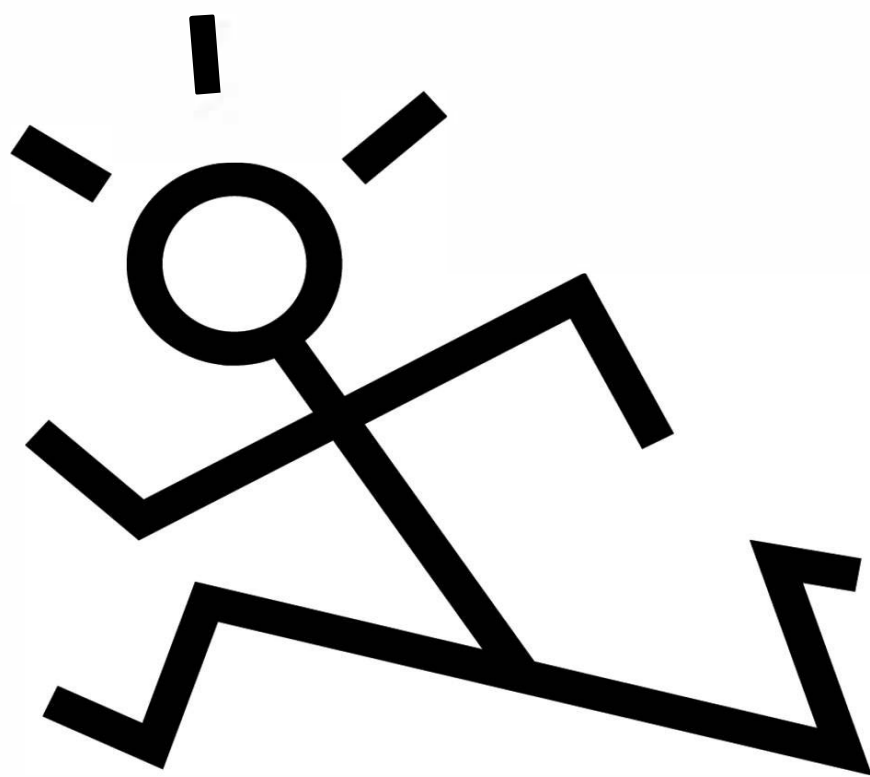


SPARK

THE REVOLUTIONARY NEW SCIENCE OF EXERCISE AND THE BRAIN



Supercharge Your Mental Circuits to Beat Stress, Sharpen
Your Thinking, Lift Your Mood, Boost Your Memory, and Much More

JOHN J. RATEY, MD

COAUTHOR OF *DRIVEN TO DISTRACTION*

with **ERIC HAGERMAN**

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The exercise program and other information contained in this book should not be followed without first consulting your health care professional.

The information contained in this book is based on sources that the authors believe to be reliable. See www.johnratey.com for source information.

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without whom this book could not have been written*

In order for man to succeed in life, God provided him with two means, education and physical activity. Not separately, one for the soul and the other for the body, but for the two together. With these two means, man can attain perfection.

— *Plato*

Introduction

Making the Connection

WE ALL KNOW that exercise makes us feel better, but most of us have no idea why. We assume it's because we're burning off stress or reducing muscle tension or boosting endorphins, and we leave it at that. But the real reason we feel so good when we get our blood pumping is that it makes the brain function at its best, and in my view, this benefit of physical activity is far more important — and fascinating — than what it does for the body. Building muscles and conditioning the heart and lungs are essentially side effects. I often tell my patients that the point of exercise is to build and condition the brain.

In today's technology-driven, plasma-screened-in world, it's easy to forget that we are born movers — animals, in fact — because we've engineered movement right out of our lives. Ironically, the human capacity to dream and plan and create the very society that shields us from our biological imperative to move is rooted in the areas of the brain that govern movement. As we adapted to an ever-changing environment over the past half million years, our thinking brain evolved from the need to hone motor skills. We envision our hunter-gatherer ancestors as brutes who relied primarily on physical prowess, but to survive over the long haul they had to use their smarts to find and store food. The relationship between food, physical activity, and learning is hardwired into the brain's circuitry.

But we no longer hunt and gather, and that's a problem. The sedentary character of modern life is a disruption of our nature, and it poses one of the biggest threats to our continued survival. Evidence of this is everywhere: 65 percent of our nation's adults are overweight or obese, and 10 percent of the population has type 2 diabetes, a preventable and ruinous disease that stems from inactivity and poor nutrition. Once an affliction almost exclusively of the middle-aged, it's now becoming an epidemic among children. We're literally killing ourselves, and it's a problem throughout the developed world, not merely a province of the supersize lifestyle in the United States. What's even more disturbing, and what virtually no one recognizes, is that inactivity is killing our brains too — physically shriveling them.

