Best Summary + PDF: Why We Sleep, by Matthew Walker

by Allen Cheng

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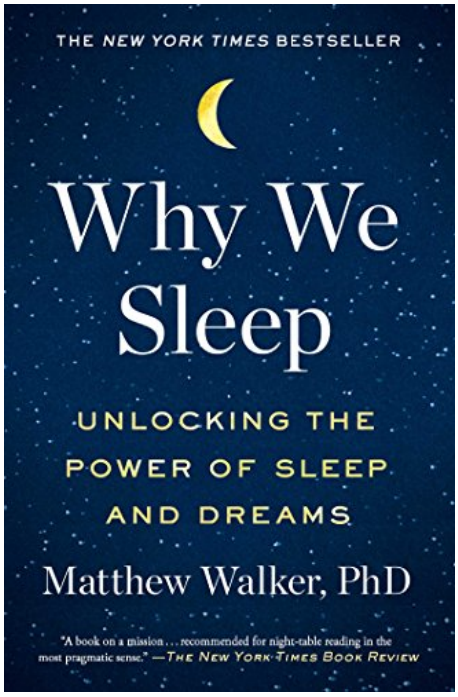


If you're like me, you sometimes try to get by with just 5 to 7 hours of sleep (or even less). You hope that you'll make it up in the extra hours of productivity, or by catching up on sleep on the weekend. There are plenty of excuses for being sleep deprived - a big deadline coming up, too much work, too binge-worthy of a TV show, social events you can't miss out on.

The book Why We Sleep argues this is totally short-sighted. More people are chronically sleep-deprived than they realize, and the punishments for this are severe - reduced productivity and happiness, and increased risk of a panel of diseases. Except for very rare genetic freaks (<1% of population), the standard sleep you should be getting every night is 8 hours, without fail.

This helpful New York Times bestseller covers how sleep happens, its major benefits, its frightening downsides when deprived, and the best ways to get better sleep.

In this book summary of Why We Sleep, learn:

- Why your insane dreams are incredibly helpful for your problem-solving
- The **5 major reasons you're getting less sleep than you should** - and how to fix it
- How being a night owl is determined by genetics - and why night owls are punished by society
- **How chronic sleep deprivation destroys your body**, from weight gain and heart disease to Alzheimer's
- A very rare inherited disease that causes incurable insomnia, then certain death, within 10 months

- How a cocaine-addicted surgeon started the insanely sleep-depriving medical residency program

Full title: Why We Sleep: Unlocking the Power of Sleep and Dreams. By Matthew Walker, PhD

1-Page Book Summary of Why We Sleep

- Sleep is universal in animals (even in insects and worms) - this alone suggests a vital function and that it isn't simply a vestigial byproduct of evolution.
- In the current nutrient-rich environment, humans in general need 8 hours of sleep to function optimally.
    - True low-sleepers (chronically < 6 hours of sleep/night without impairment of function) are incredibly rare, less than 1% of the population. Everyone else is disguising their sleep deprivation with caffeine and sleeping pills.
    - Insidiously, you're very bad at objectively assessing your decrease in performance under sleep deprivation.
    - Fasting and starvation does lower sleep, which is why hunter-gatherer tribes show 6.5 hours of sleep (which is then picked up by popular media)
- Sleep has two general types - NREM and REM.
    - NREM occurs earlier in the sleep phase, while REM is concentrated later.
    - NREM is slow (~2Hz) (like billions of neurons singing in synchrony) while REM is fast (50Hz) and looks like being awake.
    - NREM is responsible for pruning memories, transferring short-term memory to long-term memory, gaining "muscle memory," growth hormone secretion, and parasympathetic nervous system activation.
    - REM is responsible for forming new neural connections, problem solving, dreaming, blunting emotional responses to painful memories, reading other people's facial emotions, and neonatal synaptogenesis.
    - Both are generally necessary - depriving a person of either one leads to different problems.
- Sleep deprivation shows consistently worse outcomes. Nothing is reported to be beneficial from sleep deprivation.
    - higher mortality, risk of cancer, heart disease, weight gain, rate of infection, Alzheimer's, irritability, inflammation.
    - lower productivity, social fluidity, rational decisionmaking, memory recall, emotional control, testosterone, immune system function, response to flu vaccine.
    - in the extreme, chronic sleep deprivation causes death.
    - even the apparent increase in wakeful time to be productive is balanced by lower productivity and creativity.
- How to improve your sleep
    - Sleep and wake up at the same times every day.
    - Reduce light before sleep. Blue light is the most harmful, but even bedside lamps cause

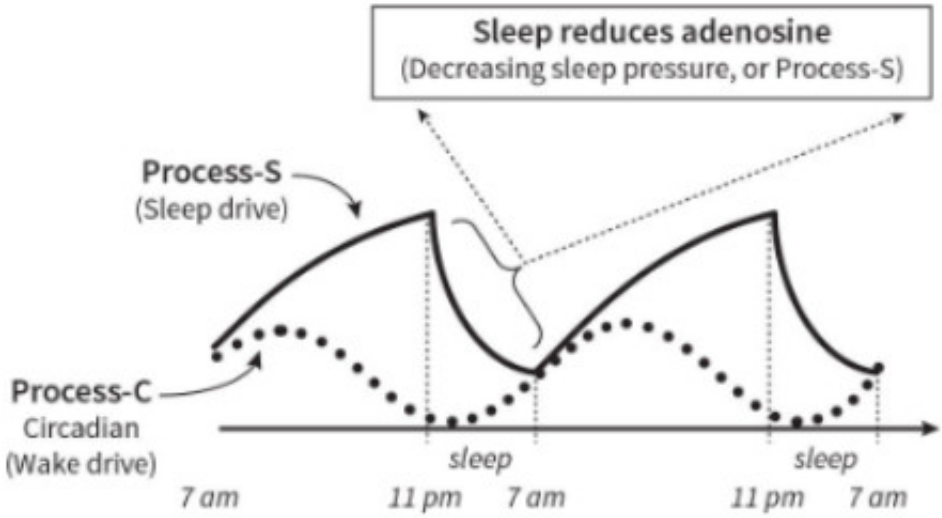
issues. Artificial light delays the circadian rhythm by hours.
    - Cool body temperature before sleep. The ideal sleeping temperature is 65F given standard bedding and clothes. Other tricks - expose your palms and feet while sleeping, take a hot bath before sleeping.
    - Don’t drink alcohol unless it is completely metabolized by sleep time (including the aldehydes produced).
    - Don’t drink caffeine at all [ha! good one], but especially not in afternoon.
    - Don’t use alarms if you can help it. Alarms cause a huge stress reaction on waking. Snoozing causes repeated traumas every morning.
    - Exercise regularly, but not 3 hours before sleep.
    - Don’t rely on sleeping pills - these are usually just sedatives that put you more in a sedation state than sleep.
- Cool future sleep-related ideas
    - In cars, detect sleep-deprived driving and react like drunk driving (shut it down, increase insurance premiums)
    - Automated household that adjusts light and temperature to each person’s circadian rhythm
    - If one can induce sleep naturally, can relieve not just insomnia but also PTSD and substance abuse

