

BIOHACKING AT THE INTERSECTION OF ART AND SCIENCE

Biohacking is the optimization of performance, health and well-being by utilizing science, technology and a deep understanding of human physiology and nutrition. Biohacking is also an art unto itself, the “sculpture” of which is the individual.

The driving force behind this book is a holistic approach to health and well-being. Human health cannot be approached in a reductionist manner if well-being is the long-term goal. The secret to a better life can therefore not be found in a pill bottle, fad diet or trendy exercise regime.

The opposite of reductionism is holism. For a long time, it was assumed that solving the puzzle of human genetics would provide answers to all questions regarding health and well-being. Instead, we have only recently begun to understand just how crucial complex environmental factors (i.e. epigenetics) are in this scenario. By studying individual genes, we have evidence that their function is indeed controlled by the impact the environment has on them.

Many modern individuals have all kinds of knowledge regarding health, yet few have applied their learning into practice. Scientific studies often attempt to identify the single factor determining the expected result. Even so, the theories studied and expert recommendations received remain only informed guesses until the reader tests what the effects are on themselves as individuals. Thus, a theory may lead to a personal experience that has real practical significance.

There is no silver bullet for better well-being. In terms of developing health and well-being, the desired holistic change can only be achieved by implementing several methods simultaneously. The compound effect indicates that $1+1=3$. In other words, holistic well-being is not the result of a single food item, dietary supplement or drug. The most significant improvement in one’s well-being can be achieved as the result of interaction between several methods. This concept of the whole being more than the sum of its parts is called emergence. For example, instead of reaching for sleeping pills, one might choose to optimize his or her nutrition, exercise regime, and other environmental factors

The pitfall of holism lies in what is called Occam's razor – for the purposes of practical implementation, theories should be as simple as possible with a reduced number of explaining factors. According to the principle of Occam's razor, out of competing theories the simplest one should be selected.

Another problem with holism is that it is difficult to navigate the terrain of complex causal relationships involving several factors in an indisputable manner. This endless exploration of the self can indeed be thought of as the final frontier or the origo that may not ever be fully captured despite efforts.

The subject matter of this book – health and well-being – presents a paradox. Due to the limited human capacity for understanding, we may never know the secret to holistic well-being or eternal life. However, with calculated guesses, comprehensive experimentation and sheer luck we may achieve exceptionally good results.

At the core of biohacking is the concept that increasing health is cheaper and more profitable than treating illness. This is also known as preventive health care. This approach taps into the knowledge of scientists and theorists as well as practical implementers. The goal is to systematically identify what brings the best results for yourself as an individual.

Indeed, biohacking places the individual at the focus of health and wellness sciences.

BIOHACKING INVOLVES SYSTEMS THINKING

A human being is an entity that consists of various systems. The goal of biohacking is to understand how these systems work. Biohacking might be compared to cybernetics (Greek *kybernetike*, "the art of navigation") which involves the study of automatic control systems. To understand the cybernetic system, it is important to grasp the concepts of input, process, output and feedback.

Biological organisms feature autoregulation mechanisms through which the organism strives for equilibrium, or homeostasis. The human organ systems involve various negative and positive feedback systems that regulate, for example, the optimal balance of many hormones in the body:

- An example of a negative feedback system is the HPA axis located between the brain and the adrenal glands that regulates body stress. Once the adrenal gland has produced plenty of cortisol (a stress hormone), a negative feedback is produced in the pituitary gland and hypothalamus that in turn reduces cortisol production.

- Similarly, in a positive feedback system a stimulus amplifies the following end result. A blood clotting is an example of this. An activated blood platelet releases chemicals that activate other platelets until the clotting action at the site of injury is sufficient to stop the bleeding.

A human being functions best while in a harmonious relationship with his or her environment. Through systems thinking, we can grasp just how dependent human beings are on various environmental factors. At their core, human beings are not mechanistic. A wide-ranging relationship with the environment is a prerequisite for a good life.

An example of this might be that a human being feels well when he or she has a balanced relationship with the bacteria, viruses and other micro-organisms that live in or on the intestine, mucous membranes and skin. A comparison could be drawn to a plant which has diverse interactions via its roots with the microbes and nutrients in the soil. In both cases, imbalance may lead to illness.

