including how they taste. At the end of the lesson, you can do an activity to explore how YOU taste.



Can you find the proboscis in this picture?

Butterflies get their energy from the nectar in flowers. Butterflies drink all their food! They use a body part called a proboscis to eat. You can think of a proboscis as a combination of a tongue, a straw and a paper towel. This body part is attached to the butterfly head, and is usually rolled up, the way you might roll up an extension cord when not in use.

When the butterfly is ready to eat, it unravels the proboscis and sticks it into a flower to get the nectar. Many people think a proboscis works like a straw, but it actually works more like a paper towel "soaking up" the nectar until it reaches the butterflies mouth!

It is crazy to think about – but the butterfly can't actually taste with its proboscis! Animals use things called *taste receptors* to taste. The butterfly doesn't have any taste receptors in its proboscis.

So where are butterflies' taste receptors? Butterflies have taste receptors in their feet! When a butterfly lands on a flower, it is able to taste the flower with its feet.

Female butterflies also use the taste receptors on their feet to determine where to lay their eggs. When picking a spot to lay eggs, the mommy butterfly tastes the leaves to make sure they are not toxic. She does this because when the baby caterpillars emerge from the eggs, they will actually start eating the leaf. The butterfly ensures the leaf is safe for eating using the taste receptors on her feet!

In humans and butterflies (and other animals), taste receptors send taste information to the brain.

If you think about it, it makes sense for a butterfly to have taste receptors in its feet because a butterfly is standing on its food source while its eating. Imagine if every time you ate a sandwich you were standing on a big piece of bread!

We don't stand on our food, so our feet do not have taste receptors. As everyone knows, we have taste receptors on our tongue. However, we don't ONLY use our tongue to taste. There is another body part that is essential to our ability to experience the full flavor of a food. That body part is . . . the NOSE.

Yes, you read that correctly. You taste with both your mouth AND your nose. But don't take our word for it – try out the next experiment to prove to yourself that your nose is an important part of perceiving flavor!

All About Senses Worksheet

NAME ______________________ DATE ____________

Student Handout

ASSESSMENT

1. What sense did this article focus on?

2. What is the name of the body part that butterflies use to drink nectar? Does this body part contain taste receptors?

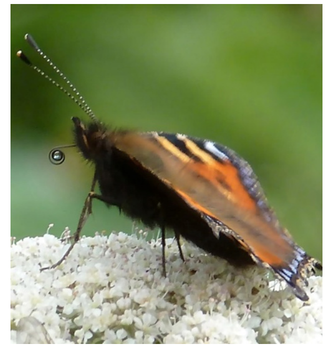
3. Why is it useful to butterflies to be able to taste with their feet? *Answer this question in terms of adaptive traits, habitats and/or survival.*

4. After reading this story about butterflies tasting with their feet you will do an activity to see if your nose helps you taste. Why do you think this story and this activity were paired together?

Tasting With Feet?

TEACHER KEY

In this lesson you are going to read about different aspects of butterflies, including how they taste. At the end of the lesson, you can do an activity to explore how YOU taste.



Can you find the proboscis in this picture?

Butterflies get their energy from the nectar in flowers. Butterflies drink all their food! They use a body part called a proboscis to eat. You can think of a proboscis as a combination of a tongue, a straw and a paper towel. This body part is attached to the butterfly head, and is usually rolled up, the way you might roll up an extension cord when not in use.

When the butterfly is ready to eat, it unravels the proboscis and sticks it into a flower to get the nectar. Many people think a proboscis works like a straw, but it actually works more like a paper towel "soaking up" the nectar until it reaches the butterflies mouth! *The proboscis works by capillary action. Capillary action is the same force that pulls water through a paper towel.*

It is crazy to think about – but the butterfly can't actually taste with its proboscis! Animals use things called ***taste receptors*** to taste. The butterfly doesn't have any taste receptors in its proboscis.

So where are butterflies' taste receptors? Butterflies have taste receptors in their feet! When a butterfly lands on a flower, it is able to taste the flower with its feet.

Female butterflies also use the taste receptors on their feet to determine where to lay their eggs. When picking a spot to lay eggs, the mommy butterfly tastes the leaves to make sure they are not toxic. She does this because when the baby caterpillars emerge from the eggs, they will actually start eating the leaf. The butterfly ensures the leaf is safe for eating using the taste receptors on her feet !*Ensure your students know that caterpillars emerge from butterfly eggs (and later turn into butterflies). (Note: Different butterfly species leave their eggs in different places. Not all butterflies lay eggs on leaves. Butterflies can also lay eggs on stalks or flowers).*

In humans and butterflies (and other animals), taste receptors send taste information to the brain.

If you think about it, it makes sense for a butterfly to have taste receptors in its feet because a butterfly is standing on its food source while its eating. Imagine if every time you ate a sandwich you were standing on a big piece of bread!

Tasting With Feet: Teacher Key *continued*

We don't stand on our food, so our feet do not have taste receptors. As everyone knows, we have taste receptors on our tongue. However, we don't ONLY use our tongue to taste. There is another body part that is essential to our ability to experience the full flavor of a food. That body part is . . . the NOSE.

Yes, you read that correctly. You taste with both your mouth AND your nose. But don't take our word for it – try out the next experiment to prove to yourself that your nose is an important part of perceiving flavor!

ASSESSMENT

1. What sense did this article focus on?

The sense of taste

2. What is the name of the body part that butterflies use to drink nectar? Does this body part contain taste receptors?

The body part butterflies use to drink nectar is called a proboscis. This body part does not contain taste receptors.

3. Why is it useful to butterflies to be able to taste with their feet? *Answer this question in terms of adaptive traits, habitats and/or survival.*

It is useful for butterflies to taste with their feet because they stand on their food source. Having taste receptors on their feet is efficient. Butterflies need to taste the leaf/flower to evaluate its suitability for 1. drinking nectar and 2. laying eggs.

4. After reading this story about butterflies tasting with their feet you will do an activity to see if your nose helps you taste. Why do you think this story and this activity were paired together?

"Tasting With Feet" was paired with an activity exploring the contributions of the nose to taste because: 1. both items explore the sense of taste and 2. both items explore using an organ not generally associated with taste (feet for the butterfly and noses for people).

Students may have other correct answers.

CLASS ACTIVITY

The Nose Tastes

Note: There is no studnet worksheet with this activity.

LEVEL 2

Why It's Easy for You

- Activity is simple and not messy.
- Activity takes ~5 min (plus a discussion)

Conditions and Challenges

- You need to buy jelly beans.
- Please ensure none of your students have allergies to ingredients in jelly beans.

