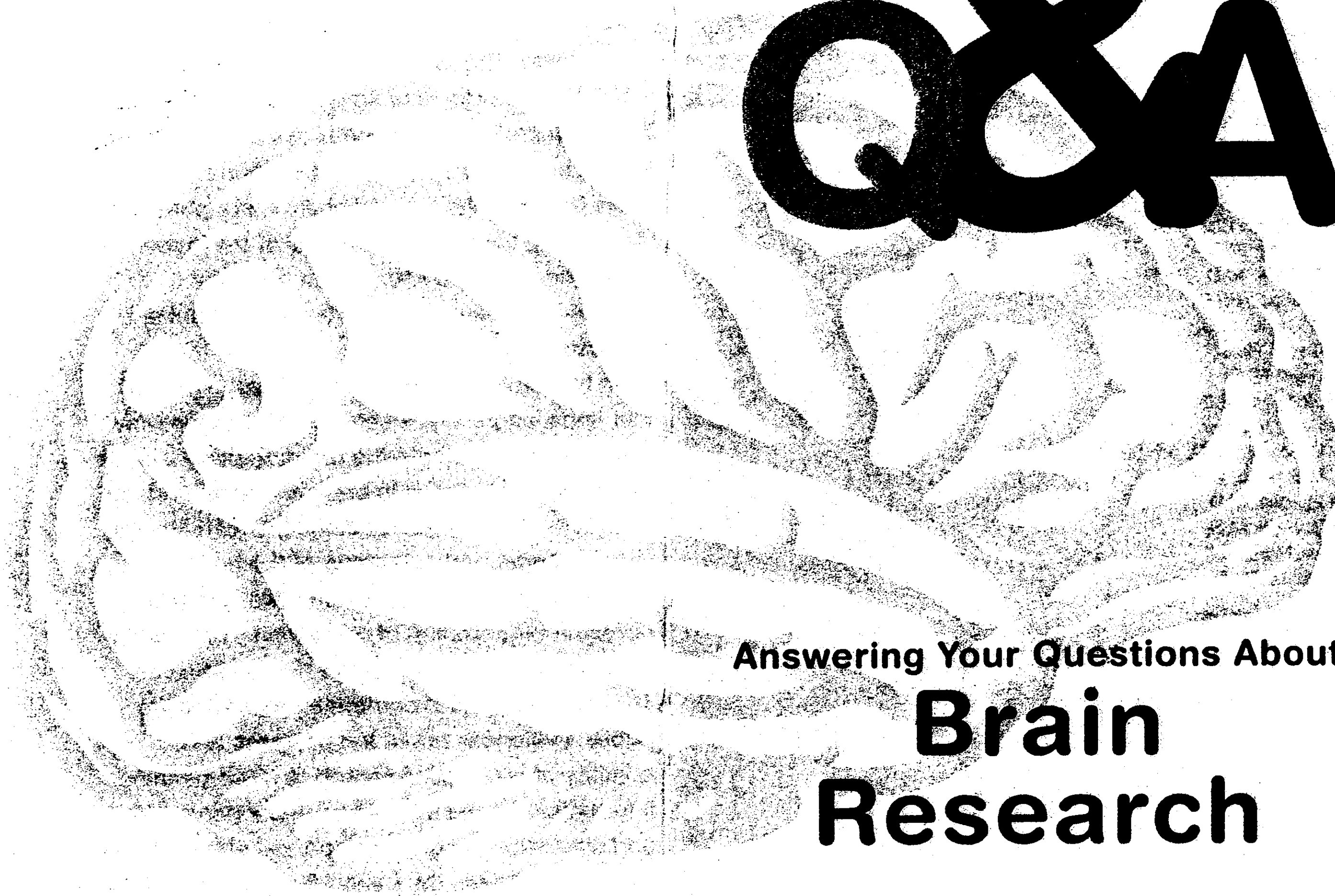

Q&A

Answering Your Questions About

Brain Research

Discover how research is advancing our understanding of the brain in health and disease.

The Dana Alliance for Brain Initiatives

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The Dana Alliance for Brain Initiatives has a vision. The Alliance imagines a world in which the scourge of brain disorders is overcome. The unprecedented advances in neuroscience research over the past several years have helped make this optimistic vision seem more possible. Harnessing the healing potential of the immense knowledge we've gained about the brain to conquer its diseases is the next great frontier of neuroscience.

In this brochure, we share with you some of that knowledge, in answers to some commonly asked questions about the brain. Explore with us the growing advances in brain research, and join us in imagining the possibilities that can emerge from a deeper understanding of the brain.

