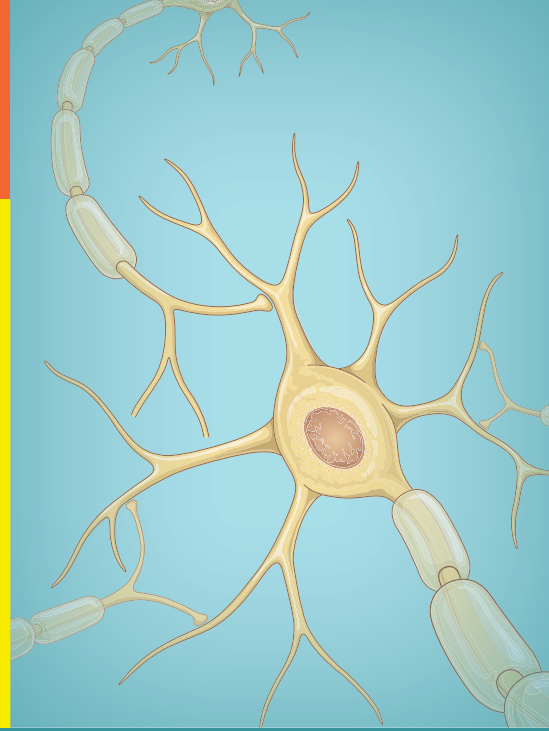
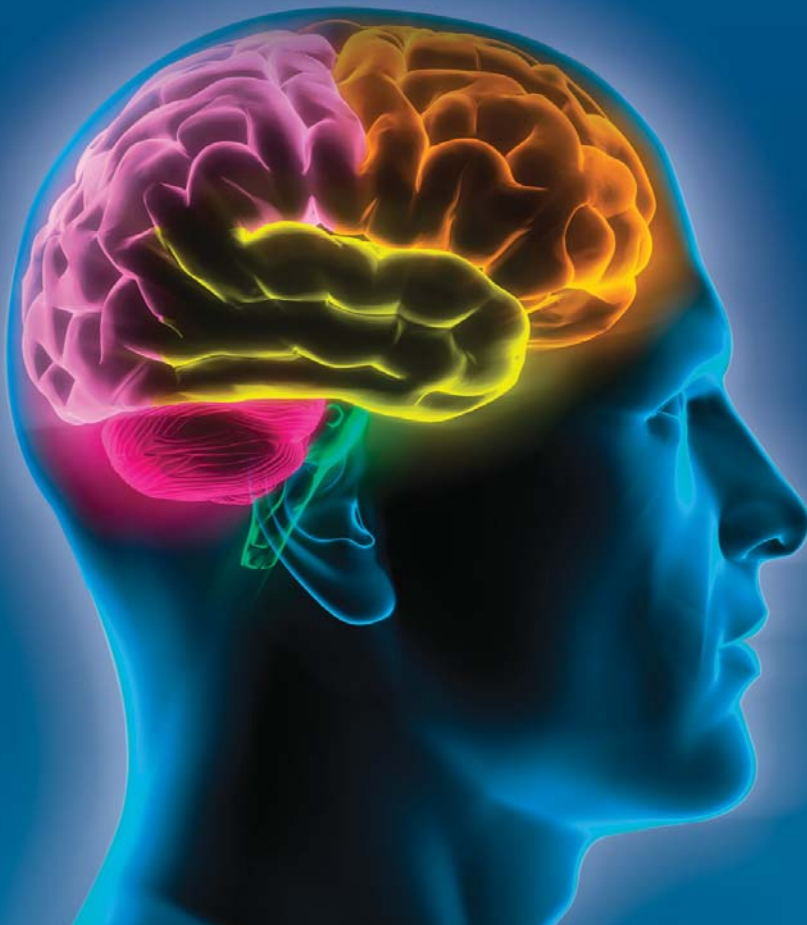


# BRAIN

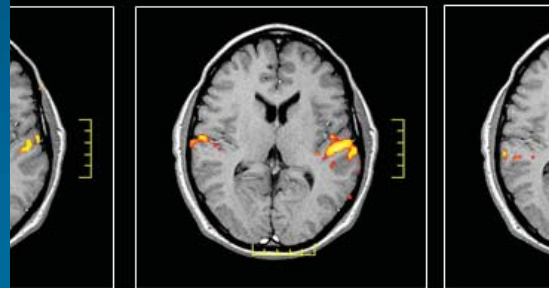
## The Inside Story



EDUCATOR'S GUIDE [amnh.org/education/brain](http://amnh.org/education/brain)