OVERVIEW

In this activity students learn that they taste with their tongue AND their nose by eating jelly beans with their nose plugged and unplugged.

LEARNING OBJECTIVE

Students understand:

1. That taste/flavor information comes from the tongue AND the nose.

2. The tongue and nose send taste/flavor information to the brain

3. That the perception of taste/flavor comes from the brain.

Materials

- Two jelly beans per student

DIRECTIONS TO GIVE TO STUDENTS

SCRIPTS ARE ON NEXT PAGE

1. Empty your hands. Hold the jelly bean with one hand, ready to eat.

2. Plug your nose with your other hand.

3. Keeping your nose plugged, put the jelly bean in your mouth.

4. Chew, but don't swallow. **Think about the flavor.**

5. Once the jelly bean is nice and chewed (but still in your mouth) unplug your nose.

6. What do you notice?

Repeat with second jelly bean or students can do their own experiments.

The Nose Tastes: Class Activity *continued*

Script A : Before Starting

We all learned in kindergarten that we use our mouth, or tongue, to taste. But would you believe me that you also taste with your nose?

Script B : Post-Experiment

From this experiment you see that you use your nose AND your mouth to taste. How can this be? After all, the food is in your mouth, not your nose!

First you need to understand that your mouth and nose are connected. Have you ever laughed and had water come out of your nose? This is because your nose and mouth are connected.

As you chew, air is shoved up from your mouth and into your nose. This air contains tiny molecules from your food! These molecules attach to receptors in your nose, and your nose sends this information to the brain. At the same time, your tongue is also sending taste information to the brain. The brain combines the information from the nose and mouth to create your perception of taste.

Script C

Have you ever noticed that food is really bland when you have a cold? This is because during a cold you nose is often blocked with mucus, preventing the food molecules from attaching to receptors in your nose!

You may also have plugged your nose if you had to eat a yucky medicine. Now you know why!

EJ tests how his nose affects taste!

Student Handout

The Star-Nosed Mole (Touch)

There are some unusual creatures in this world. One of these strange creatures in called a star-nosed mole. The star-nosed mole lives most of its life in complete darkness and is nearly blind. How does the mole survive without vision? It uses its sense of touch!

When we think about noses, we usually think about smelling. But the nose of this star-nosed mole does a lot more than just smell. This nose has 22 fleshy "appendages" that stick out in a star-like shape (11 on each side), creating what is called a "star organ" on its nose. The mole uses this star organ to explore its surroundings and find food.

The appendages that make up the star organ of the mole are very special. Why are they special? Because they are incredibly sensitive to touch. In fact, the star organ is THE most sensitive body part known in any mammal! Because of their sensitivity, the appendages on the star organ are able to detect the very small insects and larvae that the moles like to eat.

Just how does the star-nosed mole find and eats its food? As the animal moves through its underground tunnels, the appendages on its nose are quickly moving across and scanning the ground. If the mole thinks it's found something good to eat, the mole moves the potential food to the appendages closest to its mouth to explore further. (This is because the appendages closest to the mouth are the most sensitive.) If the mole confirms that the object is indeed food, it uses the appendages to place the food in its mouth, and quickly chews and swallows. The mole then continues on to find more dinner!

The star-nosed mole locates and eat its food faster than any other known animal. The time from first touching the food to ingestion is only a fraction of a second.

In this unit you are learning how the body talks to the brain to give it information about the outside world. All of our sense organs have nerves that connect to and talk to the brain. The fleshy appendage of the star-nosed mole has more nerves in it than your fingertips, even though each appendage is only 1-2 millimeters! (The adult male is smaller than your hand.) The appendages of the star organ are much more sensitive than your fingertips.

The touch abilities of the star-nosed mole are so good, that scientists believe the mole essentially "sees" with its nose. Of course, it's hard to imagine how the star-nosed mole actually *perceives* its world, but it's safe to say that touch is the sense the mole relies on the most.

The nose of the star-nosed mole is very sensitive to touch, meaning nose sends *a lot* of touch information to the brain.

NAME ______________________ DATE ____________

Student Worksheet
THE STAR-NOSED MOLE WORKSHEET

Answer the questions below and then do an activity to discover how sensitive YOUR skin is in different regions of your body.

ASSESSMENT

1. What sense did this article focus on?

2. Name somthing special about the star organ of the star-nosed mole.

3. How big is the star-nosed mole? Is its star organ bigger or smaller than your fingertip?

4. What is most interesting to you about the star-nosed mole?

The Star Nosed Mole (Touch)
TEACHER KEY

There are some unusual creatures in this world. One of these strange creatures in called a star-nosed mole. The star-nosed mole lives most of its life in complete darkness and is nearly blind. How does the mole survive without vision? It uses its sense of touch!

When we think about noses, we usually think about smelling. But the nose of this star-nosed mole does a lot more than just smell. This nose has 22 fleshy "appendages" that stick out in a star-like shape (11 on each side), creating what is called a "star organ" on its nose. The mole uses this star organ to explore its surroundings and find food.

Students may need help with the word "appendage". An appendage is something added onto something or that sticks out from something else.

The appendages that make up the star organ of the mole are very special. Why are they special? Because they are incredibly sensitive to touch. In fact, the star organ is THE most sensitive body part known in any mammal! Because of their sensitivity, the appendages on the star organ are able to detect the very small insects and larvae that the moles like to eat.

Just how does the star-nosed mole find and eat its food? As the animal moves through its underground tunnels, the appendages on its nose are quickly moving across and scanning the ground. If the mole thinks it's found something good to eat, the mole moves the potential food to the appendages closest to its mouth to explore further. (This is because the appendages closest to the mouth are the most sensitive.) If the mole confirms that the object is indeed food, it uses the appendages to place the food in its mouth, and quickly chews and swallows. The mole then continues on to find more dinner!

Ensure students understand what it means to have body parts that are sensitive to touch. Sensitive skin would respond to a very small and light object (like a flea walking on it), whereas less sensitive skin would need stronger input to react. Sensitive skin can also mean you can feel that two different points are touching you, even when these points are very close (see toothpick activity in this lesson).

The star-nosed mole locates and eats its food faster than any other known animal. The time from first touching the food to ingestion is only a fraction of a second.

An interesting tidbit you might want to share with students (found in 2005 NYT article cited in the "References" section) is about how the research on eating speed was done. Dr. Ken Catania put the mole on a glass plate, and put a high speed video camera underneath the glass. He then placed cut-up earthworms on the glass. He found the moles could identify and eat the worm pieces in about a fifth of a

The Star-Nosed Mole (Touch): Teacher Key *continued*

second. This was so much faster than expected that at first Dr. Catania thought he calibrated the camera incorrectly. But it turns out the star-nosed mole truly does eat that fast!