Our culture treats the mind and body as if they are separate entities, and I want to reconnect the two. The mind-body connection has fascinated me for years. My very first lecture, to fellow medical professionals at Harvard, in 1984, was titled “The Body and Psychiatry.” It focused on a novel drug treatment, for aggression, that affected both the body and the brain, which I stumbled on as a resident working in the Massachusetts state hospital system. My experience working with the most complicated psychiatric patients set me on a path of investigation into the ways in which treating the body can transform the mind. It’s been an enthralling journey, and though it continues, it’s time to deliver that message to the public. What neuroscientists have discovered in the past five years alone paints a riveting picture of the biological relationship between the body, the brain, and the mind.

To keep our brains at peak performance, our bodies need to work hard. In *Spark*, I’ll demonstrate how and why physical activity is crucial to the way we think and feel. I’ll explain the science of how exercise cues the building blocks of learning in the brain; how it affects mood, anxiety, and attention; how it guards against stress and reverses some of the effects of aging in the brain; and how in women it can help stave off the sometimes tumultuous effects of hormonal changes. I’m not talking about the fuzzy notion of runner’s high. I’m not talking about a notion at all. These are tangible changes, measured in lab rats and identified in people.

It was already known that exercise increases levels of serotonin, norepinephrine, and dopamine — important neurotransmitters that traffic in thoughts and emotions. You’ve probably heard of serotonin, and maybe you know that a lack of it is associated with depression, but even many psychiatrists I meet don’t know the rest. They don’t know that toxic levels of stress erode the connections between the billions of nerve cells in the brain or that chronic depression shrinks certain areas of the brain. And they don’t know that, conversely, exercise unleashes a cascade of neurochemicals and growth factors that can reverse this process, physically bolstering the brain’s infrastructure. In fact, the brain responds like muscles do, growing with use, withering with inactivity. The neurons in the brain connect to one another through “leaves” on treelike branches, and exercise causes those branches to grow and bloom with new buds, thus enhancing brain function at a fundamental level.

Neuroscientists have just begun studying exercise’s impact *within* brain cells — at the genes themselves. Even there, in the roots of our

biology, they've found signs of the body's influence on the mind. It turns out that moving our muscles produces proteins that travel through the bloodstream and into the brain, where they play pivotal roles in the mechanisms of our highest thought processes. They bear names such as insulin-like growth factor (IGF-1) and vascular endothelial growth factor (VEGF), and they provide an unprecedented view of the mind-body connection. It's only in the past few years that neuroscientists have begun to describe these factors and how they work, and each new discovery adds awe-inspiring depth to the picture. There's still much we don't understand about what happens in the microenvironment of the brain, but I think what we do know can change people's lives. And maybe society itself.

Why should you care about how your brain works? For one thing, it's running the show. Right now the front of your brain is firing signals about what you're reading, and how much of it you soak up has a lot to do with whether there is a proper balance of neurochemicals and growth factors to bind neurons together. Exercise has a documented, dramatic effect on these essential ingredients. It sets the stage, and when you sit down to learn something new, that stimulation strengthens the relevant connections; with practice, the circuit develops definition, as if you're wearing down a path through a forest. The importance of making these connections carries over to all of the issues I deal with in this book. In order to cope with anxiousness, for instance, you need to let certain well-worn paths grow over while you blaze alternate trails. By understanding such interactions between your body and your brain, you can manage the process, handle problems, and get your mind humming along smoothly. If you had half an hour of exercise this morning, you're in the right frame of mind to sit still and focus on this paragraph, and your brain is far more equipped to remember it.

Everything I have written over the past fifteen years has been aimed at educating people about their brains. Your life changes when you have a working knowledge of your brain. It takes guilt out of the equation when you recognize that there's a biological basis for certain emotional issues. On the other hand, you won't be left feeling helpless when you see how you can influence that biology. This is a point that I keep coming back to with my patients, because people tend to picture the brain as a commander mysteriously issuing orders from an ivory tower, untouchable from the outside. Not at all. Exercise breaks down those barriers. My hope is that if you understand how physical activity improves brain function, you'll be

motivated to include it in your life in a positive way, rather than think of it as something you *should* do. Of course you should exercise, but I won't be preaching here. (It probably wouldn't help: experiments with lab rats suggest that forced exercise doesn't do the trick quite like voluntary exercise.) If you can get to the point where you're consistently saying to yourself exercise is something you *want* to do, then you're charting a course to a different future — one that's less about surviving and more about thriving.