Part 1: This Thing Called Sleep

Chapter 1 of Why We Sleep is just an intro, so we'll skip to Chapter 2.

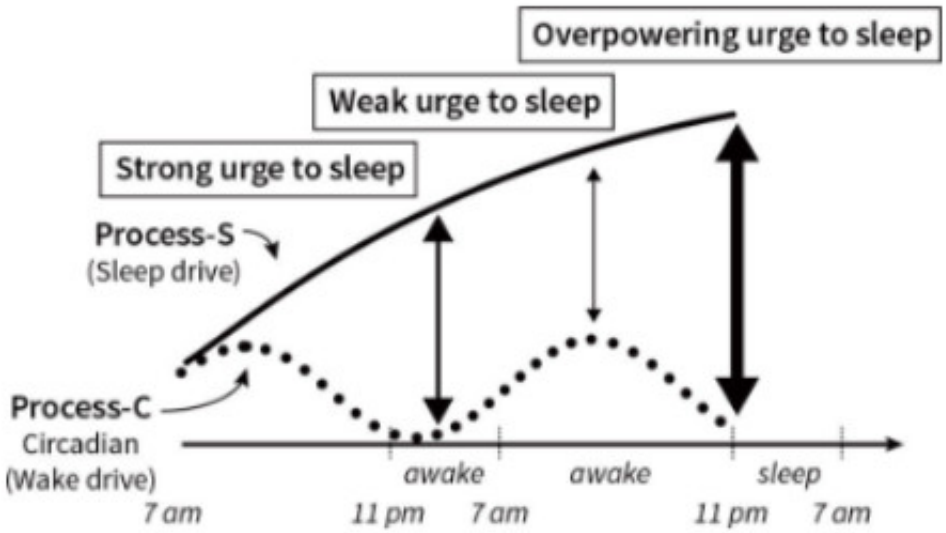
Chapter 2: Caffeine, Jet Lag, and Melatonin: Losing and Gaining Control of Your Sleep Rhythm

- Sleep is universal in animals, despite its apparent drawbacks (vulnerability, loss of time for productivity). This must point to a vital function for sleep.
- Sleep is regulated by two mechanisms:
    - A **circadian rhythm**, regulated by **melatonin** produced by the suprachiasmatic nucleus. This responds to light and darkness and is naturally 14 hours and 15 minutes long on average.
    - **Adenosine**, which rises consistently through the day absent sleep, and is depleted during sleep.



Sleep occurs when the mounting sleep pressure (adenosine) differs most with the circadian rhythm lull at nighttime.

- These two cycles explain why, during an all-nighter, you get a second wind in the morning. Here the circadian rhythm rises and reduces the circadian-adenosine gap.



- Caffeine blocks adenosine receptors.
    - Has a half-life of 5-7 hours, depending on genetics for Cytochrome P450 enzyme
    - Decaf apparently contains 15-30% of caffeine in regular coffee
    - Caffeine crash comes from increasing adenosine that is masked during caffeine active period
- Morning people and night owls prefer very different sleep times, and maximizing their energy at

different times of day.
    - These are strongly influenced by genetics.
    - Evolutionarily, having a mixture of morning people and night owls allows a population to reduce its vulnerability in nighttime to a shorter period of time.
    - But in modern times, the night owls are heavily punished, since early work times and later preferred sleep times means greater sleep deficit, causing low performance in mornings. Furthermore, by the time night owls peak in the afternoon, the work day has already ended.
- Why jetlag feels worse flying eastbound:
    - It requires falling asleep when the body wants to be awake, a more difficult task than staying awake when the body wants to sleep.
    - Since the circadian rhythm is slightly longer than a day, lengthening it is easier than shortening it.
- [Mundane sci-fi scenario - we make contact with aliens who live on a world with a totally different daytime cycle (eg 65 hours). The conceptions of time and incompatibilities lead to various amusing scenarios.]
- Signs of sleep deficit
    - Not waking up naturally at time of alarm
    - Needing to read sentence twice
    - Drowsiness a few hours after waking
    - Need for coffee to feel functional

Chapter 3: Defining and Generating Sleep: Time Dilation and What We Learned from a Baby in 1952

- Sleep cycles last 90 minutes, starting with NREM then transitioning to REM sleep. In total, there’s an 80/20 NREM/REM sleep balance.
- NREM is hypothesized to clear out old memories and mental detritus and move information into long-term storage. REM strengthens the remaining valuable connections and creatively forges novel connections. [This is probably really simplistic.]
- When recorded by EEG, NREM is characterized by slow (3-4 Hz) waves that propagate far from the cortex to the back of the brain. REM is characterized by faster (30-40 Hz) activity that looks indistinguishable from wakeful activity.
    - Wakeful thought is unsurprisingly a summation of many different neural signals occurring at once, making the synchrony of billions of neurons in slow-wave sleep really notable.
    - Analogy: the low-frequency NREM waves are like AM waves that can propagate further without attenuation. In Why We Sleep, Matthew Walker suggests that this is transferring memories from temporary parts of the brain toward more permanent storage, and allowing cross-brain communication to collaborate on their shared experience.
    - If REM sleep looks like wakefulness, how do you distinguish the two? Muscle atonia.
    - Sleep spindles (bursts of activity) occur at the end of slow waves, possibly serving a function to block external sensory input from disrupting sleep. People with more sleep spindles are heavier sleepers.