The optimization of physiological health involves balancing both the lower levels of the system (such as nutrition, mitochondria and microbiome) as well as the higher levels (such as social relations and the environment). In the spirit of the

Pareto principle, systems thinking can be used to identify the 20 % of the input that produces 80 % of the results.

SELF MEASURING INCREASES SELF-KNOWLEDGE

In 2007, editor Kevin Kelly and journalist Gary Wolf of the American technology magazine *Wired* created the concept, movement and phenomenon called the Quantified Self (QS). The frontmen of *Wired* organized the first meeting in Silicon Valley in 2008 for those interested in the topic. In the summer of 2009, *Wired* ran a cover story called “Know Thyself: Tracking Every Facet of Life, from Sleep to Mood to Pain, 24/7/365”. The *Wired* journalists started a website associated with the phenomenon which they named the Quantified Self. Their slogan defined it as “Self-knowledge through numbers”.

These days, self-measuring is a part of the mainstream culture. In the past decade, the market has been flooded with various activity trackers and measuring devices. Many smartphones also feature different types of sensors and measuring applications that produce data on movement, calorie expenditure and sleep. Various measuring techniques may also be utilized for the purpose of tracking working hours.

This phenomenon has also been studied in the authors' home country of Finland. University of Helsinki researchers Minna Ruckenstein and Mika Pantzar identified the following features of the Quantified Self movement:*

- Self-measuring is not a new phenomenon – for example, Norbert Wiener, the father of cybernetics, studied the human body as a system that produces and receives information in the early 1900s
- Self-measuring involves self-monitoring via various sensors connected to a smartphone
- Self-measuring involves “dataism”, the concept of data being an important tool in self-development
- Self-measuring highlights the visualization of data and the perception of causal relationships
- Feedback loops created by monitoring devices may help change behavior
- Transparency and sociability are emphasized in data collection and sharing
- The goal of measuring may not be optimization – it can be a way to ask oneself new questions
- Data collection and visualization may also be a means for self expression

The focus is on the individual who is both the subject and object of measuring (n=1). The main method besides data collection is data analysis and comparison with other factors. Self-measuring produces data which is meaningless without the explaining context. The numbers are visualized and may be edited for easy comparison with data produced by other people. Collective data collected on individuals can also be called “Big Data”.

Self-measuring has reached historically new areas:

- Studying gene mutations and utilizing these results for health and well-being
- Comprehensive laboratory tests and using these results to optimize nutrition
- The gamification of self-measuring, thus increasing the meaningfulness and the rewarding nature of self-measuring
- Studying the microbiome and using this information to affect the microbial strain on the mucous membranes and the intestine
- Utilizing long-distance coaching and artificial intelligence for various lifestyle recommendations

*Source: Ruckenstein, M. & Pantzar, M. (2015). Beyond the Quantified Self: Thematic exploration of a dataistic paradigm. *New Media and Society* epub ahead of print.

The potential pitfall of self-measuring is that measuring and data collection may become the goal in itself. Therefore, the information collected may not necessarily change the individual's life for the better – it may even worsen neuroses and concerns and bring forth unpleasant results. Measuring may also become addictive.

Biohacking does not equal or require self-measuring. Biohacking involves perceiving the human being as a whole and implementing change to its entire system. Self-measuring on one hand may provide a means for setting hypotheses and analyzing personal test results. Biohacking is a much wider concept than self-measuring. In an ideal situation, measuring becomes redundant as the individual is able to decipher the signals produced by their body and change their behavioral patterns accordingly. However, due to its feedback loops, self-measuring may accelerate learning.

AUTHORS



OLLI SOVIJÄRVI, M.D.

Dr Olli Sovijärvi is one of the pioneers of holistic medicine in Finland. At the beginning of his career Dr Sovijärvi worked as a medical duty officer at the Finnish Red Cross Blood Service. In 2006 he graduated from the University of Helsinki with a Licentiate degree in Medicine and became self-employed in 2008. In 2010–2011 Dr Sovijärvi completed an Integral Theory degree at the John F. Kennedy University, focusing on psychology and philosophy.