In this unit you are learning how the body talks to the brain to give it information about the outside world. All of our sense organs have nerves that connect to and talk to the brain. The fleshy appendage of the star-nosed mole has more nerves in it than your fingertips, even though each appendage is only 1-2 millimeters! (The adult male is smaller than your hand.) The appendages of the star organ are much more sensitive than your fingertips.

Students can look at rulers to see how long 1-2 millimeters is.

The touch abilities of the star-nosed mole are so good, that scientists believe the mole essentially "sees" with its nose. Of course, it's hard to imagine how the star-nosed mole actually *perceives* its world, but it's safe to say that touch is the sense the mole relies on the most.

Scientists have found that the way the nose of the star-nosed mole "maps" onto their brains is very similar to how human eyes "map" onto our brains. Eyesight is our dominant sense, and touch is the star-nosed moles' dominant sense.

The nose of the star-nosed mole is very sensitive to touch, meaning nose sends *a lot* of touch (and pain and temperature) information to the brain.

The Star-Nosed Mole (Touch): Teacher Key *continued*

Answer the questions below and then do an activity to discover how sensitive YOUR skin is in different regions of your body.

Other star-nosed mole facts:

- *They live in wetlands in Eastern North America.*
- *No other mole has a nose like the star-nosed mole.*

Most moles live in dry places. Scientists believe that the delicate skin on the star nose mole would be damaged in hard, dry tunnels. In contrast, the wetter, softer environment of the star-nosed mole allows the nose to function without damage

- *The star-nosed mole can forage and eat underwater*
- *They smell underwater by blowing and reinhaling air bubbles (the underwater smell gets trapped in the air bubble).*
- *An adult star-nosed mole is smaller than an adult human hand!*

ASSESSMENT

1. What sense did this article focus on?

The sense of touch

2. Name something special about the star organ of the star-nosed mole.

It is the most sensitive (known) organ to touch of any mammal.

It allows the animal to find and locate food faster than any other known animal. Other answers may be correct.

3. How big is the star-nosed mole? Is its star organ bigger or smaller than your fingertip?

The star-nosed mole is smaller than an adult human hand (it is about 4.5 cm long). Its star organ is smaller than a human fingertip.

4. What is most interesting to you about the star-nosed mole?

Answers will vary.

How Sensitive Is Your Skin?

TEACHER KEY

LEVEL 4

We recommend reading the "Touch" section of Science Background for Teachers before starting this activity.

Why It's Easy for You

- Activity is not messy, and can be done at student desks.
- Worksheets are ready to print.

Conditions and Challenges

- You need to buy/obtain toothpicks
- You need to find suitable items to use as blindfold for the students
- Prep for the activity is ~10-20 minutes (however, it only requires one prep, then you can use the materials indefinitely).
- Activity will take at least 30 minutes of class time.

OVERVIEW

Students use toothpicks and blindfolds to compare how sensitive their forearms and fingertips are.

This activity is often called "Two-Point Discrimination" (Because you are testing if you can tell the difference, or discriminate, between two points).

LEARNING OBJECTIVES: CONTENT

Students understand:

1. That the skin talks to the brain.

2. Certain areas of our body are more sensitive to touch than others.

3. There is a reason certain areas of our body are more sensitive to touch. (We use our fingers to explore the world and manipulate objects, they need to be sensitive. Our forearms don't do much except connect our hands to our elbows).

4. That our tactile perception of the world is ultimately controlled by the brain. Our skin isn't able to collect perfect information everywhere, so our perception can be inaccurate.

5. Certain areas of our body are more sensitive to touch than others because the skin is able to send more information to the brain in these areas.

LEARNING OBJECTIVES: SCIENTIFIC PRACTICES

Students understand:

1. That certain types of experiments have "Experimenters" and "Subjects".

2. That scientists record their data.

3. That scientists doing experiments must do "Repeated Trials". (See Background Information)

Materials (per pair)

- 3 toothpicks
- One piece of duct tape (attached to two of the toothpicks, see below)
- Blindfold

Prep

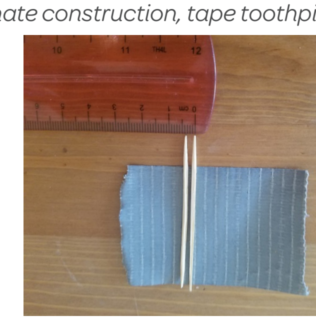
1. Gather toothpicks and duct tape

2. Place 2 toothpicks on duct tape ~2-3 mm apart, so the ends stick out, as in the image. (The distance apart is important). Make sure the tips of the toothpicks are lined up perfectly!

3. Wrap the duct tape around to secure the toothpicks, pressing down to remove any air pockets.

4. Cut off any excess duct tape.

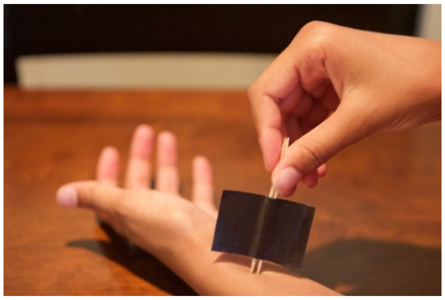
Alternate construction, tape toothpicks to a piece of cardboard.

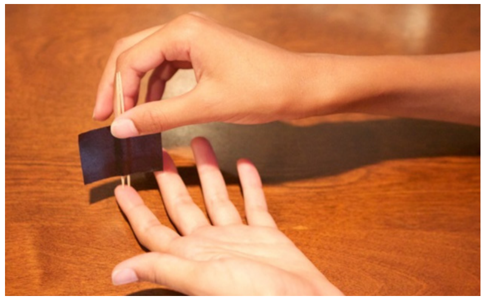


How Sensitive Is Your Skin?

Which is more sensitive, your forearm or fingertip?

You have learned about the star-nose mole whose star organ is the most sensitive organ to touch of any mammal! How sensitive is YOUR skin to touch? You will find the answer out by poking your fingertips and forearms.





Materials:

- Single toothpick
- "Double" toothpick
- Blindfold

In this activity, you will test how sensitive your fingertips and forearms are to touch!

Directions:

1. Choose one partner to start as the "Experimenter" and one partner to start as the "Subject".

2. If the Subject has long sleeves on, the Subject should roll up his/her sleeves.

3. Have the Subject put the blindfold on.

4. Have the Subject place his/her arm on the desk, palm side up.

5. The Experimenter will secretly pick either the single toothpick or double toothpick and gently poke the forearm of The Subject.

