

Saturday Night Magazine – May 1, 2001

BUILDING A BETTER BRAIN

By Norman Doidge

Palazzo Del Bo, Padua, Italy, 1594. the intimate wooden stage recedes into the ground like a grave. On the table is the body of a criminal, recently dispatched, and beside it the cadaver of an animal, which will be switched for the human corpse should the police arrive to break things up. For fear of offending the religious authorities, the "ceremony of reason" is conducted in the middle of the night, illuminated by torchlight. Three hundred crowd into il teatro anatomico, the anatomy theatre carved into the ground, to view a Renaissance performance that has a distinctly Gothic odour.

"To anatomize" has the same meaning as "to analyze," which comes from the Greek *analuein*, and means to break into pieces. Into his cupped hands the anatomy teacher receives an impressively personal object. A human brain. Perhaps he takes a moment to wonder how so many one-sided, iniquitous inclinations might have resided in such perfectly symmetrical hemispheres.

The anatomists work in January because the cold preserves the bodies. The entrance to il teatro is framed by chiselled words: *Mors Ubi Guadet Succurrere Vitae*. "This Is The Place Where Death Helps Life."

Long before functional magnetic-resonance-imaging scans were invented, the human brain was being mapped, one tragedy at a time. In 1861, a surgeon, Paul Broca, at the Society of Anthropology in Paris, started the long process of convincing medical colleagues that the brain's hemispheres are symmetrical in shape only. Broca had performed an autopsy on a patient who had lost the ability to speak. On dissecting the brain, he had found damaged tissue in the man's left frontal lobes, but not in the right frontal lobes. Skeptics doubted speech could be localized to the left frontal lobes and dismissed his findings. So Broca brought the man's brain to the next Society meeting, as his guest.

That is how it went for another hundred years. The greater the tragedy, the more refined the map. During the Franco-Prussian War, when cannon balls were flying and electricity was still a novelty, scientists found soldiers in hospitals with sections of their skulls shot off and applied electrodes to exposed brain tissue to see which muscles would twitch. "It was found quite easy to obtain eye movements by leading constant galvanic currents through the posterior part of the head . . .," wrote Fritsch and Hitzig in 1870. It didn't cause pain because there are no nerve endings in the brain. As the map of Europe was revised by Napoleon III and Bismarck, so, too, was the map of the human motor cortex.

1943. The battle of Smolensk, USSR. Sadly, a promising place for brain mapping. Modestly equipped Russians were thrown against the invading Nazi war machine. A young Russian lieutenant sustained a bullet wound to the head, with massive damage to the left occipito-parietal region deep inside his brain. For a long time he lay in a coma. When Comrade Lyova Zazetsky awoke, his symptoms were very odd. The shrapnel had lodged in the part of the brain that helps us understand relationships between symbols. He could no longer understand logic, cause and effect, or spatial relationships, or distinguish his left from his right. He couldn't understand elements of grammar that

are also about relationships. Prepositions such as "in," "out," "before," "after," "with," and "without" had become meaningless to him. He couldn't comprehend a whole word, understand a whole sentence, or recall a complete memory because each would require relating symbols. All he could grasp were fleeting fragments. Yet his frontal lobes, the mind's CEO, that allow one to seek out what is relevant and plan, strategize, form intentions, and pursue them, were spared. Thus he was left with the capacity to recognize his defects, and the wish to overcome them. Though he couldn't read, which is a perceptual activity, he could write, because it is an intentional one. He began a very fragmentary diary he called "I'll Fight On," which swelled to 3,000 pages. "I was killed March 2, 1943," he wrote, "but because of some vital power of my organism, I miraculously remained alive."

One hundred trillion connections make up the human brain, highways still mostly unmapped. Often those who do the mapping are scientists whose brains are extraordinary, working on those whose brains are damaged, in the most asymmetrical of relationships. Rarely is the person who makes a discovery the one with the defect, though there are exceptions. Barbara Arrowsmith Young is one.