Jazz Music



### INSIDE

- Suggestions to Help You **Come Prepared**
- **Essential Questions** for Student Inquiry
- Strategies for **Teaching in the Exhibition**
- **Map** of the Exhibition

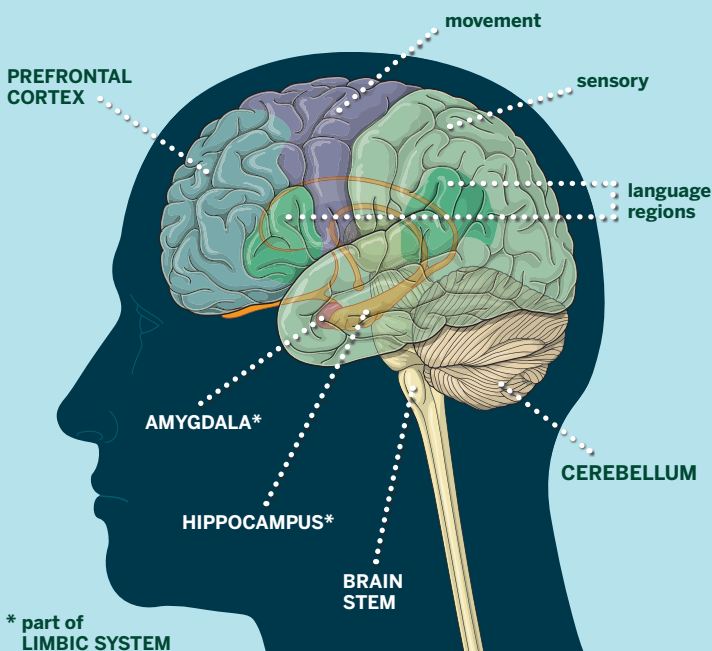
- **Online Resources** for the Classroom
- Correlation to **Standards**
- **Glossary**

# Essential QUESTIONS

Step into your brain. This exhibition explores how neurons communicate; how the brain processes sensory information, emotions, and behaviors; how the organ evolved in vertebrates; and what makes each human brain unique. **Use the Essential Questions below to connect the exhibition's themes to your curriculum.**

## What is the brain and why is it important?

The brain is our most complex organ. It connects us with the outside world, makes thinking possible, and allows us to survive. The hub of our **nervous system**, the brain weighs about 1.4 kg (3 lbs) and contains around 100 billion **neurons** and other cells that support their function. Main regions of the brain include the **brain stem**, **cerebellum**, **limbic system**, and **cortex**. These different regions interact to process everything you experience about yourself and the world.



## How does your brain work?

Communication between neurons is the basis of all brain function. Neurons send and receive messages throughout your nervous system, across an immensely complex network: from your body to your brain, within your brain, and from your brain out to your muscles and organs. Although you look with your eyes and listen with your ears, it's your brain that interprets sensory information, enabling you to see and to hear. A single neuron can launch as many as 1,000 signals per second. These **electrochemical** signals shoot from one neuron to another through a connection called a **synapse**. When a signal reaches a synapse, it triggers the release of chemical messengers called **neurotransmitters** that link up with the next neuron and trigger the next signal. When impulses travel repeatedly across the same neurons — when we repeat an experience, for example — it reinforces the electrochemical pathway. The stronger specific pathways become, the better you get at things like solving Sudoku, playing the piano, or remembering names.

## How does your brain grow and change over time?

Your brain continues to change throughout your life. At birth the basic structures for sensing, moving, and thinking are in place, and most neurons have already formed. The total number doesn't change much over a lifetime. But the number of connections between them does. As we go through life, especially during childhood and adolescence, we generate many more connections, as many as 100 trillion in all. Unused connections are pruned, making the network ever more efficient. Because brains are shaped by individual experiences (scientists call this **plasticity**), no two brains are exactly alike. Brains can often recover after serious damage. In brains damaged by strokes, for example, healthy regions may take on lost functions so the person can walk or talk again. Late in life, brain cells start to deteriorate, although physical and mental activities can help stave off decline.

## How does the brain vary across different organisms?

Many organisms (like plants, bacteria, and animals such as jellyfish) don't have brains. All **vertebrates** do. The parts of the brain that humans share with reptiles and birds control breathing, heartbeat, movement, and other bodily functions. The limbic system in the brains of mammals supports more complex behavior and social relations, as well as emotions like fear, rage, and desire. Primates (including humans) recognize facial expressions, communicate, and maintain complex social relationships using an area of the brain called the **prefrontal cortex**, which is far larger than in other mammals of the same size. In addition to what we share with lizards and other mammals, the human brain has an especially well-developed prefrontal cortex, which enhances, for example, our ability to predict consequences and to think symbolically.