For the first five years of his career as a physician Dr Sovijärvi was employed by Finland's first medical recruitment agency. The job description involved scheduled patient care as well as emergency care and being on call. He has worked at nearly 50 different clinics around Finland.

His numerous media appearances, social media articles and Finland's first health podcast have expanded the general public's awareness of what health care can be. Dr Sovijärvi has also acted as consultant to various companies and service providers operating in the fields of wellness and health technology.

Between 2013–18 Dr Sovijärvi practiced medicine at a private clinic that specializes in nutrition and holistic health care. The clinic employs physicians and nurses practicing holistic medicine. The clinic features the only trace element laboratory in Finland. At present, Sovijärvi focuses primarily on the production of scientific content for preventive health care and wellbeing. He also runs training sessions and presentations on the topics of biohacking, performance optimization, nutritional issues and maintaining the intestinal balance. In his free time he enjoys athletics, playing with his child, music and good humor.



TECHNOLOGY EXPERT TEEMU ARINA

Teemu Arina has a professional career of two decades as a technology entrepreneur, author and professional speaker. He is considered as one of the forefront thinkers on the digital transformation of humanity. His work focuses on studying the intersection of man and the machine in order to improve productivity, health and wellbeing.



Mr. Arina received the Leonardo Award (under the patronage of European Parliament and UNESCO) in 2015 with the theme "Humanity in Digitization". He was selected as Top 100 Most Influential People in IT in 2016 by TIVI and Speaker of the Year in 2017 by Speakersforum Finland. Mr. Arina has delivered popular keynote presentations in countries such as US, UK, China, Japan, the Netherlands, Italy, Spain, Russia and Germany.

Mr. Arina has advised senior top management, consulted government organisations, lectured in universities, built startup businesses and acted as the chairperson for projects funded by the European Union. In his free time he enjoys photography, videography, foraging and culinary arts.



NUTRITION EXPERT JAAKKO HALMETOJA

Jaakko Halmetoja is a nutrition expert, non-fiction writer and active lecturer. He is passionate about maintaining a state of exceptional health through nutrition and lifestyle in a way that is fun and enjoyable.

Known as a pioneer of the superfood phenomenon, popularizer of the chaga mushroom and other medicinal fungi and “chocolate alchemist”, Mr Halmetoja has introduced the general public of Finland to the health benefits and unique uses of various foods and medicinal plants through TV and radio appearances and more than 600 public lectures.



Mr Halmetoja has been running a business since he was 20 years old. He trained as a paratroop jaeger in the Finnish Defence Forces and has previously won the Finnish championship in submission wrestling. As an entrepreneur he manages cafés that specialize in producing super-healthy delicacies. More recently Mr Halmetoja has acted as an advisor to several growth companies operating in the health sector, in Finland as well as internationally. Jaakko spends his free time in the garden or outdoors getting exercise – with a smile on his face.