"Asymmetry" is the term that best describes her mind when she was a schoolgirl. She was born with a devastating set of what we now call learning disabilities, side by side with extraordinary gifts and a resolve that, after years of work, allowed her to invent the treatment that transformed her. Today, she runs the Arrowsmith School in Toronto, part one-room schoolhouse filled with warmth and encouragement, part high-tech laboratory school filled with computers and CD-based brain-exercise programs, where her revolutionary approach is changing the lives of students with similar disabilities. Young's work is also shedding light on what one might call the neurobiology of everyday life -- something that affects us all.

Born in Toronto in 1951 and raised in Peterborough, Ontario, she had areas of brilliance as a child -- her auditory memory and her visual memory were in the ninety-ninth percentile in tests done later in life. Her frontal lobes were exceptionally developed, giving her a driven, dogged quality. But her brain was "asymmetrical," meaning these parts coexisted with areas of retardation.

Asymmetry left its chaotic handwriting on her body. Her mother handled it with a joke: "The obstetrician must have yanked you out by your right leg." Barbara's right leg was longer than her left, causing her pelvis to shift. Her right arm never straightened, her right side was larger than her left, her left eye less alert. Her spine was asymmetrical as well, twisted by roto-scoliosis.

She also had a confusing array of cognitive problems. She had trouble pronouncing words, and it took a lot of mental effort to do so. The area of the brain Paul Broca discovered in 1861 was not working properly.

She had no capacity for spatial reasoning, which allows one to construct a pathway of movements internally before executing them. It's important for a baby crawling, a dentist drilling a tooth, a hockey player planning his moves. But it is also necessary for organizing one's desk, remembering where one has placed one's keys. Barbara was losing everything all the time. Having no mental map of things in space, she became one of "the pile people." For her, out of sight was literally out of mind, so she had to keep everything she was playing or working with in front of her, and her closets and dressers open. Outside, she was always getting lost.

She also had a kinesthetic problem. Kinesthetic perception allows one both to recognize objects by touch and to be aware of where one's body or limbs are in space. On her left side she could never tell how far her limbs had moved. Though a tomboy in spirit, she was clumsy. She couldn't hold a cup of juice in her left hand without spilling it. When walking, she frequently tripped or stumbled. Stairs became treacherous. She also had no tactile sense on her left and, hence, was always bruising herself on that side. When she eventually learned to drive, she kept denting the left side of the car -- a metallic advertisement of her mental asymmetry.

Her kinesthetic and spatial problems combined wreaked havoc. One day, when she was three, she decided to play matador and bull. She was the bull, and the car in the driveway was the matador's cape. She charged, thinking she would swerve and avoid it. But she misjudged the space and ran into it, ripping her head open.

Her mother declared she would be surprised if Barbara lived beyond the age of three. Her brothers kept sulphuric acid for experiments in her old nose-drops bottle. Once, when she decided to treat herself for sniffles, Barbara, being dyslexic, misread the new label they had written, mistaking it for her own drops. Lying in bed with acid running into her sinuses, she was too ashamed to tell her mother of yet another mishap.

Then there were her most debilitating problems. As with Comrade Zazetsky, the part of the brain that allows us to understand the relationships between symbols wasn't functioning normally. But whereas Zazetsky had once been normal and lost his mind, Barbara had always been that way. She too had trouble understanding logic, cause and effect, and grammar. She couldn't distinguish between "the father's brother," and "the brother's father." The double negative was impossible for her. She couldn't read a clock because she couldn't understand the relationship between the hands. She literally couldn't tell her left from her right, not only because she lacked a spatial map, but because she couldn't understand the relationship between "left" and "right." While Zazetsky had an almost total inability to relate symbols, she could understand them, but only with extraordinary mental effort and constant repetition.

This led to disorientation of many kinds. She reversed b, d, q, and p, read "was" as "saw," and learned to read and write from right to left, something called mirror writing. She was a righty, but because she wrote from right to left she smeared all her work. Her teachers thought she was being obstreperous.

