Olli Sovijärvi / Teemu Arina / Jaakko Halmetoja

BIOHACKER'S HANDBOOK

UPGRADE YOURSELF AND UNLEASH YOUR INNER POTENTIAL



Prepared exclusively for paolofabbri69@gmail.com Transaction: 6336

Biohacker's Handbook
Upgrade yourself and unleash your inner potential
1st edition

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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

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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.

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- 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.

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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.

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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.

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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.

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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.

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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.

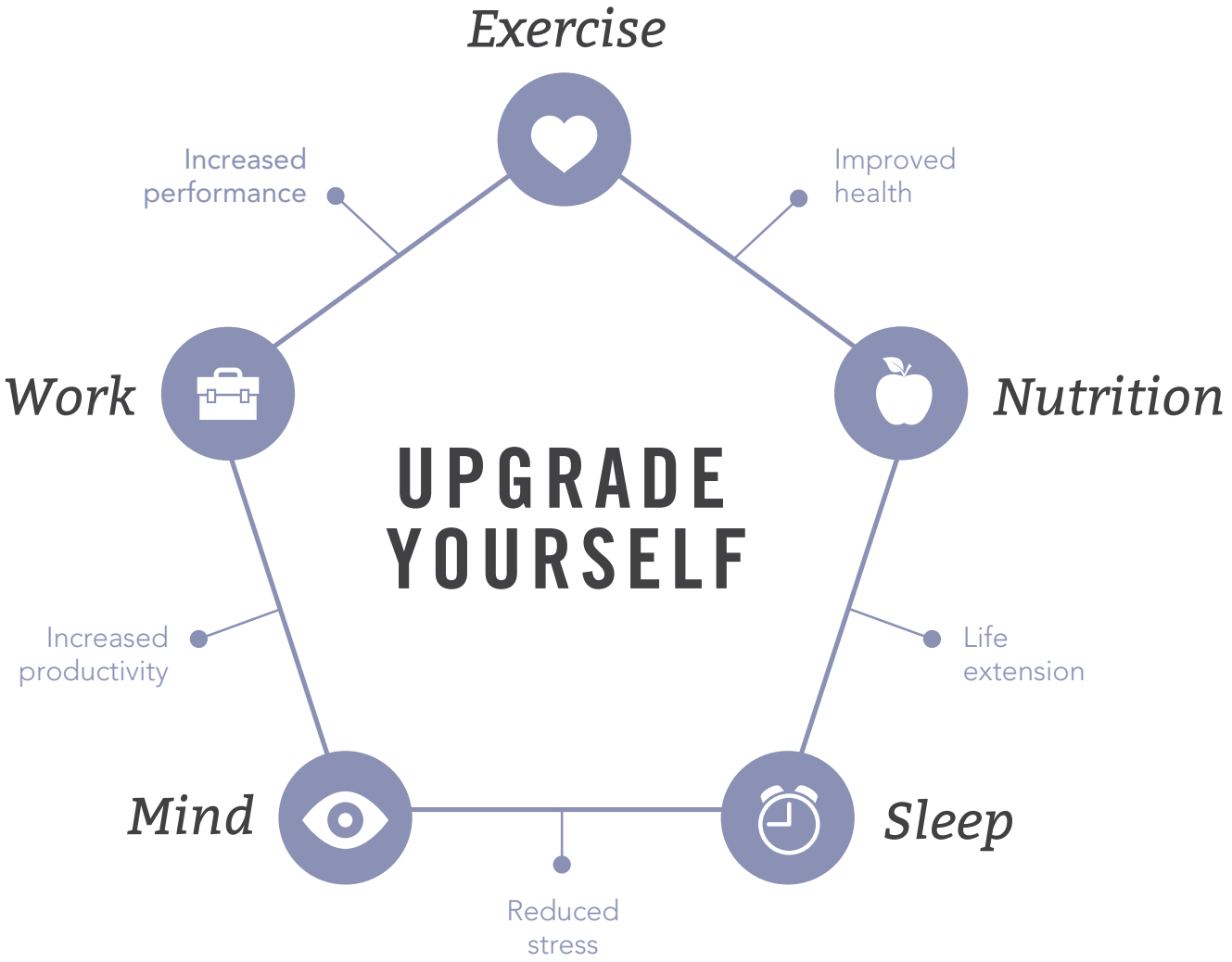
Mr Halmetoja has been running a business since he was 20 years old. He trained as a paratroop jaeger in the Finnish Defence Forces and has previously won the Finnish championship in submission wrestling. As an entrepreneur he manages cafés that specialize in producing super-healthy delicacies. More recently 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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Advisor and studio critic: **DR. SAM INKINEN**

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01 SLEEP

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"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)

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"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."

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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.



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WHY SLEEP MATTERS

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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.

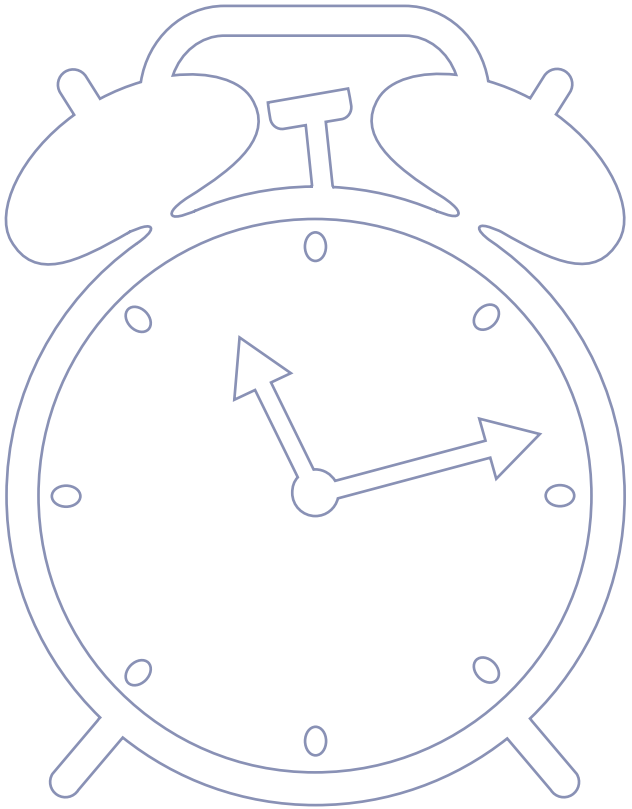
SOURCE: NATION SLEEP FOUNDATION

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 flu[7] 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]

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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?

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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

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

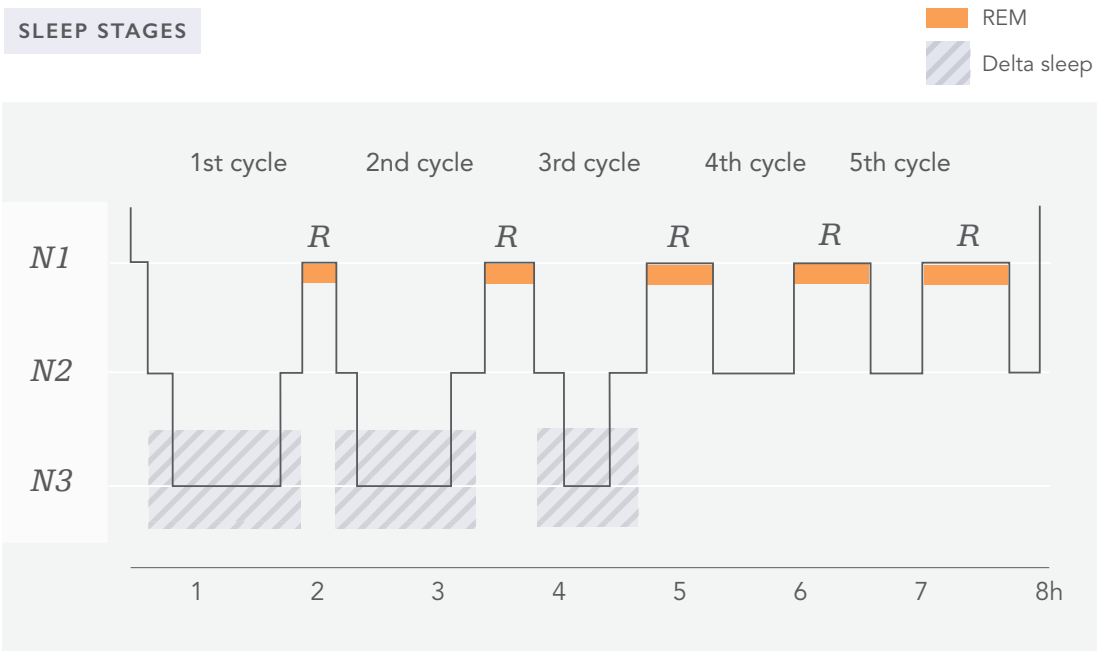
N3 – The third stage (delta waves, 0–8 Hz): A period of deep sleep, where breathing is stable and EEG readings consist of slow delta waves. Muscles are completely relaxed, and the pulse, body temperature and blood pressure have decreased. Production of human growth hormone begins, and the regenerative 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.

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R

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 STAGES

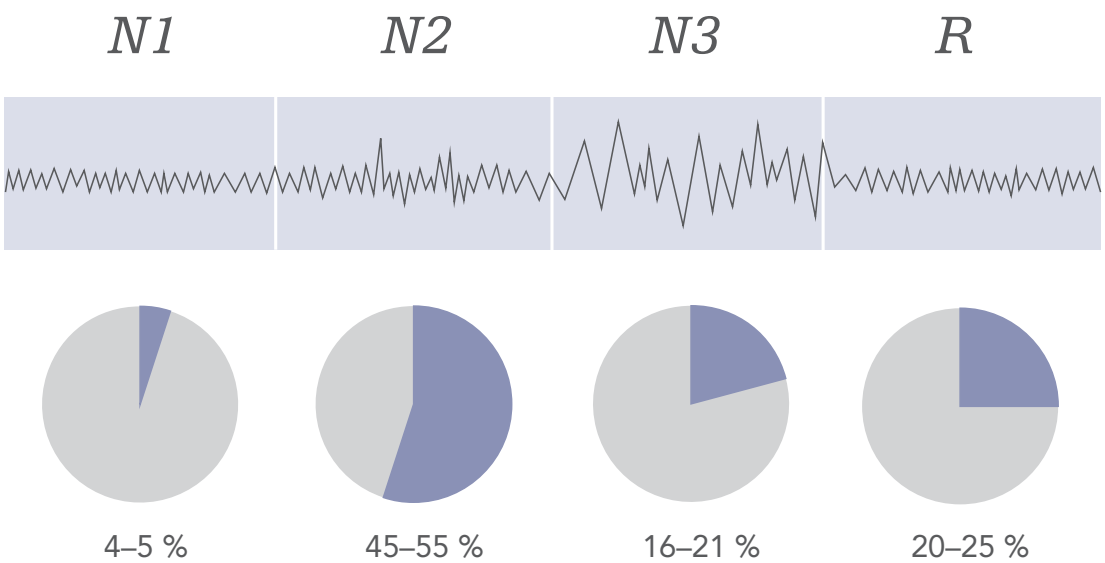


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During a typical adult's 7 to 8 hour sleep, the sleeper moves from the first stage, to the second, and to the third stage, then back again to the second stage. After this, the sleeper either wakes up or goes straight to REM sleep. From then on, the 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 memory[20] 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



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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]

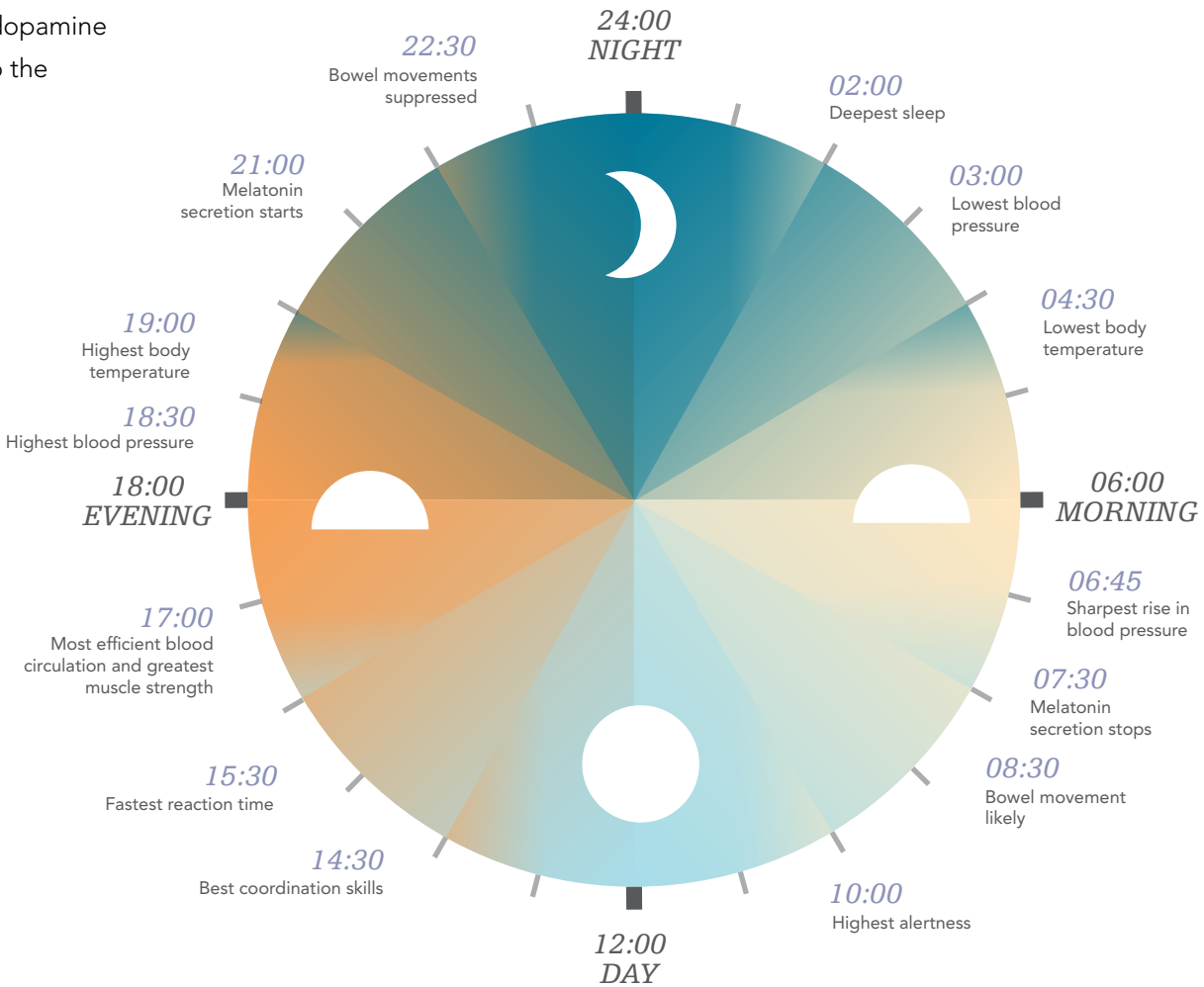
A newborn baby does not produce melatonin until it is three months old. From then on, the production increases towards adolescence, and finally settles down in adulthood. In a mid-aged person, the production of melatonin starts to decrease again. It is suspected that this is one of the reasons why older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

CIRCADIAN RHYTHM[27]



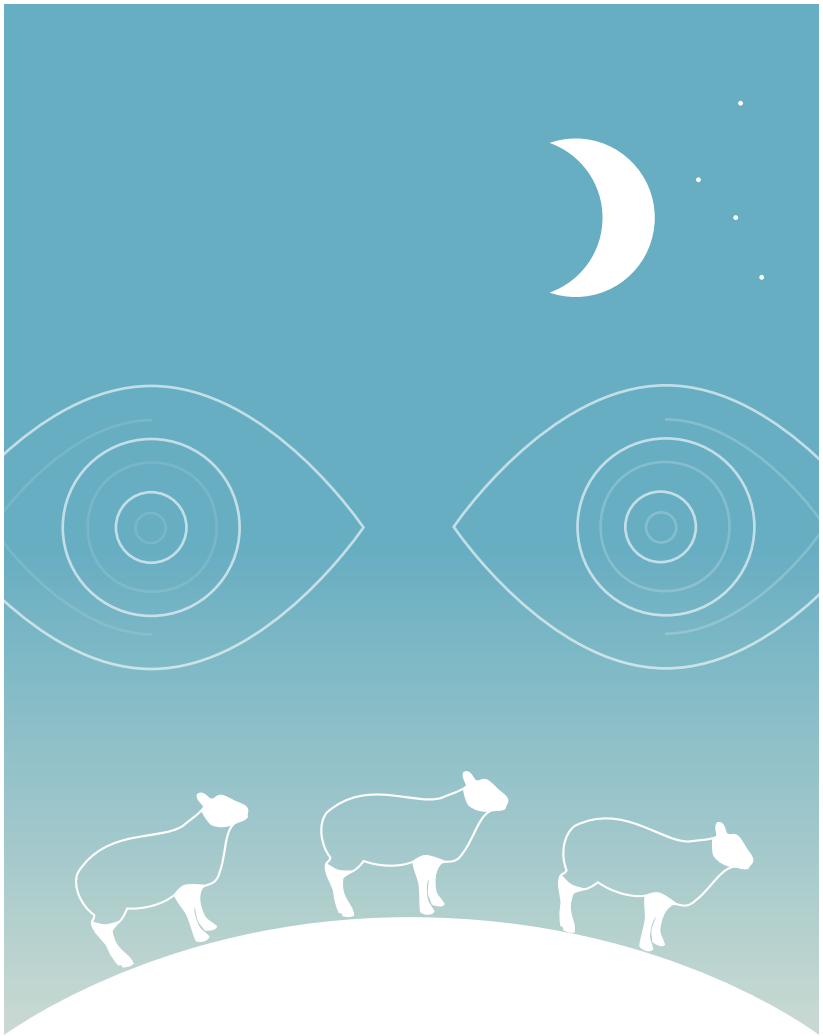
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TOOLS FOR UPGRADING SLEEP

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People who experience sleeping difficulties may first turn to prescription sleeping pills. Sleeping pills are a $1.6 billion industry in the United States alone.[28] The use of sleeping pills, however, carries a range of risks. These include dependency and withdrawal symptoms – such as sleeplessness, tiredness and memory problems – undesirable brain changes, and many others. The drug Halcion, for example, which was withdrawn from the UK market in 1993 but is still available in most other countries, despite it causing depression and memory loss.[29] In other words, the harm caused by sleep medication may outweigh its benefits.

Let's start from the basics. There are various proven methods backed by research that can be tested before relying on sleeping pills that often surpass natural mechanisms in the body and may cause more harm than good.



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SETTING UP YOUR BEDROOM



DARKENING THE ROOM AND OPTIMAL LIGHTING

Sunlight, moonlight and LEDs on electronics can disturb sleep. Instead, try:

- Using blackout curtains
- Darkening the LEDs of your electronic devices with black adhesive tape
- Switching lamps to brands that do not emit the blue spectrum of light
  - Special lamps that change the spectrum of light according to the cycle of the day
  - Dim salt lamps

BED QUALITY AND ERGONOMICS

Bed materials that do not breathe may induce allergies, and beds which are unergonomic may disturb your sleep. Instead, try:

- A mattress or futon made of organic cotton, wool, hemp or natural rubber (instead of being covered with polyurethane foam and chemicals that are potentially allergenic)
- Oat, cherry, spelt or buckwheat pillows





- Choosing materials for your sheets and blankets that promote better thermo-regulation (organic cotton, leather, silk, etc.)
- Sleeping without clothes (so that the rubber bands on the waist cannot block your lymphatic system)
- Sleeping without a pillow
- Using a pillow that supports the neck
- Having a pillow between your legs (when sleeping on your side)
- Sleeping on your back or right side. Other positions put stress on your internal organs. If you suffer from heartburn, sleeping on left side or on your back is a better option.
  - Use a heavy comforter and bed sheets if you have a tendency to change positions frequently during the night
  - Sleeping on your stomach is not recommended to anybody (except to those suffering from spinal disc herniation)
  - Sleeping on your back is not recommended if you suffer from sleep apnea due to the risk of respiratory arrest

ELECTROMAGNETIC POLLUTION

Some people may experience sensitivity to electromagnetic radiation. Dozens of studies have been conducted on electromagnetic hypersensitivity (EHS), but its existence has not been successfully verified. Some studies suggest that "grounding" can alleviate insomnia.[30]

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Instead, try:

- Using a grounding mat
- Placing WLAN routers and mobile phones at a distance, and switching mobile devices to flight mode. Please note, however, that a 20-minute call will emmit more radiation than a WLAN base station per year.
- Walking barefooted during the day, or using grounding (earthing) shoes
- Scanning the radiation levels in the bedroom (with EMF and EMC detectors)



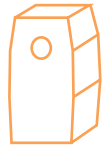
AIR QUALITY

Research shows that poor indoor air quality affects respiratory organs and can thereby cause sleeping problems.[31] Instead, try:

- Ventilating the bedroom during the day
- Excluding the possibility of mold (DIY measuring kits or measurements done by professionals)
- The use of house plants to increase humidity, turn carbon dioxide into oxygen, and release negative ions into the air (for example, golden cane palm (*Dypsis lutescens*), snake plant (*Sansevieria trifasciata*) and devil's ivy (*Epipremnum aureaum*)[32]



- Ventilating the bedroom properly at night, but avoid a direct draft near the head
- Air filtering (UV, HEPA, carbon filtering, photocatalytic oxidation, air ionizer)
- Adjusting humidity with technical tools. Most people prefer 30–50 % humidity.



- Having a house that ventilates properly and choosing appropriate indoor materials: natural construction methods, eco paints and finishing materials
- Using specific incenses and relaxing essential oils (ylang ylang, vanilla, lavender) may increase sleepiness at the cost of air quality

TEMPERATURE

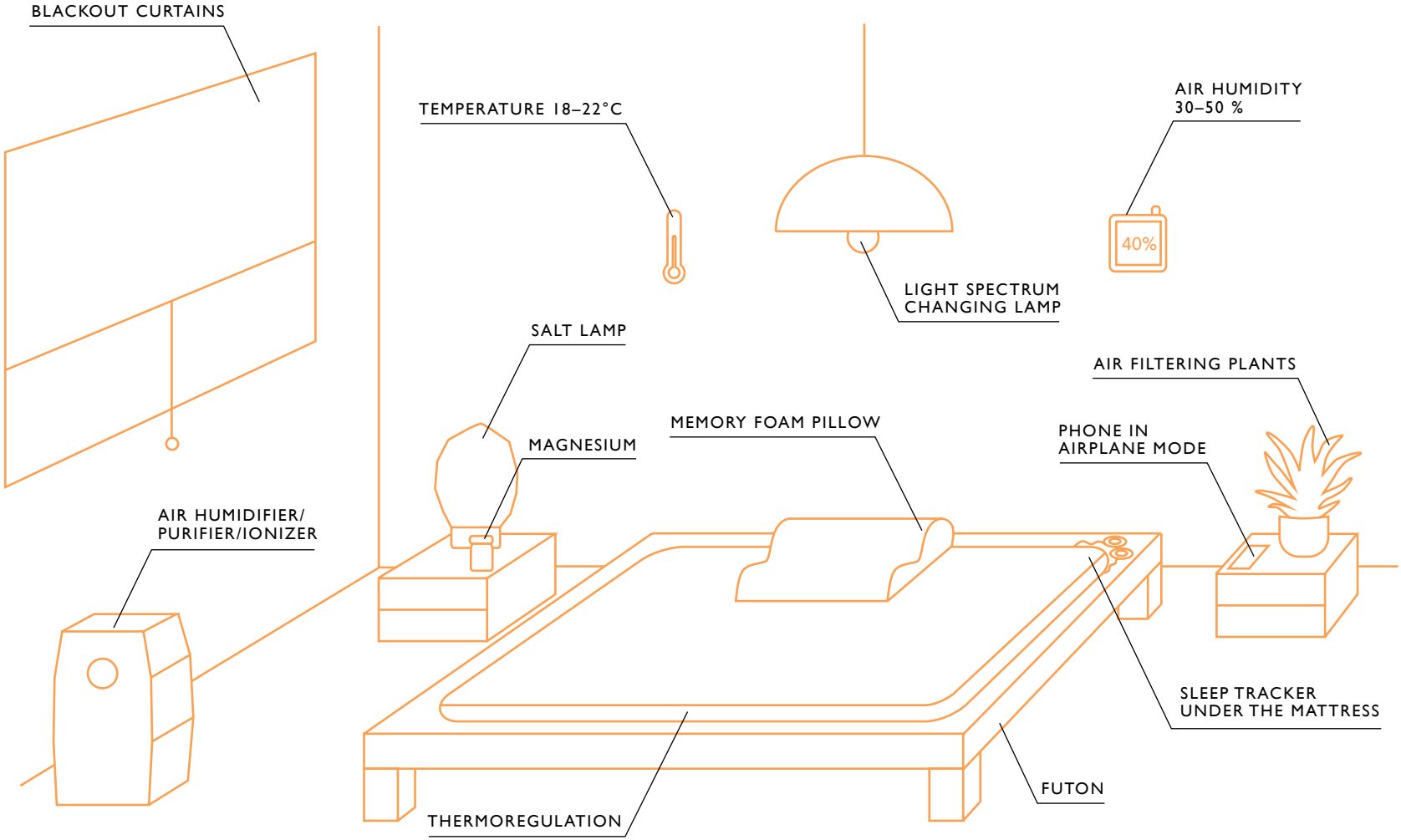
The temperature of the body drops during sleep. Sleeping in a room that is too hot, or too cold, makes it difficult to maintain optimal thermoregulation. Instead, try:



- Adjusting radiators and air conditioning
- Keeping windows open and ventilating the space properly
- The optimal temperature for most people is around 18–22 degrees Celsius (64–69 Fahrenheit)

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BIOHACKER'S BEDROOM



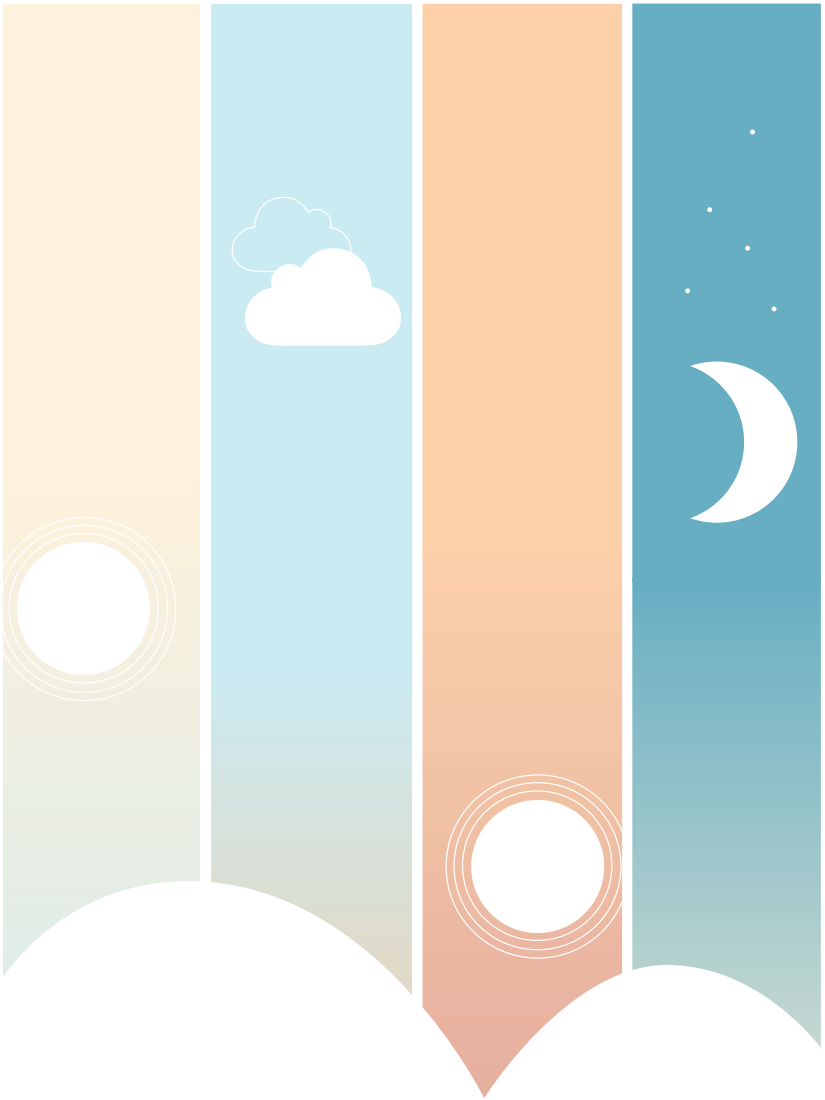
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PREPARING DURING THE DAY TO GET BETTER SLEEP AT NIGHT

GET ENOUGH BLUE SPECTRUM LIGHT

Getting enough blue spectrum light (short wavelength 450–490 nm) during the day, especially right after waking up, is an important factor in maintaining one's alertness and circadian rhythm.

- Spend time in sunlight
  - – Take a minimum 15 minute walk daily
  - – Set up your workstation next to the window
- Avoid the use of sunglasses during the day that block blue spectrum light. It may start the production of melatonin at the wrong time.
- Use a full spectrum light therapy lamp



TAKE REGULAR DAILY EXERCISE

- 20 to 30 minutes of exercise daily helps balance the daily rhythm[33] and significantly improves sleep quality[34]

GET RID OF MUSCLE TENSION

Pain in the muscles and connective tissue may cause insomnia.

- Try acupuncture, massage, sauna, yoga and stretching
- Take relaxing baths (e.g. with magnesium chloride in the bath water during evenings)

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GETTING READY FOR BEDTIME

GO TO BED BY THE CIRCADIAN RHYTHM

Going to bed and waking up at the same time every day increases the quality of sleep and decreases health risks.[35]

- Balances nocturnal body temperature
- Minimise moonlight during the night, because it can interfere with melatonin production[36]



TAKE NUTRIENTS THAT HELP WITH FALLING ASLEEP AND IMPROVING SLEEP QUALITY

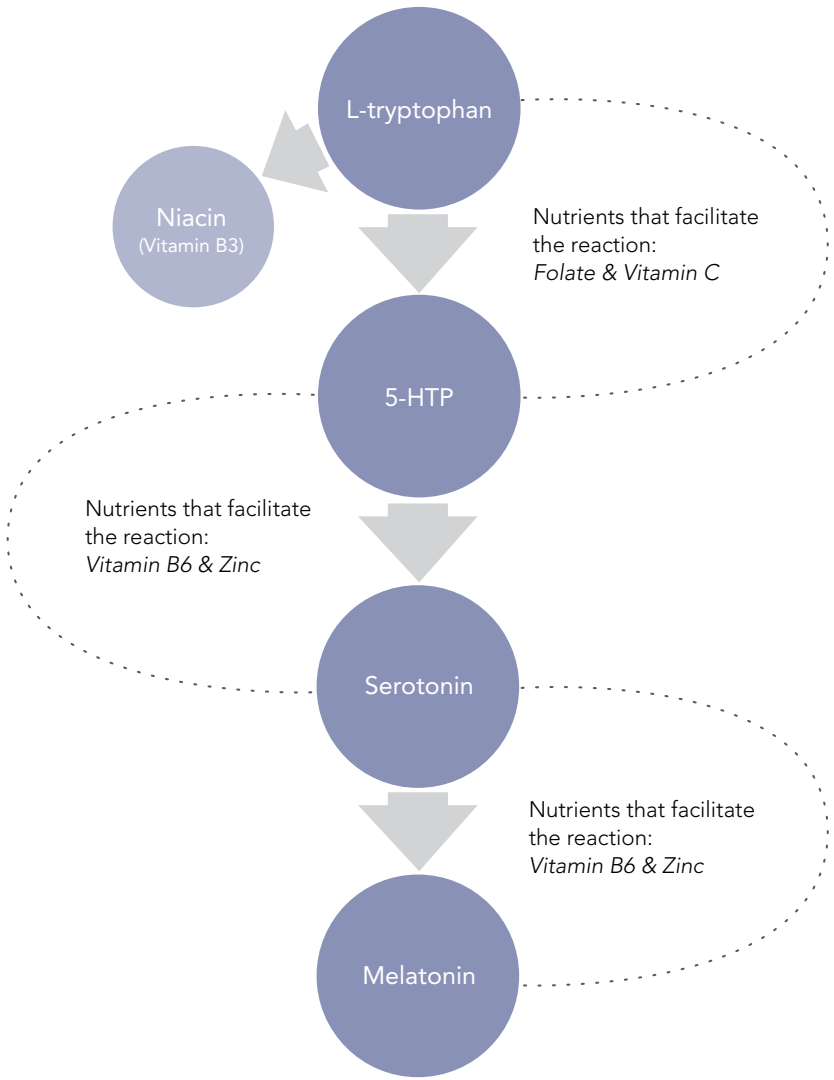
Supplements and adequate nutrients in your diet can support the body in the production of melatonin, help the body to relax, and induce brain wave patterns associated with the N1 phase.

- Magnesium citrate acts as a mild sedative that helps the body to fall asleep. It also increases the amount of deep sleep and decreases nocturnal cortisol levels.[37] [38] An appropriate dosage is 400 mg.
- Magnesium glycinate, magnesium glycerophosphate and magnesium taurate also provide amino acids that support liver functions at night. The appropriate dosage varies from 200 to 1000 mg.
- Potassium citrate, or potassium carbonate, works synergistically with magnesium. It can lower the incidence of nocturnal spasms in the limbs, and balance the quality of sleep.[39]
- Tryptophan acts as a precursor to serotonin and melatonin. Tryptophan levels can be elevated in the evening by consuming some of the following food products about 1 or 2 hours before going to bed: white and brown rice, banana (not overripe), pumpkin seeds, turkey, chicken, eggs, nuts, whole grains, brown rice, lentils, sesame seeds, sunflower seeds, white fish and avocado (not overripe). Calcium and vitamin B6 facilitate the absorption of tryptophan.
- Relaxing adaptogens: lingzhi mushsroom (reishi), holy basil and ashwagandha
- Theanine increases alpha waves and can be helpful for falling asleep.[40] Experiments with rats have shown that theanine improves the quality of sleep when coffee has been ingested during the day.[41]
- Zinc naturally raises testosterone levels.[42] Sufficient levels improve the quality of sleep.[43]

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- Taurine decreases stress and anxiety,[44] and increases the amount of the anxiety-inhibiting neurotransmitter GABA in the body.[45] An appropriate dosage is:
  - 500–1500 mg of taurine every night, 1 hour before bedtime
  - 250–500 mg of GABA, 2–3 times a day
- Supplements with a therapeutic purpose (only to be used as a last resort):
  - 100–200 mg of 5-HTP or 0.3–3 mg of melatonin an hour before going to sleep. The effect can be augmented with 50–100 mg of vitamin B6 and 15–30 mg of zinc. Their combination, ZMA (Zn+Mg+B6), is also recommended.
  - 240 mg of vitamin B6 taken before sleep can help with remembering dreams more vividly[46]
  - 500–1000 mg L-tryptophan, 1–2 times daily, preferably at night time. It is best absorbed when ingested together with carbohydrates. Folate and vitamin C help in converting it to 5-HTP.
- Take vitamin D in the morning or during the day, with fatty foods. Do not take it in the evening, since vitamin D interacts with melatonin production.[47]

FOCUS ON PRECURSORS TO SUPPORT THE PRODUCTION OF MELATONIN



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MAGNESIUM

Magnesium is one of the key minerals in more than 200 metabolic reactions. The body contains up to 20–28 grams of magnesium, one half of which is in the cells and the other half in the bones. It is estimated that 68 % of Americans suffer from magnesium deficiency of some type. Measuring the magnesium level in the blood is not sufficient to rule out possible deficiency as only 1 % of magnesium is freely available in the circulation.[48] Inadequate magnesium intake is associated with vitamin D deficiency as magnesium promotes the synthesis of vitamin D from sunlight on the skin.[49] Magnesium has significant health benefits – it prevents stress, depression and many chronic illnesses and improves the quality of sleep. Magnesium also has an important role in the energy production of muscle and cardiac muscle cells.



AVOID SUBSTANCES THAT DISTURB YOUR SLEEP

- Avoid caffeine (coffee, tea, energy drinks, guarana, maté) 5–8 hours before going to bed. You can use 1000–2000 mg of vitamin C to make caffeine leave the body quicker (Kakadu plum, camu camu, Acerola cherry, rose hip, ascorbic acid). Alternatively you can chew whole cardamom seeds (5 to 10 pieces) to destimulate the central nervous system.
- Avoid theobromine and theophylline (both found in cacao and kola nut) 6 to 10 hours before going to bed.
- Limit late-evening alcohol consumption to two doses maximum. Alcohol reduces REM sleep. Enjoy your last glass of alcohol no later than 90 minutes before going to sleep.
- Tyramine increases the production of noradrenaline, which boosts brain activity and keeps you awake. The following food products contain tyramine, so they should be avoided at dinner: bacon, cheese, chocolate, eggplant, potato, sauerkraut, sausage, spinach, tomato and wine.

