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Your Brain

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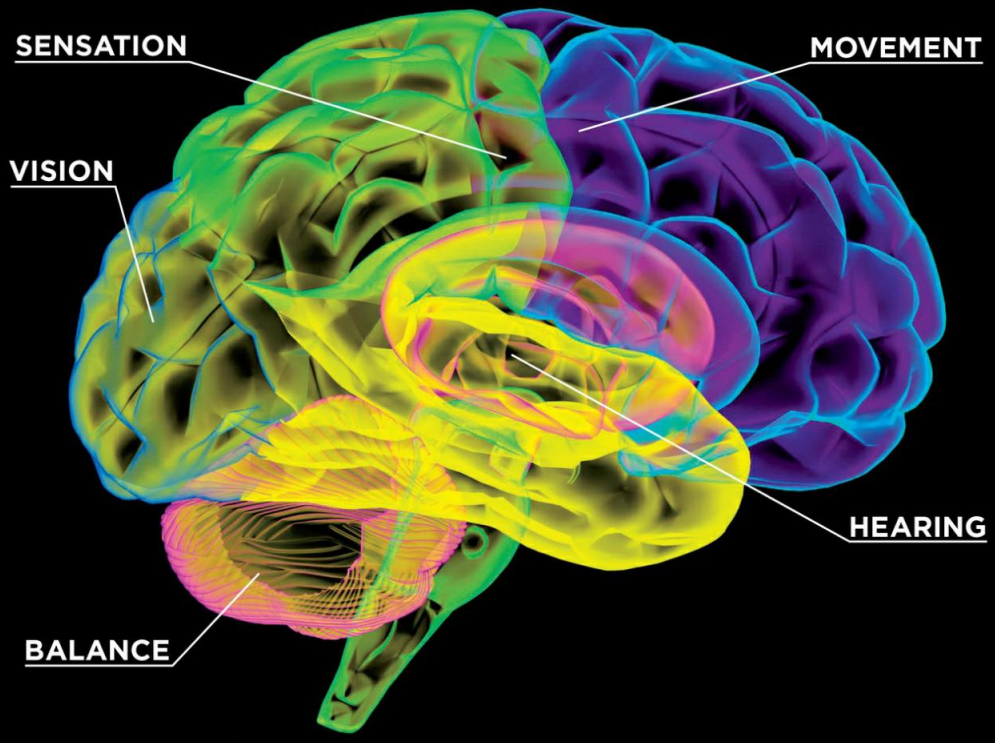

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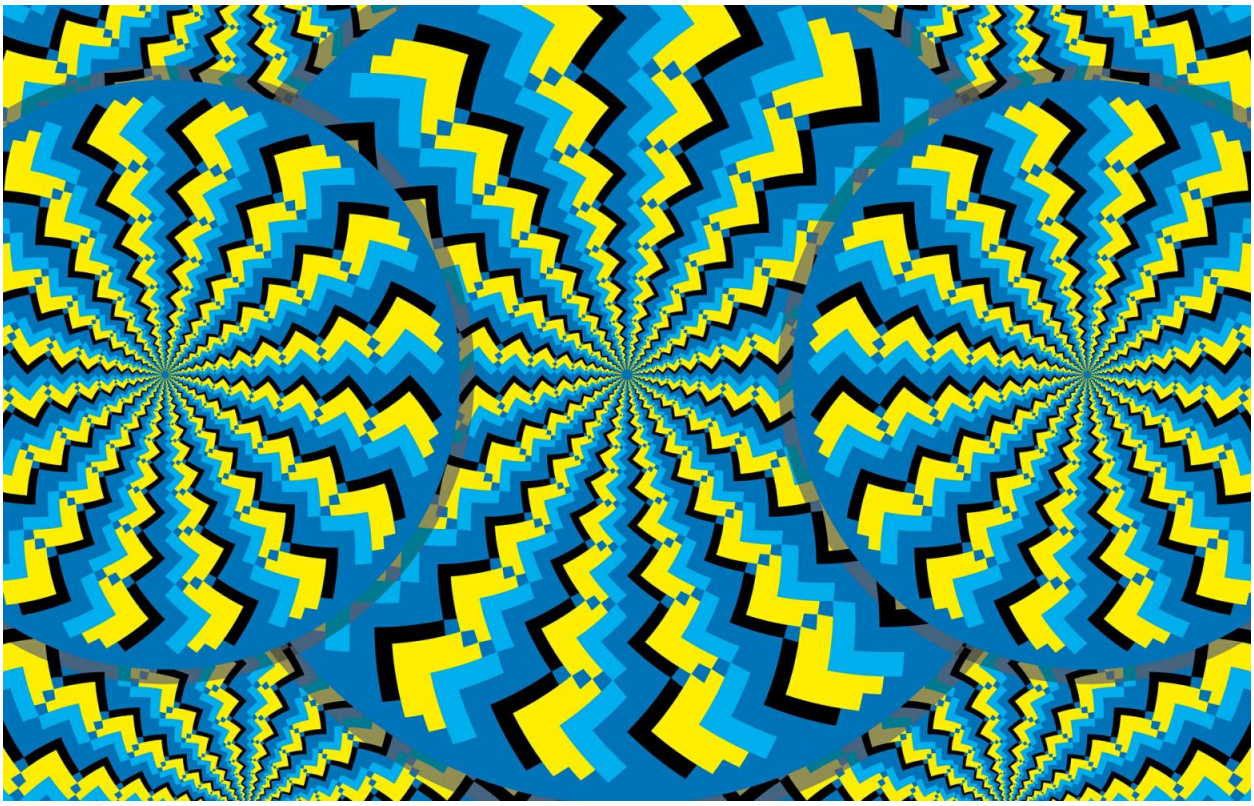
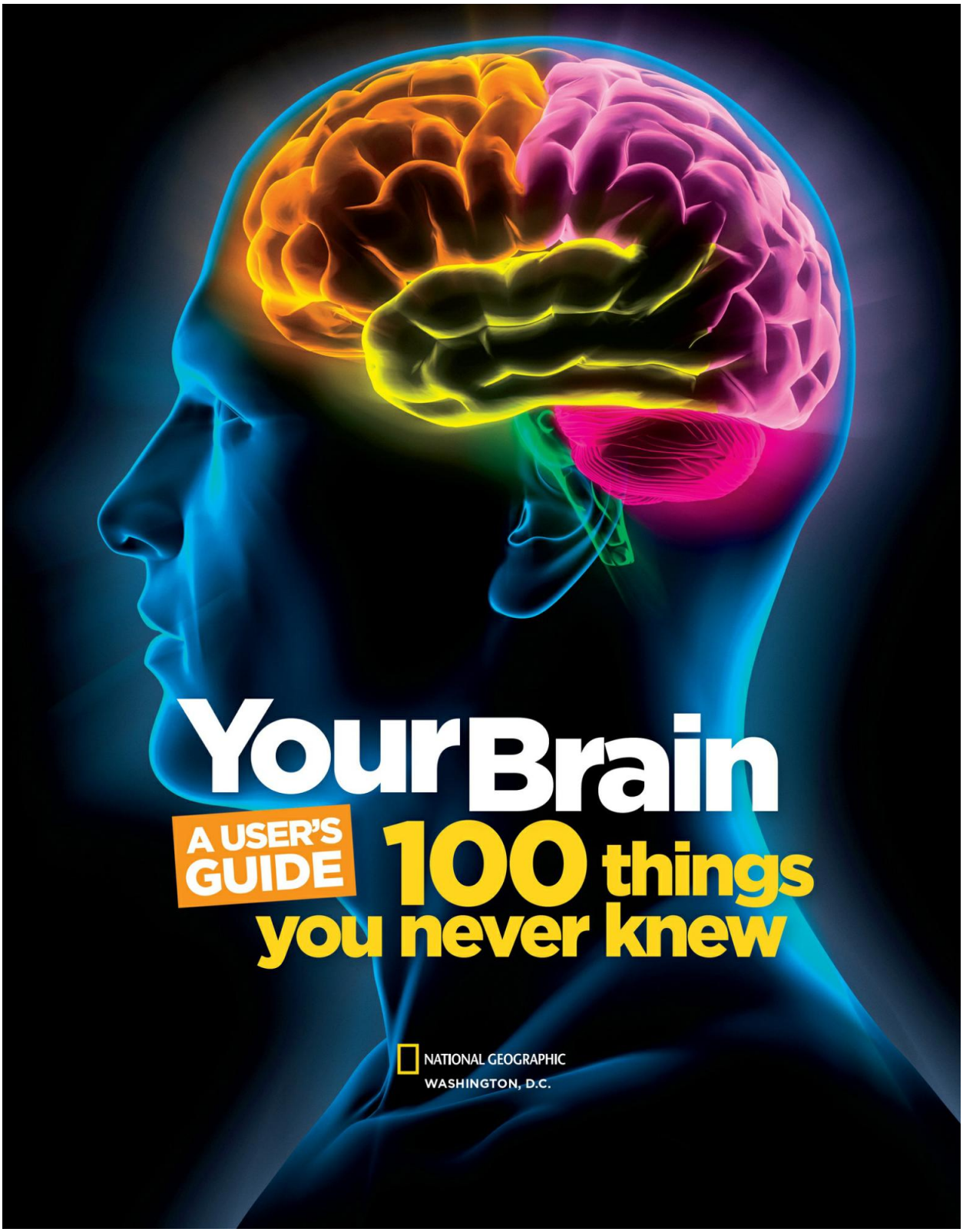


Zigzag disks appear to move, thanks to afterimages of complementary colors in our peripheral vision. Credit 2

Mirror Image

Studies of identical twins have shown that mental abilities are largely hereditary.

Credit 3


Your Brain
A USER'S GUIDE
100 things you never knew
NATIONAL GEOGRAPHIC
WASHINGTON, D.C.

Credit 1

YOUR BRAIN: A USER'S GUIDE

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CONTENTS

the aging brain

Your brain changes steadily as you age, but mental and physical exercise help maintain a healthy brain.

illustrations credits

Credit 4

1 did you know...

Different parts of the brain are responsible for counting (“how many”) and volume (“how much”).

2 did you know...

A specific kind of brain damage results in people being able to

recognize, but not name, other people.

Credit 5

3 did you know...

Some sensory memories last just a fraction of a second.

4 did you know...

About one in four people is a "supertaster," much more sensitive than others to

unpleasant tastes.

Mind Reader

A college student is wired for an encephalograph. Encephalographs have shown that the brain initiates action before the conscious mind is aware of it. Credit 6

your brain and your mind

The brain should need no introduction. After all, the brain is what makes you *you*. But it's a paradox that the organ that lets you understand the world understands so little about itself. Now, thanks to stunning research building upon decades—no, centuries—of investigation, science is peeling away the layers of mystery to reveal how three pounds of flesh create an entire universe inside your head.

In this corrugated mass, a staggeringly complex symphony of electrochemical reactions plays out every second of every day. Much of it does so without a conscious conductor. The brain makes the lungs expand with the inrush of air and the heart pump blood. It houses memories, processes sounds and sights, smells and tastes, and feelings ranging from the subtle to the sublime.

Beyond the work the brain does automatically comes something far different. Out of the human brain arises

consciousness and the mind—the unique ability of *Homo sapiens,* "thinking man," to be aware of being aware.

experiment

Who's in control?
Seeing is believing

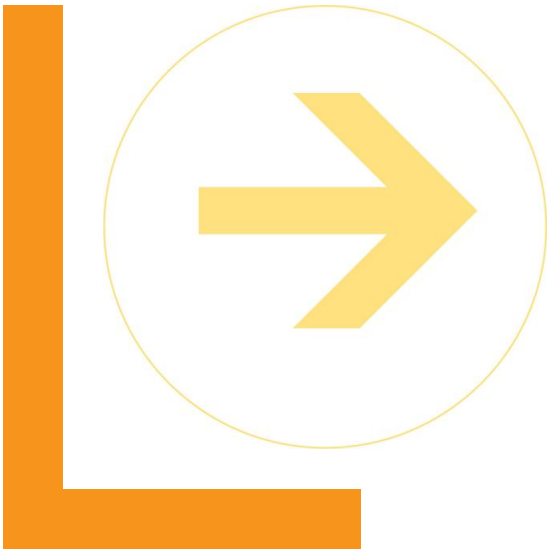
Credit 7

Step 1.
Place your index finger on the image of the button here.

Step 2.
Count backward from five to zero.
When you start to say the word zero, press the button.

Step 3.
Make your best guess: At what moment did your mind begin to tell your finger to move?

Then go here.



Credit 8

Quick Thinking

A fastball heads toward the plate. Do you swing? Part of your brain makes the decision, and another part explains it—and takes credit. Credit 9

what happened

Inside your brain, electrical activity associated with movement began increasing nearly a full second before your finger jerked at the word *zero*. Two German researchers, Hans Helmut Kornhuber and Lüder Deecke, demonstrated this gap in a series of experiments in the 1960s. They attached electroencephalographs to the scalps of test subjects to measure brain activity as the subjects executed simple finger movements. The researchers compared the results with recordings of muscle movement detectors called electromyographs. They found a precursor spike in the brain 0.8 second before movement. They dubbed it the readiness potential.

Kornhuber and Deecke also found a second, smaller spark of electrical activity at 0.05 second before finger movement. Unlike the broader readiness potential, it pinged through the specific motor region controlling the fingers. The two recordings together suggest a generalized

activation focusing itself into a specific action.

In the 1980s, another scientist, Benjamin Libet, conducted a similar experiment, but he added a new element: Volunteers moved a finger at will but used a clock to pinpoint the moment of conscious awareness of "wanting" to move. Strangely, that moment occurred significantly after the moment of readiness potential, but before sensors detected finger movement.

Conclusion: An unconscious part of your brain "wills" an action before you are consciously aware of your will to direct it.

5 did you know...

Masters of meditation, such as Zen practitioners, can change their brain waves.

Multitasking

Using electrochemical reactions, the brain can process a multitude of sensations at different levels of consciousness. Credit 10

The brain

The human brain and its consciousness contain many mysteries. In recent centuries, scientists have used an increasingly sophisticated variety of tools to find out what happens where—though much is left to learn.

A quick tour begins with the brain's protective structures. The crown of the skull is a collection of 22 bones that house the brain and protect it from harm. Inside, three membranes provide more layers of protection: the dura mater, the arachnoid, and the pia mater. Flowing between the arachnoid and pia membranes is the brain's cerebrospinal fluid. Fluid-filled ventricles curve deep into the brain and connect to the spinal cord's central canal. Cerebrospinal fluid cushions the brain and provides nourishment for tissues.

Parts of the brain By evolutionary reckoning, the oldest portion of the brain is its stem, which begins as an extension of the spinal cord. The brain stem controls basic physical actions necessary for survival, such as heartbeat and respiration. It is home to many sensory and motor nerves, the latter named for their function of controlling movement in muscle tissue.

Motor neurons also densely populate a second part of the brain, the cerebellum, at the back and bottom of the skull. The cerebellum coordinates precise, voluntary movements, such as

tying a shoe or playing a violin, and also plays a role in emotion. A third component, known as the diencephalon, lies in the brain's center. It controls the body's rhythms of sleeping and wakefulness, regulates involuntary actions of the nervous system such as digestion, and relays sensory stimuli to other brain regions.

6 did you know...

A fifth of your blood is devoted to supplying your brain.

A Look Inside

A magnetic resonance imaging (MRI) scan reveals the side view of a man's brain and its blood vessels. Credit 11

The brain

The cerebrum The fourth region, the cerebrum, is what most people think of when they envision the brain. It lies in two hemispheres, left and right, connected by a band of tissue called the corpus callosum. Although they look alike, the two halves perform and control very different functions. The left hemisphere has long been considered the dominant half because of its role in processing language, but the right hemisphere is gaining new attention for its role in emotions and spatial cognition, as well as the integrative function that helps bring bits of information together.

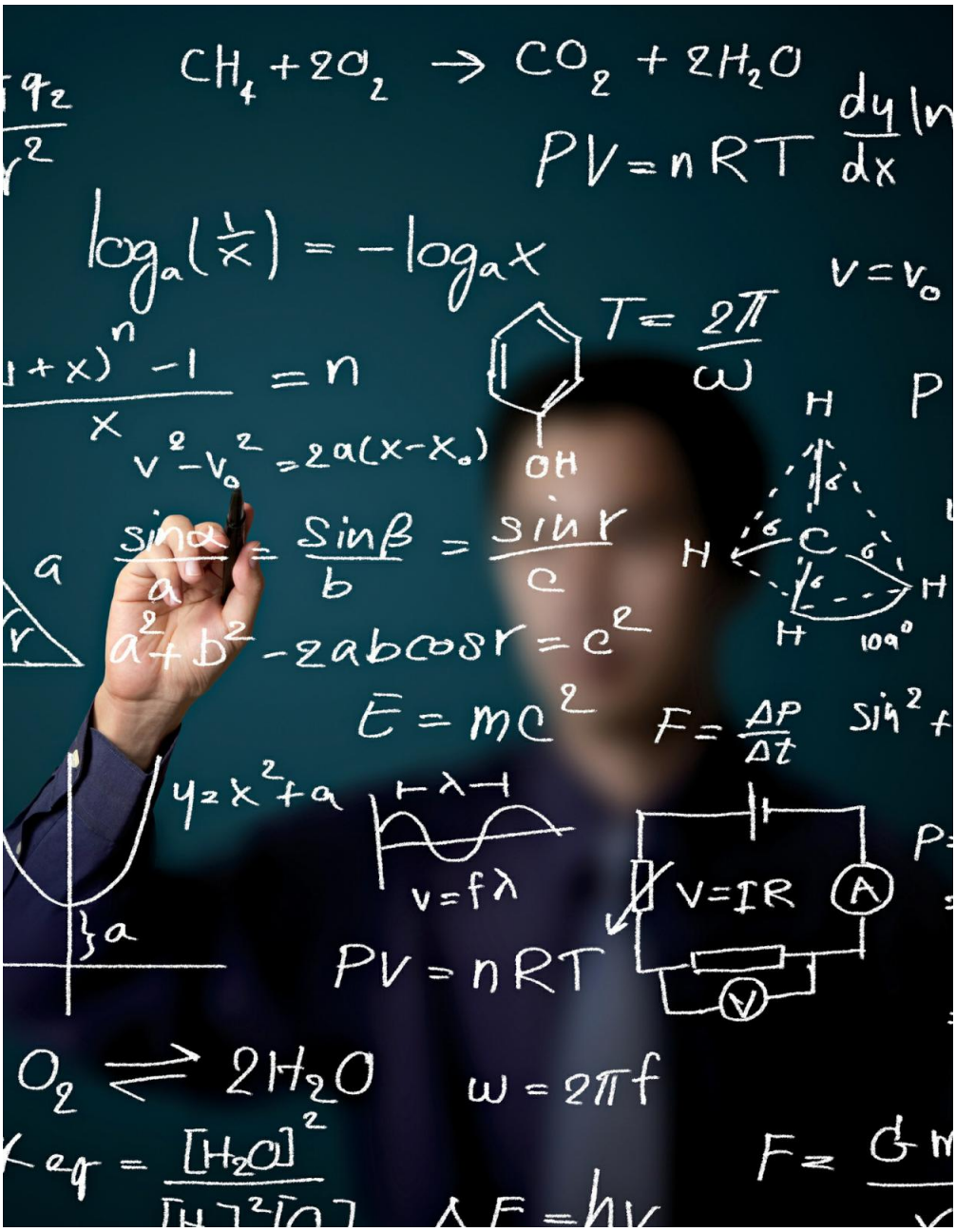
The cerebral cortex The cerebral cortex is the outermost brain layer, folded and wrinkled and resembling a squishy pink walnut. The cortex is home to the higher functions—reason, creative thinking, and language—that separate the human brain from those of other animals. The amount of neurological firepower necessary for such exploits is considerable: Of human brain mass, 76 percent lies in the cerebral cortex, a greater percentage than that of any other animal, and within the cortex lies about 75 percent of all neural connections.

The cerebral cortex processes information so that you may comprehend enough about the world to survive. Evolution and experience have molded the cortex's neural connections to favor sensory and cognitive functions that have proved successful over eons of human life. Anything that challenges your brain's time-tested circuitry, such as the experiments in this book, opens a window onto hidden depths of self-knowledge. ⦿

did you know...

Sixty percent of a dolphin's

7 brain is devoted to the cerebral cortex.



Many Variables

The brain weaves both cognitive and memory components into the complex web of learning. Credit 12

CHAPTER
ONE

the learning brain

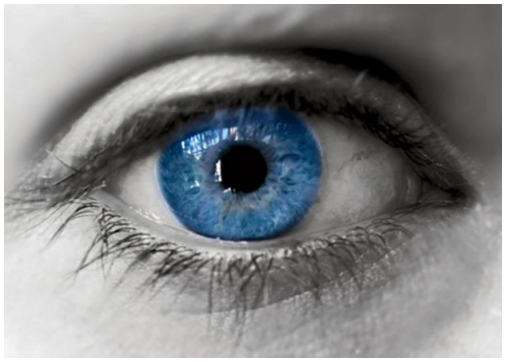
The brain constantly rewires itself to become an organ that is physically different from what it was in the preceding moment. Never resting, it churns through new experiences daily, incorporating some into its network of stored information and discarding others. The creation of memories creates personal and social identity. When disease and disorder rob the brain of memory and language, they take away what makes each person unique.