- As the sleep progresses through the night, a greater fraction of each cycle is spent in REM sleep.
    - Hypothesis: like sculpting out of a mass of clay, more NREM is needed earlier in sleep to clear out memories first, then more REM later strengthens the valuable bits that are left.
    - [If you had to be sleep deprived, it'd make sense for the more critical functions to be performed first in case you had to wake up. This suggests to me that NREM performs a more vital function.]
    - In Why We Sleep, Matthew Walker suggests this trend seems to be fixed to the time of day (like the circadian rhythm) rather than relative to the time of sleep (ie, more that the first cycle of sleep happens at 10PM-11:30PM, and not in the first 90 minutes). Therefore, losing sleep at either end of the cycle deprives the brain of that cycle.
- REM sleep is where dreams happen. At the start of sleep, the thalamus acts as a gatekeeper to filter the conscious perception of senses, but in REM sleep this blockade is released.
    - Sense of time in dreams seems dilated - an hour may seem to pass when in reality only 5 have.
- In REM sleep, your eyes move rapidly This was initially thought to be visual exploration of the dream field, but this turns out to be more related to the *creation* of REM sleep than passive observation of it.
- [Wakeful/REM sleep have been described as similar to a microphone picking up a stadium full of distinct conversations. I wonder how well Fourier transform works to unpack the component waves and enable noninvasive monitoring/mind reading.)

Chapter 4: Ape Beds, Dinosaurs, and Napping with Half a Brain: Who Sleeps, How Do We Sleep, and How Much?

- Sleep is present in all animal species, even invertebrates. And bacteria that survive for longer than 24 hours have circadian-like rhythms.
- Invert the question: if wakefulness is damaging to the body and sleep recovers it, why did life ever bother to wake up? [Naturally you can't reproduce when you're sleeping, among many other activities.]
- The amount of sleep per day varies from 4 hours in elephants to 19 hours in bats. There are no strong correlations between animal characteristics and amount of sleep, though brain complexity relative to body size increases sleep.
- Among animals, REM sleep occurs only in birds and mammals. The independent evolution of REM sleep in different phyla suggests a critical function that NREM cannot accomplish, or that REM is more efficient at accomplishing.
- Interesting animal sleep patterns
    - Cetaceans (dolphins, whales) sleep with half their brain at a time. They also don't have REM sleep (as formally defined), since the muscle atonia would prevent swimming. But they may have some harder to detect REM variant.
    - Birds in a flock will have most birds in full-brain sleep, then birds in the perimeter sleeping with half their brains to stay alert for danger
    - Similarly, humans in a new environment (eg hotel room) show one half of the brain sleeping lighter than the other, wary of dangers. This is why the first night in a new

environment can be so unrestful. This effect dissipates with more time.
    - Transoceanic birds that cross thousands of miles have ultra-power naps, sleeping for seconds at a time.
- The ideal human sleep pattern
    - Native pre-industrial tribes show a biphasic sleep pattern, with **7-8 hours at night and a 30-60 minute nap in the afternoon**. At night, they sleep 2-3 hours after sunset, awaking around dawn.
        - A study of Greek siestas showed that people who abandoned siestas (due to political and social pressure) showed 37% increase risk of death from heart disease compared to those who maintained siestas.
    - All people tend to have a dip in energy in midafternoon. (So avoid the presentation right after lunch.)
    - The European style of sleeping (two periods of sleep at night, separated by a few hours of wakefulness) is mostly a cultural artifact, and not a natural way to sleep.
- Relative to great apes, humans sleep less (8 hours vs 10-15) and have more intense REM sleep (20% vs 9%). In Why We Sleep, Matthew Walker hypothesizes this evolved as follows:
    - Apes sleep in trees and enjoy great safety at night.
    - In homo erectus, upright posture and shorter arms made sleeping in trees more difficult. REM sleep is also dangerous in trees because of falling out.
    - Production of fire enabled early humans to ward off predators and parasites at night. But danger still lurked, so humans who could sleep more efficiently for less time were evolutionarily selected for.
    - REM sleep is critical for 1) emotional regulation internally and recognition externally and 2) creativity. This led to improved survival strategies and larger social groups, which further increased brain complexity and more need for REM sleep, forming a positive feedback loop.

Chapter 5: Changes in Sleep Across the Life Span

- Babies
    - Fetuses spend almost all of its time in a sleep-like state. It doesn't yet have the muscle-atonia causing center developed, explaining its kicks and punches.
    - REM sleep ramps up in the last 2 weeks of pregnancy, up to 12 hours a day. This simulates synaptogenesis. In rats, disturbing REM sleep stalls construction of the cerebral cortex.
    - Alcohol impedes REM sleep in fetuses and babies, causing abnormal synaptogenesis. Once disrupted, it may never fully regain normal function.
        - Newborns of alcoholic mothers spend far less time in REM sleep.
        - 2 drinks reduce REM sleep and breathing rate in unborn infants.
        - When babies drink milk containing alcohol, their REM sleep reduces by 30%.
    - Because REM sleep is involved in emotional recognition and social interaction, disrupting REM sleep in utero might contribute to autism spectrum.
        - Autistic people show 30-50% less REM sleep than normal.
        - Rats deprived of REM sleep develop into socially withdrawn adults.

- Childhood
    - While starting with very irregular sleep, babies eventually show more regular sleep patterns starting at 4 months, as their suprachiasmatic nucleus and circadian rhythm develop.
    - With age, total time sleeping decreases, and the fraction of REM sleep decreases. Now that the synaptogenesis of REM finishes, NREM plays a larger role in brain *refinement*, pruning the associations that are most valuable unique to that child's life.
    - Consider NREM to actually *effect* cognitive development - changes in deep NREM sleep precede cognitive milestones, and the last maturation is in the frontal lobe, dealing with rationality.
    - Caffeine exposure here could reduce NREM sleep, delaying brain maturation and learning.
- Teens
    - In puberty, teens develop a later biological clock than adults, preferring to stay up later and wake later. This is not willful disobedience. Asking them to sleep at 10PM is like asking adults to sleep at 7PM.
    - Matthew Walker theorizes this is evolutionarily helpful for teens to gain independence from their parents, and for teens to do so collectively.
    - In the timing of school, teens are punished for early mornings.
- Adulthood/Age
    - Sleep quality starts deteriorating in the late 20s, with deep NREM sleep becoming impaired in length and power. In late 40s, you'll have lost 70% of deep sleep as a teenager; by 70, you'll have lost 90% of deep sleep.
        - This can worsen ability to cement new memories in older people.
    - Seniors sleep less, have less efficient sleep, and want to sleep earlier. This is caused by:
        - Degeneration of the mid-frontal cortex that generates sleep
        - Circadian rhythm shifting to earlier times again
        - Weakened bladders causing night interruptions
        - Lower sleep efficiency - people in 70s have 80% sleep efficiency, meaning staying awake in bed for 1.5 hours when trying to sleep 8.
    - Exacerbating this are:
        - Inability to determine our sleep quality after sleeping, which we chalk up to insomnia or other issue
        - Early-evening dozing off, which reduces the adenosine sleep pressure at night, preventing later sleep. Then the early circadian rhythm wakes them up before they can get a full night's rest.
    - Melatonin helps strengthen desire to sleep.
    - It's a myth that seniors need less sleep - that they don't sleep much could be due to inability to generate sleep. They could benefit from increased sleep.