In October of 2000 researchers from Duke University made the *New York Times* with a study showing that exercise is better than sertraline (Zoloft) at treating depression. What great news! Unfortunately, it was buried on page fourteen of the Health and Fitness section. If exercise came in pill form, it would be plastered across the front page, hailed as the blockbuster drug of the century.

Other fragments of the story I'm presenting bubble to the surface, only to sink back down. *ABC World News* reports that exercise might stave off Alzheimer's disease in rats; CNN flashes stats on the ever-expanding obesity crisis; the *New York Times* investigates the practice of treating bipolar kids with costly drugs that are only marginally effective yet carry horrendous side effects. What gets lost is that these seemingly unrelated threads are tied together at a fundamental level of biology. I'll explain how, by exploring volumes of new research that hasn't yet appeared anywhere for the general public.

What I aim to do here is to deliver in plain English the inspiring science connecting exercise and the brain and to demonstrate how it plays out in the lives of real people. I want to cement the idea that exercise has a profound impact on cognitive abilities and mental health. It is simply one of the best treatments we have for most psychiatric problems.

I've witnessed this among my patients and my friends, a number of whom have given me permission to tell their stories here. Yet it was far beyond the walls of my office that I discovered the exemplar case study, in a suburban school district outside Chicago. The implications of the most exciting new research merge in this tale of a revolutionary physical education program. In Naperville, Illinois, gym class has transformed the student body of nineteen thousand into perhaps the fittest in the nation. Among one entire class of sophomores, only 3 percent were overweight, versus the national average of 30 percent. What's more surprising — stunning — is that the program has also turned those students into some of

the smartest in the nation. In 1999 Naperville's eighth graders were among some 230,000 students from around the world who took an international standards test called TIMSS (Trends in International Mathematics and Science Study), which evaluates knowledge of math and science. In recent years, students in China, Japan, and Singapore have outpaced American kids in these crucial subjects, but Naperville is the conspicuous exception: when its students took the TIMSS, they finished sixth in math and first in the world in science. As politicians and pundits sound the alarm about faltering education in the United States, and about our students being ill-equipped to succeed in today's technology-driven economy, Naperville stands out as an extraordinary bit of good news.

I haven't seen anything as uplifting and inspiring as Naperville's program in decades. At a time when we're bombarded with sad news about overweight, unmotivated, and underachieving adolescents, this example offers real hope. In the first chapter, I'll take you to Naperville. It is the spark that inspired me to write this book.

1

Welcome to the Revolution

A Case Study on Exercise and the Brain

ON A SLIGHT swell of land west of Chicago stands a brick building, Naperville Central High School, which harbors in its basement a low-ceilinged, windowless room crowded with treadmills and stationary bikes. The old cafeteria — its capacity long dwarfed by enrollment numbers — now serves as the school’s “cardio room.” It is 7:10 a.m., and for the small band of newly minted freshmen lounging half asleep on the exercise equipment, that means it’s time for gym.

A trim young physical education teacher named Neil Duncan lays out the morning’s assignment: “OK, once you’re done with your warm-up, we’re going to head out to the track and run the *mile*,” he says, presenting a black satchel full of chest straps and digital watches — heart rate monitors of the type used by avid athletes to gauge their physical exertion. “Every time you go around the track, hit the *red* button. What that’s going to *do* — it’s going to give you a *split*. It’s going to tell you, this is how fast I did my first lap, second lap, third lap. On the fourth and final lap — which will be just as fast if you do it right — ” he says, pausing to survey his sleepy charges, “you hit the *blue* button, OK? And that’ll stop your watch. Your goal is — well, to try to run your fastest mile. Last but not least, your average heart rate should be above 185.”

Filing past Mr. Duncan, the freshmen lumber upstairs, push through a set of heavy metal doors, and in scattered groups they hit the track under the mottled skies of a crisp October morning. Perfect conditions for a revolution.

This is not good old gym class. This is Zero Hour PE, the latest in a long line of educational experiments conducted by a group of maverick physical education teachers who have turned the nineteen thousand

students in Naperville District 203 into the fittest in the nation — and also some of the smartest. (The name of the class refers to its scheduled time before first period.) The objective of Zero Hour is to determine whether working out before school gives these kids a boost in reading ability and in the rest of their subjects.