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DRINK BEVERAGES THAT HELP YOU FALL ASLEEP

Some beverages will typically affect the GABA anxiety-inhibiting neuro-transmitter in the brain.[50]

- Valerian[51] 150–300 mg, at bedtime
- Chamomile[52] 500–1500 mg, at bedtime
- Passion flower 100–200 mg, 2–3 times a day
- Hops 100–200 mg, 2–3 times a day
- Kava 120–150 mg, at bedtime

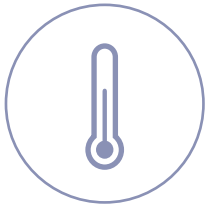


MAINTAIN ADEQUATE HYDRATION THROUGHOUT THE NIGHT

Dehydration – but also excessive water consumption – can keep you up at night.

- Drink water, especially if you've consumed common diuretics (like alcohol, coffee or tea)
- Limit your beverage consumption in the evening if you notice you often wake up at night to go to the bathroom. A good dose is 2–3 dl about 90 minutes before going to bed.
- The liver is typically at its most active between 1 a.m. and 3 a.m., and wakefulness during these hours can be a sign of dehydration
- Saw palmetto or nettle root teas might relieve prostate problems[53] [54]

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DECREASE YOUR BODY TEMPERATURE BEFORE GOING TO BED

The temperature of the body drops during the night, and the drop can be aided in a number of ways.

- Avoid exercise (= stimulation of the central nervous system and rise in body temperature) for two hours before going to bed
- Practice cold exposure in the evening (e.g. cold shower, winter swimming, or ice bath)
- Try sleeping naked



EMPTY YOUR MIND OF THE WORRIES OF THE DAY

After a long work day, or with a large workload ahead, it is especially easy to get stuck with incessant thoughts, which stimulate brain activity and prevent falling asleep.

- Use meditation to empty your mind
- Stop working an hour before going to bed
- Write down a to-do list for work tomorrow, so that unfinished business does not get stuck in your head
- Write in a gratitude journal before going to bed (e.g. three things that happened during the day that you can feel grateful for)
- Write down positive affirmations (to program your mind for the next day)

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TAKE CARE OF NIGHTLY BLOOD SUGAR LEVELS

If blood sugar levels drop during the night, it releases glucose-regulating hormones such as adrenaline, glucagon, cortisol and growth hormone. This process can wake you up. (Read more about blood sugar regulation in the Work chapter).

- Eat no later than two hours before going to bed
- Consume slowly digestible foods (such as meat) no later than four hours before bedtime. This allows the food to be digested in your system.
- Try 1 or 2 tbsp of MCT oil, or omega-3 oil, 30 to 60 minutes before bedtime
- Try 1 or 2 tbsp of collagen or whey protein
- Try a spoonful of organic honey to replenish the liver's glycogen reserves. These reserves are depleted in 12 hours.



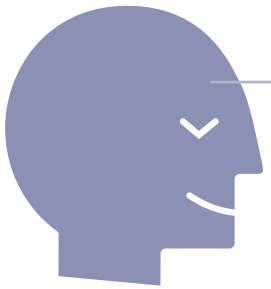
AVOID BLUE SPECTRUM LIGHT IN THE EVENING AND TRY SIMULATING SUNSET

Increasing red spectrum light and decreasing blue spectrum light kickstarts the production of melatonin.

- Avoid using the computer, mobile phone or television, for an hour before going to bed
- If you must use your computer in the evenings, filter out blue spectrum light with an appropriate computer program or a filter (a layer of film) on top of your screen
- Use special shades that filter out blue spectrum light when going to sleep or when visiting the bathroom at night

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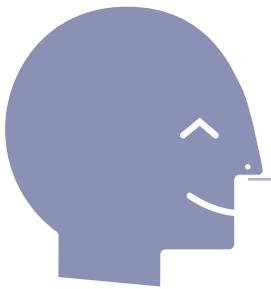
GOING TO BED



RELAXATION AND STRESS RELIEF

Sympathetic nervous system activity can disturb sleep.

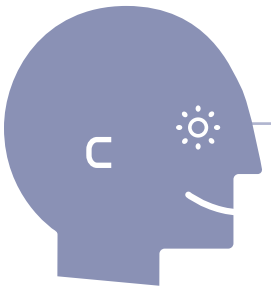
- Relieve stress with heart rate variability (HRV) training before going to bed
- Use a spike mat to improve blood circulation in the skin and the release of endorphins and oxytocin which help you to calm down and relax
- Practice breathing exercises
- Listen to relaxing audio tracks
- Have sex
- Go to sauna



OPENING UP YOUR RESPIRATORY TRACT

Breathing problems can disturb your sleep.

- Learn to breathe through your nose
- Use a nasal strip or a nasal spray to keep your respiratory tract open
- Use a neti pot for nasal cleansing
- Improve the air quality in your bedroom

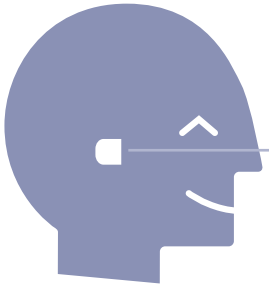


SOUND AND LIGHT STIMULATION

Many apps and devices based on sound and light stimulation are designed to help you fall asleep.

- Listen to binaural beats, a type of sound stimulation (to be used in conjunction with headphones that are compatible with sleeping)
- Create a natural soundscape with a computer or mobile apps
- Light stimulation with red spectrum light that induces melatonin production

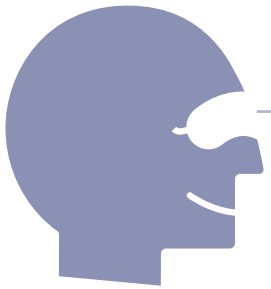
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SOUNDPROOFING

Distinctive sounds that stimulate too much cognitive activity can prevent you from falling asleep and reduce the quality of your sleep.

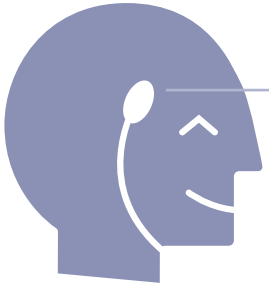
- Use earplugs suitable for sleeping
- Use pressure regulating earplugs for airplane travel



BLOCKING OUT LIGHT

Blue spectrum light, in particular, can easily disturb sleep. For example when you are travelling it is not always possible to isolate the entire room from external light sources.

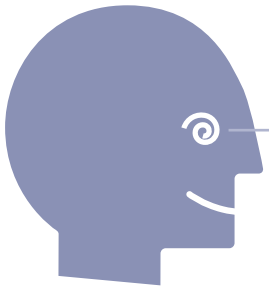
- Use eye patches or sleeping masks that prevent the light from reaching your eyes
- Use blackout curtains



ELECTRIC STIMULATION

Stimulating the brain electrically has been proven to have an effect on the production of neurotransmitters such as GABA and serotonin,[55] which can help treat sleeping problems.

- Try Cranial Electrotherapy Stimulation (CES), also known as "electrosleep" [56]



LUCID DREAMING

During a lucid dream, the person knows he or she is sleeping.

- Write down a sleep diary to help remember your dreams
- Try self-suggestion right before going to bed; and reality checks during dreams
- Wake yourself up during a lucid dream and try to remember your dreams
- So-called sleep herbs such as *Artemisa vulgaris*, *Heimia salicifolia*, *Synaptolepis kirkii* and *Huperzia serrata* may support the practice of lucid dreaming

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WAKING UP

WAKE UP NATURALLY

Emulating a natural environment can reduce the stress response caused by a regular alarm clock.

- Use a wake-up light that imitates a natural sunrise
- Create a gradually developing soundscape that emulates nature waking up to its full glory

JUMP-START YOUR BODY

The body has been fasting for the entire night. Muscles might be tense as a result – but there are ways to reduce this tension.

- Ingest 400 ml of water (for rehydration), 2 tbsp of lemon juice (to balance gastric acids) and half a teaspoon of salt (for your adrenal glands) within 30 minutes of waking up
- Try inversions, and a hand- or headstand, to improve the circulation in your body and to boost your adrenal glands
- Try yoga, jogging or stretching
- Try a warm shower or bath finished by a cold shower (that closes the pores in your skin)
- Try vibration plate, jumping jacks, or mini-trampoline to increase blood and lymph circulation



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MEASURING AND TRACKING SLEEP

The history of collecting data on the physiology of sleep goes back to the late 19th century. Sigmund Freud was already interested in dreams in a time before the invention of EEG and a proper understanding of REM sleep. In 1913, the French scientist Henri Piéron wrote *Le problème physiologique du sommeil*, in which, for the first time, sleep was dealt with from a physiological perspective. German psychiatrist Hans Berger recorded the first electroencephalogram (EEG) in 1924. The father of modern sleep research, Nathaniel Kleitman, performed ground-breaking work on the circadian clock and rapid eye movement (REM) sleep in the 1950s. Later on, in 1968, Dr. Allan Rechtschaffen and his colleague Anthony Kales co-published the iconic *A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects*. Right up to the present day, this has been the primary source for describing the various stages of sleep.

In the last ten years, technologies for measuring sleep have escaped sleep research laboratories and fallen into the hands of consumers. A modern biohacker, using affordable consumer products, can collect a lot of data from his or her sleep.

SLEEP QUALITY CAN BE MEASURED, FOR EXAMPLE, WITH THE FOLLOWING APPROACHES:

- EEG (electroencephalography): tracks the various phases and cycles of sleep
- EMG (electromyography): measures jaw muscle tension
- EOG (electrooculography): measures eye movements
- HRV (heart rate variability): measures stress level during the night and the body's response. The parasympathetic nervous system actives itself during orthodox sleep while the sympathetic nervous system activates itself during REM sleep.[57]
- Nocturnal movements: one's sleep should have periods every night that last at least 15 minutes where there is no discernible movement
- Temperature: room temperature
- MSLT (Multiple Sleep Latency Test)
- MWT (Maintenance of Wakefulness Test)
- Body temperature: drops during the night
- Melatonin readings from saliva
- Heartbeat: drops during the night
- Oxygen saturation: levels of oxygen in the blood
- Blood pressure: drops during the night
- Sound levels: background noise and snoring

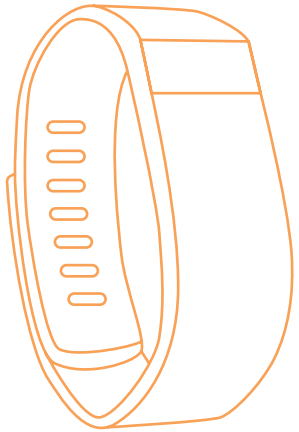
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TIPS FOR MEASURING SLEEP

There are many consumer products available for measuring sleep:

- Activity trackers and watches with a sleep tracking function
- Wearable jewelry such as smart rings and pendants with a sleep tracking function
- Sleep trackers that sense body movements during sleep using radio waves
- Sleep trackers that are placed under the bed sheets
- Sleep applications that utilize the motion sensors of a smartphone
- Sleep trackers fastened to the head that sense eye movements or electroencephalogram signals
- Heart rate belts that measure sleep quality

In terms of accuracy and user convenience, a sleep tracker placed under the bed sheets is the preferred option. A significant portion of activity meters recognizes the various stages of sleep based on body movements only. These include many activity trackers and smartphone applications. Adding a separate sensor to track the heart rate, body temperature and respiratory frequency significantly improves the measuring accuracy. There are sleep trackers available that use electroencephalograms; these may be even more accurate.



It is possible to start tracking sleep simply using a smartphone application although their accuracy is quite poor compared to devices designed specifically for the purpose. In terms of user convenience, trackers placed under the bed sheets, smart rings and contactless body movement sensors are the least likely to cause sleep disruptions.

Activity trackers, heart rate belts and various headgear may be uncomfortable to use as they may disrupt the optimal blood flow. If you are concerned about electromagnetic radiation, choose a device that is not placed directly on skin and that can be switched to flight mode during the night. In terms of the electromagnetic radiation risk, it is smart to choose a Bluetooth device with a short range (0.5–1.0 mW).

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To maximize sleep quality, aim for the following:

- REM sleep representing 20–25 % of the time spent asleep
- Deep sleep representing 10–20 % of the time spent asleep
- Sleep for 7–8 hours per night
- Falling asleep quickly (in less than 15 minutes)
- Little to no waking up during the night
- Increased heart rate variability (HRV) during the night, indicating the activation of the parasympathetic nervous system (RMSSD)
- Heart rate variability's HF component is is sufficiently high (HF increases during the activation of the parasympathetic nervous system)
- Daily resting heart rate (HR) in the morning is constant or decreasing compared to the monthly average
- Little to no snoring
- No unusual restlessness or movements during the night
- The soundcape during the night contains nothing that stands out

It is not always possible to get enough sleep – traveling or a busy work schedule may mean reduced hours of sleep. When this is the case, pay special attention to the recovery of the nervous system (HRV), the time it takes to fall asleep and the amount of deep sleep in proportion to the total time spent asleep. If the morning resting heart rate begins to creep up, try to organize rest days to boost recovery.

More device suggestions in the book's bonus materials:

biohack.to/sleep

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TIPS AND GUIDES

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POWER NAPS

The Spanish surrealist Salvador Dali loved to nap. While sleeping on his armchair, he would dangle a spoon on top of a tin plate. Upon dozing, the spoon would fall onto the dish and wake him up. Salvador's naps were real "power naps."

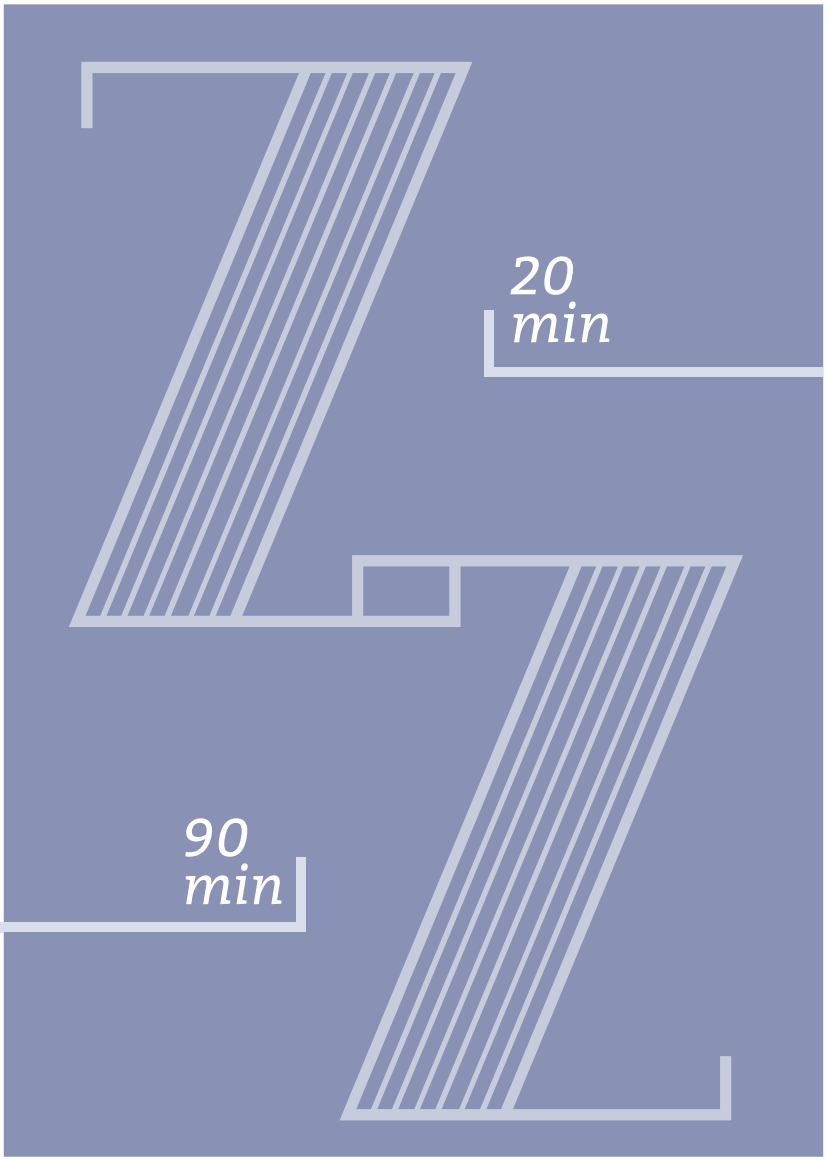
The secret to efficient napping is to prevent yourself from falling deeper than the N1 and N2 stages of sleep. Naps should last no longer than 20 minutes. Longer naps often lead to grogginess. This so-called "sleep inertia" phenomenon is caused by the increased production of adenosine. If one wishes to catch up for lost sleep, or accelerate one's ability to learn,[58] it can sometimes be beneficial to sleep a bit longer. In such cases, it is best to plan out the nap so that it lasts for a complete cycle, i.e. about 90 minutes. The best time to nap is about 6–8 hours after waking up, when the circadian dip in alertness and sleep propensity is highest.[59]

Studies show that naps can improve memory and reverse the performance deteriorating effects caused by sensory overload.[60] In studies conducted at the sleep laboratory of the University of Lougborough it was discovered that naps lasting less than 15 minutes reduced mistakes by 9 % in a monotonous driving test. In the same test, people who ingested 200 mg of caffeine before the nap made 34 % less mistakes.

Combining caffeine and napping is an efficient combo. It takes about 20–45 minutes for the caffeine to kick in. A cup of coffee right before napping doesn't begin to have an effect until after the nap is over, which means that it won't negatively affect your sleep.[61]



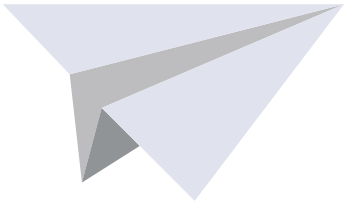
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A RECIPE FOR AN EFFICIENT NAP:

- Avoid caffeine and other stimulants 1–4 hours before the nap
- Drink a cup of coffee, or ingest 200 mg of caffeine, immediately before your nap
- Set the alarm to 20 minutes (with or without caffeine) or 90 minutes (without caffeine)
- Cover your eyes with a sleeping mask that filters out distracting light
- If you are in a noisy environment, use earplugs or experiment with headphones playing white noise
- Breathe in deeply and calmly. Impersonating someone sleeping actually may help
- Our recommendation is to try napping with a spike mat to release endorphins and oxytocin and increase blood flow

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SLEEPING IN THE AIRPLANE

A flight is a chance to make up for lost sleep, but many have found it easier said than done. Below, we have collected a number of tips that might make it easier to sleep in an airplane (or other modes of transportation):

Avoid stimulants like coffee approximately 6 hours before the flight.	Dress yourself comfortably. Wear a warm hat and replace your shoes with woollen or flight socks.
Use the toilet immediately upon boarding.	Try supplements to improve the ability to fall asleep, such as L-theanine and melatonin.
Choose a window seat. This way you don't have to make room for passengers who wish to use the toilet.	Tell the flight attendant and the person next to you that you intend to sleep and do not wish to be disturbed.
Make more leg room by selecting a seat in the Exit row, or use websites that help you to pick the ideal seat on a plane.	Remove all disturbances by wearing a sleeping mask and earplugs. From our experience, noise cancelling headphones with proper earmuffs work even better.
Avoid noisy seats immediately adjacent to the toilet or the plane's engines.	

Try to fall asleep the moment you board the plane. Takeoff and the initial ascent usually last long enough so that by the time the food arrives you feel already well-rested. However, do not adjust the backrest of the seat into a reclining position, and do not forget to fasten the seatbelt, as otherwise the flight attendant may feel compelled to wake you up. This applies to landing: learn to sleep with your backrest in a vertical position and the seatbelt fastened.

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STRESS-FREE WAKE-UP

On some mornings you may feel energised and fully active, while at other times you feel slow and groggy – no matter how many hours you have slept. This is most likely caused by waking up from the deepest stages of sleep, while adenosine is still affecting your central nervous system. A regular alarm clock is not intelligent enough to differentiate between stages of sleep.

With specific technologies, it is possible to have an alarm clock that wakes you up at the right moment. This is possible with the kind of apps that monitor the stages of your sleep and attempt to wake you up when you are in a lighter phase of sleep. In these apps, you set the time window within which you want the device to wake you up. The larger the time window the more likely it is that you will be woken up at the optimal time.

Device and app suggestions in the bonus materials:

biohack.to/sleep

Cortisol (the so-called stress hormone) production is at its peak around 30 mins after waking up. At that moment your adrenal glands will produce about 50 % more cortisol than normally.[62] Waking up earlier than you usually do further accentuates the stress response. According to various studies the stress response may be alleviated with the following methods:

- Unpronounced soundscapes during the night (sounds of nature or distant traffic noise) reduces the stress response in the morning.[63] There are apps available that produce such soundscapes.
- Waking up later in the morning.
- Waking up in the dark rather than in the daylight. From an evolutionary standpoint, it could simulate the feeling of being protected from natural predators.[64]
- Stressful experiences and thoughts about a mounting workload can increase stress response in the morning. The night before, write down wandering thoughts and three most important things you need to do the next day. After that, consider meditation. This helps you to clear your mind before going to sleep.

Kickstart your adrenal glands with the help of table salt and an inverted body position. Ingest ½ a liter of water mixed with ½ a teaspoon of salt within 15 minutes of waking up. Lay down on your back, with your legs lifted up to the wall for about 8 minutes. This helps to stimulate the adrenal glands, which in turn reduces the stress response.[65] [66]

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LATE-NIGHT SLEEP-INDUCING SNACK

Mix the following nutrients and supplements in a bowl with a fork. Ingest about an hour before going to bed.



SANDMAN'S SNACK

- *half an avocado*
- *handful of soaked and crushed almonds and/or raw pumpkin seeds (Styrian variety)*
- *1 tbsp of unpasteurized honey*
- *half a banana (not overripe)*
- *a touch of unrefined salt*

Depending on your taste, you can also add the following:

- *1 dl of relaxing tea: passionflower, chamomile, kava or valerian*
- *1 tbsp of bee pollen*

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02
NUTRITION

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"Let the food be thy medicine and medicine be thy food."
– Hippocrates (460–370 BCE)

"One should eat to live, not live to eat."
– Molière (1622–1673)

"All things are poison, and nothing is without poison: the dose alone makes a thing not poison."
– Paracelsus (1493–1541)

"Most people work hard and spend their health trying to achieve wealth. Then they retire and spend their wealth trying to get back their health."
– Dalai Lama (b. 1935)

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"I GUESS I SHOULD EAT SOMETHING..."

Mary shuffles into the kitchen while rubbing the sleep out of her eyes. Feeling lethargic, she tries to think of something convenient to take on the go. She throws a yogurt and a banana into her bag and starts the car. The morning traffic crawls along slowly. Mary snacks on the banana she brought along to postpone the hunger.

Once at the office she hangs up her coat, gets a cup of coffee and sits down for a chat with her colleagues. Half an hour later, she refills her coffee cup and heads for her desk. Mary feels restless and has difficulty concentrating. The important project on her plate will have to wait until the afternoon. Responding to emails feels less exhausting for now.

At lunch Mary selects basic cafeteria fare: a white bread sandwich with mayonnaise sauce, deli meat and a few lonely pieces of salad and cucumber. It fills the stomach but she feels fatigued. It's as if her brain was surrounded by fog. Mary daydreams about taking a long nap as soon as she gets home.

The clock strikes five and Mary grabs her bag. There's a text message from her husband: "Remember to get groceries on your way home." The supermarket is busy as ever with everyone hurrying to get home. Mary roams the familiar aisles and collects milk, bread, juice, cheese, ham, yogurt and cookies in her cart. For the kids, she picks up mac & cheese, canned soup and frozen lasagna. Finally, she adds a bottle of soda and a few bottles of beer.

At the check-out, Mary notices the radiant appearance of the woman in front of her in the line. Her skin looks amazingly smooth. Her shopping basket is full of vibrant colors: vegetables, berries and fresh produce.

A thought surfaces in Mary's mind: Could it be that her radiant skin and positive appearance have something to do with the food choices in her basket? However, the thought quickly passes as Mary remembers her hungry family waiting at home.

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BEAR: THE KING OF THE FOREST

"Well, what I like best, is not the honey but the moment just before you begin to eat honey" – Winnie the Pooh (b. 1921)

The archetype of nutrition in this book is the bear, one of the largest land predators in the Western world. The bear is the totem of many indigenous peoples, a revered and respected animal, and the symbol of the tribe and family.

Most bear species are omnivores with predominantly vegetarian diets. However, different species have adapted to their respective environmental challenges and there is significant variation between them. Polar bears' diet mainly consists of seals whereas pandas exclusively eat bamboo shoots. Although North American and Nordic bears acquire most of their nutrition from plants, they are also opportunistic carnivores. They are known to eat for example vegetables, berries, fish, mushrooms and honey. During the spring season, bears may also hunt elk.

Like bears, most people are also omnivores with predominantly vegetarian diets. Human beings are capable of adapting to their environment, using a variety of ingredients for sustenance. The goal of the Nutrition chapter of the *Biohacker's Handbook* is to crystallize the special nutritional characteristics, opportunities and practical solutions for people in various circumstances, working with different goals and resources.



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YOU ARE WHAT YOU EAT

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Tell me what you eat, and
I will tell you what you are."
– French gastronome
Jean Anthelme Brillat-Savarin (1755–1826)

Food brings people together. It is a source of pleasure and the foundation that makes other aspects of life flourish. The intelligent optimization of nutrition is a top priority in the daily life of a biohacker.

A significant challenge in nutrition is the regrettably common dualistic habit of dividing ingredients into good and bad options. However, nutrition is not as black and white as it may seem at first glance, for instance, in the controversial case of fats vs. sugars. The effect that food has on us varies depending on the quality of the ingredients, the processing methods used, as well as individual factors.

INDIVIDUAL

The following pages outline the effects of food on your body and health from deeper perspectives. The traditional and restricted division of ingredients into specific diets will not be used; rather, their detailed characteristics are examined as part of the big picture. Some highlighted features include the effects of ingredients on various equilibria of the system, preparation and processing methods that increase nutrient intake, and the basis of genetics and epigenetics.

The biohacker assumes an individual approach to nutrition while taking into consideration the quality factors of the ingredients and their expected effects on the body. Food choices are not limited to the mainstream favorites – less well known options are also explored. The biohacker sees nutrition as technology to be used for leverage in the challenges of everyday life.

OPTIMAL

We are all aware of the official dietary guidelines and the general nutrient intake recommendations. Simplification and generalization are both the strength and the weakness of these recommendations made for the general public.

The general nutrient intake recommendations often represent the threshold at which the risk to develop a certain illness is greatly reduced. However, demographic averages are not necessarily relevant for the optimal levels of an individual. Vitamin D is a good example. Genetic variation in the vitamin D receptor (VDR) in individuals affects the absorption of calcium and therefore the recommended intake.[1]

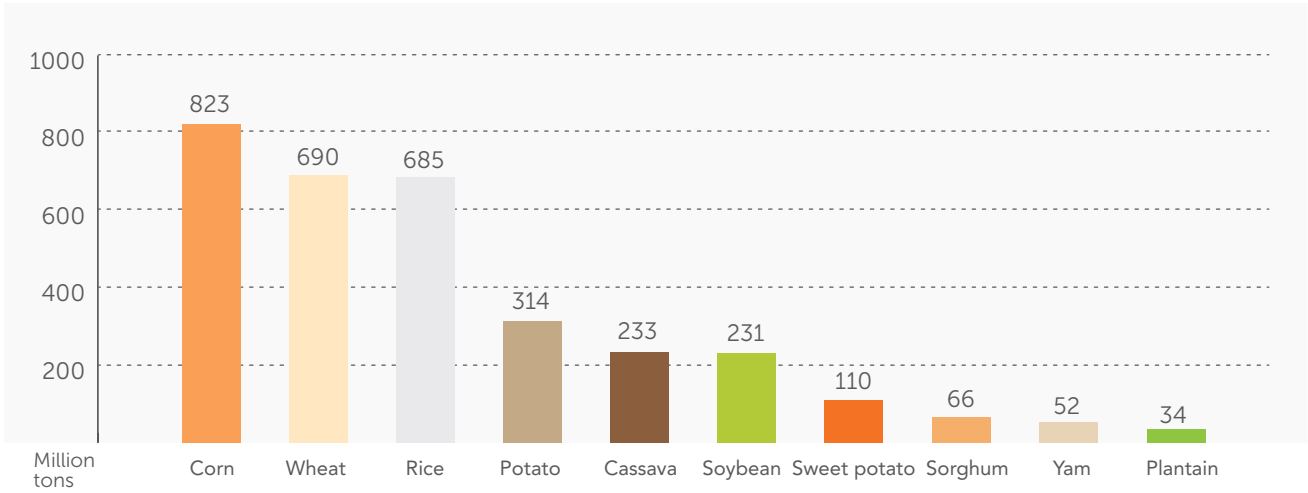
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DIVERSE

The improved standard of living is not fully reflected by improvements in nutrition. Today, we spend proportionally less money on food and our connection to the origin of the food we eat is weaker than ever before. As the diversity of food has decreased, many illnesses that were rare in our ancestors have increased.

There are approximately 50.000 edible plants in the world. The 15 of those most widely used represent roughly 90 % of energy intake. Rice, corn and wheat alone feed approximately 60 % of the world's population.[2] To compare, throughout human history, our diet has included at least a hundred plant species depending on the local habitat. It is worth remembering that in a market economy, supply will meet demand: our purchasing choices determine the direction in which the food industry develops our nutrition. The biohacker is now equipped with the latest research findings and the most advanced technology available to bring nutrition to a personalized level.

10 MOST IMPORTANT CROPS IN THE WORLD (2008)



Source: Allianz

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BIOHACKER'S NUTRITION MANIFESTO

1. Eat well for tomorrow, not just for today.
2. Improve your health even when you are healthy.
3. Quality over quantity.
4. Increase the nutritional density of your food.
5. Reduce toxins.
6. Maintain a healthy balance of various ingredients.
7. Don't eat terms. "Low fat" or "sugar-free" does not necessarily mean a healthier option.
8. Adopt nutritional principles and strategies to apply in different situations.
9. View mealtimes as means to share experiences and knowledge.
10. Consider the environment when making choices, both in the short and long term.



OBJECTIVES

1. The ability to intelligently utilize the nutritional resources available, even in challenging situations.
2. The means to maintain energy levels, clarity of mind and other objectives relevant to life and well-being.
3. The knowledge and ability to increase one's own health and well-being.



COMPASS

1. Add natural, vibrant colors and flavors to your diet.
2. Invest in the quality of ingredients, particularly for the products you use the most.
3. Regularly measure and analyze the effects of food on your system.

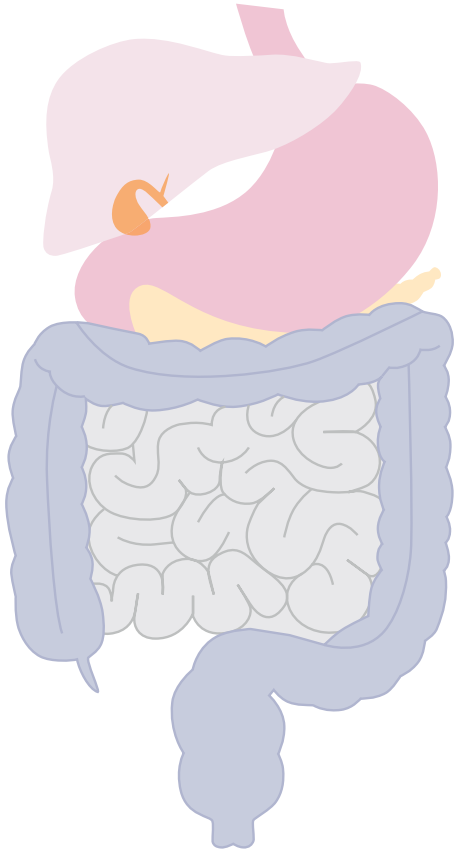
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STRUCTURE AND FUNCTIONS OF THE DIGESTIVE SYSTEM

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The digestive system consists of organs whose functions involve digestion, nutrient absorption, waste product removal and the formation of feces.

The digestive tract reaches from the mouth all the way to the anus. The most important parts of the digestive tract in terms of functions are the esophagus, stomach and duodenum in the upper gastrointestinal tract and the jejunum, ileum, colon and rectum in the lower gastrointestinal tract. The digestive system also includes the salivary glands, pancreas, liver, spleen and gallbladder, each with their own role in digestion.



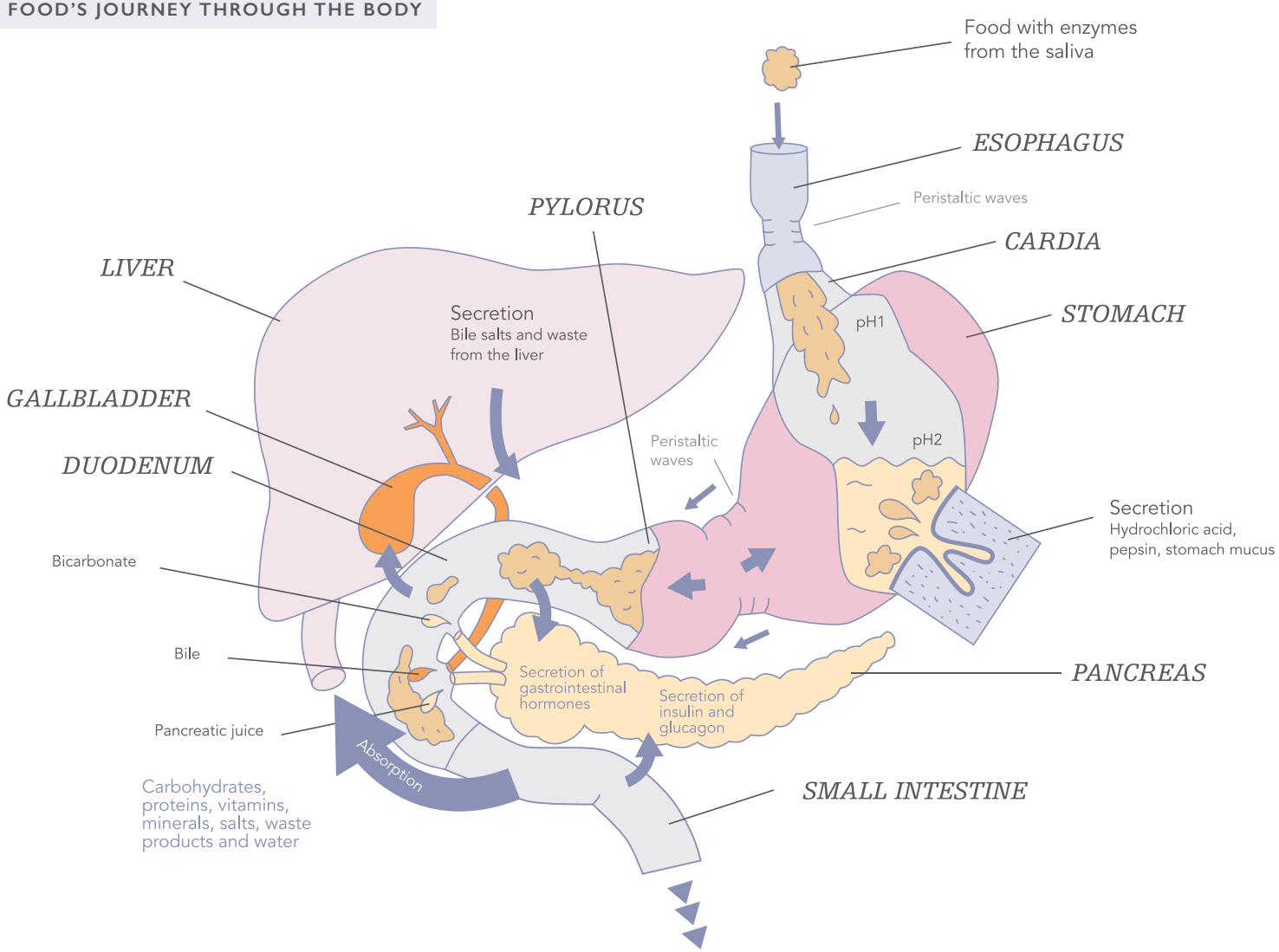
The main function of the digestive system is to break down food and absorb nutrients from the small intestine into the circulatory system. Digestion can be divided roughly into two functional phases: mechanical digestion (the food is broken into smaller pieces by chewing) and chemical digestion (enzymes break down food into molecules).