Part 2: Why Should You Sleep?

The next part in this book summary of Why We Sleep covers the various benefits to sleep, and the painful disabilities you get in sleep deprivation

Chapter 6: The Benefits of Sleep for the Brain

- Sleep provides improvements in:
    - Long-term factual recall
        - The hippocampus stores short-term memory; the cortex stores long-term memory.
        - NREM sleep moves facts from the hippocampus to the cortex. Not only does this secure memory for long-term, but it also clears out short-term memory to make room for new information.
        - Sometimes you may recall facts that you previously couldn't before sleep - corrupted memories may become accessible again
        - Conversely, sleep deprivation can prevent new memories from being formed, possibly because the hippocampus becomes less functional, partially because lack of NREM sleep prevents solidifying of new memories.
            - Making up sleep later doesn't help recover previous days' memory - if you lost it, you've lost it.
    - Prunes memories worth forgetting
        - Sleep doesn't preserve all memories equally strongly - somehow the brain knows which memories to preserve and which to discard.
        - Shown in experiments with instructions on which graphics to remember and which to forget
    - Increases "muscle memory" or motor task proficiency
        - You might struggle with a motor task (playing a tough sequence on piano) but after sleep play it flawlessly. Deals with motor cortex
        - Reduced sleep decreases aerobic capacity, time to exhaustion, and recovery; and increases risk of injury, lactic acid generation
- [Studies are cited showing a 20% improvement in memory tasks. I didn't bother to look up the original studies.]
- These benefits occur in NREM sleep, which is concentrated in the beginning of sleep. However, motor memory is associated with stage 2 NREM, which is concentrated in the last cycle of sleep.
- Sleep spindles are associated with better memory effects with sleep
- Imagine the therapies/perturbations possible to natural sleep:
    - Selectively control facts from the day to remember (good for test studying, happiness, or psychiatric illness; but also possible to have distorted memory of life).
        - Experimentally done by pairing certain images with different sounds, then playing those sounds during sleep to reinforce the associated images.
    - Delete traumatic memories (PTSD) or bad habits (substance abuse)
    - Augment natural abilities of sleep, eg with electrode stimulation of brain, pulsing sound in sync with brain waves, or rocking bed rhythmically

Chapter 7: Too Extreme for the Guinness Book of World Records: Sleep Deprivation and the Brain

- Sleep deficits are very bad for attention and concentration, eg when driving.
    - The major issue is not just slower response times - it's *total* lapses in attention, when a microsleep makes you unconscious for a few seconds at a time, possibly losing all motor control.
    - Chronic sleep deficits are as damaging to attention as all-nighters - 6 nights of 4-hour sleep are equal to one all-nighter; 10 nights of 6-hour sleep are equal to the same. Performance progressively worsens with greater sleep deficit.
    - Driving after having slept less than 4 hours increases crash risk by 11.5x.
    - Being awake for 19 hours is as cognitively impairing as being legally drunk [according to some assays - would be interesting to compare effects on decision making and emotional control.]
    - Sleep deficits and alcohol have a multiplicative effect on mistakes, not just an additive one.
- Insidiously, we underestimate poor performance during sleep deprivation. This lower state becomes a new baseline.
- Power naps are most effective at the onset of fatigue, not at the end of sleep deprivation.
- Less than 1% of the population is able to survive on six hours of sleep and show minimal impairment (relates to the BHLHE41 gene).
- Emotion
    - We know that a baby that doesn't get its nap time tends to get cranky. Adults are the same way.
    - In sleep deprivation, the prefrontal cortex control of the amygdala (responsible for fear, anxiety, etc) weakens, leading to 60% more emotional lability. The highs can be higher, and the lows lower.
    - Sleep disruption is common in all mood disorders. The causation is unclear, but Matthew Walker believes sleep plays at least some aggravating role.
    - One light of sleep deprivation can trigger a manic or depressive episode in bipolar patients.
    - Sleep deprivation might also be involved in suicidal ideation in teenagers.
    - Surprisingly, sleep deprivation makes ? of depression patients feel better, possibly by amplifying their positive emotions. However, it makes ? feel worse, so isn't best described (though it would be interesting to preclassify the groups)
    - On the other side of the spectrum, positive rewards and dopamine may be amplified too. Sleep deprivation can intensify sensation-seeking, risk-taking, and addiction.
- Alzheimer's
    - While no definitive causal link has been shown yet, sleep losses seem to contribute to Alzheimer's through a few mechanisms:
        - Frontal lobe degeneration (esp. through amyloid plaques) disrupts NREM sleep.
        - Lack of NREM sleep disrupts memory formation.
            - (Notably, the hippocampus is not affected by amyloid plaques, presenting a conundrum to scientists on why memory is disrupted in Alzheimer's)
        - Lack of NREM sleep disrupts the glympathic cleanup system, during which glia shrink to less than half their normal size and amyloid plaques are cleared out more readily.
    - It's easy to see how a vicious cycle can occur - frontal lobe degeneration disrupts NREM sleep, which causes further frontal lobe degeneration.
    - Encouraging NREM sleep, eg through brain stimulation, might be therapeutic for

Alzheimer's, and it could be prophylactic the same way statins are.
    - Sleep loss precedes Alzheimer's by several years, suggesting this could be diagnostic.

