"Building a Better Brain"
Reading Questions

Answer the following questions from the article. Use complete sentences, and put the ideas into your own words to demonstrate that you not only know where to find the answer, but that you also understand the answer.

1. What is the correlation between higher levels of education and Alzheimer's disease? Why?

2. Even among the nuns at the convent, there were some noticeable differences among those who suffer from Alzheimer's, dementia, and other debilitating brain disorders? What was the difference?

3. Why does dancing help your brain become stronger and more resilient to brain disorders? What kind of dancing is best for the brain? Why?

4. Between what years do human brains do the greatest connection-building? What happens to connections that are not used?

5. Why did Derek feel the sensation of touch in his phantom hand?

Building a Better Brain

Evidence is accumulating that the brain works a lot like a muscle—the harder you use it, the more it grows. Although scientists had long believed the brain's circuitry was hard-wired by adolescence and inflexible in adulthood, its newly discovered ability to change and adapt is apparently with us well into old age. Best of all, this research has opened up an exciting world of possibilities for treating strokes and head injuries—and warding off Alzheimer's disease.

Daniel Golden

The party last year was as rowdy as it gets in a convent. Celebrating her 100th birthday, Sister Regina Mergens discarded her habit in favor of a daring red gown, downed two glasses of champagne and proclaimed her intention to live to 102. She didn't quite make it. Now, at vespers on a March afternoon in Mankato, Minn., dozens of nuns file past the open casket where Mergens, 101, lies, rosary beads in her hands.

Concealed from view is an incision in the back of Mergens's head through which her brain has been removed. Mergens and nearly 700 elderly sisters in her order are the largest group of brain donors in the world. By examining these nuns, as well as thousands of stroke victims, amputees and people with brain injuries, researchers are living up to the promise of a presidential proclamation that the 1990s be the Decade of the Brain. Scientists are beginning to understand that the brain has a remarkable capacity to change and grow, even in old age, and that individuals have some control over how healthy and alert their brains remain as the years go by. The Sisters of Mankato, for example, lead an intellectually challenging life, and recent research suggests that stimulating the mind with mental exercise may cause brain cells, called neurons, to branch wildly. The branching causes millions of additional connections, or synapses, between brain cells. Think of it, says Arnold Scheibel, director of UCLA's Brain Research Institute, as a computer with a bigger memory board: "You can do more things more quickly."

The capacity of the brain to change offers new hope for preventing and treating brain diseases. It helps explain why some people can:

- Delay the onset of Alzheimer's disease symptoms for years. Studies now show that the more educated a person is, the less likely he or she is to show symptoms of the disease. The reason: Intellectual activity develops surplus brain tissue that compensates for tissue damaged by the disease.
- Make a better recovery from strokes. Research indicates that even when areas of the brain are permanently damaged by stroke, new message routes can be created to get around the roadblock or to resume the function of that area.
- Feel sensation in missing limbs. Scientists no longer think that complaints of pain in amputated body parts are psychosomatic. The feelings, which eventually fade, turn out to be the brain's way of keeping once-busy neurons active, evidence that the brain's plasticity can trick as well as treat and that areas of the brain no longer useful can be taken over by nearby regions of the cortex.

New knowledge about the brain may emerge from the obscure convent in Minnesota, a place where Ponce de León might have been tempted to test the waters. Mankato is the site of the northwest headquarters of the School Sisters of Notre Dame, where a long life is normal. In part because the nuns of this order don't drink much, smoke or die in childbirth, they live to an average age of 85, and many live far beyond that. Of the 150 retired nuns residing in this real-life *Cocoon*, 25 are older than 90.

But longevity is only part of the nuns' story. They also do not seem to suffer from dementia, Alzheimer's and other debilitating brain diseases as early or as severely as the general population. David Snowdon of the Sanders-Brown Center on Aging at the University of Kentucky, the professor of preventive medicine who

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How to Make Your Dendrites Grow and Grow

What can the average person do to strengthen his or her mind? "The important thing is to be actively involved in areas unfamiliar to you," says Arnold Scheibel, head of UCLA's Brain Research Institute. "Anything that's intellectually challenging can probably serve as a kind of stimulus for dendritic growth, which means it adds to the computational reserves in your brain."

So pick something that's diverting and, most important, unfamiliar. A computer programmer might try sculpture; a ballerina might try marine navigation. Here are some other stimulating suggestions from brain researchers:

■ Do puzzles. "I can't stand crosswords," says neuroscientist Antonio Damasio of the University of Iowa, "but they're a good idea." Psychologist Sherry Willis of Pennsylvania State University says, "People who do jigsaw puzzles show greater spatial ability, which you use when you look at a map."

