Why We Sleep

UNLOCKING THE POWER OF SLEEP AND DREAMS

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To Dacher Keltner, for inspiring me to write.

PART 1

This Thing Called Sleep

CHAPTER 1

To Sleep . . .

Do you think you got enough sleep this past week? Can you recall the last time you woke up without an alarm clock feeling refreshed, not needing caffeine? If the answer to either of these questions is "no," you are not alone. Two-thirds of adults throughout all developed nations fail to obtain the recommended eight hours of nightly sleep.[I]

I doubt you are surprised by this fact, but you may be surprised by the consequences. Routinely sleeping less than six or seven hours a night demolishes your immune system, more than doubling your risk of cancer. Insufficient sleep is a key lifestyle factor determining whether or not you will develop Alzheimer's disease. Inadequate sleep—even moderate reductions for just one week—disrupts blood sugar levels so profoundly that you would be classified as pre-diabetic. Short sleeping increases the likelihood of your coronary arteries becoming blocked and brittle, setting you on a path toward cardiovascular disease, stroke, and congestive heart failure. Fitting Charlotte Brontë's prophetic wisdom that "a ruffled mind makes a restless pillow," sleep disruption further contributes to all major psychiatric conditions, including depression, anxiety, and suicidality.

Perhaps you have also noticed a desire to eat more when you're tired? This is no coincidence. Too little sleep swells concentrations of a hormone that makes you feel hungry while suppressing a companion hormone that otherwise signals food satisfaction. Despite being full, you still want to eat more. It's a proven recipe for weight gain in sleep-deficient adults and children alike. Worse, should you attempt to diet but don't get enough sleep while doing so, it is futile, since most of the weight you lose will come from lean body mass, not fat.

Add the above health consequences up, and a proven link becomes easier to accept: the shorter your sleep, the shorter your life span. The old maxim "I'll sleep when I'm dead" is therefore unfortunate. Adopt this mind-set, and you will be dead sooner and the quality of that (shorter) life will be worse. The elastic band of sleep deprivation can stretch only so far before it snaps. Sadly, human beings are in fact the only species that will deliberately deprive themselves of sleep without legitimate gain. Every component of wellness, and countless seams of societal fabric, are being eroded by our costly state of sleep neglect: human and financial alike. So much so that the World Health Organization (WHO) has now declared a sleep loss epidemic throughout industrialized nations.[II] It is no coincidence that countries where sleep time has declined most dramatically over the past century, such as the US, the UK, Japan, and South Korea, and several in western Europe, are also those suffering the greatest increase in rates of the aforementioned physical diseases and mental disorders.

Scientists such as myself have even started lobbying doctors to start "prescribing" sleep. As medical advice goes, it's perhaps the most painless and enjoyable to follow. Do not, however, mistake this as a plea to doctors to start prescribing more sleeping *pills*—quite the opposite, in fact, considering the alarming evidence surrounding the deleterious health consequences of these drugs.

But can we go so far as to say that a lack of sleep can kill you outright? Actually, yes—on at least two counts. First, there is a very rare genetic disorder that starts with a progressive insomnia, emerging in midlife. Several months into the disease course, the patient stops sleeping altogether. By this stage, they have started to lose many basic brain and body functions. No drugs that we currently have will help the patient sleep. After twelve to eighteen months of no sleep, the patient will die. Though exceedingly rare, this disorder asserts that a lack of sleep can kill a human being.

Second is the deadly circumstance of getting behind the wheel of a motor vehicle without having had sufficient sleep. Drowsy driving is the cause of hundreds of thousands of traffic accidents and fatalities each year. And here, it is not only the life of the sleep-deprived individuals that is at risk, but the lives of those around them. Tragically, one person dies in a traffic accident every hour in the United States due to

a fatigue-related error. It is disquieting to learn that vehicular accidents caused by drowsy driving exceed those caused by alcohol and drugs combined.

Society's apathy toward sleep has, in part, been caused by the historic failure of science to explain why we need it. Sleep remained one of the last great biological mysteries. All of the mighty problem-solving methods in science—genetics, molecular biology, and high-powered digital technology—have been unable to unlock the stubborn vault of sleep. Minds of the most stringent kind, including Nobel Prize–winner Francis Crick, who deduced the twisted-ladder structure of DNA, famed Roman educator and rhetorician Quintilian, and even Sigmund Freud had all tried their hand at deciphering sleep's enigmatic code, all in vain.

