KIM PEEK, who is developmentally disabled, knows more than 7,600 books by heart as well as every area code, highway, zip code and television station in the U.S. He provided the inspiration for the character Raymond Babbitt in the movie *Rain Man*.

Islands of Genius

Artistic brilliance and a dazzling memory can sometimes accompany autism and other developmental disorders

By Darold A. Treffert and Gregory L. Wallace

Photographs by Ethan Hill

LESLIE LEMKE is blind and has never studied piano. Although he suffers from cerebral palsy and is developmentally disabled, he composes music and is able to play thousands of pieces flawlessly, even when he has heard them only once.

Leslie Lemke is a musical virtuoso. At the age of 14 he played, flawlessly and without hesitation, Tchaikovsky's Piano Concerto No. 1 after hearing it for the first time while listening to a television movie several hours earlier. Lemke had never had a piano lesson—and he still has not had one. He is blind and developmentally disabled, and he has cerebral palsy. Lemke plays and sings thousands of pieces at concerts in the U.S. and abroad, and he improvises and composes as well.

Richard Wawro's artwork is internationally renowned, collected by Margaret Thatcher and Pope John Paul II, among others. A London art professor was "thunderstruck" by the oil crayon drawings that Wawro did as a child, describing them as an "incredible phenomenon rendered with the precision of a mechanic and the vision of a poet." Wawro, who lives in Scotland, is autistic.

Kim Peek is a walking encyclopedia. He has memorized more than 7,600 books. He can recite the highways that go to each American city, town or county, along with the area and zip codes, television stations and telephone networks that serve them. If you tell him your date of birth, he can tell you what day of the week it fell on and what day of the week it will be when you turn 65 "and can retire." Peek can identify most classical compositions and knows the date the music was published or first performed as well as the composer's birthplace and dates of birth and death. He is also developmentally disabled and depends on his father for many of his basic daily needs. His abilities provided the inspiration for the character Raymond Babbitt, whom Dustin Hoffman played in the 1988 movie *Rain Man*.

Lemke, Wawro and Peek all have savant syndrome, an uncommon but spectacular condition in which people with various developmental disabilities, including autism, possess astonishing islands of ability and brilliance that stand in jarring juxtaposition to their overall mental handicap. Savant syndrome is seen in about one in 10 people with autism and in approximately one in 2,000 people with brain damage or mental retardation. Of the known savants, at least half are autistic and the remainder have some other kind of developmental disorder.

Much remains mysterious about savant syndrome. Nevertheless, advances in brain imaging are permitting a more complete view of the condition, and a long-standing theory of left hemispheric damage has found support in these imaging studies. In addition, new reports of the sudden appearance of savant syndrome in people with certain forms of dementia have raised the intriguing possibility that some aspects of such genius lie dormant in all of us.

Down's Definition

DESCRIPTIONS of savant syndrome appear in the scientific literature as early as 1789. Benjamin Rush, the "father of American psychiatry," described the lightning-quick calculating ability of Thomas Fuller, who understood little math more complex than counting. When Fuller was asked how many seconds a man had lived by the time he was 70 years, 17 days and 12 hours old, he gave the correct answer of 2,210,500,800 a minute and a half later—and he had taken into account 17 leap years.

It was not until 1887, however, that the remarkable coexistence of deficiency and superiority was more completely laid out. That year J. Langdon Down, who is best known for having identified Down syndrome, described 10 people with savant syndrome. He had met these fascinating individuals during his 30 years as superintendent of the Earlswood Asylum in London. He coined the now discarded term "idiot savant," using the then accepted classification of an idiot as someone with an IQ of less than 25, combined with a derivative of the French word *savoir*, which means "to know."

More than a century has passed since Down's original description. Today we know a great deal more about this perplexing set of abilities from the 100 or so cases described in the scientific literature. It is now clear that savant syndrome generally occurs in people with IQs between 40 and 70—although it can occur in some with IQs as high as 114. It disproportionately affects males, with four to six male savants for every one female. And it can be congenital or acquired later in life following disease (such as encephalitis) or brain injury.