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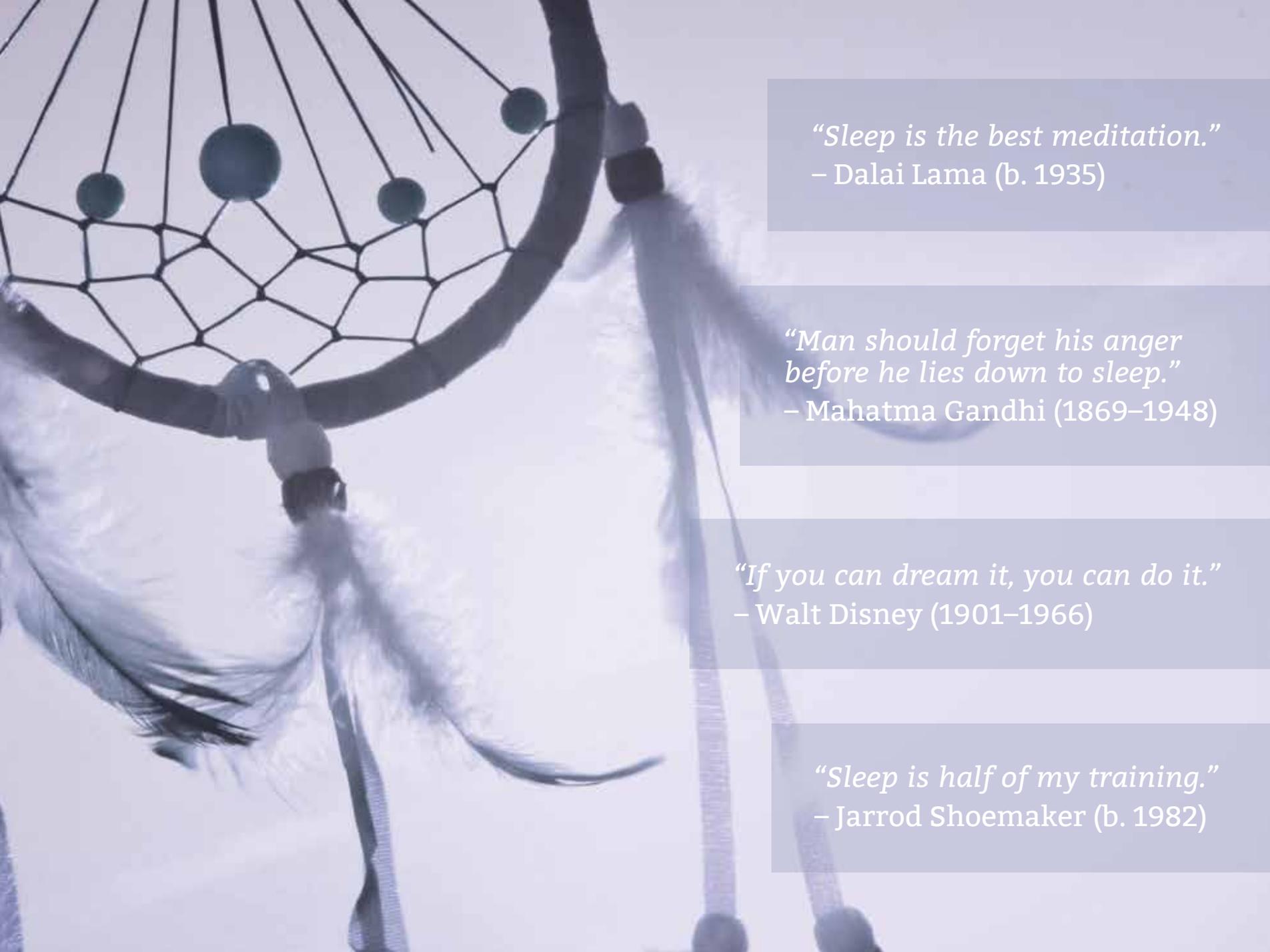
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01
SLEEP



“Sleep is the best meditation.”
– Dalai Lama (b. 1935)

*“Man should forget his anger
before he lies down to sleep.”*
– Mahatma Gandhi (1869–1948)

“If you can dream it, you can do it.”
– Walt Disney (1901–1966)

“Sleep is half of my training.”
– Jarrod Shoemaker (b. 1982)

“I’LL READ JUST ONE MORE ARTICLE...”

John is a modern-day knowledge worker who, despite the fact that it is already late, decides to browse through just one more article before going to sleep. Some vital emails are also awaiting his response. On top of it all, tomorrow’s presentation is still not ready. The rainy Thursday night is destined to be long, like many previous nights. Although his eyes feel heavy, push on he must.

Despite John’s mounting tiredness, the presentation gets finished. It is 3 o’clock at night already. John shuts down his computer and goes to bed, even though plenty of work remains. He has difficulty going to sleep, although the alarm is set to ring in 4 hours and 30 minutes. He is dead tired. Anxiety lurks as thoughts about tomorrow’s presentation wander through his mind. The sound of cars passing beneath the window disturbs his rest. John stares at the blue light emanating from the wireless router. His eyes are red and squinted. He wastes another hour twisting and turning in bed, until sleep finally descends upon him.

In the morning, the noise of the alarm pierces his dormant mind. In confusion, John rolls around in bed for another 10 minutes. He doesn’t feel like waking up, although he absolutely must. He only has 45 minutes to get out of the

apartment. His thoughts are fuzzy and unfocused, and his willpower is gone. In stress, he charges out of the bed. He doesn’t have time to prepare breakfast or eat anything. Driving out of his garage, he almost collides with another car. Close call.