Chapter 8: Cancer, Heart Attacks, and a Shorter Life: Sleep Deprivation and the Body

Sleep deprivation disrupts the normal function of many physiological processes, likely contributing to chronic diseases. At a high level, sleep deprivation triggers the sympathetic nervous system (fight or flight response) and disrupts hormonal balances. This also implies, inversely, that sleep is necessary for the normal maintenance of physiology.

[Many of the population studies cited in the book Why We Sleep are correlational - e.g. people who sleep less are more likely to have heart disease (even after controlling for many other factors associated with heart disease). Other than a causative explanation (lack of sleep causes heart disease), the causality could work the other direction - e.g. non-controlled factors that predispose people to get heart disease (eg a high baseline level of stress) also reduce sleep.

To address this, the *experimental* studies attempt to link lack of sleep to a middleman disrupted physiological state, which itself is causative for the disease. For instance, lack of sleep increases blood pressure, which the medical consensus believes is causative for heart disease.

The "smoking gun" experiment would be to randomize people into normal-sleep and low-sleep groups for years, then observe the rate of disease. However, this is impractical (hard to run very long studies like this, also impossible to double-blind) and likely unethical (if low sleep is already believed to cause severe disease).]

- Heart disease
    - Sleep deprivation has a number of effects related to CHD:
        - **Activates the sympathetic nervous system**, leading to
            - Increased heart rate
            - Increased vasoconstriction -> increased blood pressure
            - Increased cortisol
            - Increased atherosclerosis (esp of coronary arteries)
        - Through hormone signaling, decreases HDL (good cholesterol) and growth hormone (promotes recovery of blood vessel endothelium)
    - A population study showed 45% increased risk of developing CHD
    - **Interesting**: daylight savings time is a natural sleep experiment that typically increases or decreases sleep by 1 hour. When the clock moves forward, there is a significant spike in heart attacks and number of traffic accidents.
- Diabetes
    - Sleep deprivation reduces insulin responsiveness, which causes hyperglycemia.

        - In an experiment, after 4 hours of sleep a night for 6 nights, subjects were 40% less effective at absorbing a standard dose of glucose.
    - In a population study, those sleeping < 6 hours a night showed higher rates of T2D (after controlling for body weight, alcohol, smoking, etc)
- Obesity, Weight Gain
    - Sleep deprivation
        - Reduces leptin (makes you feel full) and increases ghrelin (makes you feel hungry)
        - Increases endocannabinoids (reduces pain sensation but increases appetite; also released in runner's high), which increases eating.
        - Makes you feel lethargic, which makes you less likely to exercise
    - In an experiment, subjects were randomized into a normal 8-hr sleep group, and a low 4-hr sleep group. Both groups were carefully monitored and controlled for physical activity.
        - The low-sleep group ate 300 more calories each day, even after just 4 days of sleep deprivation.
        - The low-sleep group was also more prone to overeating each meal, consuming 330 more calories in snack foods after a meal.
    - One might argue that decreased sleep naturally causes more calorie burn, but **an all nighter actually consumes only 147 more calories than sleeping**. Sleep is metabolically more intense than you imagine.
    - Sleep deprivation also disrupts the linkage between the rational prefrontal cortex and the primal appetite center in the brain (similar to emotional control in the last chapter).
    - Finally, if you're on a diet and under sleep deprivation, 70% of weight loss comes from lean body mass, compared to under 50% with plentiful sleep.
- Reproductive System
    - In males, sleep deprivation decreases testosterone, testical size, sperm count.
        - Experimentally, the is acute - 5 hours of sleep for one week "ages" a man 10-15 years by testosterone
    - Beyond libido, testosterone also governs bone density and muscle mass.
    - In females, sleep deprivation reduces follicular-releasing hormone (necessary for conception), increases abnormal menstrual cycles, and had more issues with infertility.
    - Your face is rated as more attractive and healthier after one night of short sleep.
- Immune system
    - Sleep deprivation reduces your ability to ward off infectious disease
        - In an experiment, subjects exposed to low sleep over 1 week were 50% likely to develop a cold when exposed to rhinovirus, vs 18% in normal-sleep
        - Sleep deprivation reduces the immune response to flu vaccines by over 50%
        - Sleep deprivation reduces circulating levels of natural killer cells
- Cancer
    - Sleep deprivation increases inflammation, which increases cancer severity:
        - Promotes angiogenesis
        - Promotes lability of cancer cells, leading to metastasis
        - Downregulates M1 macrophages and upregulates M2 macrophages, both changes increasing cancer risk.
        - [It's unclear why increasing inflammation like this decreases response to infectious disease agents, in the last bullet point]
    - Mouse models show increase in speed and size of cancer growth when sleep deprived.

    - Population studies show a link between nighttime shift work and risk of cancer (eg nurses, pilots).
        - Denmark now pays worker comp to women with breast cancer after doing night-shift work in government-sponsored jobs
- Aging
    - Telomere shortening is associated with sleep deprivation.
    - Gene expression profiles are distorted under sleep deprivation [though I see this as a natural consequence of the vastly different physiology in sleep deprivation, and not alarming in itself like the uathor presents.]

[Evolutionarily, these responses might promote survival as follows: in caveman days, times of low sleep may mean conditions that threaten survival (tough weather, hostility with another tribe, anxiety from disease). Hoarding calories, increasing the sympathetic nervous system, and decreasing during this time might promote short-term survival.]

Part 3: How and Why we Dream

The next portion of this Why We Sleep book summary covers REM sleep in particular, and the benefits of the mysterious phenomenon of dreaming.

Chapter 9: Routinely Psychotic: REM-Sleep Dreaming

- Most vivid dreaming happens during REM sleep (though NREM sleep has some vague non-vivid dreaming).
- During REM dreaming, your visual, motor, memory, and emotional areas of the brain are active. Your prefrontal cortex (governing rationality) is muted.
- In the ancient past, Egyptians and Greeks wondered if dreams were divine gifts from gods. Freud helped dispel this, firmly centering it within the human brain.
- Freud considered dreams as evocations of repressed desires, and he built a movement around interpreting dreams as such.
    - The critical flaw was its unprovability - the interpretation methods were so subjective that different approaches yielded different results, and there was no strict hypothesis -> outcome that was testable.
    - Furthermore, the interpretations were horoscopically vague, thus seeming full of significance but not providing any practical insight (eg “your dream is reminding you of how little time you have to do all the things you want to do.”)
- Do dreams replay events of the day, or do they reflect our emotional concerns?
    - Only a small fraction (1-2%) of dreams replay the literal events of the day.
    - A **greater fraction (~45%) reflect our underlying emotional worries we have while awake.**
- Interesting: **it may be possible to predict what you’re dreaming about through fMRI.**

    - To build a profile of your brain, you look at different images while awake, and the fMRI signature is captured.
    - Then as you dream, your dreaming fMRI is matched to your awake fMRI profiles, predicting what you're currently looking at while dreaming.