Narrow Repertoire

THE SKILLS THAT savant syndrome gives rise to are limited for the most part, and they tend to be based in the right hemi-

RICHARD WAWRO is an internationally renowned Scottish painter who has been exhibiting his work since he was 17 years old. He is autistic.

sphere. That is, they are predominantly nonsymbolic, artistic, visual and motor. They include music, art, mathematics, forms of calculating and an assortment of other abilities, such as mechanical aptitude or spatial skills. In contrast, left hemisphere skills are more sequential, logical and symbolic; they include language and speech specialization [see "The Split Brain Revisited," by Michael S. Gazzaniga; SCIENTIFIC AMERICAN, July 1998].

Most musical savants have perfect pitch and perform with amazing ease, most often on the piano. Some are able to create complex compositions. And for some reason, musical genius often seems to accompany blindness and mental retardation, as it does for Lemke. One of the most famous savants was "Blind Tom" Bethune, who lived from 1849 to 1908. In his time, he was referred to as "the eighth wonder of the world." Although he could speak fewer than 100 words, he could play beautifully more than 7,000 pieces on the piano, including many of his own works. (Some of his compositions were recently recorded by musician John Davis and released on CD.)

For their part, savant visual artists use a variety of media, although they most frequently express themselves through drawing and sculpture. Artistic savant Alonzo Clemons, for example, can see a fleeting image of an animal on a television screen and in less than 20 minutes sculpt a perfect replica of that animal. His wax model will be correct in every detail, every fiber and muscle and proportion.

Mathematical savants calculate incredibly rapidly and often have a particular facility with prime numbers. Curiously, the obscure skill of calendar calculating that Peek demonstrates is not confined to mathematical savants; it seems to coexist with many different skills.

Several other abilities appear less frequently. A rare savant may have extensive language ability—that is, the capacity to memorize many languages but not to understand them. Other unusual traits include heightened olfactory, tactile and visual sensitivity; outstanding knowledge in fields such as history, neurophysiology, statistics or navigation; and spatial ability. For instance, a musical and blind savant named Ellen can navigate in thick forests or other unfamiliar spaces without running into objects. Ellen also has a perfect appreciation of passing time despite the fact that she doesn't have access to a watch or clock, even in Braille. This ability was discovered one day when her mother let her listen to the "time lady" on the telephone. After listening for a short while to the recorded voice intone the hour and seconds, Ellen apparently set her own internal clock. Since then, she has been able to tell what time it is to the second, no matter the season.

Savant skills are always linked to a remarkable memory. This memory is deep, focused and based on habitual recitation. But it entails little understanding of what is being described. Some early observers aptly called this "memory without reckoning." Down himself used the phrase "verbal adhesion" to characterize it. One of his patients was a boy who had read the six-volume *History of the Decline and Fall of the Roman Empire,* by Edward Gibbon, and could recite it back word for word, although he did so without any comprehension.

Although they share many talents, including memory, savants vary enormously in their levels of ability. So-called splinter-skill savants have a preoccupation and mild expertise with, say, the memorization of sports trivia and license plate numbers. Talented savants have musical or artistic gifts that are conspicuously above what would be expected of someone with their handicaps. And prodigious savants are those very uncommon people whose abilities are so advanced that they would be distinctive even if they were to occur in a normal person. Probably fewer than 50 prodigious savants are alive at the moment.