## How do we study the brain?

Until fairly recently, most of what we knew came from looking at the brains of people who had died, observing the behavior of people with brain injuries, or studying animal brains. Since the 1970's, new technologies (see insert) have emerged that image the living brain, enabling researchers to observe which regions are active during different experiences, from gambling to hearing music. At the same time, scientists have learned how to sequence genomes, and more about how genes, drugs, and neurotransmitters work. These discoveries are improving our ability to repair, and even enhance, brain function.

# GLOSSARY

**brain stem:** all information to and from the rest of the body passes through the brain stem, which controls breathing and heartbeat and plays a vital role in attention and arousal.

**cerebellum:** the region involved with coordinating complex voluntary muscular movement, balance, and posture

**cognitive:** related to conscious intellectual activity, such as reasoning, imagining, or memorizing

**cortex:** thin outer layer of the brain that helps mammals process sensory information and make decisions. In humans, an expanded cortex makes complex thought and reasoning possible.

**electrochemical:** involving both electrical and chemical processes. In the brain, neurons communicate across synapses when chemical signals called neurotransmitters trigger reactions in the cell that change the electrical properties of the next cell.

**limbic system:** a set of brain structures present in mammals that help generate emotional responses, motivations, and memory, particularly ones related to survival.

**nervous system:** a branching network of neurons that sends, receives, and processes nerve signals throughout the body. Organs and muscles rely upon these impulses to function.

**neurons:** key building blocks of the nervous system responsible for processing and transmitting electrical and chemical information. These cells have long, slender extensions that can connect to other neurons or muscle and gland cells.

**neurotransmitters:** chemicals released by a neuron to transmit signals across a synapse to another cell

**plasticity:** the ability of the brain to change in response to experience by forming new neuronal connections. This allows it to learn and compensate for injury or disease.

**prefrontal cortex:** the front of the cortex, responsible for complex cognitive behaviors, including mediating conflicting thoughts, evaluating decisions, and predicting future events

**synapse:** connection point where one neuron communicates with another

**vertebrate:** any member of the large group of animals that possess a backbone or spinal column, such as lizards, mammals, birds, and fish

## Come Prepared

**Plan your visit.** For information about reservations, transportation, and lunchrooms, visit [amnh.org/education/plan](http://amnh.org/education/plan).

**Read the Essential Questions** in this guide to see how themes in *Brain: The Inside Story* connect to your curriculum. Identify the key points that you'd like your students to learn from the exhibition.

**Review the Teaching in the Exhibition section** of this guide for an advance look at the objects, models, and interactives that you and your class will be encountering.

**Review the activities and student worksheets** in this guide. Designed for use before, during, and after your visit, these activities focus on themes that correlate to the NYS Science Core Curriculum:

- Sensing our Environment (grades K–5)
- Senses and Survival (grades 6–8)
- Brain and Neurons (grades 9–12)

Decide how your students will explore *Brain: The Inside Story*. Suggestions include:

- You and your chaperones can facilitate the visit using the **Teaching in the Exhibition** section of this guide.
- Your students can use the **student worksheets** to explore the exhibition on their own or in small groups.
- Students, individually or in groups, can use copies of the **map** to choose their own paths.

## Correlations to National Standards

Your visit to the *Brain: The Inside Story* exhibition can be correlated to the national standards listed below. See the end of this guide for a full listing of New York State standards.

### Science Education Standards

**All Grades** • A1: Abilities necessary to do scientific inquiry  
• A2: Understanding about scientific inquiry • G1: Science as a human endeavor • G3: History of Science  
**K–4** • C1: Characteristics of organisms • C2: Life cycles of organisms • F1: Personal health  
**5–8** • C1: Structure and function of living systems • C3: Regulation and behavior • E2: Understandings about science and technology  
• F1: Personal health • F5: Science and technology in society  
**9–12** • C1: The cell • C3: Biological evolution • C6: Behavior of organisms • E2: Understandings about science and technology  
• F1: Personal and community health • F6: Science and technology in local, national, and global challenges

# Teaching in the EXHIBITION

**Brain: The Inside Story** uses objects, models, games, interactives, videos, and more to explore how the most complex organ in the body has evolved, how it works, and how it makes us human. This guide divides the exhibition into five areas, which correspond to the map and to the text below.