The importance of chewing for nutrient absorption is often insufficiently considered. Eating slowly and chewing the food thoroughly may create a greater feeling of fullness and increase the absorption of nutrients.[3]

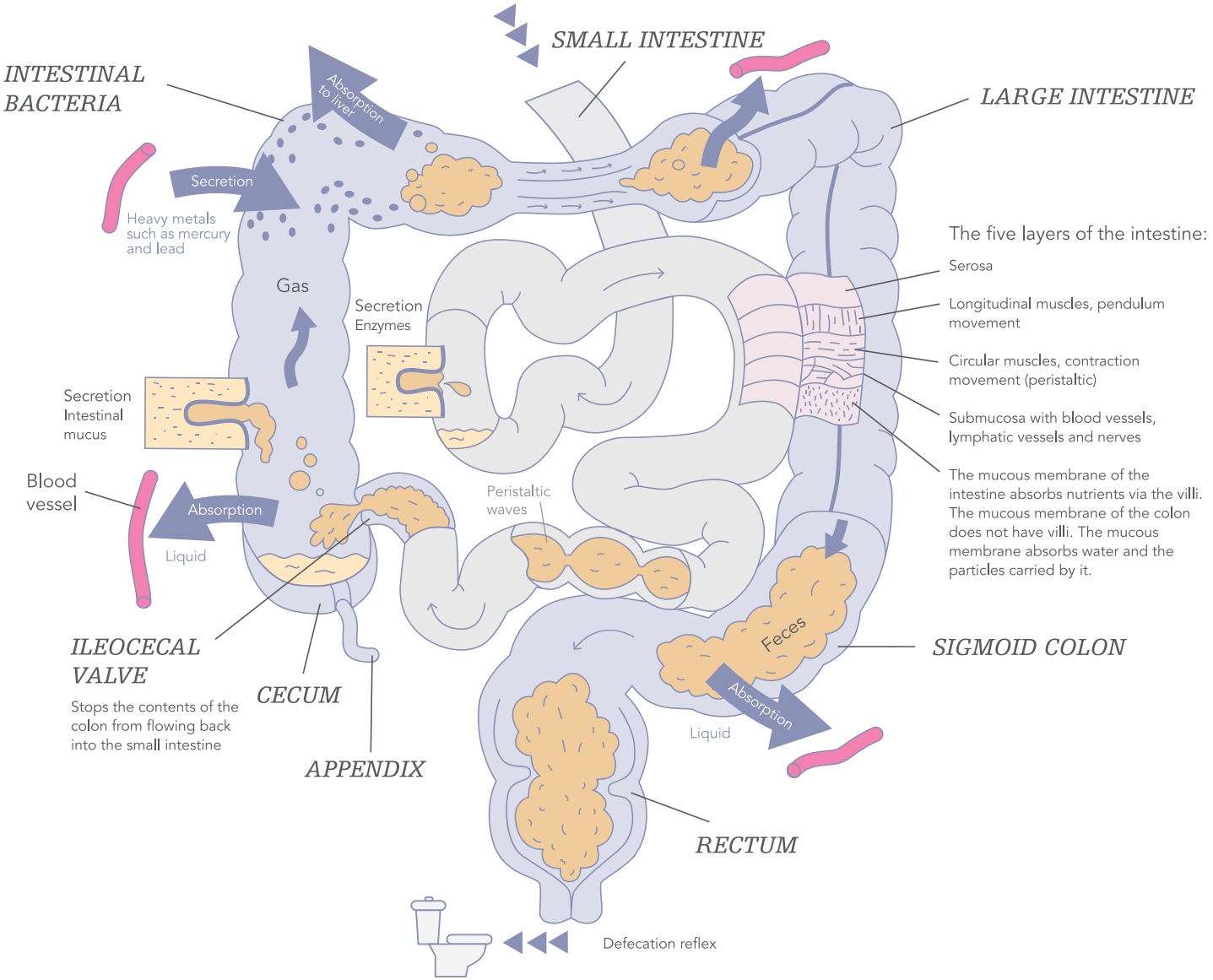
Another important function of the digestive system is the maintenance of the body's defense system against pathogens. This is discussed in more detail in the "Microbiome" section.

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FOOD'S JOURNEY THROUGH THE BODY

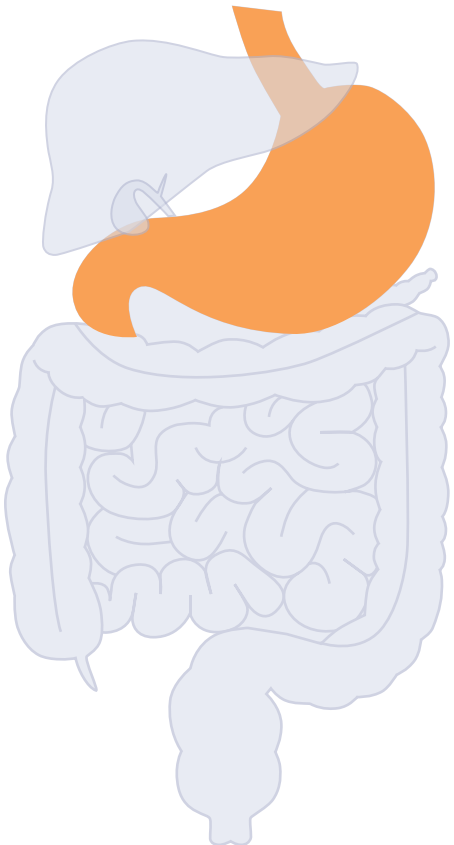


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PARTS OF THE DIGESTIVE SYSTEM



STOMACH

The stomach is located between the esophagus and the duodenum in the top left corner of the abdominal cavity, immediately below the diaphragm. The stomach contains two sphincters that control the volume and movement of the stomach contents: the lower esophageal sphincter and the pyloric sphincter allow the mass of food to enter the duodenum.

The capacity of an empty adult stomach is approximately 75 milliliters (2.54 ounces). It can take in roughly a liter of food.[4] The stomach secretes gastric juice which contains hormones and enzymes necessary for digestion, hydrochloric acid for breaking down food and intrinsic factor (IF) required for the absorption of vitamin B12.[5]

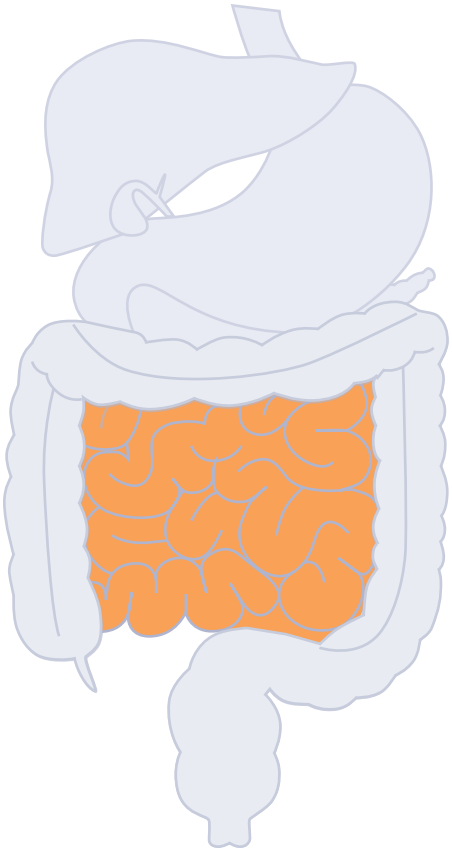
The acidity of gastric juice destroys harmful micro-organisms present in food. However, many people suffer from a deficiency in the production of hydrochloric acid due to stress, poor diet or harmful chemicals.[6] Hypochlorhydria (the low level of hydrochloric acid) contributes to nutritional deficiencies, osteoporosis,[7] various infections,[8] and stomach cancer. The long-term use of acid blockers may cause anemia,[9] vitamin B12 deficiency,[10] and overgrowth of stomach and intestinal bacteria.[11]

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HORMONE	FUNCTION IN THE STOMACH
Gastrin	Promotes the formation of hydrochloric acid and increases gastric movement
Histamine	Contributes to the regulation of stomach acidity through H2 receptors
Cholecystokinin	Curbs the emptying of the stomach
Somatostatin	Inhibits the secretion of gastrin, secretin and histamine in the stomach -> slows down digestion
Gastric inhibitory peptide (GIP)	Inhibits the secretion of hydrochloric acid and reduces gastric movement
Enteroglucagon	Inhibits the secretion of hydrochloric acid and reduces gastric movement
Leptin	Regulates appetite
Ghrelin	Stimulates appetite and promotes the emptying of the stomach

ENZYME / OTHER COMPOUND	FUNCTION IN THE STOMACH
Pepsin	Breaks down proteins into peptides
Lipase	Breaks down fats into fatty acids
Intrinsic factor (IF)	Binds to vitamin B12 and promotes its absorption in the small intestine
Mucin	Mucous matter that protects the stomach lining from damage
Gastric lipase	Breaks down fats into fatty acids

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SMALL INTESTINE

The small intestine is located between the stomach and the colon. The small intestine forms a coil-like structure roughly seven meters in length. It is located in the abdominal cavity, surrounded by the colon. The small intestine consists of the duodenum, jejunum and ileum.

The small intestine receives pre-digested food from the stomach and continues to break down ingredients. The digestive process is assisted by bile (formed in the liver but secreted through the gallbladder) as well as pancreatic juice which contains plenty of digestive enzymes.

The small intestine breaks down three main groups of nutrients: proteins, fats and carbohydrates. Proteins are broken down into peptides and amino acids. Fats are broken down into fatty acids and glycerol. Carbohydrates are broken down into monosaccharides (for example glucose) and starch into oligosaccharides. Once broken down, the nutrients are absorbed through the intestinal wall. Thanks to the structure of the small intestine villi and microvilli, the surface area available for nutrient absorption is enormous, roughly one half of a badminton court.[12]

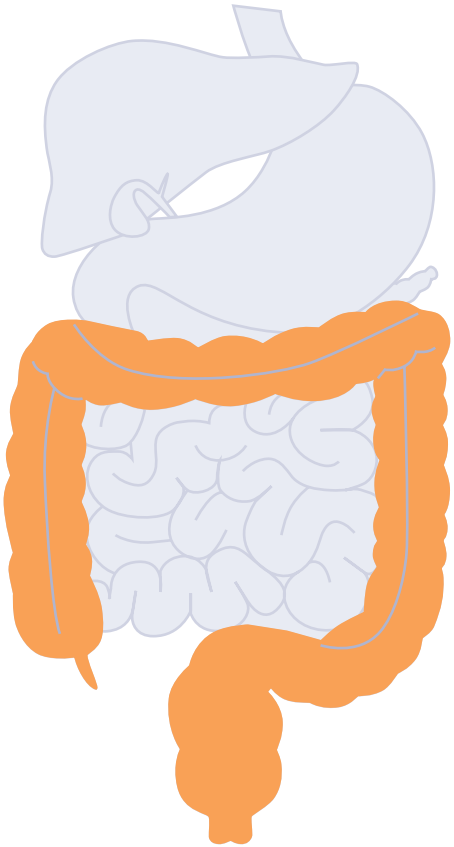
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ENZYME	FUNCTION IN THE SMALL INTESTINE
Amylase	Breaks down carbohydrates into shorter chains of saccharides or sugars
Lactase*	Breaks down lactose into glucose and galactose
Maltase	Breaks down maltose into glucose
Sucrase	Breaks down sucrose into fructose and glucose
Glucoamylase	Breaks down glucose polymers (for example starch) into glucose
Trypsin	Breaks down proteins into amino acids
Chymotrypsin	Breaks down proteins into amino acids
Aminopeptidase and dipeptidase	Break down polypeptides and dipeptides into peptides and amino acids
Lipase (several types)[13]	Breaks down triglycerides into fatty acids and glycerol
Phospholipase (several types)[14]	Breaks down phospholipids into fatty acids and other fat-soluble substances

HORMONE	FUNCTION IN THE SMALL INTESTINE
Cholecystokinin	• Stimulates gallbladder contractions and intestinal movements • Stimulates the secretion of insulin, glucagon and pancreatic polypeptides
Secretin	• Stimulates the secretion of pancreatic bicarbonate, enzymes and insulin • Curbs the movements of the stomach and small intestine • Inhibits the secretion of gastrin
Vasoactive intestinal peptide (VIP)	• Relaxes the smooth muscles of the intestine, and promotes the secretion of water and electrolytes in the pancreas and small intestine • Releases other hormones from the pancreas, intestine and hypothalamus
Entero-glucagon	Inhibits the secretion of insulin
Glucagon-like peptide-1	Promotes the secretion of insulin

*not present or deficient in 75% of the world population

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COLON

The colon is located between the small intestine and the anus. It is roughly 1.5 meters long and consists of the cecum, ascending colon, transverse colon, descending colon and sigmoid colon. The colon is located in the abdominal cavity where it surrounds the small intestine.

The functions of the colon include the maintenance of the bacterial strain in the intestine as well as the absorption of water and the remaining nutrients before the feces move on to the rectum. The vitamins absorbed include K vitamins, thiamine (B1) and riboflavin (B2).[15]

The colon turns digested food into fecal matter. The bacterial strain in the intestine feeds on the fiber mass in the feces and produces fatty acids which are used as a source of energy (see the "Microbiome" section for more details).[16] The bacteria also help remove waste products and toxins.

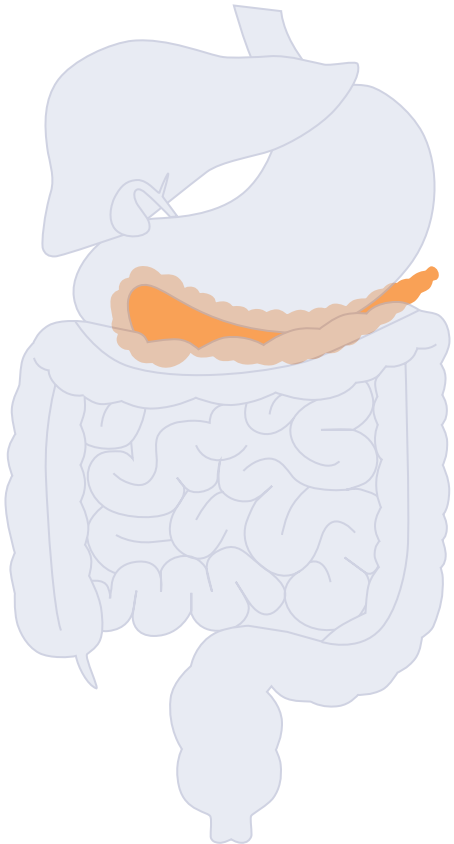
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The appendix is located below the cecum in the colon. It produces hormones that regulate eating (*peptides*). The appendix acts as a storage space for beneficial bacteria[17] and may offer protection from some infections.[18] A popular notion in medicine is that the appendix is unnecessary and may be removed in the event of adulthood appendicitis. Recent studies suggest that treatment with antibiotics will often lead to equally good results.[19]

For example in Finland the prevalence of inflammatory bowel diseases (IBD), such as ulcerative colitis and Crohn's disease, has nearly tripled in the past 15 years.[20] There is a link between the Western diet consisting of large amounts of processed food and the development of inflammatory bowel diseases.[21] These diseases may appear in genetically predisposed individuals due to changes in the bacterial strain of the intestine and disturbances in the immune response. According to the latest research, these diseases are also linked to the leaky gut syndrome and an environmental trigger factors such as an infection.[22]

A diet that removes potentially intestine-damaging antinutrients (see the "Antinutrients" section for more details) and reduces inflammation is usually very beneficial for recovery from the illness.[23] Specifically, the role of gluten[24] in the development of IBD and the genetic link to celiac disease have been indicated in recent studies.[25] Based on the review of fairly recent research (2014), the majority of IBD patients benefit from removing gluten from their diet.[26]

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PANCREAS

The pancreas is located in the abdominal cavity, behind the stomach and next to the spleen, surrounded by the duodenum. The pancreas is connected to both the small intestine and the gallbladder. The pancreas has two distinct functions: the endocrine part that consists of millions of islets (2 % of the pancreas) secretes hormones such as insulin and glucagon, while the exocrine part (98 % of the pancreas) boosts the digestive process.

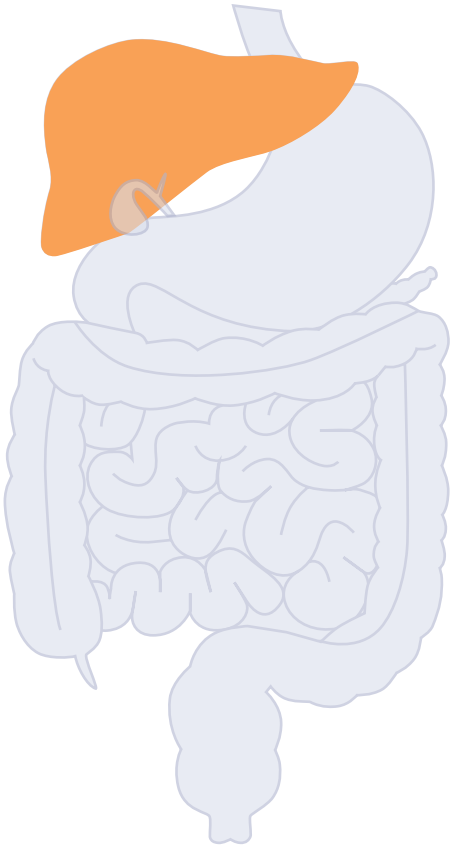
ENZYME	FUNCTION IN THE PANCREAS
Trypsinogen	Is converted into trypsin by enteropeptidase[28] in the small intestine
Chymotryp-sinogen	Is converted into chymotrypsin by enteropeptidase in the small intestine (see small intestine)

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ENZYME	FUNCTION IN THE PANCREAS
Carboxy-peptidase	Cleaves amino acids at the ends of proteins
Pancreatic lipase	Breaks down triglycerides into fatty acids and glycerol
Phospholipase	Breaks down phospholipids into fatty acids and other fat-soluble substances
Pancreatic amylase	Breaks down starch and glycogen into glucose
Nucleases	Break down nucleic acids (DNA and RNA)
Elastase (several)	Breaks down elastin and a few other proteins into amino acids

HORMONE	FUNCTION IN THE PANCREAS
Glucagon (from alpha cells)	• Raises the concentration of glucose in the blood by converting glycogen stored in the liver and muscles
Insulin (from beta cells)	• Lowers the concentration of glucose in the blood by promoting its absorption into muscles and adipose tissue • Other metabolic effects (see section "Blood sugar regulation" for more details)
Somatostatin (from delta cells)	• Inhibits the secretion of insulin and glucagon • Inhibits the secretion of digestive enzymes
Pancreatic polypeptide (from gamma cells)	• Regulates the secretion functions of the pancreas (endocrine and exocrine) • Increased secretion after eating -> reduced appetite, less food eaten[27]

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LIVER

The liver is located in the top right corner of the abdominal cavity, immediately below the diaphragm, to the right of the stomach. Below the liver is the gallbladder. Compared to other internal organs, the liver has a doubleblood supply via the portal vein and the hepatic arteries.This is indicative of the importance of the liver to the entire system.

The liver also contains the bile duct system which collects the bile produced by the liver. Bile ducts generally refer to all ducts through which bile travels from the liver to the gallbladder and duodenum.

Main functions of the liver:[29]

- Carbohydrate metabolism:
  - Produces glucose from amino acids, lactic acid and glycerol
  - Breaks down glycogen into glucose
  - Forms glycogen from glucose
- Fat metabolism:
  - Oxidizes fatty acids into energy
  - Produces large amounts of cholesterol, phospho-lipids and lipoproteins (such as LDL, HDL, VLDL)

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- Protein metabolism:
  – Breaks down amino acids
  – Converts toxic ammonia into urea (urea cycle)
  – Produces blood plasma proteins (including albumin)
  – Produces amino acids and converts them into other compounds
- Bile secretion
- Production of red blood cells and coagulation agents
- Storing glucose (glycogen), fat-soluble vitamins (A, D, K) and vitamin B12, iron and copper

Cleaning and defense functions:

- Breaks down several hormones (including insulin)
- Breaks down and neutralizes toxins (detoxification)
- Removes (through urine) bilirubin released by red blood cells

Liver disease mortality has tripled in the last 40 years.[30] Today's stressful work culture, alcohol, problematic diet and other environmental burdens have led to impaired liver function in some individuals.[31] Abdominal obesity in particular contributes to the development of fatty liver disease.[32] Various medicines also have a significant role in the development of liver damage. More than 900 medicines have been reported to cause liver damage. One half of all acute cases of liver failure are caused by various medicines.[33] Some medicinal herbal products may also be harmful for the liver.[34]

The liver has an amazing ability to regenerate. Indeed, it is the only internal organ that is capable of this. Even when 75 % of the liver has been destroyed, it may return to a normal state.[35] The functions of the liver can be supported through nutrition. This involves supporting the cytochrome P450 enzyme system which is central to the liver detoxification function. The system consists of two distinct phases (1 and 2).[36]

DID YOU KNOW

HEPATITIS C, FATTY LIVER, AND ALCOHOL ABUSE ARE THE MOST COMMON CAUSES OF CIRRHOSIS OF THE LIVER. BETWEEN 10 AND 20 PERCENT OF HEAVY DRINKERS WILL DEVELOP CIRRHOSIS. NEARLY 88 000 PEOPLE DIE OF ALCOHOL RELATED DISEASES. IT IS THE FOURTH LEADING CAUSE OF DEATH IN THE UNITED STATES.

Source: Stahre, M. & Roeber, J. & Kanny, D. & Brewer, R. & Zhang, X. (2014). Contribution of excessive alcohol consumption to deaths and years of potential life lost in the United States. *Preventing Chronic Diseases* 11: E109.

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DETOXIFICATION MECHANISM OF THE LIVER

TOXINS

Including metabolic byproducts, pesticides, environmental toxins, additives and medicines.

PHASE 1

Converting foreign matter into harmless compounds. Supporting nutrients:

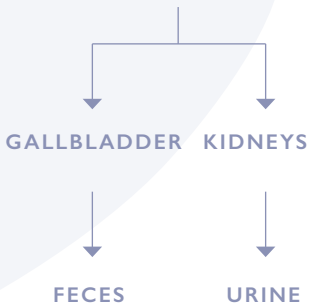
- Vitamin B complex
- Glutathione (the main antioxidant in the liver)
- Branched-chain amino acids (BCAA)
- Flavonoids
- Phospholipids
- Carotenoids
- Vitamin C
- Vitamin E
- Selenium, zinc, copper and manganese
- Ubiquinone (coenzyme Q10)
- Silybum marianum (Milk thistle)
- Artichoke
- Turmeric
- Cruciferous plants (such as broccoli)
- Grapefruit

PHASE 2

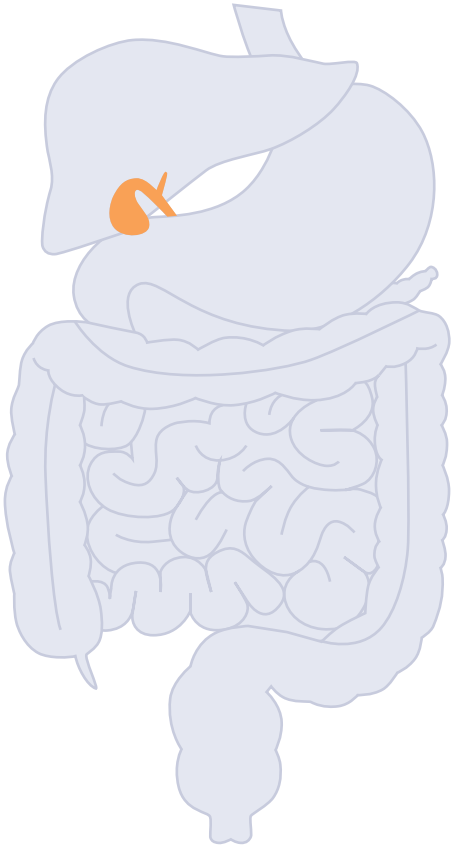
A water-soluble molecule is bound to the substance to be removed in order for the compound to be safely removed through the intestine or the kidneys. Supporting nutrients:

- Alpha lipoic acid (ALA)
- N-acetylcysteine (NAC)
- Calcium D-glucarate
- MSM
- Amino acids:
  - Glycine
  - Taurine
  - Glutamine
  - Cysteine
  - Methionine
- Ingredients that contain sulfur:
  - Egg
  - Cruciferous plants
  - Garlic and other onions

EXIT FROM THE BODY



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GALLBLADDER

The gallbladder is located below the right lobe of the liver. It is a small organ, approximately 8 centimeters in length, and its main function is to store the bile produced by the liver. The gall-bladder and the hepatic duct merge to form the bile duct which leads bile into the small intestine from the ampulla of Vater (a merging point with the pancreatic duct).[37]

Bile is secreted from the gallbladder into the small intestine during the digestive process. Bile facilitates the formation of micelles which are essential for the absorption of fats. Bile also has an important role in the absorption of fat-soluble vitamins (A, D, E and K) and the recycling of bilirubin in the body.[38] Bile acids function in a manner similar to hormones, participating in metabolism (energy balance, regulation of fat meta-bolism and glycemic control).[39] Deficiency in the production of bile and bile acids may cause significant health problems such as excess weight and insulin resistance.[40] The gallbladder may also form gallstones due to indigestion or imbalanced diet. For instance a deficiency in the production of bile salts in the liver, in combination with a diet rich in cholesterol, may be a predisposing factor for the formation of gallstones.[41]

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Risk factors contributing to the formation of gallstones include excess weight, rapid weight loss, constipation and the decreased intake of fiber and nutrients (folate, magnesium, calcium and vitamin C). A dietary supplement of vitamin C may prevent the formation of gallstones.[42] Melatonin may also be used to prevent the formation of gallstones and possibly even treat cholelithiasis.[43]

Ingredients and compounds that promote the production of bile and bile acids as well as the flow of the bile are:

- Soluble fiber (for example from oats)
- Phenolic compounds (for example from artichoke)
- Turmeric
- Flavonoids
- Orange
- Dandelion
- Bitters

GALLSTONE DISEASE

In the United States, an estimated 10 to 15 percent of adults have gallstone disease. About a million new cases are diagnosed each year, and some 800,000 operations are performed to treat gallstones, making gallstone disease the most common gastro-intestinal disorder requiring hospitalization. Many people carry gallstones unknowingly – nearly half of all cases involve no symptoms at all. Gallstones are usually formed of bile salts and cholesterol. In rare cases gallstones may be so-called pigment stones which are formed of calcium and bile pigments.

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MICROBIOME

The microbiome refers to the colonies of symbiotic (both parties benefit from each other), commensal (one party unilaterally benefits from the other) and pathogenic (illness-causing) micro-organisms. These colonies exist for example on the skin's surface, on the mucous membrane of the mouth, the conjunctiva and the intestine.

It is estimated that there are 500–1000 distinct bacterial species living in the intestine. The most common bacterial species in the intestine are Bacteroides, Clostridium, Fusobacterium and Bifidobacterium. Other known strains include Escherichia and Lactobacillus.[46] The Bifidobacterium and Lactobacillus strains are typically present in probiotic products due to the fact that these are most widely studied.[47]

The functions of the bacteria in the intestine include breaking down carbohydrates (fermentation) that the body cannot otherwise digest. This process creates short-chain fatty acids which are used for energy in the organism. For example butyrate is utilized by the surface cells of the intestine, propionate by the liver and acetate by muscle cells.[48]

Therefore, the condition of the intestine also has a significant influence on energy production. The intestinal bacterial strain also contributes to the absorption of K vitamins, B vitamins and some minerals (magnesium, calcium and iron), the production of bile acids as well as the immune system. Furthermore, it acts as a protective wall against various pathogens.[49]

DID YOU KNOW

DID YOU KNOW THAT ONLY 40–50 % OF THE CELLS IN YOUR SYSTEM ARE OF HUMAN ORIGIN? THE OTHER 50–60 % IS MADE UP OF THE CELLS OF THE BACTERIA, FUNGI AND MICRO-ORGANISMS LIVING IN YOUR BODY.[44] IN TERMS OF GENES, THE DIFFERENCE IS MUCH GREATER – FOR EACH HUMAN GENE THERE ARE 100 MICRO-ORGANISM GENES.[45]

ANTIBIOTICS AFFECT THE BACTERIAL STRAIN OF THE INTESTINE

A single course of antibiotics can affect as much as 30 % of the entire bacterial flora of the intestine and can throw off the bacterial balance from six months up to two years.[50]

However, antibiotics are necessary when a harmful pathogenic bacterium, such as Salmonella, Shigella, Campylobacter or Yersinia, has entered the intestine. Alongside viruses, these bacteria are also the most common causes of traveler's diarrhea and intestinal infections.

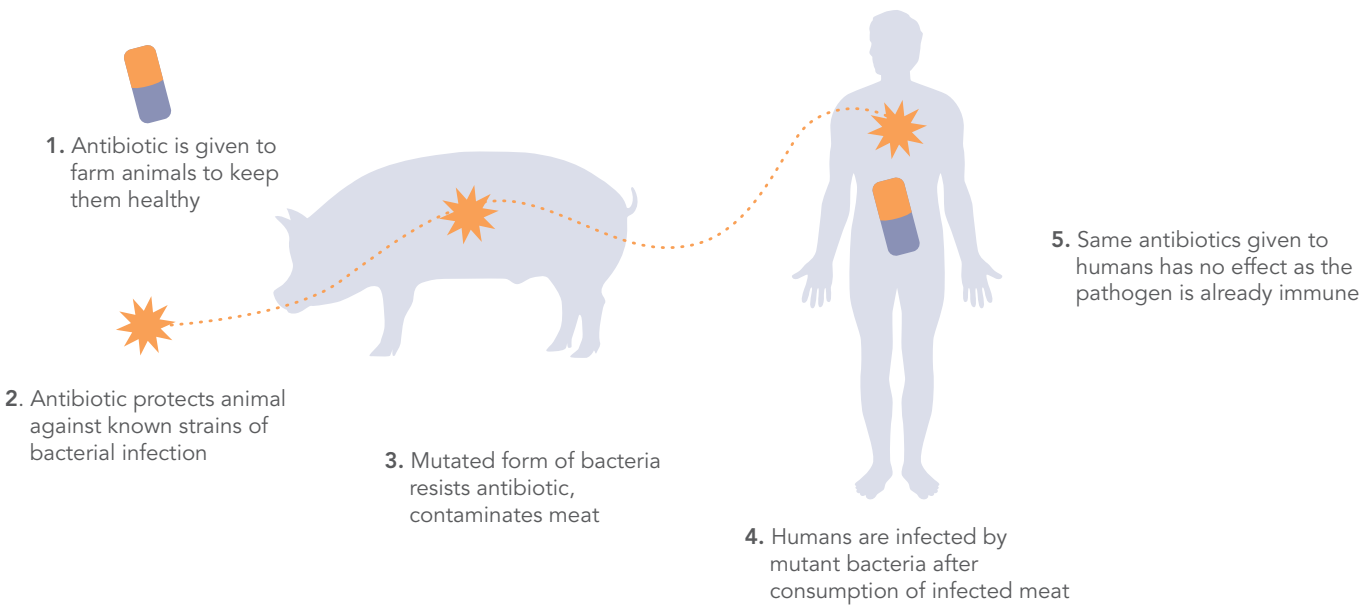
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Depending on the individual's bacterial balance, the liberal use of antibiotics may cause predisposition to diarrhea[51] and the Clostridium difficile infection[52] as well as overgrowth of other harmful bacteria.[53] The increased use of antibiotics has also resulted in an increase in antibiotic resistant bacteria around the world.[54]

GUT-BRAIN AXIS

The gut-brain axis refers to the neurological and biochemical connection between the enteric nervous system of the intestine and the central nervous system. The intestinal microbiome (bacterial strain) is known to affect the function of the immune system, the nervous system,[55] behavior,[56]

THE DEVELOPMENT OF ANTIBIOTIC RESISTANT BACTERIA



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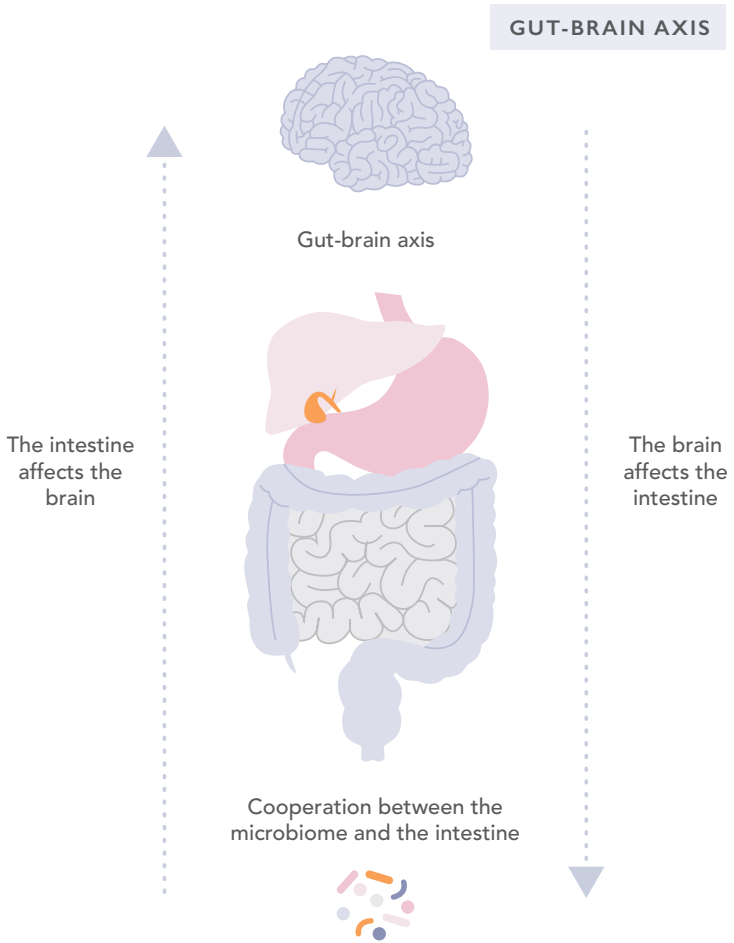
stress tolerance,[57] mood[58] and issues such as anxiety and depression.[59] In the past two decades in particular there has been a growing understanding of the significance of the intestine for the well-being of the brain.

Researchers in the University of Alabama (2018) have potentially made a groundbreaking discovery from the brain. According to their preliminary study they found out there are living bacteria in the brain. Most of the bacteria were from three phyla common to the gut: Firmicutes, Proteobacteria, and Bacteroidetes. This finding is yet to be scientifically repeated and verified by other research groups.[60]

The brain communicates with the intestine via two distinct autonomic branches of the nervous system: the HPA axis (hypothalamus – pituitary gland – adrenal gland) and the sympathetic nervous system – adrenal gland axis which regulates the lymphatic system of the intestine.[61]

It is important to understand the continuous nature of the communication between the brain and the intestine and the bilateral regulatory mechanisms involved. A good example of this is a strong emotional reaction that causes "butterflies in the stomach."[62] Conversely, the intestine sends the brain information about the food eaten and its effects on the intestine.

The first signs of impaired brain function may also be detectable in digestion – the impaired secretion of pancreatic enzymes, weak gallbladder activity and the general impairment of intestinal balance and function.[63]



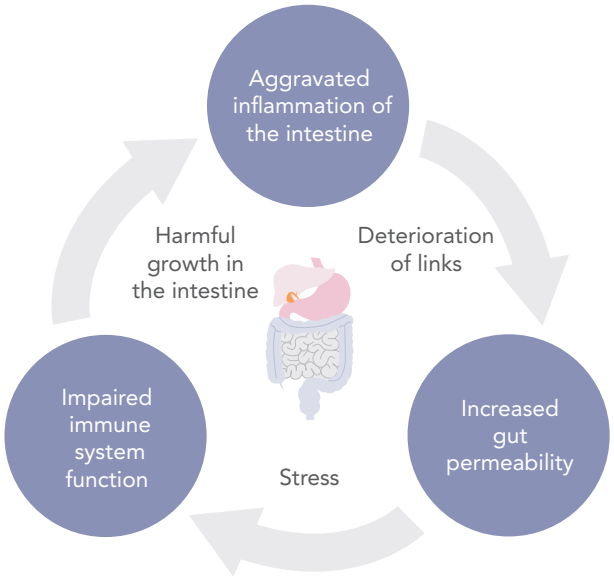
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VICIOUS CIRCLE

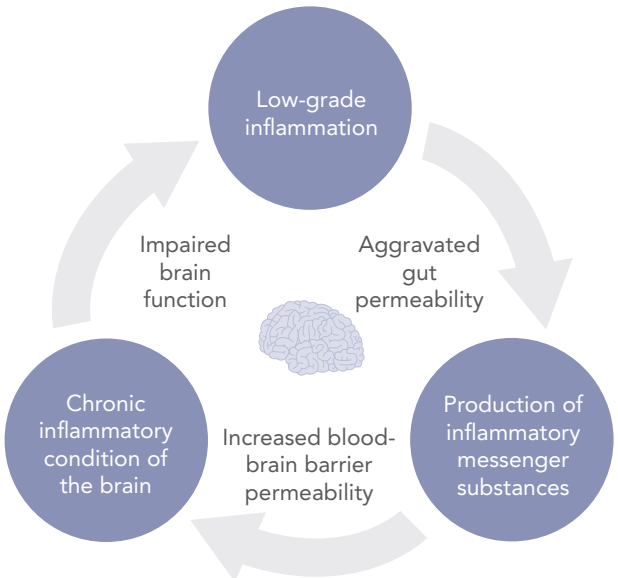
The bilateral nature of communication between the brain and the intestine may form a so-called vicious circle (*circulus vitiosus*).