Learning and memory work together. Some learning is transformed into lasting memories; other experiences prove ephemeral. Eric R. Kandel, who received a Nobel Prize for research on the molecular foundations of memory, draws this distinction: "Learning is how you acquire new information about the world, and memory is how you store that information over time." Learning includes not just cognitive components, such as solving quadratic equations, but also motor components, such as tying a necktie in a perfect Windsor knot, and affective

components, such as feeling shame at a social faux pas.

experiment

How we read
Letter perfect

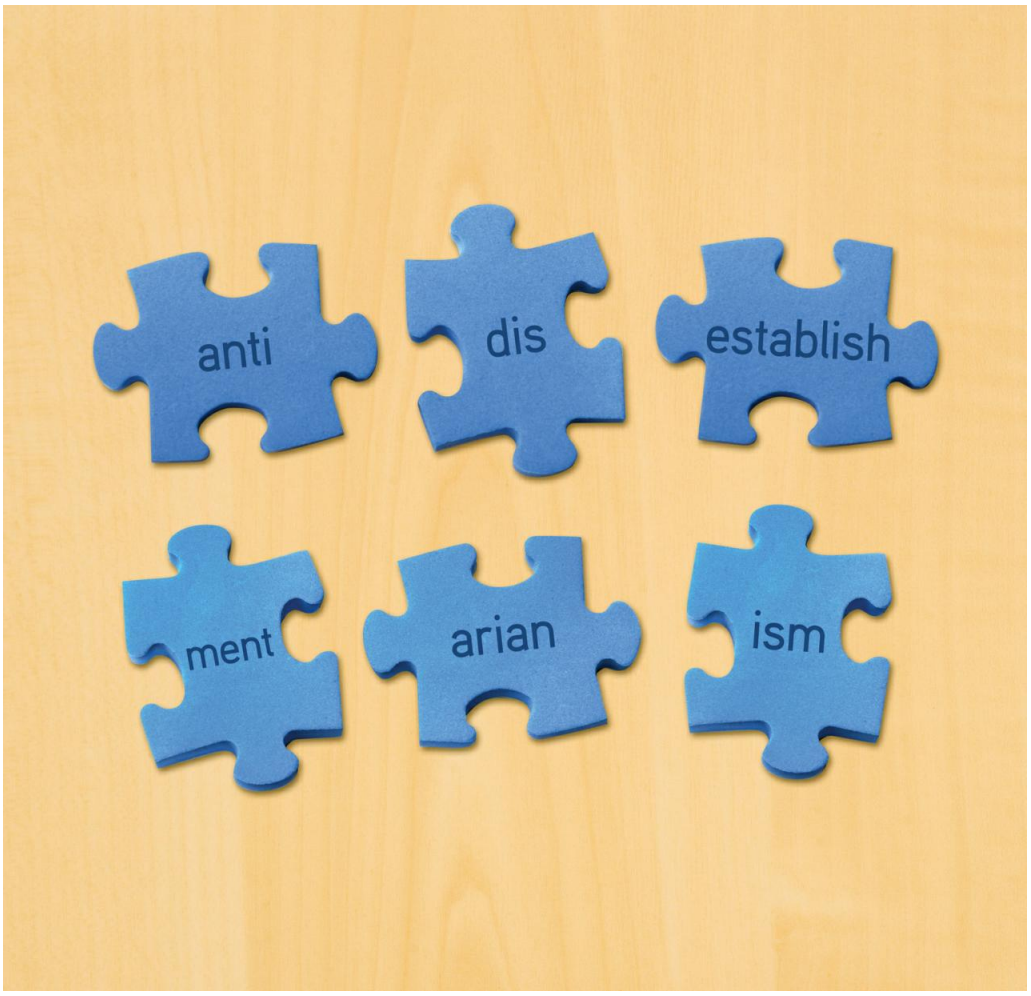


Credit 13

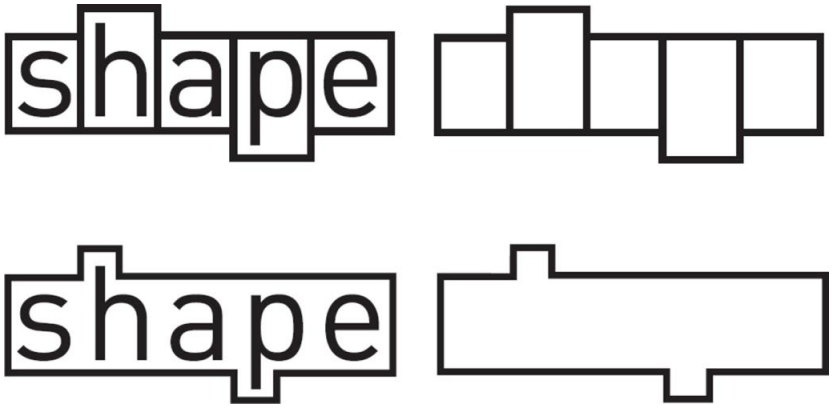
Do This:
Read the words here.

Then go here.

Aoccdrnig to a rscheearch sudty at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are; the olny iprmoetnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a toatl mses, and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.



Credit 14



Word Contours

Your brain learns to read by learning letters and groups of letters and then linking them to create meaning. Experienced readers also use context and clues such as shape and letter order to identify words. Credit 15

what happened

The text you just read is a hoax. A compelling, scalp-scratching hoax, but a hoax just the same. This scrambled paragraph circulated on the Internet in 2003. When it came to the attention of researchers at Cambridge University, they denounced the fraud. Then they explained how, although it contains a grain of truth, it also flies against linguistic research.

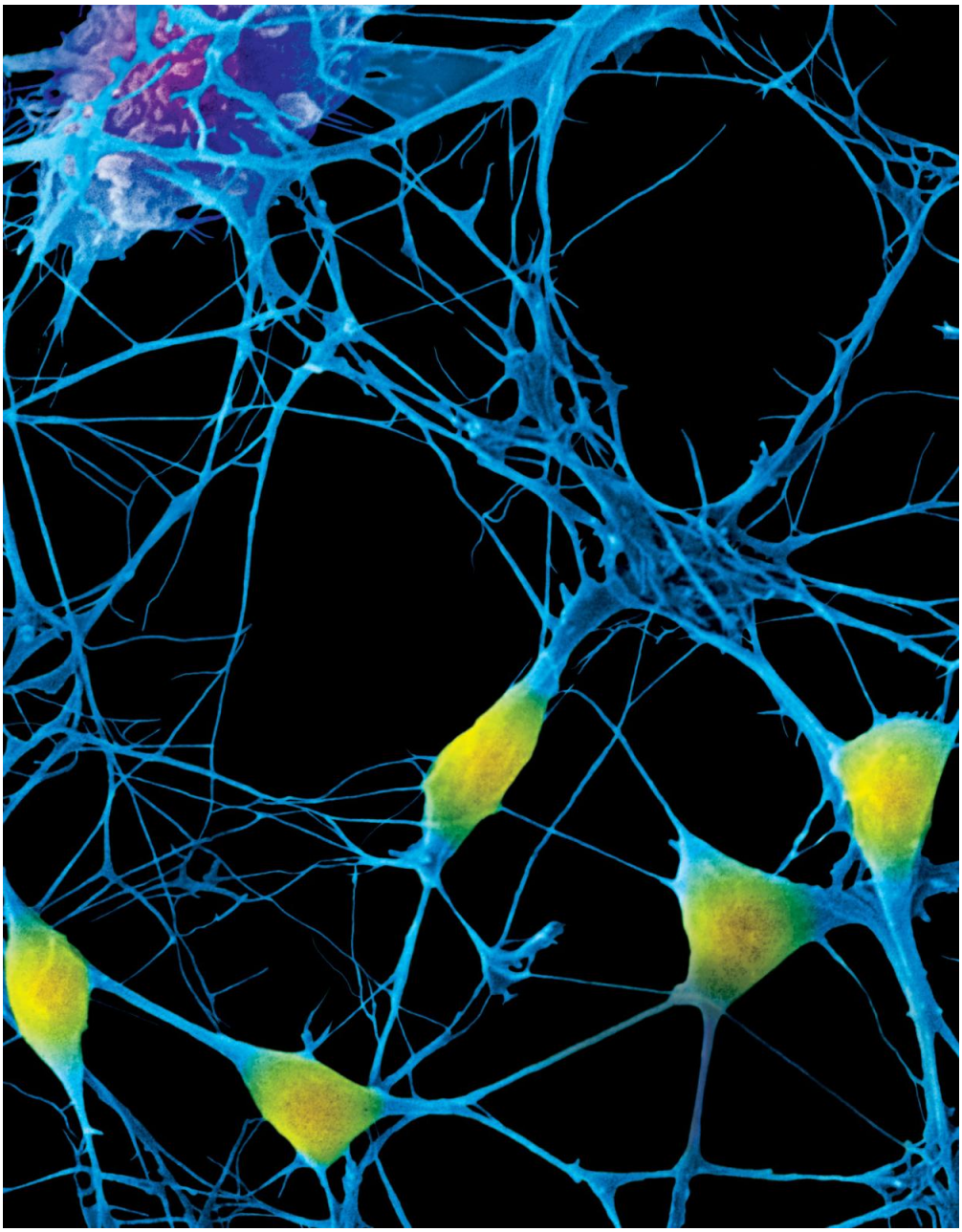
First, the truth: Shape is one variable, out of many, that the brain uses to decode printed words. James Cattell, the founder of psycholinguistics, proposed the word–shape model of reading in 1886. He flashed words and letters at test subjects for fractions of a second to test memory. Surprisingly, they recognized words, and the letters they contained, better than letters alone. Cattell concluded that their brains processed word shapes all at once. For example, the brain would recognize the word *shape* by the ascending h in the second position and the descending p in

the fourth. The brain also picks out letters more quickly in the middle of a word than in isolation.

Matt Davis of Cambridge's MRC Cognition and Brain Sciences Unit has noted that the claim about the significance of the first and last letters is false. He provides this sentence, in which words' first and last letters are intact, as a test: "A dootcr has aimttded the maglтheuansr of a tageene ceacnr pintaet who deid aetfr a hatospil durg blendur." Unscrambled, it says, "A doctor has admitted the manslaughter of a teenage cancer patient who died after a hospital drug blunder." The hoax text contains short words that were never scrambled and many words that can be guessed from context. Davis believes letter order, word shape, and context all play roles in reading.

8 did you know...

Lipreading activates both the visual and auditory centers of the brain.



Making Connections

Cortical neurons and a supporting neuroglial cell (top left) grow in a culture.
Credit 16

Brain cells

reading, learning, pattern recognition, and so much more all begin with the fundamental unit of the brain, the nerve cell, or neuron.

Some chains of neurons send information to the brain from the body's extremities; others send information from the brain to the body. Still other chains share data among themselves to construct subconscious or conscious thoughts and feelings.

Axons and dendrites Each neuron contains a cell body with a long, taillike fiber called an axon, which sends electrical impulses to other cells. Some axons are short, extending only to adjacent cells in the brain. Others are much longer, carrying impulses down the spinal cord to move the arms, legs, and feet. Axons may split and branch into as many as 10,000 knob-like endings that disperse impulses across many cells. Each neuron also extends into networks of dendrites, thin, short fibers that transport electrical signals to the main body of the neuron from outside sources.

The human brain contains perhaps 100 billion neurons. Each links to so many others that the entire network forges literally trillions of connections, making the brain the most complicated object in the universe. ⊙

9

did you know...

Neurons can live more than a hundred years.

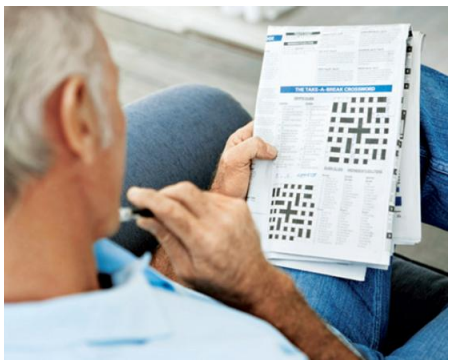
mental muscle

Exercising your neurons

Both the brain and the body need regular exercise if neurons are to remain sharp. Repetition of newly learned tasks helps make neurons' connections stronger. But "use it or lose it" also applies to physical stimulation of the brain. Like other organs, the brain works better when the body is healthy. Exercising regularly appears to help ward off Alzheimer's disease, as do reducing body weight, lowering blood pressure, and eating a more healthful diet.

To spur on the brain to make new neuronal connections and protect the ones it has, try such activities as:

- **Learning a new language.**
- **Listening to classical music.**
- **Solving mental puzzles and games, like crossword puzzles and Sudoku.**
- **Eating a healthful diet.**
- **Walking, jogging, or cycling regularly to promote cardiovascular health.**



Credit 17

Neurotransmitters

When a neuron sends an electrical discharge along the length of its axon, it halts at the synapse like a car at the edge of a cliff. There, the impulse activates electrically charged molecules stored in the neuron's cell wall. These molecules, known as neurotransmitters, leave the membrane of the first neuron, move across the synaptic cleft, and dock at a second neuron. The receptor cell's surface contains specially shaped docking sites, so particular neurotransmitters can dock only at the appropriate places.

The arrival of a neurotransmitter alters the electric charge at the edge of the new neuron and sparks a new electrical impulse. It travels the length of the new cell until it reaches the synapse of another receptor cell, and starts the process all over again.

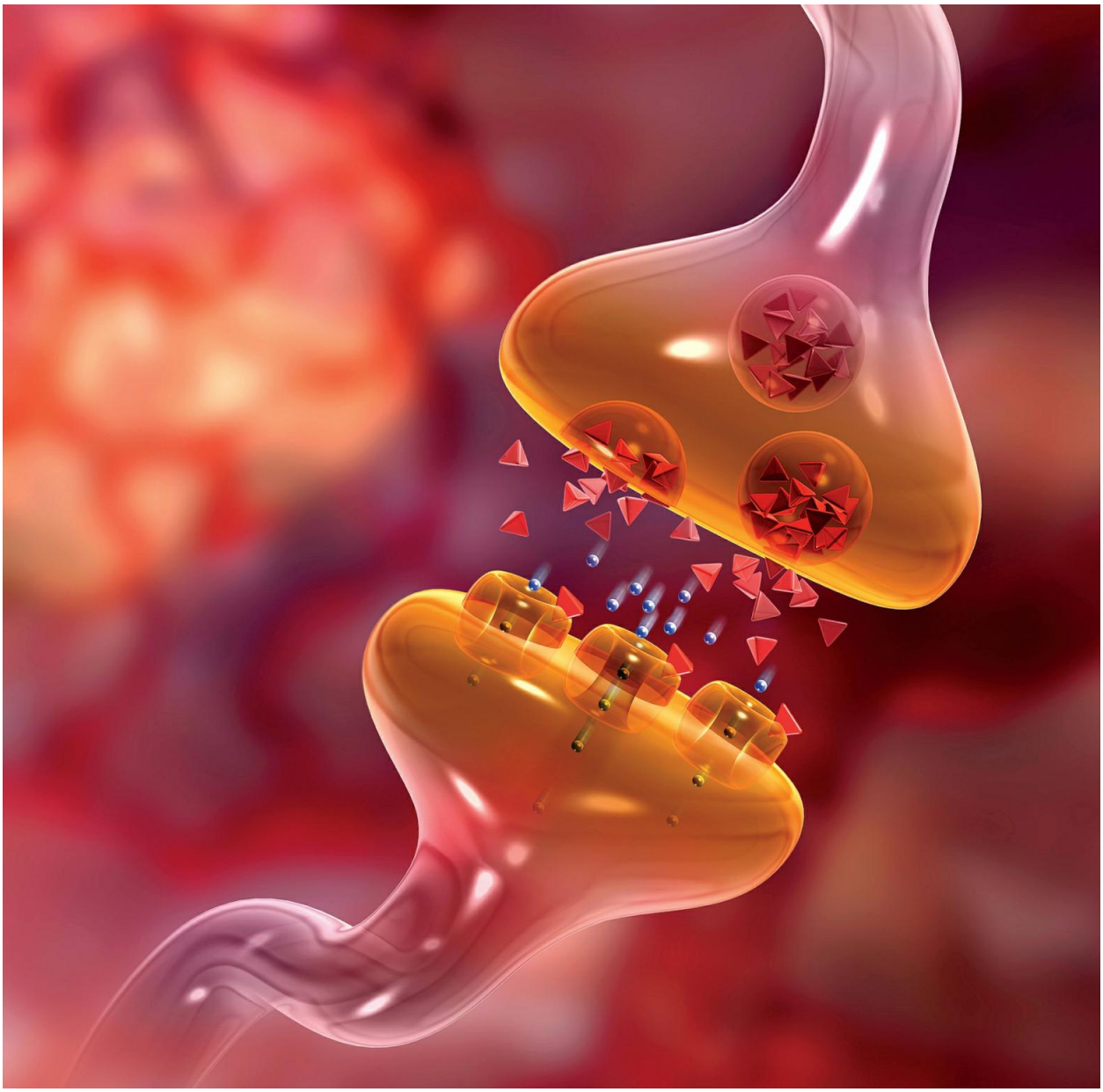
Electrical networks As impulses pass among complicated chains in the central nervous system, they form networks that specialize in performing particular functions, such as understanding language, remembering experiences from the past, and comprehending the outside world. All information processed by the brain is nothing more than electricity passing through neuron after neuron and pausing only to be converted into chemical energy as it leaps across each synapse.

Dozens of neurotransmitters have been identified, and more

discoveries are expected. Certain neurotransmitters make muscles contract, help regulate sleep, and block pain. Neurotransmitter disorders have been linked to Parkinson's disease, depression, Alzheimer's disease, schizophrenia, and a host of other illnesses. ⦿

did you know...

Nerve impulses travel at between 9 and 400 feet per second.



Jumping the Gap

Neurons transform the electrical impulses they carry into chemical codes that leap the gaps separating the cells. Such changeable connections let the brain rewire itself as you learn. Credit 18

Newborn Neurons

Premature births pose special challenges to the brain, as the child emerges from the womb before its neural networks have been fully established. Credit 19

The growing brain

The nascent brain makes its first appearance about four weeks after conception, when a thin, spoon-shaped layer of cells called a neural plate emerges at the head end of an embryo. As the fetus grows, swellings in the original spoon shape eventually become the major sections of the brain, from the cerebrum at the top of the head to the thalamus, hypothalamus, cerebellum, and spinal cord at the back and lower end.

Neuron migration The most dynamic growth occurs in the cerebral cortex, the outermost layer of the brain. During early fetal development, when 250,000 new nerve cells are being created every minute, neurons begin to take on specialized tasks.

First, they inch their way from where they were formed to their permanent home in other regions of the brain. Most go toward the cortex, but some move into the cerebellum and other portions of the brain. This process, known as migration, is remarkable for the distance the neurons must travel as well as their ability to navigate along the tangled pathways of the developing brain. Millions of neurons migrate a distance equivalent to a person hiking from Los Angeles, California, to Boston, Massachusetts.

did you know...

The neurons you have at birth are all you will ever have.

case history

“Genie”

Language must be acquired at an early age, early linguists believed, but they were unable to test that hypothesis.

Then, in 1970, a 13-year-old girl was rescued from her captivity in a home in Los Angeles. From birth, “Genie” had been kept locked in a single room and beaten if she made noise. Muffled sounds from beyond her walls gave her an inkling of speech, but she never developed normal language.

Four years of training gave Genie the basics of communication, including sign language. She also developed a simple vocabulary, pairing words with objects. But Genie could not articulate sentences. The left hemisphere of her cerebral cortex had never received the sensations required for normal speech development. Starved for stimuli, Genie’s speech centers had suffered irreparable damage. After years of rehabilitation, Genie wound up in a series of foster homes and her language skills regressed.

Credit 20

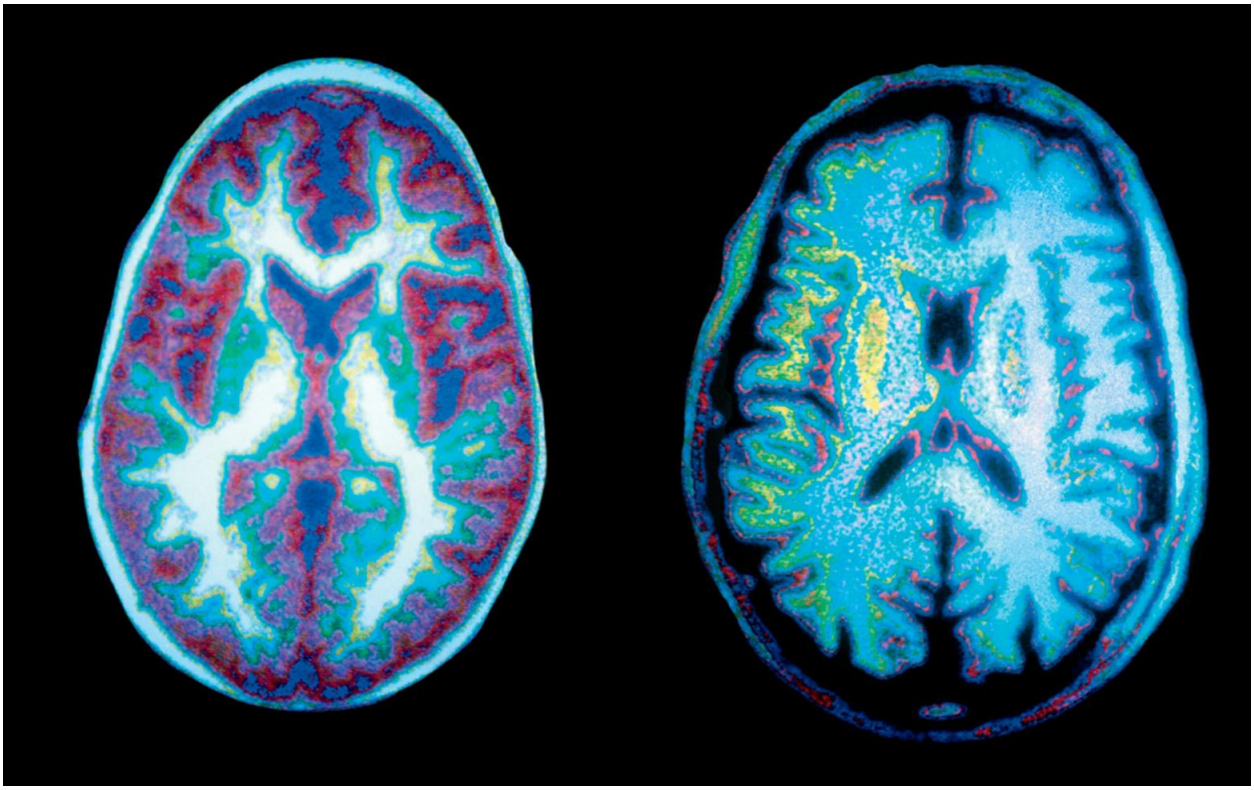
Continuing Developments

Getting plenty of exercise is important to the mental and physical health of both a mother and her developing baby Credit 21

The growing brain

Survival of the fittest The brain of a fetus at about eight months after conception weighs only a pound, or about a third of an adult's, but contains twice as many neurons. The brain cannot sustain biochemical reactions across all of its neural connections, and so the weakest of them begin to die, through a process known as pruning. In the last stages of fetal development, about half of all neurons die.