## Look up!

As the class enters the exhibition, students will see **a sculpture overhead with moving beads of light**. Explain that the lights represent the electrochemical signals that race across an incredibly complex network inside our brains — so that we can think, feel, and move.

## 1. Your Sensing Brain

Everything we know about the world comes to us through our senses. This part of the exhibition investigates how the brain creates meaning from the flood of sensory data. This is how we understand what we see, hear, touch, smell, and taste.

### GUIDING QUESTION

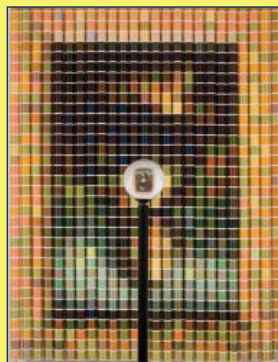
How do our brains integrate information from the outside world?

*(Answer: Specific areas of the nervous system (senses) are devoted to seeing, hearing, smelling, tasting and touching. They translate physical information like light and pressure into sensory signals that can be carried by neurons to the brain. The brain interprets all that sensory information, which allows us to make sense of the world around us.)*

### GUIDED EXPLORATION

#### Look (thread installation):

Invite students to look at this artwork, guess what it represents, then look through the glass for a different view. Ask what they first saw. When did the colors and shapes snap into an image? Then explain that in some ways, this experience is like what happens in the brain when we see. Ask what this suggests about the way vision works.



*(Answer: Vision involves more than our eyes, and more than the passive reception of light. We also draw on parts of the brain and on what we already know about the world to help interpret and understand what we see.)*

**Listen (rainy scene):** Have students guess what sound they're hearing, then check their answers on the next panel. Ask them if their brains perceived the sound and image as two separate things, or tried to connect them. What does this experience demonstrate about the senses?

*(Answer: Your senses are interconnected, so you experience the world as a unified whole. Because the brain is always building a unified perception from packets of incomplete information, it is easily tricked.)*

**Connect (Kiki & Booba shapes):** Suggest that students compare the two models and consider why our brains match sound and shape the way they do. Tell students that this capacity is remarkably consistent across cultures and languages. Ask them what they think this tells us about the brain.

*(Answer: People often connect sights, sounds and other sensations that have similar qualities, in this case the sound of the name assigned to objects of distinct shapes. Some researchers consider this tendency a mild form of synesthesia, a rare type of sensory blending in which people taste words, feel flavors, or see sounds as colors.)*

## 2. Your Emotional Brain

Here the exhibition examines the importance and evolutionary roots of emotions across animals. Emotions evolved and are expressed in much the same way among all mammals. Humans have an especially large prefrontal cortex, which gives us the ability to think about our emotions before we act on them.

### GUIDING QUESTIONS

How are our emotional responses like or unlike those of other animals? What kinds of events trigger which emotions — and what kinds of responses?

*(Answer: Basic emotions such as fear, anger, joy, separation distress, etc., are similar in all mammals and expressed in much the same way. Fear is the brain's way of alerting us to danger; anger prepares us to fight; a loss makes us feel sad; we're happy when we feel safe and loved. Responses to those emotions are behaviors such as smiling, snarling, and crying, which help humans communicate what they're feeling.)*

## GUIDED EXPLORATION

**Evolving Emotions:** Have students compare and contrast the brains of a sea snail, iguana, raccoon, macaque monkey, and human. What does the brain of each species allow it to do? How do emotions help organisms survive?

*(Answers may include: Emotions tell us how important things are, whether our needs are being met and what we want to do about it. Ultimately, all emotions motivate organisms to do things that promote survival and reproduction, like finding shelter and seeking companionship. Evolution does not go “up” towards humans. It goes “out” in many directions. All organisms are equally capable of gathering information about their environment and bodies, and respond accordingly to allow the survival of the individuals and ultimately the species.)*

**Build a Brain:** As students assemble the components of the human brain, ask them to observe what key structures are shared by other animal species. What is unusual about the human brain, and what does it allow us to do?

*(Answers may include: An expanded prefrontal cortex is unique to humans. It allows us to choose between conflicting impulses, predict consequences, relate past and present, and regulate emotions in favor of reaching a balance between our thinking and emotional brains.)*



**How Do You Feel?:** Have students explore this interactive to find out how levels of different neurotransmitters rise and fall during specific emotional states.

*(Students may observe: At any given moment, various chemical messengers, or neurotransmitters, activate or inhibit specific the activity in regions of your brain. By layering these chemical signals on other signals, your brain can adjust how you respond to things—including by putting you in different moods.)*

## 3. Your Thinking Brain

In humans, the cortex has evolved to produce much more complicated thought than in other animals. This part of the exhibition explores three different capacities of the human brain that are essential to the way we think: language, memory, and reasoning — or what scientists call executive function.