The continuous inflammatory condition or imbalance of the intestine may cause deterioration of the links between the enterocytes on the surface of the intestine, causing gut permeability. Similarly, impaired brain function or stress-related hyperactivity of the sympathetic nervous system undermines the function of the vagus nerve.[64] This impairs the function of the immune system and reduces blood circulation in the intestine which in turn increases the growth of harmful fungi and bacteria in the intestine.[65] They can damage the surface tissue of the intestine and aggravate gut permeability (leaky gut syndrome).[66 67]

A continuous low-grade inflammation of the system may also aggravate gut permeability.[68 69] This results in the production of cytokines (inflammatory messenger substances)



VICIOUS CIRCLE

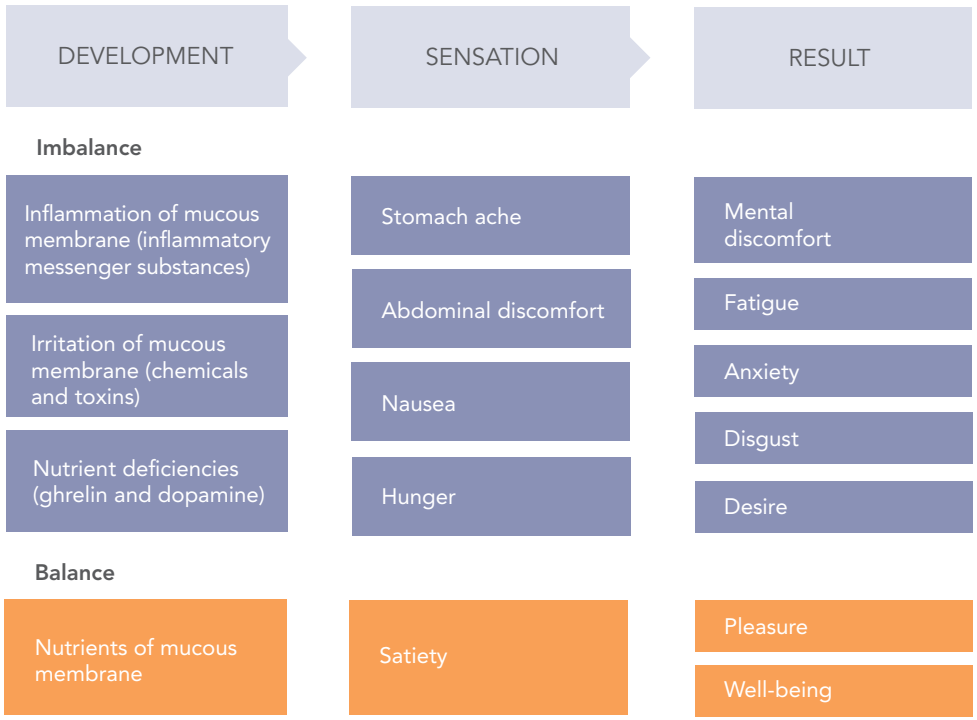


INFLAMMATORY CYCLE

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in the intestine.[70] Due to gut permeability, the messenger substances are able to enter the circulation and the brain via the blood-brain barrier. The inflammation causes the blood-brain barrier to also become permeable, which in turn activates the connective tissue cells of the brain, also known as microglia cells.[71] The result is a chronic inflammatory condition of the brain that impairs brain function and may cause anxiety and depression.[72]

Thus completing the vicious circle which will get worse unless corrective measures such as those outlined in this book are implemented.



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BRISTOL STOOL CHART

Type 1		• Separate, small, hard lumps • Feces have remained in the bowel for too long, absorbing the water • Not enough fiber in the diet
Type 2		• Solid, firm, visibly lumpy • Often appears when constipated • Typical of irritable bowel syndrome
Type 3		• Solid, firm, cracks in the surface • Similar to Type 2 but passed through the bowel more quickly
Type 4 (ideal)		• Solid, soft and smooth • Good amount of fiber in the diet • Typical of people who defecate regularly once a day
Type 5 (ideal)		• Separate, soft, clearly defined blobs • Typical of people who defecate 2–3 times per day, after each main meal
Type 6		• Fluffy pieces, mushy stool • May indicate high blood pressure • Typical of individuals who react to stress with their stomachs
Type 7		• Entirely liquid • May be normal diarrhea or appear together with Type 1 • Typical of the elderly and children

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STOOL COLOR

Light to medium brown
Normal

Black, tar-like or red
Bleeding in the upper digestive tract or a sign of inflammatory bowel disease. NB: Medication or food (for example blueberry, beetroot, licorice) may cause unusual stool color.

Pale brown, gray or white
Bile deficiency or a sign of cirrhosis, hepatitis or pancreatic disease

Yellow
Gallbladder problem or parasitic infection (Giardia)

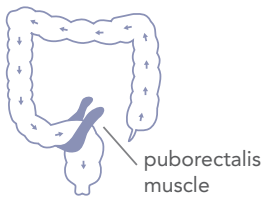
DEFECATION POSITION

We are designed to squat



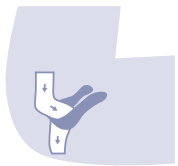
Humans have squatted for millenia – until the advent of the modern toilet.

Your colon (3–6 feet long)



The colon moves waste to the rectum for elimination. It has a natural kink that maintains continence.

Sitting stops the flow



The puborectalis muscle partially relaxes, keeping the colon kinked and blocking the flow of waste.

Squatting position opens the colon



The puborectalis muscle fully relaxes allowing the colon to empty quickly and completely.

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HYPERSENSITIVITY AND TOXINS

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Many ingredients affect the digestive system both positively or negatively. Allergenic foods, toxins occurring naturally or artificially in food, and intestinal bacteria reacting to food all represent unique challenges. On the other hand, many ingredients reduce the inflam-matory reaction of the intestine, facilitate the digestive process or provide materials necessary for tissue regeneration.

ALLERGENIC AND HYPERSENSITIVITY-INDUCING FOODS

A food allergy is an adverse immune response to a particular protein in the food. The immune system treats the foreign protein as harmful, causing a quick antibody response (immunoglobulin E). Food allergies unrelated to the immunoglobulin E reaction, such as celiac disease and enterocolitis, are more rare. Factors that may increase the likelihood of allergies include the liberal intake of antibiotics in early childhood,[73] the allergenic diet of the mother,[74] certain vaccines[75 76] and particularly the adjuvants thereof[77] as well as various chemicals (such as pesticides containing dichlorophenol).[78]

The foods that most commonly cause allergic reactions are nuts (tree nuts), milk products, cereal products, egg, fish and shellfish, as well as peanut, soy and other legumes. Together they represent 90 percent of all food allergens.

Food allergies are often found during childhood and they may disappear with age. Allergic reactions to food are usually quick and intense compared to hypersensitivity reactions which involve symptoms that are milder and more varied.[79]

Typical allergic reactions to food include:

- Nettle rash
- Itchy skin
- Difficulties swallowing
- Runny or blocked nose
- Sneezing
- Nausea and vomiting
- Abdominal pain



The causes of food-related hypersensitivity reactions are:[80]

- Digestive malabsorption
- General digestive disorders
- Increased gut permeability
- Immunological reactions (immunoglobulins)
- Toxins (additives and natural compounds)[81]
- Psychological reactions

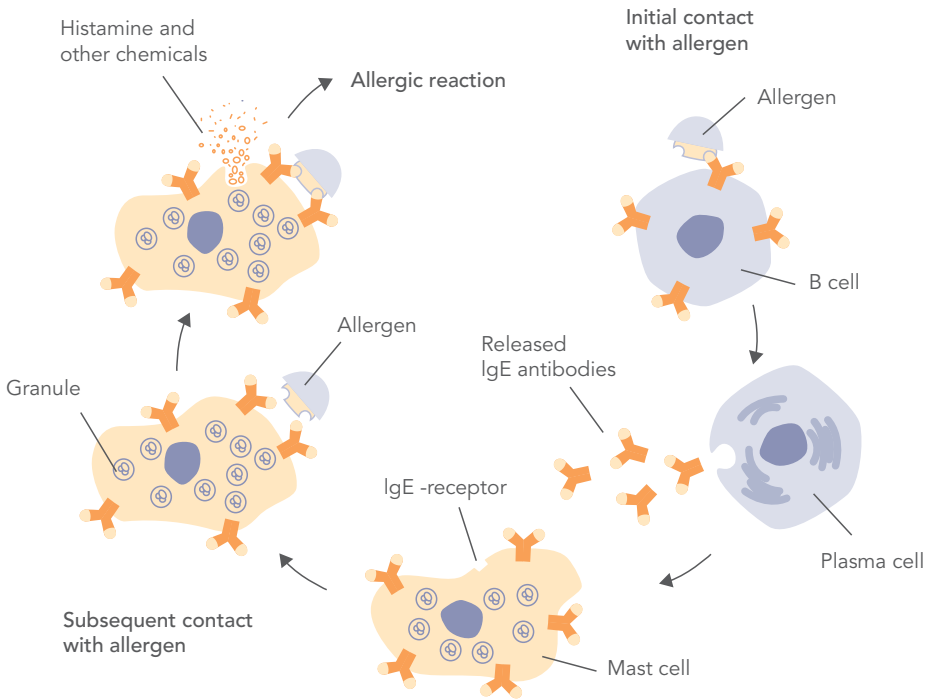
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Food hypersensitivity may also be caused by the histamine, tyramine or other biogenic amine present in the food (chocolate, red wine, tuna or fermented ingredients such as cheese). In some cases, food (for example tomato or pineapple) may release histamine in the body. This is referred to as Histamine Intolerance Syndrome (HIS).[82] Individuals with HIS typically have a low level of diamine oxidase, an enzyme that metabolizes histamine in the system.[83]

This is something to consider if tests do not show a clear root cause but the individual still suffers from symptoms. Typically histamine increases the heart rate and causes nasal congestion and flushing.

Histamine may also cause intestinal symptoms such as diarrhea and abdominal pain, as well as neurological symptoms such as dizziness and headaches. Tyramine may trigger a migraine attack.[84] Intense histamine reactions may be prevented with antihistamines or enzyme preparations containing diamine oxidase.

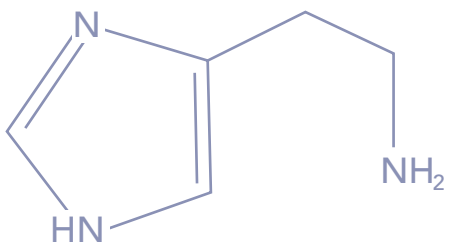
ALLERGIC REACTION



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Foods rich in histamine or other vasoactive amines:

- Wine, alcoholic cider, beer and other fermented alcoholic drinks
- Fermented foods (sauerkraut, wine vinegar, soy sauce, kefir, yogurt, kombucha)
- Aged cheeses
- Processed meat products (sausage, ham, salami, bacon)
- Smoked animal products
- Dried fruit
- Nuts (walnut, cashew, peanut)
- Yeast (promotes histamine production in food)
- Products made from wheat
- Eggplant, spinach and tomato
- Certain types of fish such as mackerel, tuna, anchovies and sardines



Foods that release histamine in the system:

- Banana
- Chocolate and cocoa
- Cow's milk
- Papaya
- Pineapple
- Citrus fruits
- Strawberry
- Nuts
- Tomato
- Spinach
- Pork
- Egg white (raw)
- Food additives

Diamine oxidase blockers:

- Alcohol
- Black tea
- Energy drinks
- Green tea
- Yerba maté

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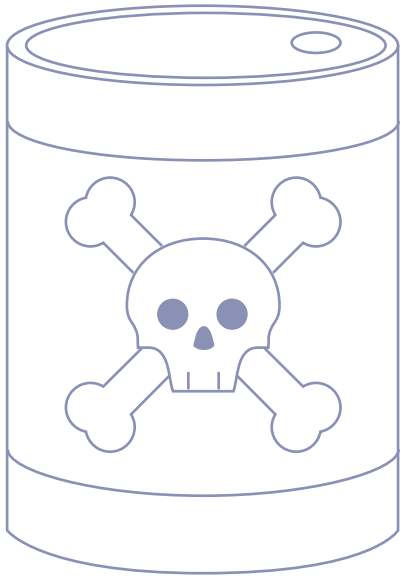
TOXINS

Many foods contain useful compounds such as vitamins, minerals, trace elements and fatty acids, but also unnecessary or harmful compounds, i.e. toxins. Whether or not they cause symptoms depends on the nature of the toxin, the toxin levels in the plant eaten and the individual's sensitivity to various substances. Proper processing methods can often reduce the level of harmful substances. For example, the false morel mushroom contains gyromitrin, a hazardous cytotoxin; but gyromitrin is water-soluble and can be removed by blanching. Thus, it is possible to avoid naturally-occurring toxins in food by selecting and processing it properly.

Pesticides are used in the food production industry to prevent plant diseases, to control the effects of pests such as weeds, insects and mites, and to regulate growth.

Toxins that have adverse effects on the body include:

- Heavy metals
- Dioxins and PCB compounds
- Organotin compounds such as PVC
- Microplastics
- Volatile organic compound (VOC) emissions
- Radioactive compounds
- Mycotoxins
- Carcinogens
- Xenoestrogens which imitate the effects of estrogen
- Antinutrients
- Certain pesticides
- Certain fertilizers
- Residues of medicinal products
- Other harmful organic compounds



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XENOESTROGENS

Xenoestrogens imitate the effects of estrogen in the body. They can be synthetic or naturally-occurring compounds. Typical sources of xenoestrogens are plastic bottles and containers, hygiene products and cosmetics, teflon pans, shop receipts and canned food. For example polycarbonate (PC) plastic may release bisphenol A (BPA) which has been associated with endocrine disorders and a weakened immune system.[85] BPA and phthalates have epigenetic effects (activating certain genes).[86] One can cut their consumption of these with smart choices[87] for example by discontinuing the use of plastic water bottles.[88]

Products containing xenoestrogens:[89]

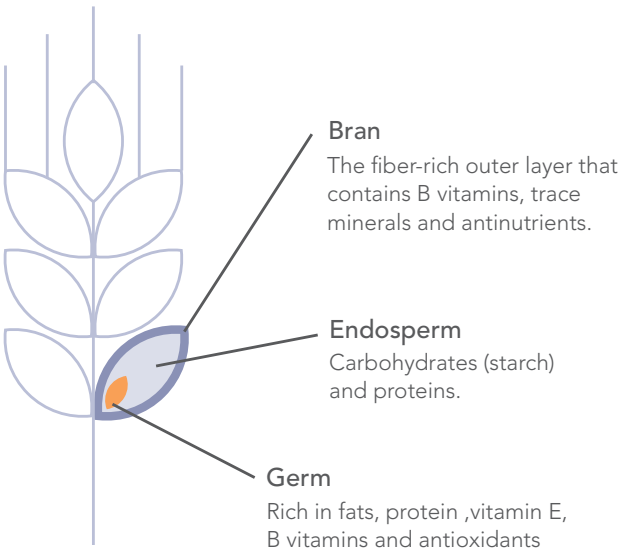
- Intensively farmed meat
- Canned food
- Plastics and plastic cling film
- Styrofoam cups and containers
- Pesticides
- Paints, varnishes and solvents
- Many hygiene products
- Phytoestrogens (estrogens derived from plants)
- Synthetic fragrances
- Contraceptive pills and spermicides
- Cosmetics (including hair dyes)
- Detergents
- Air fresheners



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ANTINUTRIENTS

Antinutrients are natural or synthetic compounds that prevent nutrients from being absorbed, and may cause health problems. It is therefore useful to know which foods contain them and how food can be processed to minimize their harmful effects.



KERNEL COMPOSITION

Antinutrients are often found in plant roots and seeds, nuts, legumes and nightshades. All plants have protective mechanisms. The purpose of antinutrients is to protect the plant from external factors such as bacteria, molds, insects and pests. Indeed, it makes sense for the protective measures of plants to also cause intestinal problems.

LECTINS

Lectins are carbohydrate-binding proteins that appear in plants and animals. Lectins protect plants from various micro-organisms such as insects and pests.[90] The roots and seeds of plants are particularly rich in lectins.[91] Foods containing lectins include legumes (beans, peas, lentils, soybeans, peanuts), cereals ,potatoes, nuts and seeds.[92 93]

Lectins have the ability to bind with the surface cells of the digestive tract. This may cause increased gut permeability and disruptions in digestion.[94] Raw kidney beans are particularly toxic. They contain high levels of hemagglutinin, a substance that has the ability to cause red blood cells to agglutinate.

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It has been suggested that a link exists between lectins and some autoimmune diseases such as rheumatoid arthritis.[95] According to one research hypothesis, lectins may cause leptin resistance (cf. insulin resistance) that may contribute to the development of obesity and metabolic disorders.[96]



PHYTATES

Phytic acid is present in plants in salt form, i.e. phytates. Phytic acid can be found in the seeds of cereals and legumes as well as nuts. Phytic acid forms chelates with zinc, manganese, copper, iron and magnesium and may therefore impair the absorption of these minerals.[97] Typically the bacterial strain of the intestine contains few phytase enzymes which are able to break down phytates.



CYANOGENIC GLYCOSIDES

Cyanogenic glycosides consist of a sugar molecule bound to a cyano group via a glycosidic bond. They are so-called phytotoxins which function as a part of the plant's defense system. Edible plants that contain significant amounts of these compounds include cassava and sorghum.

Phytotoxins can also be found in bamboo shoots, almonds, and the seeds of plums, cherries, peaches and apricots.[98]



OXALATES

Oxalates are compounds consisting of oxalic acid and anions, salts or esters. Oxalic acid is a poisonous substance that may damage the intestinal wall and cause kidney stones by forming calcium oxalate crystals.[99] Plants rich in oxalate include spinach, parsley, wood sorrel[100] and rhubarb as well as beetroot, black pepper, cocoa beans, cereals, legumes (particularly soybeans) and nuts.[101]



SAPONINS

Saponins are glycosides consisting of steroids and triterpenes. They were named after their ability to form soap-like foamy structures in solutions. They are an essential part of the plant's defense system.[102] Saponins are found in vegetables such as soybeans, beans, peas, as well as quinoa, oats, asparagus, licorice root, sunflower seeds and ginseng.

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Saponins have several beneficial effects (including anti-carcinogenic and immune system stimulating).[103] On the other hand, saponins have harmful digestive effects (impaired absorption of proteins and minerals, particularly in the case of soybeans)[104] and hypoglycemic effects (sharp drop in blood sugar).



GLYCOALKALOIDS

Glycoalkaloids are organic compounds bound with various sugar groups. They are naturally-occurring poisons in certain plants and their purpose is to protect these plants from animals. Nightshades generally contain various amounts of glycoalkaloids. A typical example is the solanine found in potatoes. It is poisonous when ingested raw in large quantities (breaks down cell membranes[105] and inhibits cholinesterase, i.e. the functioning of substances that break down acetylcholine, etc.). Potato skins may cause intestinal damage, particularly when fried and consumed regularly for long periods of time.[106] Raw green tomatoes also contain high levels of glycoalkaloids (tomatine).[107]



PROLAMINS

Prolamins are nitrogen-storing proteins found in cereals. Prolamins are rich in glutamine and proline (amino acids). They include gliadin (a part of the wheat gluten protein), hordein (barley), secalin (rye), avenin (oat) and zein (corn). The core parts of oats and rice grains contain relatively low levels of prolamin.

Prolamins cause intestinal damage particularly in individuals suffering from celiac disease. Celiac disease involves gliadin attaching itself onto the surface of the epithelial cells in the intestine and releasing zonulin which causes gut permeability by damaging the tight junctions between the epithelial cells.[108] In healthy individuals, the effect of gliadin on gut permeability is significantly lesser although perceptible.[109]



GOITROGENS

Goitrogens are substances that interfere with the iodine storage process of the body. Goitrogens include soy-beans,[110] pine nuts, peanuts, linseeds, spinach, peaches,

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strawberries, and plants of the Brassica genus such as broccoli, Brussels sprouts, cauliflower, radishes, kale and Chinese cabbage, as well as rapeseeds and horseradishes.[111]

More so than food, the main cause of the goitrogenic effect in the body is due to goitrogens such as heavy metals, insecticides, dioxin, PCB, and several medicines such as NSAIDs and cholesterol medicines.[112]



PHYTOESTROGENS

Phytoestrogens are plant-derived xenoestrogens (substances that imitate estrogen) that affect the functions of the endocrine system. The highest level of phytoestrogen in food is found in soybeans. Other sources include legumes, alfalfa, vegetable oils (rapeseed/canola and sunflower), cereal products and processed meat products.[113]

Phytoestrogens bind to estrogen receptors[114] and thus may interfere for example with the female menstrual cycle. It is recommended that pregnant women or those trying to become pregnant avoid phytoestrogens due to their estrogenic effects. The use of soy-based infant formula is also not recommended.[115]

Phytoestrogens were previously believed to have an effect on male fertility and testosterone levels. However, a meta-analysis study on the subject published in 2010 did not indicate negative or positive effects on fertility or testosterone levels in the blood.[116]



ENZYME INHIBITORS

Enzyme inhibitors are molecules that occur naturally in some plants. They interfere with the function of various digestive enzymes. For example, protease inhibitors that inhibit the function of trypsin and pepsin can be found in raw soybeans.[117] Amylase inhibitors, high levels of which are found in kidney beans, are another example of enzyme inhibitors. Amylase inhibitors interfere with the breakdown and absorption processes of starch and other complex carbohydrates in the digestive system.[118]

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METHODS OF REDUCING ANTINUTRIENTS[119 120 121]

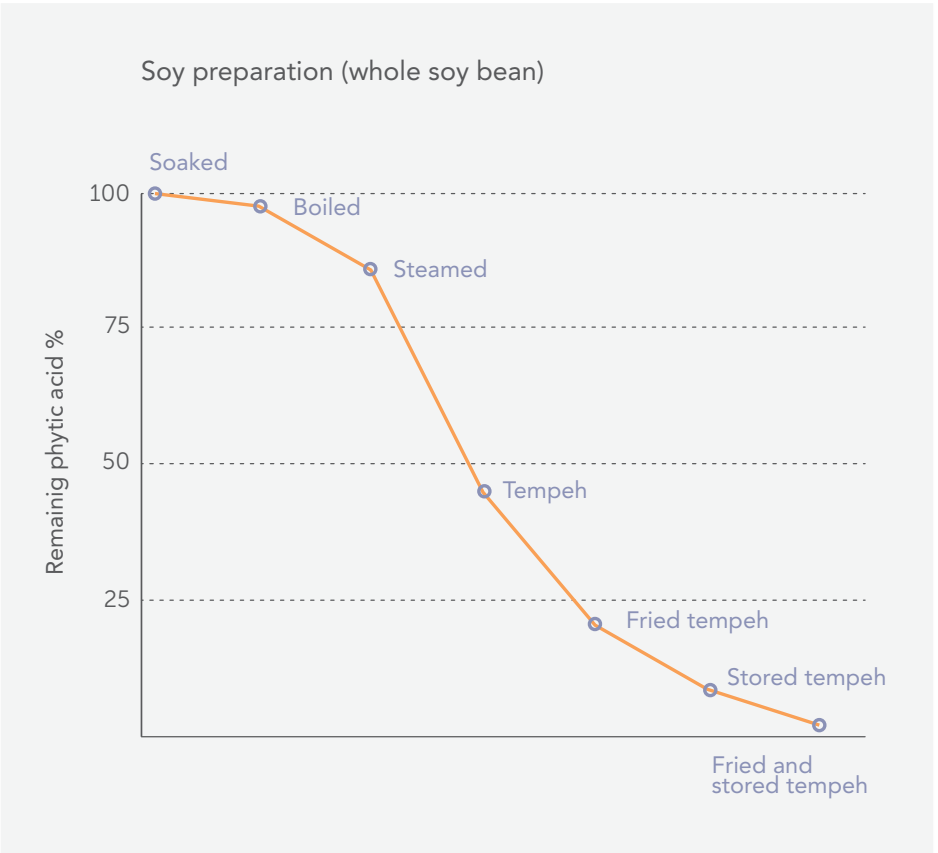
- **Sprouting**
- **Soaking** (adding lactic acid bacteria, diluted hydrogen peroxide, iodine, vinegar or baking soda to the soaking water may boost the soaking process, e.g. for removal of phytates)
- **Boiling or blanching** (reduces oxalate levels, etc.)
- **Cooking** (significantly reduces lectin and oxalate levels)
- **Lactic acid fermentation** (significantly reduces phytotoxins in cassava and phytic acid in cereal products)

It is recommended to combine several methods to achieve the desired effect.[122] The condition of the intestinal mucous membranes may be improved by using lactic acid bacteria,[123] colostrum,[124] glutamine[125] and silica.[126]

PROCESS OF QUINOA PREPARATION	PHYTATE REDUCTION
Cooking (25 minutes, 100°C / 212°F)	15–20 %
Soaking (12–14 hours, 20°C / 68°F) and cooking	69–77 %
Fermenting with whey (16–18 hours, 20°C / 68°F) and cooking	83–88 %
Sprouting (30 hours, 30°C / 86°F), soaking, lacto-fermenting and cooking	97–98 %

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REDUCING PHYTATE LEVELS USING VARIOUS METHODS



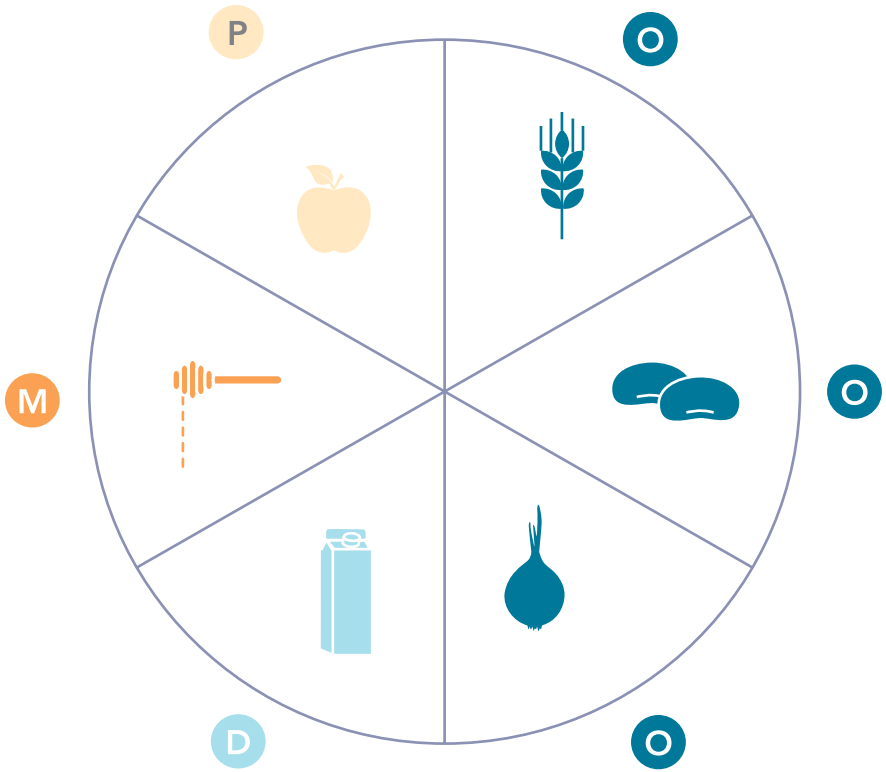
Source: Reddy, N. et al. (2001). *Food Phytates*. CRC Press.

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FODMAP CARBOHYDRATES

The acronym FODMAP is derived from *Fermentable Oligo-, Di-, Mono-saccharides And Polyols*. In practice it means carbohydrates that are particularly suitable for fermentation by the bacteria in the colon. Fermentation produces short-chain fatty acids (SCFA) that have significant health-promoting effects[127] (see section "Microbiome" for more details).

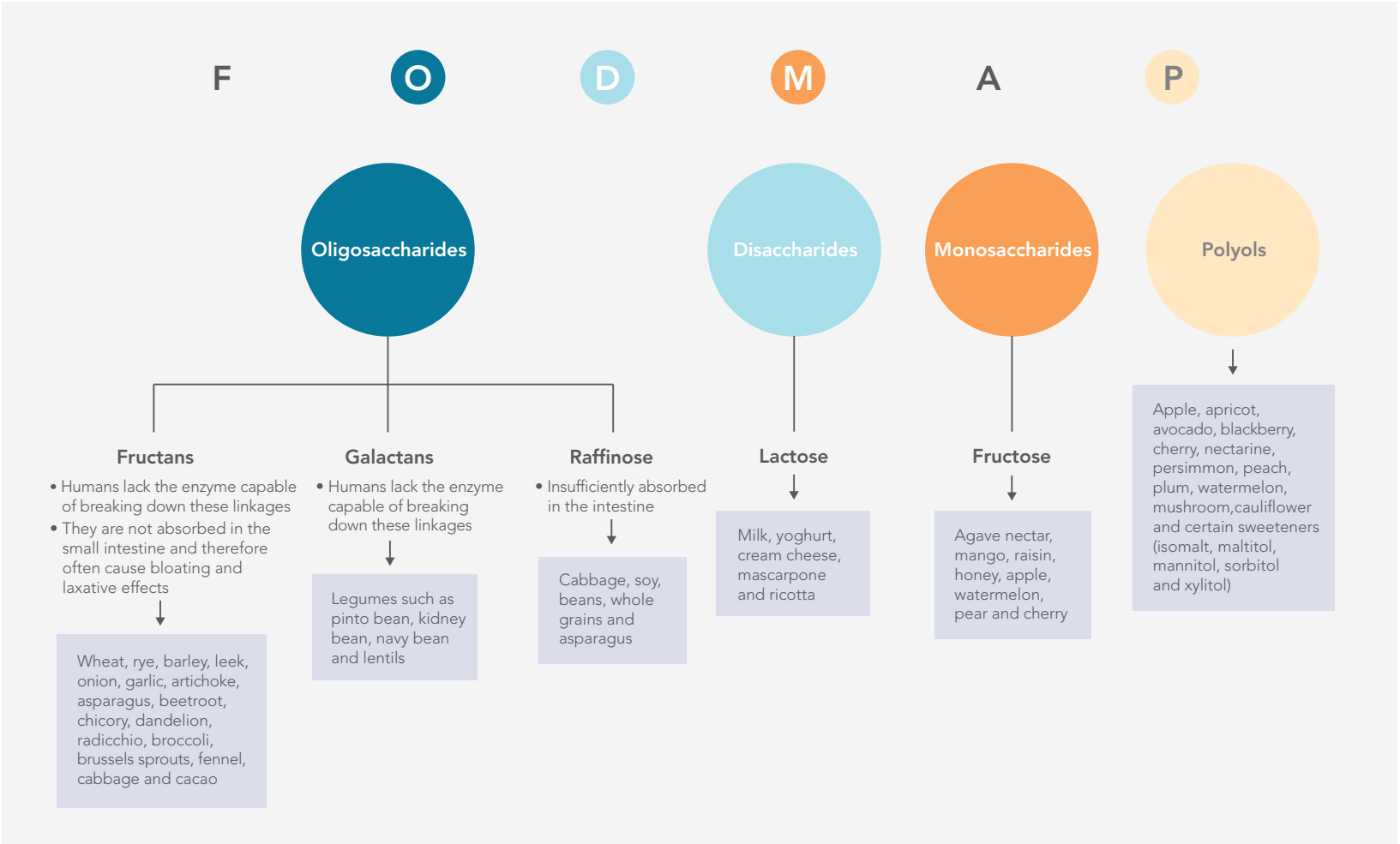
On the other hand, the fermentation process forms gases in the intestine, potentially causing bloating and flatulence. The FODMAP carbohydrate restrictions are particularly suitable for individuals suffering from irritable bowel syndrome (IBS).[128] The recommended restriction for IBS is less than 10 grams per day.[129]



EXAMPLES OF FODMAP FOODS

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FODMAP CATEGORIES



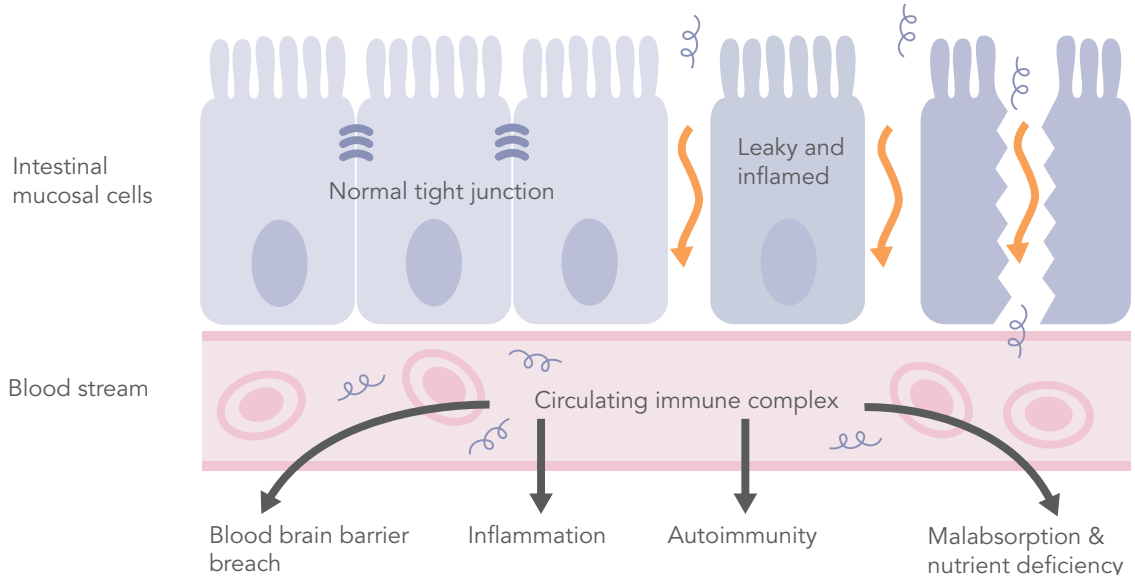
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INTESTINAL BACTERIAL STRAIN AND HOW TO SUPPORT THE DIGESTIVE FUNCTION

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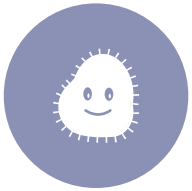
The bacterial strain of the intestine changes quickly whenever dietary adjustments are made. Studies on mice have found that upon changing the diet, the microbiome may change overnight. Similar changes also take place in humans but the exact time span is currently not known.[130] Switching to a more intestine-friendly diet has brought positive results in the treatment of chronic inflammation, obesity and gut permeability.[131]

Gut permeability refers to the changed state of the epithelial cells on the surface of the intestine. Normally nutrients are absorbed through the epithelial cells. However, sometimes, the cells and the tight junctions between them start to "leak" and allow harmful substances into the circulation. Celiac disease is a typical example of an autoimmune disease involving gut permeability. Increased gut permeability (leaky gut syndrome) is one of the key factors in the development of autoimmune diseases. However, whether it is a cause or an effect is currently not known.[132 133]



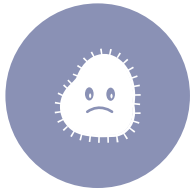
SO-CALLED LEAKY GUT

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Add these to support the microbiome:

- Fermentable fibers, i.e. prebiotics[134] [135]
  - For example inulin, pectin and oligofructose
- Fermented foods (see section "Probiotics" for more details)[136] [137]
- Resistant starch[138] [139]
  - Found for example in green bananas, cooked and subsequently refrigerated rice and potatoes as well as cereals
- Polyphenols[140]
- Dark chocolate (contains polyphenols and fermentable fibers)[141]
- Pistachios[142]
- Probiotics (certain bacterial strains, particularly soil-based ones)



Avoid these to protect the microbiome:

- Antibiotics (unless absolutely necessary for the treatment of illness)[143]
- Pesticides containing glyphosate (including Roundup)[144]
  - Used as a pesticide particularly on cereals, genetically modified soybeans and corn
  - Meat from animals that have fed on the plants mentioned above
  - May be one of the main factors contributing to the development of celiac disease[145]
- Smoking[146]
- Alcohol[147]
- Chronic stress[148]
- Continuous negative thoughts and feelings[149] [150]

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PROBIOTICS

Probiotics refer to living microbes that have positive effects on health. The benefits become apparent through the balancing of the microbiome in the digestive tract. Probiotic bacteria can be created in laboratory conditions or used as soil-based organisms (SBO).