Chapter 10: Dreaming as Overnight Therapy

- **REM sleep function: blunts the emotional pain of a memory**
    - Dreaming about the upsetting content itself, or its emotional themes, is necessary to have this emotional blunting effect. REM sleep by itself does not.
    - In REM sleep, norepinephrine is reduced to zero, which possibly allows the brain to process upsetting memories in a "safe" brain environment.
    - PTSD patients have elevated norepinephrine in REM sleep. They also have recurring nightmares where the pain of the memory does not fade, either dreaming or wake.
        - Reducing norepinephrine levels pharmacologically reduces PTSD severity in a subset of patients.
    - In an experiment, subjects were shown a series of emotionally triggering images two separate times, separated by ~12 hours. One group saw set 1 before sleeping and set 2 after sleeping. The other group saw both in the same day without sleeping, set 1 in morning and set 2 at night. The former group reported much less emotional disturbance upon seeing the second time, also with less amygdala activity under fMRI.
- **REM sleep function: reading other people's facial emotions**
    - Sleep deprivation reduces interpretation of the subtleties of facial expressions, causing the sleep deprived person to more likely interpret faces as hostile and aggressive
    - Suggestive: kids on the autism spectrum have disrupted REM sleep. They also have issues reading people's facial expressions
    - This function seems to begin in adolescence, when kids have to start navigating the social world independently
    - Imagine the mistakes sleep-deprived professionals can make - police, medical staff, parents - if they mistake faces for aggression.

Chapter 11: Dream Creativity and Dream Control

- REM sleep function: creates novel associations between ideas, increasing creativity and solving problems
    - Narratively, the brain asks: **"how can I connect what I've recently learned with what I already know, thus discovering insightful revelations?** What have I done in the past that might be useful in solving this new problem?"
    - Experimental theme: split subjects into a sleep group and non-sleep group. Show that more REM sleep (observed by electrodes on head) increases performance further.
    - REM sleep creates novel connections, between distantly related concepts

        - Different concepts are associated together semantically (eg pairwise relationships are synthesized to form one giant relationship. Eg teach A->B and B->C separately, and the brain forms A->B->C)
        - New experiences can be matched to old ones (eg solving a maze today vs navigating a maze in Thailand 5 years ago) [possibly to piggyback previously learned skills to new ones]
        - [this is akin to how LSD seems to open new channels between parts of the brain that normally don't communicate, possibly leading to creativity]
    - REM sleep creates higher-level comprehension of ideas, finding the patterns among the vast noise
        - eg language learning as a child; finding easier ways to solve repetitive problems
    - **The *content* of REM sleep matters when solving that problem**
        - In an experiment, subjects were given a maze to solve and given a chance to nap. People who dreamt about issues related to mazes were 10x better at solving the maze upon waking, vs people who didn't dream about mazes.
        - Matthew Walker cites Mendeleev in dreaming about arranging the periodic table.
    - People in REM sleep are able to better solve creative problems
        - In an experiment, subjects in sleep were woken up to solve anagrams (eg OEOSG = GOOSE). Those waking up from REM sleep solved 15-35% more puzzles than those in NREM sleep or while awake.
    - Thomas Edison would reportedly fall asleep holding metal ball bearings, releasing them as he entered REM sleep and waking up to write down his dream ideas
- Lucid dreamers are able to voluntarily control their actions during dreaming
    - This was verified by prearranging eye movements and hand signals during REM sleep (hand signals were read by fMRI because of muscle atonia)
    - <20% of people in the population are capable of lucid dreaming, suggesting it might not be a hugely advantageous capability

Part 4: From Sleeping Pills to Society Transformed

The final section of this book summary of Why We Sleep covers hindrances and therapies for sleep deprivation, and Matthew Walker's suggestions to reorganize our society around getting helpful sleep.

Chapter 12: Things that Go Bump in the Night: Sleep Disorders and Death Caused by No Sleep

The book Why We Sleep covers a variety of diseases related to abnormal sleep:

- Somnambulism
    - aka sleepwalking
    - Happens in NREM sleep (not REM dreaming sleep, like some think) in response to an

unexpected spike in nervous system activity, getting stuck between sleep and wakefulness.
    - Automatic nonconscious routines are executed - brushing teeth, opening the refrigerator
    - In the extreme, **the sleepwalker murders someone** (a wife, in-laws). In some cases the murderer is exculpated as not being in control of his or her actions, though this defense doesn't always work
    - More common in children than adults, for unknown reason - maybe because kids spend more time in NREM sleep
- Insomnia
    - Defined as making enough time for sleeping, but being unable to sleep for more than 3 months. Characterized by difficulty falling asleep, waking up in middle of night, feeling unrefreshed
    - **1/9 people suffer from insomnia. 2x as common in women than men, and in blacks/Hispanics than whites, for unknown reasons.**
    - Most common triggers are emotional concerns or distress.
    - **The biological cause is linked to an overactive sympathetic nervous system**. This raises body temperature and levels of cortisol/epinephrine.
        - In turn, the thalamus, hippocampus, and amygdala all remain more active than in normal sleeping patients
    - When they do sleep, insomniacs have more fragmented REM sleep and shallower brainwaves in NREM.
    - Given the complex physiology, blunt instruments like sleeping pills are unlikely to fix the root cause.
- Sleep deprivation and death
    - In rodent studies, **REM sleep deprivation causes death over the same period as food deprivation** - about 15 days.
        - NREM sleep deprivation causes death too, after 45 days.
        - Sleep-deprived rats lose body weight, despite eating more. Related: they can no longer regulate their body temperature, causing intense metabolism. The immune system is also destroyed, causing widespread skin sores.
        - The cause of death is universally septicemia, caused by the gut microbiome.
    - A very rare inherited condition - **fatal familial insomnia** - is caused by prion disease (PrNP). The thalamus is destroyed, and the victim is totally unable to sleep, even with heavy sedatives. **Death occurs without remedy within 10 months**, after severe disability (dementia, speech disorders) worsens over months.
        - Autosomal dominant. Found in only 40 families worldwide.
- Narcolepsy
    - Shows sudden bouts of extreme sleepiness during the day
        - Some people who are chronically sleep deprived think they're narcoleptic. The severity of feeling for narcolepsy is far more severe, equivalent to the feeling after 3 consecutive all-nighters. Narcolepsy occurs in just 1/2000 people
    - Also experience sleep paralysis (waking up in REM sleep during muscle atonia), accompanied by a feeling of dread (which comes from being unable to move in response to possible threat).
        - Many UFO sightings are attributed to sleep paralysis
    - Also experience cataplexy (sudden loss of muscle control)
        - **These are triggered by strong emotional reactions**, positive or negative (jokes,