At birth, brain development expands to include processing responses to new experiences—sights, sounds, smells, actions, and emotions. Networks of neurons compete for survival as environmental stimuli strengthen some connections, while others wither. ⦿



By age five, a child's brain (above, left) is the size of an adult's, but is still undergoing folding, which maximizes cortical surface area. Credit 22

did you know...

12 The human brain has about 50 trillion neuroglia, support cells for neurons.

13 Addictive drugs work by mimicking or altering the work of neurotransmitters.

14 Unconsciousness occurs eight to ten seconds after loss of blood supply to the brain.

15 Your brain is 60 percent white matter and 40 percent gray matter.

16

Wounds to the back of the head, injuring the visual cortex, can cause blindness.

17

Infants who have one brain hemisphere removed generally grow up with normal brain function.

18

The brain burns 20 percent of the body's oxygen and glucose.

19

Gray matter is thickest in girls at age 11, in boys at 12 years of age.

20

Your skin weighs twice as much as your brain.

21

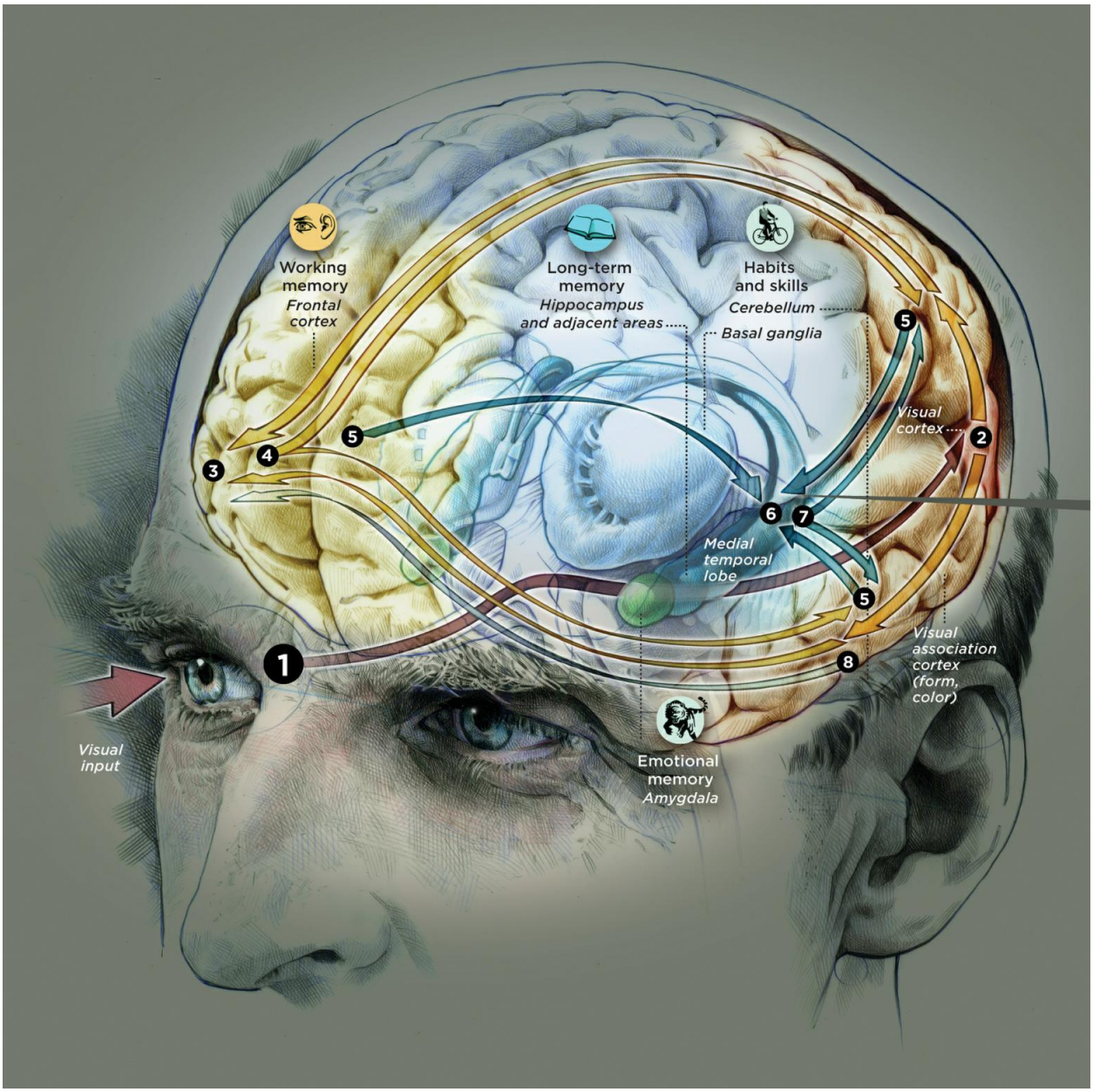
Your brain uses about 12 watts of power—a fraction of the energy of a household light bulb.

22

Hyperthymestic syndrome describes a superior memory for autobiographical events.

23

At about 11 months, babies start to lose the ability to distinguish nonnative language sounds.



From Vision to Memory

Light stimulates the retina (1), which transmits impulses to the visual cortex (2) and on to the frontal cortex (3), which coordinates their immediate use by other parts of the cortex (4, 5). The hippocampus (6) and other areas of the medial temporal lobes (7) turn short-term memories into long-term ones and activate stored memories into working memory (8). Credit 23

Memory

Without memory, people would live in a never-ending now, with no idea of where they have been or where they might go. The memory of representations of the world gives humans the unique ability to think about the past, present, and future.

Scientists who study memory find it a tough nut to crack. Neural circuits responsible for memories lie scattered throughout the brain. Experts have found some brain regions to be particularly crucial, however. The hippocampus, so-called because it resembles a sea horse (*hippos* is Greek for "horse"), plays a significant role in emotion and memory. Lying deep in the forebrain, it receives sensory data from the senses and integrates them into a single experience.

Working and long-term memory Some memories last less than a minute. Some last a lifetime. Working memory, a type of short-term memory, holds sensations for a few seconds. You remember the last few words you spoke or the last few ingredients you put in the stew so you may complete the tasks you have begun. Then working memory clears, and you move on.

Long-term memory is more like a filing cabinet. Some documents from a computer screen or tabletop get filed for later use. Information is more likely to make the transition from

working to long-term memory if you pay particular attention to it, repeatedly try to remember it, or associate it with strong emotions. These memories are useful not as much for navigating through the moment as for making good choices and succeeding at life. ⦿

did you know...

After hearing it twice, Mozart played a 12-minute choral composition from memory.

Memory categories

Although a keen observer could no doubt create a very long list of attributes for a delicious red apple, the information would fall into four categories of memory: sensory, motor, visuospatial, and language.

Sensory memory Sensory memory involves the five senses, with smell the most powerful memory trigger. As the senses create our appreciation of the world, it's not surprising that many memories can be recalled via sensory cues. A certain song, for example, might bring up memories of a wedding or family reunion. People with powerful memories often create visual cues in their imagination to increase the strength of their long-term memories.

Motor memory Motor memory provides fine motor control for practiced actions. These include everything from the subtle controls over the vocal cords to produce speech to the motor control that underlies the complicated act of walking without losing one's balance. Motor memory is tied to the learning of skills. Damage to brain areas that affect one invariably affect the other. Recent research suggests that motor memory's application to learning new skills takes place in two stages. The first stage recruits neural networks that best represent the motions required

for the skill, such as eyes, ears, and fingers for playing a piano. The second stage occurs after the basic motions are mastered and implicitly memorized, when the brain recruits additional neurons to refine the motions. That's the difference between the adequate performance of a weekend musician and one who practices for a seat in a symphony orchestra.

did you know...

Most people can remember as many as 10,000 faces.

Aspects of Apples
Attributes of an apple—such as color, taste, and name—are stored in separate neural circuits. Credit 24

Memory categories

Visuospatial memory Visuospatial memory combines the neural pathways of the visual cortex and the spatial orientation of the temporal lobes. The left hemisphere is significant in perceiving details, while the right hemisphere works to integrate the details as a whole. Together, they let you see the trees *and* the forest.

Language memory Language memory leads to the ability to associate words with objects, the crucial foundation of communication. The grounding of communication in the brain's hard wiring to acquire language can lead to serious consequences from verbal memory disorders. These can not only interfere with communication, but they also can distort the perception of reality of someone who may be unable to discriminate between statements that have a source in true memories or those that draw on fantasies. Unable to tell the true stories from the false, these people may struggle with the concept of truth.

The process of remembering by retrieving information from storage, and then restoring it, colors memories with additions, subtractions, and substitutions. The more time that has elapsed since an event, the more likely the brain has rearranged the memory of it. ⦿

did you know...

Memories are more likely to stick if they combine information and emotion.

mental muscle

The Roman room

An ancient system for retaining facts in memory, known as the Roman room after a technique explained by Cicero, works on the principle of inventing images for things you want to remember, and then situating those images in places that naturally form a progression. For instance, try imagining your living room. Now associate images representing the information you want to remember with the objects scattered around the room.

The technique still works astonishingly well, as demonstrated by National Basketball Association Hall of Fame member Jerry Lucas. He has used the Roman room to memorize the content of various magazines and books, including the entire New Testament, which he said took him a year to commit to memory.

Even extremely long strings of numbers, objects, or words (in case you're wondering, there are 180,000 or so words in the New Testament) can be remembered by being broken into "chunks," or small groups of objects, and then the groups retrieved in order—although seven is about as many numbers as the average brain can remember at a time (like a telephone number).

Credit 25

Trial Run

Pausing at a dead end, a hamster takes its bearings in a test maze in Germany.

Credit 26

Memorable Images

Some mind-bending contemporary films, including *Memento,* deal with the subject of memory failure. Credit 27

Unreliable memory

Memory disorders, which range from the transient losses of concussion to the devastation of dementia, can have a profound effect on a person's sense of identity and reality.

Amnesia For instance, a bizarre disorder of memory typically caused by alcohol abuse, Korsakoff's psychosis, eliminates the brain's ability to create and store new memories. If you meet a patient with Korsakoff's, chat for a few minutes, and then leave, the patient won't recognize you when you return. However, if you suggest that you've met before, he or she will fabricate a story to describe the previous meeting.

False memories False memories are also common in healthy people. In one experiment, Elizabeth Loftus gave adult subjects lists of things that really happened to them as young children. However, Loftus added a lie to the roster: The subject had gotten lost at a mall. About a quarter of the participants said they remembered the false event, and many gave elaborate details. "People's memories are not only the sum of all that they have done but...also the sum of what they have thought, what they have been told, what they believe," Loftus says. ⦿

did you know...

Treatments to lift depression usually improve memory.

case history

Living in the moment

More than any poet, mystic, or lover, H. M. lived in the moment. It was all he had.

Having suffered a serious head injury as a child, Henry Gustav Molaison (written up in scientific literature as H. M.) underwent a radical brain operation at the age of 27. Immediately, it became clear that his memory had been adversely affected; the surgeon had cut into the hippocampus. Molaison could remember much of what had happened before the surgery, yet he could not form new memories. Brenda Milner, a psychologist in Montreal, began traveling to his hospital regularly to test Molaison. Each visit seemed the first for the patient.

Milner learned two critical things: that damage to the hippocampus could have such profound results, and that Molaison had retained a form of memory based not on cognition but on motor skills—his "motor learning" evidently involved other brain regions.

Credit 28

Language

Language, including speech and reading, is so important to human survival that it accounts for a massive amount of cranial space.

Reading and listening Reading letters silently on the page initiates action to sense the shapes of letters and words in the primary visual cortex at the back of the brain. It also places demands on working and short-term memory to hold those words long enough for the reader to make sense of how they form sentences, as well as analytical functions to pull those sentences apart for meaning.

When a child hears words spoken aloud, the auditory association area of the brain is activated. Understanding speech requires encoding and decoding of language in the receptive language areas, which take in signals from auditory association areas and, if the words are seen on a page, from the visual association areas.

A parent reading aloud uses a different brain circuit from that of the child being read to. Reading generally begins with activation of the visual cortex, which sends signals to Wernicke's area, whereas speaking aloud activates an adjacent region called Broca's area. Reading aloud requires the cooperation of both these areas.

did you know...

Reading and writing use different neural networks.

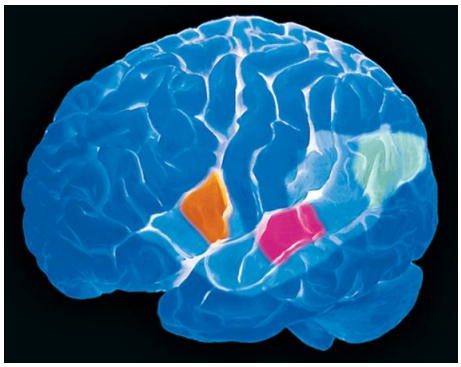
mental muscle

Children and language

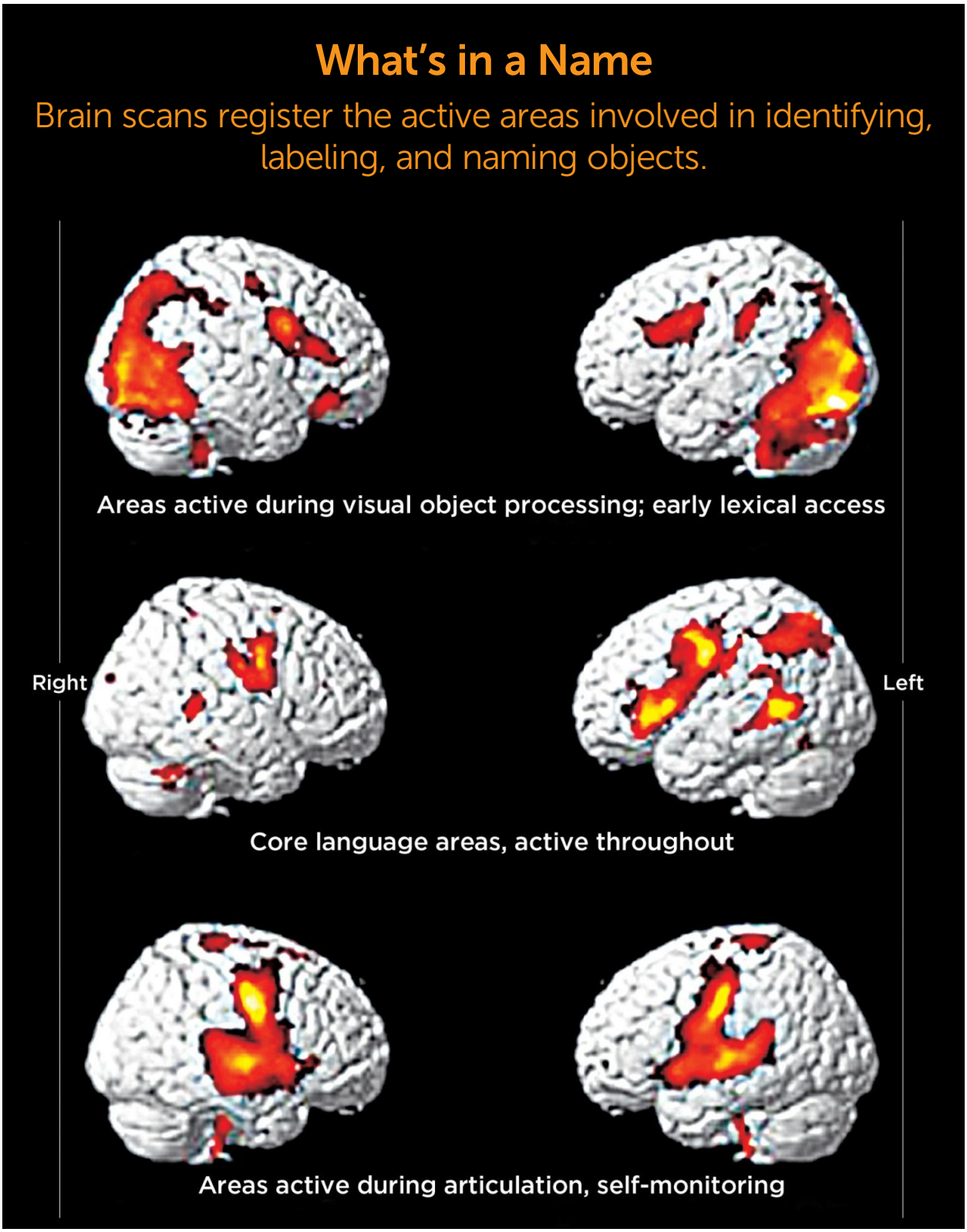
Children raised in a home where two languages are spoken grow up fluent in both and don't have an accent. Adults, on the other hand, often struggle to pick up a second language, and even when they succeed, they don't sound like native speakers.

The difference lies in the greater plasticity of a child's brain. Young children recognize a greater range of language sounds than adults. They pick up vocabulary and syntax more easily. And they process languages more efficiently, activating smaller regions of their brain than do adult learners.

Although the brain is particularly sensitive to learning languages at a young age, it's never too late to benefit from the mental gymnastics of wrestling with a new tongue. Adding a second language improves cognitive skills and memory, as well as exposes learners to new ideas.



Credit 29


What's in a Name
Brain scans register the active areas involved in identifying, labeling, and naming objects.
Areas active during visual object processing; early lexical access
Right
Left
Core language areas, active throughout
Areas active during articulation, self-monitoring

Credit 30

Broca's Bequest

Surgeon Paul Broca, who identified a language center in the brain, preserved a sample from his patient for future study. Credit 31

Language

The evolution of language Although some scientists believe the mind can exist without language, others argue that language produces mind. "Without language, I wouldn't say that it is impossible to have mental experiences, but I'd say the mental experiences would not be very coherent," said Derek Bickerton, an expert on Creole languages.

According to Bickerton, pidgin is the first developmental step in the creation of language. Pidgin languages form when people come together who cannot communicate in a common tongue, such as slaves taken from various tribes of West Africa and placed in the New World. Pidgin assigns words to objects but lacks grammar and thus complexity. "Arrow...deer" might be a command to help kill a deer or an announcement that a hunter has just done so.

Bickerton believes that the increasing complexity of a child's brain and its accompanying ability to master speech may mirror the evolutionary history of human language.

Animal communication Even animals have developed their own complex ways to communicate, whether acoustic, visual, chemical, or tactile. Each animal's choice of communication method relies on its strongest and most sensitive neural receptors. Animals, like humans, also can combine sensory stimuli for more sophisticated communication. The great apes, closest to humans in evolutionary development, possess a communication system that incorporates gestures, postures, expressions, and vocalized sounds. The Gorilla Foundation taught a lowland female named Koko about 1,000 words of American Sign Language. ⦿

did you know...

Koko the gorilla uses sign language to make a sentence three to eight words long.

Disorders

Many common disorders involve the complex tasks of speech and reading.

Stuttering Until recently, doctors considered stuttering a nervous or emotional condition. Now, the condition that affects about three million Americans falls within the realm of neurology. Stuttering usually begins between the ages of two and six, as children accelerate their learning of language. Three-quarters of those children spontaneously lose their stutters. The exact cause of stuttering has eluded research, but it's believed to have a genetic component. Brain scans of people who do not stutter show speech processing most often performed in the left hemisphere of the cortex, whereas people who stutter have an unusual amount of activity in the right hemisphere.

Dyslexia Learning disabilities result from faulty reception, processing, and communication of information within the brain. One of the most common, dyslexia, is a disorder of language processing. People with dyslexia struggle with decoding phonemes into words that have meaning; some have difficulty holding sounds in short-term memory. Researchers focus on a variety of possible causes. Physical impairments of the angular gyrus and the rear of the left hemisphere, active during reading,

have received attention. Functional MRI scans of people with dyslexia reveal decreased activity in both parietal and posterior temporal lobes. Many people with dyslexia are artists and musicians. Research suggests they may have enhanced abilities to hear bass notes and see sharper colors in peripheral vision. ⦿

30

did you know...

The “choral effect” suppresses stuttering when people sing with others.