The Dana Alliance for Brain Initiatives is a nonprofit organization of more than 270 leading neuroscientists, including ten Nobel laureates. The Dana Alliance is committed to advancing public awareness about the progress and benefits of brain research and to disseminating information on the brain in an understandable and accessible fashion. Supported entirely by the Dana Foundation, the Dana Alliance does not fund research or make grants.

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The Three-Pound Marvel

The inner workings of the brain have fascinated people throughout history, and the quest to reveal its secrets is stronger than ever. This is no simple feat, given the brain's incredible complexity. Within its three-pound mass are roughly a billion nerve cells, billions more "support" cells, and a hundred trillion or more synaptic connections linking them all together. The brain accounts for a mere two percent of our body weight, but consumes 20 percent of the oxygen we breathe and 20 percent of the energy we take in. Our brains are what set us apart from every other species on Earth.

Disorders of the brain are a major cause of death and disability worldwide. As the world population ages the problem will grow, because many brain disorders disproportionately affect older people. Finding ways to prevent, treat, and cure the disorders of the nervous system is a primary goal of neuroscience research.

How does the brain work?

This is one of the fundamental questions that drives basic neuroscience research. Advances in the last decade, including powerful brain-imaging methods, have helped paint an increasingly clear picture of normal brain function.

Essentially, specialized brain cells called neurons receive and send information encoded in electrical impulses and neurochemicals. A nerve impulse—literally, a microjolt of electricity—travels along nerve fibers to the junctions where neurons make connections

(called "synapses") with other neurons or with sensory organs. At the synapse, the electrical signal triggers the release of chemicals called neurotransmitters. These act as couriers, carrying a molecular message across the synaptic gap to influence the activity of neighboring cells. Some neurotransmitters "excite" neurons—that is, activate them to fire—while others inhibit firing.

Each neuron can make as many as a thousand synapses. At any given moment, millions of synapses might be actively sending messages along intertwined networks of neurons that have been sculpted out to serve particular neural processes.

Think of little electrical storms raging on and off throughout your brain, precisely choreographed to what you are doing. Greet a neighbor, language areas light up. Ride a bike, motor and coordination areas flare. Any external sensory cue or internal process (such as recalling a memory or planning something) triggers this intricate dance of electrical and chemical signaling. Other brain cells called astrocytes join in as well, regulating the levels of neurochemicals around neurons to influence how a neuron will dance with its synaptically linked neighbors.

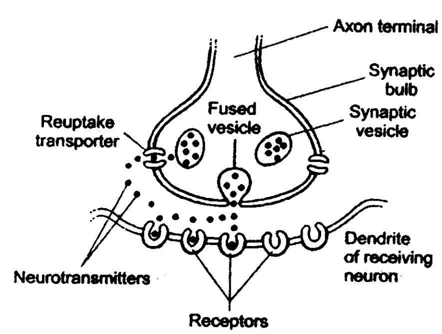

Diagram of a transmitting and receiving neuron

How do we learn?

Every time we learn something of consequence, we change our brains a little bit. Learning involves physical alterations in neurons and in the synapses that link them together. These minute structural changes in individual neurons underlie broader changes in the functional organization of the brain. Learning induces the formation of new synapses, and this in turn seems to make neurons more efficient or more powerful. Practicing something repeatedly is an effective way to learn something because it involves repeated activation of the same neural pathways, which become stronger and more efficient each time.

Metaphorically, learning could be compared to forging a new path through a thicketed wood. Each time the same path is used, it becomes clearer and more easily navigated. If used enough, the path can become a permanent addition to the landscape. The same principle holds true for neural pathways when we practice something repeatedly, such as when learning a musical instrument.

Over the course of a lifetime, learning and life experiences create a rich network of circuits uniquely fine-tuned to each individual. Learning literally shapes and reshapes the brain in this way.

Learning literally shapes and reshapes the brain over the course of a lifetime.

Multi-tasking has become the norm for many people; how does the brain accomplish multiple tasks at once?

It seems intuitive that doing more than one thing at once saves time, but from the brain's point of view, the opposite is true. A growing body of neuroscience research is showing that the brain's capacity for processing more than one task simultaneously is sharply limited. The brain needs to attend to one task at a time; it can't just double or triple its processing power in line with how many things we're trying to do at once. In experimental studies where participants were required to juggle two tasks simultaneously while undergoing a brain scan, neural activity actually decreased in comparison to focusing on one task alone.

