TWO

The Lost Hour

Around the world, children get an hour less sleep than they did thirty years ago. The cost: IQ points, emotional well-being, ADHD, and obesity.

Morgan Fichter is a ten-year-old fifth-grader in Roxbury, New Jersey. She's fair-skinned and petite, with freckles across her nose and wavy, light brown hair. Her father, Bill, is a police sergeant on duty until three a.m. Her mother, Heather, works part-time, devoting herself to shuffling Morgan and her brother to their many activities. Morgan plays soccer (Heather's the team coach), but Morgan's first love is competitive swimming, with year-round workouts that have broadened her shoulders. She's also a violinist in the school orchestra, with two practices and a private lesson each week, on top of the five nights she practices alone. Every night, Heather and Morgan sit down to her homework, then watch *Flip This House* or another design show on TLC. Morgan has always appeared to be an enthusiastic, well-balanced child.

But once Morgan spent a year in the classroom of a hypercritical teacher, she could no longer unwind at night. Despite a reasonable bedtime of 9:30 p.m., she would lay awake in frustration until 11:30, sometimes midnight, clutching her leopard-fur pillow. On her fairy-dust purple bedroom walls were taped index cards, each a vocabulary word Morgan had trouble with. Unable to sleep, she turned back to her studies, determined not to let her grades suffer. Instead, she saw herself fall apart emotionally. During the day, she was crabby and prone to crying easily. Occasionally Morgan fell asleep in class.

Morgan moved on from that teacher's classroom the next year, but

the lack of sleep persisted. Heather began to worry why her daughter couldn't sleep. Was it stress, or hormones? Heather forbade caffeinated soda, especially after noon, having noticed that one cola in the afternoon could keep her daughter awake until two a.m. Morgan held herself together as best she could, but twice a month she suffered an emotional meltdown, a kind of overreacting crying tantrum usually seen only in three-year-olds who missed their nap. "I feel very sad for her," Heather agonized. "I wouldn't wish it on anyone—I was worried it was going to be a problem forever."

Concerned about her daughter's well-being, Heather asked the pediatrician about her daughter's sleep. "He kind of blew me off, and didn't seem interested in it," she recalled. "He said, 'So, she gets tired once in a while. She'll outgrow it.'"

The opinion of Heather's pediatrician is typical. According to surveys by the National Sleep Foundation, 90% of American parents think their child is getting enough sleep.

The kids themselves say otherwise: 60% of high schoolers report extreme daytime sleepiness. A quarter admit their grades have dropped because of it. Depending on what study you look at, anywhere from 20% to 33% are falling asleep in class at least once a week.

The raw numbers more than back them up. Half of all adolescents get less than seven hours of sleep on weeknights. By the time they are seniors in high school, according to studies by Dr. Frederick Danner at the University of Kentucky, they're averaging only slightly more than 6.5 hours of sleep a night. Only 5% of high school seniors average eight hours. Sure, we remember being tired when we went to school. But not like today's kids.

It is an overlooked fact that children—from elementary school through high school—get an hour less sleep each night than they did thirty years ago. While modern parents obsess about our babies' sleep, this concern falls off the priority list after preschool. Even kindergartners get thirty minutes less a night than they used to.

There are as many causes for this lost hour of sleep as there are types of family. Overscheduling of activities, burdensome homework, lax bedtimes, televisions and cell phones in the bedroom—they all contribute. So does guilt; home from work after dark, parents want time with their children and are reluctant to play the hardass who orders them to bed. (One study from Rhode Island found that 94% of high schoolers set their own bedtimes.) All these reasons converge on one simple twist of convenient ignorance—until now, we could ignore the lost hour because we never really knew its true cost to children.

Using newly developed technological and statistical tools, sleep scientists have recently been able to isolate and measure the impact of this single lost hour. Because children's brains are a work in progress until the age of 21, and because much of that work is done while a child is asleep, this lost hour appears to have an exponential impact on children that it simply doesn't have on adults.