From Stutter to Shakespeare

James Earl Jones overcame his stutter to achieve fame as an actor and a famous voice. Credit 32

I.Q. Apparatus

A 1937 Stanford-Binet intelligence test includes miniatures and printed matter. The test has been revised repeatedly over the years. Credit 33

Intelligence

Although IQ tests have been in use since the 1900s, neuroscientists still don't agree on just how to define intelligence, or on how much of it is genetically determined. Some early IQ tests measured knowledge of facts, which is a function of education and memory rather than the ability to reason. In general, however, a person's performance on a problem-solving test is a good predictor of performance on a wide range of mental exercises.

Scientists use the term *g-factor* when discussing the general measure of mental ability, found in vocabulary size, mechanical reasoning, and arithmetical computations. They relate it to the properties of efficient neural functioning, rather than knowledge in its own right. The prefrontal cortex, right behind the forehead, is the most likely home for many of the neural processes associated with the g-factor. When it's damaged, a person suffers a variety of impairments to abstract reasoning, and it lights up during brain scans taken during some intelligence tests.

The role of heredity Genetics seems to play a role, but not an overwhelming one, in intelligence. Identical twins separated at birth and raised separately in similar environments show a 72 percent correlation in intelligence. Perhaps heredity sets an upper limit for intelligence, which then becomes subject to other

forces. Political scientist James R. Flynn noted that IQ scores have dramatically increased over the past several decades in many countries. He attributes the so-called Flynn effect not to genetics but to increases in modern humans' ability to solve abstract problems, possibly from living in a more intellectually stimulating world. ⦿

did you know...

Two-thirds of a population will have IQ scores between 85 and 115.

Gaining a Perspective

Lining up a bottle in the extreme foreground with a person in the far distance creates a perspective illusion. Credit 34

CHAPTER
TWO

the perceptive brain

Locked up safely within the skull, the brain experiences the outside world through the senses. Seeing, hearing, tasting, smelling, and feeling are how human beings collect information about the world. These data are relayed to the brain, which uses them to formulate ideas and opinions, assess situations, generate reactions, and then store what it has learned as memories. Information that enters the brain through the senses powerfully influences thoughts, emotions, and personality. Put another way, what you see and hear—and taste, smell, and touch, for that matter—has much to do with who you are.

The first responders in the sensory process are sensory receptors, specialized neurons that react to environmental changes, known as stimuli when they register on the nervous system. Sensation is the awareness of the stimulus, such as the knowledge of music coming from your stereo. Perception is an interpretation of what the stimulus means, such as that the music is a little bit too loud or that the song is a favorite.

experiment

Color cues
Context is everything

Credit 35

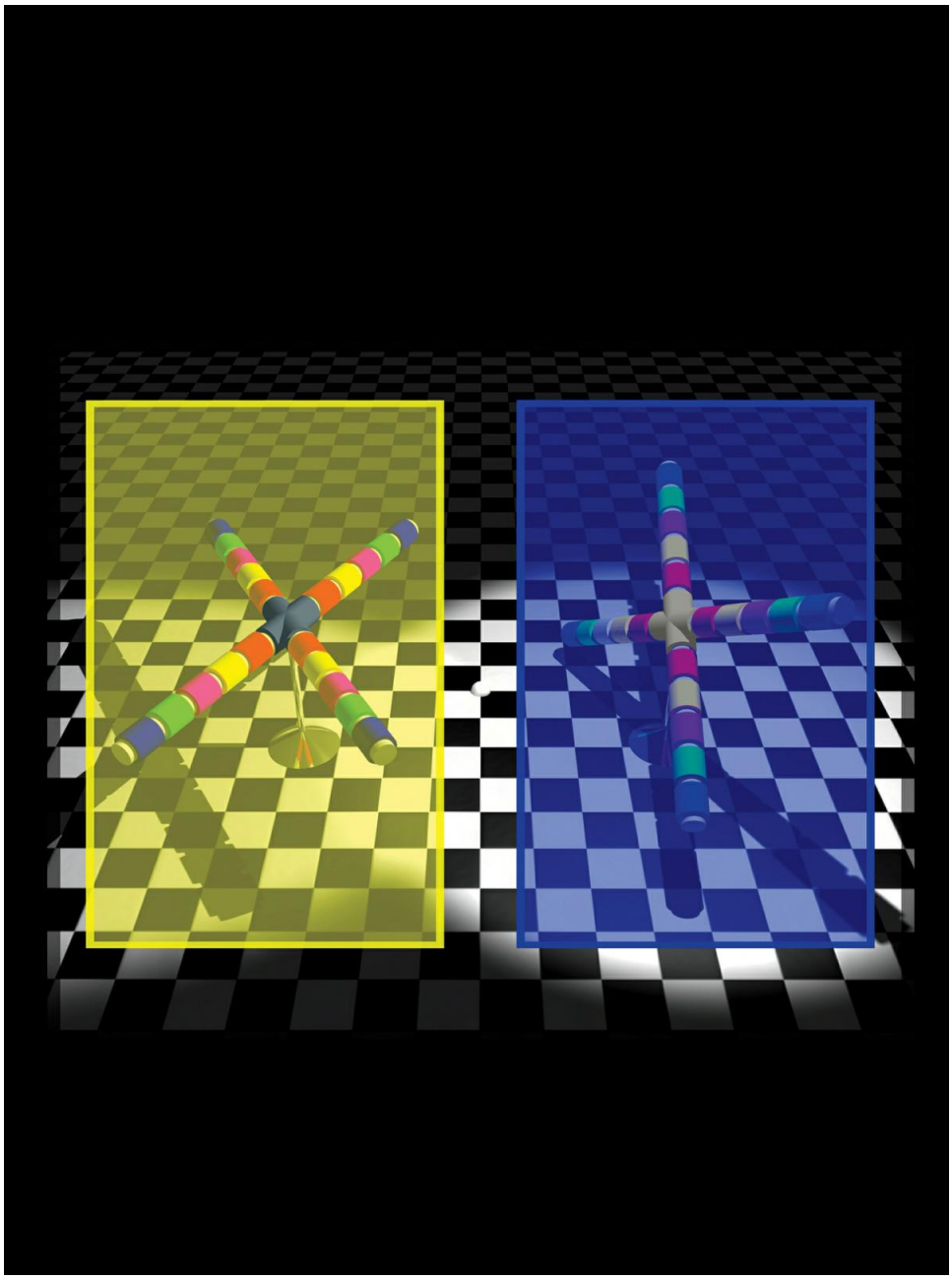
Step 1.
Study the artwork here.

Step 2.
Name the color where the bars intersect in the left-hand illustration, under a yellow mask.

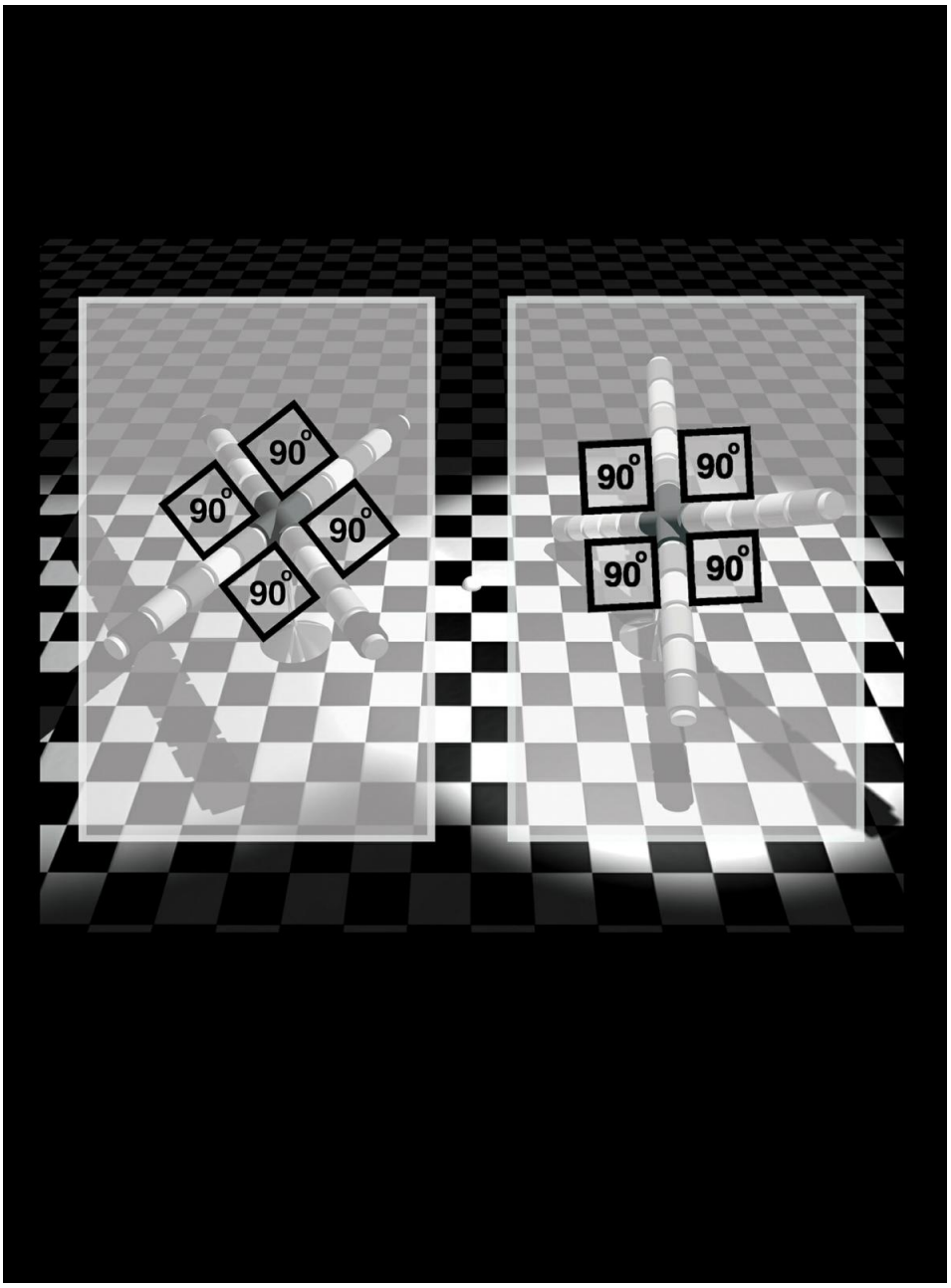
Step 3.
Now name the color in the similar intersection in the right-hand illustration.

Step 4.
Examine the four angles where the bars cross. Would you call the angles acute and obtuse, or perpendicular?

Then go here.



Credit 36



Credit 37

what happened

Did you call the color in the left illustration blue and the one in the right yellow? Congratulations. You have a normal interpretation of the visible spectrum of light. Your retinas and your brain react the "right" way: They assign the most commonly selected colors to the light reflected by the two illustrations.

You're also wrong. The two colors are exactly the same shade of gray. Likewise, the two sets of colored sticks intersect at 90-degree angles.

You can prove this to yourself. Get a few index cards or a pad of gummed memo papers, the kind used for sticking notes on desks and papers, and place them around the central elements of the two crosses to isolate them from the surrounding colors. The blue becomes gray. So does the yellow. To check the angles of the intersecting banded sticks, use the edge of an index card or a piece of paper. Each is a right angle.

Your brain judges color through its experience of color. In nature, colors don't exist in isolation, a fact that becomes important when the paint you liked in the hardware store doesn't look right on your bedroom walls. In making interpretations, your brain seeks cues such as the quality of light and the context of adjacent colors. Manipulation of context and light can alter perception so that a particular color appears radically different, even when presented near its twin. Similarly, cues suggesting three-dimensional perspective influence your perception of lines and angles. Context is everything.

32

did you know...

Aging eyes have trouble distinguishing among shades of blue.

From eyes to brain

As you read this sentence, the visual networks of your brain are taking in more than 100 million bits of information. Your eyes flit from place to place, usually never landing longer than a split second on any one word. You may think you see the world as a seamless whole, but your retinas are segregating information into categories, a screening process that keeps the brain from getting overwhelmed by too much visual stimulation.

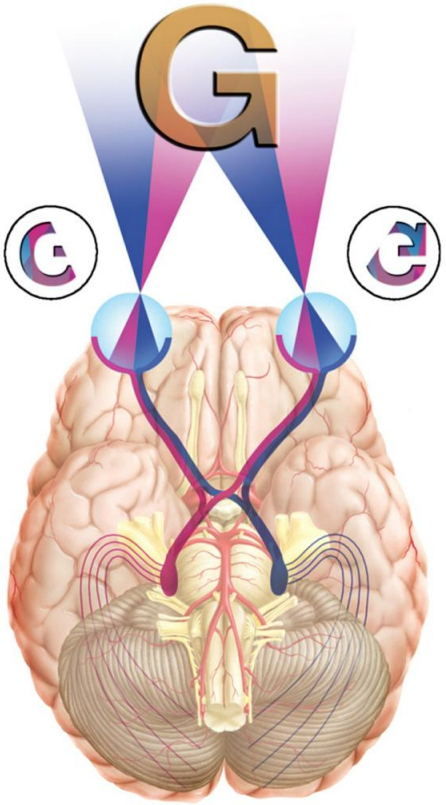
Vision in the brain Vision begins with light of wavelengths between 400 and 700 nanometers striking the retina at the back of the eyeball. Four types of photoreceptive cells in the retina react to different wavelengths and intensities of light. Other neurons measure relative brightness, distance, or motion. The visual neurons send electrochemical signals via the optic tract to the visual cortex, which is located in the occipital lobes at the back of the brain. Once there, the information is redistributed to at least 30 neural networks for processing attributes including color, shape, and texture.

Each lobe, in the right or left hemisphere, receives half the visual information. These regions integrate the two images and finally forward a unified single image to the frontal cortex for analysis. Only then does the brain "realize" what it's looking at. ⦿

33

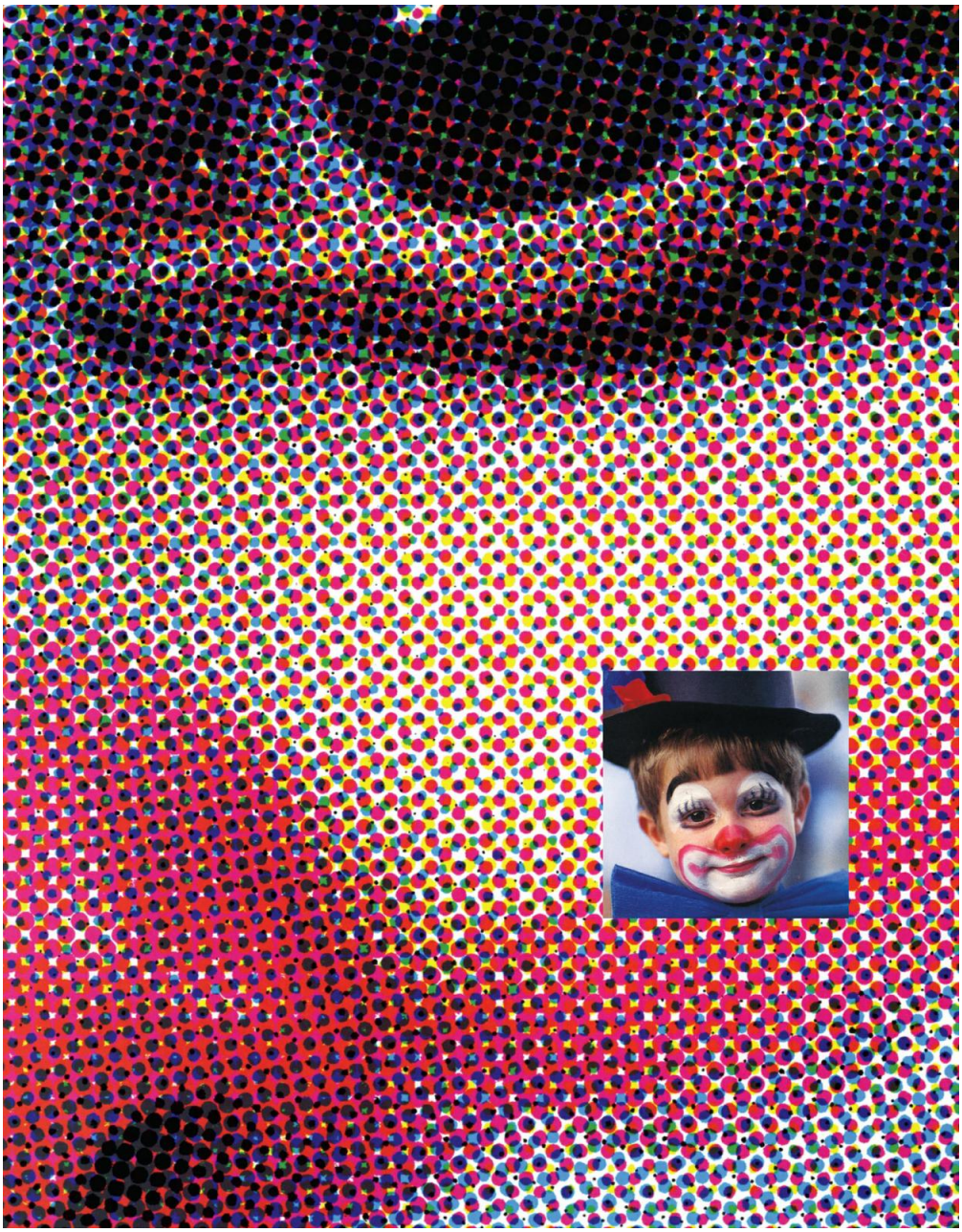
did you know...

Only a tiny region in the center of the eye can see sharply.



The Big Picture
Each eye takes in a slice of the visual world, which is processed in the opposite brain hemisphere before integration into a coherent image. Credit 38

Neurologist Richard Restak suggests that closely observing all facets of an object such as a bonsai tree may help you to build your neural networks. Credit 39



Components of Color

Color registers on the retina as bits of energy that activate cones sensitive to red, green, or blue. These bits form a whole, in much the same way that colored dots in the close-up of a printed page merge when seen from a distance. Credit 40

Color perception

Our sense of color—one of the most mysterious of our perceptions—depends upon three varieties of cone cells in the retina. Cones react to wavelengths of bright light associated with green, red, and blue. As the intensity of the color grows stronger, these neurons ratchet up the strength of the electrochemical signals that eventually wend their way to the brain's visual center.

Neural networks create other colors by mixing the sensation of the three primary colors of light (red, yellow, and blue) in varying intensities. But this mixing doesn't work in the same way as combining colors of paint. If you blend red and green paint, you get brown. However, mixing red and green wavelengths of light creates yellow. If the cones have an impaired or absent ability to register all hues of the visual spectrum, the result is color blindness.

The fourth type of light-sensitive neurons is called rods. They register light when its intensity is low, as on a moonless night, but do not add to the mix of primary colors from the cones. ⦿

did you know...

The eye contains 91 million

rods but just 4.5 million cones.

case history

Not-see

Blame it on the storm of 1775. That year, Typhoon Lengkieki crashed across Pingelap, a tiny and isolated Micronesian island. Flooding and starvation killed all but about 20 of the island's inhabitants.

The island revived, but the typhoon played a long-lasting trick on the people. Their gene pool had shrunk to only a handful of fertile adults. In such situations, any rare genetic traits may spread.

One did. As the survivors bred, a dormant gene for total color blindness found expression far beyond its incidence rate in the outside world. Achromatopsia—the condition of having nonfunctional cone cells, and thus being able to see only blacks, whites, and grays—exists in about 1 in every 30,000 to 40,000 humans. On Pingelap today, it strikes 1 in 12. The people of Pingelap call their color blindness *maskun,* meaning "not-see."

Credit 41

Hearing & listening

hearing is often ranked as the most important sense after sight. The brain registers sound when air pressure stimulates the auditory region of the temporal lobe of the cerebral cortex. To get to that region, pressure waves must transfer their energy through the air to membranes, fluids, and bones in the ear, and on to receptor cells of the so-called spiral organ (organ of Corti) in the inner ear. When these signals reach the brain stem, neural networks sort them by tone and by quality. The brain stem eliminates those echoes that are commonly created by vibrations bouncing off walls, ceilings, and floors. If a sound is new or strange, though—a potential threat, for example—the brain stem lets it through. The brain stem also begins the processing of phonemes to start the comprehension of speech.

Synthesizing sound Auditory impulses are then routed to the midbrain's superior colliculus. Once there, the sensations of sound are synthesized with those of other senses to begin creating a unified experience of the world—such as hearing a boom and smelling gunpowder when witnessing the flash of a musket at a pioneer celebration.

Auditory sensations then rise through the thalamus to reach the primary auditory complex, where they interact with other neural networks that link sound to memory, other senses, and

awareness.