The notion that it might is supported by emerging research showing that physical activity sparks biological changes that encourage brain cells to bind to one another. For the brain to learn, these connections must be made; they reflect the brain’s fundamental ability to adapt to challenges. The more neuroscientists discover about this process, the clearer it becomes that exercise provides an unparalleled stimulus, creating an environment in which the brain is ready, willing, and able to learn. Aerobic activity has a dramatic effect on adaptation, regulating systems that might be out of balance and optimizing those that are not — it’s an indispensable tool for anyone who wants to reach his or her full potential.

Out at the track, the freckled and bespectacled Mr. Duncan supervises as his students run their laps.

“My watch isn’t reading,” says one of the boys as he jogs past.

“*Red* button,” shouts Duncan. “Hit the *red* button! At the end, hit the *blue* button.”

Two girls named Michelle and Krissy pass by, shuffling along side by side.

A kid with unlaced skateboarding shoes finishes his laps and turns in his watch. His time reads eight minutes, thirty seconds.

Next comes a husky boy in baggy shorts.

“Bring it on in, Doug,” Duncan says. “What’d you get?”

“Nine minutes.”

“Flat?”

“Yeah.”

“Nice work.”

When Michelle and Krissy finally saunter over, Duncan asks for their times, but Michelle’s watch is still running. Apparently, she didn’t hit the *blue* button. Krissy did, though, and their times are the same. She holds up her wrist for Duncan. “Ten twelve,” he says, noting the time on his clipboard. What he doesn’t say is “It looked like you two were really loafing around out there!”

The fact is, they weren’t. When Duncan downloads Michelle’s monitor, he’ll find that her average heart rate during her ten-minute mile

was 191, a serious workout for even a trained athlete. She gets an A for the day.

The kids in Zero Hour, hearty volunteers from a group of freshmen required to take a literacy class to bring their reading comprehension up to par, work out at a higher intensity than Central's other PE students. They're required to stay between 80 and 90 percent of their maximum heart rate. "What we're really doing is trying to get them prepared to learn, through rigorous exercise," says Duncan. "Basically, we're getting them to that state of heightened awareness and then sending them off to class."

How do they feel about being Mr. Duncan's guinea pigs? "I guess it's OK," says Michelle. "Besides getting up early and being all sweaty and gross, I'm more awake during the day. I mean, I was cranky all the time last year."

Beyond improving her mood, it will turn out, Michelle is also doing much better with her reading. And so are her Zero Hour classmates: at the end of the semester, they'll show a 17 percent improvement in reading and comprehension, compared with a 10.7 percent improvement among the other literacy students who opted to sleep in and take standard phys ed.

The administration is so impressed that it incorporates Zero Hour into the high school curriculum as a first-period literacy class called Learning Readiness PE. And the experiment continues. The literacy students are split into two classes: one second period, when they're still feeling the effects of the exercise, and one eighth period. As expected, the second-period literacy class performs best. The strategy spreads beyond freshmen who need to boost their reading scores, and guidance counselors begin suggesting that all students schedule their hardest subjects immediately after gym, to capitalize on the beneficial effects of exercise.

It's a truly revolutionary concept from which we can all learn.

FIRST-CLASS PERFORMANCE

Zero Hour grew out of Naperville District 203's unique approach to physical education, which has gained national attention and become the model for a type of gym class that I suspect would be unrecognizable to any adult reading this. No getting nailed in dodgeball, no flunking for not showering, no living in fear of being the last kid picked.

The essence of physical education in Naperville 203 is teaching fitness

instead of sports. The underlying philosophy is that if physical education class can be used to instruct kids how to monitor and maintain their own health and fitness, then the lessons they learn will serve them for life. And probably a longer and happier life at that. What's being taught, really, is a lifestyle. The students are developing healthy habits, skills, and a sense of fun, along with a knowledge of how their bodies work. Naperville's gym teachers are opening up new vistas for their students by exposing them to such a wide range of activities that they can't help but find something they enjoy. They're getting kids hooked on moving instead of sitting in front of the television. This couldn't be more important, particularly since statistics show that children who exercise regularly are likely to do the same as adults.

But it's the impact of the fitness-based approach on the kids while they're still in school that initially grabbed my attention. The New PE curriculum has been in place for seventeen years now, and its effects have shown up in some unexpected places — namely, the classroom.