surprise, a nice shower, playing with kids, a horn when driving)
        - The narcoleptic "is banished to a monotonic existence of emotional neutrality" to avoid cataplexy
        - In cataplexy, patients aren't asleep, they're fully active but paralyzed.
    - Wakefulness is signaled by the neurotransmitter orexin in the hypothalamus; in sleep, this is shut off. In narcoleptic patients, 90% of orexin-secreting cells are destroyed, and orexin receptors are downregulated.
        - This insufficient signaling causes the body to exist in a not-awake not-asleep purgatory throughout the day and night.
    - No current effective treatments
        - Amphetamine/provigil used for daytime sleepiness
        - Antidepressants suppress REM sleep, which helps with sleep paralysis and cataplexy
        - New drugs like suvorexant (meant to block orexin at night) caused patients to fall asleep just 6 minutes faster.
- Sleep studies of hunter-gatherer tribes
    - Reports that natural tribes sleep just 6.5 hours have led to popular press that this is a universally "natural" state for all humans
    - However, **this is confounded by the low caloric intake of hunter-gatherer tribes.** Starvation naturally induces less sleep [likely to encourage more hours to forage]. They also tend to have shorter life spans than typical humans.
    - In nutrition-rich situations outside hunting-gathering, the sleep need appears to be 8 hours.
- Sleeping too much
    - Some population studies show increased risk of death when sleeping over 9 hours. Matthew Walker argues this is confounded by infection and cancers in long-sleeping people [though these confounds should already have been controlled for].
    - In Why We Sleep, Matthew Walker argues there is no evidence that sleeping more causes any health defects

Chapter 13: iPads, Factory Whistles, and Nightcaps: What's Stopping You from Sleeping?

Why We Sleep covers five major perturbations to normal sleep:

- Light
    - The suprachiasmatic nucleus responds to light to regulate the circadian rhythm (by signaling to the pineal gland to secrete melatonin).
    - **Any light is disruptive to the circadian rhythm.**
        - Electric light delays your 24-hour circadian rhythm 2-3 hours each evening.
        - Even 8-10 lux delays melatonin release. A bedside lamp is 20-80 lux, and a living room is 200 lux, suppressing melatonin by 50%.
    - Blue light is most problematic, suppressing melatonin at twice the levels of warm light.
        - We respond most to blue light because we evolved from marine creatures, and blue

light penetrates water best.
        - Reading on an iPad vs a book causes 50% less melatonin secretion and delayed the rise by 3 hours.
    - Light can suppress melatonin for days after usage stops.
- Constant temperature
    - In natural environments, the temperature rises and falls with the day. This is used by the hypothalamus, along with light, to set the circadian rhythm.
    - Before sleep, the body ejects heat through densely perfused areas like hands, feet, and face.
    - **We tend to now homogenize our temperatures**, suppressing the highs in the day and raising the lows with pajamas and blankets.
    - The best temperature to sleep at with standard bedding and clothing is 65F, which is far lower than most keep bedrooms.
    - Activities that help remove heat from the body: hot bath before bed (expands capillaries, which after bath drops temperature); splashing water on skin; sticking hands and feet outside blanket.
    - Experiments using water cooling through a body suit reduced time to sleep and quality of NREM sleep in insomniacs and older people.
- Alcohol
    - **Alcohol is a sedative, causing what appears to be sleep but is really more like anesthesia**. It disrupts sleep by suppressing REM sleep and causing waking throughout the night.
        - This is caused by aldehydes from alcohol metabolism.
    - Alcoholics are so sleep-deprived that their brain imposes REM-like behavior during wakefulness - hallucinations, scattered thinking.
    - In an experiment, subjects were tasked with learning a new grammar on day 1. When exposed to alcohol on the first night, they lost 50% compared to the abstinent group. Surprisingly, those getting alcohol on night 3 lost 40%.
        - [It’s unclear if this effect dissipates after night 4.]
    - [An unfortunate vicious cycle can result here - alcohol disrupts sleep, which causes more fatigue and less behavior control when awake, which prompts more alcohol.]
- Alarms
    - The best path to waking is natural, without alarms.
    - Alarms cause stress responses, raising cortisol, heart rate, and blood pressure. Snoozing causes multiple stress responses.
    - **“Life hacks” on how to defeat the snooze button are missing the point** - rearrange your sleep so you wake up naturally.
- Caffeine (discussed in chapter 2)