The surprise is not merely that sleep *matters*—but how much it matters, demonstrably, not just to academic performance and emotional stability, but to phenomena that we assumed to be entirely unrelated, such as the international obesity epidemic and the rise of ADHD. A few scientists theorize that sleep problems during formative years can cause permanent changes in a child's brain structure—damage that one can't sleep off like a hangover. It's even possible that many of the hallmark characteristics of being a tweener and teen—moodiness, depression, and even binge eating—are actually just symptoms of chronic sleep deprivation.

Dr. Avi Sadeh at Tel Aviv University is one of the dozen or so bigwigs in the field, frequently collaborating on papers with the sleep scholars at Brown University. A couple years ago, Sadeh sent 77

fourth-graders and sixth-graders home with randomly-drawn instructions to either go to bed earlier or stay up later, for three nights. Each child was given an actigraph—a wristwatch-like device that's equivalent to a seismograph for sleep activity—which allows the researchers to see how much sleep a child is really getting when she's in bed. Using the actigraphy, Sadeh's team learned that the first group managed to get 30 minutes more of true sleep per night. The latter got 31 minutes less of true sleep.

After the third night's sleep, a researcher went to the school in the morning to give the children a test of neurobiological functioning. The test, a computerized version of parts of the Wechsler Intelligence Scale for Children, is highly predictive of current achievement test scores and how teachers rate a child's ability to maintain attention in class.

Sadeh knew that his experiment was a big risk. "The last situation I wanted to be in was reporting to my grantors, 'Well, I deprived the subjects of only an hour, and there was no measurable effect at all, sorry—but can I have some more money for my other experiments?'"

Sadeh needn't have worried. The effect was indeed measurable—and sizeable. The performance gap caused by an hour's difference in sleep was bigger than the gap between a normal fourth-grader and a normal sixth-grader. Which is another way of saying that a slightly-sleepy sixth-grader will perform in class like a mere fourth-grader. "A loss of one hour of sleep is equivalent to [the loss of] two years of cognitive maturation and development," Sadeh explained.

"Sadeh's work is an outstanding contribution," says Penn State's Dr. Douglas Teti, Professor of Human Development and Family Studies. His opinion is echoed by Brown's Dr. Mary Carskadon, a specialist on the biological systems that regulate sleep. "Sadeh's research is an important reminder of how fragile children are."

Sadeh's findings are consistent with a number of other researchers' work—all of which points to the large academic consequences of

small sleep differences. Dr. Monique LeBourgeois, also at Brown, studies how sleep affects prekindergartners. Virtually all young children are allowed to stay up later on weekends. They don't get less sleep, and they're not sleep deprived—they merely shift their sleep to later at night on Fridays and Saturdays. Yet she's discovered that the sleep shift factor alone is correlated with performance on a standardized IQ test. Every hour of weekend shift costs a child seven points on the test. Dr. Paul Suratt at the University of Virginia studied the impact of sleep problems on vocabulary test scores taken by elementary school students. He also found a seven-point reduction in scores. Seven points, Suratt notes, is significant: "Sleep disorders can impair children's IQ as much as lead exposure."

If these findings are accurate, then it should add up over the long term: we should expect to see a correlation between sleep and school grades. Every study done shows this connection—from a study of second- and third-graders in Chappaqua, New York, up to a study of eighth-graders in Chicago.

These correlations really spike in high school, because that's when there's a steep drop-off in kids' sleep. University of Minnesota's Dr. Kyla Wahlstrom surveyed over 7,000 high schoolers in Minnesota about their sleep habits and grades. Teens who received A's averaged about fifteen more minutes sleep than the B students, who in turn averaged fifteen more minutes than the C's, and so on. Wahlstrom's data was an almost perfect replication of results from an earlier study of over 3,000 Rhode Island high schoolers by Brown's Carskadon. Certainly, these are averages, but the consistency of the two studies stands out. Every fifteen minutes counts.

With the benefit of functional MRI scans, researchers are now starting to understand exactly how sleep loss impairs a child's brain.

Tired children can't remember what they just learned, for instance, because neurons lose their plasticity, becoming incapable of forming the new synaptic connections necessary to encode a memory.