Processing sound is not evenly divided between the brain's hemispheres. The left hemisphere decodes musical rhythms better than the right, while the right specializes in the quality, or timbre, of sound. ⦿

35

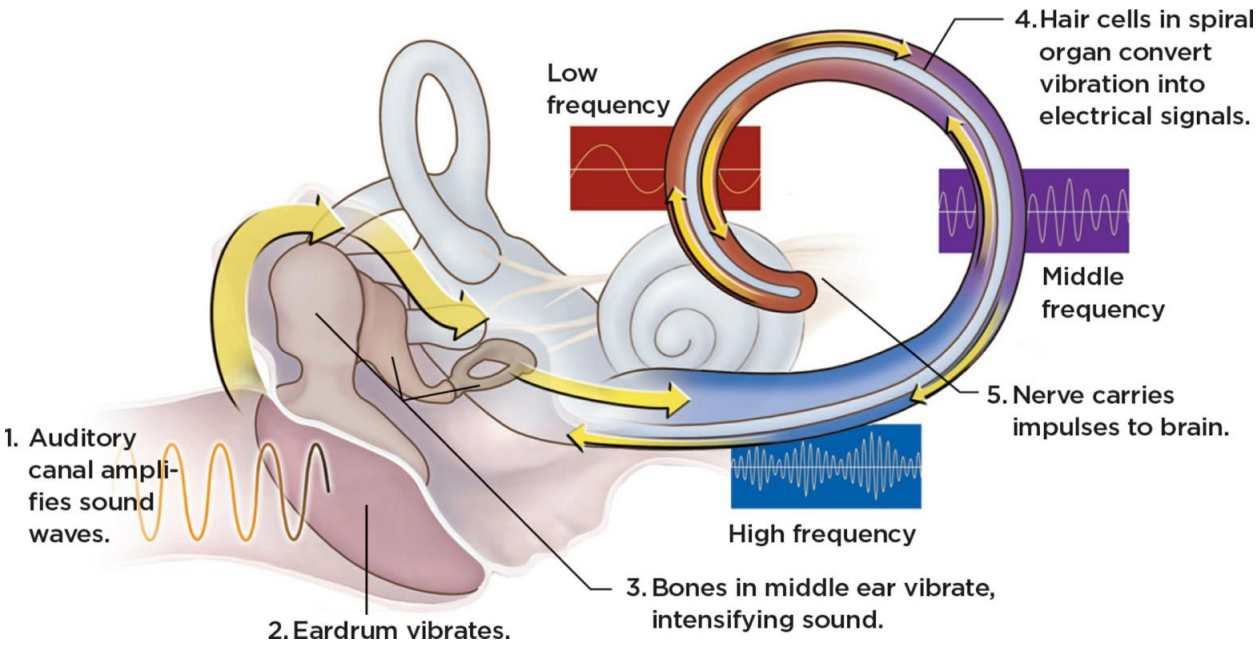
did you know...

The brain can signal the ear to reduce the reaction to loud sounds.

Blown Away

When sound volume increases, more neural networks become active, giving the sensations greater intensity. Credit 42

How We Hear



After striking the eardrum, sound waves are converted inside the ear to nerve impulses that are carried to the brain's auditory center. Credit 43

Smell & taste

Smell and taste are separate senses, but they have much in common. They analyze molecules entering the body from the outside world. They screen out harmful threats, and together maximize appreciation of food and drink.

Smell Smell, the most ancient of senses, takes a direct path to the brain, its sensations going straight into the amygdala and olfactory cortex, both parts of the limbic system, without stopping at the thalamus along the way. Smell is also hardwired to the brain's emotional centers. When you smell something, the sensation rushes, practically unfiltered, into the frontal lobes. As the amygdala directly influences the sympathetic branch of the nervous system, smells can trigger a rise in heartbeat and blood pressure or bring on a feeling of calm and well-being. Direct wiring into the brain's emotional and memory centers empowers odors to trigger past events.

Taste About three-quarters of what the brain perceives as taste also enters our perception through the nose. Only a fraction of a flavor enters through the taste buds of the tongue, along with the perception of the food's texture and temperature.

When you sip orange juice, the chemicals that give it its flavor mix with saliva, contact the taste pores of the taste buds, and

touch the gustatory cells of the tongue. Nerve fibers forward taste sensations to the medulla, and from there, to the thalamus and gustatory cortex. Gustatory fibers also connect to the hypothalamus and limbic system. There, in regions associated with emotions, the brain forms its appreciation of the orange-y flavor. ⦿

did you know...

Smells such as ammonia trigger pain receptors in the nose.

A Fine Nose

Smell and taste, though different senses, are linked, and work together to maximize the pleasure of food and drink. Credit 44

Touch

researchers believe human contact plays a crucial role in development. In a famous set of experiments in the 1960s, psychologist Harry Harlow tested infant rhesus monkeys. The monkeys had the choice of accepting one of two mothers. The first was draped in terry cloth but had no food; the second had a body of bare wire and a baby bottle filled with milk. The monkeys preferred to cling to the terry cloth mothers, whose reassuring contact was apparently more important than food.

Babies begin experiencing the sense in the uterus and are born with their neural wiring for touch significantly further developed than networks for vision and hearing. As a newborn reaches out to touch its environment, it develops its cerebral cortex.

Receptors for touch Pressure, heat, vibration, pain, and other sensations of touch register on specialized receptors in the skin and organs. Receptors are unevenly scattered all over the skin, and the brain allocates space for analysis based on how many receptors the body part contains. Thus, the number of neurons devoted to sensations from the face, a relatively small area, is larger than the number allocated for several other body parts combined. ⦿

did you know...

"Haptic touch" refers to handling objects to sense their tactile qualities.

mental muscle

The benefits of touch

Given the importance of touch and the abundance of receptors in the skin, it's not surprising that touch can have therapeutic value for people of any age. Full-body massage has been shown to ease the symptoms of diabetes and hyperactivity and improve the immunity of HIV-positive patients. Massage can relieve the pain of migraines, help people with asthma breathe, and increase the mental focus of children with attention deficit disorder. The rubbing action of massage stimulates neural networks that cause the brain to lower the levels of the stress-related hormones cortisol and epinephrine.

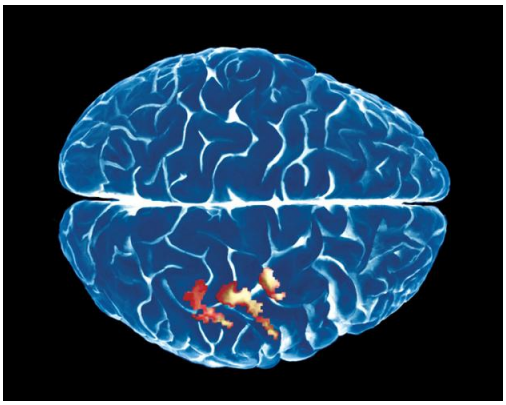
Touch also communicates at a basic level, more profoundly than words. A gentle caress says "I love you" better than words.

Credit 45

Close Comfort

A mother holds her sleeping baby. Newborns require physical contact for proper development. Credit 46

Crossing the Wires
Ferrets whose neurons were rewired at birth, switching the receptors for visual and auditory processing, learned to see with new areas of the brain. Credit 47



An MRI of the brain shows right hemisphere regions that move the left hand.
Credit 48

Integration

Although neural networks are attuned toward registering perceptions of light, sound, and so on, they often work together. Perception functions particularly well when objects are appreciated by a variety of senses. A person's walk, for example, registers in the brain as visual stimulation as you watch the moving body, as well as auditory stimulation from the clacking of a walker's heels. An examination of a handful of coins is perceived not only as the sight of the images on "heads" and "tails," but also as the tactile stimulation of the hard, round, and smooth or ridged edge.

Rerouting vision Sensory stimuli are associated with specific regions of the brain, but these areas apparently are not predetermined genetically. This was demonstrated by a series of classic experiments on plasticity between 1990 and 2000. Neurophysiologist Mriganka Sur of the Massachusetts Institute of Technology took newborn ferrets and surgically rewired their brains, routing the ferrets' visual impulses to the regions normally associated with auditory processing. The ferrets soon began seeing the world with brain tissue normally used for hearing. The new wiring wasn't a perfect substitution; the ferrets lost some of their visual acuity, having perhaps 20/60 vision instead of 20/20. Nevertheless, the experiment raises the intriguing idea that

blindness at birth could one day be corrected by surgery to reroute visual signals to healthy neural networks in other regions. Creating detours around damaged neurons would also open new avenues for treating strokes and other injuries.

did you know...

As many as 1 in 23 people may have some synesthetic ability.

Method in Motion

A woman who follows a recipe is executing a series of motor functions, including analysis and prediction. Credit 49

Integration

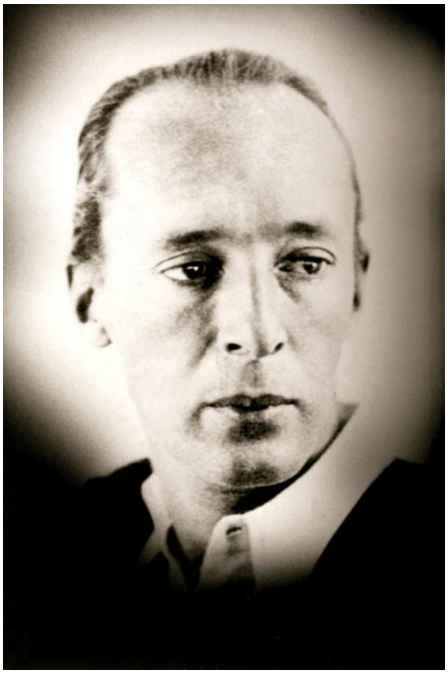
Gestalt perceptions In the brain, neural networks act together to integrate sensations. Many networks actually do double duty, reacting with a primary response to one sense and a secondary response to another. Among cats, for example, cells in the superior colliculus respond to both sights and sounds. And in the human brain, an old idea of common threads among the senses is gaining new adherents. Yale University psychologist Lawrence Marks argues that all senses evolved from the tactile function of the skin, and still retain connections to it. He suggests that stimuli such as “brightness” exist across the senses. ⦿

case history

Synesthesia

The human brain appears to naturally associate various senses. Sights and sounds, for example, are often paired. We think of sad music as being blue, while fast and furious high notes strike us as red-hot. Today, neuroscientists recognize a condition known as synesthesia, in which the senses are conjoined. People who have this condition describe seeing colors when hearing music, and vice versa, as well as other sensual combinations.

Contemporary composer Michael Torke, for instance, cannot imagine music without color. The key of G major appears bright yellow, while its G minor is a toned-down ochre. Russian writer Vladimir Nabokov saw the letter q as "browner than k, while s is not the light blue of c, but a curious mixture of azure and mother-of-pearl."



Credit 50

did you know...

Every retina has a **blind spot** where the optic nerve exits to the brain.

People with just one kind of cone typically **cannot distinguish** between red and green.

Birds have **four kinds** of cones in **their eyes.**

The brain is wired to see patterns in **all objects.**

43 The sparsest concentration of touch receptors is in your back.

44 The five basic tastes are sweet, sour, salty, bitter, and umami (a beefy flavor).

45 Some odor receptors can detect just a few molecules among billions.

46 You cannot tickle yourself, because your brain anticipates the touch.

47

Some smells can trigger a rise in blood pressure.

48

Humans have about 10,000 taste buds.

49

The brain recognizes some smells, such as rotting food, at birth.

Motion

On the surface, the study of motion seems so simple: The brain sends out the appropriate stimulus through its network of nerves. And *voilà*, muscles move.

But motion has proved to be far more complicated than that. It may be voluntary or involuntary, or some mix of the two. It may involve skeletal muscles activated by the central nervous system, or, in the case of peristalsis (the rhythmic contractions that push food through the digestive tract), it may automatically call into play the smooth muscles of internal organs. It may occur consciously, take place at a level below awareness, or even, in the case of a reflex, not involve the brain at all. It may be executed through a hardwired set of instructions available at birth, or learned and refined after much practice.

Imagining movement All motion requires events in sequence. What may be surprising, however, is that when the brain simply ponders action, its neural firing patterns appear similar to ones for execution of actual movements.

Think about the layout of your house. In your imagination, take a walk through its rooms. As you performed this mental task, you probably didn't move any muscles other than to scan your eyes across the page before you. But your brain "moved." Merely thinking about moving from room to room activated both

cognitive and motor regions in your brain. Synapses fired in your occipital, parietal, and frontal lobes, as well as in the cerebellum, just as they would have if you had actually gotten up to make the trip. ⦿

did you know...

Reflex responses, like a knee jerk, come from the spinal cord, not the brain.

Synchronized Signals

Nicholas McCrory and David Boudia execute a complex sequence of precise movements during their diving routine in the 2012 Olympics. Credit 51

Invisible Controls

Without unconscious management of such tasks as regulating heartbeat, moving muscles, processing emotions, and so on, your conscious mind would bog down in the demands of simply living. Credit 52

the unconscious brain

Asleep or awake, the brain is always active. It works in times of razor-sharp alertness, in the chaos of dreams, and at levels below self-awareness. Even when the body rests deeply in a coma, beyond the reach of sensation and thought, the brain works to pump blood, move air into and out of the lungs, and digest food. At the other extreme of mental activity, drugs may push the brain into altered states of hyperactivity or distorted perception for good or ill.

Humans are the only known animals capable of thinking about thinking, and when they do, they focus much of their attention on how the brain perceives the world and processes information to reach the state of awareness we call cognition. Yet research shows us that the supposedly unconscious mind can register sensations and store memories. Where is the dividing line between the unconscious and the alert, conscious brain?

experiment

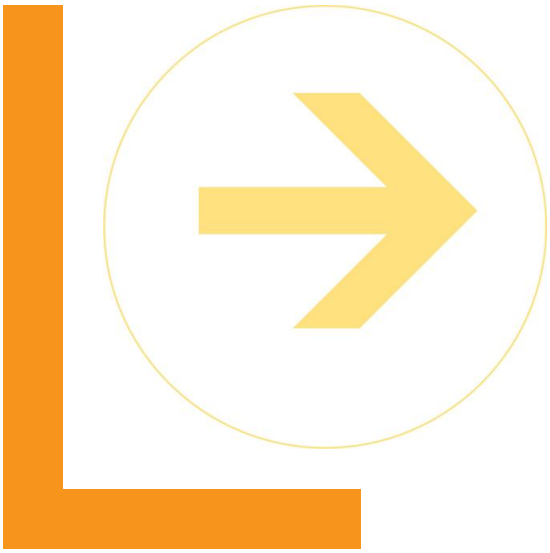
An active mind
The illusion of intention

Credit 53

Step 1.
Imagine you're in a college acting class. A professor assigns you to prepare a dramatic speech as if you were someone famous. To challenge yourself, you choose a political figure (though not a monstrous one) you dislike. The big day comes, and you give a great speech.

Step 2.
Ask yourself:
Have you changed your attitude about the person you mimicked?

Now go here.



Credit 54

Acting the Part

Tina Fey (left) and Amy Poehler (right) played the roles of Governor Sarah Palin and Senator Hillary Clinton on the television show *Saturday Night Live.* Credit 55

what happened

Your appreciation of the famous figure likely would grow. Scientists have replicated versions of this experiment many times and found that to be true.

But that's not all. After giving the speech, you also might rationalize the choice by unconsciously altering memories of your old attitudes. Like Aesop's fox who wanted the grapes but pronounced them sour after he could not reach them, your brain plays with your intentions after you act.

Psychologist Leon Festinger argued in proposing his theory of cognitive dissonance that people revise feelings to be consistent with actions. Any inconsistency, such as your giving a well-received speech in the role of a politician you dislike, causes mental discomfort. The brain resolves the conflict by changing attitudes to match behaviors. If you buy a car knowing that it has a bad transmission, you might actually come to value the car more because of the defect, as if you had decided it must be terrific despite the

flaw.

Neural circuitry that carries out action is distinct from circuitry that explains action. People not only can, but also often do, act unconsciously. Then they feel a need to justify their actions because of their perception of conscious will. In the case of cognitive dissonance, "the theory suggests that actions can 'sneak by' without sufficient intention," wrote Harvard psychologist Daniel M. Wegner, "but that once having sneaked, they can become unpleasantly inconsistent with those contrary prior intentions and prompt the revision that creates a new intention."

51

did you know...

Ads often use unidentified celebrities' voices, which may unconsciously influence consumers.

Aware and unaware

although the brain acts mechanically, it is nothing like a motor or a lightbulb. Except in the most extreme circumstances, it doesn't simply turn on and off.

Listening in Consider anesthesia. Until 1964, doctors who gave patients anesthesia before surgery assumed they would be unable to perceive anything while unconscious. However, in that year, a University of California at San Francisco physician, D. B. Cheek, discovered that after the patients woke up, they could sometimes recall word for word under the influence of hypnosis what their doctors had said while they were supposedly insensate.

Such studies underscore the difficulty of making black-and-white distinctions about states of the brain. In a typical day, every person goes through two obvious states, waking and sleeping, but each of these has sublevels of awareness based upon controlled and automatic mental processes. In a conscious state, the brain turns its attention to one thing after another, like a spotlight swinging through a dark night. The unconscious mind takes in information at the edge of the light, and sometimes even in the darkness. ⦿

did you know...

A Polish man, Jan Grzebski, went into a coma in 1988 and awoke in 2007.

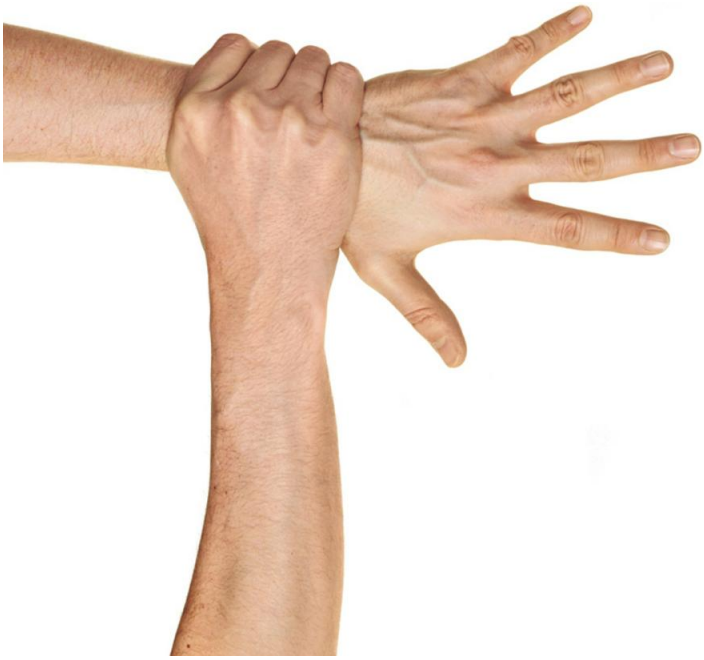
case history

Alien hand syndrome

When he was 56, a patient identified as J. C. suffered a stroke in his left frontal lobe. It extended into his corpus callosum, the fibers that connect the brain's hemispheres. Four weeks later, his right hand seemed to become possessed.

J. C. tucked his shirt into his pants with his left hand; his right untucked it. He grabbed papers with his left hand; his right ripped them free. He restrained his right hand but couldn't tame it.

His condition, called alien hand syndrome, is very rare—only about 50 cases had been documented between the first in 1909 and J. C.'s in 2006. It springs from damage to the medial frontal lobe, the corpus callosum, or both. Research into this syndrome has found that unplanned movements begin in the brain's "motor strip" without a cue from the frontal lobe. This seemingly spontaneous firing has defied explanation.



Credit 56

Under but Not Out

The mind may be aware of its surroundings even while under anesthesia. Credit 57

Rise and Shine

All humans follow a regular sleep–wake cycle. During sleep, the brain works to consolidate memories. Credit 58

Cycles

Neurons in your brain constantly communicate with one another, even if they are not performing specific tasks. You must sleep, but a healthy brain never totally does.

Waking or at times while sleeping, all regions of the cerebral cortex hum with a background electrical energy of 40 cycles per second, or hertz. This background pattern is one of many bands of "brain waves," which are rhythmic electrical pulses created by actions in various brain regions. Patterns tend to be relatively stable for individuals and reveal underlying brain states. As measured by an electroencephalogram (EEG), they range from slow to rapid cycles per second, with each band assigned a Greek letter for identification: delta, theta, alpha, beta, and gamma. Each set of brain waves has been associated with different states of mind and with different functions. Delta waves (0.1 to 4 hertz), for instance, occur most commonly during deep, dreamless sleep, when you're unconscious, and in the brains of newborn babies. Beta waves (12 to 13 to about 30 hertz) are present when the brain is actively engaged in problem solving, decision making, and analytical thinking.

Circadian rhythms Your mental states also go through daily cycles. The sleep–wake cycle, or circadian rhythm, governs our daily routine, from the most subdued moments of brain activity,

to the most hyperactive, mountaintop experiences where thoughts flow lucidly and creatively, to the deepest, darkest sleep where dreams cease to play in our minds. ⦿

did you know...

Alpha brain waves dominate when people feel calm and in control.

The mystery of sleep

Who can put a price on a good night's sleep? Without it, humans have trouble remembering what they've learned. They experience emotional upheavals and make poor decisions. They also may suffer health problems including increased risks of diabetes and obesity.

Despite evidence about the importance of sleep, science is only beginning to scratch the surface of why humans and other creatures need sleep and how the brain regulates sleeping and wakefulness.

The evolution of sleep Some animals, such as the bullfrog and salamander, never really sleep. Instead, these animals, which were among the first to evolve as land creatures, alternate between long periods of rest and short periods of motion. Among reptiles and other lower vertebrates, sleep induces a slow, rhythmic pattern of brain waves, somewhat like the slow-wave EEGs recorded when humans enjoy deep stages of sleep. As evolution created a more complex brain in birds and mammals, sleep stages expanded to include patterns that appear to resemble wakeful stages.

Human sleep occurs in five stages. After transitioning through all five, the cycle repeats itself. Stage 1 is light sleep; in Stage 2, about half of the adult sleep cycle, brain wave activity decreases

and eye movements stop. Stage 3 and Stage 4 form a very deep layer of sleep, in which it is difficult to awaken sleepers. Stage 5, or REM sleep, is marked by rapid eye movements and vivid dreaming.

did you know...

Sleepy people get an energy boost at 4 a.m., no matter how much they've slept.