*(Answers may include: The human brain has an especially developed prefrontal cortex that enhances abilities like predicting consequences and thinking symbolically.)*

### GUIDING QUESTIONS

Have you ever wondered how you think? Or about the fact that only a human could ask that question?

### GUIDED EXPLORATION

This “walk-through brain” shows how different parts of our brain contribute to language, memory, and reasoning (such as planning, problem-solving, and decision-making). Have students explore the variety of “brain games,” puzzles, and activities in each section below.

**Language section:** Ask students how many languages they speak. What does learning a foreign word involve? Why is it easier for very young kids to learn a new language?

*(Answers may include: The human brain is built for language, but languages must still be learned. At birth your brain is capable of learning any language, and the language regions are most flexible during childhood.)*

**Memory section:** Have students identify different kinds of memory and point to which areas of their brains are involved. Ask them to pick one of those kinds of memory and to share an example from their own lives.

*(Answers may include: Types of memory include short term, or working memory (used when recalling something like a phone number or address), which is stored in the prefrontal cortex; long-term memory (for the sights and sounds of an event that happened years ago, for example), which is stored in the hippocampus; procedural memory (for activities like tying your shoes), which involves structures deep within the brain called basal ganglia; and emotional memory (of highly emotional events), which is stored in the amygdala.)*

**Reasoning section (Focus & Plan Ahead):** First, have students look at the two columns of colored words. Ask them to say the *color* of the words in the left column, then the column on the right, and to compare the results. Then, invite students to play the stacking game. Have them plan their moves in advance and then complete the game. Ask them what makes stacking the blocks difficult? What parts of the brain are involved in this kind of planning?

*(Students may observe: In the Word-Color test, one region of the brain identifies the meaning of the word, another the actual color seen, and yet another recognizes the conflict. The region that recognizes the conflict informs the thinking brain and this helps you to focus your attention on the color alone.)*

*The stacking game is a classic test of executive function because it involves thinking spatially, using logic, and controlling movement. Thanks to the executive centers at the front of your brain, you can imagine different strategies, evaluate them and choose the best one—all before making a move.)*

A	B
orange	yellow
green	blue
black	orange
blue	black
red	red
purple	green
yellow	purple

Name the **colors** of the words (don't read them!).

Most people take longer to complete column B than column A. When the words and colors conflict, the brain must struggle to ignore competing information.

## 4. Your Changing Brain

Even though all human brains share the same structure, no two are exactly alike. This section explains how the things we do (meditate, ride a bike, play piano) change our brains by making neural connections. We can strengthen those connections by repeating the actions. Certain types of learning are easier at specific developmental stages, but learning never stops.

### GUIDING QUESTIONS

From birth to old age, how does the brain develop? How can we keep it working as well as possible as we grow old?

*(Answers may include: At birth most neurons have already formed. As we go through life we generate many more connections between neurons, while unused connections are pruned. Physical and mental activities can help stave off decline in late life.)*

### GUIDED EXPLORATION

**Growing:** Ask students to find themselves on this timeline and describe what's going on in their brains at their stage of development. What will be different in a few years?

*(Answers will vary depending on age of student. There are spurts in brain growth during childhood and adolescence. The neuronal paths connecting different parts of the brain are shaped by different activities, from kicking a ball to conjugating verbs to practicing yoga.)*

**Living and Aging:** Ask students to consider what makes each human brain unique. How do they think their hobbies and habits have shaped their brains, and how do they hope to sharpen them in the future?

*(Answers may include: Because your brain changes every day, forming new connections as you learn and react to the world, no two brains are alike. Each has different strengths, which depend on how you use it.)*

**Brain Training:** Have students play these brain-building exercises. What changes do they observe in their reaction times? Can they explain what's happening in their brains to make this possible?

*(Answers may include: Every experience leaves its mark in the brain, as signals race down pathways from neuron to neuron. When you remember or repeat the experience, signals retrace and reinforce those pathways.)*

## 5. Your 21st-Century Brain

Therapies ranging from drugs to surgery are already altering our brains, and new technologies are in the pipeline. This part of the exhibition discusses the way technologies are changing how we diagnose and treat disease, and presenting us with challenging decisions.

### GUIDING QUESTION

How are new insights into brain function allowing us to repair — even enhance — the brain?