■ Try a musical instrument. "As soon as you decide to take up the violin, your brain has a whole new group of muscle-control problems to solve. But that's nothing compared with what the brain has to do before the violinist can begin to read notes on a page and correlate them with his or her fingers to create tones. This is a remarkable, high-level type of activity," says Scheibel.

■ Fix something. Learn to reline your car's brakes or repair a shaver, suggests Zaven Khachaturian, a brain expert at the National Institute of Aging. "My basement is full of electronic gadgets, waiting to be repaired. The solution is not the important thing. It's the challenge."

■ Try the arts. If your verbal skills are good, buy a set of watercolors and take a course. If your drawing skills are good, start a journal or write poetry.

■ Dance. "We keep seeing a relationship between physical activity and cognitive maintenance," says Harvard brain researcher Marilyn Albert. "We suspect that moderately strenuous exercise leads to the development of small blood vessels. Blood carries oxygen, and oxygen nourishes the brain." But be sure the activity is new and requires thinking. Square dancing, ballet or tap is preferable to twisting the night away.

■ Date provocative people. Better yet, marry one of them. Willis suggests that the most pleasant and rewarding way to increase your dendrites is to "meet and interact with intelligent, interesting people." Try tournament bridge, chess, even sailboat racing.

And remember, researchers agree that it's never too late. Says Scheibel: "All of life should be a learning experience, not just for the trivial reasons but because by continuing the learning process, we are challenging our brain and therefore building brain circuitry. Literally. This is the way the brain operates."

has been studying the nuns for several years, has found that those who earn college degrees, who teach, who constantly challenge their minds, live longer than less-educated nuns who clean rooms or work in the kitchen. He suspects the difference lies in how they use their heads.

Within the human brain each neuron contains at one end threadlike appendages called axons, which send signals to other nearby neurons. At the other end of the neuron are similar threadlike appendages called dendrites, which receive messages from nearby cells. Axons and dendrites tend to shrink with age, but experiments with rats have shown that intellectual exertion can spur neurons to branch like the roots of a growing tree, creating networks of new connections. Once a skill becomes automatic, the extra connections may fade, but the brain is so plastic that they can be tapped again if needed. Like the power grid of an electric company, the branching and connections provide surplus capacity in a brownout. Snowdon and some neuroscientists believe that people with such a surplus who find their normal neural pathways blocked by the tangles that characterize Alzheimer's disease can reroute messages. To be sure, every brain is limited by genetic endowment, and flexibility does decrease with age. But new thinking in brain science suggests that whether someone hits that wall at age 65 or at age 102 may be partly up to the individual. Even Harvard's David Hubel, who shared a Nobel prize just 13 years ago for vision experiments showing that parts of the brain become fixed in infancy, is surprised that new research shows the brain "is much more modifiable than we ever suspected."

Professor Snowdon says the nuns of Mankato demonstrate this. He expects to prove that the better-educated sisters have significantly more cortex and more synaptic branching of neurons than their less-educated counterparts, which would allow the former to cope better with Alzheimer's disease, dementia and stroke.

Brain exercising is a way of life at the nunnery, where the sisters live by the principle that an idle mind is the devil's plaything. They write spiritual meditations in their journals and letters to their congressmen about the blockade of Haiti, and do puzzles of

The Brain of a Child

"It's crazy," says Pasko Rakic, a Yale neurobiologist. "Americans think kids should not be asked to do difficult things with their brains while they are young: 'Let them play; they'll study at the university.' The problem is, if you don't train them early, it's much harder."

It is never too early for a child to exercise his mind. Some of the benefits of early brain workouts have been known for centuries. Teachers of music, gymnastics and chess, for example, have long insisted that practicing begin early. Linguists have marveled that children can learn a new language without an accent, while adults cannot. "In order to pronounce certain words, you have to put the vocal cord in a certain tension," Rakic says. "To do that, you have to contract throat muscles. Control of these muscles is in the synapses that were formed before puberty."

There is, says Rakic, a fairly simple scientific explanation: Children's brains can make far more synaptic connections than can adults'. Shortly after birth, the brain makes connections at an incredible pace. As puberty approaches, the number tapers off. Then two processes begin—functional validation, in which the connections the brain finds useful are made permanent, and selective elimination, in which those that are not useful, not continually used, are eliminated. Says Rakic: "We chisel our brain from the larger stone, so to speak." The greatest chiseling is accomplished between the ages of two and 11.