Unable to understand cause and effect, she did odd things socially because she couldn't connect behaviour with its consequences. In kindergarten, she didn't understand why, if her brothers were in the same school, she couldn't leave class and visit them whenever she wanted. In math, she could recall that $5 \times 5 = 25$ but couldn't understand why. She could memorize math procedures but couldn't understand math concepts. Her teachers responded by giving her extra drills. Her father spent hours tutoring her, to no avail. The attempts at remediation didn't get at the root of the problem; they just made it more agonizing. Her mother held up flash cards with simple math problems on them. Barbara couldn't figure them out but found a place to sit where the sun made the paper translucent, so she could read the answers on the back.

Wanting desperately to do well, she got through elementary school by memorizing during her lunch hours and after school. In high school, her performance was extremely erratic. She learned to

exercise her memory to cover over her deficits and could remember pages of facts. Before tests she prayed they would be fact-based, knowing she could score 100 percent; but she also knew that if they were based on understanding relationships, she would probably score in the low teens.

She understood nothing in real time, only lag time. She lived by reviewing the past in the present, to make its fragments come together and come alive. Simple conversations, movie dialogue, and song lyrics were replayed over twenty times because, by the time she got to the end of a sentence, she couldn't recall what the beginning meant. She simply could not hold all the relationships described in her head.

Her emotional development suffered. Because she couldn't pick up on logical inconsistencies in the lines of smooth talkers, she was never sure whom to trust. Friendship became difficult, and she couldn't have more than one relationship at a time. But what plagued her the most was the chronic doubt and uncertainty that attached to everything, that never allowed meaning to solidify.

Novelists often depict nihilistic characters who believe they live in a world without meaning and mock those around them who think life has significance. Barbara's problem was the opposite. She sensed meaning everywhere but could never verify it, could never say or feel "Eureka!" "I don't get it," were her watchwords. "I live in a fog, and the world is no more solid than cotton candy," she told herself. Like many kids with multiple learning disabilities, she started to think she might be crazy. In elementary school she had already become depressed and suicidal.

Now, after years in that cotton-candy world, Barbara Arrowsmith Young has a velvety presence, wispy amber hair. She looks younger than her almost fifty years. The fact that she is now running a school that treats similarly disabled children is even more astonishing when you consider she grew up at a time when little help was available.

"In the 1950s, in a small town like Peterborough, you didn't talk about these things," she says. "The attitude was, you either make it or you don't. There were no special-ed teachers, no visits to medical specialists or psychologists. The term 'learning disabilities' wouldn't be widely used for another two decades. My grade-one teacher told my parents I had 'a mental block' and I wouldn't ever learn the way others did. That was as specific as it got. You were either bright, average, slow, or mentally retarded."

If you were mentally retarded, you were placed in "opportunity classes." But they were not the place for a girl with a brilliant memory who could ace vocabulary tests. Donald Frost, a sculptor and Barbara's childhood friend, says, "She was under incredible academic pressure. The whole Young family were high achievers. Her father, Jack, was an electrical engineer and inventor with thirty-four patents for Canadian General Electric. If you could pull Jack from a book for dinner it was a miracle. Her mother, Mary, was the education trustee who would later introduce local enrichment classes and had the attitude: 'You will succeed; there is no doubt,' and 'If you have a problem; fix it.' Barbara was always incredibly sensitive, warm, and caring," Frost continues, "but she hid her problems well. It was hush-hush. In the post-war years, there was a sense of integrity that meant you didn't draw attention to your disabilities any more than you would to your pimples."

Up to the early seventies, the science of learning disorders was in a relatively dark age. The diagnostic classifications were imprecise. A neurologically inclined physician -- noting the

asymmetries and multiple difficulties Barbara had -- might have used the term "minimal brain dysfunction." Had she seen a speech therapist, she might have been called dyslexic. A psychiatrist might have focused on her emotional conflicts related to learning. Today, she might be called "learning-disabled gifted," a term that describes individuals with both substantial gifts and substantial disabilities, a less extreme version of the idiot savant.