Room for Rest

Japanese capsule hotels employ streamlined mass production for business travelers seeking a single night's rest. Credit 59

The Science of Sleep

Sleep researcher Jacques Touchon studies the effect of aging on sleep. In the background are EEG traces used to measure brain activity. Credit 60

The mystery of sleep

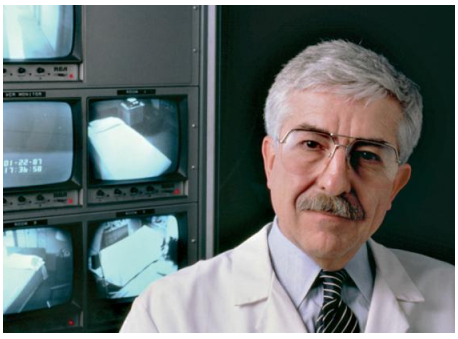
Sleep's Purpose It's believed that sleep allows the brain to "consolidate" memories. Data you learn over the course of a day are collected, sorted, and dispersed by the hippocampus. Gradually, in a process not fully understood, the data in those memories are redirected to long-term storage in various brain regions. In the 1990s, researchers at Israel's Weizmann Institute noted that when they awakened test subjects 60 times a night during REM sleep, the subjects lost the ability to learn new information. Similar interruptions during non-REM sleep had no such effect, suggesting REM sleep plays a key role in organizing information and forming lasting memories. ⦿

case history

Narcolepsy

Narcolepsy affects 135,000 Americans, even those who typically get a good night's rest. In daytime attacks lasting from a few seconds to a half hour, they may experience sudden muscle weakness, drowsiness, hallucinations, and periods of sudden sleep.

The disorder appears to cause symptoms of REM sleep to break through during periods of wakefulness. Working with dogs in 1999, Stanford University researchers, including William C. Dement (below) and lead researcher Emmanuel Mignot, discovered a gene that causes narcolepsy. It leads to severe lack or absence of hypocretin, a neurotransmitter that promotes wakefulness. Mignot studies the neurons that create hypocretin, which die in people with narcolepsy and late-stage Parkinson's disease. He believes that the research will expand what science knows about how and why people sleep.



Credit 61

did you know...

55 The idea for Frankenstein came to Mary Shelley in a dream.

56 Dogs, cats, goats, sheep, and other mammals can be narcoleptic.

57 Milk, cheese, and peanuts can help induce sleep.

58 Sleep-deprived drivers have reaction times like those of drunk drivers.

It is safer to wake a

59

sleepwalker than to let him or her keep walking.

60

Starving or thirsty people rarely dream of eating or drinking.

61

Brown bats, giant armadillos, and opossums are among the sleepiest animals.

62

The longest bout of sleeplessness on record is 11 days.

About 10 to 15 percent of adults have chronic insomnia.

63

64 Heart attacks increase by 5 percent in the week after daylight savings time starts.

The dreaming brain

The science of dreams, like the mechanics of sleep, is a vast jungle that science has only begun to explore. Although dreams and their interpretations have carved out a huge space in human history, religion, and literature, modern researchers believe dreams arise from basic brain functions. Harvard University researchers J. Allan Hobson and Robert McCarley developed the "activation synthesis" theory of dreams in 1977. It says dreams aren't stories with symbolic meaning but rather the brain attempting to impose order on the static caused by the random firing of neural networks connecting the pons and the cerebral cortex.

Some researchers believe dreams rehash fragments of daily life in a process known as incorporation. In a 1978 experiment, test subjects fitted with red goggles for several days began to see more and more red-tinted objects in their dreams.

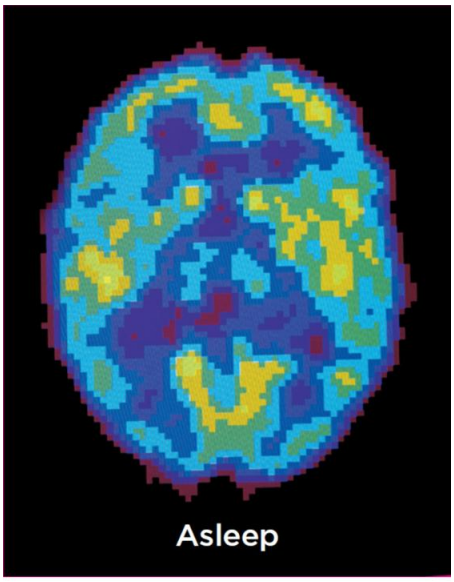
Not-so-sweet dreams However, if dreams incorporate bits and pieces of everyday life, they pick up on stress and anxiety in disproportionate amounts. In the 1940s, researcher Calvin S. Hall of Case Western Reserve University cataloged the content of more than 1,000 test subjects' dreams. Anxiety ranked as the most common emotion of those dreams, and negative content outnumbered positive content.

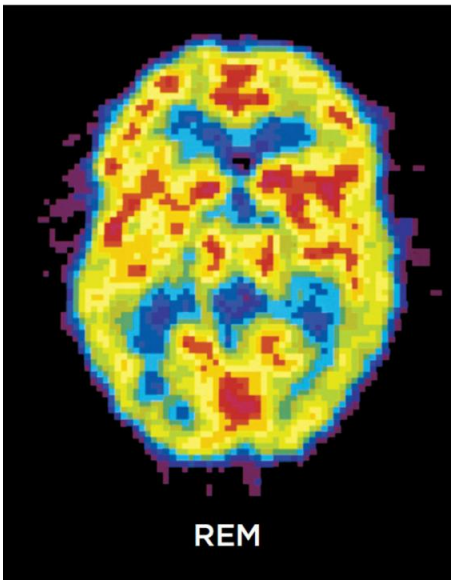
Out of all the dreams we dream, many, if not most, are forgotten quickly. Only the ones that, by chance, seem to correctly predict the future become the stuff of legend. ⊙

65

did you know...

Dreams of being chased occur in 80 percent of the population.





A Message in the Night?
Brain scans show the brain during normal sleep (top) and REM sleep. Credit 62

Most dreams occur during REM sleep, but their purpose is unknown. They may rehash parts of daily life, or they may be the result of random neural signals.
Credit 63

Altered states

Altered states of consciousness arise from conditions that push the brain into something other than the normal waking state. Problems processing information may arise from internal causes, such as schizophrenia, or from external stimuli, including substances such as medications, illegal drugs, alcohol, or tobacco.

The brain on drugs Most mind-altering substances change the functioning of neurotransmitters. Some mimic the work of the brain's neurotransmitters, whereas others prevent them from doing their jobs. Imbalances in a class of neurotransmitters called monoamines, including dopamine, serotonin, and adrenaline, play key roles in disorders such as depression, Parkinson's disease, schizophrenia, and irregular sleep patterns.

Prozac, commonly prescribed for depression, prevents serotonin in the synaptic cleft from being reabsorbed by neighboring neurons. As a result, serotonin molecules are able to forward electrochemical communications for longer periods of time. The street drug Ecstasy works the same way, except almost immediately.

Some drugs become habit forming, exerting powerful influence on the neural networks associated with rewards. The similarity of the reward response to drugs and to natural,

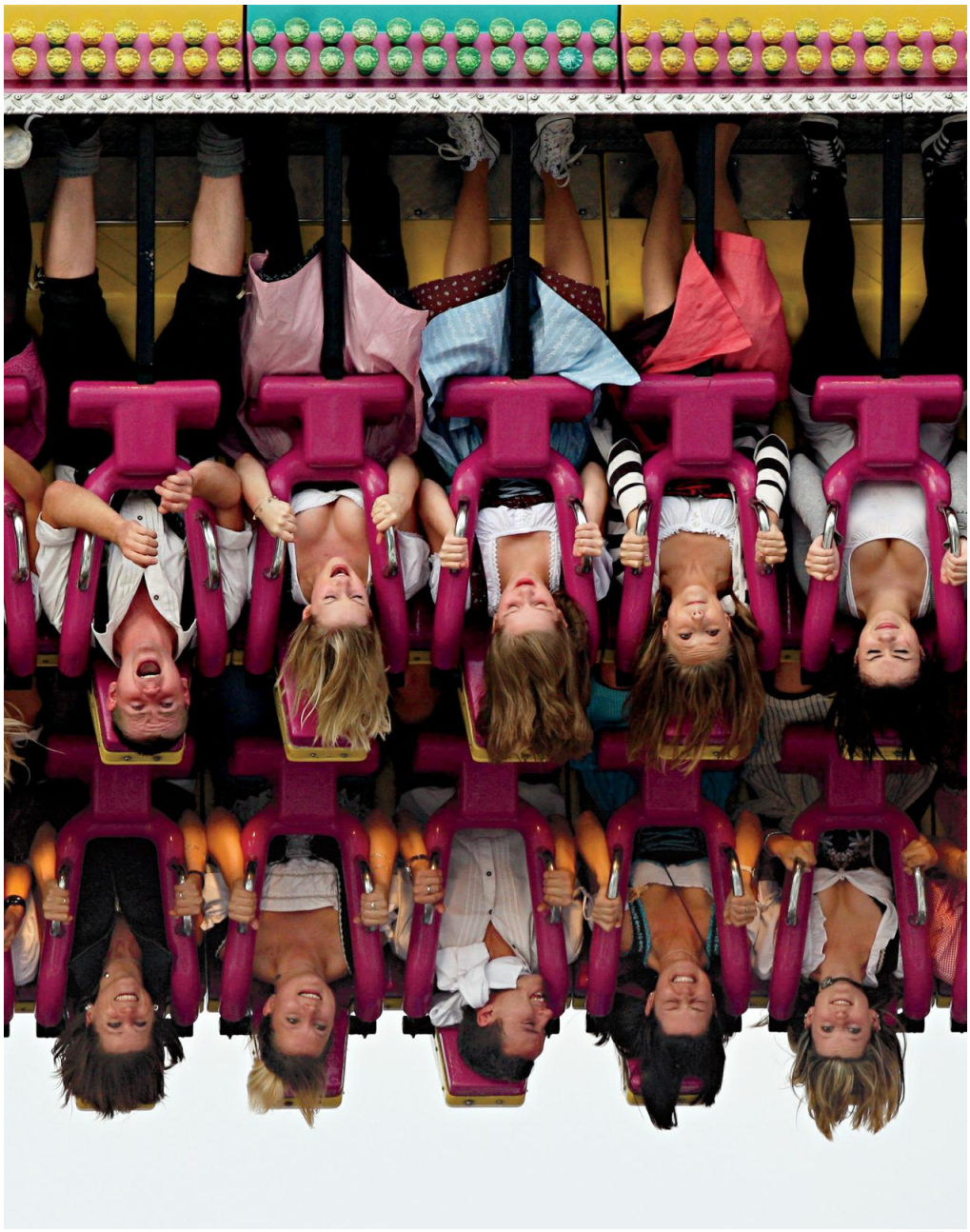
environmental stimuli such as food and sex makes it difficult to treat addictions. However, research has found several genetic markers associated with addiction. Future research might be able to identify prime candidates for addiction and find ways to modify genes or block addictive behavior. ⦿

did you know...

Like cocaine and heroin, nicotine activates the brain's dopamine systems.

Mixed Messages

Altered states of consciousness often bring on distorted perceptions. They can be caused by mental disorders such as schizophrenia or by substances such as alcohol or drugs. Credit 64



Ups and Downs

Physical and emotional reactions are intertwined, as in the experience of riding a roller coaster. Credit 65

the emotional brain

There's *motion* inside the word *emotion*, and for good reason. Emotions not only bring on highs and lows but they also communicate via gesture and expression. These physical manifestations provide the crucial distinction separating emotion from other behaviors. Emotions manifest themselves outwardly in visible changes to the body, such as muscle contractions, blood vessel dilations, and facial expressions. Powerful emotions can deeply carve events into memory, alter behavior and physical health, contribute to good (or bad) decision making, and even cause a person to be literally scared to death. Scientists are only beginning to understand their importance.

Aristotle classified more than a dozen emotions, including envy and pity. Today, most scientists recognize fear, anger, sadness, and joy, while some add surprise and disgust, referring to the complete list of six as "primary" or "universal" emotions. Many casual observers would add love to the list, but researchers are divided over classifying it as emotion or drive.

experiment

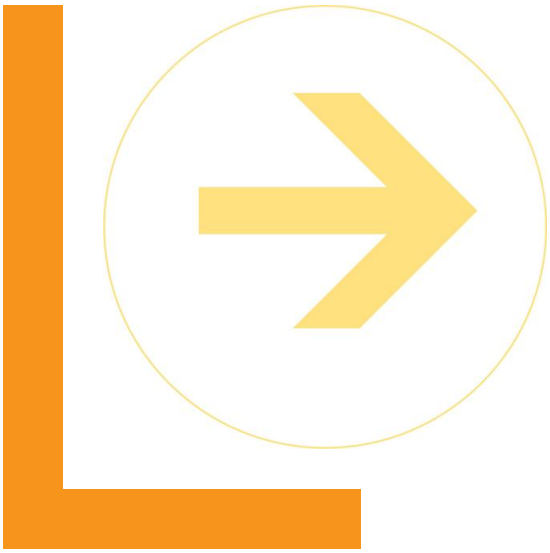
State of mind
Foggy forecasts

Credit 66

Read this:
Predict the length and intensity of your feelings if the following happened today:

- You won the lottery.
- Your salary doubled.
- Your favorite sports team won a big game against its chief rival.
- Someone close to you, such as a spouse or child, died.
- You got an unexpected refund of $20, or you lost $20 from your wallet.
- You got fired.

Now go here.



Credit 67

Credit 68

what happened

In the case of winning the lottery, did you imagine bliss stretching for months or years? Did you foresee ongoing devastation from being fired? Either way, you'd likely turn out to be wrong. When you predict emotions, you employ affective forecasting. And you're probably bad at it. Humans have what psychologists call an impact bias toward overstating the intensity and duration of emotional states in response to events they cast as good or bad.

"Nothing in life is quite as important as you think it is while you are thinking about it," psychologist Daniel Kahneman says. The brain's emotional circuitry is well grounded; it turns crises into blips. Events viewed as life changing end up being more like the loss or gain of $20. Even the pain of losing a child or spouse usually fades with the intensity of new experiences.

Foggy forecasts exist for several reasons. First, the brain falls victim to what Kahneman calls the focusing illusion.

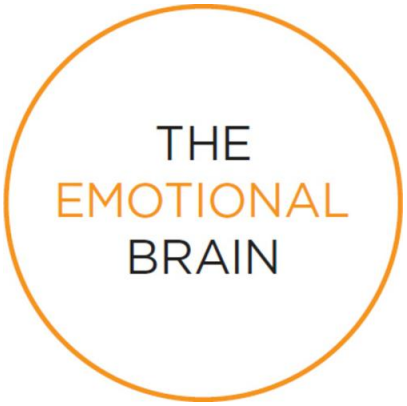
Happiness arises from many things, but people tend to exaggerate the importance of a single factor, such as money or love.

Second, people overestimate how they will feel in the future because they underestimate their own resilience. They do not realize how quickly they return to an emotional set point—an equilibrium that fluctuates and then stabilizes. And though the saying has it that "getting there is half the fun," psychologists will tell you that getting there may be more fun: The anticipation of a goal can feel as good as, if not better than, reaching that goal.

67

did you know...

A study found that playing with dogs increased levels of joy-inducing hormones.



Mapping emotion

Emotions appear to be processed in complex ways. There is no single emotion circuit; instead, a number of brain regions induce emotions, which then are processed by a variety of neural networks. Given their ancient evolutionary history, it's not surprising that most of the significant emotional centers lie below the cerebral cortex, which separates humans from all other animals. These "subcortical" emotional regions include the brain stem, the hypothalamus, and the basal forebrain. PET scans reveal that the brain processes sadness, for example, mainly in the brain stem and hypothalamus, as well as the cortical region known as the ventromedial prefrontal cortex.

Right and left Although emotions are not encoded in particular neurons, brain scans have led researchers to generally assign negative emotions such as sadness to the right hemisphere and positive emotions such as joy to the left hemisphere. For at least a century, neuroscientists have noted a link between damage to the brain's left hemisphere and negative moods, including depression and uncontrollable crying. Damage to the right, however, has been associated with a broad array of positive emotions. In the past two decades, University of Wisconsin researcher Richard Davidson has seen similarities in healthy, undamaged brains. Patients with more general activity in the left

hemisphere tend to be happier than people with a more active right hemisphere. ⦿

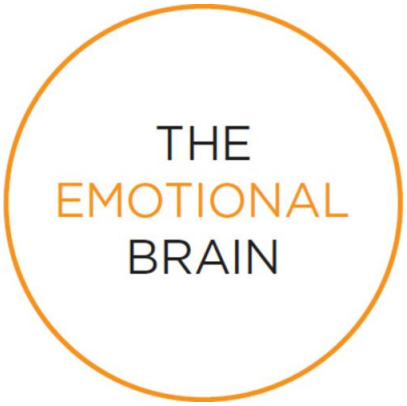
68

did you know...

Emotions help memories form and stick.

Tears of Joy

Actress Halle Berry's emotions burst forth as she accepts her Best Actress Oscar in 2002. Credit 69



Seeing emotions

Humans communicate emotions through facial gestures. Control of these expressions lies in the brain stem and amygdala, beyond consciousness. Evidence for this conclusion comes from patients who have pseudobulbar palsy, a disease that impairs voluntary control in the motor cortex. Such patients cannot control the muscles of their face. However, they still laugh and cry and show features of true emotions when moved by involuntary responses.

Mimicking emotion We begin to recognize emotions in others at an early age and copy what we see. Imitation helps create the parent–child bond during the first months of a child's life. This urge to mimic the emotional behavior of others, called emotional contagion, continues throughout life. When you look at another's facial expression, you often take on aspects of that expression yourself. The brain perceives an emotion in the face of another and automatically signals its own emotional circuits.

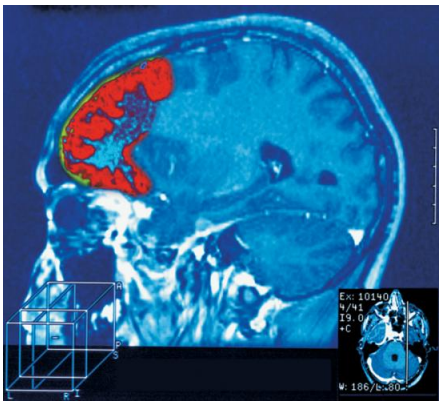
Many people with autism struggle with decoding the emotional content of faces, bodies, and sounds. Their inability to see things from another's perspective makes it hard for them to recognize sarcasm or deceit. Autopsies have found correlations between autism and cellular anomalies in the cerebellum, hippocampus, and amygdala, as well as shrinkage of the cerebellar vermis.

Other findings indicate that autism may result from disorders in the portions of the brain that specialize in imitation. So-called mirror neurons are less active in children with autism than in control groups of people without autism asked to imitate or merely observe facial expressions. ⦿

69

did you know...

Seeing someone in distress makes "mirror neurons" in your brain cause similar feelings.



Seeing Eye to Eye

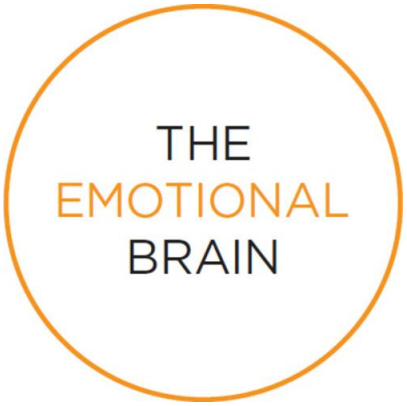
Emotional activity lights up the frontal lobe in this magnetic resonance image.

Credit 70

Newborns and their parents strengthen emotional bonds as they mirror each other's expressions. Credit 71

Love Potions

Scientists are unromantically beginning to link the pleasurable state of love to neurotransmitters and pheromones. Credit 72



The bright side

Of all the positive, pleasurable states, none has commanded so much attention as love. In the laboratory, love has gone under the microscope, to be dissected into categories and probed for possible clockwork mechanisms. Helen Fisher, a Rutgers University anthropologist, charts three kinds of physiological and emotional love: lust, attraction, and attachment. All arose through evolution to promote the continuation of the species through mating and parental bonding.

Fisher claims each type of love has its own purpose and chemistry. Lust sends people out into the world looking for a mate. It's associated with the hormones estrogen and androgen. Attraction focuses that physical energy on one person instead of spreading it too thin. The desire for emotional connections is believed to be associated with serotonin. Attachment keeps Mom and Dad together for the evolutionary advantage of having two parents. The neurotransmitters that keep two people together have been harder to find, but experiments with animals have turned up neurochemicals that promote pair bonding.

Chemical romance Brain scans of people in love show activation in the caudate nucleus, putamen, and insula, along with the anterior cingulate and the cerebellum. On the other hand, brain

regions associated with sadness, anxiety, and other negative emotions are suppressed in lovelorn people. Maternal love may share some of the same neural circuits as romantic love. The neuromodulator oxytocin is released during childbirth and breast-feeding to promote mother–child bonding.

70

did you know...

Exposure to oxytocin increases the level of trust people have for each other.

Naturally Happy

Much of the ability to feel happiness is determined by a person's genetic makeup.

Credit 73

The bright side

Joy Happiness, or joy, one of the universally recognized emotions, seems to be more nature than nurture. Neuroscientists have determined that more than 60 percent of an individual's tendency to have a character dominated by positive emotions comes from his or her genetic makeup. The rest is learned through experiences, emotions, and thoughts.

Research has targeted some of the regions for happiness. They include the hypothalamus along with the nucleus accumbens and septum. Each pleasure region releases neurotransmitters and endorphins, as well as dopamine, which has gained the most attention as an inducer of positive emotions. ⦿

case history

Happy dogs

Domestication of the dog has resulted in friendly pets. But are there physical traits associated with domestication? Russian geneticist Dmitri Belyaev began an experiment breeding Russian silver foxes in 1959, choosing tolerance for human contact as his sole criterion for reproduction. His 40-year project yielded a group of kits as playful as golden retrievers. In 1985, the fox colony not only exhibited docility, but also floppy ears, rolled tails, and white patches of fur, which suggests that the genes that encode for human-pleasing behavior are associated with a variety of physical traits that can be seen in dogs as well.