6. Have the Subject tells the Experimenter if he/she is being poked by ONE or TWO toothpicks. No peeking! The Subject should not try to guess, but say what he/she really feels.

7. For each trial, the Experimenter should write down how many toothpicks he/she used, what the Subject guessed, and whether the Subject was right or wrong.

8. The experimenter must do repeated trials. Continue Steps 5-7 for 8 trials.

9. Repeat Steps 3 – 8, but now poke the **fingertip** of the index finger instead of the forearm.

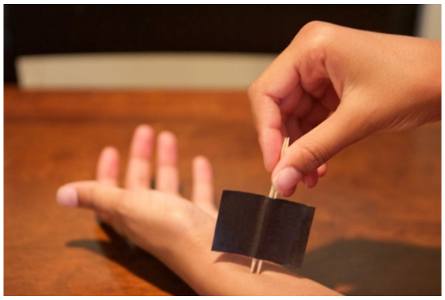
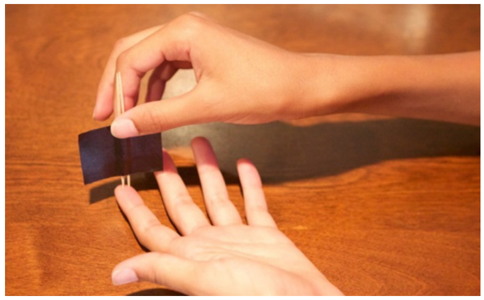
10. Switch positions. The Experimenter is now the Subject, and the Subject, is now the Experimenter. Repeat Steps 2-9.

11. Answer the questions on your lab sheet. You may discuss the answers with your partner, but each student must write his or her own answers.

How Sensitive Is Your Skin?

Which is more sensitive, your forearm or fingertip?

You have learned about the star-nose mole whose star organ is the most sensitive organ to touch of any mammal! How sensitive is YOUR skin to touch? You will find the answer out by poking your fingertips and forearms.

Materials:

- Single toothpick
- "Double" toothpick
- Blindfold

In this activity, you will test how sensitive your fingertips and forearms are to touch!

Before starting, go over the terms "The Experimenter", "The Subject", "trials" and "repeated trials". Each student will be both the Experimenter and Subject, then they will switch positions.

Directions:

1. Choose one partner to start as the "Experimenter" and one partner to start as the "Subject".
Explain to students that the "Experimenter" is the scientist and the "Subject" is the person who is being experimented on. Make sure students understand each student will work in both positions.
2. If the Subject has long sleeves on, the Subject should roll up his/her sleeves.
3. Have the Subject put the blindfold on.
4. Have the Subject place his/her arm on the desk, palm side up.
5. The Experimenter will secretly pick either the single toothpick or double toothpick and gently poke the forearm of The Subject.
6. Have the Subject tells the Experimenter if he/she is being poked by ONE or TWO toothpicks. No peeking! The Subject should not try to guess, but say what he/she really feels.
7. For each trial, the Experimenter should write down how many toothpicks he/she used, what the Subject guessed, and whether the Subject was right or wrong.
8. The experimenter must do repeated trials. Continue Steps 5-7 for 8 trials.
9. Repeat Steps 3 – 8, but now poke the **fingertip** of the index finger instead of the forearm.
The experimenter will be poking both the forearm and fingertip of the subject.
10. Switch positions. The Experimenter is now the Subject, and the Subject, is now the Experimenter. Repeat Steps 2-9.
11. Answer the questions on your lab sheet. You may discuss the answers with your partner, but each student must write his or her own answers.

NAME ____________________ DATE ____________

Student Worksheet

How Sensitive Is Your Skin?

You are **The Experimenter**. Fill the sheet out according to your partners answers.

FOREARM

Trial 1: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 2: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 3: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 4: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 5: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 6: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 7: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 8: I poked with ____toothpicks. My partner thought that I poked with ______toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

NAME ______________________ DATE ____________

FINGERTIP (INDEX FINGER)

Trial 1: I poked with ____toothpicks. My partner thought that I poked with _____toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 2: I poked with ____toothpicks. My partner thought that I poked with _____toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 3: I poked with ____toothpicks. My partner thought that I poked with _____toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

Trial 4: I poked with ____toothpicks. My partner thought that I poked with _____toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

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Trial 8: I poked with ____toothpicks. My partner thought that I poked with _____toothpicks.
My partner got the answer: ☐ Right ☐ Wrong

NAME ____________________ DATE ____________

DATA SUMMARY

How Sensitive Is Your Skin?

Add up up the number of correct responses for the forearm and fingertip condition.

For the **forearm**, my partner got the answer correct in______trials.

For the **fingertip**, my partner got the answer correct in __________trials.

1. Which body part is more sensitive, the forearm or fingertip? Why do you think that is?

____

____

2. Predict how sensitive other parts of your body are. Your teacher will let you know the answers!

Back

Eyelids

Palm

Lips

Calf

3. Why is it important for scientists to do repeated trials?

____

____

____

How Sensitive Is Your Skin?

TEACHER KEY

1. **Which body part is more sensitive, the forearm or fingertip? Why do you think that is?**

   The fingertip is more sensitive. We need our fingertips to be sensitive because we use our hands to manipulate objects and explore the world. We don't use our forarms to explore the world, so they don't need a lot of sensitivity.

   (Example 1: For example, if we were reaching into a tree to find fruit, but couldn't see very well, due to dense leaves, we'd want to be able to tell the difference, through touch between leaves and the fruit, and ripe fruit and rotten fruit. Our fingertips are good at this, our forearms would be terrible!).

   (Example 2: It requires energy and space in the brain to support sensitive skin regions. Our body and brain aspire to be efficient. That's why, if it's not important for a skin region to be sensitive, it is not!)

2. **Predict how sensitive other parts of your body are. Your teacher will let you know the answers!**

   Back *not sensitive*

   Eyelids *sensitive*

   Palm *sensitive*

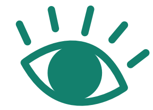
   Lips *sensitive*

   Calf *not sensitive*

3. **Why is it important for scientists to do repeated trials?**

   Repeated trials make outliers less likely and give scientists the best chance of getting accurate, reliable and correct data.

Brain & Body Communication: In Rhyme

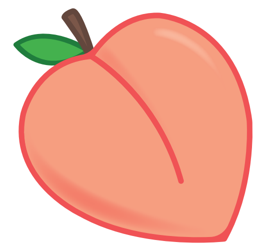


I see a fruit on the table and I really want to chew it
How does my body know how to do it?

First the light information has to go to my eyes
To tell me the object's color, position, texture, shape and size.