Whatever their talents, savants usually maintain them over

THE AUTHORS

DAROLD A. TREFFERT and *GREGORY L. WALLACE* share a long-standing interest in savant syndrome. Treffert is a psychiatrist at St. Agnes Hospital in Fond du Lac, Wis., and has done research on autism and savant syndrome since 1962, the year he met his first savant. (His e-mail address is dtreffert@pol.net) Wallace is a visiting researcher at the Social, Genetic and Developmental Psychiatry Research Center at the Institute of Psychiatry in London. He is currently conducting research on why individuals with autism are more likely to develop savant skills. (His e-mail address is g.wallace@iop.kcl.ac.uk)

ALONZO CLEMONS can create perfect wax replicas of any animal he sees, no matter how briefly. His bronze statues are sold by a gallery in Aspen, Colo., and have earned him national repute. Clemons is developmentally disabled.

the course of their life. With continued use, the abilities are sustained and sometimes even improve. And in almost all cases, there is no dreaded trade-off of these wonderful abilities with the acquisition of language, socialization or daily living skills. Instead the talents often help savants to establish some kind of normal routine or way of life [*see box on page 85*].

Looking to the Left Hemisphere

ALTHOUGH SPECIALISTS TODAY are better able to characterize the talents of savants, no overarching theory can describe exactly how or why savants do what they do. The most powerful explanation suggests that some injury to the left brain causes the right brain to compensate for the loss. The evidence for this idea has been building for several decades. A 1975 pneumoencephalogram study found left hemispheric damage in 15 of 17 autistic patients; four of them had savant skills. (A pneumoencephalogram was an early and painful imaging technique during which a physician would inject air into a patient's spinal fluid and then x-ray the brain to determine where the air traveled. It is no longer used.)

A dramatic study published by T. L. Brink in 1980 lent further credence to the possibility that changes to the left hemisphere were important to savant syndrome. Brink, a psychologist at Crafton Hills College in California, described a normal nine-year-old boy who had become mute, deaf and paralyzed on the right side when a bullet damaged his left hemisphere. After the accident, unusual savant mechanical skills emerged. He was able to repair multigeared bicycles and to design contraptions, such as a punching bag that would weave and bob like a real opponent.

The findings of Bernard Rimland of the Autism Research Institute in San Diego support this idea as well. Rimland maintains the largest database in the world on people with autism; he has information on more than 34,000 individuals. He has observed that the savant skills most often present in autistic people are those associated with right hemisphere functions and the most deficient abilities are associated with left hemisphere functions.

In the late 1980s Norman Geschwind and Albert M. Galaburda of Harvard University offered an explanation for some causes of left hemispheric damage—and for the higher number of male savants. In their book *Cerebral Lateralization,* the two neurologists point out that the left hemisphere of the brain normally completes its development later than the right and is therefore subject to prenatal influences—some of them detrimental—for a longer period. In the male fetus, circulating testosterone can act as one of these detrimental influences by slowing growth and impairing neuronal function in the more vulnerable left hemisphere. As a result, the right brain often compensates, becoming larger and more dominant in males. The greater male-to-female ratio is seen not just in savant syndrome but in other forms of central nervous system dysfunction, such as dyslexia, delayed speech, stuttering, hyperactivity and autism.

Newly Savant

IN RECENT YEARS, more data have emerged to support the left hemisphere hypothesis. In 1998 Bruce L. Miller of the University of California at San Francisco examined five elderly patients with frontotemporal dementia (FTD), one form of presenile dementia. These patients had developed artistic skills with the onset and progression of their dementia. They were able to make meticulous copies of artworks and to paint beautifully. Consistent with that in savants, the creativity in these five individuals was visual, not verbal. Single-photon-emission computed tomography (SPECT) showed that injury was predominantly on the left side of the brain. Miller examined seven other patients who had developed musical or artistic ability after the appearance of FTD. He found damage on the left as well.

Miller, Craig Hou of Washington University and others then compared these images with those of a nine-year-old artistic autistic savant named DB. SPECT scans of DB revealed a higher-than-normal blood flow in part of his neocortex but decreased flow in his left temporal lobe. (The neocortex is involved with high-level cognitive function; the temporal lobe is responsible for some aspects of memory and emotion.) Miller is hoping to study other artistic savants to see if the findings hold true for them as well. But the fact that DB and older FTD patients with newfound savant skills have the same pathology is quite striking and suggests that researchers will soon be able to identify pre-

cisely the neurological features associated with savant syndrome.