It was Barbara's memory that preserved her, allowing her to pass high school, after which she gravitated towards the study of child development, hoping to somehow sort things out for herself. At the University of Guelph, as an undergraduate, her teachers noted that she had a remarkable ability to pick up non-verbal cues in the child-observation laboratory and she was asked to teach the course. She felt there must have been some mistake. Then she was accepted to graduate school at the Ontario Institute for Studies in Education (OISE). Whereas most students read a research paper once or twice, she typically had to read one twenty times, and also had to read many of the sources cited in the bibliography, to get a fleeting sense of the meaning. She survived on four hours of sleep a night.

Kazan, USSR, 1922. Aleksandr Romanovich Luria, barely twenty, reads the letter in front of him. He has written to Sigmund Freud, and Freud has responded.

Luria was born in 1902. A genius deeply interested in psychoanalysis, he corresponded with Freud and wrote papers on the psychoanalytic technique of "free association" in which patients say everything that comes to mind. The granddaughter of the Russian novelist Fyodor Dostoevsky was said to have been his patient. His goal was to develop objective methods to assess Freudian ideas, a science that took into account both subjectivity and objectivity, both psychoanalysis and the Russian behaviourist tradition. While still in his twenties, Luria rigged up a freely associating murderer to one of his electric measuring devices to see if he was showing changes in his nervous reactions when the crime was referred to. In the process, Luria invented the prototype of the lie detector.

In 1929, Joseph Stalin, whose name literally means "man of steel," assumed control of the Soviet Union and began slicing through the soft tissue of the Russian intelligentsia. The Great Purges began. Psychoanalysis became *scientia non grata*, and Luria was denounced. By the early 1930s, less than a month after delivering a sympathetic discussion of Freud's work, and fearing for his academic future, if not for his life, Luria delivered a public recantation, admitting to having made certain "ideological mistakes." To remove himself from view, he went to medical school to study neurology and wrote a dissertation on aphasia, or speech loss.

But he quietly transposed aspects of the psychoanalytic method and psychology into neurology, becoming the founder of "neuropsychology," the field that brings the two disciplines together. Instead of reporting brief vignettes describing symptoms, Luria described his cases with the same attention to the whole person that Freud used. As Oliver Sacks -- whose own writing on neurology was inspired by Luria -- wrote, "Luria's case histories, indeed, can only be compared to Freud's in their precision, their vitality, their wealth and depth of detail. . . ."

Luria took another important thing from Freud. Freud had been a neurologist and an anatomist for twenty years before inventing psychoanalysis, and wrote his own book on aphasia. Freud realized there wasn't always a one-to-one relationship between a symptom, such as speech loss, and

damage in a single brain area. Most complex mental activities were the product of interacting brain areas. Neurological deficits had to be analyzed individually and in detail to determine which underlying component functions were damaged.

Luria began analyzing complex mental activities, breaking them down into component functions. Take an activity like reading. Living in an information society, we forget that reading is not a natural activity. Our hunter-gatherer ancestors didn't read. Someone invented the idea of linking speech with pictures, and then symbols. Reading involves strapping together numerous mental activities. The eyes must visually track across the page, which requires a functioning premotor cortex. Then visual symbols, called graphemes, must be processed in the occipital lobes at the back of the brain. These graphemes are linked up to sounds or phonemes, involving intact temporal lobes. To read aloud, the same frontal area that Paul Broca discovered (Broca's area) must be working. Other areas, too, are required for comprehension -- including the part that was destroyed in Zazetsky and weak in Barbara. A weakness in any of these areas can lead to reading problems.

At the end of May, 1943, a man who seemed like a boy entered Luria's office in the rehabilitation hospital. It was Zazetsky. Over the next thirty years, Luria would observe him and reflect upon how his particular wound affected countless mental activities. He would witness Zazetsky's relentless fight "to live, not merely exist."

A brain, even a relatively normal brain, is like a bustling city filled with disparities. Yet, we have an extraordinary tendency to overlook these disparities, and to think generally and bluntly about our brains. We are smart, or stupid, or average, and these evaluations are often coloured by how we feel about ourselves at a given moment.