It's no coincidence that, academically, the district consistently ranks among the state's top ten, even though the amount of money it spends on each pupil — considered by educators to be a clear predictor of success — is notably lower than other top-tier Illinois public schools. Naperville 203 includes fourteen elementary schools, five junior highs, and two high schools. For the sake of comparison, let's look at Naperville Central High School, where Zero Hour began. Its per-pupil operating expense in 2005 was \$8,939 versus \$15,403 at Evanston's New Trier High School. New Trier kids scored on average two points higher on their ACT college entrance exams (26.8), but they fared worse than Central's kids on a composite of mandatory state tests, which are taken by every student, not just those applying to college. And Central's composite ACT score for the graduating class of 2005 was 24.8, well above the state average of 20.1.

Those exams aren't nearly as telling as the Trends in International Mathematics and Science Study (TIMSS), a test designed to compare students' knowledge levels from different countries in two key subject areas. This is the exam cited by *New York Times* editorialist Thomas Friedman, author of *The World Is Flat*, when he laments that students in places like Singapore are "eating our lunch." The education gap between the United States and Asia is widening, Friedman points out. Whereas in some Asian countries nearly half of the students score in the top tier, only 7 percent of U.S. students hit that mark.

TIMSS has been administered every four years since 1995. The 1999 edition included 230,000 students from thirty-eight countries, 59,000 of whom were from the United States. While New Trier and eighteen other schools along Chicago's wealthy North Shore formed a consortium to take the TIMSS (thereby masking individual schools' performance), Naperville 203 signed up on its own to get an international benchmark of its students' performance. Some 97 percent of its eighth graders took the test — not merely the best and the brightest. How did they stack up? On the science section of the TIMSS, Naperville's students finished first, just ahead of Singapore, and then the North Shore consortium. *Number one in the world.* On the math section, Naperville scored sixth, behind only Singapore, Korea, Taiwan, Hong Kong, and Japan.

As a whole, U.S. students ranked eighteenth in science and nineteenth in math, with districts from Jersey City and Miami scoring dead last in science and math, respectively. "We have huge discrepancies among our school districts in the United States," says Ina Mullis, who is a codirector of TIMSS. "It's a good thing that we've at least got some Napervilles — it shows that it can be done."

I won't go so far as to say that Naperville's kids are brilliant specifically because they participate in an unusual physical education program. There are many factors that inform academic achievement. To be sure, Naperville 203 is a demographically advantaged school district: 83 percent white, with only 2.6 percent in the low income range, compared with 40 percent in that range for Illinois as a whole. Its two high schools boast a 97 percent graduation rate. And the town's major employers are science-centric companies such as Argonne, Fermilab, and Lucent Technologies, which suggests that the parents of many Naperville kids are highly educated. The deck — in terms of both environment and genetics — is stacked in Naperville's favor.

On the other hand, when we look at Naperville, two factors really stand out: its unusual brand of physical education and its test scores. The correlation is simply too intriguing to dismiss, and I couldn't resist visiting Naperville to see for myself what was happening there. I've long been aware of the TIMSS test and how it points to the failings of public education in this country. Yet the Naperville 203 kids aced the test. Why? It's not as if Naperville is the only wealthy suburb in the country with intelligent, educated parents. And in poor districts where Naperville-style PE has taken root, such as Titusville, Pennsylvania (which I'll discuss

later), test scores have improved measurably. My conviction, and my attraction to Naperville, is that its focus on fitness plays a pivotal role in its students' academic achievements.

THE NEW PE

The Naperville revolution started, as such things often do, with equal parts idealism and self-preservation. A visionary junior high physical education teacher named Phil Lawler got the movement off the ground after he came across a newspaper article in 1990 reporting that the health of U.S. children was declining.

“It said the reason they weren't healthy was that they weren't very active,” recalls Lawler, a tall man in his fifties, with rimless glasses, who dresses in khakis and white sneakers. “These days everybody knows we have an obesity epidemic,” he continues. “But pick up a paper seventeen years ago and that kind of article was unusual. We said, We have these kids every day; shouldn't we be able to affect their health? If this is our business, I thought, we're going bankrupt.”

He already felt like his profession received no respect; schools had started cutting phys ed from the curriculum, and now this. A former college baseball pitcher who missed out on the majors, Lawler is a sincere salesman and a natural leader who became a gym teacher to stay close to sports. In addition to teaching PE at District 203's Madison Junior High, he coached Naperville Central's baseball team and served as the district coordinator for PE, but even in these respectable posts, sometimes he was embarrassed to admit what he did for a living. Part of what he saw in that article was an opportunity — a chance to make his job matter.