Probiotics have numerous health benefits that have been widely studied in meta-analysis studies:

- Alleviating constipation[151]
- May help in the treatment of acute diarrhea[152]
- Preventing traveler's diarrhea (particularly Saccharomyces Boulardii)[153]
- Facilitating the treatment of irritable bowel syndrome[154]
- Stopping the progress of inflammatory intestinal diseases, may facilitate recovery (particularly Lactobacillus acidophilus and Bifidobacterium lactis)[155] [156]
- Facilitating recovery from non-alcoholic fatty liver disease[157]
- May prevent a common cold[158]
- Preventing and treating diarrhea caused by antibiotics[159]

Probiotics available from food:

- Sauerkraut and other fermented vegetables[160]
- Fermented vegetable juices
- Kefir
- Kombucha
- Kimchi
- Natto
- Tempeh
- Jun tea (fermented tea beverage)

Probiotics in the book's bonus materials:

biohack.to/nutrition

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PREBIOTICS

Prebiotics refer to indigestible fiber compounds such as oligo- and polysaccharides used as a growth medium by the bacterial strain of the intestine. The use of prebiotics promotes the growth of benign probiotic bacteria such as bifidobacteria and lactic acid bacteria in the intestine. The intake of prebiotics may have positive effects on the absorption of trace elements,[161] the immune system,[162] blood pressure, and the reduced risk of colon cancer.[163]

PREBIOTICS AVAILABLE FROM FOOD

The table shows the foods richest in prebiotics. High levels of prebiotics can also be found for example in potato starch which has been introduced in recent years as a dietary supplement to support the bacterial balance of the intestine. Potato starch is rich in resistant starch which is beneficial to the microbiome.[164] In addition to general prebiotic health benefits, resistant starch has been shown to have beneficial effects on insulin sensitivity and obesity as well as hunger regulation both in rodents[165 166 167] and humans.[168 169 170 171] Inulin and oligofructose are prebiotics that promote the well-being of the intestine. They also have health benefits similar to those of dietary fiber.

THE RATIO OF INULIN TO OLIGOFRUCTOSE PER 100 G[172]

Chicory root	41.6 g / 2.9 g
Jerusalem artichoke	18 g / 1.5 g
Dandelion leaves	13.5 g / 10.8 g
Garlic	12.5 g / 5 g
Leek	6.5 g / 5.2 g
Asparagus	2.5 g / 2.5 g
Banana	0.5 g / 0.5 g

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METHODS THAT SUPPORT DIGESTION

REVIEW EATING HABITS

- Chew carefully
- Avoid stress at mealtimes
- Spend at least 20 minutes eating
- Avoid drinking liquids during meals (dilutes stomach acids)

REVIEW FOODS THAT SUPPORT DIGESTION

- Fresh carrot juice (supports intestinal mucous membranes)
- Celery juice (promotes intestinal movements and alleviates constipation)
- Level of hydrochloric acid (betaine hydrochloride, HCL)
- Carminatives reduce gas in the intestine:
  - Orange, fennel, ginger, cinnamon, cardamom, cilantro, caraway, licorice, oregano, parsley, peppermint oil, rosemary, sage, lemon balm, dill, thyme, garlic
- Bitters stimulate the production of stomach acids and digestive enzymes:
  - Jerusalem artichoke, Angelica sylvestris root, yellow gentian, Angelica archangelica root
- Other foods that support digestion:
  - Aloe vera, pineapple, chia seeds, chlorella, sauerkraut, currants, Iceland moss, chamomile, cranberries, oats, meadowsweet, blueberries, oregano, chaga mushrooms, papaya, linseeds, horse radishes, lingonberries, psyllium, rhubarb root, plantago, rosehip, spirulina, sea buckthorn, raspberry leaf, wheatgrass, valeriana

REVIEW DIETARY SUPPLEMENTS THAT SUPPORT DIGESTION[173]

- Hydrochloric acid and pepsin
- L-glutamine:[174]
  - Maintains the condition of the intestinal mucous membrane
  - Repairs gut permeability
- Silica and silicic acid-carmellose gel:[175]
  - Protects the mucous membrane of the stomach
- Magnesium

– May facilitate defecation and improve the movements of the digestive tract

– An important mineral for the intestinal epithelium

- Vitamin B12
- Vitamins A, D and E:
  - Improve the regeneration of mucous membranes
- Phospholipids and lecithin:
  - Promote the absorption of fats
- Digestive enzymes

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FOOD PREPARATION METHODS

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Choosing a food preparation method carefully can have a significant effect on the quality and absorbability of the resulting meal, as well as the amount of any harmful compounds in it.

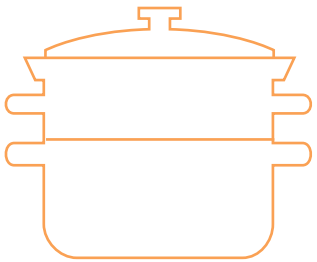
No single preparation method is perfect. Some ingredients are best eaten raw, whereas in many cases proper preprocessing improves nutrient absorption and significantly facilitates the function of the digestive system.

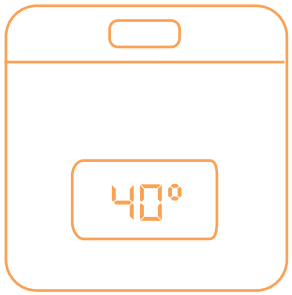
A balanced mixed diet consists of both cooked and fresh ingredients. The benefits and disadvantages of cooking complement each other when executed properly.

Quality-minded food preparation methods improve flavor, retain precious nutrients and reduce the amount of harmful compounds formed when the food is treated in high temperatures.

+ Favor the following preparation methods:

- Slow cooking
- Boiling
- Stewing
- Steaming
- Oven-baking slowly
- Sous-vide
- Raw food
- Fermentation
- Frying with water





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– Avoid or use sparingly the following preparation methods:

- Frying at temperatures higher than 140 °C (285 °F)
- Stewing in tinfoil
- Grilling
- Cooking in the microwave oven
- Flambéing
- Smoking
- Deep frying

Harmful bacteria, viruses and parasite eggs are destroyed during cooking. Heating also breaks down certain harmful compounds. For example, the oxalic acid level in spinach is reduced when heated, and the potentially carcinogenic compounds in champignons break down when the mushrooms are adequately cooked.

Some nutrients are lost upon heating. For example, many of the proven beneficial agents in broccoli are destroyed when heated.[176] The levels of water-soluble Vitamins B and C are reduced when the ingredients are boiled. Many minerals are also dissolved in cooking water. Steamed food retains its nutrients significantly better.

Cooking may improve the absorption of certain nutrients. The beta-carotene in carrots and lycopene in tomatoes are absorbed more efficiently once cooked.[177] Only 4 % of the beta-carotene in a raw carrot is absorbed. Pureeing and cooking may increase the absorption rate fivefold. On the other hand, carotenoids may become less beneficial when cooked.

The Maillard reaction (browning) improves the flavor of food but impairs the absorption of proteins.[178] The reaction forms compounds that produce brown color and flavors that are central to the color and taste of many foods (MRP compounds). The Maillard reaction starts at approximately 140 °C (285 °F). The Maillard reaction also produces carcinogenic compounds when the temperature exceeds 180 °C (355 °F).[179]

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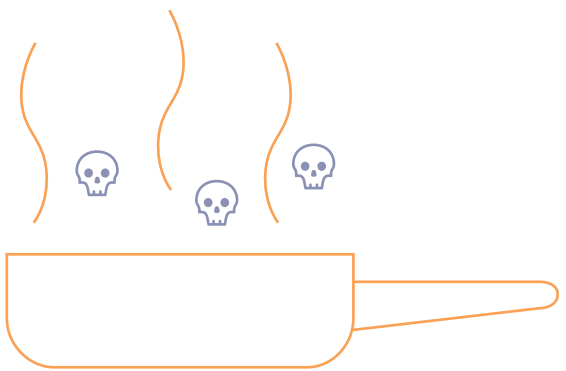
COOKING AND HARMFUL COMPOUNDS

Harmful compounds form in food at high temperatures. These include glycotoxins (advanced glycation end-products, AGEs), heterocyclic amines (HCAs), polycyclic aromatic hydrocarbons (PAHs) and acrylamide (AA). Food that contains high levels of cooking-induced toxins is harmful because it increases oxidative stress, raises the levels of inflammatory biomarkers and weakens the arterial walls.[180] Thus it can increase the risk of diabetes and cardio-vascular diseases.[181]

Cut the intake of glycotoxin-rich foods such as full fat cheese, butter, bacon, sausage and processed meat. Acrylamide, formed during the browning of vegetables, has a distinctive yellow or dark brown color. The toxins formed while frying fat and protein-rich foods are more harmful than those formed while frying carbohydrate-rich foods.[182]

Instead of frying, consider boiling. For example, a chicken breast fried for 8 minutes forms more than 6 times the amount of harmful glycotoxins compared to a chicken breast boiled for an hour. Temperature, not cooking time, is key.

Tinfoil is typically used for stewing meat or fish on a grill or in an oven. Stewing in tinfoil reduces the formation of glyco-toxins and HCAs, but the amount of aluminum released into the food is up to 6 times the amount considered a safe daily upper limit.[183]



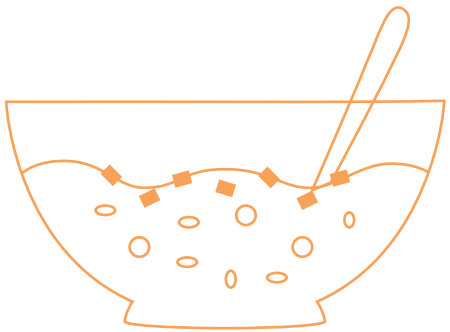
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MARINADES

Throughout history, food has been marinated in herbs, fats, citrus fruit, vinegar and alcoholic beverages such as wine and beer to preserve the food and improve its flavor. Studies have also found that marinades affect the amount of harmful compounds forming in cooked food.

Reducing harmful compounds by marinading:

- The amount of HCAs is reduced by up to 90 % when the meat is marinated for 4 hours or more in alcoholic beverages and strong spices such as garlic, ginger, thyme, rosemary and chili,[184] or when food is marinated for 6 hours or more in beer[185]
- Cherries, blueberries, blackcurrants, plums and kiwifruit used in marinades effectively reduce the amount of HCAs[186]
- Adding vitamin E to the marinade reduces the amount of HCAs[187]
- Adding vitamin C reduces the amount of glycotoxins[188]
- Adding turmeric diminishes the effect of glycotoxins[189]
- Frying in extra virgin olive oil produces the least HCAs compared to other oils such as rapeseed oil[190]
- The amount of AGEs can be reduced by using sour ingredients such as lemon juice and vinegar in the marinade[191]
- The amount of potentially carcinogenic substances can be reduced by adding glucose during browning[192]
- The amount of acrylamide in potatoes can be reduced by blanching them before frying[193]
- Adding amino acids such as glycine and glutamine to the dough before baking reduces the amount of acrylamide by up to 90 %[194]



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SOUS-VIDE

With the sous-vide method, food is prepared under water in a sealed vacuum bag while maintaining careful control over the temperature.

Benefits of the sous-vide method:

- Close control of the temperature-induced changes of ingredients
- Cooking temperature can be reduced
- Cooking time can be increased
- Pathogens can be minimized through pasteurization
- Precooking extends the shelf life and makes cooking quicker and easier
- Flavors, nutrients and liquids are retained better (particularly in the case of vegetables such as carrots)[195]

Disadvantages of the sous-vide method:

- Sous-vide bags may release toxins
- Sous-vide bags are expensive and not ecological

To ensure safety, attention should be paid to the recommended cooking temperature and time of the chosen ingredient. As a rule of thumb, cooking at a minimum of 55 °C (131 °F) for an hour or more is usually sufficient to destroy pathogens such as Listeria, Salmonella, Helicobacter pyroli and Trichinella.[196]

TIP

TRY COMBINING MUSTARD SEEDS AND BROCCOLI IN A SOUS-VIDE BAG

Eating fresh, uncooked broccoli with a meal reduces the mutagenic effect of HCAs.[197] This is thanks to broccoli's sulphur-rich compounds which are normally weakened upon cooking. The effects of the compounds can be retained when using sous-vide by adding mustard seeds into the bag.[198]

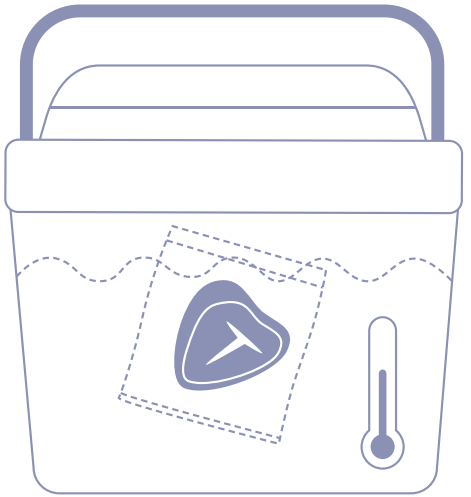
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RECIPE

DIY SOUS-VIDE

If you are not yet ready to invest in a sous-vide cooker, you can test the technique at home by using common utensils. You just need a thermometer, a cooler box and a watertight ziplock bag.

Place the food in the ziplock bag. Lower the bag into the water and squeeze the air out of the opening. Close the bag just before the opening reaches the water surface. Fill the cooler box with water that is 2 degrees (35 °F) warmer than the target temperature. Lower the bag into the water and close the lid. Check the water temperature every 20 minutes. If needed, add warm water to maintain the target temperature. After a sufficient cooking time, remove the bag from the water and enjoy.



Food that has been properly precooked, rapidly cooled and kept refrigerated in an unopened sous-vide bag will usually keep for at least a week, or several months if frozen. Adding marinades or vitamins C or E[199] to the sous-vide bag will extend the shelf life due to reduction of the oxidation of ingredients. Favor bags that do not contain BPAs, phthalates or plasticizers. Bags made out of polyethylene or silicon are usually the safest.

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PRESERVING

In the course of history, a wide variety of methods has been used to preserve food. In recent decades the food industry has made significant developments in food additives and preservatives as well as introducing new processing methods. In practical terms most of us preserve food in a refrigerator, freezer or pantry on a regular basis. In addition to this, the lifespan of various ingredients can be extended with smart choices of storage material, correct preservation methods and high quality health-promoting preservatives.

Avoid using photodegradable materials such as plastic containers for preserving food. Favor ceramics, metal and glass.

Recommended approaches to preservation:

- Protecting from light in dark or tinted containers
- Protecting from heat for example by utilizing a root cellar or refrigerator
- Protecting from air in an airtight container or vacuum bag
- Drying and freeze-drying
- Sterilizing at high temperatures
- Preventing oxidation with strong spices
- Preventing oxidation with vitamins C and E
- Preserving in a modified atmosphere, honey, sugar, alcohol, vinegar, lemon juice, salt or oil



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ENSURING THE SUFFICIENT INTAKE OF NUTRIENTS

To a large extent, nutrient intake guidelines are based on population-wide studies regarding the frequency of deficiencies and certain illnesses caused by poor nutrition.[200] However, these guidelines do not necessarily reflect an individual's optimal nutritional level which can vary considerably due to genetic and epigenetic factors. Mutations are constantly taking place in each one of us. These mutations can cause unique differences in the DNA sequence.[201]

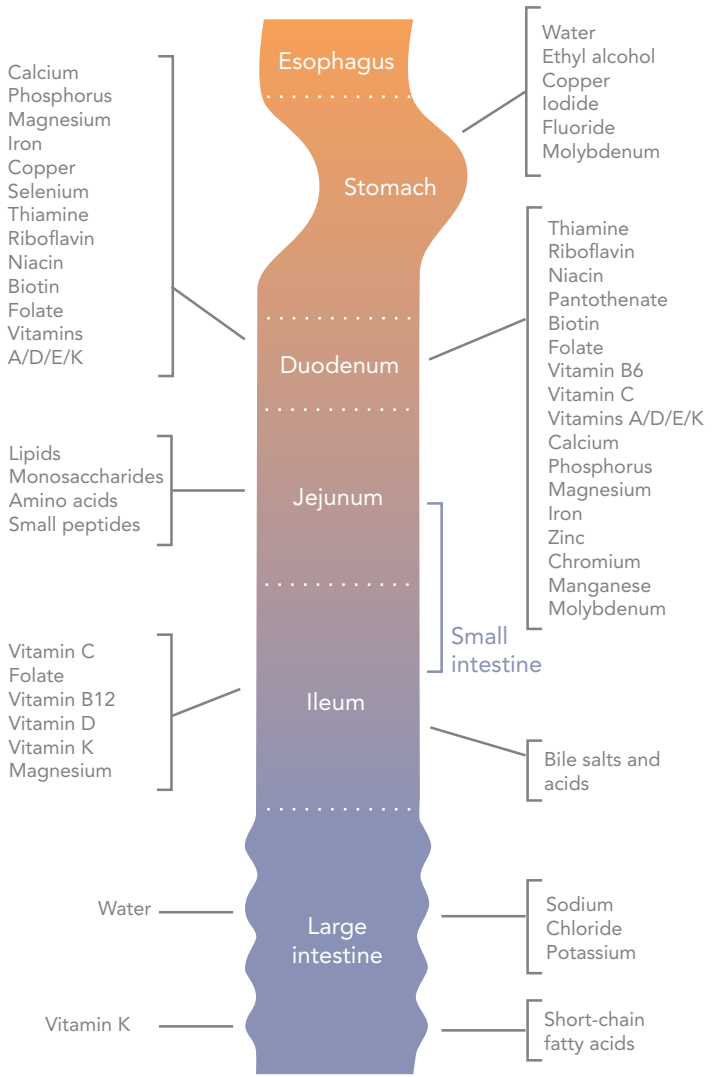
From the viewpoint of dietetics and nutrition, these differences can alter the individual requirements of certain trace elements and vitamins. In many cases, mutations directly affect the coenzyme function of vitamins and trace elements (for example zinc, vitamin B6 or choline) and the requirements for these nutrients in the body.[202] Assessing the individual nutritional requirements should therefore always be the first priority for designing dietary recommendations.

DIETARY REFERENCE VALUES	DESCRIPTION
Lower intake level	The minimum amount required to prevent deficiency. Not sufficient to maintain good health and nutrition.
Average requirement	The nutrient amount that meets the average requirements of general population or a specific population group.
Recommended intake	The nutrient amount that meets the nutritional needs of nearly all healthy individuals.
Optimal intake	The individual's current optimal nutrient amount that helps to achieve the best possible state of health.

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Nutrient levels depend greatly on unique absorption rates. It is not possible to take this factor into account when drafting general dietary guidelines. If the digestive functions are not performing, nutrients are not absorbed to the extent perhaps expected. Optimal nutrient intake should therefore begin by improving digestive processes.

Bruce Ames, an American professor of biochemistry and molecular biology, has studied cancer and aging over the course of several decades. According to Ames' triage theory of micronutrients and aging, the body uses the nutrient reserves of various internal organs to maintain short-term health in a state of malnutrition. For example, in the event of iron deficiency, the body uses the iron reserves of the liver to maintain normal bodily functions. Long-term deficiency of minerals and vitamins weakens the body and causes DNA and mitochondrial damage.[203] This may lead to cancer and the acceleration of aging. Ames' recommendation for longevity is to meet the micronutrient requirements at all stages of life.[204]



NUTRIENT ABSORPTION

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THE MOST COMMON MICRONUTRIENT DEFICIENCIES AND THEIR AVAILABILITY IN FOOD

MICRONUTRIENT	FREQUENCY OF DEFICIENCY	AVAILABILITY FROM FOOD AND OTHER REMARKS	HEALTH PROBLEMS CAUSED BY DEFICIENCY
Iron	Particularly in developing countries and some vegan individuals. Celiac disease, Crohn's disease and pregnancy are predisposing factors.	Blood, bovine liver, oysters, mussels, beef, sardines, dark green vegetables. Vitamin C promotes the absorption of iron.	The most common nutrient deficiency in the world. Causes anemia, susceptibility to infections, respiratory problems, hair loss, muscular problems, headaches, heart problems, fatigue, etc.
Vitamin B12	Particularly in vegans but increasingly common for other diets as well.	Bovine liver, sardines, salmon, eggs, soil.	Causes pernicious anemia, fatigue, dementia and depression. Increases the risk of coronary artery disease and osteoporosis.
Vitamin D	Deficiency occurs particularly in the northern hemisphere where sunlight is scarce.	The sun, fish, fish oil and mushrooms. Sufficient intake from food alone is difficult.	Predisposing factor for osteoporosis,[205] infections,[206] diabetes,[207] cancer,[208] cardiovascular diseases[209] and various neurological diseases.[210]
Iodine	A serious public health problem in the developing world, but as much as approx. 40 % of the people in the world are at risk.	Seaweed (particularly kelp/kombu), seafood and egg yolk. Impoverished soil is a predisposing factor for iodine deficiency.	Predisposing factor for hypothyroidism and goitre. Deficiency during pregnancy predisposes the child for cretinism.

Source: Ames, B. (2006). Low micronutrient intake may accelerate the degenerative diseases of aging through allocation of scarce micronutrients by triage. *Proceedings of the National Academy of Sciences of the United States of America* 103 (47): 17589–17594. Review.

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MICRONUTRIENT	FREQUENCY OF DEFICIENCY	AVAILABILITY FROM FOOD AND OTHER REMARKS	HEALTH PROBLEMS CAUSED BY DEFICIENCY
Selenium	Mild deficiency is common.	Brazil nuts, wild salmon, kidneys, mutton, egg yolk. Impoverished soil is a predisposing factor for selenium deficiency.	Increased risk of inflammatory diseases, cardiovascular diseases and cancer. Impaired immune response and activation of thyroid hormones.
Magnesium	Mild deficiency is very common around the world. Magnesium deficiency is particularly common in diabetic individuals.	Dark green vegetables, cocoa, nuts and seeds. Regulates the functioning of more than 300 enzymes in the body. Impoverished soil is a predisposing factor for deficiency.	Predisposing factor for cardiovascular diseases, diabetes, hypertension, fibromyalgia, osteoporosis, constipation and stress.
Zinc	Mild deficiency is relatively common particularly in vegans and the elderly. The low level of hydrochloric acid in the stomach is a predisposing factor for zinc deficiency.	Insects, oysters, calf liver, beef, pumpkin seeds, mutton. Regulates the functioning of more than 200 enzymes in the body.	Predisposing factor for poor condition of skin, hair and nails, weakened immune system and f ertility problems.
Vitamin K2	"The forgotten vitamin." A large proportion of people are deficient in vitamin K2. One of the leading causes for this deficiency is the use of antibiotics.	Natto, miso, sauerkraut, grass-fed butter, roe, fermented foods in general. Intestinal bacteria produce a small amount of vitamin K2.	Predisposing factor for tooth decay, dental plaque, osteoporosis and artery calcification.

Source: Ames, B. (2006). Low micronutrient intake may accelerate the degenerative diseases of aging through allocation of scarce micronutrients by triage. *Proceedings of the National Academy of Sciences of the United States of America* 103 (47): 17589–17594. Review.

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MEASURING THE STATE OF NUTRITION

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French chemist and physicist Nicholas Clément (1779–1841) introduced the concept of the calorie in the early 1800's.[211] *Calorie* is French and refers to a unit of energy that raises the temperature of 1 kg of water by one degree centigrade. The term gained popularity in measuring the energy content of food at the beginning of the 20th century.[212] However, the official term *kilojoule* is used in nutrition research and discourse as the unit of energy provided by food.

The importance of certain trace elements such as iron, iodine and zinc was realized as early as the 19th century. In his research, French chemist Jean-Baptiste Boussingault (1801–1887) proved that iron is an essential nutrient for human beings. Iodine deficiency was understood to cause goiter and cretinism – conditions in which the thyroid produces an insufficient amount of thyroxine. In France, schoolchildren were given iodine tablets to prevent goiter. In 1912, Cambridge University scientist Frederick Hopkins (1861–1947) discovered that in addition to macronutrients, human beings need so-called accessory factors to support the functions of the body.[213] Later these nutritional factors became known as vitamins.

The concept of micronutrients was introduced in the 1930's in the context of trace elements required by plants. Research on the recommended levels of micronutrient intake and their significance for health began in the 1940's. According to comprehensive studies, micronutrient deficiencies were very common in the industrialized countries. The proposed solution to this problem included introducing fish liver oil and modifying everyday food items (e.g. adding iodine to salt).[214]

The biohacker measures the functions of his/her body in relation to nutrition to acquire information about blood cells, vitamins, micro- and macronutrient levels, the microbiological status of the intestine, special genetic traits and any food-related hypersensitivities or allergies.

MEASURING THE NUTRITIONAL STATUS

It is wise to find out what your nutritional starting point is before making any significant dietary changes or investing in supplements. Have your nutrient levels and key blood values measured. Even if you feel healthy, getting tested may be beneficial for prevention.

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- Levels of micronutrients and trace elements
  - From blood
  - From hair
  - From urine
- Fatty acids
  - From blood
- Amino acids
  - From blood
  - From urine
- Heavy metals
  - From blood
  - From hair
  - From urine

TESTING FOR FOOD ALLERGIES AND HYPERSENSITIVITIES

Identifying the foods that are harmful or detrimental to the function of the body is particularly important. Eliminating these makes for significantly better physical and psychological performance and, above all, improved overall health.

Testing for food allergies:

- Trial elimination diet
- Skin prick test
- IgE and IgG antibody tests
- Open food challenge (milk and cereals)

ANALYZING THE INTESTINAL FUNCTION AND THE MICROBIOME

The intestinal function and bacterial balance of an individual can change very rapidly. These changes are linked to several illnesses that could be prevented or treated effectively by analyzing the functionality and microbiological balance of the intestine. Physical and psychological performance is also strongly linked to the condition of the intestine.

Digestion analyses:

- Comprehensive digestion analysis
- Measuring gut permeability and malabsorption
- Measuring the possible small intestinal bacterial overgrowth (SIBO)
- Measuring stomach acid and enzymes
- Testing for Helicobacter pylori

Microbiome analysis:

- Balance of the microbial bacteria
- Helpful bacterial strain
- Harmful bacterial strain
- Yeast fungi
- Amoebas and other parasites



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DAILY FOOD DIARY

Track the following nutritional factors:

- Macronutrient ratios (carbohydrates, sugars, fats)
- The micronutrient amounts available from the food eaten
- Calorie intake compared to the daily energy expenditure (basal metabolic rate and physical activity)
- The amount of water consumed (1.5–2 litres / 50–65 fl oz per day is recommended)
- The amount of caffeine consumed (max. 400 mg per day is recommended)
- The amount of salt present in the food eaten (max. 5 g per day is recommended)
- The regularity of mealtimes
- Photos of the meals eaten

There are smart scales and smartphone applications that estimate the nutritional content of a product by reading the bar code on the packaging.

GENE TESTS IN NUTRITION

Gene tests can be used to identify increased individual risks of various illnesses which are then taken into account when making lifestyle choices. It is important to understand that your lifestyle (including your diet) controls the function of your genes. Not all genes are constantly active. Epigenetics (the activation or deactivation of genes by factors external to the genome) can be perceived for example in the increased or decreased function of certain genes due to environmental factors such as diet.

Nutrigenomics involves the study of the effects of nutrition on the function of genes. For example, researchers at the Norwegian University of Science and Technology (NTNU) have found that cutting sugar consumption (to less than 40 percent of the energy content of the meal) can lower the risk of cardiovascular diseases, dementia, some types of cancer and diabetes.[215] Genes affect metabolism in a comprehensive way. Because of this, it would be a mistake to expect that a particular diet (such as a low-fat or low-carbohydrate diet) would produce the same results for everyone.

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Listed below are some gene variants that are worth noting in terms of diet:

VARIANT APOE4 OF THE APOE GENE

- Apolipoprotein E (APOE) is crucial for fat metabolism, particularly for breaking down lipoproteins (including LDL).
- Types 3/4 and especially 4/4 are associated with high cholesterol levels, carotid artery disease and Alzheimer's disease.[216]
- Although the cognitive processes of individuals with a type 4 variant deteriorate faster than usual, their brain function early in life is enhanced, particularly in the hippocampus.[217]

VARIANT PRO12ALA OF THE PPARG2 GENE

- PPARG (Peroxisome Proliferator-activated Receptor Gamma) is a nuclear protein that has an effect on obesity.
- The Ala type is associated with a lowered risk of developing type 2 diabetes.[218]
- However, a study conducted on mice found that for individuals with this variant, a high-fat diet increased obesity more rapidly and thus formed a predisposing factor for diabetes.[219]

VARIANTS IVS4G>T AND IVS3C>T OF THE TCF7L2 GENE

- TCF7L2 is a protein transcription factor.
- These variants are associated with an increased risk of developing type 2 diabetes.[220]

VARIANT TRP64ARG[221] OF THE B3AR GENE AND VARIANT GLN27GLU[222] OF THE B2AR GENE

- Beta-adrenergic receptors have a significant effect on energy production and the function of the sympathetic nervous system.
- These variants are associated with obesity.

VARIANT RS9939609(A) OF THE FTO GENE

- FTO = fat mass and obesity-associated protein
- Individuals with a type A variant have a significantly increased risk of obesity and developing type 2 diabetes.[223] [224]

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VARIANT RS4988235 OF THE MCM6 GENE

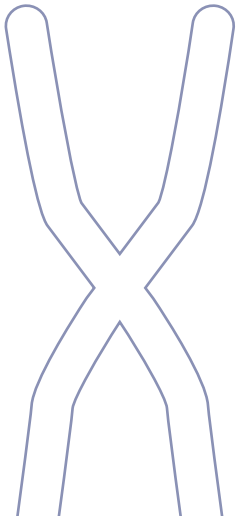
- Affects the production of the lactase enzyme (LCT).
- Individuals with a T type variant usually tolerate lactose.
- The C/T type variant is associated with obesity.[225]
- Individuals with a C/C type variant are likely to be lactose intolerant.[226]

VARIANTS HLA-DQ2 AND HLA-DQ8 OF THE HLA-DQ GENE

- HLA-DQ genes encode certain proteins as a part of the immune system.
- These variants are strongly associated with celiac disease.[227]

VARIANT A118G OF THE OPRM1 GENE

- The OPRM1 gene encodes opioid receptors.
- The type G variant can significantly increase alcohol dependency[228]



VARIANT I148M OF THE PNPLA3 GENE

- This variant of the PNPLA3 gene related to fat metabolism slows the breakdown of triglyceride fats in the liver and thus promotes the onset of fatty liver disease.[229]

VARIANT 164A>C OF THE CYP1A2 GENE

- Caffeine, mycotoxin and paracetamol (among others) are broken down in the liver mainly by the CYP1A2 enzyme.
- Each individual's CYP1A2 enzyme system functions at a different rate.
- Individuals with a type C variant have a slow enzyme system. For these individuals, drinking coffee can increase the risk of heart attack[230] and/or high blood pressure.[231]

VARIANTS C677T AND A1298C OF THE MTHFR GENE AND VARIANT A66G OF THE MTRR GENE

- Methylene tetrahydrofolate reductase (MTHFR) is an enzyme needed to convert folic acid and certain other forms of folate into methylfolate (5-MTHF). Folic acid can be found in vitamin supplements and vitamin-enriched foods.

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- Individuals with these variants are unable to efficiently convert folic acid into active folate. This results in a high homocysteine level, a known risk factor for cardiovascular diseases, particularly in individuals with variants C677T and A66G.[232]
- Switching from folic acid to more efficient methylfolate is recommended.

VARIANT A1 (TAQ1A POLYMORPHISM) OF THE ANKK1 GENE[233]

- ANKK1 (ankyrin repeat and kinase domain containing 1) is fundamentally linked to the dopamine D2 receptor (DRD2), i.e. reward and motivation.
- A mutation in this gene is a predisposing factor for addictive behavior (alcohol, tobacco, sugar, gambling, opiates).[234]
- The A1 allele is especially found in obese (BMI > 30) individuals.[235]

VARIANT RS1229984 OF THE ADH1B GENE

- Accelerates the conversion of alcohol into acetaldehyde (a more rapidly developing hangover).
- Individuals with this variant have a lowered risk of developing alcoholism.[236]

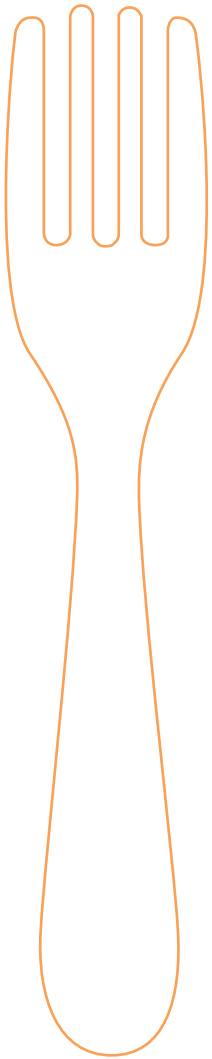
MUTATION OF THE ALDH2 GENE IN ISOENZYME ALDH2-2

- Significantly lowered isoenzyme ALDH2-2 activity (typically found in North Asia).
- A predisposing factor for adverse effects from alcohol and alcohol poisoning.[237]

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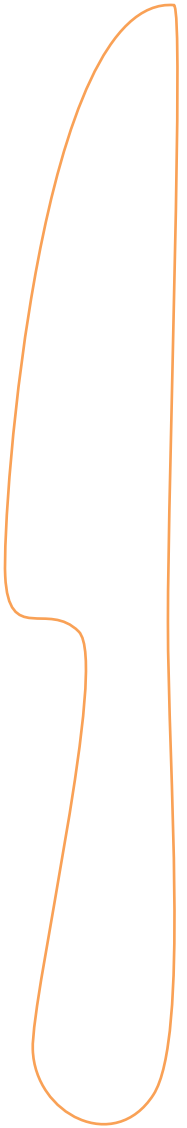
REVIEWING NUTRIENTS

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"EVERYTHING SHOULD BE MADE AS SIMPLE AS POSSIBLE, BUT NOT SIMPLER."