To better frame this state of prior scientific ignorance, imagine the birth of your first child. At the hospital, the doctor enters the room and says, "Congratulations, it's a healthy baby boy. We've completed all of the preliminary tests and everything looks good." She smiles reassuringly and starts walking toward the door. However, before exiting the room she turns around and says, "There is just one thing. From this moment forth, and for the rest of your child's entire life, he will repeatedly and routinely lapse into a state of apparent coma. It might even resemble death at times. And while his body lies still his mind will often be filled with stunning, bizarre hallucinations. This state will consume one-third of his life and I have absolutely no idea why he'll do it, or what it is for. Good luck!"

Astonishing, but until very recently, this was reality: doctors and scientists could not give you a consistent or complete answer as to why we sleep. Consider that we have known the functions of the three other basic drives in life—to eat, to drink, and to reproduce—for many tens if not hundreds of years now. Yet the fourth main biological drive, common across the entire animal kingdom—the drive to sleep—has continued to elude science for millennia.

Addressing the question of why we sleep from an evolutionary perspective only compounds the mystery. No matter what vantage point you take, sleep would appear to be the most foolish of biological phenomena. When you are asleep, you cannot gather food. You cannot socialize. You cannot find a mate and reproduce. You cannot nurture or protect your offspring. Worse still, sleep leaves you vulnerable to predation. Sleep is surely one of the most puzzling of all human behaviors.

On any one of these grounds—never mind all of them in combination—there ought to have been a strong evolutionary pressure to *prevent* the emergence of sleep or anything remotely like it. As one sleep scientist has said, "If sleep does not serve an absolutely vital function, then it is the biggest mistake the evolutionary process has ever made."[III]

Yet sleep has persisted. Heroically so. Indeed, every species studied to date sleeps.[IV] This simple fact establishes that sleep evolved with—or very soon after—life itself on our planet. Moreover, the subsequent perseverance of sleep throughout evolution means there must be tremendous benefits that far outweigh all of the obvious hazards and detriments.

Ultimately, asking "Why do we sleep?" was the wrong question. It implied there was a single function, one holy grail of a reason that we slept, and we went in search of it. Theories ranged from the logical (a time for conserving energy), to the peculiar (an opportunity for eyeball oxygenation), to the psychoanalytic (a non-conscious state in which we fulfill repressed wishes).

This book will reveal a very different truth: sleep is infinitely more complex, profoundly more interesting, and alarmingly more health-relevant. We sleep for a rich litany of function*s*, plural—an abundant constellation of nighttime benefits that service both our brains and our bodies. There does not seem to be one major organ within the body, or process within the brain, that isn't optimally enhanced by sleep (and detrimentally impaired when we don't get enough). That we receive such a bounty of health benefits each night should not be surprising. After all, we are *awake* for two-thirds of our lives, and we don't just achieve one useful thing during that stretch of time. We accomplish myriad undertakings that promote our own well-being and survival. Why, then, would we expect sleep—and the twenty-five to thirty years, on average, it takes from our lives—to offer one function only?

Through an explosion of discoveries over the past twenty years, we have come to realize that evolution did not make a spectacular blunder in conceiving of sleep. Sleep dispenses a multitude of health-ensuring benefits, yours to pick up in repeat prescription every twenty-four hours, should you choose. (Many don't.)

Within the brain, sleep enriches a diversity of functions, including our ability to learn, memorize, and make logical decisions and choices. Benevolently servicing our

psychological health, sleep recalibrates our emotional brain circuits, allowing us to navigate next-day social and psychological challenges with cool-headed composure. We are even beginning to understand the most impervious and controversial of all conscious experiences: the dream. Dreaming provides a unique suite of benefits to all species fortunate enough to experience it, humans included. Among these gifts are a consoling neurochemical bath that mollifies painful memories and a virtual reality space in which the brain melds past and present knowledge, inspiring creativity.