Because Barbara was brilliant in many ways, and so adept at child observation in particular, even her teachers in grad school had trouble believing she was disabled. It was another gifted but learning-disabled student at OISE, Joshua Cohen, who first understood. Running a small clinic for learning-disabled kids, Cohen used the standard treatment, "compensation." It was based on the accepted theory of the time: once brain cells die or fail to develop, they cannot be restored. Compensations, hence, work around the problem. People with trouble reading are told to listen to audio tapes. Those who are "slow" are given more time on tests. Those who have trouble following an argument are told to colour-code the main points. Joshua designed a compensation program for Barbara, but she found it too time-consuming. Moreover, her thesis, an outcome study of learning-disabled children being treated with compensations at the OISE clinic, showed that most were not really improving. And because she herself had so many deficits, it was sometimes hard to find healthy functions to use to work around her deficits. Because she had had so much success developing her memory, she told Joshua there must be a better way.

One day Joshua suggested she look at some books he'd been reading by Aleksandr Luria. She tackled them, going over the difficult passages countless times, especially a section in Luria's *Basic Problems of Neurolinguistics* about people with strokes or wounds in the juncture of the parietal and occipital lobes who had trouble with grammar, logic, and reading clocks. This led her to *The Man with the Shattered World*, Luria's summary of and commentary on Zazetsky's diary. Their illnesses seemed symmetrical. Twin wounds. She thought, "He is describing my life."

"I knew what the words 'mother' and 'daughter' meant but not the expression 'mother's daughter,' " Zazetsky wrote. "The expressions 'mother's daughter' and 'daughter's mother' sounded just the same to me. I also had trouble with expressions like 'Is an elephant bigger than a fly?' All I could figure out was that a fly was small and an elephant is big, but I didn't understand the words bigger and smaller."

Watching a film, he wrote, "Before I've had a chance to figure out what the actors are saying, a new scene begins."

Luria began to make sense of the problem. Zazetsky's bullet was lodged in the left hemisphere, where the temporal (having to do with sound and, hence, language), occipital (having to do with sight), and parietal (having to do with kinesthetic sensation) input is brought together and where symbols are related. While Zazetsky could perceive properly, Luria realized he could not relate perceptions, or parts of things, or, most importantly, symbols. With no semantic net to catch and hold words, he spoke malapropisms, since no word could be definitely defined. He lived with fragments and wrote, "I'm in a fog all the time. . . . All that flashes through my mind are images . . . hazy visions that suddenly appear and just as suddenly disappear. . . . I simply can't understand or remember what these mean."

For the first time, Barbara realized her brain deficit had an address. But Luria did not provide the one thing she needed: a treatment. Realizing how impaired she was, she found herself, like many learning-disabled people in their twenties, progressively more exhausted and depressed. She resolved she could not go on this way. On subway platforms she contemplated where she might jump from for maximum impact.

It was at this point in her life, at twenty-eight, while still in graduate school, that a paper came across Barbara's desk. Professor Mark Rosenzweig of Berkeley had studied rats in stimulating and non-stimulating environments. In post-mortem exams, he found that the brains of the stimulated rats had more neurotransmitters, were heavier, and had better blood supply than those from the less stimulating environments. He was one of the first scientists to demonstrate "neuroplasticity," a century-old theory that nerve-cell activity might produce changes in the function and structural wiring of the brain.

Lightning struck for Barbara. She saw the implications of Rosenzweig's work immediately. He had shown, in essence, that the brain can be modified. Though many doubted it, to her this meant that compensation might not be the only answer. Her own breakthrough was to link Rosenzweig's and Luria's research together. She embarked on what would be her life's work.