A different mechanism causes children to be inattentive in class. Sleep loss debilitates the body's ability to extract glucose from the bloodstream. Without this stream of basic energy, one part of the brain suffers more than the rest—the prefrontal cortex, which is responsible for what's called "Executive Function." Among these executive functions are the orchestration of thoughts to fulfill a goal, prediction of outcomes, and perceiving consequences of actions. So tired people have difficulty with impulse control, and their abstract goals like studying take a back seat to more entertaining diversions. A tired brain perseverates—it gets stuck on a wrong answer and can't come up with a more creative solution, repeatedly returning to the same answer it already knows is erroneous.

Both those mechanisms weaken a child's capacity to learn during the day. But the most exciting science concerns what the brain is up to, when a child is asleep at night. UC Berkeley's Dr. Matthew Walker explains that during sleep, the brain shifts what it learned that day to more efficient storage regions of the brain. Each stage of sleep plays its own unique role in capturing memories. For example, studying a foreign language requires learning vocabulary, auditory memory of new sounds, and motor skills to correctly enunciate the new word. The vocabulary is synthesized by the hippocampus early in the night during "slow-wave sleep," a deep slumber without dreams. The motor skills of enunciation are processed during stage 2 non-REM sleep, and the auditory memories are encoded across all stages. Memories that are emotionally laden get processed during REM sleep. The more you learned during the day, the more you need to sleep that night.

To reconsolidate these memories, certain genes appear to upregulate during sleep—they literally turn on, or get activated. One of

these genes is essential for synaptic plasticity, the strengthening of neural connections. The brain does synthesize some memories during the day, but they're enhanced and concretized during the night—new inferences and associations are drawn, leading to insights the next day.

Kids' sleep is qualitatively different than grownups' sleep because children spend more than 40% of their asleep time in the slow-wave stage (which is ten times the proportion that older adults spend). This is why a good night's sleep is so important for long-term learning of vocabulary words, times tables, historical dates, and all other factual minutiae.

Perhaps most fascinating, the emotional context of a memory affects *where* it gets processed. Negative stimuli get processed by the amygdala; positive or neutral memories gets processed by the hippocampus. Sleep deprivation hits the hippocampus harder than the amygdala. The result is that sleep-deprived people fail to recall pleasant memories, yet recall gloomy memories just fine.

In one experiment by Walker, sleep-deprived college students tried to memorize a list of words. They could remember 81% of the words with a negative connotation, like "cancer." But they could remember only 31% of the words with a positive or neutral connotation, like "sunshine" or "basket."

"We have an incendiary situation today," Walker remarked, "where the intensity of learning that kids are going through is so much greater, yet the amount of sleep they get to process that learning is so much less. If these linear trends continue, the rubber band will soon snap."

While all kids are impacted by sleep loss, for teenagers, sleep is a special challenge.

Brown's Mary Carskadon has demonstrated that during puberty,

the circadian system—the biological clock—does a "phase shift" that keeps adolescents up later. In prepubescents and grownups, when it gets dark outside, the brain produces melatonin, which makes us sleepy. But adolescent brains don't release melatonin for another 90 minutes. So even if teenagers are in bed at ten p.m. (which they aren't), they lie awake, staring at the ceiling.

Awakened at dawn by alarm clocks, teen brains are still releasing melatonin. This pressures them to fall back asleep—either in first period at school or, more dangerously, during the drive to school. Which is one of the reasons young adults are responsible for more than half of the 100,000 "fall asleep" crashes annually.

Persuaded by this research, a few school districts around the nation decided to push back the time school starts in the morning.

The best known of these is Edina, Minnesota, an affluent suburb of Minneapolis, which changed its high school start times from 7:25 to 8:30. The results were startling, and it affected the brightest kids the most. In the year preceding the time change, math/verbal SAT scores for the top 10% of Edina's 1,600 students averaged 683/605. A year later, the top 10% averaged 739/761. In case you're too drowsy to do that math, getting another hour of sleep boosted math SAT scores of Edina's Best and Brightest up 56 points, and their verbal SAT score a whopping 156 points. ("Truly flabbergasting," gasped a stunned and disbelieving Brian O'Reilly, the College Board's Executive Director for SAT Program Relations, when he heard the results.) And the students reported higher levels of motivation and lower levels of depression. In short, an hour more of sleep improved students' quality of life.