“I must get a cup of coffee.” At the conference cafeteria, face flushing red he quickly downs a cup of coffee, followed by another, waiting for the conference to start. After a while it is his turn to take the stage. John’s presentation doesn’t go exactly as he envisioned: He is mixing up with his words, slides appear to have spelling mistakes and arguments seem disintegrated and clumsy. Final judgement from the audience: lukewarm applause. “Well, that wasn’t exactly my best performance”.

At lunchtime, he gobbles down more food than usual. After the meal he visits the restroom. His stomach is acting up and his chest hurts, too. “What a nighmarish day!” he mumbles. He feels like going straight back to bed, to make up for those lost hours of sleep, but his various afternoon meetings are right around the corner. “Ugh... At least it’s Friday.”

OWL – THE KING OF THE NIGHT

"When the owl sings, the night is silent."

– Charles de Leusse (b. 1976)

The archetype of sleep is naturally the owl – the quiet observer of night-time and dusk. The owl is known for its sharp night vision and nearly silent flight. Owls also have a very keen sense of hearing thanks to their large ear openings and the feathers that bounce sound waves.

In ancient times it was believed that eating owl eyes improved night vision. The owl appears in folklore as the symbol of wisdom. In Ancient Greece, the owl was the symbol of Athena, the goddess of wisdom.

In the dream world, the owl is also considered the symbol of insight, magic and expanded consciousness.



WHY SLEEP MATTERS

John's case underlines the importance of a good night's sleep for performance, cognitive functioning and health. Using appropriate strategies, John could have fallen asleep earlier, improved the quality of his sleep, and faced the challenges of the day with ease. John was already tired to begin with and the night stretched even longer due to decreased productivity. With sufficient sleep behind him, he would have achieved better results in a shorter time frame. The presentation, too, would have been of higher quality and delivered with fewer mistakes.

There is plenty of evidence that sleep is important. We can all recognize its value in our personal lives. Sleep is an anabolic state during which the body replenishes its energy storages, regenerates tissues and produces proteins. Without enough sleep, the human body cannot function properly.

Staying up late releases cortisol, which is known to increase the production of cell signalling molecules like cytokines, which are a sign of inflammation. Sleep deprivation causes unhealthy changes in the immune system of the body, including white blood cells. The common marker of inflammation, C-reactive protein (CRP), may also increase.¹

DID YOU KNOW

48 % OF AMERICANS REPORT
INSOMNIA OCCASIONALLY, WHILE
22 % EXPERIENCE INSOMNIA EVERY
OR ALMOST EVERY NIGHT.