She isolated herself and began toiling to the point of exhaustion, week after week -- with only brief breaks for sleep -- at mental exercises she had designed, with no guarantee they would lead anywhere. Instead of working around the problem, she exercised her most weakened function -- relating symbols -- progressively. One exercise involved reading hundreds of cards with clock faces showing different times on the front. She had Joshua Cohen write the correct time on the back. The cards were shuffled so she couldn't memorize the answers. She turned up a card, attempted to determine the time, checked the answer, then moved on to the next card, as fast as she could. She started with two-handed clocks, making numerous mistakes. When she couldn't get the time right, she'd spend hours with a mechanical clock, turning it slowly, to try and understand why, at 2:45,

the hour hand was three-quarters of the way towards the three. At some point, she started to get the answers right, so she began adding hands for seconds and sixtieths of a second.

At the end of many exhausting weeks, not only could she read clocks faster than normal people, but she noticed improvements with her other difficulties relating symbols. She began for the first time to grasp grammar, math, and logic, and most importantly, what people were saying as they said it. She left lag time behind.

Many thought neuroplasticity a dreamy hypothesis when it was first proposed at the turn of the last century by Ramón y Cajal. Work by this year's winner of the Nobel Prize in medicine, Eric Kandel, however, has provided further laboratory evidence to support it. Kandel demonstrated how the branches between neurons can grow and change with learning, and that neurons that fire together wire together. In 1996, Dr. Fred Gage of the Salk Institute for Biological Studies in La Jolla, California, using bromodeoxyuridine, a chemical that enters only newly dividing cells and makes them visible, demonstrated the existence in humans of brain "stem cells." Stem cells are "baby" cells, deep in the adult brain, that can develop into new neurons -- another sign the brain can repair and regenerate itself in some situations. Recent discoveries have shown that following amputations, the area of the brain that used to serve the lost limb, instead of lying dormant, gets converted for other uses. The nervous system can reorganize itself.

The discovery of neuroplasticity is the continental divide of neuroscience. Before it, conventional wisdom about treating many brain problems flowed in one direction -- towards compensation. But neuroplasticity challenges the idea that the only way to treat a learning disability is to "go around" a weak area or function, and hence, never stimulate it.

Barbara Arrowsmith Young has been going in the other direction, putting neuroplasticity into practice, for more than two decades. After her first success, she designed exercises for her spatial, kinesthetic, and visual disabilities (her visual span only took in a few letters at a time, making reading agonizing) and brought them up to the average level. Then her knowledge of the devastation these disorders cause drove her on. Barbara and Joshua Cohen married, and in 1980, they opened Arrowsmith School, a private school in Toronto. They wanted to have children of their own, but Barbara had several miscarriages. They did research together, and Barbara continued to develop brain exercises and to run the school day-to-day. Eventually they parted, and Joshua died last year.

Because she understood the implications of neuroplasticity so early on, there was often no context in which to understand her work. She was viewed by some critics as making claims that couldn't be substantiated. She presented work at the American Psychological Association, but in other quarters it was often ignored. Far from being plagued by uncertainty, she continued designing exercises for the nineteen brain areas most commonly weakened in those with learning disabilities. True to an old family name, she became a kind of arrow smith herself. Using Luria's bullet-based brain map in the years before high-tech brain scans were available, she formed focal exercises, targeting precise areas prone to deficits.

Arrowsmith School is hidden above an antique shop in Toronto's Yonge and Summerhill neighbourhood. To be admitted, children are individually assessed, a process that takes twenty to forty hours, to determine precisely which brain areas are weak, and whether they might be helped.

It's a purely private operation -- tuition is \$15,000 per year -- and this year, thirty-one children are enrolled, though outreach programs take the Arrowsmith method to many more.

Students, many of whom were distracted in regular schools, sit quietly, working at their computers. These include those who had been diagnosed as having attention-deficit and learning disorders. Some are on Ritalin, and some, as their exercises progress, safely come off medication, revealing that their attention problems were secondary to their underlying learning disorders. One can see kids who previously couldn't read a clock working at computers reading ten-handed clocks in mere seconds. At other tables children are studying Urdu and Persian characters to strengthen their visual memories. The exercises are taxing because the weak area has to be worked till it is strained.