That's particularly remarkable since most kids get less sleep during high school, and their quality of life goes down: University of Kentucky's Danner has studied how, on a national level, sleep decreases each year during high school. In their first year, 60% of kids got at least

eight hours on average. By the second year, that was down to 30%. Right alongside this decline went their moods; dropping below eight hours doubled the rate of *clinical-level* depression. Over one-eighth of the students reached this classification, which makes one only wonder how many more suffer from melancholy of a lesser degree.

Another trailblazing school district is Lexington, Kentucky, which also moved its start time an hour later. Danner has been studying the before/after equation. The finding that most jumps out from his data is that after the time change, teenage car accidents in Lexington were down 25%, compared to the rest of the state.

While the evidence is compelling, few districts have followed this lead. Conversely, 85% of America's public high schools start before 8:15 a.m., and 35% start at or before 7:30 a.m.

Obstacles against later start times are numerous. Having high schools start earlier often allows buses to first deliver the older students, then do a second run with the younger children. So starting later could mean doubling the size of the bus fleet. Teachers prefer driving to school before other commuters clog the roads. Coaches worry their student-athletes will miss games because they're still in their class at kickoff time. Many simply aren't persuaded by the science. When Westchester schools declined an initiative to start high schools later, then-superintendent Dr. Karen McCarthy opined, "There's still something that doesn't click for me."

Dr. Mark Mahowald has heard all those arguments. As Director of the Minnesota Regional Sleep Disorders Center, he's been at the center of many school start time debates. But of all the arguments he's heard, no one's argument is that children *learn more* at 7:15 a.m. than at 8:30. Instead, he forcefully reasons, schools are scheduled for adult convenience: there's no educational reason we start schools as early as we do. "If schools are for education, then we should promote learning instead of interfere with it," he challenges.

"We thought the evidence was staggering," Carole Young-Kleinfeld recalled.

Kleinfeld is a mother in Wilton, Connecticut, thirty miles up I-95 from New York City. Wilton, too, had saved money by running buses in two shifts, starting the high school at 7:35. Then a few years ago, Kleinfeld was at a meeting for the local League of Women Voters. Then-state senator Kevin Sullivan spoke about Carskadon and others' research, and how starting high school at a more reasonable hour was the answer.

Kleinfeld had a sullen teenager of her own, and when she went to local high schools to register kids to vote, she regularly saw students sleeping in the halls during class. So the idea hit home. She and others formed a committee to learn about the issue. Eventually, they convinced the district to move the high school's start time to 8:20.

For Kleinfeld, the change "was a godsend."

Her son Zach had once been a perfectly happy kid, but when he hit high school he became the prototypical disengaged, unenthralled-by-everything teen. He was so negative, so withdrawn that "I really thought we'd lost him," Kleinfeld sighed. "We'd lost that sense of connection."

After the high school start time shifted, Kleinfeld couldn't believe it. "We got our kid back." Zack would bound downstairs in the morning with a smile, wanting to share a funny story he'd read in *The Onion*. His SAT scores went up, too.

Several scholars have noted that many hallmark traits of modern adolescence—moodiness, impulsiveness, disengagement—are also symptoms of chronic sleep deprivation. Might our culture-wide perception of what it means to be a teenager be unwittingly skewed by the fact they don't get enough sleep?

University of Pittsburgh's Dr. Ronald Dahl agrees, observing: "Is it adding one percent or sixty percent, we don't know. But clearly a lack of sleep makes it much worse."

Let's consider the hidden role sleep has played in the obesity epidemic.

It's often noted that in the last three decades childhood obesity has tripled. Half of all kids are at least "at risk of being overweight"—a BMI score two clicks down from obesity.