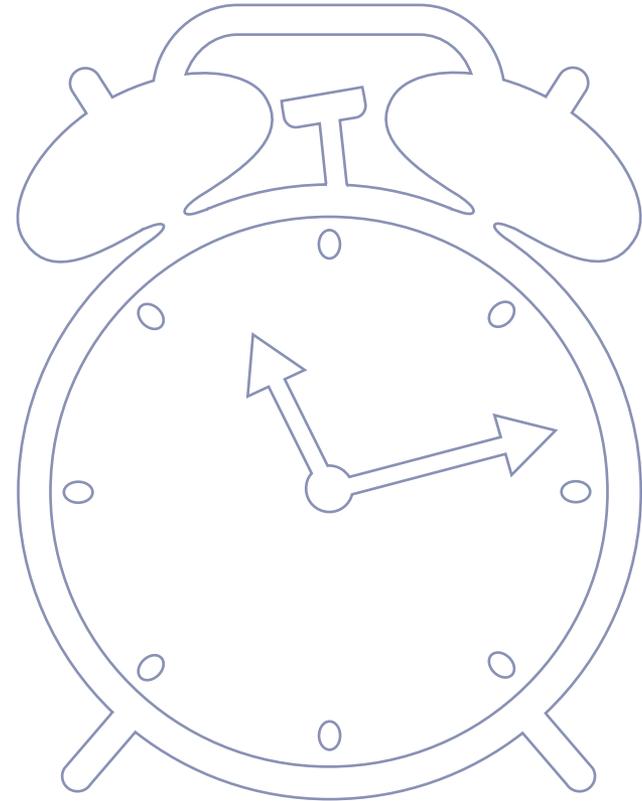
SOURCE: NATION SLEEP FOUNDATION

Sleep deprivation has been shown to raise systolic blood pressure and increase the consumption of fat-heavy and sugar-heavy foods. Chronic sleep deprivation leads to insulin resistance, even with young test subjects. Lack of sleep has been shown to be a predictor of weight gain,² and increases the risk of traffic accidents,³ the diagnosis of type 2 diabetes,^{4,5} mental illnesses such as depression,⁶ seasonal flu⁷ and cardiovascular diseases.^{8,9}

Sleeping problems have increased in conjunction with sitting and the increased usage of electronic devices. According to a 2011 study by National Sleep Foundation, 63 % of Americans say they do not sleep enough during the week. About 15 % of adults between 19 and 64 say they sleep less than six hours on weeknights. 95 % use some type of electronics like a television, computer, video game or cell phone at least a few nights a week within the hour before bed. Artificial light exposure can disrupt sleep by suppressing release of the sleep-promoting hormone melatonin.¹⁰

From the biohacker's perspective a sufficient and good sleep at night contributes to better performance, awareness, mood, ability to handle stress, skin quality,¹¹ sports performance, the capacity to learn new things, and the ability to maintain general wellbeing. The aim of the biohacker is to reserve as much time as possible for important things, while simultaneously making sure that sleep is not compromised. This ensures that recovery becomes possible and that new learnings can be integrated and assimilated.

It is common wisdom that adults should get at least 7 to 8 hours of sleep every night. A systemic review conducted at the University of Warwick observed that the risk of mortality amongst people who got 6 hours or less of sleep per night increased by 12 %, but also the risk of mortality amongst those who slept for nine hours or more increased by as much as 30 %.¹² However, sleeping ten hours is beneficial for those with increased need for sleep, for example for recovering athletes, chronically stressed individuals and growing children. The studies also show that there are some people – i.e. those who carry a variation of the DEC2 gene – who can survive with two hours less sleep on average than other people. What is then enough? How can we make sure we get enough quality sleep without sacrificing any of the vital tasks that we want to get done every day?



SLEEP STAGES – THE SECRET TO BETTER SLEEP

Sleep alternates between two phases: orthodox sleep and REM sleep. These phases can be distinguished from one another in EEG (electroencephalography). The majority of sleep is orthodox sleep (deep sleep, quiet sleep, slow-wave sleep) that can be further divided into three NREM (non-rapid eye movement) stages: N1, N2 and N3. These are in contrast to REM sleep, or R sleep (paradoxical sleep, rapid eye movement sleep).¹³

W – Wakefulness (beta waves): infrequent and low-frequency beta waves predominate in the EEG.

Meditative state with one's eyes closed: increasingly synchronised alpha and theta waves are visible in EEG, along with increased production of serotonin. A number of proven health benefits have been observed while using techniques such as meditation to increase one's alpha and theta waves.^{14 15 16}

N1 | **N1 – The first stage (theta waves, 4–8 Hz):** EEG shows irregular oscillations. Theta waves are slower and higher in frequency than alpha waves. This is a transitory phase from wakefulness to light sleep. The sleeper changes position

frequently, and is in a deep meditative state. However, if someone were to wake the person up, he or she might not feel like they had fallen asleep. Duration: about 10 minutes.

N2 – The second stage (sleep spindles, 11–16 Hz):

A period of light sleep, during which there is little movement and the breathing is quiet. The second stage involves periodic surges in brain wave frequency, the so-called sleep spindles. Brain activity during the second stage is more active than in the first stage. Dreaming becomes possible. Getting enough stage two sleep improves motor skills.¹⁷ The person can still be easily woken up during this stage. Duration: 20 to 30 minutes.