Downstairs in the body, sleep restocks the armory of our immune system, helping fight malignancy, preventing infection, and warding off all manner of sickness. Sleep reforms the body's metabolic state by fine-tuning the balance of insulin and circulating glucose. Sleep further regulates our appetite, helping control body weight through healthy food selection rather than rash impulsivity. Plentiful sleep maintains a flourishing microbiome within your gut from which we know so much of our nutritional health begins. Adequate sleep is intimately tied to the fitness of our cardiovascular system, lowering blood pressure while keeping our hearts in fine condition.

A balanced diet and exercise are of vital importance, yes. But we now see sleep as the preeminent force in this health trinity. The physical and mental impairments caused by one night of bad sleep dwarf those caused by an equivalent absence of food or exercise. It is difficult to imagine any other state—natural or medically manipulated—that affords a more powerful redressing of physical and mental health at every level of analysis.

Based on a rich, new scientific understanding of sleep, we no longer have to ask what sleep is good for. Instead, we are now forced to wonder whether there are any biological functions that do *not* benefit by a good night's sleep. So far, the results of thousands of studies insist that no, there aren't.

Emerging from this research renaissance is an unequivocal message: sleep is the single most effective thing we can do to reset our brain and body health each day—Mother Nature's best effort yet at contra-death. Unfortunately, the real evidence that makes clear all of the dangers that befall individuals and societies when sleep becomes short have not been clearly telegraphed to the public. It is the most glaring omission in the contemporary health conversation. In response, this book is intended

to serve as a scientifically accurate intervention addressing this unmet need, and what I hope is a fascinating journey of discoveries. It aims to revise our cultural appreciation of sleep, and reverse our neglect of it.

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Personally, I should note that I am in love with sleep (not just my own, though I do give myself a non-negotiable eight-hour sleep opportunity each night). I am in love with everything sleep is and does. I am in love with discovering all that remains unknown about it. I am in love with communicating the astonishing brilliance of it to the public. I am in love with finding any and all methods for reuniting humanity with the sleep it so desperately needs. This love affair has now spanned a twenty-plus-year research career that began when I was a professor of psychiatry at Harvard Medical School and continues now that I am a professor of neuroscience and psychology at the University of California, Berkeley.

It was not, however, love at first sight. I am an accidental sleep researcher. It was never my intent to inhabit this esoteric outer territory of science. At age eighteen I went to study at the Queen's Medical Center in England: a prodigious institute in Nottingham boasting a wonderful band of brain scientists on its faculty. Ultimately, medicine wasn't for me, as it seemed more concerned with answers, whereas I was always more enthralled by questions. For me, answers were simply a way to get to the next question. I decided to study neuroscience, and after graduating, obtained my PhD in neurophysiology supported by a fellowship from England's Medical Research Council, London.

It was during my PhD work that I began making my first real scientific contributions in the field of sleep research. I was examining patterns of electrical brainwave activity in older adults in the early stages of dementia. Counter to common belief, there isn't just one type of dementia. Alzheimer's disease is the most common, but is only one of many types. For a number of treatment reasons, it is critical to know which type of dementia an individual is suffering from as soon as possible.

I began assessing brainwave activity from my patients during wake and sleep. My hypothesis: there was a unique and specific electrical brain signature that could

forecast which dementia subtype each individual was progressing toward. Measurements taken during the day were ambiguous, with no clear signature of difference to be found. Only in the nighttime ocean of *sleeping* brainwaves did the recordings speak out a clear labeling of my patients saddening disease fate. The discovery proved that sleep could potentially be used as a new early diagnostic litmus test to understand which type of dementia an individual would develop.

Sleep became my obsession. The answer it had provided me, like all good answers, only led to more fascinating questions, among them: Was the disruption of sleep in my patients actually contributing to the diseases they were suffering from, and even causing some of their terrible symptoms, such as memory loss, aggression, hallucinations, delusions? I read all I could. A scarcely believable truth began to emerge—nobody actually knew the clear reason why we needed sleep, and what it does. I could not answer my own question about dementia if this fundamental first question remained unanswered. I decided I would try to crack the code of sleep.

I halted my research in dementia and, for a post-doctoral position that took me across the Atlantic Ocean to Harvard, set about addressing one of the most enigmatic puzzles of humanity—one that had eluded some of the best scientists in history: Why do we sleep? With genuine naïveté, not hubris, I believed I would find the answer within two years. That was twenty years ago. Hard problems care little about what motivates their interrogators; they meter out their lessons of difficulty all the same.