That's not to say that walking and chewing gum isn't possible. But in general, tasks that require mental processing seem to be handled sequentially by the brain, not simultaneously. We may think we are multi-tasking, but in reality, our brain is rapidly switching its attention resources back and forth from one task to the next. There is a cost in terms of time—some studies suggest it takes the brain up to 50 percent more time to do two tasks at once vs. one at a time.

The bottom line is that multi-tasking may not be the most efficient use of brainpower. Focusing on one task at a time is likely to get the job done more quickly and with better results.

How does the brain influence and regulate the function of other body systems?

The brain ultimately controls every other system in our body. What's known as the autonomic nervous system regulates essential physiological functions such as heart rate, food digestion, and the "fight or flight" response to stress. Nerve fibers originating in the brain innervate all the organs and tissues of the body, monitoring their activity and then integrating all of the information to enable immediate, involuntary adjustment as necessary.

The immune system has a particularly complex relationship with the central nervous system, both influencing it and being influenced by it. While the brain was long thought to be "immune-privileged"—sequestered from the normal trafficking of immune cells that occurs elsewhere in the body—it is now known that the immune system actually plays a vital role in normal brain function. Recent brain research shows for example that specialized immune proteins called MHC class 1 proteins, which were thought not to be present in the brain at all, in fact appear to help regulate one of the brain's most fundamental capacities, its ability to adapt and rewire its synaptic connections (called "plasticity").

DID YOU KNOW?

New nerve cells are generated throughout life in certain areas of the brain, a process known as neurogenesis. Aerobic exercise can help increase the rate of neurogenesis, and stress can decrease it.

What happens to the brain as we age?

Not all brains age the same, just as not all bodies age the same. Intense basic and clinical research aims at understanding the "normal" changes in brain structure and function that are associated with aging and why the aged brain is more susceptible to many neurological disorders. While there are some generalizations that can be made about the physical changes the brain undergoes as it ages—such as decreased levels of certain neurotransmitters or degradation of discrete neuron populations—there is also wide variation in how those physical changes impact cognitive function. In other words, everyone's brain ages differently.

The good news is that the brain is adaptable at any age. It continues to add and modify its synapses and neural pathways throughout life, in an experience-dependent manner. That means "use it or lose it." Brain pathways that are inactive are eventually lost, while an enriching and stimulating life creates a richer network of synapses. This may act as a "neural reserve" against cognitive decline: if the brain is flush with neural pathways then it may be able to use alternate routes to accomplish tasks—like taking a detour around a highway that's jammed with traffic or under construction.

There have now been a number of cases reported in the scientific literature of older people who had normal or near-normal cognitive function at death, but whose autopsy studies showed extensive brain damage such as what might occur in Alzheimer's disease. It's as if their brains had found a way to adapt to a degree of disease pathology that would typically cause severe impairment.

How can I keep my brain young?

It turns out that there are a lot of things we can do throughout life to take charge of our brain health. Converging evidence from multiple areas of brain research is beginning to clarify the kinds of every-day activities that contribute to "cognitive fitness," or the maintenance of optimal mental functioning. Taken as a whole, such studies point to a number of factors that seem to contribute to a brain-healthy lifestyle, including:

- Incorporating physical activity—especially aerobic exercise—into our daily schedule, even if only for 10 minutes at a time.
- Stimulating our mind with mental activities and novel experiences that challenge the brain and activate new neural pathways.
- Interacting with other people and engaging in social activities.
- Having a sense of self-worth and self-efficacy, the feeling that what we do matters.
- Reducing cardiovascular risk factors such as high blood pressure and high cholesterol.
- Eating a healthful diet that includes plenty of colorful fruits and vegetables (for antioxidants and other vitamins and minerals) and fatty fish or nuts (sources of Omega-3 fatty acids), and that limits trans fat and saturated fats.
- Managing stress and finding healthful ways to cope with high-stress periods.
- Getting adequate amounts of sleep—about 8 hours for most adults.
- In addition, population-based studies seem to suggest that mild to moderate alcohol consumption—from a couple of drinks a week up to about two a day—is associated with longer life, and in some cases better cognitive functioning. However, it is not at all clear if this is due to a true biological effect of alcohol or because the people who drank alcohol tended to also be doing something else good for their brain health, such as interacting socially.

Think about how you can work brain-friendly activities into your day in each of these areas. It's never too late (or too early) to start. Studies suggest even the "oldest olds" can benefit cognitively from brain builders like exercise, mental stimulation, and social engagement.

DID YOU KNOW?