The federal government spends over $1 billion a year on nutrition education programs in our schools. A recent review by McMaster University of 57 such programs showed that 53 had no impact at all—and the results of the four good ones were so meager it was barely worth mentioning.

For a long time, there's been one culprit to blame for our failed efforts: television. Rather than running around the neighborhood like when we were young, today's kids sit in front of the boob tube an average of 3.3 hours a day. The connection to obesity seemed so obvious, and was so often repeated, that few people thought it even needed to be supported scientifically.

Dr. Elizabeth Vandewater at the University of Texas at Austin got fed up with hearing fellow scholars blame it all on television with only weak data to support their claim. "It's treated as gospel without any evidence," she grumbled. "It's just bad science." Vandewater analyzed the best large dataset available—the Panel Study of Income Dynamics, which has extensively surveyed 8,000 families since 1968. She found that obese kids watch no more television than kids who aren't obese. All the thin kids watch massive amounts of television, too. There was no statistical correlation between obesity and media use, period. "It's just not the smoking gun we assumed it to be."

Vandewater examined the children's time diaries, and she realized why the earlier research had got it wrong. Kids don't trade television time for physical activity. "Children trade functionally-equivalent

things. If the television's off, they don't go play soccer," she said. "They do some other sedentary behavior."

In fact, while obesity has spiked exponentially since the 1970s, kids watch only seven minutes more of TV a day. While they do average a half-hour of video games and internet surfing on top of television viewing, the leap in obesity began in 1980, well before home video games and the invention of the web browser. This obviously doesn't mean it's good for the waistline to watch television. But it does mean that something—other than television—is making kids even heavier.

"We've just done diet and exercise studies for a hundred years and they don't work well, and it's time to look for different causes," proclaimed Dr. Richard Atkinson, co-editor-in-chief of the *International Journal of Obesity*.

Five years ago, already aware of an association between sleep apnea and diabetes, Dr. Eve Van Cauter discovered a "neuroendocrine cascade" which links sleep to obesity. Sleep loss increases the hormone ghrelin, which signals hunger, and decreases its metabolic opposite, leptin, which suppresses appetite. Sleep loss also elevates the stress hormone cortisol. Cortisol is lipogenic, meaning it stimulates your body to make fat. Human growth hormone is also disrupted. Normally secreted as a single big pulse at the beginning of sleep, growth hormone is essential for the breakdown of fat.

It's drilled into us that we need to be more active to lose weight. So it spins the mind to hear that a key to staying thin is to spend more time doing the most sedentary inactivity humanly possible. Yet this is exactly what scientists are finding. In light of Van Cauter's discoveries, sleep scientists have performed a flurry of analyses on large datasets of children. All the studies point in the same direction: on average, children who sleep less are fatter than children who sleep more. This isn't just here, in America—scholars all around the world are considering it, because children everywhere are both getting fatter and getting less sleep.

Three of those studies showed strikingly similar results. One analyzed Japanese first graders, one Canadian kindergarten boys, and Australian young boys the third. They showed that those kids who get less than eight hours sleep have about a 300% higher rate of obesity than those who get a full ten hours of sleep. Within that two-hour window, it was a "dose-response" relationship, according to the Japanese scholars.

Research in the Houston public schools proved this isn't just fattening up young kids. Among the middle schoolers and high schoolers studied, the odds of obesity went up 80% for each hour of lost sleep.

Van Cauter has gone on to discover that the stage of slow-wave sleep is especially critical to proper insulin sensitivity and glucose tolerance. When she lets subjects sleep, but interrupts them with gentle door knocks just loud enough to keep them from passing into the slow-wave stage (without actually waking the subjects), their hormone levels respond in a way that's akin to a weight gain of twenty to thirty pounds. As previously noted, children spend over 40% of their asleep time in this slow-wave stage, while older adults are in this stage only about 4% of the night. This could explain why the relationship between poor sleep and obesity is much stronger in children than in adults.