"Of course," Rakic adds, "this doesn't mean you cannot learn in later life. You can learn tremendously. But in childhood there is an ability to learn quickly which is unparalleled."

all sorts. Although more than a few were born when Grover Cleveland was President, they are adept at debating Bill Clinton's health-reform proposals. Current-events seminars are held every week. Raised before radio, the nuns are more skilled at answering questions on the TV program *Jeopardy* than the actual contestants. One 99-year-old, Sister Mary Esther Boor, takes advantage of slow minutes while working as the complex's receptionist to solve brainteasers—some with words in Spanish.

And Willard Scott, take note: Five nuns in Mankato will turn 100 within a few months. One, Sister Matthia Gores, will hit 101. Like many of the sisters, she taught school into her seventies, and she is still sharp enough to recite her rosary and knit gloves for poor children at the same time, without missing a stitch. "I pray for a happy death," she says. "That's the most important thing in life—to die well." But she is in no hurry for that prayer to be answered. Having overcome cancer and a recent nasty bout with the flu, she looks forward to daily exercise sessions. Born two years after Dr. James Naismith invented basketball, she likes the geriatric version of the sport: shooting a Nerf ball through a hoop. Leaning on her walker one afternoon, she swishes three in a row.

Like the aging nuns of Mankato, Henry Carr is determined to exercise his brain. The 81-year-old stroke victim's chances of recovery depend on ...s brain's ability to redesign itself and grow new ...utes of communication.

His body motionless, his face straining with determination. Carr lies in a metal doughnut known as a Positron Emission Tomograph (PET) scanner as a technician comes rushing into the room with a syringe of radioactive water. He injects it into Carr's arm, and the scan begins to track the radioactivity, which has a half-life of only two minutes. Wasting no time, Dr. Holley Dey begins to rub a toothbrush against the fingertips of Carr's left hand.

"Can you feel that?" asks Dey, clinical director of the Yale/Veterans Affairs PET Center in West Haven, Conn. "Try and move your left hand. Try and move your fingers, Mr. Carr." Carr, who suffered a stroke two weeks earlier that paralyzed most of his left side, tries. Instead, his right hand makes a fist—involuntarily. This may indicate, scientists say, that Carr's brain is trying to use its left hemisphere, which normally controls the right side of the body, to find new neural pathways to move the left arm. Scan results confirm this.

Most of the 500,000 Americans who have a stroke each year recover some lost function. Before the development of advanced imaging techniques, neurologists thought stroke victims regained use of bruised brain tissue as swelling in the area subsided. PET scans now show that a stroke victim may recover even if the neurons in the affected part of the brain are permanently damaged. Scientists like Dr. Lawrence Brass, associate professor of neurology at Yale, believe that the brains of stroke patients may form new dendritic connections, indicating that even an aging adult's brain can grow in response to injury. Recovery depends in part on the type and location of the stroke, and the patient's age and medical history. In some patients, scientists believe, nearby neurons enlarge their networks and take over for the damaged tissue, or other brain centers that govern involuntary actions expand

their role. In Carr's case, for example, the left side of his mouth still droops. But when he smiles without thinking, it rises as readily as the right. The reflexive system that raises his mouth involuntarily may find a way to take over other movements.

The plasticity of the brain can be a burden as well as a blessing, especially in cases of amputation. Then, a whole area of the cortex previously devoted to a part of the body has nothing to respond to. Derek Steen learned to compensate after his left arm was amputated above the elbow following a motorcycle crash in 1985. Before long he could tie his shoelaces with one hand and shoot pool so well with one arm that his friends in Poway, Calif., began calling him "the Bandit." But the 27-year-old hasn't been able to adjust to the mysterious aching in his lost limb. It hurts so much that Steen has often been unable to sleep. His happy-go-lucky personality has turned sour, and his temper has cost him one job after another. "I'm not the same Derek I was," he says. Until recently no one was able to explain why the pain was intense when he was shaving his left cheek or when his face was buffeted by wind.

For centuries phantom pain has puzzled researchers. Some have interpreted it as psychosomatic, others as a cry of protest from truncated nerve endings in the stump. Now research links phantom pain, like recovery from stroke, to the brain's capacity to flex and grow. In the cortex, each area of the body is represented in proportion to its importance as a sensory receptor. Fingers take up more neurons than do shoulders. But boundaries in the brain can shift as often as they do in the Balkans, and each section of cortex can control its neighbor's territory.

Not long ago it was believed that when a limb was amputated, the corresponding brain cells withered away. Then professor Michael Merzenich of the University of California at San Francisco severed the nerve of the middle finger in an adult monkey. Deprived of normal stimuli, the related cortex did not die. Instead, nearby neurons activated by other fingers filled in the dormant region. In effect, the brain tried to compensate for lost feeling in the finger by reallocating its share of cortex to the rest of the hand.