– Albert Einstein (1879–1955)

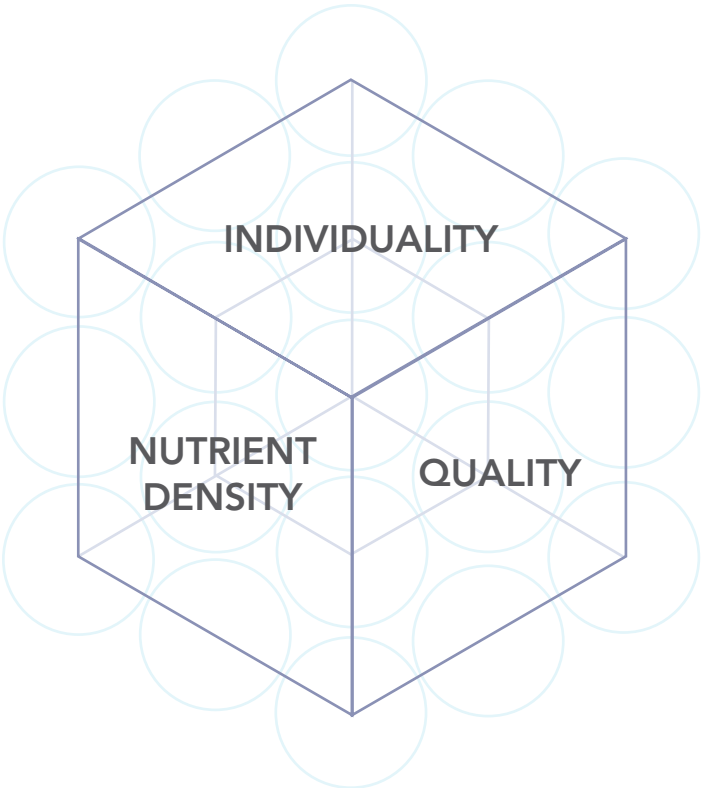


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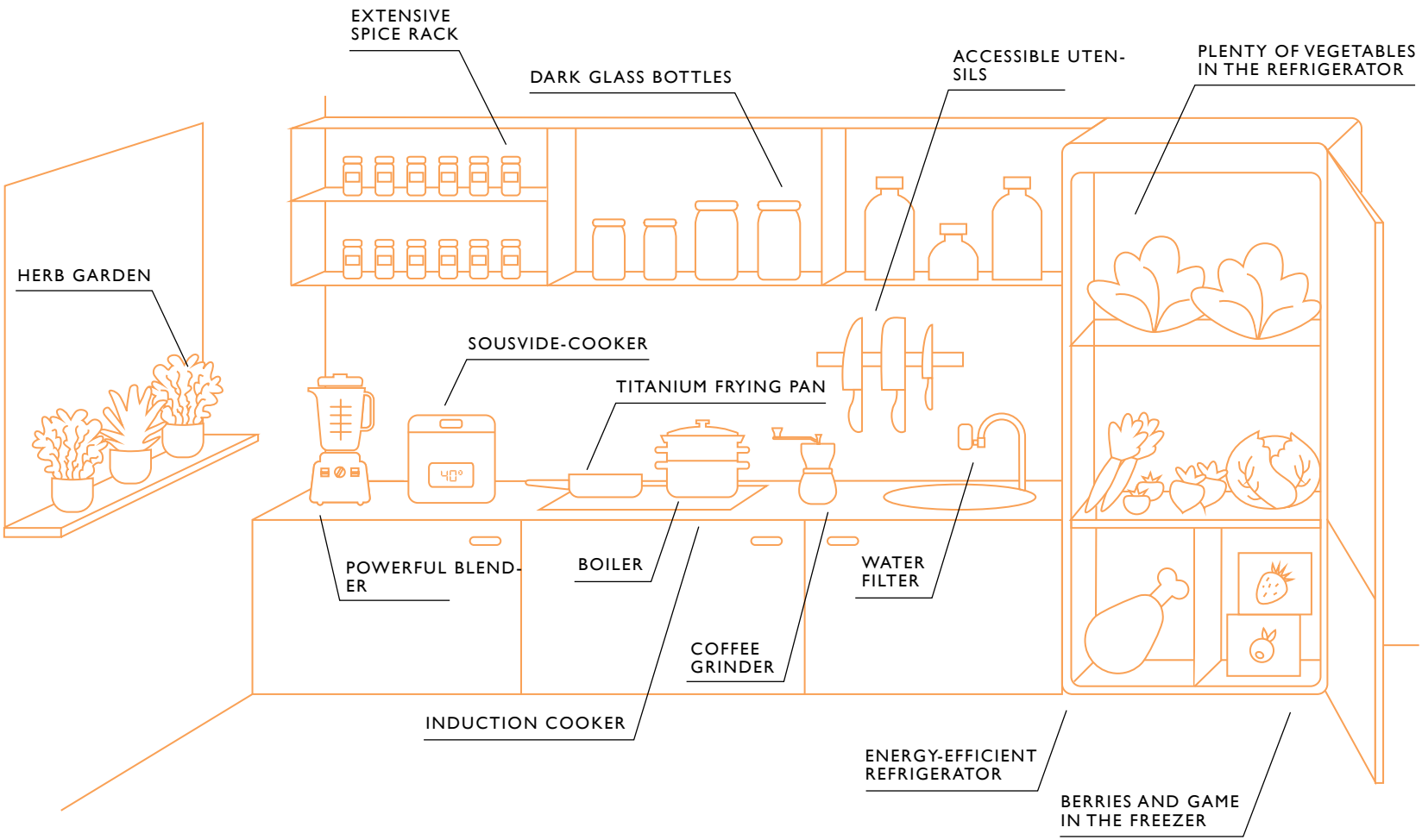
Dietary changes should be implemented with care. For instance, studies indicate that current, popular extreme diets can lead to micronutrient deficiencies.[238] On the other hand, ordinary home-cooked food may not fulfill dietary guidelines, either.

In this chapter we give guidelines for better, more nutrient-rich choices for individual ingredients. Low quality ingredients are relatively easy to rule out by applying a few core principles. To paraphrase Michael Pollan, the Knight Professor of Science and Environmental Journalism at UC Berkeley: "Do not buy anything your grandmother would not have recognized as food 50 years ago." This quickly eliminates convenience foods and the lowest quality products.

The rule of thumb is that the closer the food is to its original state, the more likely it is to have health-promoting properties. Meta-analyses have found that organically produced ingredients contain significantly more anti-oxidants and less heavy metals and pesticides than non-organic ingredients.[239]



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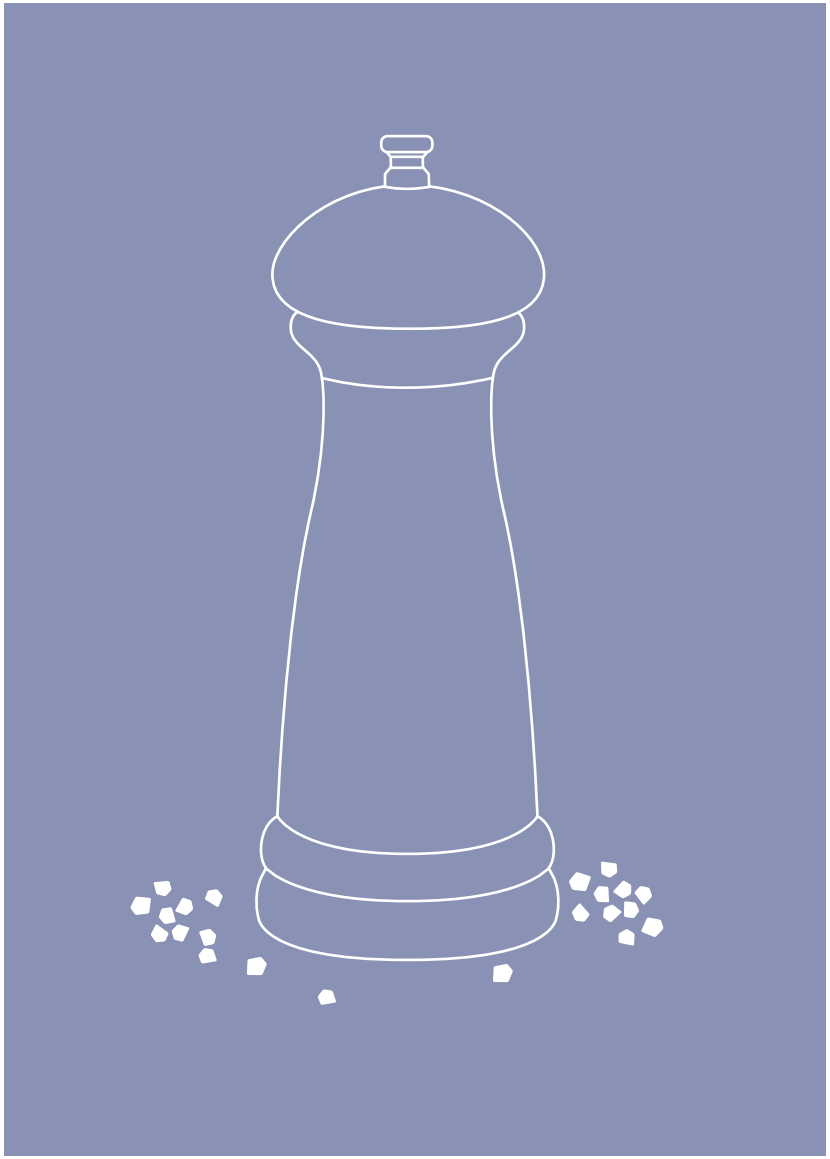
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SALT

In the Mediterranean countries, salt was once considered as valuable as gold. Soldiers of the Roman legion were partially paid in salt. It was referred to as *salarium argentum*, "salt money". This is also where the English term "salary" originates from. The Latin word "sal" is also thought to be the origin of the Roman word "salute," which in turn is associated with the Arabic "salaam," meaning "peace."

The global average salt intake in 2010 was around 10 grams per person per day. Around 80 % of total salt intake is so-called hidden salt that can be found in several processed foods (such as grain and meat products). For example bread can have as much salt as potato chips.

Cutting the consumption of table salt and hidden salt is generally recommended, as is using mineral salt which is rich in potassium and magnesium. Favoring mineral salt makes it possible to lower blood pressure without cutting salt consumption.[240] It should be noted that although excessive intake of salt is strongly associated with high blood pressure, insufficient salt intake is a health risk that is even more serious.[241]



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High quality salt enhances flavors, preserves food and maintains the fluid balance of the body. Sodium is essential to the body for carrying nerve impulses, maintaining muscle function and regulating fluid balance and blood pressure. Chloride is needed for digestion and respiration.

Natural salts are produced either by evaporating seawater or by mining ancient sea sediments. Favor coarse salt crystals and grind them at home using a salt mill. Consider the possible risk of heavy metals (including nickel) or plastic particles from poor quality salt mills contaminating the salt. The quality of the salt also depends on the cleanliness of the sea and the area in which the salt is handled.

Several countries add iodine to table salt to address the iodine deficiency problem. However, salt is not the best source of iodine. For example, one teaspoon of kelp provides as much iodine as one pound of iodine-enriched sea salt.

TIP

MIX TOGETHER DIFFERENT TYPES OF SALT (such as sea salt, rose salt and black salt) and dried herbs (such as rosemary, basil and mint), if desired. This increases the nutritional density and aromas of the salt used.

+ Favor:

- Purity-tested, unrefined sea salts
- Mineral salts
- Pink salts sold under various names (Himalayan salt, rose salt, rock salt, halite)
- Black salts
- Herbamare seasoning
- Rare specialty salts (bamboo salt, river salt)

− Avoid:

- Common refined salt and table salt
- Seasoned salt (with monosodium glutamate, MSG)

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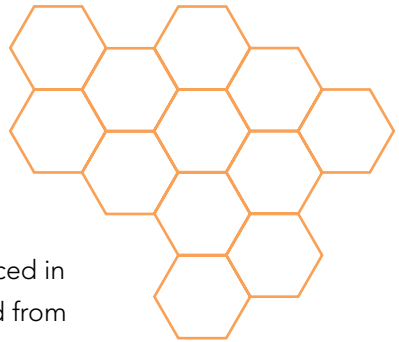
SUGAR

In the United States, the average person consumes more than 126 grams of sugar per day. That is more than twice the recommendation for daily intake by the World Health Organization. Around 70–80 % of this sugar is so-called hidden sugar. It is plentiful in many processed foods such as yogurt, juice, soda, cold cuts, pizza, soy sauce, mayonnaise and many convenience foods.

Compared to cane sugar, white refined sugar contains no trace elements or minerals. White refined sugar can interfere with the absorption of calcium, magnesium, zinc and iron. It also consumes the body's supplies of trace elements and minerals, as sugar metabolism requires several different trace elements.

The excessive use of white sugar is associated with numerous metabolic disorders such as type 2 diabetes and metabolic syndrome,[242] disrupted fat metabolism and systemic inflammation, cardiovascular diseases[243 244 245] and Alzheimer's disease.[246 247] In addition, sugar and fructose strain the liver.[248] What is worse, studies have found that sugar causes physical dependence.[249]

We recommend replacing white sugar with alternatives that contain trace elements, and avoiding sources of hidden sugar such as flavored yogurt, juice, soda and convenience foods.



HONEY

Favor:

- Unheated and unfiltered
- Unprocessed local honey, produced in an unpolluted area and collected from a single farm
- Varietal honey (for example buckwheat, manuka, tualang)
- The darker the color, the better

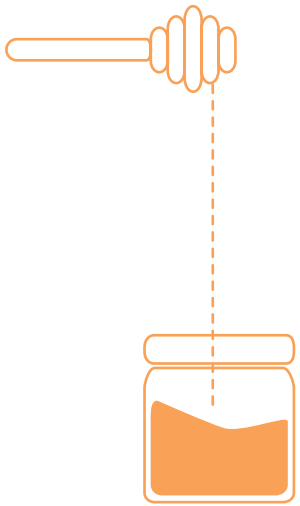
The lower age limit for honey consumption is generally 12 months because of the higher risk of infants developing botulism caused by Clostridium botulinum due to underdeveloped intestinal flora. Honey has yielded good results in the treatment of acute coughing in children[250 251] as well as in allergy desensitization therapy.

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RECIPE

HERB HONEY

Mix genuine vanilla, spirulina or for example nettle seeds in honey. Honey is a wonderful preservative and the spices or herbs mixed in it give a nice touch to its flavor.



CRYSTALLIZED SUGARS

Favor:

- Coconut sugar
- Whole cane sugar (unrefined and processed as little as possible, often sold under more unusual names such as Indian, rapadura, kokuto or mascobado sugar).

Avoid:

- Bleached sugar
- Brown sugar (partially bleached raw cane sugar, also sold under more unusual names such as muscovado, demerara or molasses sugar)
- Baking sugar (including icing sugar, soft brown sugar, vanillin sugar)
- Fructose



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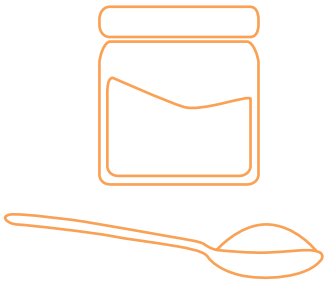
HIGH INTENSITY SWEETENERS AND SUGAR ALCOHOLS

Favor:

- Birch-based xylitol
- Green stevia (leaves of the whole plant)

Avoid:

- GMO xylitol
- Erythritol
- Sorbitol
- Steviol glycoside extracts (white stevia)
- Aspartame
- Acesulfame K



SYRUPS



Favor:

- Maple syrup
- Coconut syrup
- Yacón syrup
- Kitul palm (caryota urens) syrup
- Spruce tip syrup

Avoid:

- Fructose-glucose syrup (corn syrup)
- Agave, sugar syrup, flavor syrups

OTHER

Use as sweetener when needed:

- Luo han guo (monk fruit)
- Lucuma
- Nopal cactus (prickly pear)
- Inulin
- Licorice root

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SPICES

Spices are used to add flavor and preserve food. Spices can be strongly flavored or aromatic plant parts, components extracted from plants, or minerals.

Many spices and herbs have both health-promoting and illness-preventing qualities. Several spices also stimulate the function of digestive system.

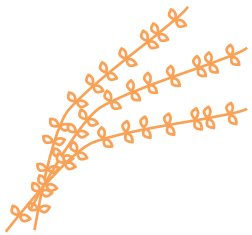
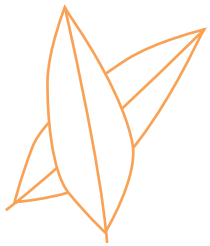
Flavor and scent are sourced from the oxidizing and vaporizing plant parts. Therefore, ground spices gradually lose their flavor and any medicinal effects. Whole spices keep for approximately two years, whereas ground spices keep for six months or so; however, the flavor may suffer much sooner.

+ Favor:

- Wild vegetables and wild spices
- Fresh ginger and turmeric
- Garlic and onions
- Chili, cayenne and black pepper
- Ceylon cinnamon, cardamom, caraway, fennel and bay leaves
- Rosemary, oregano, thyme, dill, tarragon, coriander, mint, basil, parsley and sage
- Maintaining your own miniature herb garden near a window or on a balcony
- Purchasing organic spices whole (not ground)

– Avoid:

- Highly irradiated spices
- Expired spice shakers that have been constantly exposed to light, heat and moisture
- Many spices such as peppers can easily go moldy if handled directly over the cooktop

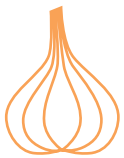



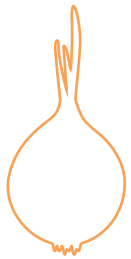
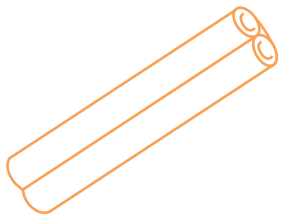


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Coumarin is an aromatic compound found naturally in many plants. Its main source in food is cinnamon. In Europe and the United States, Chinese cassia (*cinnamomum cassia*) is the most common type of cinnamon used, and it contains large quantities of coumarin. The rare, more expensive Ceylon cinnamon (*cinnamomum zeylanicum*) contains very little coumarin. Coumarin is toxic to the liver (hepatotoxic), although to reach the toxicity level one would have to regularly consume more than two tablespoonfuls daily. In 2004 the European Food Safety Authority (EFSA) set a tolerable daily intake for coumarin at 0.1 mg per one kilo of body weight per day. The regular liberal use of cinnamon is not recommended.

Alzheimer's disease is most common in Western Europe, and North America is close behind. The use of turmeric might provide some protection against neurological disorders.[252] It may also have a positive impact on several inflammatory illnesses such as arthritis[253] [254] and ulcerative colitis.[255] Turmeric also has antibacterial, antiviral and anti-fungal properties in humans.[256] It may also have a cancer preventive effect.[257] [258]



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ANIMAL PRODUCTS

When consuming animal products, favor quality over quantity. Eat a wide variety of animals and their parts. Using the entire animal for food by "eating from nose to tail" provides a wide variety of nutrients, for instance in the form of bone broth and offal. Favor intelligent preparation methods that enhance flavor and nutrient absorption as well as reduce the amount of harmful compounds. Use more spices and not just for garnish. This promotes digestion and provides the system with anti-inflammatory compounds.

MEAT

The consumption of meat is a divisive topic. The consumption of intensively farmed meat has been linked to various illnesses in numerous studies. On the other hand, high quality animal products can be one of the most nutrient dense elements of a diet. The higher you are in the food chain, the more the links below affect the quality and nutrient density of your food. The animal's genetics, environment, diet, freedom of movement, quality of drinking water, veterinary medicines used and many other factors have a significant impact on the fatty acid composition of the meat, the amount of nutrients or possible harmful substances in it and the effect the food has on the body.

Meat products have different health impacts depending on the animal and the farming method used. The liberal consumption of highly processed meat may increase the risk of bowel cancer,[259] type 2 diabetes,[260] stroke,[261] esophageal cancer[262] and gastric cancer.[263] The demographic group that consumes the most processed meat products has a higher mortality rate than the group that consumes the least.[264] The risks vary depending on the animal species. For instance, compared to beef, bison meat, has not been found to cause an increase in low-grade inflammation.[265 266] In addition, the meat from grass-fed animals has a better fatty acid composition and contains more antioxidants than intensively farmed meat.

Unbalanced animal consumption (for instance, only favoring muscle meat) can cause an amino acid imbalance in the body. Muscle tissue is rich in methionine, the excessive consumption of which has been found in animal tests to increase oxidative stress and to accelerate aging.[267 268 269] Muscle tissue is scant in glycine, an essential amino acid that is plentiful in collagen-rich animal parts. These include connective tissue, bone marrow and skin. Some connective tissue containing glycine can also be found in minced meat. The harmfulness of methionine may well be related to the lack of glycine in our diets. In animal tests, glycine has been found to have lifespan-extending qualities[270] and similar effects are probable in humans.[271]

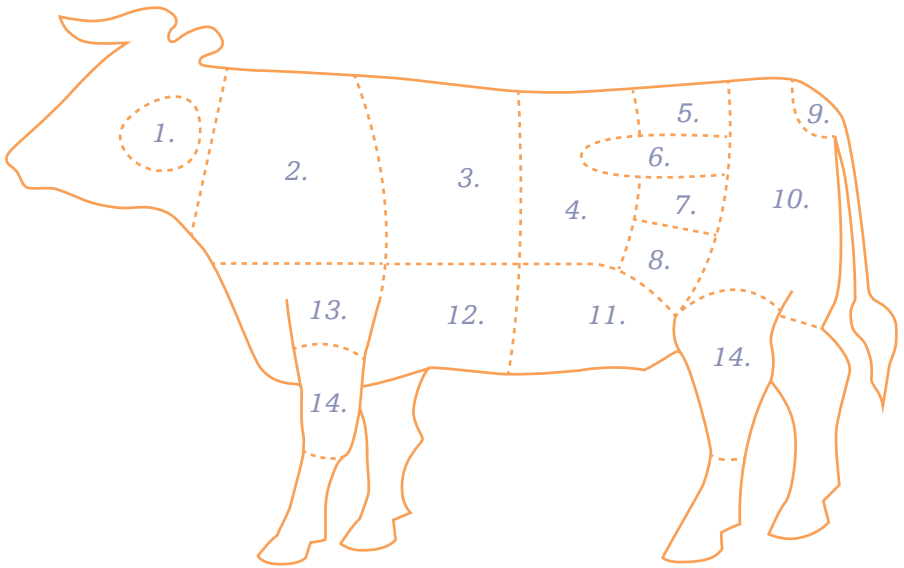
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The preparation method used for the meat is of utmost importance. In addition to harmful AGE and PAH compounds (see the section titled "Cooking and harmful compounds"), the meat's heme iron causes oxidation upon heating and promotes the formation of cancer-causing nitrosamine compounds.[272]

When using meat, favor the following principles:

- Eat a wide variety of animal parts (including bones, bone marrow, tongue, connective tissue and offal such as liver and heart)
- Eat various types of animals
- Favor grass-fed animals, game and indigenous breeds (Finncattle, Highland cattle, bison and sheep)
- Hunt your own meat or arrange for a direct connection to the origin of the meat
- Avoid intensively farmed meat, sausages and cold cuts
- Favor long cooking times at low temperatures, i.e. slow cooking and boiling
- Avoid high temperatures, i.e. frying, grilling and deep frying
- When consuming meat, add spices that support digestion and absorption (such as herbs, peppers, ginger and turmeric) and foods that support absorption (such as pineapple, papaya and sauerkraut)

CUTS OF BEEF



1. Cheek 2. Chuck 3. Rib 4. Short loin 5. Sirloin
6. Tenderloin 7. Top sirloin 8. Bottom sirloin 9. Ox tail
10. Round 11. Flank 12. Plate 13. Brisket 14. Shank

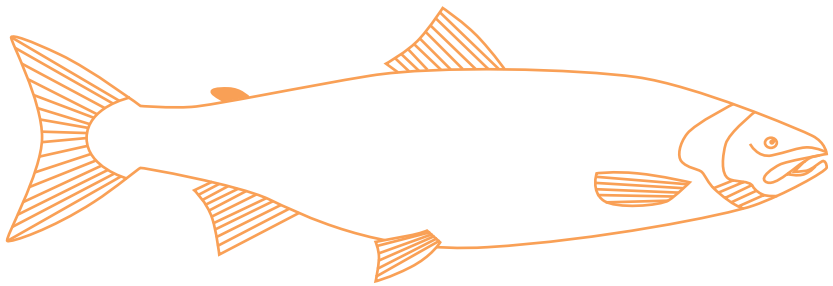
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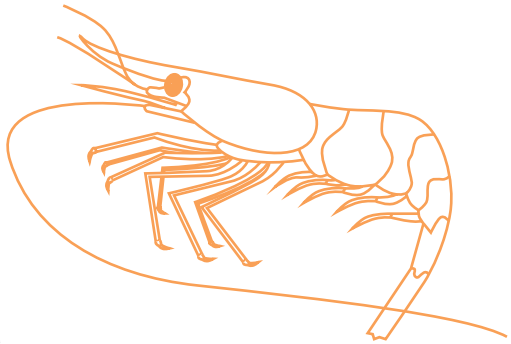
FISH

According to general dietary guidelines fish is recommended for nutrition and should be consumed at least twice per week. Fish is rich in healthy fatty acids, trace elements, vitamins and amino acids. Numerous studies have indicated that fish is an excellent source of omega-3 fatty acids and vitamin D. The consumption of fish is associated with a lower risk of cardiovascular diseases.[273] [274]

Environmental toxins such as dioxins and PCBs are concentrated in fish fat. The fattier the fish, the higher the level of toxins. The highest levels of mercury can generally be found in sharks, swordfish and bigeye tuna. Toxins become concentrated in long-lived and large predatory fish.

In 2013 more than 90 countries signed the Minamata convention in Japan. The convention prohibits the import and export of mercury and mercury-containing products.[275]

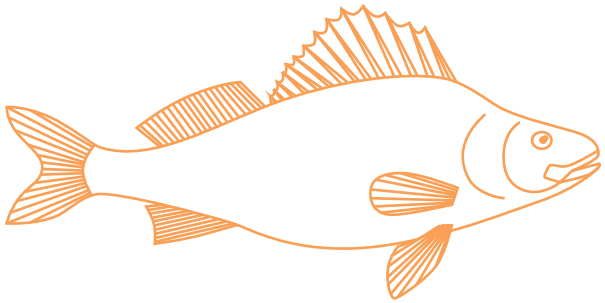




The convention also limits mercury emissions for example by prohibiting the introduction of new mercury mining sites. It has been estimated that as a result of the Minamata convention, the mercury levels of fish will fall within decades. Toxic, carcinogenic substances are largely released into the environment by human industrial activity (such as coal-fired electricity generation, smelting and the incineration of waste).

According to several studies, the benefits of eating fish exceed any disadvantages involved.[276] Liberal fish consumption may reduce the risk of developing coronary artery disease,[277] lung cancer[278] and type 2 diabetes.[279] [280] Fish oil (and fresh fish) raises the adiponectin level in the body,[281] Adiponectin deficiency can be a predisposing factor for obesity, metabolic syndrome and other metabolic disorders. Adiponectin has anti-inflammatory and oxidative stress preventive effects.[282]

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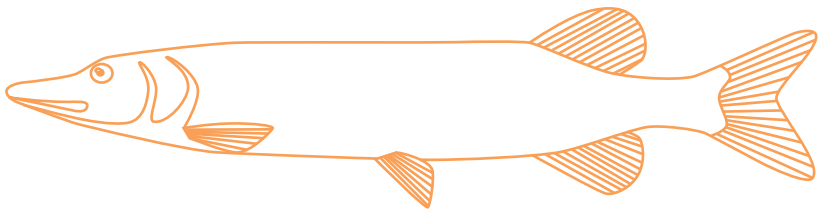


When using fish, favor the following principles:

- Eat the whole fish and use the nutritionally valuable guts for fish stock
- Eat various types of fish that contain few chemicals and heavy metals (see the image on the following page)
- Favor wild fish and supplement your diet with organically farmed fish
- Catch your own fish or arrange for a direct connection to the origin of the fish
- Avoid intensively farmed fish, processed fish products and deep fried fish products
- Favor long cooking times at low temperatures, i.e. slow cooking and boiling
- Avoid high temperatures, i.e. frying, grilling and deep frying
- When consuming fish, add spices that support digestion and absorption (such as herbs, peppers, ginger, dill, turmeric and coriander)
- You can alleviate any impact of the heavy metals contained by the fish by adding seaweed, chlorella and coriander

The health impact of wild fish compared to farmed fish:[283 284 285]

- Wild fish has a higher level of omega-3 and more trace elements and vitamins
- Wild fish contains fewer poor quality fat compounds
- Antibiotics, hormones, PCB, neurotoxins, pesticides and other toxins have been found in farmed fish
- Wild fish may contain more mercury than farmed fish



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MERCURY LEVELS IN SEAFOOD

LOW

Safe to eat 2–3 times per week

Flounder
Shrimp
Salmon (farmed)
Common sole
Octopus/squid
Crayfish and crab
Sardine
Whitefish
Herring
Mussels, clams and oysters
Trout
Cod

MODERATE

Safe to eat approx. once per week

Perch
Lobster
Atlantic salmon
Burbot
Seabass
Monkfish
Atlantic halibut
Tuna (canned, Skipjack)

HIGH

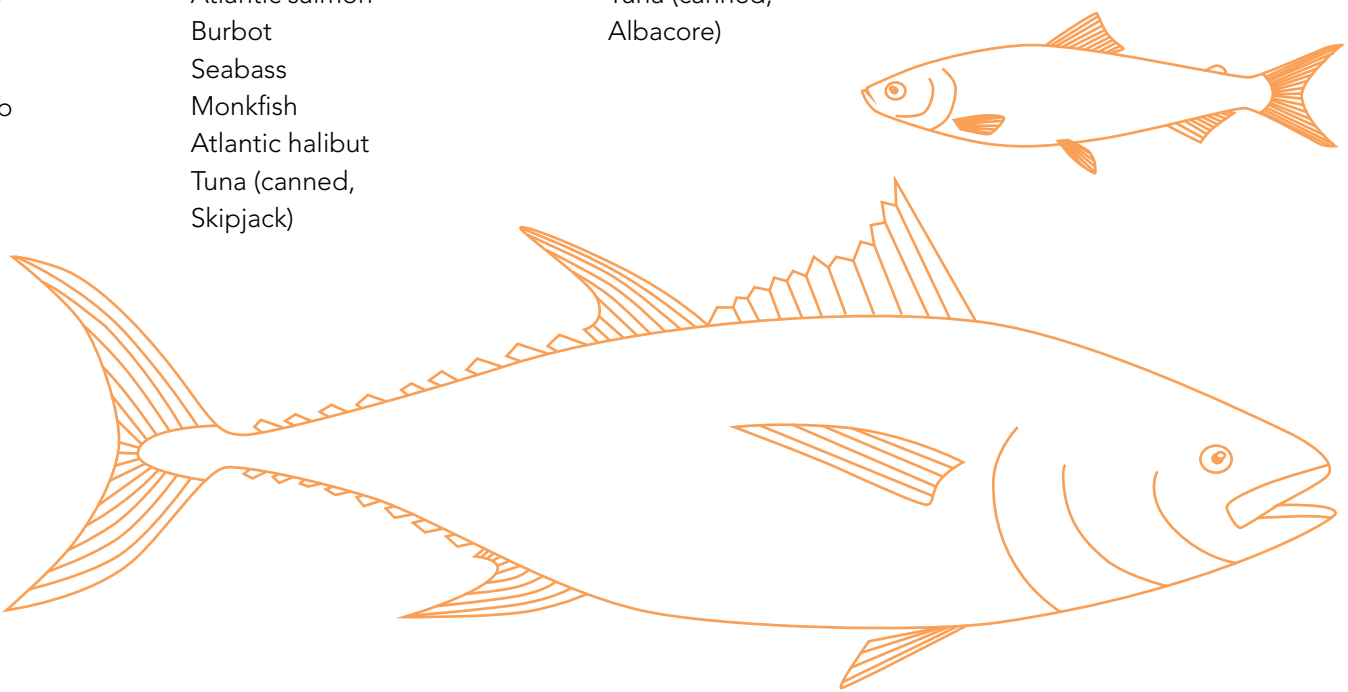
Safe to eat 1–2 times per month

Pike
Yellowfin tuna
Tuna (canned, Albacore)

VERY HIGH

Avoid

Bigeye tuna
Swordfish



See the WWF or the Seafoodwatch lists of seafood species to avoid (overfishing etc). Favor MSC certified fish.

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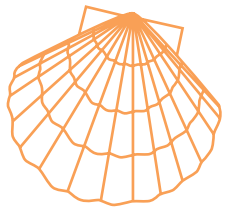
CRUSTACEANS AND MOLLUSCS

Two warring New Guinea tribes agree on a cease-fire to do trade: the coastal tribe offers crustaceans and in return receives root vegetables from the tribe inhabiting the highlands. The nutritional value of crustaceans and molluscs has been well known historically. For instance oysters have been used as an aphrodisiac.

Crustaceans usually include crabs and lobster. Molluscs include clams, oysters, snails and cuttlefish. Shellfish has been used as a food item for over hundreds of thousands of years especially in the coastal regions (for example in the Mediterranean).

Oysters are by far the most nutrient rich of the molluscs. Oysters contain the most zinc in proportion to their weight. For instance, four medium-sized oysters provide 33 mg of zinc, an enormous amount of selenium, vitamins of the B complex, vitamin E, copper, as well as proteins and omega-3 fatty acids.[286]

Other nutritious species include clams, mussels, lobsters and snails. It should be noted that the ever-popular shrimp are nutritionally lacking compared to other crustaceans and may contain harmful bacteria and traces of medicines due to intensive farming. As much as 74 % of shrimp farmers in Thailand have used antibiotics to treat various shrimp diseases.[287]



+ Favor:

- Oysters
- Clams
- Mussels
- Scallops
- Lobster, crab and crayfish
- Snails
- Cuttlefish



− Avoid:

- Shrimp



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EGGS

As is the case for most containers of a new life, an egg is close to perfect food. Eggs are rich in protein, vitamins, minerals and other beneficial nutrients (including phospholipids, lutein, zeaxanthin and choline). Eggs are a good source of xanthophylls which are essential to the eye health of the elderly in particular. They increase the carotenoid levels of the blood serum as well as eye tissue.[288] Lutein and zeaxanthin reduce the risk for macular degeneration and cataracts. Macular degeneration most commonly occurs in people over the age of fifty. In the United States, it is the most common cause of vision loss within this age group.[289]

Many people continue to avoid the regular consumption of eggs even though the link to increased risk of coronary artery disease has been refuted in all recent studies and meta-analyses.[290 291 292] Studies conducted have found no evidence of a link between egg con-sumption and high cholesterol levels.[293] Indeed, studies have found that individuals who consume more eggs have a 25 % lower risk of having a hemorrhagic stroke. Eggs do not increase the risk of cardiovascular diseases or stroke, even when consumed daily.

However, eggs are not suitable for everyone. Some people are allergic to eggs, some suffer from hereditary dysfunctions in fatty-acid metabolism, and some people (around 20 % of the population in the US) have the ApoE4-allele (genetic variant) which might cause dysregulation of cholesterol metabolism. A 2016 study conducted on over 1000 Finnish males found that egg or cholesterol intakes were not associated with increased coronary artery disease risk, even in ApoE4 carriers (i.e., in highly susceptible individuals).[294] Still, it might be wise to limit egg consumption if you have both E4 alleles (homozygote) until conclusive information on the potential health risks is available.

There is a more realistic risk of developing a hyper-sensitivity to egg proteins as a result of regular egg consumption. Due to this, everyone who consumes eggs should take regular breaks in egg consumption.

In Australia and the European Union, eggs are graded by the hen farming method (free range, battery caged, etc). The US Department of Agriculture grades eggs by the interior quality of the egg and the appearance and condition of the egg shell. Only about 4 % off the eggs are produced organically. The color of the shell has nothing to do with egg quality, rather it is indicative of the breed of the chicken that laid it.

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When selecting eggs, note the following criteria:

- Fresh eggs sink in water, old eggs float
- The egg whites of fresh eggs are firmer, the whites of older eggs are more watery
- The more vivid yellow the yolk is, the more it contains fat-soluble vitamins and carotenoids
- Favor organic free range/pastured eggs. Studies have found these eggs to have significantly higher levels of good fatty acids and fat-soluble vitamins and carotenoids.
- Avoid indoor eggs (including cage-free eggs) and caged eggs. Caged eggs carry an increased risk of salmonella.
- Note the packaging date if you buy eggs from a supermarket
- Vary the type of eggs you eat (for example quail, duck and goose)

Eggs should be prepared in a way that maintains the flavor and nutrient density as well as possible:

- The main egg white protein consisting of albumin contains enzyme inhibitors when raw. Because of this, the egg white should be cooked.
- Avoid eating just the egg white.
- Conalbumin interefes with iron absorption, avidin hinders the absorption of the vitamin B complex
- The yolk should be eaten raw or slightly cooked. Frying or boiling oxidizes fats, denatures proteins and destroys one half of the precious xanthophylls of the egg.
- In terms of flavor and consistency, even a small difference in the cooking water temperature changes the egg structure
- Keep eggs in room temperature and use within 7–10 days
- Refrigerated eggs will keep for approx. 30–45 days
- Do not eat eggs that are old, have a broken shell or a watery egg white



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RECIPE

COOKING THE PERFECT EGG

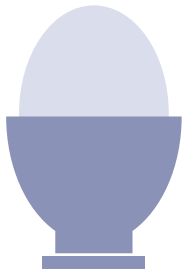
Option 1

Place the eggs in water and raise the water temperature. When the water is boiling, remove from heat and leave to sit under a lid for 6 minutes. The internal temperature of the eggs will keep for several minutes, whereas the shells are much less likely to crack when removed from heat.

Pour the hot water out and replace with cold water. Add 1 tsp of baking soda. The raised pH of the water detaches the egg white from the shell. Leave the eggs in cold water for 2–5 minutes before eating. An egg that has been completely detached from the shell can be peeled in an impressive way by blowing the egg out.

Option 2

Set the sous-vide temperature to 64.7 C (148.5 °F) and cook for a minimum of 50 minutes. Remove the eggs and place in cold water for two minutes before peeling. This method produces an egg that is perfectly *al dente*. Place the eggs on a plate, cut in half and add unrefined sea salt, pepper and herbs.



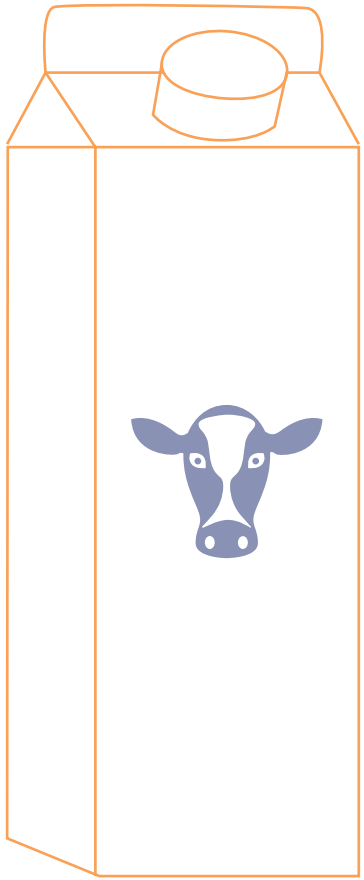
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MILK PRODUCTS

Finns consume the most dairy products in the world (over 200 kg per person / year). The global average is about 110 kg per person per year. The consumption of milk and fat-free milk products in particular may be linked to deaths caused by heart disease.[295] [296] [297] On the other hand, some studies indicate that the consumption of full-fat milk products may prevent cardiovascular diseases and heart attack,[298] abdominal obesity[299] and type 2 diabetes.[300] According to studies, it seems as though it is the milk fat (trans-palmitoleic acid) that prevents obesity and the development of type 2 diabetes.[301] The positive effects of the milk fat may also be due to CLA, vitamin K2 and butyric acid.