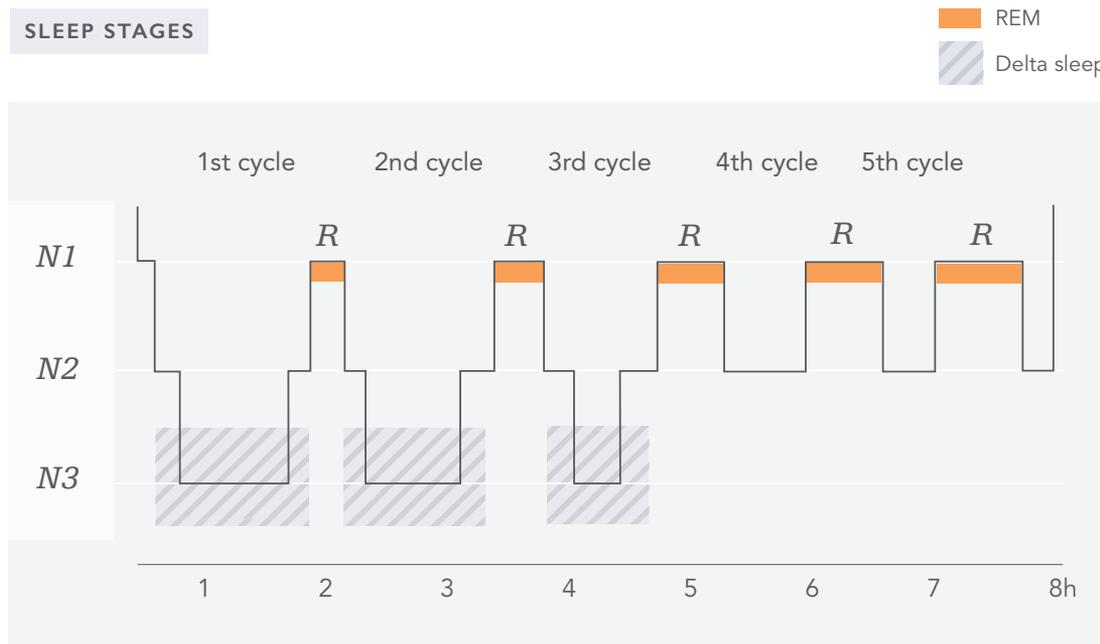
N3 – The third stage (delta waves, 0–8 Hz): A period of deep sleep, where breathing is stable and EEG readings consist of slow delta waves. Muscles are completely relaxed, and the pulse, body temperature and blood pressure have decreased. Production of human growth hormone begins, and the regenerative mechanisms of the body are activated. The sleeper will not wake if another person walks into the room. Pulse, blood pressure and body temperature are at their lowest. Duration: 30 to 40 minutes. Elderly people experience a shorter duration, by as much as six minutes.

N2

N3

R – REM Sleep (alpha and beta waves): During REM sleep, the brain is awake, but the rest of the body is asleep. The muscles in the neck and the body are paralysed to prevent sleepwalking. During REM, the eyes are moving under the eyelids, and dreaming is at its peak. The typical adult has an average of 4 to 5 REM stages every night. The first stage lasts about 10 minutes, while subsequent stages are often

longer, around 30 minutes. REM sleep is important for the regeneration of the brain's nerve cells.¹⁸ Tests measuring the effects of sleep deprivation have shown that REM sleep is absolutely indispensable as deprivation leads to irritability, fatigue, memory loss and reduced capacity for concentration. Infants experience a lot of REM sleep: On average 50 % of the total 16 hours of sleep per night is REM sleep.¹⁹