*(Answers may include: New medications, stem cell research, genetic modification, digital implants, and other biological research have the potential to repair brain damage from stroke and Alzheimer's disease, eliminate pain, reduce the need for sleep, control appetite, improve memory, increase creativity, replace lost senses, and prevent aging.)*

### GUIDED EXPLORATION

**New therapies and ethics section:** Ask students which of these new technologies they find the most surprising. What do they think about using these tools to repair brain function? How about to enhance it? Would they want to install computers in their brains if they could? How about connecting their brains to the internet?

*(Answers may vary and open to a rich discussion on issues such as the incredible advances of technology and science; our cultural belief that technology can fix everything; and the ethical question of whether being able to do something implies we should do it).*

**“Brain lounge”:** Seat students in a circle around this projection to watch the brain in action. Have them observe and think about which areas are involved in different activities, like playing the cello or shooting hoops.

*(Answers may include: The simultaneous translator uses both sides of her brain, instead of only the left side. The basketball player uses the parts of the brain that have to do with motor planning and coordination, but also language syntax and self-reference and self-correction. The cello player, besides using the auditory and visual cortexes, uses the language cortex and the part related to the integration of patterns and sensory signals. The guitar player, besides using the auditory cortex, uses the parts related to self-correction and self-reference.)*

# Online RESOURCES

## **Brain: The Inside Story Exhibition Website**

[amnh.org/brain](http://amnh.org/brain)

Access featured videos, interactives, photo galleries, and more from the exhibition.

## **Brain: The Inside Story for Educators**

[amnh.org/education/brain](http://amnh.org/education/brain)

This website lists all exhibition-related resources and tips on planning your visit.

## **Brain OLogy**

[amnh.org/ology/brain](http://amnh.org/ology/brain)

Games, puzzles, and activities help kids explore how the brain enables us to think and move.

## **Science Bulletins**

[amnh.org/sciencebulletins](http://amnh.org/sciencebulletins)

Check out the Human Bulletin for recent discoveries about neuroanatomy, symbolic thought, and the wiring and evolution of the human brain.

## **Neuroscience for Kids**

[faculty.washington.edu/chudler/neurok.html](http://faculty.washington.edu/chudler/neurok.html)

This searchable site for middle- and high-school students combines science basics with new discoveries in brain research, experiments, and lesson plans for teachers.

## **Brain Atlas**

[brainexplorer.org/brain\\_atlas/Brainatlas\\_index.shtml](http://brainexplorer.org/brain_atlas/Brainatlas_index.shtml)

This illustrated atlas explains brain anatomy, how it works, and current knowledge about a range of brain disorders.

## **The Brain from Top to Bottom**

[thebrain.mcgill.ca/flash/index\\_d.html](http://thebrain.mcgill.ca/flash/index_d.html)

Browsable by module and topic, high-school students can explore the brain from synapse to social constructs.

## **Charlie Rose: The Brain Series**

[charlierose.com/view/collection/10702](http://charlierose.com/view/collection/10702)

In each episode of this PBS monthly series, a panel of experts discusses a different aspect of brain function and research.

## **Society for Neuroscience: NERVE**

[ndgo.net/sfn/nerve/](http://ndgo.net/sfn/nerve/)

This regularly updated site provides information and tools for teachers. Searchable by grade level, topic, and keyword.

## **Society for Neuroscience: Brain Facts**

[sfn.org/index.aspx?pagename=brainFacts](http://sfn.org/index.aspx?pagename=brainFacts)

Aimed at high-school students and teachers, this free downloadable book is a primer on the brain and nervous system.

## **Brain Busters**

- **Half a million neurons** form every minute during the first five months in the womb.
- **The brain of a medium-sized dog** weighs around 3 ounces (80 g), the same as a small kiwifruit.
- **A one-year-old child's brain** weighs about 2 pounds (950 g), ten times the size of the average dog's brain.
- **The primate cortex** is so large that it has to be folded to fit inside the skull. That's why the surface of the brain is wrinkly.
- **Plants** have no nerves and no brain.
- **Some animals**, like earthworms, snails, and spiders, have nerves but not actual brains.
- **The nervous system runs on electricity**, but the levels are low. Brain signals involve less than one-tenth the voltage of an ordinary flashlight battery.
- **Some messages shoot through the nervous system faster than others.** When you pet a fluffy dog, one signal races from your fingertip to your brain in 10 to 20 milliseconds, letting you know she is soft. Another signal reaches your brain a few milliseconds later, telling you she is warm.
- **The longest neuron** in the animal kingdom goes all the way down the giraffe's neck.