Next my eyes talk to my brain and they give it a list
They say this thing's pink, round, fuzzy and the size of my fist.

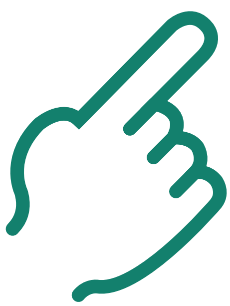
My brain compares this object to what it's seen in the past
(This step happens really quick, the brain is super-fast)



"I know what that is!" my brain says with a screech,
I've seen that thing before, it's delicious and it's a peach!

Now that the object identification stage is complete
What happens next that allows me to eat?

My stomach's sending a single to my brain, it says "HUNGER"
So my brains says "Eat this peach, I'm not getting any younger!"



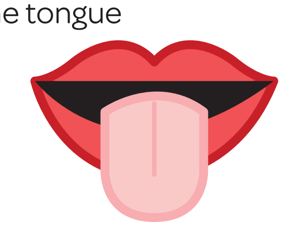
My brain needs talk to my body and COMMAND!
It signals down the nerves to one arm and one hand.

It tells the arms to reach and the fingers to grasp
In just the right way, not too hard, not too fast

If the brain and body did their job just right
I'm now holding a peach and getting ready to bite

(It's important to point out to make sure you understand
The brain is getting feedback from the fingers and the hand)

The brain must keep on working as its job is not done
It must coordinate the hands, fingers, mouth and the tongue



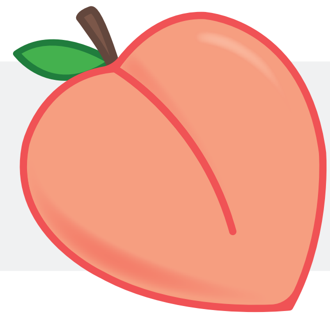
It instructs the hand to lift and the tells mouth to open
The tongue gets into position to prevent me from chokin'

I bite into the peach now that everything's in place
Juice flows into my mouth and this tells my brain the taste!

We are going to stop the story (although it's not really done
The brain and body always talk, there's always more to come)

You might think eating is easy and it's not a lot to ask
But a lot has to happen to accomplish this "simple" task.

So the next time that you eat, walk or even feel some pain,
Think about all the communication between your body and your brain!



Brain & Body Communication: In Rhyme

TEACHER KEY

I see a fruit on the table and I really want to chew it
How does my body know how to do it?

The opening lines get to the heart of the standard - > how do we see, process and react to information in our environment? (Like seeing a peach)

First the light information has to go to my eyes
To tell me the object's color, position, texture, shape and size.

These two lines describe how the information is getting to our body. Light travels from the object and into our eyes. Our eyes don't "know" the object is a peach, but they do encode the color, position, texture, shape and size of the object (along with other information)

Next my eyes talk to my brain and they give it a list
They say this thing's pink, round, fuzzy and the size of my fist.

These lines describe which information is delivered to the brain.

My brain compares this object to what it's seen in the past
(This step happens really quick, the brain is super-fast)

"I know what that is!" my brain says with a screech,
I've seen that thing before, it's delicious and it's a peach!

These 4 lines briefly describe the processing that happens in the brain. The brain uses the information from the eyes and compares it to past information to identify the object.

Now that the object identification stage is complete
What happens next that allows me to eat?

My stomach's sending a single to my brain, it says "HUNGER"
So my brains says "Eat this peach, I'm not getting any younger!"

The brain now needs to tell the body what to do.

My brain needs talk to my body and COMMAND!
It signals down the nerves to one arm and one hand.

Commands from the brain travel to the body through nerves.

It tells the arms to reach and the fingers to grasp
In just the right way, not too hard, not too fast

The body has to grasp objects just right. If you picked up a peach the way you would pick up a baseball your fingers would probably break the skin of the peach and make a mess!

If the brain and body did their job just right
I'm now holding a peach and getting ready to bite

Brain & Body Communication In Rhyme: Teacher Key *continued*

(It's important to point out to make sure you understand
The brain is getting feedback from the fingers and the hand)

The "feedback" in this last line refers to the information sent from the body to the brain. This feedback is occurring constantly, allowing you to make minor and major body adjustments to properly interact with objects.

The brain must keep on working as its job is not done
It must coordinate the hands, fingers, mouth and the tongue

It instructs the hand to lift and the tells mouth to open
The tongue gets into position to prevent me from chokin'

I bite into the peach now that everything's in place
Juice flows into my mouth and this tells my brain the taste!

Many activites use multiple senses. Eating uses vision, smell, taste and touch!

We are going to stop the story (although it's not really done
The brain and body always talk, there's always more to come)

You might think eating is easy and it's not a lot to ask
But a lot has to happen to accomplish this "simple" task.

Many things we do that seems "easy" actually took a lot of training for the brain to learn. Much of this training happens when we are babies! Once you are trained to do something it can feel easy, like reading and writing. But adults who didn't train their brain to read have a hard time learning to read and write.

So the next time that you eat, walk or even feel some pain,
Think about all the communication between your body and your brain!

The brain and body are in constant, non-stop communication!

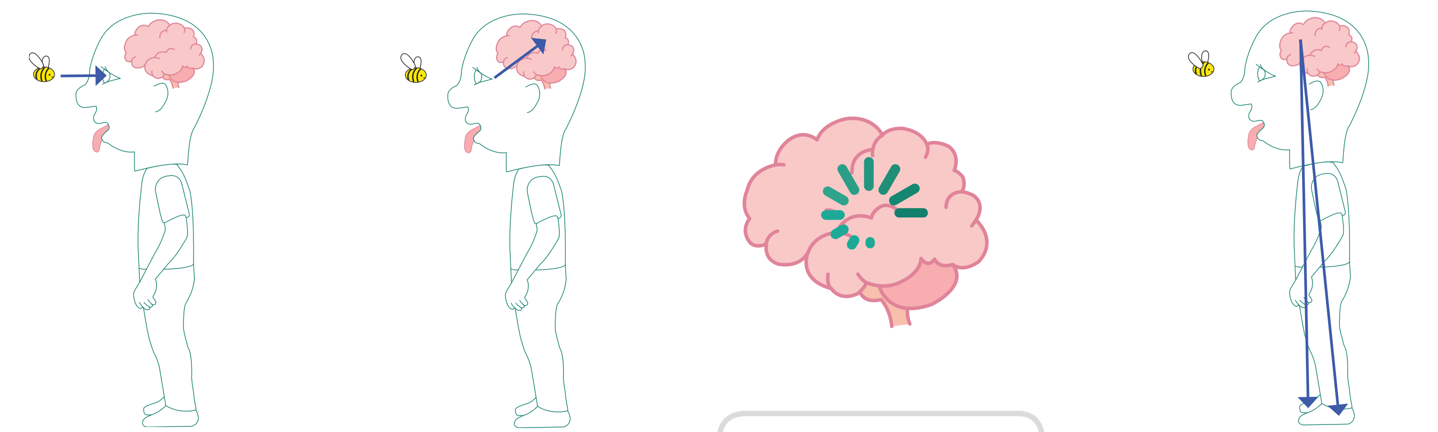
NAME ______________________ DATE ______________

Student Worksheet

Drawing Information Pathways

Draw the pathway of information for the following scenarios. Use arrows to show the "information pathway" for each step. Use the example as a guide.