Dan Cooper, a graduate of Arrowsmith, is an American. When he was thirteen, his math and reading skills were at a grade-three level, and he was told after neuropsychological testing at Tufts University that he would never read at a level beyond that. His mother, who had a degree in special education, tried him in ten different U.S. schools, but none helped. He moved to Toronto, boarded with a local family, and after three years at Arrowsmith was reading and doing math at a grade-ten level. He went on to graduate from college and now works in venture capital. "I was totally demoralized," he says, "because I had been in an environment of constant failure since kindergarten. Arrowsmith helped me defy the odds everyone said I would never overcome. Compared to the other programs, none of which touched my problems, Arrowsmith helped me to penetrate and actually resolve the problems. But it only works if you work, the way a bodybuilder has to."

Jeremy Johnson is at Arrowsmith now. Jeremy came from Haliburton, Ontario. At sixteen, he was reading at a grade-one level. His parents, who are both teachers, tried all the compensatory techniques. After fourteen months at the school, he's reading at a grade-seven level.

Academic improvement and cognitive capacity are measured every six months with standardized tests. The Toronto Catholic District School Board is now using Young's techniques in five different Catholic schools. Three other Ontario private schools have Arrowsmith programs, and Arrowsmith School itself will be expanding next year. The program also helps adults. Those with less severe problems come to the school part-time. Young has even helped people with brain injuries.

Digesting the revolutionary significance of neuroplasticity can take time. Lynda Widhofer, a teacher and specialist in learning disabilities with thirty-four years' experience in public and separate schools, was skeptical when asked by the local Catholic school board four years ago to run a pilot project of Arrowsmith techniques. "I didn't think it was possible to change these kids. We'd keep them for five years in traditional special ed, and they might move half a grade level in reading. We had grown wary of anything new. But the clear and distinct difference I saw was that Arrowsmith pinpointed the problems and strengthened the weakened areas to the point that the children could reach their potential, and get to their grade level. The kids' parents started noticing changes at three months, and said, 'Our kids have started learning and listening, becoming more focused and happier.' " Widhofer has since decided to come out of retirement to work for Arrowsmith.

Neuroplasticity applies not only to children -- though it is at its peak up to the age of eleven. Advanced rehabilitation programs are discovering that we have underestimated the capacity of the damaged geriatric brain to improve itself. A Georgetown University team recently showed that adult

dyslexics participating in an intensive reading program showed increased right inferior parietal activity on brain scans. And a new U.S. program, called Fast ForWord, using a technique similar to the one Barbara developed, has demonstrated, using brain scans and large-group control studies, that in eight intensive weeks, children with decoding difficulties can learn to read normally. Arrowsmith School will also offer Fast ForWord starting next term. Meanwhile, Toronto's George Brown College is looking for funding to launch the first-ever Arrowsmith program at the post-secondary level.

Just how broad an effect neuroplasticity-based techniques might have is clear once Barbara Young begins to talk about what one might call the neurobiology of everyday life. She distinguishes between learning disabilities (e.g., the inability to read), which affect some, and weakened brain-based functions (such as auditory-memory problems), which probably affect us all.

"Because complex mental operations involve multiple functions, our mental operations are only as strong as the weakest link in the chain," says Young. "It is as though these weak links lead to 'bottlenecking.'" Few of us have a precise idea of our weaker brain areas. We may know we have trouble comprehending math, or drawing well, but not which brain area causes the problem. Young explains, "Weak brain areas can often function with effort -- though they are often the first to underperform when we are sick or fatigued -- something Luria himself studied." Once we are in "overload" we usually don't know which area is causing the problem, only that we have mental gridlock. Sometimes we only discover weak areas when memory load to that area increases, as happens to some who do well in high school but then crash and burn in university.