Now, after two decades of my own research efforts, combined with thousands of studies from other laboratories around the world, we have many of the answers. These discoveries have taken me on wonderful, privileged, and unexpected journeys inside and outside of academia—from being a sleep consultant for the NBA, NFL, and British Premier League football teams; to Pixar Animation, government agencies, and well-known technology and financial companies; to taking part in and helping make several mainstream television programs and documentaries. These sleep revelations, together with many similar discoveries from my fellow sleep scientists, will offer all the proof you need about the vital importance of sleep.

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A final comment on the structure of this book. The chapters are written in a logical order, traversing a narrative arc in four main parts.

Part 1 demystifies this beguiling thing called sleep: what it is, what it isn't, who sleeps, how much they sleep, how human beings should sleep (but are not), and how sleep changes across your life span or that of your child, for better and for worse.

Part 2 details the good, the bad, and the deathly of sleep and sleep loss. We will explore all of the astonishing benefits of sleep for brain and for body, affirming what a remarkable Swiss Army knife of health and wellness sleep truly is. Then we turn to how and why a lack of sufficient sleep leads to a quagmire of ill health, disease, and untimely death—a wakeup call to sleep if ever there was one.

Part 3 offers safe passage from sleep to the fantastical world of dreams scientifically explained. From peering into the brains of dreaming individuals, and precisely how dreams inspire Nobel Prize–winning ideas that transform the world, to whether or not dream control really is possible, and if such a thing is even wise—all will be revealed.

Part 4 seats us first at the bedside, explaining numerous sleep disorders, including insomnia. I will unpack the obvious and not-so-obvious reasons for why so many of us find it difficult to get a good night's sleep, night after night. A frank discussion of sleeping pills then follows, based on scientific and clinical data rather than hearsay or branding messages. Details of new, safer, and more effective non-drug therapies for better sleep will then be advised. Transitioning from bedside up to the level of sleep in society, we will subsequently learn of the sobering impact that insufficient sleep has in education, in medicine and health care, and in business. The evidence shatters beliefs about the usefulness of long waking hours with little sleep in effectively, safely, profitably, and ethically accomplishing the goals of each of these disciplines. Concluding the book with genuine optimistic hope, I lay out a road map of ideas that can reconnect humanity with the sleep it remains so bereft of—a new vision for sleep in the twenty-first century.

I should point out that you need not read this book in this progressive, four-part narrative arc. Each chapter can, for the most part, be read individually, and out of order, without losing too much of its significance. I therefore invite you to consume

the book in whole or in part, buffet-style or in order, all according to your personal taste.

In closing, I offer a disclaimer. Should you feel drowsy and fall asleep while reading the book, unlike most authors, I will not be disheartened. Indeed, based on the topic and content of this book, I am actively going to encourage that kind of behavior from you. Knowing what I know about the relationship between sleep and memory, it is the greatest form of flattery for me to know that you, the reader, cannot resist the urge to strengthen and thus remember what I am telling you by falling asleep. So please, feel free to ebb and flow into and out of consciousness during this entire book. I will take absolutely no offense. On the contrary, I would be delighted.

I. The World Health Organization and the National Sleep Foundation both stipulate an average of eight hours of sleep per night for adults.

II. *Sleepless in America*, National Geographic, http://channel.nationalgeographic.com/sleepless-in-america/episode/sleepless-in-america.

III. Dr. Allan Rechtschaffen.

IV. Kushida, C. *Encyclopedia of Sleep*, Volume 1 (Elsever, 2013).

CHAPTER 2

Caffeine, Jet Lag, and Melatonin

Losing and Gaining Control of Your Sleep Rhythm

How does your body know when it's time to sleep? Why do you suffer from jet lag after arriving in a new time zone? How do you overcome jet lag? Why does that acclimatization cause you yet more jet lag upon returning home? Why do some people use melatonin to combat these issues? Why (and how) does a cup of coffee keep you awake? Perhaps most importantly, how do you know if you're getting enough sleep?