When Lawler and his staff at Madison took a close look at what was happening in gym, they saw a lot of inactivity. It's the nature of team sports: waiting for a turn at bat, waiting for the center's snap, waiting for the soccer ball to come your way. Most of the time, most of the players just stood around. So Lawler decided to shift the focus to cardiovascular fitness, and he instituted a radical new feature to the curriculum. Once a week in gym class, the kids would run the mile. Every single week! His decision met with groans from students, complaints from parents, and notes from doctors.

He was undeterred, yet he quickly recognized that the grading scale

discouraged the slowest runners. To offer nonathletes a shot at good marks, the department bought a couple of Schwinn Airdyne bikes and allowed students to earn extra credit. They could come in on their own time and ride five miles to raise their grades. “So any kid who wanted to get an A could get an A if he worked for it,” Lawler explains. “Somewhere in this process, we got into personal bests. Anytime you got a personal best, no matter what it was, you moved up a letter grade.” And this led to the founding principle of the approach he dubbed the New PE: Students would be assessed on effort rather than skill. You didn’t have to be a natural athlete to do well in gym.

But how does one judge the individual effort of forty kids at a time? Lawler found his answer at a physical education conference he organized every spring. He worked hard to turn the event into an exchange of fresh ideas and technologies, and to encourage attendance he talked the vendors into donating door prizes. Each year at the beginning of the conference, he would push a towel cart through the aisles, collecting bats and balls and other sporting goods. Cast in among the bounty one year was a newfangled heart rate monitor, which at the time was worth hundreds of dollars. He couldn’t help himself; he stole it for the revolution. “I saw that son of a buck,” he freely admits, “and I said, That’s a door prize for Madison Junior High!”

During the weekly mile, he tested the device on a sixth-grade girl who was thin but not the least bit athletic. When Lawler downloaded her stats, he couldn’t believe what he found. “Her average heart rate was 187!” he exclaims. As an eleven-year-old, her maximum heart rate would have been roughly 209, meaning she was plugging away pretty close to full tilt. “When she crossed the finish line, she went up to 207,” Lawler continues. “*Ding, ding, ding!* I said, You gotta be *kidding* me! Normally, I would have gone to that girl and said, You need to get your ass in gear, little lady! It was really that moment that caused dramatic changes in our overall program. The heart rate monitors were a springboard for everything. I started thinking back to all the kids we must have turned off to exercise because we weren’t able to give them credit. I didn’t have an athlete in class who knew how to work as hard as that little girl.”

He realized that being fast didn’t necessarily have anything to do with being fit.

One of Lawler’s favorite statistics is that less than 3 percent of adults over the age of twenty-four stay in shape through playing team sports, and

this underscores the failings of traditional gym class. But he knew he couldn't have the students run the mile every day, so he set up a program of what they have termed "small-sided sports" — three-on-three basketball or four-on-four soccer — where the students are constantly moving. "We still play sports," Lawler says. "We just do them within a fitness model." Instead of being tested on such trivia as the dimensions of a regulation volleyball court, Naperville's gym students are graded on how much time they spend in their target heart rate zones during any given activity.

"We developed the program not knowing what we were doing," Lawler says. And yet, the New PE has managed to put into practice principles consistent with all the new research about exercise and the brain.

CARRYING THE TORCH

Every revolutionary leader needs a lieutenant, and Lawler couldn't have chosen a more able agitator than Paul Zientarski, Naperville Central High School's physical education coordinator and former football coach. To students and colleagues, Zientarski is Mr. Z, a gray-haired furnace of a man with steady eyes and a facts-is-facts delivery. He has the presence of Mike Ditka and Bill Parcells rolled into one formidable figure of authority. "It took me the longest time to convince him of this stuff," says Lawler of his friend and ally. "But once he buys into it, get out of his way. Because he's going to shove it down your throat if he has to."

As their movement grew, Lawler would take the lead in proselytizing the outside world with the fitness-not-sports message, talking to *Newsweek* and testifying before the U.S. Senate, and Zientarski would become the unwavering enforcer of the mission back home, transforming the phys ed program at Naperville Central into a well-oiled working model of the New PE. Lawler retired from teaching in 2004 after being diagnosed with colon cancer, but he has continued to lobby for daily physical education even during his back-and-forth battle with the disease.

They've both become grassroots experts on the subject of exercise and the brain. They learned by grilling speakers from the conferences Lawler organized, attending sports physiology seminars, reading neuroscience research papers, and constantly e-mailing their findings to each other. And they've taken it upon themselves to educate their colleagues as well. It's