Chapter 14: Hurting and Helping Your Sleep: Pills vs Therapy

- The best sleep practices
    - **Keep the same waking and sleeping time**

    - Practice sleep hygiene - lower temperature, reduce noise, reduce light
    - No alcohol, caffeine, exercise, or long naps before sleep
    - **Exercise seems to increase total sleep time and increase quality of sleep**
        - However, this does not seem to act minutely on a day-to-day scale - exercise on one day doesn't necessarily lead to better sleep that night. But worse sleep on one night does lead to worse exercise the following day.
    - Eat a normal diet (not severe caloric restriction). Avoid very high carb diets (>70% of calories) since this decreases NREM and increases awakenings.
- Sleeping pills are typically sedatives that put the body into a state that doesn't fully resemble sleep (similar to alcohol). Deepest brainwaves are lacking.
    - Sleep timing with a sleeping pill is no better than placebo (even though self-reported satisfaction is higher). This causes daytime sleepiness.
    - **A heavily medicated vicious cycle:**
        - Poor sleep practices or stress reduces sleep.
        - Sleeping pills cause next day drowsiness.
        - Caffeine use and naps reduce drowsiness but also reduce ability to sleep at night, causing more sleeping pill usage
        - Tolerance of sleeping pills causes insomnia withdrawal when stopped, thus maintaining the habit.
    - Population studies show that sleeping pills increase mortality in a dose-dependent way. Suggestive causes, possibly with a root cause of abnormal sleep:
        - Increased drowsiness in day -> car accidents
        - Increased risk of cancer
        - Increased infection risk (esp bad for elderly)
        - [Can't rule out that something upstream that disrupts sleeping is also causing all these other disease risks.]
- CBT for Insomnia
    - More effective than sleeping pills
    - In addition to sleep practices above, a big part of alleviating insomnia is redeveloping confidence around ability to sleep. Forcibly staying tired and sleeping for at least 6 hours helps kick off confidence to keep adding on sleep time.
    - Other prescriptions:
        - Don't have clock nearby or you'll clock watch
        - If unable to sleep, get out of bed and go back when sleepy. Don't lie in bed awake
        - Go to bed only when sleepy
        - Avoid daytime napping
        - Reduce anxiety-provoking thoughts before bed

Chapter 15: Sleep and Society: What Medicine and Education are Doing Wrong; What Google and NASA are Doing Right

Our society has structurally locked in sleep deprivation in 4 ways:

- Work
    - The ethos at many companies thinks sleep is for the week and lionizes the road warrior who fearlessly crosses time zones on tiny amounts of sleep and answers emails at 1AM. More hours worked = more productivity.
    - The effects of sleep deprivation are costly:
        - Lost productivity per sleep deprived worker is in the thousands of dollars a year. In Why We Sleep, Matthew Walker argues insufficient sleep costs 2% of GDP.
            - In a natural experiment studying workers on opposite edges of a time zone, workers who obtained an hour of extra sleep earned 5% higher wages.
        - Reduced work performance, creativity, motivation, social cohesion. Increased risk-taking, impulsiveness, and desire to cheat.
        - Leaders who sleep worse are rated worse by their team (even on a day-by-day resolution) and caused less engagement in their workers.
        - **Workers who sleep less rate their leaders as less charismatic,** regardless of the leader's sleep level (thus forming a multiplicative effect where sleepless leaders and workers make everyone miserable)
        - Insidiously, workers don't perceive themselves as performing worse when sleep deprived.
    - **Another vicious cycle: people sleep less because of the amount of work they have to do, but their low sleep reduces their productivity and increases the work remaining.**
    - Focus less on hours worked, but on real productivity and output
    - The tide is shifting with flexible work hours (to suit personal circadian rhythms), nap pods, and adaptive office lighting.
- Education
    - To match parent's schedules, primary/secondary school often begins at 8AM, sometimes 7AM. **Kids who need to catch a long bus ride have to wake at 5:30AM or earlier.**
    - Remember that children have delayed circadian rhythms. This is akin to forcibly waking adults at 3:30AM everyday.
    - Kids with lower sleep show lower motivation, academic performance, IQ; greater irritability, distraction, anxiety, substance abuse, risk of traffic accidents.
    - Unfortunately, kids from poorer families are less likely to be driven to school [which may reduce their academic performance, which reduces their future income, which then punishes their own kids in the same way.]
    - Many kids diagnosed with ADHD may actually have sleep disorders (Matthew Walker estimates >50% are misdiagnosed)
        - Unfortunately, they're treated with amphetamine (adderall), causing even worse sleep problems.
    - Structurally, school start times may be locked in by bus driver unions, parent schedules [and maybe teacher unions?]
- Medical training
    - The medical residency training system began with a **cocaine-addicted surgeon** (William Halsted) in New York in the 1880s. Viewing sleep as the enemy, he instituted 30-hour shifts.
    - Sleep-deprived residents show greater risk of medical errors, surgical errors, misdiagnoses, and careless deaths.
        - Recall that after 22 hours without sleep, performance is impaired to the same level

as being legally drunk.
    - First-year residents are now limited to 24-hour shifts and 80-hour weeks. Later-year residents have no such restriction, since the ACGME claims the medical error studies were done only on first-year residents.
    - Structurally, change is resisted for fear of limiting patient volume for training purposes, and encouraging laziness relative to what the attending doctors had to suffer through.
- Torture
    - Sleep deprivation reduces the quality of information (harms memory recall) and increases the risk of lying and false confessions, just to get some sleep.
    - This is recognized by many countries as unethical, but still practiced by others (like the US in Abu Ghraib)

Chapter 16: A New Vision for Sleep in the Twenty-First Century

Chronic sleep deprivation has a variety of causes, from the individual scaling up to the societal. In Why We Sleep, Matthew Walker suggests a variety of fixes:

- Individual
    - Automated “internet of things” household that can automatically sense your circadian rhythm and personalize the temperature and lighting to maximize sleep.
        - Furthermore, if you have an upcoming disruption to your sleep schedule (like a flight), it can adjust your circadian rhythm to smoothen the transition.
    - Sophisticated body trackers that record sleep, physical activity, light exposure, temperature, heart rate, mood, happiness, social performance, productivity - and shows how your sleep correlates with better performance on all dimensions
        - Can also predict when it’s best to get a flu shot (since sleep affects responsiveness to vaccine)
        - Patients given tools to show their compliance with a program (like BP monitors, scales) increase compliance rates.
    - Cars that sense sleep driving through facial recognition and driving behavior. Can shut down car, or lead to lower insurance rates.
- Educational
    - Having sleep be a mandatory subject in physical education (like drugs and diet)
    - Having predictive tools that show the costs to health and income if you continue your poor sleep habits
    - Instructing populace on sleepy driving as much as drunk driving
- Organizational
    - Companies should be more flexible about work hours, allow naps, and de-emphasize hours worked in favor of real productivity
    - Employers and insurance companies can incentivize sleep - for consecutive days of over 7 hours of sleep (as tracked by sleep monitor), get extra vacation days, more pay, or reductions in premiums.
    - Hospitals should promote sleep hygiene for patients, esp in ICU and NICU. Change the

harsh white lighting, dispense earplugs and eye masks, reduce alarms and beeps, and schedule lab tests to align better with sleep schedule.

- Better sleep is shown to reduce sensitivity to pain, and increase weight gain and O2 sat levels in neonates.