How sleep impacts hormones is an entirely different way of explaining what makes people fat or thin—we normally just think of weight gain as a straightforward calories-consumed/calories-burned equation. But even by that familiar equation, the relation of sleep to weight makes sense. While very few calories are being burned while blacked out on the sheets, at least a kid is not eating when he's asleep. In addition, kids who don't sleep well are often too tired to

exercise—it's been shown that the less sleep kids get, the less active they are during the day. So the net calorie burn, after a good night's rest, is higher.

In a 2005 paper in *Archives of Internal Medicine*, Dr. Fred Turek called out traditional obesity researchers for ignoring sleep's effect on metabolism. Turek is Director of Northwestern University's Center for Circadian Biology and Medicine. He noted that a standard reference guide for physicians on childhood obesity never discusses the effect of sleep loss on weight—not once in 269 pages.

Dr. Atkinson believes the research he's seen on children's sleep loss and obesity is positively "alarming." Yet he regrets that it is just off the radar screens of most obesity researchers.

In 2007, the United States Department of Agriculture and the Centers for Disease Control reported to us that they'd done no independent research on the issue. They weren't even willing to offer an opinion on the work already done—despite the fact they annually spend hundreds of millions on obesity research and prevention programs. However, within a year, the data had become too powerful to ignore. The CDC now recommends that high schools consider later starts: its representatives are now opining that a change in school start times can change lives.

Despite how convincing all this science is, somehow it still feels like a huge leap of faith to consider giving back an hour of our children's lives to slumber. Statistical correlations are fine evidence for scientists, but for parents, we want more—we want control.

Dr. Judith Owens runs a sleep clinic in Providence, affiliated with Brown. Recently, a father came in with his fifteen-year-old daughter, who was complaining of severe headaches. Interviewing the patient, Owens quickly learned that her daily routine was a brutal grind; after

flute lessons, bassoon lessons, dance classes, and the homework from honors classes, she was able to get only five hours sleep a night before waking every morning at 4:30 to tromp off to the gym. The father wanted to know if a lack of sleep could be causing her headaches. Owens told him that was probably the case. She recommended his daughter cut back on her schedule.

The word "probably" made this father hesitant. He would let her cut back, but only if Owens could *prove*, in advance, that sacrificing an activity would stop the headaches. Sure, he knew that sleep was important, but was it more important than Honors French? Was it more important than getting into a great college?

Owens tried her standard argument. "Would you let your daughter ride in a car without a seat belt? You have to think of sleep the same way."

But Owens' pleadings didn't persuade. In this dad's mind, the transaction went the other way around: cutting back was putting his daughter at risk. What if the headaches didn't stop, and she gave up one of her great passions, like dance, for no reason?

Long before children become overscheduled high schoolers gunning for college, parents—guardians of their children's slumber—start making trade-offs between their sleep and their other needs. This is especially true in the last hour of our child's day—a time zone let's call the Slush Hour. The slush hour is both a rush to sleep and a slush fund of potential time, sort of a petty cash drawer from which we withdraw ten minute increments. During the slush hour, children *should* be in bed, but there are so many priorities lobbying for another stroke of attention. As a result, sleep is treated much like the national debt—what's another half-hour on the bill? We're surviving; kids can too.

Sleep is a biological imperative for every species on earth. But humans alone try to resist its pull. Instead, we see sleep not as a physical need but a statement of character. It's considered a sign of

weakness to admit fatigue—and it's a sign of strength to refuse to succomb to slumber. Sleep is for Wusses.

But perhaps we are blind to the toll it is taking on us. University of Pennsylvania's Dr. David Dinges did an experiment shortening adults' sleep to six hours a night. After two weeks, they reported that they were doing okay. Yet on a battery of tests, they proved to be just as impaired as someone who has stayed awake for 24 hours straight.

Dinges did the experiment to demonstrate how sleep loss is cumulative, and how our judgment can be fooled by sleep deprivation. Nevertheless, it's tempting to read of his experiment and think, "I would suffer, but not *that* bad. I would be the exception." We've coped on too-little sleep for years, and managed to get by. We have some familiarity with this.

But when it comes to a child's developing brain, are we willing to keep taking the same brazen dare?