The idea that we use only 10 percent of our brain at any given time is a myth. It seems to have arisen out of early neuroscience findings that identified "silent" areas in the cortex that were not responsive to sensory stimulation. It is now known that these areas, far from silent, are actually involved in higher cognitive processing.

Can the brain heal itself from trauma or injury?

The long-accepted dogma that the brain or spinal cord cannot be repaired after an injury is slowly being revised as the science of regenerative medicine evolves. The simple observation that most people with severe brain or spinal cord trauma do not recover to full function makes it clear that there is limited inherent capacity for self-repair in the nervous system.

At the same time, it is also clear that self-repair mechanisms exist in the nervous system. We now know, for example, that new neurons are generated in the brain throughout life, and that there are stem cells in the brain that can migrate to areas of damage (such as from stroke). There is also increasing evidence that after an injury such as spinal cord trauma, the nervous system tries to recapitulate early developmental processes in order to repair and rebuild its damaged structure.

These lines of evidence offer tantalizing clues about how to effect repair in the nervous system. If scientists can figure out the fundamental mechanisms that underlie the inherent, albeit limited, self-repair mode of the nervous system, they might then be able to harness those mechanisms to steer or speed up the rebuilding process.

Understanding the inherent self-repair mechanisms of the nervous system could lead to new treatments for spinal cord injury, stroke, and other disorders.

What are neurodegenerative diseases?

The major neurodegenerative diseases are Alzheimer's disease, Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis (ALS). While each has a distinct set of symptoms, all involve progressive degeneration and death of nerve cells in discrete brain areas. In Parkinson's for example, cells that produce the transmitter dopamine degenerate, while ALS affects motor neurons. Alzheimer's disease attacks neurons in the cortex, where cognitive functions are performed.

There are other commonalities as well. Each involves toxic build-up of certain proteins (e.g., amyloid in Alzheimer's; alpha synuclein in Parkinson's), but it's not clear why these proteins accumulate or what ultimately triggers their production. Oxidative damage caused by the production of "free radicals" represents another mechanism that appears to be common across all neurodegenerative disorders.

These common links suggest possible therapies that might be used to target the underlying causes of neurodegeneration and prevent, stop, or reverse its course rather than just treating the physical symptoms, as current drugs do. Yet in each of these diseases, it is still not clear why nerve cells die. This is a critical question that needs to be answered in order to develop truly rational therapies that address the root causes of disease and arrest cell death. In the meantime, scientists are pursuing several investigational approaches to therapy. These include transplanting cells to replace those lost to degeneration, and supplying neuron-supporting growth factors to the brain to try to reverse degeneration or shore up normal cells that remain.

Why do some people develop mental illnesses?

Some people may think mental illnesses are rare, or only happen to "other people." The fact is that mental illness can strike anyone; it knows no sociodemographic or geographic boundaries. Recent studies indicate that as many as one in five Americans over 18, and about 12 million children 18 and younger, suffer from a diagnosable mental disorder, according to the National Institute of Mental Health (NIMH). In about five percent of adults, the illness is serious enough to interfere with their ability to function normally on a day-to-day basis. It is not known what makes any one person susceptible to developing a mental illness, but research suggests that a complex interplay of genetic and environmental influences is involved.

The NIMH defines a mental illness as a health condition that changes a person's thinking, feelings, or behavior (or all three), and that causes the person distress and difficulty in functioning. There are many different mental illnesses, including depression, schizophrenia, addictions, eating disorders such as bulimia and anorexia, developmental and learning disorders such as attention deficit hyperactivity disorder (ADHD) and autism, and anxiety disorders, which include generalized anxiety and obsessive-compulsive disorder. Each alters a person's thoughts, feelings, and/or behaviors in distinct ways.

What is clear is that mental illnesses are disorders of brain function associated with physical changes in neural circuitry or structure. Many are treatable with drugs currently available—though today's drugs are not perfect. By elucidating the mechanisms underlying mental illnesses, neuroscience research is helping drive the development of better, more targeted therapies.

How does the brain develop from birth to adulthood?

The development of the human brain is a complex, dynamic process that unfolds over the course of two decades or so. It is driven partly by genetic programming and partly by interactions with the environment, both of which conspire to shape the "wiring diagram" of the brain.

At birth, the human brain is equipped with only a small proportion of the synapses it will eventually have, like the initial rough frame of a house being built. A baby's brain is primed for learning, ready to integrate early experiences onto this framework to fill out the walls, roof, and interior rooms. In early development, synaptic connections are added primarily through synapse overproduction and loss—essentially, genetic programming sets up a large number of connections, then experience plays upon this network to strengthen some synapses and eliminate others. The timing of this process varies by brain region, with different areas primed for sculpting by experience at different time

How can I become involved in supporting brain research?