Excessive milk consumption stimulates mucus production in the respiratory tract via the β-casomorphin-7 peptide of which there is plenty in milk. This peptide stimulates mucus production particularly in asthmatic individuals and may worsen the symptoms of asthma.[302] For some individuals, giving up milk entirely may help in the recovery from chronic sinus infection. The inflammatory cycle is particularly common in people who unknowingly suffer from milk hypersensitivity.[303]

It is commonly believed that milk is a good source of calcium. However, care should be taken with liberal milk



consumption and particularly when using calcium supplements as recent studies have indicated that these are associated with the development of coronary artery disease and a significant increase in the risk of a heart attack.[304]

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High calcium intake causes magnesium deficiency. Several studies have indicated that magnesium is one of the main factors in the prevention of coronary artery disease.[305] A calcium-magnesium imbalance significantly increases the risk of a heart attack and may increase the risk of breast cancer in post-menopausal women.[306] A study conducted on Finnish males showed that large amounts of calcium in the drinking water is linked to coronary heart disease and coronary thrombosis.[307]

A comprehensive Swedish study published in the esteemed British Medical Journal found that the liberal consumption of milk (more than three glasses per day) may be associated with premature death. The same demographic study also found that milk consumption does not prevent the development of osteoporosis. In fact, it even increases the risk of bone fractures in women. The liberal consumption of milk also appears to contribute to low-grade inflammation and oxidative stress of the body.[308] A systematic review and meta-analysis published in 2016 however found that there is no evidence for a decreased or increased risk of all-cause mortality, coronary heart disease, and stroke associated with adult milk consumption.[309]

The qualities of milk products vary depending on the cattle breed of origin. Often the terms A1 milk and A2 milk are used. The distinction is made according to differences in milk proteins between cattle breeds. A2 milk produced by indigenous cattle breeds cause significantly fewer health problems. Conversely, A1 milk proteins are associated with heart disease and intestinal inflammation.[310] [311] [312] The A1 type is the most common type found in cow's milk in Europe (excluding France), the USA, Australia and New Zealand.

The diet and living conditions of the cow also have an enormous impact on the quality of the resulting milk products. For example, the milk of grass-fed cows contains significantly more omega-3 fatty acids.[313] In addition, the proportion of grass in the cattle diet is directly proportional to the nutritional value of the butter produced.[314] Organic milk products also contain more omega-3 fatty acids and CLA compared to conventional milk products.[315]

+ Favor:

- Milk products made from the milk of goats, sheep, Scottish Highland, Limousin, Piedmontese or other indigenous breeds of dairy cattle
- Fermented milk products (kefir)
- Grass-fed and organic butter
- Raw milk from small farms

– Avoid:

- Highly processed milk and fat-free milk products
- Processed milk products such as milk-based drinks
- Yogurts sweetened with sugar and digestive yogurts

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CEREALS

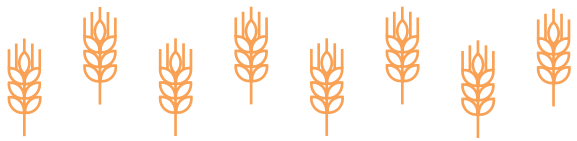
The global consumption of grains is mainly divided into three different grains: wheat (Europe, Middle-East, North Africa and Australia), corn (North and South America, Southern Africa) and rice (Asia). The global per capita wheat consumption is around 67 kg. 70 % of the cereals eaten are refined. Refining significantly undermines the nutritional value of cereals (vitamin B complex, zinc, magnesium, phytoestrogens and selenium are removed with the husk).

Consuming whole grains has been linked to better health by epidemiological population studies. The health benefit is likely to be due to the overall better living habits of people who consume wholegrain cereals, as well as the reduced consumption of processed cereals, rather than the increased consumption of wholegrain cereals.[316] For instance, wholegrain cereals by themselves do not lower the levels of inflammatory markers or improve insulin sensitivity.[317] More so than cereals, there is significantly more positive evidence for the consumption of vegetables preventing many illnesses.[318 319]

GLUTEN, CELIAC DISEASE AND GLUTEN HYPERSENSITIVITY

Gluten is a large-scale protein molecule that consists of numerous peptides. At least fifty of these have been found to destroy epithelial cells in the intestine, disrupt the immune function and cause leaky gut syndrome. A pioneer in celiac disease research, Dr Alessio Fasano, found in his research that there is increased occurrence of the zonulin protein in autoimmune diseases such as celiac disease. Zonulin modulates the tight junctions between intestinal cells. The more zonulin there is, the more permeable the gut.[320]

When a celiac individual eats gluten, the production of zonulin proteins increases immediately.[321] This in turn stimulates the secretion of inflammatory cytokines, causing the loosening of the tight junctions and, if prolonged, their destruction. This process can be almost entirely prevented by avoiding gluten in the diet. Over time, the amount of zonulin is reduced and the epithelial cells and tight junctions of the intestine are repaired.





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Gluten hypersensitivity is many times more common in humans than celiac disease. Testing for celiac disease with laboratory tests does not rule out gluten hypersensitivity, as the latter cannot currently be reliably tested in a laboratory. However, recent years have seen the development of laboratory tests (such as LBP, FABP2 and EndoCAb antibodies) that will make the diagnosis of gluten hypersensitivity using blood tests possible in the future.[322] Increased gut permeability has not been found in individuals with gluten hypersensitivity. As a result it is not considered an autoimmune disease. Gluten hypersensitivity and celiac disease are entirely distinct.[323]

Many individuals who have experimented with a grain-free diet report experiencing health benefits. Typically a grain-free diet is attempted when an individual suffers from irritable bowel syndrome, celiac disease or other autoimmune diseases or certain psychiatric illnesses.[324] Many people consider gluten to be the culprit of intestinal symptoms. In addition to gluten, the cause may be the FODMAP carbohydrates found in cereals (see the section titled "FODMAP carbohydrates")[325] and other cereal proteins.

We recommend relying on vegetables and root crops for dietary carbohydrate needs and adding gluten-free products such as oat, quinoa and buckwheat as needed. Favor indigenous varieties of cereals over highly processed ones. For example, indigenous wheat varieties alleviate the inflammation and symptoms of IBS patients,[326] whereas modern wheat varieties worsen them.[327]

+ Favor:

- Amaranth
- Millet
- Oat
- Canihua
- Quinoa
- Buckwheat
- Teff

− Avoid:

- Wheat and other wheat varieties that contain gluten (spelt, einkorn and emmer wheat)
- Barley
- Rye
- Maize

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RICE

Rice is a type of grass. According to some estimates, more than 90 % of the world's rice is grown in Asia. Rice is one of the main sources of nutrition for up to one half of the world's population.

Rice is typically categorized into long, medium and short grain varieties. Long grain varieties are rich in amylose. Short-chain and some long grain rice varieties are rich in amylopectin, for example in Thai sticky rice. Due to the function of digestive enzymes amylopectin may raise the blood sugar level more rapidly than amylose.[328]

Wholegrain rice is more nutrient rich than white rice. However, it contains antinutrients that interfere with nutrient absorption (see the section titled "Antinutrients"), as well as other toxins such as soil-based arsenic. The nutritional value of wholegrain rice decreases significantly upon cooking. White rice varieties (such as basmati and jasmine rice) are less nutrient rich than wholegrain rice. However, they do not contain antinutrients. White rice mainly consists of starch, some protein and certain trace elements. To remove impurities, rice should always be properly soaked.

The biohacker uses rice mainly to provide glucose for the nervous system and supplement the glycogen reserves in the muscles and liver, as a part of an otherwise nutrient-rich diet.

+ Favor:

- Basmati rice
- Jasmine rice
- Other types of long grain rice
- Organic black rice

− Avoid:

- Instant rice
- Porridge rice
- Short grain rice
- Wholegrain rice
- Brown rice



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MAIZE

Maize (corn) is a member of the grass family. It is an old staple crop with an estimated cultivation history dating as far back as 9000 years ago in Mexico.[329] Today maize is the most widely grown grain in the world. As much as 40 % of all maize is produced in the United States, of which, up to 86 % is genetically manipulated. In 2011, 32 % of the maize produced in the world was genetically manipulated. Intensive maize farming is also harmful to the environment, for instance, via groundwater pollution.[330]

In the United States, 40 % of the maize grown is used for the production of ethanol. Maize is also used as animal feed, most commonly for pigs but also for cattle. Maize feed fattens up the livestock rapidly, facilitating high livestock production volumes.

For human consumption, maize is traditionally used in tortillas, porridge, polenta, popcorn and corn flakes.Mexican cuisine in particular holds maize in a key role. There are six varieties of maize: dent corn, sweet corn, flour corn, flint corn, popcorn and pod corn. Most of the maize grown in the United States is yellow dent corn.

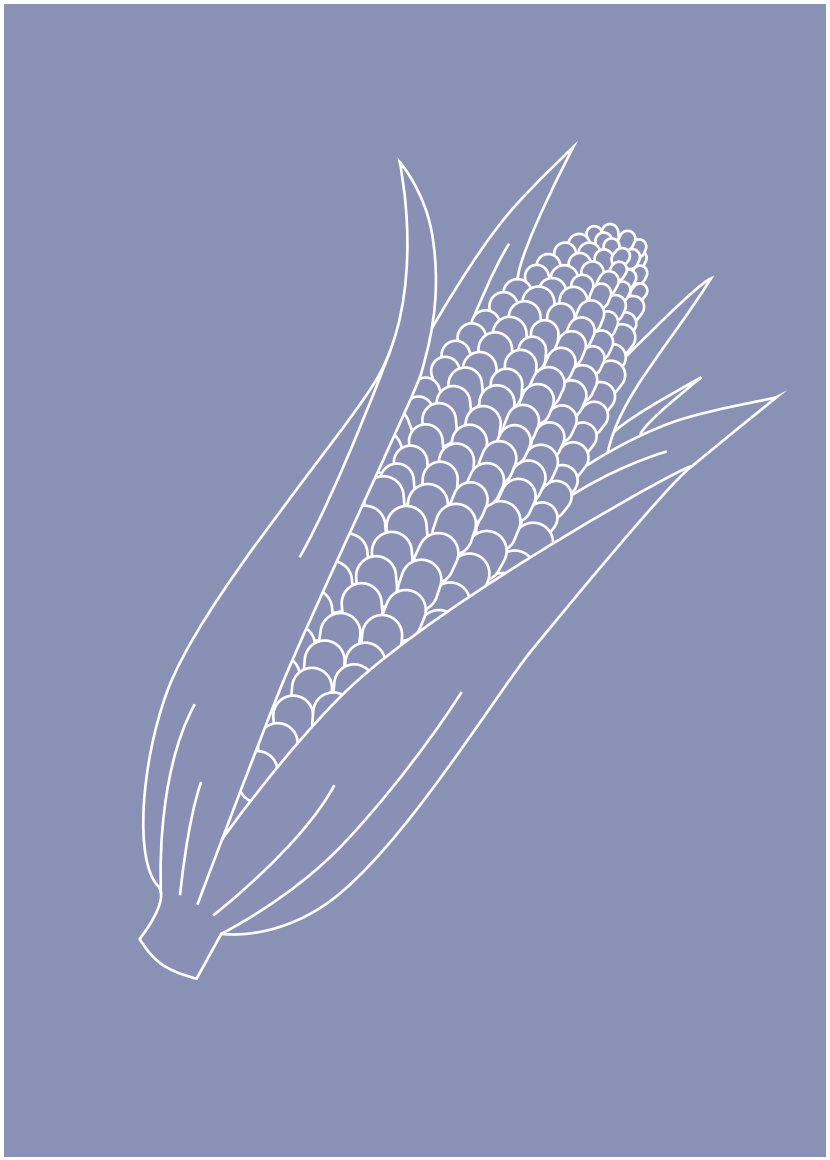
On a global scale, maize is one of the most significant sources of starch.[331] Used in its original form, organic non-GMO corn can be a fairly economical and solid option to supplement one's diet particularly during seasons that are optimal for grilling. However, maize is not suitable for consumption for some celiacs due to its zein content (a gluten-like prolamine compound) which may cause an immune reaction in the intestine similar to celiac disease.[332]

Maize is frequently turned into high fructose corn syrup which is used as a sweetener in many foods and drinks. The abundant use of high fructose corn syrup has been linked to the occurrence of diabetes in various countries.[333] It is also a predisposing factor for excess weight, metabolic syndrome and the onset of fatty liver disease.[334] Some scientists suggest that the contribution of high fructose corn syrup to excess weight is primarily due to an unnoticed increase in energy intake.[335]

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The consumption of foods containing high fructose corn syrup has also been found to have a dose-response relationship to the onset of coronary artery disease – the higher the consumption of high fructose corn syrup, the higher the risk of the disease.[336] Maize is also used to make corn oil, of which the fatty acid composition is unfavorable for humans.

Corn oil contains high levels of polyunsaturated omega-6 fatty acids (54 %) that oxidize readily and, when consumed excessively, predispose the body to silent inflammation.[337] In the United States, corn oil in particular is likely to be one of the main reasons for the extremely poor ratio of omega-6 and omega-3 fatty acids in the population (up to 20:1).



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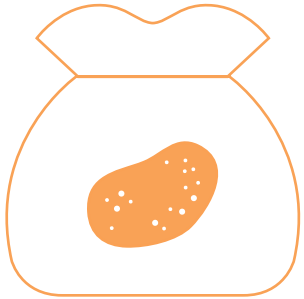
ROOT VEGETABLES AND TUBERS

Root vegetables refer to the underground parts of a plant that are used for food. Root vegetables include the roots, shoots and bulbs of many seed plants. Root vegetables are very common all over the world. There are more than 50 types of storage roots, which are categorised in bulbs, rhizomes and tubers. The most common ones are carrots, beetroots, cassava, rutabaga, turnips, yams, sweet potatoes, radishes and celeriac. Root vegetables are nutritionally valuable due to the fiber, vitamin C, vitamin B complex and calcium contained by them. Carrots contain particularly high levels of beta-carotene and other carotenoids.[338]

POTATO

The potato was slowly adopted into Europe in as late as the 19th century, but it soon after became an important staple food. Potatoes at that time were used to prevent scurvy because of their vitamin C content.

Contrary to common belief, the potato is not a root vegetable but a nightshade. Other similar nightshades are eggplants, tomatoes and peppers.



Potatoes are fairly rich in nutrients such as potassium, vitamin B complex and vitamin C.[339] The potato is also one of the prime foods to promote the feeling of satiety.[340]

Potatoes contain some glycoalkaloids (alpha-solanine and beta-chaconine) which are toxic to humans. However, their levels in cultivated potato varieties are low. The solanine level of a potato may be significantly increased if it is exposed to sunlight during the growing season. Toxic potatoes can be identified based on their green color or sprouting. Early crop potatoes contain the most solanine. Glycoalkaloids may cause symptoms such as headache, diarrhea, restlessness and nausea.[341]

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Glycoalkaloids are present particularly in potato skins. As a result, peeling the potatoes significantly reduces their solanine content. Unpeeled potatoes fried in oil are especially problematic as glycoalkaloids are oil-soluble. Potatoes cooked in high temperatures also produce toxic compounds such as acrylamide and acrolein.

SWEET POTATO

The consumption of sweet potatoes increased in popularity after Christopher Columbus introduced it in Europe. Sweet potatoes are often used as a replacement for white potatoes. They are more nutrient rich than the conventional potato. For instance, sweet potatoes contain more beta-carotene, anthocyanins, vitamin C and fiber. It also raises the blood sugar level more slowly compared to potatoes.[342]

On the other hand, potatoes contain more resistant starch that may be helpful in the maintenance of the bacterial strain of the intestine (see the section titled "Prebiotics").[343] We recommend that potatoes and sweet potatoes be consumed especially after strenuous exercise to supplement the depleted glycogen reserves in the muscles.

+ Favor:

- A wide variety of seasonal root vegetables
- Organic potatoes
- Boiling and steaming potatoes
- Seasonally grown local potatoes
- Large-sized tubers (less glycoalkaloids)
- So-called almond potatoes (mostly grown in Finland, Sweden and Norway), which have high levels of resistant starch

− Avoid:

- Potatoes deep fried in oil
- Potato chips
- Other heavily processed potato products
- Eating potato peels
- Green and damaged potatoes
- Very small-sized tubers (more glycoalkaloids)

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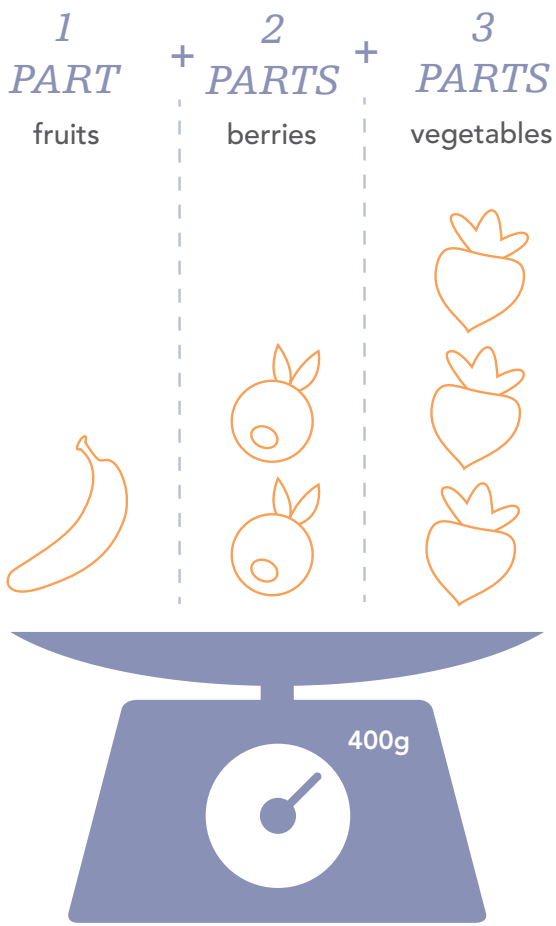
VEGETABLES, FRUITS AND BERRIES

It is generally recommended to eat 5–9 portions (around 400 grams) of fruits, vegetables and berries daily. Only about 10 % of people meet these recommendations. A study conducted in Finland showed that 75 % of Finnish males ate only two servings of fruits, vegetables and berries per day.[344]

Comprehensive meta-analyses have found that the liberal consumption of vegetables, berries and fruits is linked to a lowered risk of death, particularly in relation to cardio-vascular diseases.[345]

There is significant variability in the absorption of many vegetables, fruits and berries depending on the preparation method. The same compound may also be absorbed differently from different ingredients. For example, the beta-carotene and lycopene contained by papaya are more readily absorbed compared to those in carrots.[346]

RECOMMENDED DAILY INTAKE



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It is recommended to acquire nutrients from vegetables and berries by consuming them with fat to improve absorption.[347] Fruits and root vegetables may be used to supplement the diet particularly after exercise or in the evening to encourage sleep.

FRUITS

Some fruits can be used strategically for specific health benefits. For instance, kiwi fruit has been found to promote the growth of probiotic bacteria in the intestine[348] and help in the treatment of irritable bowel syndrome.[349] The polyphenols in kiwi fruit act as antioxidants and protect the body from oxidative stress.[350] Kiwi fruit also contain five times more vitamin C than oranges, for example.

90% of pesticide residues come from intensively farmed, imported fruit.[351] When buying fruit it is worthwhile to invest in organic produce to minimize the amount of harmful toxins.

TIP

RIPENING AVOCADOS

In nature, avocados only ripen once they fall off the tree. You can ripen avocados by keeping them in room temperature. To speed up the process, place the avocados together with bananas in a small bag (for example a biowaste bag) overnight. Bananas are treated with ethylene, a plant hormone gas used to speed up the ripening process. This compound also accelerates the ripening of avocados.



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+ Favor:

- Locally grown, seasonal fruit (for example apples)
- Organic fruit
- Fatty fruits (such as avocado, olive)
- Low-sugar fruits (lemon, lime, grapefruit, kiwi fruit)
- Nutritious fruits that contain slightly more sugar (papaya, nectarines, peaches, watermelon, pomegranates, apples)

Use sparingly:

- Varieties cultivated for extreme sweetness
  - Mango, fig, banana and dried fruits such as dates, raisins and apricots
  - Optimal time of consumption is after exercise or in the evening
- Varieties cultivated for sweetness
  - Mandarin, orange, pear, plum and pineapple

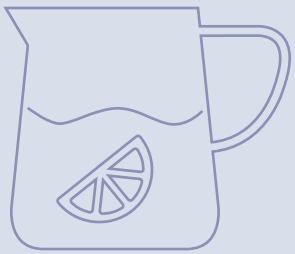
– Avoid:

- Commercial fruit juices and concentrated juice
- Artificially added fructose

TIP

LEMON WATER

Get hydrated first thing in the morning by squeezing the juice of half a lemon into approximately half a quart of water mixed with half a teaspoon of high quality salt. Lemon juice supports the digestive system and acts as a diuretic, increasing the need to urinate and hence removing waste products that have accumulated in the body overnight. Salt helps the adrenal glands produce cortisol needed for waking up – essential in the early hours of the morning.



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THE SUGAR AND NUTRIENT CONTENT OF FRUITS

Source: Fineli (National Food Composition Database in Finland), 2015.

FRUIT	SUGAR	MAIN NUTRIENTS
Apple (peeled)	8.2 %	Quercetin, epicatechin, fibers (2.4 %).
Apricot (de-stoned)	10.6 %	Carotenoids, potassium, manganese, vitamin A.
Avocado (peeled, de-stoned)	0.7 %	Monounsaturated fatty acids, linoleic acid and alpha-linolenic acid. Sterols, potassium, magnesium, phosphorus, carotenoids, vitamin K, vitamin B complex.
Banana (peeled)	13.5 %	Potassium, tryptophan, manganese, magnesium, vitamin B6.
Date (dried)	38.2 %	Potassium (687 mg / 100 g), magnesium, phosphorus, vitamin B complex, manganese.
Fig (fresh)	16 %	Potassium, magnesium, phosphorus, carotenoids, vitamin K.
Grape (de-stoned)	15.5 %	Vitamin K, vitamins B1, B2 and B6.
Grapefruit (peeled)	6.5 %	Vitamin C, carotenoids, pantothenic acid, pectin, lycopene. Grapefruit seed oil has antimicrobial properties.
Kiwifruit (peeled)	6.8 %	Vitamin C (100 mg / 100 g), pantothenic acid, vitamin E.
Lemon (de-stoned)	2.2 %	Vitamin C (51 mg / 100 g), vitamin B6, iron.

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FRUIT	SUGAR	MAIN NUTRIENTS
Lime (peeled)	1.7 %	Vitamin C, some vitamin B complex, calcium and iron.
Mandarine (peeled)	8.2 %	Vitamin C, carotenoids, potassium.
Mango (peeled)	13.7 %	Folate, vitamin C, carotenoids, potassium.
Olive (de-stoned)	0 %	Monounsaturated fatty acids, vitamin E, sodium.
Orange (peeled)	8.9 %	Vitamin C, potassium, calcium.
Papaya	10.7 %	Vitamin C, carotenoids, potassium.
Peach (peeled, de-stoned)	7.8 %	Potassium, niacin, phenols.
Pear (peeled)	8.0 %	Vitamin C, potassium, fibers.
Pineapple (peeled)	11.2 %	Potassium, vitamin B complex, vitamin C, carotenoids; bromelain enzyme.
Plum (de-stoned)	8.2 %	Potassium, carotenoids, vitamin K.
Pomegranate	13.7 %	Linoleic acid, ellagitannin, anthocyanin, vitamin B complex.
Watermelon (peeled)	7.1 %	Carotenoids, vitamin C, citrulline.

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BERRIES

If there is one dietary recommendation that all experts agree on, it is the health benefits of berries. Regardless of the diet type, nearly all dietary guide-lines recommend the daily consumption of 150–200 g (5–7 oz) of berries.

In general, berries are rich in vitamins, flavonoids, polyphenols, anthocyanins and insoluble fiber. They contain less sugar compared to fruit. Polyphenols give berries their distinctive color and act as part of various defense mechanisms. Whenever possible it is very beneficial to eat nutrient rich wild berries as they have much higher levels of polyphenols compared to cultivated berries. Cultivated berries often contain pesticide residues, such as non-organic strawberries which contain high levels of pesticides.[352]

The regular consumption of berries protects the cardiovascular system from oxidative stress, lowers blood pressure and reduces the level of inflammatory agents in the blood. Berry consumption also lowers the risk of type 2 diabetes. Additionally, berries have properties that promote the health of the eyes and brain.[353]

In tests conducted on animals, bilberries were found to have a positive effect on cognitive functions.[354] The consumption of bilberries has been found to lower the risk of cardiovascular disease in individuals suffering from metabolic syndrome.[355] In tests conducted on rats, wild blueberries were found to promote the bacterial balance and general well-being of the intestine.[356] The anthocyanins contained by bilberries and black currants have been found to improve night vision, ease eye fatigue and help in the treatment of glaucoma.[357] [358]



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Be careful when buying imported frozen berries. There have been many cases of outbreaks in which frozen berries have been contaminated with the norovirus, the hepatitis A virus or campylobacter. Boil your frozen berries for at least two minutes, or cook at 90 °C / 194 °F for five minutes to avoid food poisoning.[359] Exotic berries such as goji, inca and mulberry have been trendy in the past decade. The nutritional values of these berries are indeed good, however they may contain pesticide residues and sulfur dioxide used as a preservative.

+ Favor:

- Wild berries: bilberries, lingonberries, cranberries, blackcurrant, sea buckthorn, blackberries, cloudberries, chokeberries (aronia), arctic raspberries, crowberries, rowanberries, wild raspberries and wild strawberries
- Locally grown cultivated berries
- Berry powders
- Imported organic berries (such as inca berries, mulberries and goji berries)

− Avoid:

- Imported frozen berries

TIP

BERRY POWDER MIX

Berries contain important building blocks for eyes. Mix berry powders of different color in equal measure, for example:

- Blue: bilberry and black currant
- Red: cranberry and lingonberry
- Yellow: sea buckthorn and cloudberry

Mix one tablespoon of the powder in your breakfast each morning. For comparison, 1 teaspoon of high quality berry powder is equivalent to a half a cup of berries.



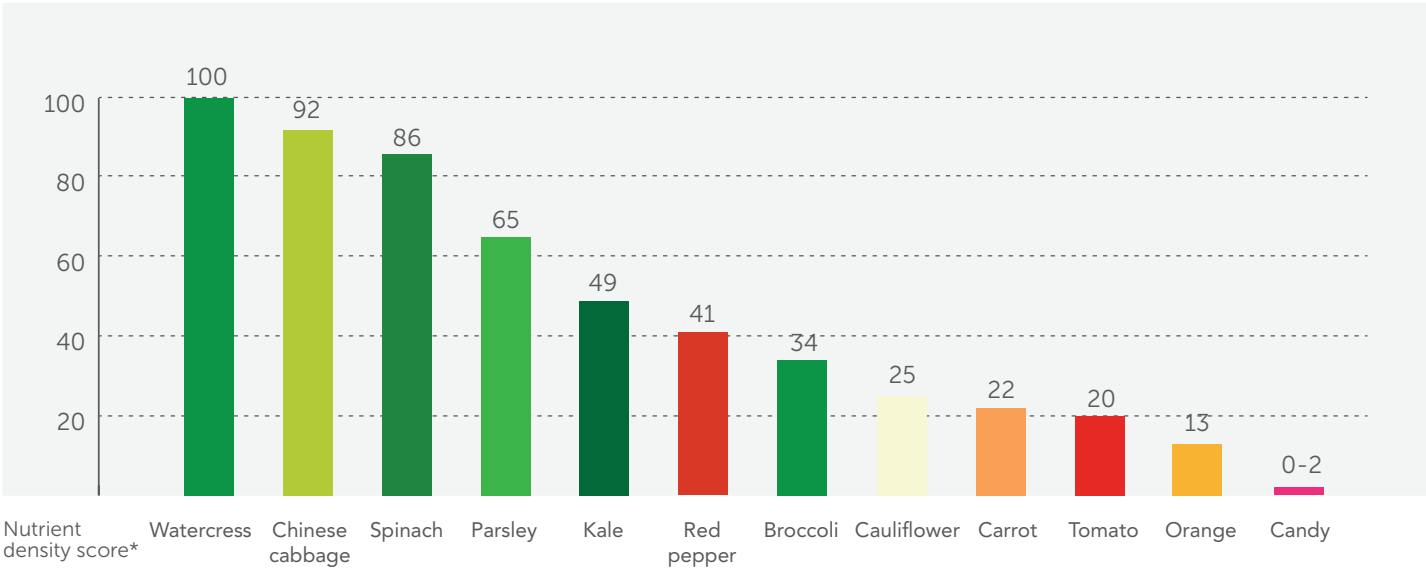
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VEGETABLES

Vegetables mainly refer to cultivated plants of which the juicy parts growing above ground are used for food. The top five vegetables in the US, based on how much households spend on them, have remained almost the same for the past 20 years: tomatoes, potatoes, mushrooms, lettuce and carrots. The most popular vegetable is tomato, which is not a bad choice. Lycopene in tomatoes has been found to protect from cancer, stroke and cardiovascular disease.[360]

Numerous studies done on vegetables advocate their consumption. Eating plenty of green vegetables is particularly beneficial. Vegetables are rich in phytonutrients such as flavonoids and polyphenols as well as trace elements and vitamins. The darker the color, the more likely the vegetable is to contain plenty of these protective nutrients that reduce silent inflammation[361] and prevent various kinds of cancer.[362]

NUTRIENT DENSITY CHART



* The levels of 17 nutrients (fiber, protein, calcium, potassium, zinc, thiamin, vitamins B1, B2, B3, B6, B9, B12, A, C, D, E and K) in relation to the daily recommended values. Nutrient density score of 100 indicates that 100 kcal of the food in question fulfills 100% of the daily recommended value.

Source: CDC

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Intensely colored vegetables also have properties that protect from type 2 diabetes, which was not evident for example in relation to fruits.[363] [364] [365] The liberal consumption of vegetables also lowers the risk of coronary artery disease and stroke.[366] [367]

Eating cruciferous vegetables such as broccoli lowers the risk of stomach[368] and lung[369] cancer. Broccoli contains sulforaphane which has been found in several studies to have breast cancer preventive effects.[370] [371] For men, four servings of broccoli per week may prevent prostate cancer.[372] Eating broccoli regularly helps the liver remove various toxins from the system, supports endocrine function and maintains the function of antioxidants in the system.[373]

WILD GREENS

Harvesting wild greens is called foraging. In Greece, for example, foraging is a long-standing tradition.

Wild plants are not just worthless weeds. The interest in foraging these has seen a rapid rise in popularity in the recent years. The most well-known and easy-to-use wild greens include nettle, dandelion, fireweed, yarrow, ground elder and plantago.

FLAVONOID SUB-CATEGORY	TYPICAL FOOD SOURCES
Anthocyanins	Red, blue and purple berries; red and purple grapes; red wine
Flavanols	*Catechins:* Tea (particularly green and white tea), chocolate, grapes, berries, apples *Theaflavins and thearubigins*: Tea (particularly black and oolong tea) *Proanthocyanidins:* chocolate, apples, berries, red grapes, red wine
Flavones	Citrus fruit (such as oranges, grapefruit and lemons)
Flavonols (such as quercetin)	Capers, yellow onions, lovage, dill, leeks, spring onions, cabbage, broccoli, apples, berries, tea
Flavones	Parsley, thyme, celery, hot peppers
Isoflavones	Soybeans, legumes

Source: Linus Pauling Institute

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Wild greens are hardier than traditional cultivated plants, contain more antioxidants, vitamins and trace elements and do not contain pesticides. Wild greens are also significantly stronger in flavor than traditional vegetables. However, select the harvesting site carefully to minimize pollution caused by traffic, etc.

Many wild greens are superior when compared to supermarket offerings. For example, nettle contains five times more iron than spinach. In studies, nettle has been found to lower blood sugar in type 2 diabetics,[374] ease joint pain[375] and reduce prostatic hyperplasia.[376] Similarly, dandelion is generally much more nutrient-rich than cultivated lettuce.

+ Favor:

- Wild greens
- The darkest green vegetables such as kale and chard
- Sprouts and new crops
- Cabbages
- Onions (particularly colorful ones)

− Avoid:

- Iceberg lettuce and other similar varieties containing few nutrients
- Pale, wilted or translucent vegetables
- Mass produced vegetables
- Uncooked nightshades that are rich in antinutrients and particularly eggplant if you are sensitive to nicotine

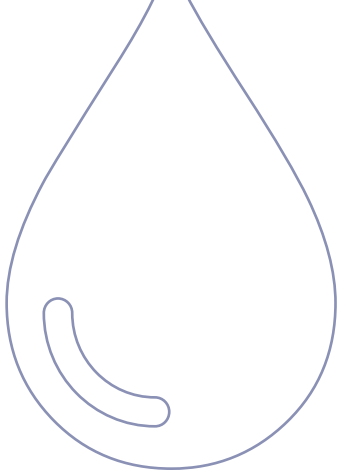
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FATS AND OILS

All butter sold in the United States must be composed of at least 80 % milk fat. In Europe, the EU legislation dictates that butter cannot have any additional ingredients, such as vegetable oils added to it. Butter made from a fermented cream is known as cultured butter, whereas butter made from pasteurized fresh cream is called sweet cream butter. Throughout Europe cultured butter is preferred, while sweet cream butter is more prevalent in the United States. France ranks first in per capita butter consumption with over 8 kg (17 pounds) per person per year. Margarine has become a major part of the Western diet and had overtaken butter in popularity in the mid-20th century.

According to folklore, saturated fats (i.e. hard fats) cause cardiovascular diseases. A comprehensive meta-analysis from 2014 does not support this hypothesis.[377] [378] Systematic research preceding this study also showed that there is no causality between saturated fat and cardiovascular disease.[379] [380]

The health benefits of fats and oils are often seen only from the viewpoint of fatty acids and fat metabolism. However, many oils also contain other health beneficial compounds such as polyphenols. Adding fats or for example avocado into food may also improve the absorption of fat-soluble compounds.[381]



The processing method used in the oil has a crucial impact on its health benefits. If the oil is refined instead of cold-pressed, i.e. if it is heated to up to 260 °C (500 °F), the quality and properties are significantly compromised. The refinement and impurity removing process also removes plant sterols, chlorophyll, flavoring agents, polyphenols acting as anti-oxidants, lignans, lecithin, squalene and other fat-soluble active substances.

COCONUT OIL

Cold-pressed virgin coconut oil should not be confused with coconut shortening often used for deep frying. Virgin coconut oil does not contain traces of the solvents used when processing shortening, nor has the oil been refined, bleached or hydrogenated. Virgin coconut oil contains phenolic compounds that act as antioxidants (such as ferulic acid, p-Coumaric acid and tocopherols) which are not present in coconut shortening.

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Virgin coconut oil has been shown to have a better antioxidant effect than highly processed coconut oil.[382] The polyphenols of virgin coconut oil have been found to calm inflammation.[383] In animal tests, virgin coconut oil was found to improve fat metabolism and lower the risk of coronary artery disease.[384]

BUTTER AND GHEE

Butter contains many nutrients such as CLA and vitamins A, D and K. High quality butter also contains trace amounts of omega-3 fatty acids. The quality and healthiness of the butter depends on the proportion of grass in the producing cow's diet,[385] the cow's general health and the time it spent outdoors, as well as the level of nutrients in the soil.

Saturated fat and in particular the fatty acids present in butter are needed for the normal function of cell membranes and the heart, to carry calcium into the bones and for hormone production. The saturated fat in butter also significantly increases the feeling of satiety.

The traditional Indian method of making clarified butter (ghee) removes the milk proteins from the butter, making

RECIPE

MAKING A HIGH QUALITY SPREAD

Use a blender to mix in equal amounts:

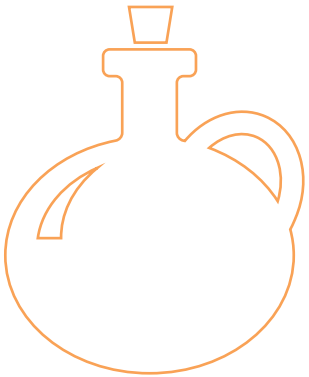
- *As high quality butter as possible (grass-fed, unsalted butter)*
- *Cold-pressed organic virgin olive oil*
- *Spring water*

For example, combine 100 g (1 stick) of butter, 1 dl (half a cup) of olive oil and 1 dl (half a cup) of water. Blend the ingredients and season with high quality salt and for example garlic or basil.