There are two main factors that determine when you want to sleep and when you want to be awake. As you read these very words, both factors are powerfully influencing your mind and body. The first factor is a signal beamed out from your internal twenty-four-hour clock located deep within your brain. The clock creates a cycling, day-night rhythm that makes you feel tired or alert at regular times of night and day, respectively. The second factor is a chemical substance that builds up in your brain and creates a "sleep pressure." The longer you've been awake, the more that chemical sleep pressure accumulates, and consequentially, the sleepier you feel. It is the balance between these two factors that dictates how alert and attentive you are during the day, when you will feel tired and ready for bed at night, and, in part, how well you will sleep.

GOT RHYTHM?

Central to many of the questions in the opening paragraph is the powerful sculpting force of your twenty-four-hour rhythm, also known as your circadian rhythm. Everyone generates a circadian rhythm (*circa*, meaning "around," and *dian*, derivative of *diam*, meaning "day"). Indeed, every living creature on the planet with a life span of more than several days generates this natural cycle. The internal twenty-four-hour clock within your brain communicates its daily circadian rhythm signal to every other region of your brain and every organ in your body.

Your twenty-four-hour tempo helps to determine when you want to be awake and when you want to be asleep. But it controls other rhythmic patterns, too. These include your timed preferences for eating and drinking, your moods and emotions, the amount of urine you produce,[I] your core body temperature, your metabolic rate, and the release of numerous hormones. It is no coincidence that the likelihood of breaking an Olympic record has been clearly tied to time of day, being maximal at the natural peak of the human circadian rhythm in the early afternoon. Even the timing of births and deaths demonstrates circadian rhythmicity due to the marked swings in key life-dependent metabolic, cardiovascular, temperature, and hormonal processes that this pacemaker controls.

Long before we discovered this biological pacemaker, an ingenious experiment did something utterly remarkable: stopped time—at least, for a plant. It was in 1729 when French geophysicist Jean-Jacques d'Ortous de Mairan discovered the very first evidence that plants generate their own internal time.

De Mairan was studying the leaf movements of a species that displayed heliotropism: when a plant's leaves or flowers track the trajectory of the sun as it moves across the sky during the day. De Mairan was intrigued by one plant in particular, called *Mimosa pudica*.[II] Not only do the leaves of this plant trace the arching daytime passage of the sun across the sky's face, but at night, they collapse down, almost as though they had wilted. Then, at the start of the following day, the leaves pop open once again like an umbrella, healthy as ever. This behavior repeats each and every morning and evening, and it caused the famous evolutionary biologist Charles Darwin to call them "sleeping leaves."

Prior to de Mairan's experiment, many believed that the expanding and retracting behavior of the plant was solely determined by the corresponding rising and setting of the sun. It was a logical assumption: daylight (even on cloudy days) triggered the leaves to open wide, while ensuing darkness instructed the leaves to shut up shop, close for business, and fold away. That assumption was shattered by de Mairan. First, he took the plant and placed it out in the open, exposing it to the signals of light and dark associated with day and night. As expected, the leaves expanded during the light of day and retracted with the dark of night.

Then came the genius twist. De Mairan placed the plant in a sealed box for the next twenty-four-hour period, plunging it into total dark for both day and night. During these twenty-four hours of blackness, he would occasionally take a peek at the plant in controlled darkness, observing the state of the leaves. Despite being cut off from the influence of light during the day, the plant still behaved as though it were being bathed in sunlight; its leaves were proudly expanded. Then, it retracted its leaves as if on cue at the end of the day, even without the sun's setting signal, and they stayed collapsed throughout the entire night.

It was a revolutionary discovery: de Mairan had shown that a living organism kept its own time, and was not, in fact, slave to the sun's rhythmic commands. Somewhere within the plant was a twenty-four-hour rhythm generator that could track time without any cues from the outside world, such as daylight. The plant didn't just have a circadian rhythm, it had an "endogenous," or self-generated, rhythm. It is much like your heart drumming out its own self-generating beat. The difference is simply that your heart's pacemaker rhythm is far faster, usually beating at least once a second, rather than once every twenty-four-hour period like the circadian clock.

Surprisingly, it took another two hundred years to prove that we humans have a similar, internally generated circadian rhythm. But this experiment added something rather unexpected to our understanding of internal timekeeping. It was 1938, and Professor Nathaniel Kleitman at the University of Chicago, accompanied by his research assistant Bruce Richardson, were to perform an even more radical scientific study. It required a type of dedication that is arguably without match or comparison to this day.