Example: You see a bee buzzing around your head and run away from it.



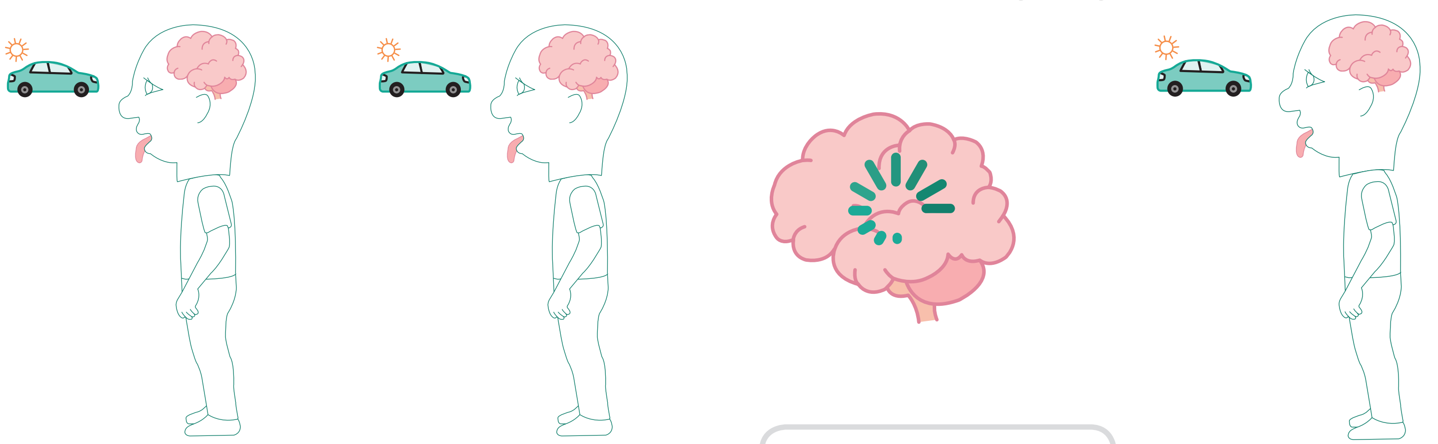
Step 1
Light reflects off the bee and enters the eye.

Step 2
The eyes send light information to the brain.

Step 3
The brain processes the light information and determines that it's seeing a bee! The brain decides it wants you to run away from the bee.

Step 4
The brain sends commands to the legs/body to run away from the bee.

1. You touch a hot car under the sun and quickly move your hand to avoid getting burned.



Step 1
Heat from the car turns on temperature and pain receptors in your hand.

Step 2
Your hand sends pain signals to your brain through nerves.

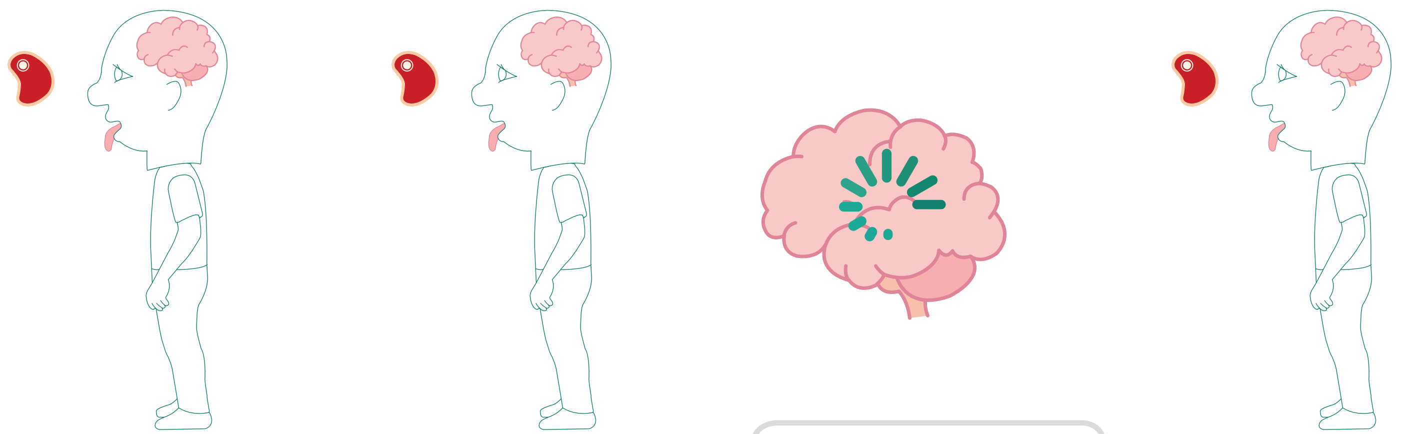
Step 3
The brain processes the pain and temperature signals. The brain identifies that the source of pain is the hot car and decides to move away.

Step 4
The brain tells the muscles in your hand to move the hand off the car!

All About Senses Worksheet

NAME ______________________________ DATE ______________

2. You take a bite of meat and realize it's rancid. You spit the meat out.
(Hint: Remember you taste with your tongue AND nose).