Trouble thinking on one's feet, writing neatly, or reading quickly is often caused by a weakness in the area of the left premotor cortex, which converts sequential symbolic processes into sequential motor actions. (This function is called motor-symbol sequencing.) People with such a weakness can often type or print adequately because each letter is made the same way every time. But cursive writing, which connects all the letters, overloads the memory of that capacity. Their writing is jerky because they can't develop what Luria called a single "kinetic melody," so they must use multiple separate movements. (Yet such individuals might be great artists, because that depends on right-hemisphere functions.) Speech also involves converting symbolic sequences into motor movements. Some people may find their thoughts come faster than they can convert them into speech, and they often leave out chunks of information when speaking, or have trouble finding words and ramble. Reading is slowed because it, too, involves integrating symbolic sequences with motor movements of the eyes. People with this difficulty may skip words or find reading involves too much mental effort. Arrowsmith treats this difficulty by having children trace complex figures, including Chinese characters, with the left eye patched, so the left premotor cortex is stimulated by input from the right eye.

Children or adults who forget instructions are often thought of as irresponsible or lazy, but many have auditory memory deficits. Whereas the average person can remember seven unrelated items (as in the seven-digit phone number), these people can remember two or three. It's as though they lack sufficient auditory ram. They become compulsive note-takers and in severe cases, can't follow a song lyric. But, interestingly, they have difficulty remembering not only external language, but their own train of thought, because thinking with language is slowed. Indeed, recent brain-scan experiments have shown that the same parts of the brain involved in processing melodies or images are the ones that light up when one remembers those same melodies or images. At Arrowsmith

School, people with weak auditory memory are given specific memory exercises to work that part of the brain.

Two more areas of the brain Young has investigated are fascinating. One is the right frontal brain area involved in interpreting non-verbal cues. Those with defects here can't "read people." They often stop looking before they have taken in the whole picture. Exercises in which students must focus on non-verbal cues have led them to have more awareness not only of the emotions of others, but of their own, and made them less prone to impulsiveness.

Another cause of impulsiveness is weakness in the left frontal lobes, which are important for planning, strategizing, sorting out what is relevant, forming intentions, and sticking to them. People with deficits here often lack drive, can't develop their own study strategies, appear disorganized, don't learn from their mistakes, and appear flighty. It's likely that many people labelled "hysterical" and some with "anti-social" personality disorders have weaknesses in this area.

Most careers require the use of multiple brain areas, but how many of us, like the history buff who could not master languages, have had to forgo our first choice, because of one under-functioning brain area? Arrowsmith School has treated people such as the talented artist who had great drawing ability and sense of colour but weak object recognition -- the external-patterning skill that allows some people to excel at games like Where's Waldo? The school helped a promising litigator who, because of a Broca's pronunciation deficit, couldn't speak well in court. Since the extra mental effort required to support a weak area seems to divert resources from strong areas, someone with a Broca's problem may also find it harder to think while talking.

This work has major implications for education in an information age. Clearly, many children would benefit from a brain-area-based assessment. As well, some teaching techniques abandoned in the sixties as too rigid may be worth bringing back: rote memorization probably strengthened visual and auditory memory (and hence thinking in language and pictures) just as an almost fanatical attention to handwriting probably helped strengthen motor- symbol-sequencing capacities -- and thus not only helped handwriting, but added speed, automaticity, and fluency to reading and speaking. The Arrowsmith system of assessment may also give us more insight into the causes of learning disabilities, which are currently attributed to both genetics and environment.

Some things can never be put together again. Lyova Zazetsky's diaries are mostly a series of fragments till the end. Aleksandr Luria, the man who figured out the meaning of those fragments, but who could not really help him, was again threatened, and the authorities removed him from the Institute of Neurosurgery during a virulent period of Soviet anti-Semitism. Years later he was permitted to study neuropsychology once more. He died in 1977, the Iron Curtain firmly in place.

Today, Barbara Arrowsmith Young is sharp, funny, and there are no noticeable bottlenecks in her mental processes. She flows from one activity to the next, from one child to the next, a master of multitasking. Far from being caught in lag time, her work has advanced ahead of that of many international programs. Yet she carries herself with a humility that doesn't befit the achievement -- perhaps a trace of thinking herself mentally deficient for three decades, before she came out of the fog.