Here are some ways you can support brain research:

- Join in the activities of Brain Awareness Week. To find events in your area, visit www.dana.org/brainweek.
- Donate your time and support to the brain organization or advocacy group of your choice.
- If you or someone you love has a brain disorder, stay informed of the latest developments in treatments and clinical trials, and ask your doctor about them.
- Write to your Congressional representatives to let them know that you think brain research is a good investment.
- Stay informed on the brain. Read articles and books and watch science programs that discuss new advances in brain research.
- Volunteer to be a research subject for a brain study at an accredited research institution. Studies about how the normal brain functions are crucial to finding the answers to brain disorders.
- Write to newspapers and broadcasters to let them know that you follow and appreciate their media coverage of the brain.

www.dana.org

Your gateway to the latest news and information about the brain and brain research.

Visit **www.dana.org** for free resources, accessible news and information about the brain, links to many brain-focused organizations, and special sections for children and seniors, including:

Brain Connections: Your Source Guide to Information on Brain Diseases and Disorders
An online guide that lists more than 240 organizations likely to help those looking for information, referrals, and other guidance in connection with brain-related disorders.

It's Mindboggling!
Packed with information about the brain in a fun format of games, riddles, and puzzles. Also available in Spanish.

More Mindbogglers!
An addition to *It's Mindboggling!*, a closer look at learning and memory, the senses, drug addiction, and how the brain and nervous system work ... still in a fun format.

Staying Sharp
A series of booklets on such brain topics as Learning Throughout Life, Memory Loss and Aging, Chronic Health Issues, Quality of Life, and Depression.

Subscriptions to free Dana Press periodicals
Including *Brain in the News* and *BrainWork: The Neuroscience Newsletter*.

Dana BrainWeb
Offers links to Internet sites with validated current information useful for the lay person. Covering 25 common brain diseases and disorders, *BrainWeb* provides the latest research, treatment options, support for families and caregivers, and sources for more information.

Webcasts and Podcasts
Webcasts from the Dana Centre in London and the Dana Center in Washington, DC, and podcasts of the *Gray Matters* radio series and other Dana-supported programs.

Dana Press books
Dana Press publishes non-fiction health and popular science books for general readers with a special focus on the brain.

points. This is why neuroscientists talk about "critical periods" or "sensitive periods" for learning certain skills such as language. Synapses are also added by learning and experience throughout life.

Around adolescence, the brain undergoes a second burst of synapse overproduction, followed by another dramatic "pruning" period during which underused synapses wither and die back. This final developmental wave of synaptic fine-tuning proceeds from the back of the brain to the front, making the prefrontal cortex the last area of the brain to develop. This region is associated with advanced cognitive functions such as planning, reasoning, and inhibiting impulsive behavior.

The teenage years represent one of the most dynamic phases of brain development, a period during which the brain is "hyper-plastic"—highly adaptable—as it shapes and refines the neural pathways that will support it through adulthood. This can be a double-edged sword, for the same mechanisms that appear to make the teen brain exquisitely primed for learning also make it vulnerable. Drugs of abuse, for example, seem to have longer-term effects on the brain when they are used during adolescence than at other ages.

Are there practical clinical applications of neuro-imaging?

Techniques such as magnetic resonance imaging (MRI) and positron emission tomography (PET), which capture pictures of the living human brain, have become indispensible tools for neuroscience research and are increasingly being applied to solve clinical problems related to diagnosis and treatment of brain disorders. Greater availability of the scanning machines, combined with new techniques for manipulating scan data and growing research on the clinical utility of imaging, is contributing to their expanded use in clinical practice.

One of the most robust clinical uses of brain imaging is to facilitate safer, more effective surgery in the brain or spinal cord. For example, anatomical scans can identify the precise borders of a brain tumor to guide the surgeon's scalpel as the tumor is removed. Functional imaging techniques (e.g., PET, functional MRI) can identify brain structures that the surgeon must avoid so as not to disrupt language or other critical functions. Imaging can also be used to diagnose stroke, seizure activity, or brain shrinkage associated with Alzheimer's disease.

DID YOU KNOW?

"Neuroethics" refers to the exploration of ethical issues surrounding advances in neuroscience. For example, the prospect of medications that improve memory raises ethical issues about the potential "lifestyle" use of such drugs (e.g., by college students seeking to boost exam scores).