Credit 74

did you know...

Strong ties to friends and family increase levels of happiness.

In the long run, lottery winners are no happier than anyone else.

Charitable actions increase levels of happiness.

Experiences make people happier than possessions.

Some mice pass pheromones

through the male's tears.

Older people are more satisfied with their lives than younger people.

Memories of an experience rely on the moment of peak intensity and the final moment.

Psychologist Martin Seligman lists three components of happiness: pleasure, engagement, and meaning.

Men are more likely than women to

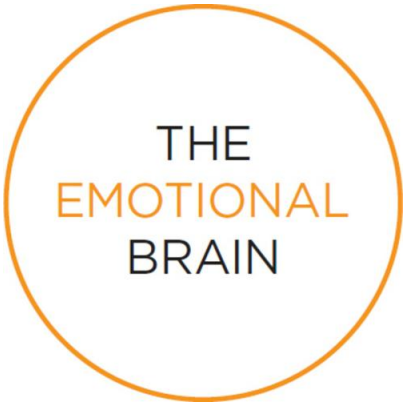
hide the symptoms of depression.

Anthropologists have found accounts of romantic love in 147 of 166 societies.

When exposed to the neurochemical arginine vasopressin, promiscuous voles became monogamous.

Agony Versus Ecstasy

Negative feelings such as sadness, fear, and anxiety affect the brain more powerfully than positive feelings do. Credit 75



The dark side

The human brain exhibits what psychologists call a negativity bias. Bad news sticks longer in memory than good news, and unpleasant encounters affect the brain more powerfully than pleasant ones. The brain's supersensitivity to negative emotions emerged at the dawn of the human species. Fear, anxiety, and anger prepared the body for fight or flight.

Fear and anger The physical manifestations of fear are well known. Fear activates the autonomic system and releases stress hormones, including adrenaline. The amygdala and thalamus mobilize the body by increasing heart rate and blood pressure, as well as by sharpening the focus of the senses. Meanwhile, slower sensory signals move from the thalamus to the frontal cortex to identify and reassess the source of fear's signal. The fast response of the amygdala has the evolutionary advantage of preparing the body for a worst-case scenario, while the slow response of the cortex keeps the body from running away from every shadow.

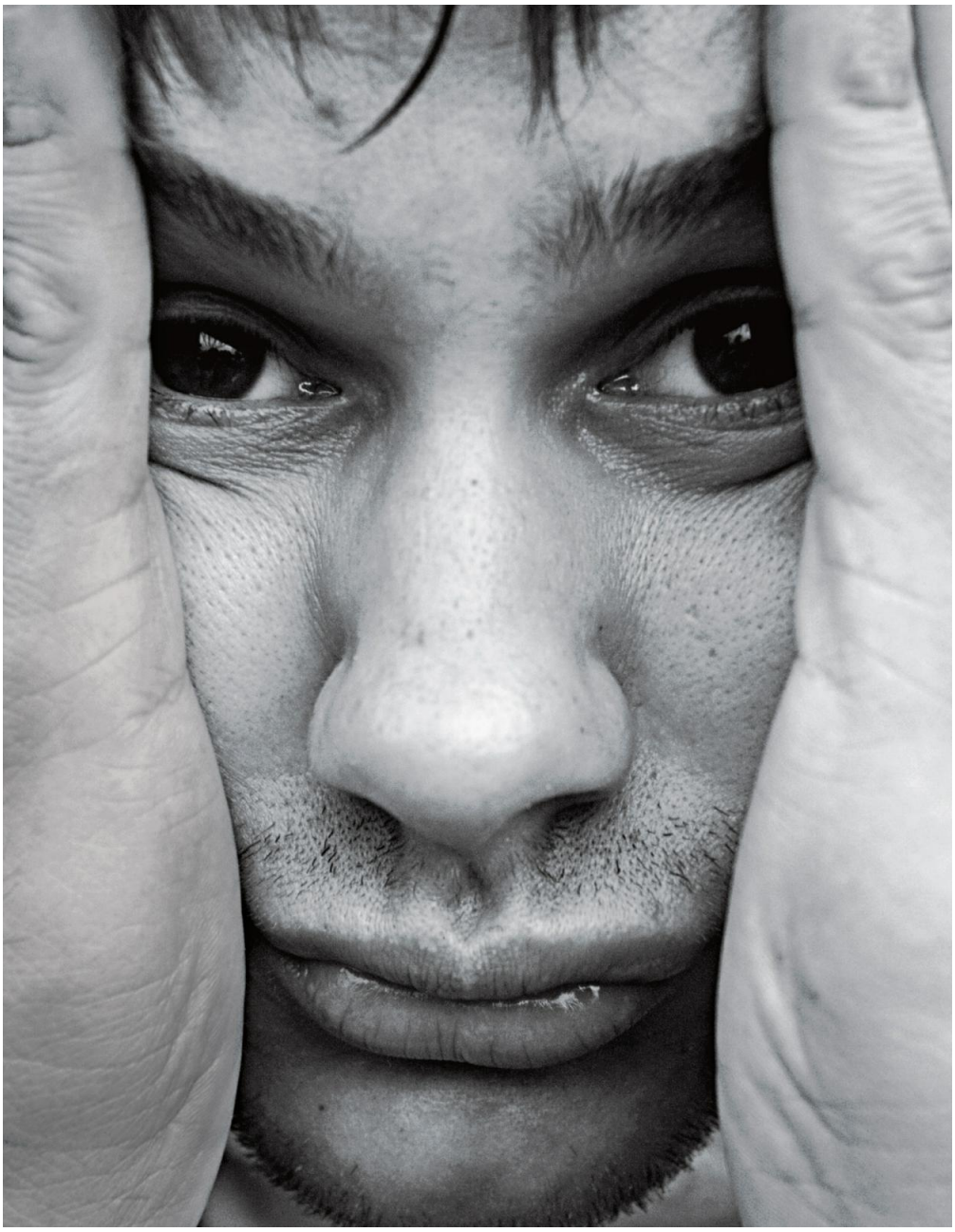
Anger, like fear, manifests itself through a variety of pathways starting with the limbic system. Anger releases cortisol in the brain, which promotes feelings of stress and frustration. Habitually angry people appear to have reduced neural activity in their frontal lobes, which communicate with the amygdala as the mind seeks a balance between reason and emotion. High and

low levels of serotonin and high testosterone levels also contribute to aggressive behavior, through mechanisms that are not entirely understood.

82

did you know...

Pain is not an emotion, although it can bring on emotional reactions.



An Unbalanced Perspective

Depression occurs when neurotransmitters are out of balance in many regions of the brain. Credit 76

The dark side

Feeling down The emotions of sadness and grief serve practical purposes. They may have evolved to let the brain slow down and recognize the impact of loss and the effect of negative behaviors.

Brain scans associate sadness with increased activity in the left hemisphere of the amygdala and the right hemisphere of the frontal cortex, and decreased activity in the right hemisphere of the amygdala and the left hemisphere of the frontal cortex. Long bouts of sadness may inhibit neurotransmitters in the frontal lobe and amygdala, leading to a numb and empty form of depression.

Depression Symptoms of depression, as opposed to sadness, include persistent sad or empty moods, a chronic drop in energy, loss of pleasure in things that usually bring enjoyment, guilty and helpless feelings, and a general feeling of not being one's usual self.

Research suggests depression arises from imbalances of neurotransmitters. It involves many regions of the brain, including the cerebral cortex, amygdala, hypothalamus, and other regions. People with depression exhibit shrinkage of the hippocampus, a brain region that regulates stress. Antidepressants such as Prozac can start to reset the balance among these regions of the brain. ⦿

did you know...

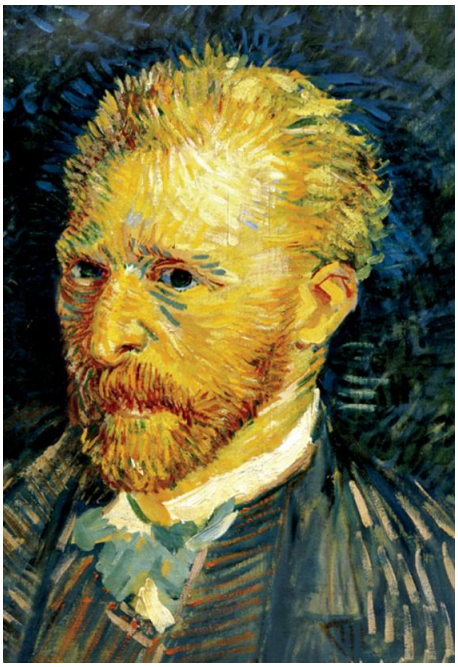
People with depression suffer the most in the early morning.

case history

Vincent van Gogh

Johns Hopkins University psychiatry professor Kay Redfield Jamison has suggested causal linkages in the overlapping moods and creative temperaments of brilliant authors and musicians, including Lord Byron, Virginia Woolf, and Robert Schumann. Nineteenth-century Dutch painter Vincent van Gogh, for instance, filled letters to his brother, Theo, not only with descriptions of his struggles as an artist but also with his depression. "[H]ow miserable the 'dregs' of the work are, that depression after overexertion," he wrote Theo in 1883. "Life is then the colour of dishwater."

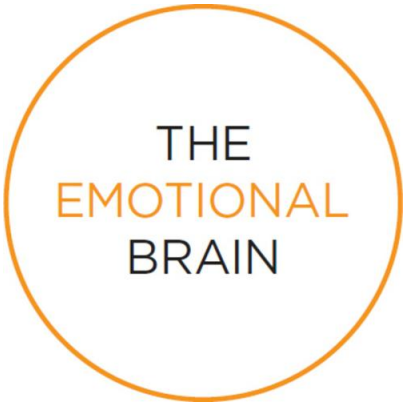
Van Gogh failed at many things—during his lifetime, he sold only one painting. Ultimately, he went into the hospital for his mental illness. He was released, and committed suicide, failing at that, too, lingering for days after a self-inflicted gunshot wound.



Credit 77

Jumping to Conclusions

The mind uses both intuition and conscious judgment in making a decision. Your unconscious mind may fear heights while your conscious mind assures you that your equipment will keep you safe. Credit 78



Emotion & decisions

The mind needs both unconscious intuition and reasoned judgment. Intuition reaches quick conclusions about things being good or bad. It's a fast and easy pathway to decisions. Many intuitive decisions are also logically sound because the brain accesses emotional memories from similar situations in the past and applies them to a snap decision in the present. However, many people assume that their decisions are made as part of a conscious and logical process, when in fact they stem from deeper, emotional needs.

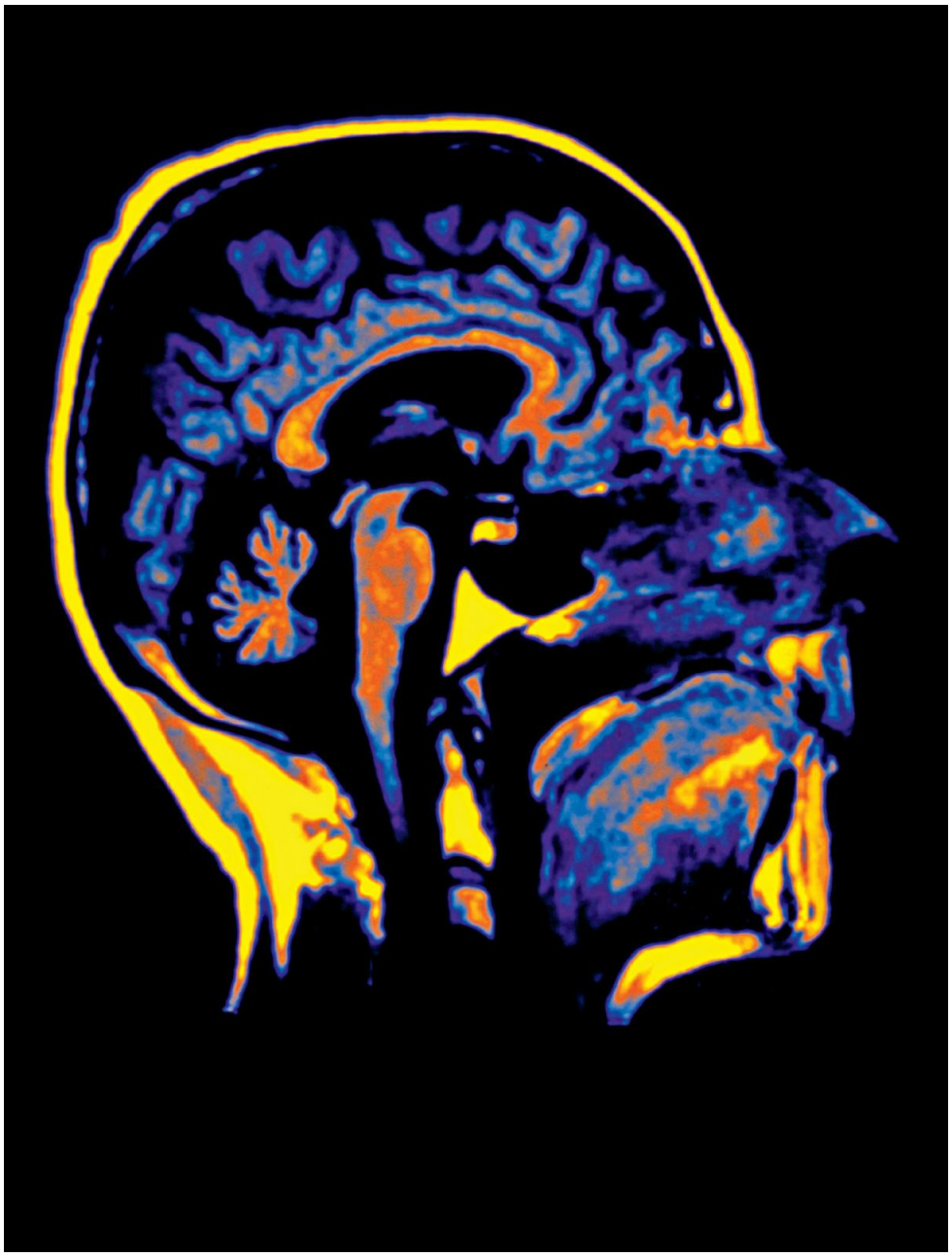
The illusion of control For instance: Imagine that your office has a lottery. All 200 tickets sell for one dollar apiece. At the end of two weeks, a drawing will determine the $200 winner. You buy a ticket and choose the number 65, for the day that you were married, June 5. Now imagine that a co-worker asks you to trade tickets because she likes that number better than her 23. Would you trade, even-steven? If not, what would you consider a fair deal?

If you're like most people, you'd be reluctant to trade your ticket for another one, although each has exactly 1 chance in 200 of winning. By selecting the number and purchasing your ticket, you likely consider it "your" ticket. Furthermore, your freedom of choice endowed the selection with what Harvard

psychologist Ellen Langer calls “the illusion of control.” It reflects the brain’s preference for controlling situations—even the uncontrollable ones. ⦿

did you know...

Nursing home residents who are given some control over their surroundings live longer.



Headroom

A scan shows atrophy of the brain tissue, which can occur as people age. Credit 79

the aging brain

With the exception of a lightning-like stroke, an aging brain changes gradually in its abilities to perceive sensations, process information, create and store memories, and learn. Some neurons die through normal aging or through disease or injury. Yet, except for a decrease in processing speed, healthy mature brains perform about as well as youthful ones in any task requiring planning, analysis, and organization of information. Some areas of mental ability actually increase with age. For instance, in the absence of disease, an elderly brain enjoys a larger vocabulary and sharpened language skills.

A host of disorders and diseases can affect the aging brain, from hearing loss to dementia. However, maintaining a healthy brain through mental and physical exercise, as well as medical treatment, can add life to one's final years. Education, sensory challenges, cognitive puzzles, and exercises to improve blood flow, balance, and muscle mass all support the most important organ in the body.

experiment

Number skills

The power of seven

Credit 80

Step 1.
Start at the top of the list of numbers here.
Look at the number, try to memorize it, and then cover it with your hand.

Step 2.
Immediately say the number out loud, one digit at a time, without pausing.
You would say the first number as "four-nine-two-six."

Step 3.
Continue along the list of numbers. Note the point at which your memory starts to falter in your attempts to recall the entire number.

Then go here.

4926

57843

02685

953456

684712

1537923

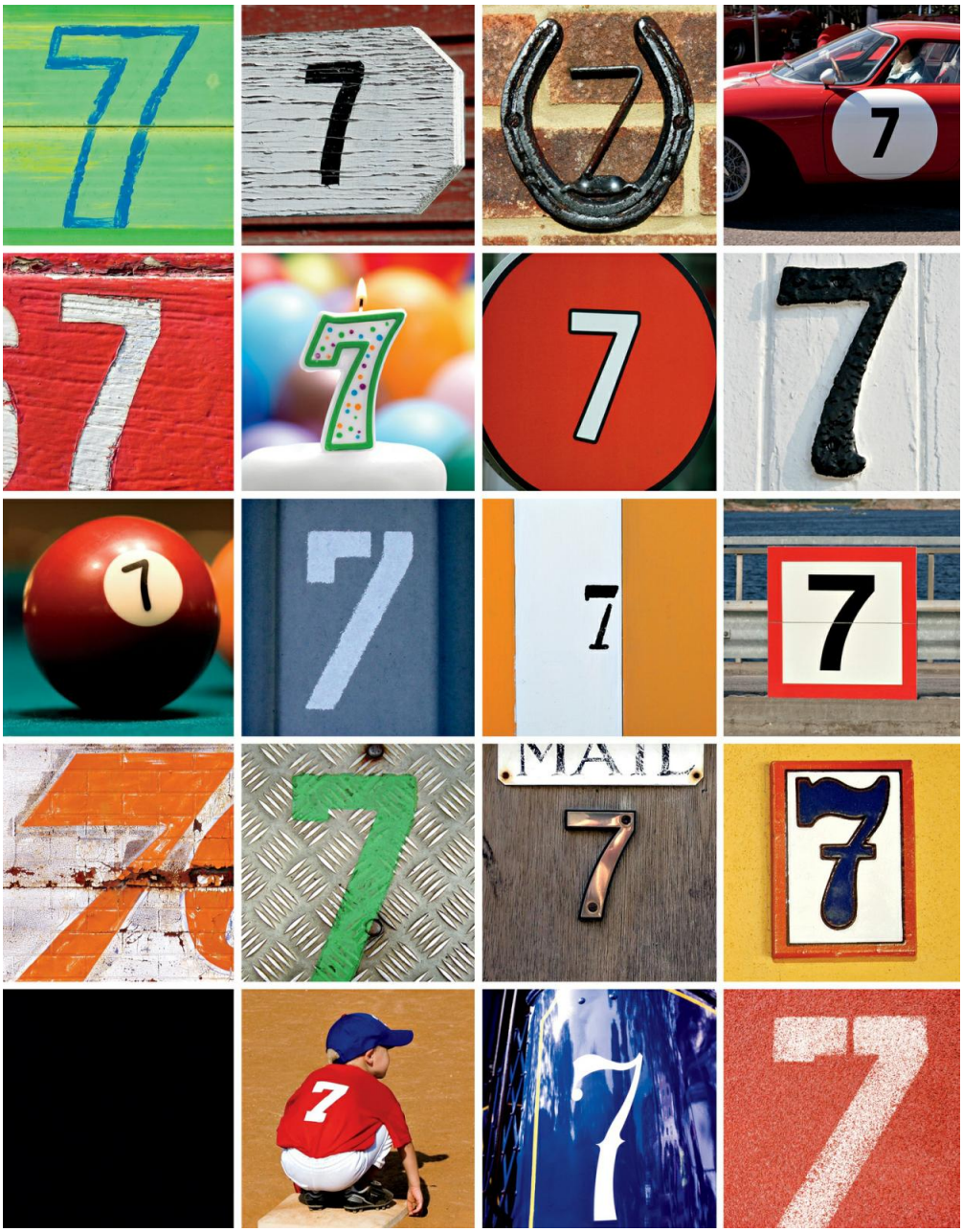
7430673

89314289

85371067

639818531

9278369708



Significant Seven

Some psychologists believe that the number 7 has special significance in mythology because it is the largest number of digits easily remembered. Credit 81

what happened

Did the number that beat you begin with 8?

The strings of digits that start with an 8 are also eight digits long. Chances are, those numbers, and the longer ones below, gave you trouble.

For a long time, observers have noted that the mind can manipulate only so much information at one time. You may have noticed that when a friend tells you a new phone number, you likely forget it if your friend asks you a question while you write it down. Your brain cannot handle the overload. But at what point does the brain rebel against handling too much at once?

Pioneering cognitive psychologist George Miller conducted a series of experiments and proposed the answer in 1956 in the *Psychological Review:* "My problem is that I have been persecuted by an integer," reads his paper's famous opening. The mysterious numeral is evident from the article's title: "The Magical Number Seven, Plus or Minus

Two."

Miller found most people could keep about seven new pieces of information in memory. Through subsequent experiments, researchers have tweaked Miller's numbers in certain situations and added insights into how different kinds of information affect memory's boundary. Some have questioned Miller's finding that active memory can hold about seven items, regardless of whether the data exist as numerals, letters, words, or some other form. Nevertheless, the end of Miller's article asks an intriguing question: Is it just coincidence that there are seven seas, seven ancient wonders, or seven deadly sins?

did you know...

Working memory resides in the prefrontal lobes.