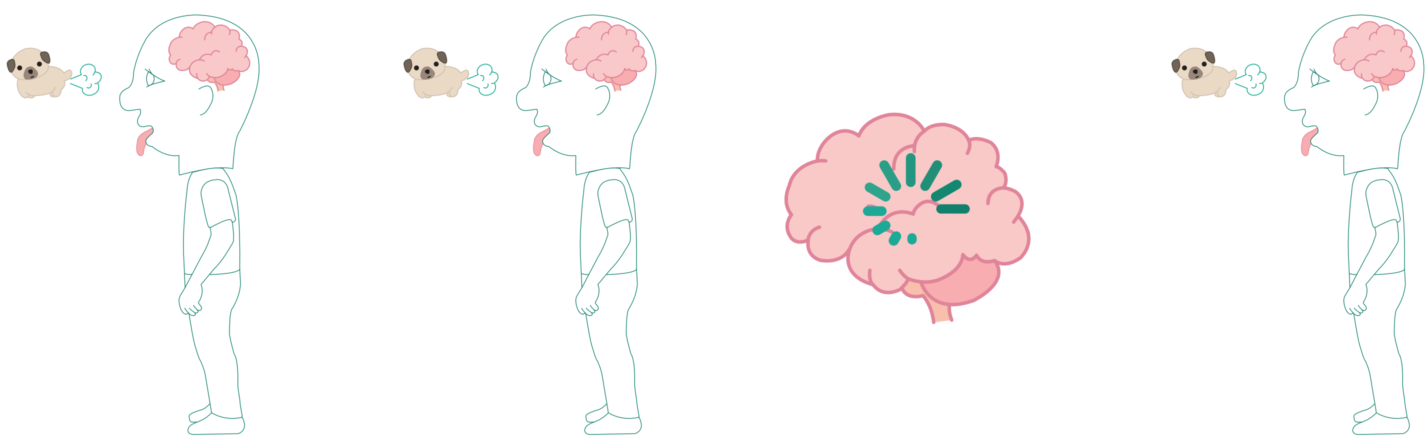
Step 1
Small bits of the chewed meat attach to receptors on your tongue and nose.

Step 2
The tongue and nose send information about the food to the brain.

Step 3
Your brain processes the information from the tongue and nose and realizes the meat has gone bad! Your brain decides to spit out the meat.

Step 4
The brain sends commands to the muslces in the mouth and tongue to spit the food out.

3. You smell a fart from your dog and plug your nose.



Step 1
Small gas molecules from the dog's fart attach to receptors in your nose.

Step 2
Your nose sends your brain information about smell through nerves.

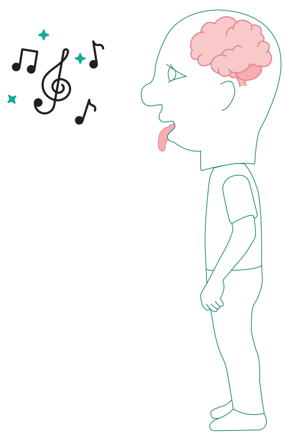
Step 3
Your brain processes the smell information and identifies the smell as a fart. Your brain decides you want to plug your nose.

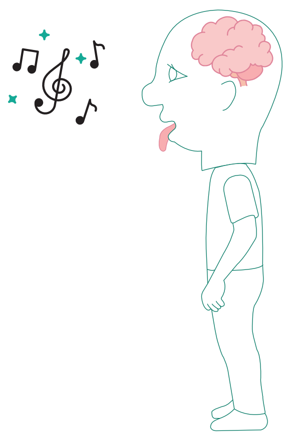
Step 4
The brain sends commands to the muscles in your hand to move to plug your nose.

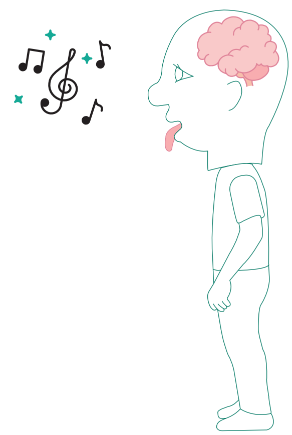
All About Senses Worksheet

NAME ______________________ DATE ____________

4. You hear your favorite song and start to dance.







Step 1
Small sound vibrations vibrate receptors in the ears.

Step 2
Receptors in the ears send the sound information to the brain.

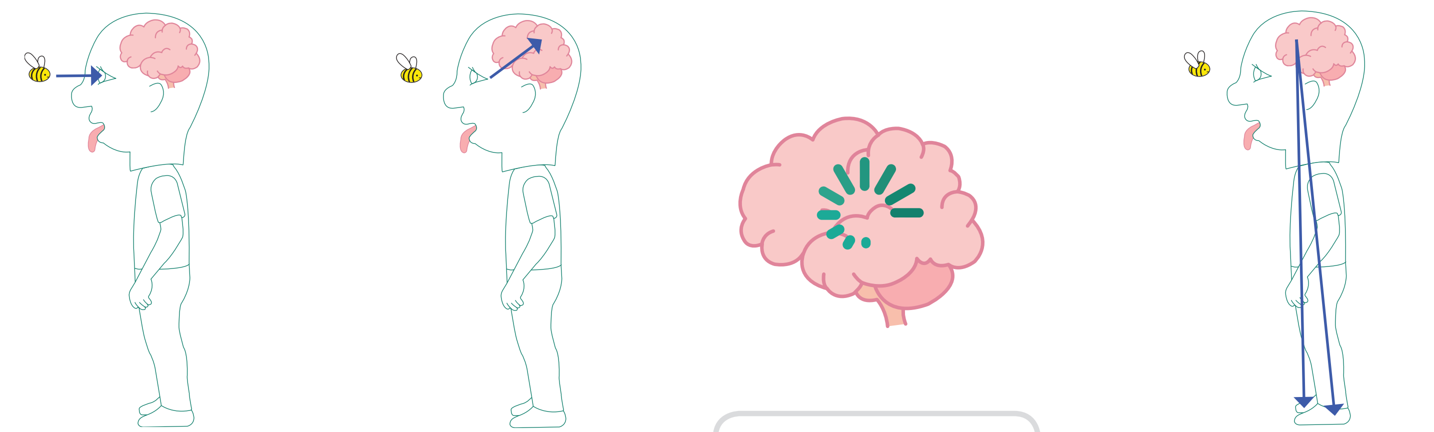
Step 3
Your brain processes the sound information and determines you are hearing your favorite song! Your brain decides it wants to dance.

Step 4
The brain sends commands to the muscles all over your body to dance.

Drawing Information Pathways

TEACHER KEY

Example: You see a bee buzzing around your head and run away from it.