The seemingly limitless memory of savants will mostly likely be harder to pinpoint physiologically. Mortimer Mishkin of the National Institute of Mental Health has proposed different neural circuits for memory, including a higher-level corticolimbic circuit for what is generally referred to as semantic or cognitive memory, and a lower-level corticostriatal circuit for the more primitive habit memory that is most often referred to as procedural memory. The memory of savants seems to be the noncognitive habit form.

The same factors that produce left hemispheric damage may be instrumental in producing damage to higher-level memory circuits. As a result, savants may be forced to rely on more primitive, but spared, habit memory circuits. Perhaps brain injuries—whether they result from hormones, disease, or prenatal or subsequent injury—produce in some instances certain right brain skills linked with habit memory function. In those situations, savant syndrome may appear.

Rain Man in Us All?

THE EMERGENCE of savantlike skills in people with dementia raises profound questions about the buried potential in all of us. Accordingly, several researchers are seeking to unlock what has been called the "little Rain Man in each of us." One group has used a technique called repetitive transcranial magnetic stimulation (rTMS) in 17 normal individuals, eight male and nine female. Tracy Morrell of the University of South Australia, Robyn L. Young of Flinders University in Adelaide and Michael C. Ridding of Adelaide University applied magnetic stimulation to the area in the left temporal lobe that Miller identified as damaged in his FTD patients.

In their as yet unpublished study, the team reports that only two participants experienced a series of short-lived skills, such as calendar calculating, artistic ability and enhanced habit memory. Others discovered a new skill here and there, also lasting just a few hours. The researchers suggest that savant skills may be limited to a small percentage of the normal population in the same way that they are limited to a small percentage of the disabled population.

Nevertheless, many experts believe that real potential exists to tap into islands of savant intelligence. Allan Snyder and John Mitchell of the Centre for the Mind in Canberra, Australia, argue that savant brain processes occur in each of us but are overwhelmed by more sophisticated conceptual cognition. Autistic savants, they conclude, "have privileged access to lower levels of information not normally available through introspection."

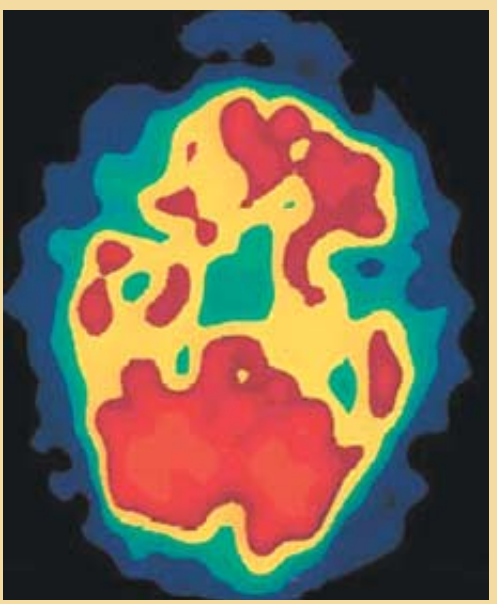
Our view is also that all of us have some of the same circuitry and pathways intrinsic to savant functioning but that these are

Emerging Savants

IN RECENT YEARS, researchers have discovered that certain patients who have frontotemporal dementia (FTD) can paint beautifully when they previously had no such talent. In short, they have become savantlike as dementia has taken hold.

This painting of horses (*right*) was made by one of these patients, a 64-year-old woman with FTD. Bruce L. Miller of the University of California at San Francisco has examined many FTD patients and has documented damage to the left side of their brain. One theory suggests that savant skills may emerge in the more artistic right hemisphere as a way of compensating for damage in the left. In this SPECT image (*left*) of an FTD patient, enhanced blood flow can be seen in a part of the right hemisphere (*red*).