The Fog of Age

Vision grows worse as we age, when the muscles controlling the expansion and contraction of the pupils grow less efficient. Credit 82

Changing senses

As we age, our senses become less acute through changes in the sense organs themselves as well as changes in the brain. Minimum levels of stimulation, called thresholds, are required before the brain perceives a sensation. With age, these thresholds rise, requiring greater stimulation before sensations register.

In addition, aging brains suffer a decline in working memory, making them more prone to distraction. That's why driving, especially in heavy traffic, becomes more difficult with age.

Vision and hearing Eyes and ears suffer the most dramatic ravages. Nearly everyone older than 55 needs corrective lenses at least part of the time. Some studies have found that impaired vision in the elderly is linked to mental decline. Why that's so isn't clear, but logic suggests the lack of clear vision for reading and performing eye–hand coordination would limit the ability to do brain-strengthening exercises.

Ears also suffer abuses through age, with the ability to hear high-pitched sounds the first function to disappear. Once considered a disease of old age, the loss of hearing in the high registers is now appearing in younger patients, thanks to our noisy world. ⦿

did you know...

Age-related damage to the inner ear can result in dizziness and falls in the elderly.

mental muscle

Video games

In 2008, researchers at the University of Illinois demonstrated that when the elderly play video games, they improve cognitive skills and maintain those improvements for weeks. Even better, the skills transfer to tasks in the real world.

The study had 20 adults older than 60 play a game, while another 20 served as a control group. The game players outscored the nonplayers on measures of alertness, working memory, and ability to shift between tasks. The takeaway?

Strategy-based games could become a way for the elderly to maintain and perhaps even improve some of the cognitive abilities that decline with aging, according to Art Kramer, author of the study. Video games can help seniors have fun and create or support social networks, while those that require body movement encourage physical exercise and eye–hand coordination.

Credit 83

Memory & learning

For centuries, observers have known that people process information more slowly as they age. But as a trade-off for their decline in speed, the elderly tend to consider problems more carefully and then offer well-reasoned responses.

One area concretely affected by age is memory. Recalling facts and autobiographical data may be clouded by anxiety, depression, and other negative states, which are more common among the elderly than young people. Nevertheless, when controlling for these variables, it becomes clear that aging weakens memory. Normal degradation of memories occurs both for events of the recent past and those long ago. Furthermore, the elderly lose a degree of working memory, the "mental desktop" that allows them to hold and manipulate information for a few seconds.

Scanning older brains Positron-emission tomography (PET) scans of elderly brains reveal how they differ in memory tasks from younger brains. Both young and old brains activate the hippocampal regions in both hemispheres to begin the process of encoding memories. However, during experiments aimed at testing their recognition of a set of 32 faces, the elderly showed lower levels of activation in the hippocampus than more youthful brains.

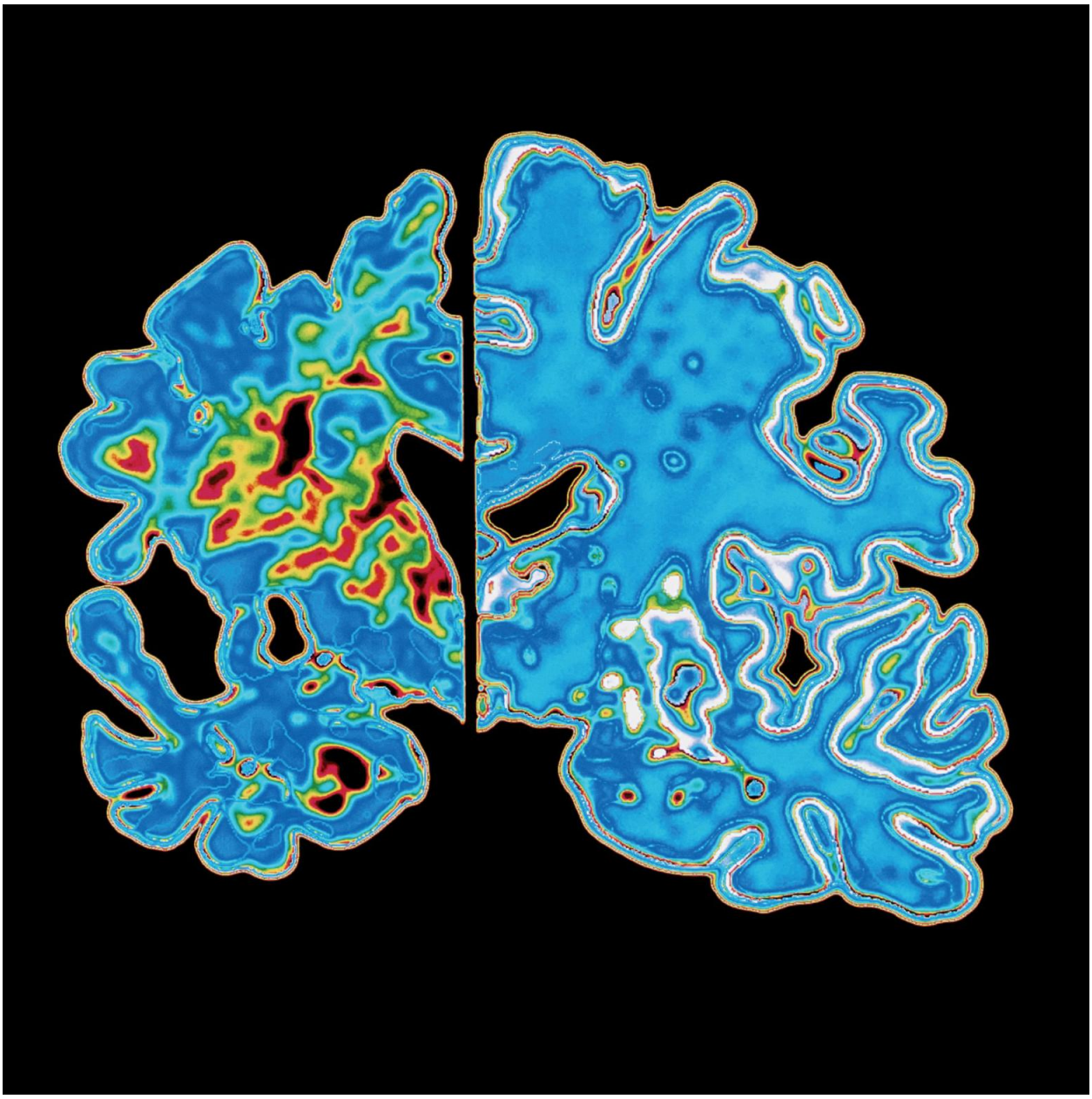
An elderly brain may attempt to force the recall of uncertain information by calling on the frontal lobes to assist in memory, but PET scans reveal older brains have more trouble activating these lobes, particularly in the left hemisphere. Even so, minor problems with memory are not a cause for concern until they become serious enough to interfere with daily life. ⦿

did you know...

The hippocampus loses about 5 percent of its neurons in normal aging.

Picturing the Past

Memory, including the ability to recall autobiographical events, is affected by age.
Credit 84



The Diminished Brain

Vertical slices of a brain affected by Alzheimer's disease, at left, and a normal brain, at right, show considerable shrinkage in the former. Credit 85

Coping with impairments

Today's scientists know that dementia and strokes are not normal parts of the aging process. Dementia, from the Latin for "apart" and "mind," describes a variety of symptoms that stem from as many as 50 disorders of the brain. All involve neuron destruction. Physicians diagnose dementia if two or more brain functions, typically including memory and language skills, are significantly impaired.

Thunderstruck Unlike dementia, a stroke occurs in an instant. The ancient Greek physician Hippocrates described stroke as *plesso,* meaning "to be thunderstruck." A stroke occurs when a blood clot or broken artery cuts off the flow of blood to the brain. Without oxygen-rich blood, brain cells die, taking with them the cognitive and motor functions they make possible.

Types of strokes Thrombotic strokes occur when an artery serving the brain closes through the buildup of fatty deposits on its inner walls. Embolic strokes occur when a fatty clot forms elsewhere in the body, such as in the walls of the heart, and flows through open arteries until it lodges like a dam in a blood vessel of the brain. Together, these two account for 80 percent of strokes. Hemorrhagic strokes occur when an artery ruptures in the brain, usually as a result of high blood pressure.

Although strokes happen in the brain, they affect the whole body. They are one of the leading causes of death and disability among older people, but the brain has remarkable abilities to recover even from stroke damage. With therapy, most people recover some or all physical functions, especially if they receive treatment within the first three hours.

did you know...

Past head injuries can accelerate the onset of dementia.

Shutting Down

Dementia patient Herb Winokur snoozes at breakfast with his caregiver and grandson. There are at least 50 different causes of dementia. Credit 86

Coping with impairments

Alzheimer's disease Alzheimer's disease is the most common form of dementia, targeting the portions of the brain that are crucial to remembering, thinking, and reasoning. It is marked by an accumulation of plaques and tangles in the brain. Dense bundles of fibers formed by a molecule called tau inside the neurons alter plaques and tangles from orderly patterns of neural connections to chaotic twists and turns. Outside the afflicted cells lie fatty globs of plaque. The accumulation of plaques and tangles makes neurons shrink and disappear. Drugs are now available to treat progressive dementias including Alzheimer's disease. For now, they offer only relief from, not a reversal of, disease. ⦿

case history

Alois Alzheimer

"She sits on the bed with a helpless expression. What is your name? Auguste. Last name? Auguste. What is your husband's name? Auguste, I think. Your husband? Ah, my husband. She looks as if she didn't understand the question."

So opens the first entry in a long-lost file of a woman identified only as Auguste D. The interview occurred November 26, 1901, and the physician was neuropsychiatrist Alois Alzheimer. Alzheimer described Auguste's symptoms as progressive cognitive impairment, hallucinations, delusions, and psychosocial incompetence. He observed her until her death in 1906. That year, Alzheimer described what he found in Auguste's brain during autopsy, including neurofibrillary tangles, cortical shrinkage, and plaque buildup between neurons. It was the first description of what became known as Alzheimer's disease.

Credit 87

did you know...

The risk of developing dementia **decreases** in your 80s.

Musical memories often **outlast** verbal memories in Alzheimer's patients.

Optimistic older people **live longer** than pessimists.

Alcohol affects older brains **more strongly** because of lower metabolic rates.

93

Patients with dementia are often more confused at sundown.

94

Disordered REM (dreaming) sleep can be an early symptom of dementia.

95

A typical 20-year-old takes 8 minutes to fall asleep, while a typical 80-year-old requires 18 minutes.

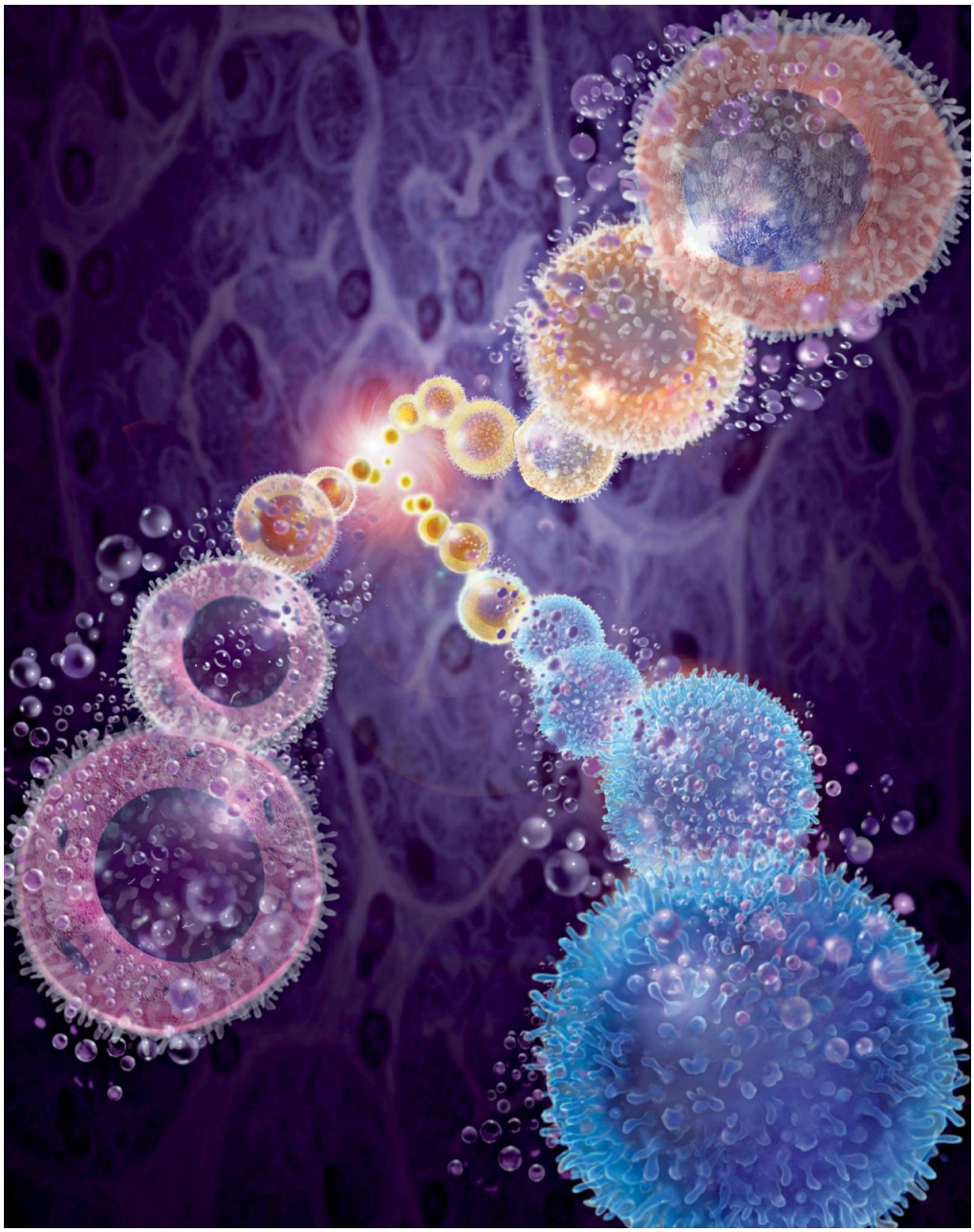
96

Tai chi can relieve depression.

Strategy-based games help older

brains stay sharp.

Older brains take longer than younger ones to recognize complex shapes.



Rebuilding the Brain

Stem cells, recently discovered in the brain, may one day be used to repair areas of damaged neurons. Credit 88

New directions

In the fetal brain, unspecialized stem cells grow into hundreds of particular kinds of neurons, each appropriate to its location and function. Until 1998, scientists believed the adult brain contained no stem cells and that no neurons could form after early childhood. However, the discovery that year of stem cells in the hippocampus, and the subsequent recognition of stem cells in the olfactory bulb and caudate nucleus, touched off a frenzy of speculation about ways they might be induced to create replacement neurons for damaged parts of the brain. Research is now focusing on finding the right chemical stimuli to turn a laboratory dish of stem cells into mature nerve cells.

Precursor cells Another thread of research aims to prompt precursor cells already in the brain to migrate to damaged areas and change into the necessary replacements. Jeffrey Macklis of Harvard University has induced the birth of neurons in mature mice brains, cells that moved toward areas of cortical damage and developed into mature neurons that acted just like those already there. With more research, doctors hope to be able to induce the body's most complex organ to heal itself. ⦿

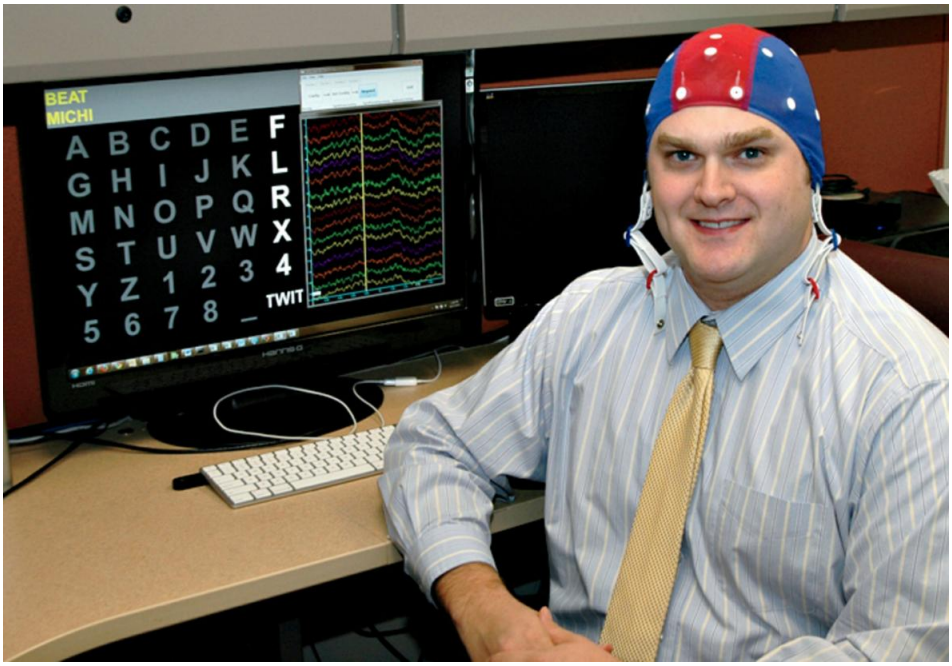
did you know...

Magnetic pulses aimed at the frontal lobes may lessen the grip of obsessive–compulsive disorder.

case history

Brain tweets

University of Wisconsin biomedical engineering doctoral student Adam Wilson took it as a personal challenge when he heard someone say how cool it would be to post messages to the social networking site Twitter simply by thinking. In spring 2009, Wilson demonstrated he could do just that during an interview with CNN. Wilson accomplished the feat by concentrating on one letter at a time to "type" his message, then posted it to the Internet by focusing on the word "twit" on his computer screen.



Credit 89

Credit 90

did you know...

The part of your brain that recognizes an object is different from the part that locates it.

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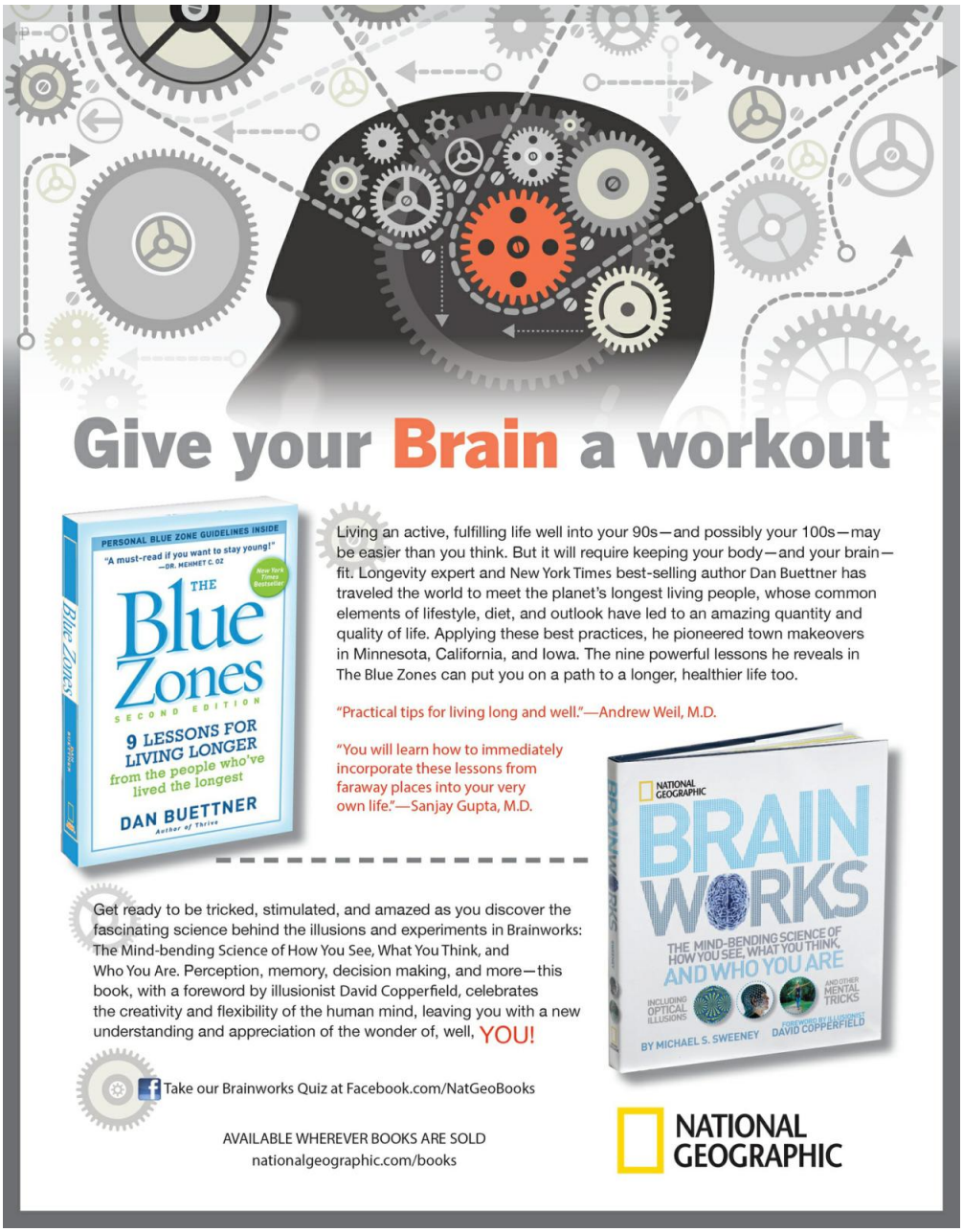

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