## **CREDITS**

**Brain: The Inside Story** is organized by the American Museum of Natural History, New York ([www.amnh.org](http://www.amnh.org)), in collaboration with the Guangdong Science Center, Guangzhou, China; and Parque de las Ciencias, Granada, Spain.

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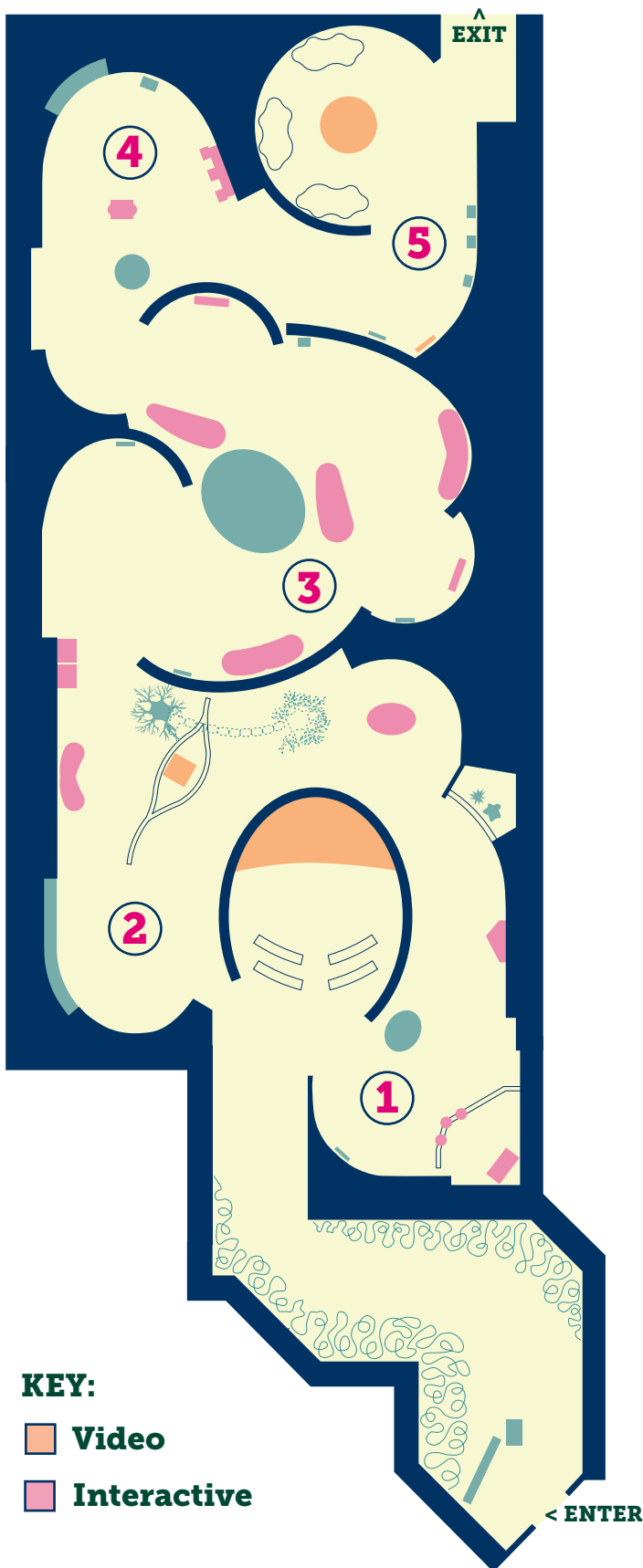


## **Photo Credits**

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# BRAIN: The Inside Story



## Map of the Exhibition

*Brain: The Inside Story* uses objects, models, games, interactives, videos, and more to explore how the most complex organ in the body has evolved, how it works, and how it makes us human.

### 1. Your Sensing Brain

Everything we know about the world comes to us through our senses. This part of the exhibition investigates how the brain creates meaning from the flood of sensory data. This is how we understand what we see, hear, touch, smell, and taste.

### 2. Your Emotional Brain

Here the exhibition examines the importance and evolutionary roots of emotions across animals. Emotions evolved and are expressed in much the same way among all mammals. Humans have an especially large prefrontal cortex, which gives us the ability to think about our emotions before we act on them.

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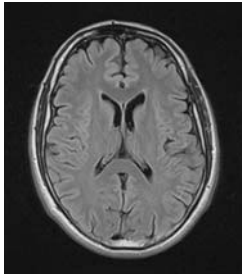
### 5. Your 21st-Century Brain

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# BRAIN: The Inside Story

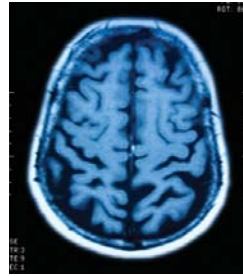
## Brain Imaging Technology

Explore some of the technologies that enable us to image the living brain and observe it at work.