—D.A.T. and G.L.W.



COURTESY OF BRUCE L. MILLER *U.C.S.F.*

Living with Savant Syndrome

A FEW REPORTS in the literature suggest that when savants are encouraged to acquire better language skills they lose their special artistic talents. Perhaps the most famous of these cases is that of Nadia, a girl with autism who by the age of three was producing astounding drawings. When she turned seven, Nadia entered a school for autistic children that focused on verbal abilities; by the time she was a teenager, Nadia was more verbal but could no longer create brilliant and intricate drawings.

This trade-off between talent and language or socialization is not something we have witnessed. Instead the exceptional abilities of savants have proved to be strengths that are built on and used as a conduit toward normalization; these skills have helped individuals develop improved social skills, better language acquisition and greater independence. Savants gain a sense of accomplishment because of their talent; that sense, in turn, allows them to participate more fully in the world. Musical prodigy Leslie Lemke has become more animated, performing concerts and interacting with audiences. Painter Richard Wawro feels delight and excitement when he finishes a work, and he seeks out celebration. And memory wizard Kim Peek has emerged from the social isolation that characterized him before the movie *Rain Man* was made; he now travels the country talking to hundreds of school groups.

Fortunately, simultaneously encouraging savant abilities and normalization is proving to be the accepted approach to such individuals' care. Savants are being placed in some classes for the gifted and talented, an opportunity that promotes social growth for both them and their classmates. Some new programs, such as the one at Hope University in Anaheim, Calif., cater entirely to these exceptional individuals. Others include people with similar disorders as well; for example, music and art camps have been established for those with Williams syndrome, many of whom have savantlike musical skills [see "Williams Syndrome and the Brain," by Howard M. Lenhoff, Paul P. Wang, Frank Greenberg and Ursula Bellugi; SCIENTIFIC AMERICAN, December 1997]. Nurturing the talent is the most fulfilling approach. *—D.A.T. and G.L.W.*

FERRY BOAT TO TIREÉ, SCOTLAND, was painted in 1978 by Richard Wawro. Wawro is cared for by his father, who enthusiastically supports his painting. Most researchers believe that such artistic skill may help savants develop better social skills.

less accessible—in part because we tend to be a left-brain society. Sometimes, though, we can find elements of the savant in ourselves. At certain moments, we just "get" something or discover a new ability. And some procedures—including hypnosis; interviews of subjects under the influence of the barbiturate sodium amytal, which induces relaxation; and brain stimulation during neurosurgery—provide evidence that a huge reservoir of memories lies dormant in every individual. Dreams can also revive those memories or trigger new abilities.

A Window into the Brain

NO MODEL OF BRAIN FUNCTION will be complete until it can explain this rare condition. Now that we have the tools to examine brain structure and function, such studies can be correlated with detailed neuropsychological testing of savants. We hope the anecdotal case reports that have characterized the literature on this topic for the past century will soon be replaced by data comparing and contrasting groups of normal and disabled people, including prodigies, geniuses and savants.

Savant syndrome provides a unique window into the brain with regard to questions of general intelligence versus multiple forms of intelligence. It may also shed light on brain plasticity and central nervous system compensation, recruitment and repair—areas of research that are vital in understanding and treating such diverse conditions as stroke, paralysis and Alzheimer's disease.

But savant syndrome has relevance outside the scientific realm. Many lessons can be learned from these remarkable people and their equally remarkable families, caretakers, therapists and teachers. One of the greatest lessons is that they have been shaped by far more than neural circuitry. The savants thrive because of the reinforcement provided by the unconditional love, belief and determination of those who care for them. Savant syndrome promises to take us further than we have ever been toward understanding both the brain and human potential. SA

MORE TO EXPLORE

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