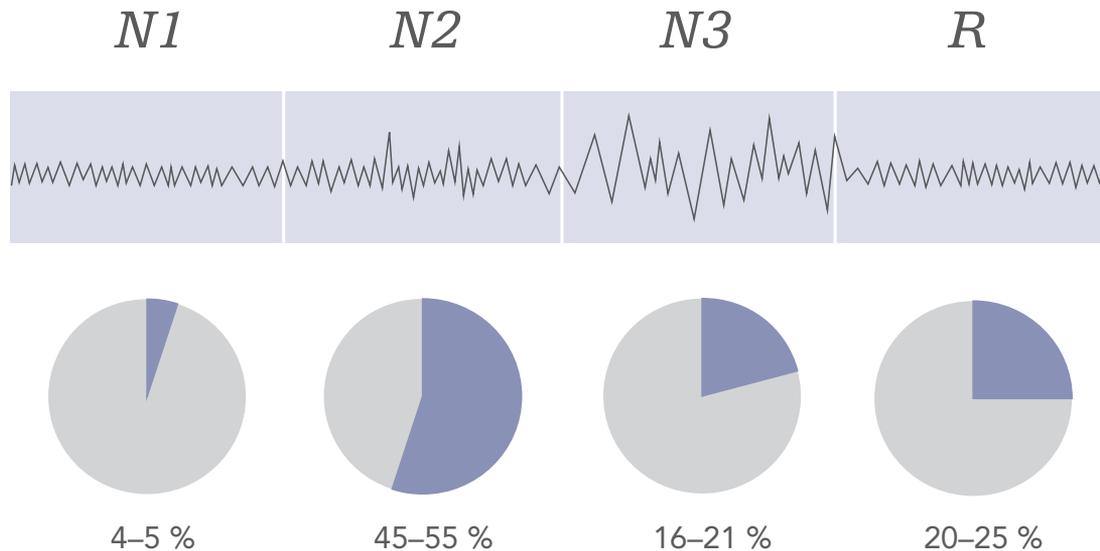


SLEEP

During a typical adult's 7 to 8 hour sleep, the sleeper moves from the first stage, to the second, and to the third stage, then back again to the second stage. After this, the sleeper either wakes up or goes straight to REM sleep. From then on, the cycle repeats itself some 4–5 times.

One full cycle lasts about 90 minutes. From the perspective of getting a good night's sleep, it is paramount to maximise the amount of deep sleep (N3) by going through at least three cycles. Getting enough sleep reorganises one's memory²⁰ and improves one's learning capacity.²¹ In the later cycles, the amount of REM increases and the amount of deep delta sleep decreases, until eventually the latter disappears completely.

DIFFERENT STAGES OF A SLEEP CYCLE AS SEEN ON EEG



CIRCADIAN RHYTHM FOR MAINTAINING ENERGY LEVELS AND IMPROVING SLEEP

Circadian rhythms are biological processes linked to the cycles of the day. Many bodily functions vary according to these rhythms, including the following:

- **Body temperature**
- **Pulse rate and blood pressure**
- **Reaction time and performance**
- **The production of melatonin, serotonin and cortisol**
- **Intestinal activity**

Travellers who make frequent long-distance flights often have direct experience in the importance of getting acclimated to a new time zone. One's inability to adjust can lead to sleeping problems and disturbances in cognitive functions. People who do shift work, or work under bright lights, can face similar issues. Problems arise whenever the daily rhythm is disturbed.

Human beings have an internal clock that lasts about 25 hours and resets itself daily when it is exposed to daylight.²² Blind people can thus have sleeping problems, and yet, even without the ability to see sunlight, their bodies function mostly just fine.²³

Light clearly has a central role in the regulation of our daily lives, and can be used to reset our circadian rhythms.

Luminosity should reach at least 1000 lux in intensity to have such an effect – compare this to the 320–500 lux in a typical office and the 32,000 to 130,000 lux in direct sunlight.

Light directly affects the production of melatonin, the so-called “hormone of darkness”, which is secreted mostly by the pineal gland during the hours of darkness. Melatonin plays a crucial role in the regulation of the sleep–wake cycle.²⁴

A newborn baby does not produce melatonin until it is three months old. From then on, the production increases towards adolescence, and finally settles down in adulthood. In a mid-aged person, the production of melatonin starts to decrease again. It is suspected that this is one of the reasons why older people do not usually get as much sleep as younger people.²⁵

The intensity of light isn't the only factor in melatonin production; its wavelength also has an effect. During daylight, blue light (short wavelength, around 420–485 nm) dominates, which blocks melatonin production. Research shows that white LED lighting is five times more efficient at blocking the production of melatonin than incandescent light bulbs.²⁶

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In order to optimize sleep, it is important to understand how other hormones influence circadian rhythms. High levels of dopamine and serotonin have been linked to the feeling of alertness, and adversely low levels to sleepiness. Cortisol, known as “the stress hormone,” contributes to sudden wakefulness in the middle of the night. Its production is especially active for the first 30 minutes or so after waking up.