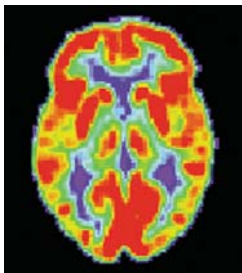
### CAT or CT

**Computerized axial tomography** scans are a series of x-rays of the skull taken from many different directions. CAT scans generate cross-sections of the brain that show its structure in detail.



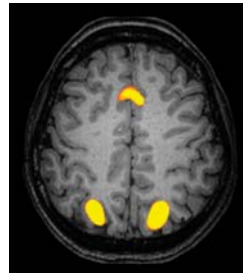
### MRI

**Magnetic resonance imaging** uses magnetic fields and radio waves to produce highly detailed 2- or 3-D images of internal organs.



### PET

**Positron emission tomography** was the first technique to capture brain activity. Scans measure emissions from radioactive chemicals injected into the bloodstream, producing 2- or 3-D images that reflect the amount of activity in various brain regions.

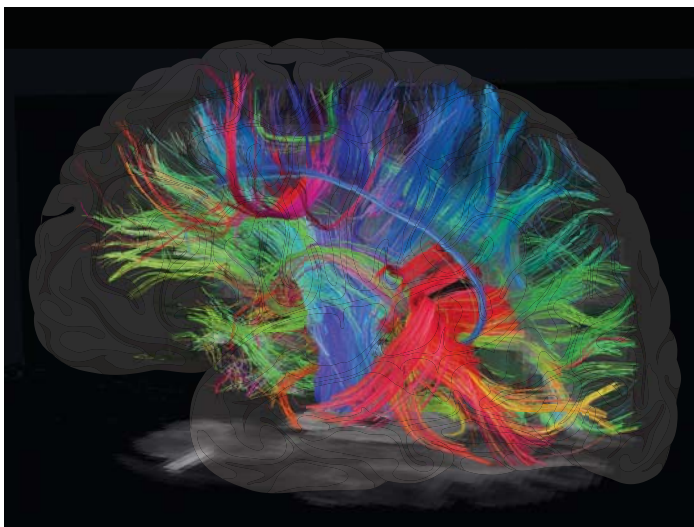


### fMRI

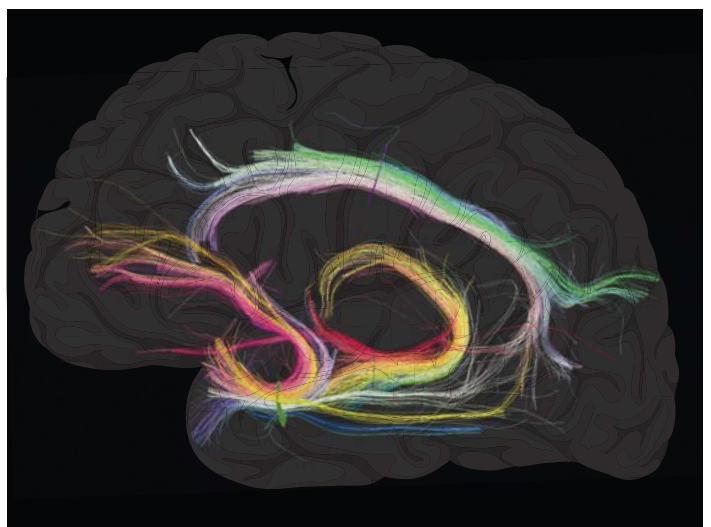
**Functional magnetic resonance imaging** is a special type of MRI that images changes in blood flow to specific areas of the brain as the subject performs a specific task. fMRI scans provide both an anatomical and a functional view of the brain.

### DSI

**Diffusion spectrum images** use magnetic resonance to track the movement of water molecules along nerve fibers. DSI images show multiple pathways in 3 dimensions, giving researchers a more complete picture of the brain's internal communication network.



The brain's outer layer, the cortex, is crucial for thinking — but it does not work alone. This DSI scan reveals the countless connections between the cortex and subcortical regions. While many different regions are involved in thinking, the connections between these regions are equally important.



In this DSI scan, looping bundles of fibers connect the regions of the limbic system, including the amygdala, hippocampus, and other areas. These brain parts are referred to as a single "system" because of the communication pathways that link them together.