Merzenich's finding inspired professor Vilayanur Ramachandran of the University of California at San Diego to study human amputees. Last year he began seeing Derek Steen, the one-armed pool player. Ramachandran asked Steen to close his eyes. Then the doctor touched Steen's cheek, asking where he felt a sensation. In his phantom hand, Steen said. When Ramachandran stroked Steen's jaw with a cotton swab, the patient felt movement across his missing limb.

Ramachandran was not surprised. In the cortex, neurons for the face are next to those for the arm. Once Steen's brain stopped receiving signals from the arm, stimuli from the cheek filled in, a development confirmed by magnetic mapping of Steen's brain waves. Yet Steen's mind attributed the sensations to the phantom limb, indicating that some higher centers of the brain that coordinate sensory information cannot easily adjust to something as drastic as an amputation.

And the effects of filling in are not always predictable. Most amputees, for example, feel pain in their missing limbs, but not all do. Deborah Finnegan-Ling, a graduate student in neuroscience at the University of Vermont, is a disciple of Ramachandran. She is writing her dissertation on phantom pain, a phenomenon with which she is familiar: Her lower left leg was amputated after a farming accident three years ago. Because the area of the brain for the foot is adjacent to the area

Century of Mind Gains

1901	Russian physiologist Ivan Pavlov coins the term "conditioned reflex" to describe why his dogs salivate at the sound of a bell.
1906	Alois Alzheimer discovers a severe age-related neurological disorder that leads to dementia and death.
1906	Anatomist Santiago Ramón y Cajal wins a Nobel for showing that neurons are separate cells connected by synapses.
1911	Eugen Bleuler identifies schizophrenia, a major mental disease.
1929	German psychiatrist Hans Berger uses the electroencephalograph to discover human brain waves.
1952	Two French psychiatrists, Jean Delay and Pierre Deniker, introduce chlorpromazine to treat psychoses, ushering in the age of psychopharmacology.
1971	A new tool is made available for imaging the brain: computerized axial tomography (CAT scan).
1988	Prozac is introduced by Eli Lilly and Co. as an antidepressant. Patients report unparalleled improvement, and before long it is prescribed for everything from panic attacks to dieting.
1991	Nitric oxide is found to be a neurotransmitter and a key compound in stroke damage. The discovery may lead to effective drug therapy for strokes.

for genitalia. Finnegan-Ling's missing limb aches when she makes love. I consider myself tough," she says. "But the pain is so acute that I'll cry." Nobody knows why, but some amputees feel phantom pleasure rather than pain. Told about a man who feels an orgasmic sensation in his lost foot during sex, Finnegan-Ling sighs. "I wish," she says.

As David Snowdon table-hops in the Mankato cafeteria, greeting nuns by name and inquiring after their health, his interest is professional as well as personal. Someday soon the researcher likely will be looking at their brains under a microscope, but that prospect, like death itself, doesn't seem to bother anyone, and the nuns continue to tease the 41-year-old about his long hair and his bachelor lifestyle. "I've spent so much time in convents lately," he jests. "that it has kind of crimped my social life." He was less at ease three years ago when he first stood up and described his study. Snowdon worried that asking nuns to give their brains to science was like asking them to boo Notre Dame.

"The sisters talked about it seriously and severely," says Sister Matthia Gores. But the nuns' intellectual curiosity prevailed. As a gerontologist intrigued by aging, Snowdon wanted only the brains of nuns who were 75 years or older, and most agreed to participate. Other School Sisters across the country followed. Every year they undergo a battery of mental and physical tests.

So far, Snowdon's team has examined the brains of 90 nuns for signs of dementia. He has found Alzheimer's in about 40 percent of the brains. In the general population, Alzheimer's is found in as many as 50 percent of those over 85. Soon researchers will look for proof of dendritic growth in the nuns' brains.

Of the 678 subjects in Snowdon's study, Regina Mergens was the 95th to die. Just before viewing her body, 30 nuns past the age of 85, all in the nursing home wing, gathered to celebrate St. Patrick's Day. Entering the room, they were given cardboard shamrocks to pin on their habits beside their purple ribbons for Lent.

Accompanied by an accordion-playing nun in a green hat, they sang, "When Irish Eyes Are Smiling." Just for fun, the activities director asked them to name as many green foods as they could. They reeled off 25 answers.

"See," the director cried. "Nothing wrong with our memories."

Additional reporting by **Anne Hollister** and **Sasha Nyary**