Step 1
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Step 2
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Step 3
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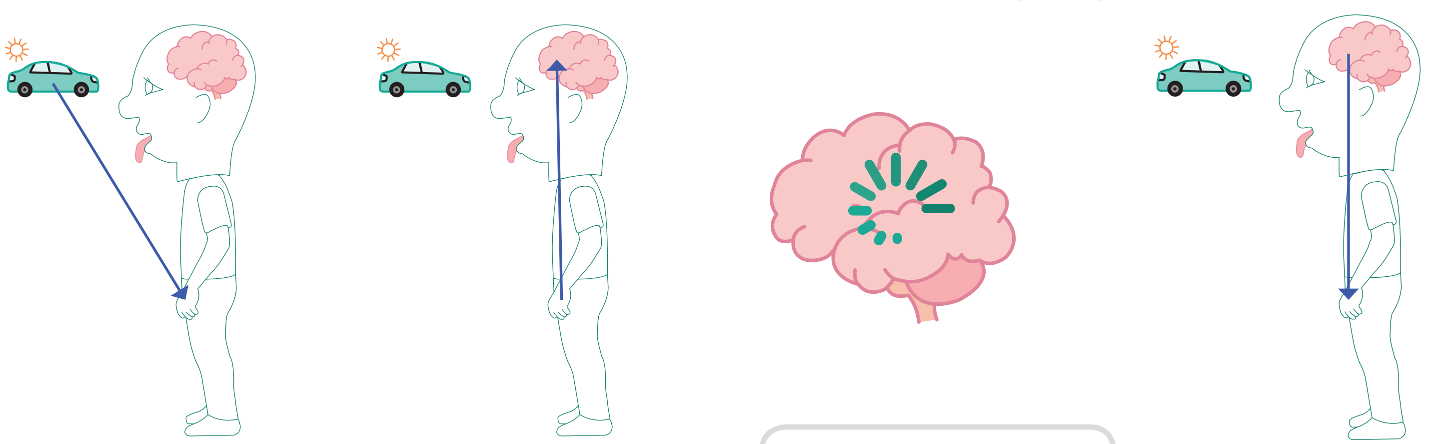

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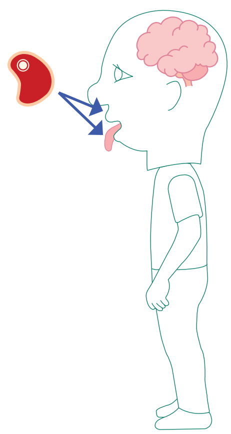
The brain tells the muscles in your hand to move the hand off the car!

Drawing Information Pathways: Teacher Key *continued*

2. You take a bite of meat and realize it's rancid. You spit the meat out.
(Hint: Remember you taste with your tongue AND nose).



Step 1
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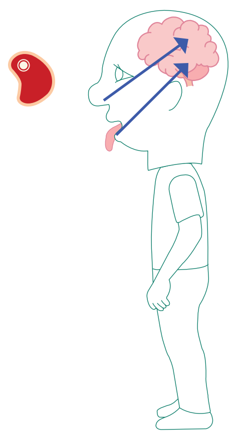
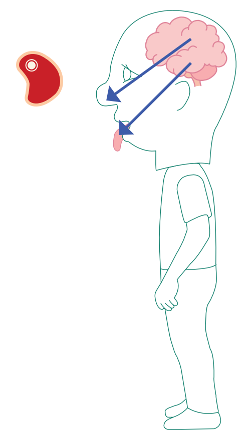


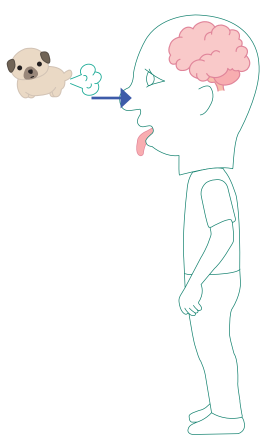
Step 2
The tongue and nose send information about the food to the brain.

Step 3
Your brain processes the information from the tongue and nose and realizes the meat has gone bad! Your brain decides to spit out the meat.



Step 4
The brain sends commands to the muslces in the mouth and tongue to spit the food out.

3. You smell a fart from your dog and plug your nose.



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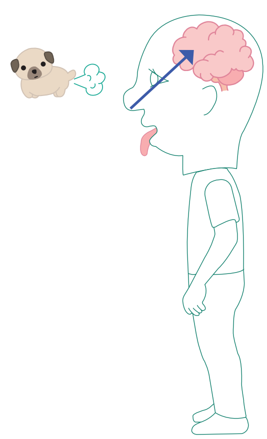
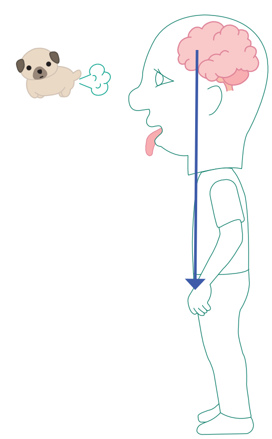


Step 2
Your nose sends your brain information about smell through nerves.

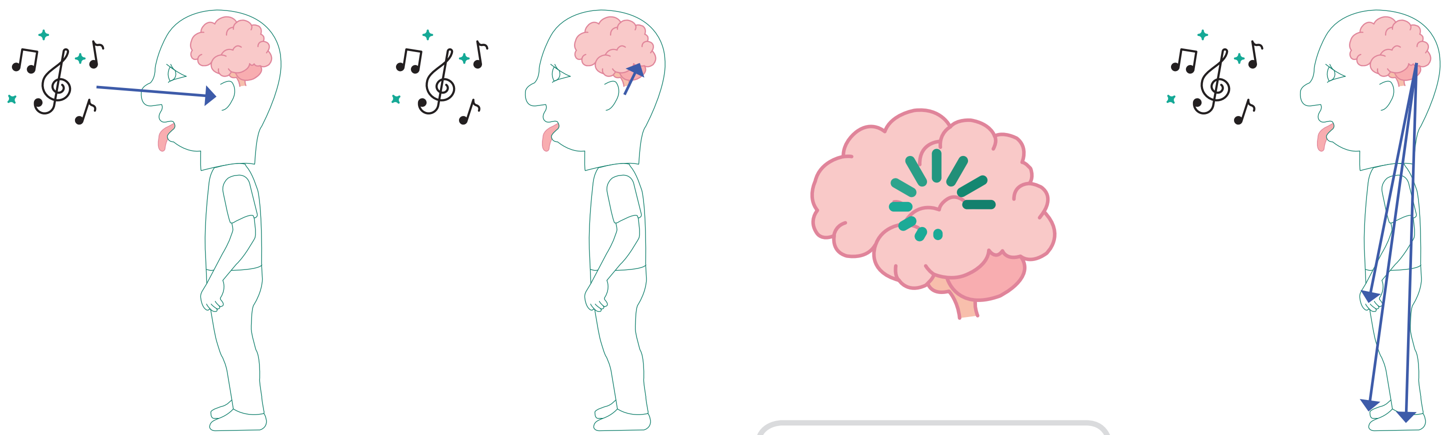
Step 3
Your brain processes the smell information and identifies the smell as a fart. Your brain decides you want to plug your nose.



Step 4
The brain sends commands to the muscles in your hand to move to plug your nose.

Drawing Information Pathways: Teacher Key *continued*

4. You hear your favorite song and start to dance.



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