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the resulting product lactose-free. Because ghee contains no milk protein, it can withstand high temperatures. This makes it a very good oil for cooking. Ghee does not contain harmful trans fats that can cause heart disease and other serious health problems. Ghee and butter contain butyric acid which can reduce intestinal inflammation.[386] [387]



OLIVE OIL

Good olive oil is made by picking and selecting the olives by hand. The olives are pressed within 18 hours of picking. The pressing occurs at a temperature below 27 °C (80 °F), retaining all of the natural antioxidants of the olives.

High quality olive oil has been shown to have similar inflammation-reducing effects as anti-inflammatory drugs.[388] These and numerous other benefits occur thanks to the many phenol compounds of virgin olive oil.[389] Oleocanthal in particular has been found to have therapeutic properties.[390] It has been assessed that virgin olive oil is the primary component of the Mediterranean diet in treating chronic illnesses, due to its anti-inflammatory properties.[391]

The regular use of virgin olive oil is associated with a lower risk of stroke, cerebrovascular disorder and various types of cancer.[392] Virgin olive oil has also been shown to lower the risk of cardiovascular disease.[393] [394] In addition, brain health and performance may be improved with the regular use of virgin olive oil.[395] [396]

FISH OIL AND FISH LIVER OIL

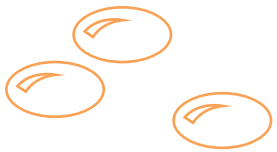
Fish oil and fish liver oil are recommended for individuals who do not eat enough fatty fish. General guidelines recommend eating fatty fish twice per week. Fish and other seafood contain long-chain omega-3 fatty acids (EPA and DHA). Omega-3 fats can be found in many vegetable oils, but they mostly contain short-chain alpha-linolenic acid (ALA) which is poorly absorbed particularly in men.

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Fish oil and fish liver oil are sold in various formats. When using omega-3 capsules it is important to make sure the capsules do not react with light or air. The oxidation of omega-3 fats causes harmful reactions in the system.[397]

The intake of omega-3 fatty acids improves mood, increases attentiveness and generally improves cognitive functions.[398] According to a study report, omega-3 fatty acids (particularly EPA) are highly beneficial especially in the treatment of depression.[399] The intake of omega-3 fatty acids (particularly E-EPA) reduces the silent inflammatory condition of the system which is often a contributing factor to many chronic illnesses.[400]

Docosahexaenoic acid (DHA) has been shown to improve memory and reaction time in healthy young adults.[401] In addition, DHA slows down the aging of the brain, may prevent dementia[402] and improves learning.[403]



Omega-3 preparations are often used as dietary supplements to promote cardiovascular health. However, in light of recent meta-analyses, the evidence is inconclusive.[404 405] Omega-3 fatty acids do lower blood pressure[406] and DHA also improves blood lipid levels.[407] In women, the use of omega-3 appears to reduce the risk of stroke.[408]

VEGETABLE OILS

High quality vegetable oil blends may help in achieving a good balance of fatty acids in the system. However, some vegetable oils are not beneficial due to their high level of omega-6 fatty acids. Processed vegetable oils are also highly oxidizing and may increase inflammation in the system for that reason alone.[409]

The balance ratio of omega-6 and omega-3 in indigenous people was approximately 2:1 which is considered ideal. The imbalance of fatty acids may cause silent inflammation in the system.[410] In Europe the ratio is on average 8:1 and in the US up to 20:1.

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+ Favor:

- Organic fats and oils rich in omega-3 fatty acids
- Ghee and butter
- Fish liver oil and krill oil
- Cold-pressed virgin olive and coconut oils
- Cold-pressed avocado, macadamia and hemp oils
- Oils stored in dark glass bottles, protected from light and heat
- High quality cold-pressed vegetable oil blends
- Dietary supplements of cold-pressed linseed oil and wheat germ oil

– Avoid:

- Hydrogenated vegetable fats
- Vegetable oils rich in omega-6 fatty acids
- Oils stored in plastic bottles
- Oxidized oils, oils exposed to light and heat

VEGETABLE OIL LEVELS (OMEGA-6 AND OMEGA-3)

OIL	OMEGA-6 LEVEL	OMEGA-3 LEVEL
Canola	20 %	9 %
Hemp	55 %	22 % (ALA)
Linseed	14 %	57 % (ALA)
Macadamia	3 %	0 %
Maize	54 %	0 %
Peanut	32 %	0 %
Rapeseed	20 %	9 %
Soy	51 %	7 %
Sunflower	65 %	0 %
Walnut	52 %	10 % (ALA)

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RECIPE

MATCHAGYVER ICE CREAM

This heavenly ice cream combines the nutrient-rich properties of egg yolks, the benefits of fats, green tea polyphenols, trace elements and vitamins B, C and E. Instead of causing sluggishness, the ice cream increases mental agility and improves cognitive performance due to the combined effect of fats, xylitol and caffeine, and theanine from the green tea. If MacGyver were to start his day with ice cream, this would be it.

4 whole organic eggs
4 organic egg yolks
2 tsp Bourbon vanilla
2 tsp amla extract
1 tsp apple cider vinegar
Juice from half a lemon
2 tbsp matcha powder
1 stick organic or grass-fed butter
100 g (½ cup) virgin coconut oil
50 g (1/4 cup) MCT oil
120 g (4.25 oz) xylitol
100 g (½ cup) spring water or coconut water
Pinch of unrefined sea salt

Melt butter and virgin coconut oil in a water bath. Mix all ingredients in a blender and pour into a dish. Freeze overnight in a freezer or prepare in an ice cream maker. Garnish with bee pollen, coconut shavings or sea buckthorn berries.



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NUTS

Nuts are extremely nutrient dense and rich in protein, good fatty acids, minerals, fiber and vitamin E and B complex. The flavor, consistency and convenience of nuts has made many people increase the amount of various nuts in their diet.

The regular consumption of nuts is associated with a significantly lower risk of coronary artery disease[411] and lower mortality in individuals at risk of cardiovascular disease.[412] In 2013, a study spanning 30 years was published in the esteemed *New England Journal of Medicine*. The study showed that the regular consumption of nuts was associated with a longer lifespan and a lower mortality of cardiovascular disease.[413] Individual studies have found nuts to improve the antioxidant capacity of blood.[414]

HEALTH BENEFITS OF NUTS:



- Compared to other nuts, **pistachios** are rich in beta-carotene and lutein. The consumption of pistachios has been found to have a positive effect on the intestinal microbiome.[415] Pistachios balance blood sugar when eaten with a high-carbohydrate meal.[416] Pistachios also reduce the oxidative stress of the system and improve cholesterol levels.[417]



- **Brazil nuts** contain the most selenium out of all foods. Eating two Brazil nuts per day may raise the selenium level of the body as much as a 100 mcg selenium tablet.[418]

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- **Walnuts** are exceptionally rich in short-chain omega-3 fatty acids (ALA) and may improve blood cholesterol levels.[419]



- **Almonds** make an excellent snack that reduces hunger and maintains a constant blood sugar level.[420] In addition, almonds may improve insulin sensitivity[421] and blood sugar regulation when eaten with carbohydrates.[422] They may also lower the risk of coronary artery disease.[423]



- **Pecan nuts** improve the antioxidant capacity of the body and inhibit the oxidation of LDL cholesterol.[424]



- **Macadamia nuts** have the highest fat content of all nuts. It contains nearly 80 % fat, the majority of which consists of monounsaturated fatty acids. Macadamia nuts have been found to have properties that lower oxidative stress, inflammation and cholesterol particularly in individuals with markedly increased cholesterol levels.[425] [426]

Approximately 2 % of the population suffers from a nut allergy. It is the most common cause of food allergy induced death. From the epigenetic viewpoint, it is interesting to note that mothers who eat nuts during pregnancy are less likely to have children with a nut allergy.[427]

Nuts contain relatively high levels of antinutrients that may cause hypersensitivity and inhibit the absorption of minerals (see the section titled "Antinutrients"). Soaking and sprouting reduce these compounds, and for instance a small amount (50 mg) of vitamin C taken concurrently prevents the negative effect of inhibiting iron absorption.[428]

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Nuts sold at the supermarket vary greatly in quality. We recommend vacuum-packed nuts that have been protected from light. For fatty acid balance and health, a handful of nuts is a good daily amount.

+ Favor:

- Walnuts
- Brazil nuts
- Macadamia nuts
- Almonds
- Pistachios
- Pecan nuts
- Cashew nuts

− Avoid:

- Peanuts (in spite of the name, they are in fact legumes; rich in antinutrients and highly allergenic)
- Hazelnuts (readily cause allergy)
- Roasted, rancid, salted and coated nuts

RECIPE

MAKING NUT MILK

- *1 dl (½ cup) nuts (soaked)*
- *4 dl (1 ½ cups) spring water*

Mix the ingredients in a blender until a milky white liquid forms. Strain using a metal sieve or for example a nylon fruit bag. If desired, you can flavor the liquid with a teaspoonful of domestic honey or genuine vanilla. Fresh nut milk can be used as a beverage base or milk substitute.



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SEEDS

Seeds are extremely nutrient dense. However, they are plant parts rich in compounds with which the plants attempt to protect the seeds from damage. Due to this, preprocessing seeds by soaking and sprouting is fairly important for the absorption of nutrients and the removal of harmful substances (antinutrients; see the section titled "Antinutrients").

Various seeds may be used to supplement the diet depending on individual needs:

- Linseeds counterbalance the spike in blood sugar after a meal. They may also alleviate constipation.[429]
- Chia seeds resemble linseeds in terms of nutritional content. They are rich in manganese, magnesium and calcium.[430]
- Soaked chia seeds may improve performance in endurance sports.[431]
- Pumpkin seeds are rich in zinc, magnesium, fibers, antioxidants and monounsaturared fatty acids.[432]
- Shelled hemp seeds are a good source of protein and magnesium.[433]

Favor:

- Hemp seeds (particularly the Finnish Finola variety)
- Chia seeds
- Linseeds
- Pumpkin seeds (particularly the Austrian Styrian variety)

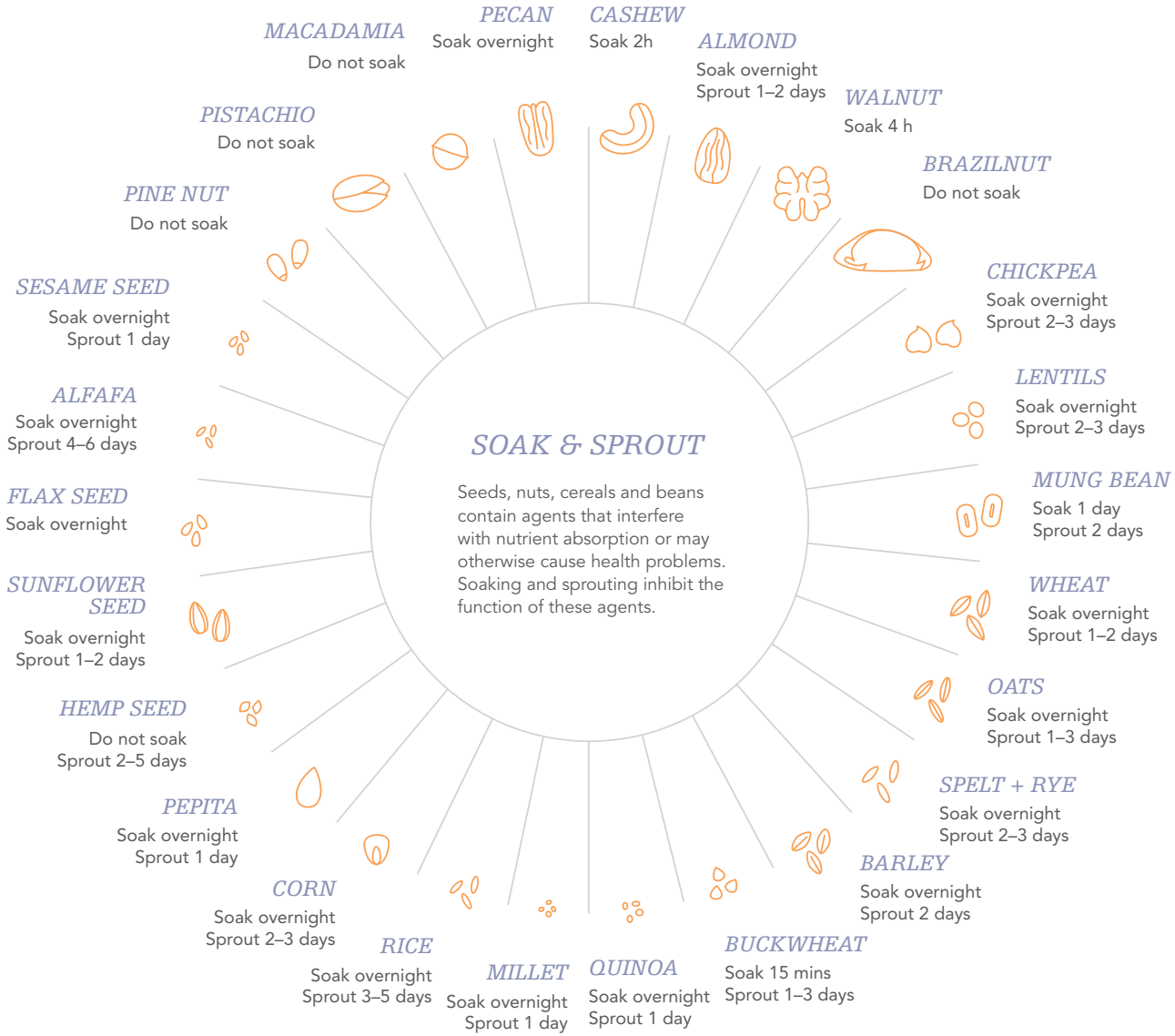
Additionally, many seeds have therapeutic value:

- Pine nuts (may increase the feeling of satiety)[434]
- Grapefruit seeds (oil made from seeds may have antimicrobial properties)[435]
- Milk thistle seeds (liver detoxifying and fat-reducing effect)[436 437]
- Pomegranate seeds (oxidative stress reducing and nerve cells protecting effect)[438]
- Cumin seeds (antibacterial effect)[439]

Use sparingly:

- Sunflower seeds
- Sesame seeds

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LEGUMES

The fruit produced by legumes are called pods. The term legume generally includes various pea plants and cultivated legumes (leguminous plants). The most commonly used legumes include soybeans, peanuts, lentils, chickpeas, beans and peas. More than 40 % of legumes are dried for human consumption. The vast majority of the world's bean production takes place in India.[440]

Interest in the consumption of legumes has piqued especially given the increasing popularity of vegetarian diets. Supermarkets stock products like precooked lentils, chickpeas, mung beans, string beans and various soy products such as tofu.

Legumes are quite rich in agents intended for the protection of their seeds, i.e. antinutrients. These include trypsin inhibitors, lectins (particularly in soybeans), saponins and glycosides (see the section titled "Antinutrients"). For this reason, legumes should always be soaked and cooked thoroughly. Soaking legumes also reduces their level of galactan – an agent which for many people causes flatulence.[441] A particularly harmful legume is the red kidney bean which is rich in lectins. Consuming beans that have been soaked but not cooked (in salads for example) typically causes gastrointestinal symptoms.

In terms of their amino acid composition, the protein structure of legumes is similar to that of animal protein although it lacks sulfur-containing amino acids. For example, broad beans contain up to 35 % protein. They are also rich in slowly digestible starch, some of which is resistant starch that is useful for the intestinal bacterial strain. Broad beans have been farmed in Finland since the 7th century. The Finnish broad beans are not very rich in glycosides because of the successful cultivation.[442]

A large proportion of beans belongs to the *Phaseolus vulgaris* genus. These beans are very rich in antinutrients. This genus includes black beans, cannellini beans, green beans, kidney beans, pinto beans and white beans, among others.[443]

THE HEALTH IMPACTS OF LEGUMES

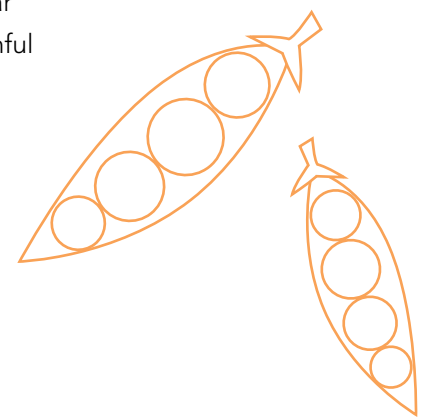
Despite the antinutrients, legumes also have health benefits. Population-based epidemiological studies have yielded results of legumes reducing the risk of intestinal cancer.[444] Hypotheses for the cause include the effects of isoflavones, lignans and various antioxidants in the intestine.[445] Another

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interesting finding is the effect of legumes (with the exception of soybeans) in reducing silent inflammation (lower highly sensitive CRP).[446] The regular use of these legumes may also lower blood pressure[447] and cholesterol levels.[448]

Many bean lectins, particularly PHA (phytohemagglutinin), are not completely destroyed even after soaking and prolonged cooking.[449] The more PHA-rich the individual's diet, the more problems it may cause, particularly in the intestine. PHA has been found to damage the surface of the intestine and to cause silent inflammation.[450] [451] The soybean lectin (SBA) and peanut lectin (PNA) also permeate the intestinal wall[452] and, based on animal tests, may present a predisposing factor for atherosclerosis.[453]

Pea and lentil lectins appear to be significantly less harmful compared to the lectins of other legumes.



Reasons to avoid soy products:[454]

- Soy is rich in phytates that inhibit the absorption of nutrients in the intestine[455]
- Trypsin inhibitors in soy may impair the absorption of proteins
- Phytoestrogens in soy may interfere with normal female hormonal activity,[456] impair thyroid function,[457] cause infertility in men[458] and promote the development of breast cancer in women[459] [460]
- Soy and the saponins of soy protein in particular may damage the intestine and increase its permeability to various other toxins;[461] saponins may also cause the hemolysis (rupturing) of red blood cells[462]
- As much as 94 % of American soy and more than half of soy worldwide is genetically modified (GMO)[463]

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Prepare beans/lentils as follows:

- Soak the beans overnight (12 hours minimum)
  - Tip: boost the lectin removal process by adding baking soda to the soaking water
- Rinse the beans thoroughly
- Cook in boiling water for a minimum of 30 minutes (some beans require significantly longer, 90 minutes)

Other useful methods for preparing beans:

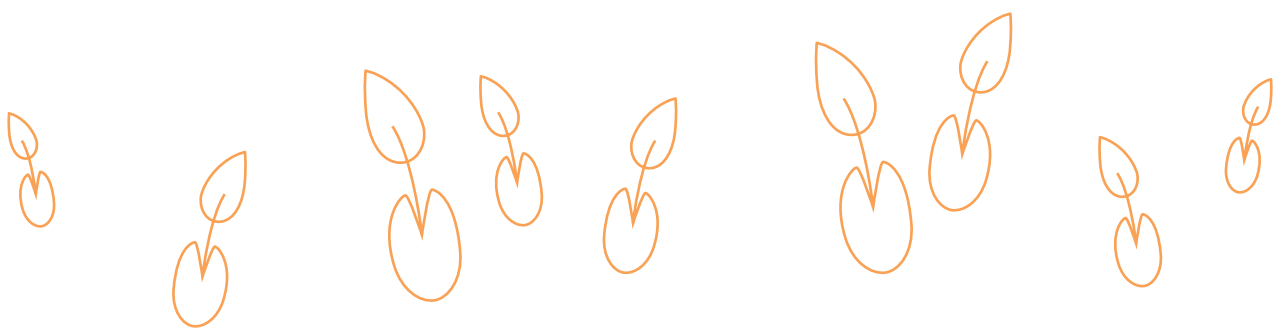
- Sprouting (for example mung bean sprouts)
  - Significantly reduces the lectin and saponin content of beans
- Fermenting (for example, tempeh made from soy; see the section titled "Antinutrients")
  - Does not remove all lectins however

+ Favor:

- Lentils (particularly beluga lentils and red lentils)
- Mung beans, soaked and sprouted
- Fermented tempeh and natto (non-GMO)
- Green peas and broad beans, boiled and peeled

– Avoid:

- Soybeans and tofu
- Beans (particularly kidney beans)
- Peanuts
- Soy protein and other soy products



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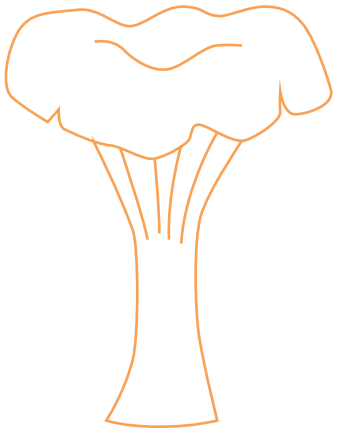
FUNGI

Fungi have been used for medicinal purposes for thousands of years, particularly in Asia. More than 2000 years ago the Greek physician Dioscorides (approx. 40–90 CE) described in his classic work *De Materia Medica* the use of agarikon *(fomitopsis officinalis*) in the treatment of tuberculosis. It is only in recent decades that the medicinal use of fungi has significantly increased in the Western world. There are known to be approximately 140,000 fungus species in the world, only 10 % of which have been scientifically studied.

Generally speaking fungi are rich in fiber, vitamins B1, B2, B3 and D2, selenium, antioxidants and protein. Many fungi contain an amino acid called l-ergothioneine which has been found to protect cells and DNA from damage. L-ergothioneine stimulates the breakdown of sugar and imitates carnitine in its ability to carry fat to cell mitochondria.[464] In addition, many fungi contain compounds that have been shown to have antibacterial, antiviral, antifungal, anti-inflammatory, pain relieving and cancer cell destroying properties.[465] In his book *Fungal Pharmacy* (2011) fungus expert Robert Rogers states that fungi have been shown to have at least 126 distinct medicinal properties.[466]

In nature fungi compete with various microbes, which is why they specialize in producing antibiotics and various antiviral compounds. The medicinal properties of fungi are usually polysaccharides or triterpenes. In addition to these, the glycoproteins, sterols and certain metabolic products (such as antibiotics) of fungi are utilized for medicinal purposes. Numerous important medicines such as penicillin, griseofulvin, erythromycin and cyclosporin were isolated from fungi.

The most well-known medicinal fungi are shiitake (*lentinula edodes*), lingzi mushrooms (*ganoderma lucidum*), turkey tail (*trametes versicolor*), caterpillar fungus (*ophiocordyceps sinensis*), hen-of-the-woods (*grifola frondosa*), agaricus blazei, matsutake (*tricholoma matsutake*), lion's mane (*hericium erinaceus*) and chaga mushrooms (*inonotus obliquus*).[467]

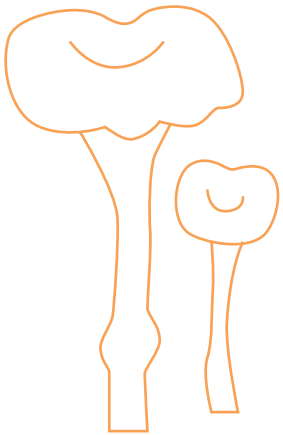


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It is important to pick fungi from an unpolluted site. Fungi collect heavy metals and radioactive cesium from the environment. There are also deadly poisonous varieties such as the European destroying angel, the livid entoloma, lethal webcaps and the funeral bell mushroom.[468] To minimize toxins and cesium, many fungi (such as the morel) should be boiled twice and then rinsed in cold water.[469] If you don't recognize a fungus – leave it be.



+ Favor:



- Double extracted (water and alcohol extracted) medicinal mushroom powders and tinctures
- Using mushrooms with medicinal properties in cooking
- Shiitake and oyster mushrooms are well suited for stews and soups
- Utilizing chaga tea in soup, rice cooking water and as a coffee base
- Extract powders mixed with chocolate, coffee, tea or smoothies
- Yellowfoot
- Golden chanterelle (rich in vitamin D2)
- Black chanterelle (rich in nutrients)
- Penny bun (rich in selenium, protein and fibers)
- Russula mushrooms (yellow swamp russula, russula decolorans, russula paludosa, darkening brittlegill, crab brittlegill, bare-toothed russula)
- Oyster mushrooms (improves fat metabolism and immunity)
- Ceps (orange birch bolete, bay bolete, slippery jack, penny bun, velvet bolete)
- Milkcaps (northern bearded milkcap, weeping milkcap, red hot milkcap, orange milkcap, candy cap, common lactarius, false saffron milkcap, ugly milkcap, woolly milkcap, lactarius lignyotus)
- Sheep polypore, terracotta hedgehog, sheathed woodtuft, morel, gypsy mushroom, slimy spike-cap, pestle puffball, scaly tooth

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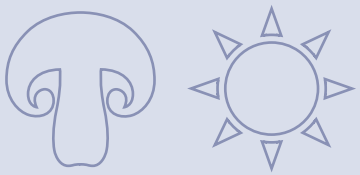
Avoid:

- The excessive daily consumption of fungi (many edible mushrooms such as the yellow knight, penny bun, russula mushrooms, chanterelle and sheep polypore strain the kidneys and liver)[470]
- Fungi that irritate the digestive tract when uncooked (always cook the orange birch bolete, rough-stemmed bolete, honey fungi, shiitake, shaggy parasol, clouded agaric and tangy milkcaps and russulas)
- Poisonous fungi
- Consuming the common ink cap or club-footed clitocybe with alcohol
- Fungi that have collected a lot of heavy metals or radioactive cesium

TIP

VITAMIN D FROM MUSHROOMS

Dry mushrooms in sunlight to multiply their vitamin D content. Studies conducted on shiitake mushrooms indicate that 100 g (3.5 oz) of fresh mushrooms, after having been placed in the sun for 12 hours, contained an additional 1000 µg vitamin D2.[471]



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WATER

On average, human beings are 65 % water. Dehydration at only a few percentage points significantly impairs our general ability to function. Fluid balance regulation is one of our most important regulatory mechanisms.

Water is essential for life. The significance clean drinking water to health of therefore cannot be overemphasized. Fresh water is currently a diminishing natural resource due to intensive farming among other things. As much as 70 % of the world's water resources, including groundwater, is used in agriculture.[472] The United Nations has estimated that the consumption of fresh water has increased six-fold in the past century.

If the raw water (groundwater) contains organic matter suitable as a source of impurities (surface water), impurities remain in the water even after disinfection.

Finland was one of the first countries to change its water purification systems when the negative effects of trihalomethane, furans and bromate became present.[473]

When the disinfection method used is the most common one – chlorination – various chlorinated compounds form as chlorine and organic matter react. Demographic studies have indicated that the long-term use of drinking water made from surface water through chlorination may increase the risk of cancer.[474] However, the advantages of chlorination outweigh the disadvantages.

Even 50+ year old water pipes can leak impurities into the drinking water.[475] [476] In some rural areas, tap water contains excess calcium which can be a predisposing factor for coronary artery disease and heart attacks.[477] In drilled wells, a brown color and unpleasant odor may be a sign of high iron and manganese levels in the water.

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Official guidelines recommend drinking a minimum of 1–1.5 litres (35–50 fl oz), preferably 2–3 litres (70–100 fl oz) of water per day. The water requirement increases with rising temperatures. The elderly should also drink more fluids due to the impaired ability of their kidneys to filter urine.[478]

Store water in a dark glass bottle whenever possible. Avoid plastic as harmful compounds such as BPA or phthalates may dissolve in the liquid. These compounds are present in plastic bottles marked with a recycling symbol with the number 03 or 07. These compounds have a harmful effect on the functions of the endocrine system.[479]

+ Favor:

- Naturally flowing spring water (microbiologically tested)
- Liquid contained by plants (freshly squeezed juice, sap, coconut water)
- Drilled well water and well water
- Purified tap water (separate filtering device or filter attached to tap)
- Reverse osmosis (RO), activated carbon filtering, ion exchange
- High quality spring water or mineral water sold in glass bottles (such as Pellegrino)

– Avoid:

- Water packaged in plastic bottles
- Vitamin-enriched water
- Carbonated water
- Tap water

Locate drinkable spring water around the world:

www.findaspring.com

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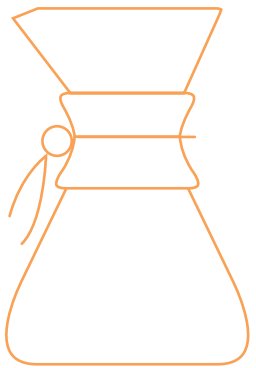
COFFEE

Finns drink the most coffee in the world, 12 kg (26 pounds) per capita. The other Nordic countries are also frequent coffee drinkers. US consumes a little over 4 kg (9 pounds). Besides oil, coffee is the world's most actively traded commodity. Due to this, large quantities of various pesticides are used to maximize production. It is worthwhile to invest in high quality coffee and a proper preparation method, if only for a more satisfying coffee experience.

Coffee that has been grown and processed with quality in mind contains fewer harmful substances and more of coffee's beneficial active agents, and in terms of ethics, it is a significantly more sustainable choice compared to intensively produced coffee. High quality coffee has a well-rounded flavor in that its aromas need not be covered up with sugar, milk or cream.

For most people, reasonable coffee consumption (3–4 cups per day) is compatible with a healthy, balanced diet and an active lifestyle.[480] According to a comprehensive meta-analysis, reasonable coffee consumption may extend the life span, lower the risk of developing type 2 diabetes[481] and cardiovascular diseases[482] and prevent premature death from these illnesses.[483] The health benefits of coffee are most likely due to the anti-oxidants it contains, such as polyphenols. Indeed, more than 1,000 antioxidant compounds have been found in coffee, even more than in green tea and cocoa.[484]

A great many people enjoy coffee daily due to its effects in stimulating and lifting the spirits. However, the effects of coffee depend on one's genetic makeup. For example, the CYP1A2 gene affects the body's ability to remove caffeine from the system, and the VDR gene is associated with caffeine's negative effects on bone health. For these reasons the same amount of caffeine may have a different effect on different individuals.[485]



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The primary risk factors in terms of harmful substances affecting the quality of coffee are pesticides and mycotoxins. Water washing significantly reduces the level of mycotoxins[486] and when washed properly, the ochratoxin A (OTA) level of green coffee beans is reduced by 90 %.[487] In addition to this, roasting destroys 69–96 % of the remaining OTA.[488]

According to a report published by the Finnish Customs in 2012, 12 % of the tested instant coffees, roasted coffees and hot chocolate drinks were contaminated by mycotoxins (OTA, aflatoxins).[489] Coffee producers have been actively involved in initiatives to guide farmers in implementing the best farming practices to minimizethe risk of mold.[490]



BIOHACKER'S COFFEE MANIFESTO

- Favor organic or pesticide-free, pure coffee
- Favor single origin coffee
- Favor water washed coffee
- Favor coffee grown at high altitudes
- Avoid instant coffee, blends of several coffee bean varieties and coffee grown near sea level (at low altitudes)
- Time coffee consumption at a sensible part of your day
- Purchase freshly roasted coffee
- Grind the coffee beans yourself immediately before use
- Use a metal filter, avoid paper filters processed with chemicals
- Only purchase coffee for a maximum of two weeks' consumption at a time
- Always store coffee in an airtight container
- Use kitchen scales to measure the ratio of coffee to water
- Do not over brew coffee
- Do not add sugar, milk or cream to coffee

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RECIPE

BIOHACKER'S COFFEE

- *16 g (½ oz) high quality coffee beans (grown in volcanic soil at high altitude, Central American, water washed, organic)*
- *250 ml (1 cup) nearly boiling spring water or filtered tap water (91 °C / 196°F)*
- *1 tbsp grass-fed butter*
- *1 tbsp caprylic acid, MCT oil or cold pressed coconut oil*
- *Add flavor with a pinch of genuine vanilla, Ceylon cinnamon and/or chaga extract*



First grind the beans into a fine powder. Bring the filtered water to a nearly boiling temperature 91 °C (196 °F) and preheat the blender, glass, thermos and other accessories with hot water. Place the ground coffee and flavorings (vanilla, cinnamon, chaga extract) into a suitable preparation device (Aeropress, Chemex, French press, dripper) and pour one half of the water in.

Mix for 10 seconds and add the remaining water. Brew for 1–4 minutes. Remove hot water from the blender. Add butter, MCT oil and other ingredients into the blender. Press the coffee through the filter. Add the coffee into the blender and mix at full speed for 15–20 seconds.

Pour the foamy coffee into a glass or a thermos. Sip slowly. The fats in the coffee provide a constant source of energy and improve cognitive functions. Also try adding theanine (200 mg) to balance coffee's stimulating effects.

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TEA

Tea is the world's second most popular drink after water. Tea is typically prepared by infusing the leaves of the tea bush (*camellia sinensis*). The history of tea begins during the Shang dynasty of China (1766–1050 BCE) when it was used predominantly for medicinal purposes. In the Himalayan region of India, tea has been used for medicinal purposes for nearly as long. Tea only arrived in Europe at the turn of the 17th century and later became an extremely popular beverage particularly in England.

Turkish people drink the most tea in the world, over 7 kg (15 pounds) per capita. Other big tea drinking countries are Ireland and the United Kingdom. These countries also prefer tea over coffee.

Teas are typically divided into various categories depending on the processing method. The six most common ones are green tea, yellow tea, white tea, oolong tea, black tea and post-fermented tea. Beverages made from leaves other than tea leaves are called herbal teas. The medicinal use of tea beverages is extensive particularly in oriental cultures.

Tea quality depends on several factors. Aside from processing methods, the primary factor is the age of the tea leaves. The most valued tea leaves are the new leaves growing near the blooms. Tea leaves are rich in polyphenols such as flavonoids, theanine, theophylline, epigallocatechin-3-gallate (EGCG) and other catechins. In addition, all teas contain 30–90 mg of caffeine per cup depending on the tea variety and the preparation method.[491]

Each tea variety has a specific brewing time and temperature as well as traditional methods of use. These have a significant impact on the antioxidants, caffeine, flavor and health benefits of the tea. We encourage you to consult expert tea traders regarding optimal brewing times and temperatures. Some tea varieties may contain heavy metals and environmental toxins,[492] highlighting the importance of ensuring that the tea is of high quality.



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GREEN TEA

Green tea is probably one of the most studied tea varieties for its health benefits. Green tea contains 30–40 % of water-soluble polyphenols, whereas black tea contains only 3–10 %. Green tea is also suitable for individuals sensitive to caffeine due to its theanine content. Theanine reduces the unpleasant side effects of caffeine.[493]

Comprehensive meta-analysis studies reveal that the consumption of green tea lowers blood pressure,[494 495] the levels of both total cholesterol and LDL cholesterol[496] as well as the levels of fasting glucose and long-term glucose.[497] Green tea may also slow down the deterioration of memory. The optimal health benefits are achieved by drinking 5–7 cups per day.[498] An alternative to drinking abundant amounts of tea is to take green tea extract with a meal. Extracts may also have a slimming effect.[499]

YERBA MATÉ

Yerba maté (mate) is a beverage prepared by steeping the leaves and new shoots of the maté tree. Technically, it is not a variety of tea but it is used in very similar manner. Traditionally, maté has been used as an empowering drink amongst the indigenous people of South America.

Yerba maté is rich in antioxidants such as quercetin, vitamins B and C and minerals (magnesium, potassium, zinc).[500] Maté also contains several stimulating and refreshing xanthines that are also present in coffee (caffeine), tea (theophylline) and cocoa (theobromine). Maté may improve mood,[501] lower cholesterol levels and reduce inflammation[502] as well as balance blood sugar.[503]



PU-ERH TEA

Pu-erh tea is black tea originating from the Yunnan province in China. The fermenting method used to prepare pu-erh tea makes it significantly healthier than black tea. The longer pu-erh tea is fermented and matured, the more valuable and healthy it is. Some pu-erh tea cakes may keep for nearly a hundred years.

Pu-erh tea is rich in polysaccharides, polyphenols and statins. Pu-erh tea contains slightly less caffeine than coffee. Several animal tests have found positive effects on fat metabolism[504] and body weight.[505 506] Very little pu-erh tea research has been conducted on humans.

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OOLONG TEA

In terms of oxidation level, oolong tea is placed between green tea (little oxidation) and black tea (great oxidation). The same leaves can be used for steeping several times. Like green tea, oolong tea is rich in antioxidants such as various catechins and polyphenols.

A comprehensive Chinese demographic study showed that the long-term use of oolong tea was associated with improved blood lipid values.[507] Unlike other tea varieties, oolong tea also has a strong effect on the GABA-A receptors (calming neurotransmitter).[508]



WHITE TEA

White tea comes from China, particularly the Fujian province. It is a lightly oxidized, fine tea prepared from the young buds and leaves of the tea bush. White tea is significantly more rare than the other tea varieties. White tea contains slightly more caffeine and equal amounts of antioxidants compared to green tea.[509]

The consumption of white tea may reduce the risk of stroke[510] and based on animal tests, also prevent atherosclerosis.[511 512] Used topically, white and green tea may protect the skin from the harmful UV rays of the sun.[513 514]

+ Favor:

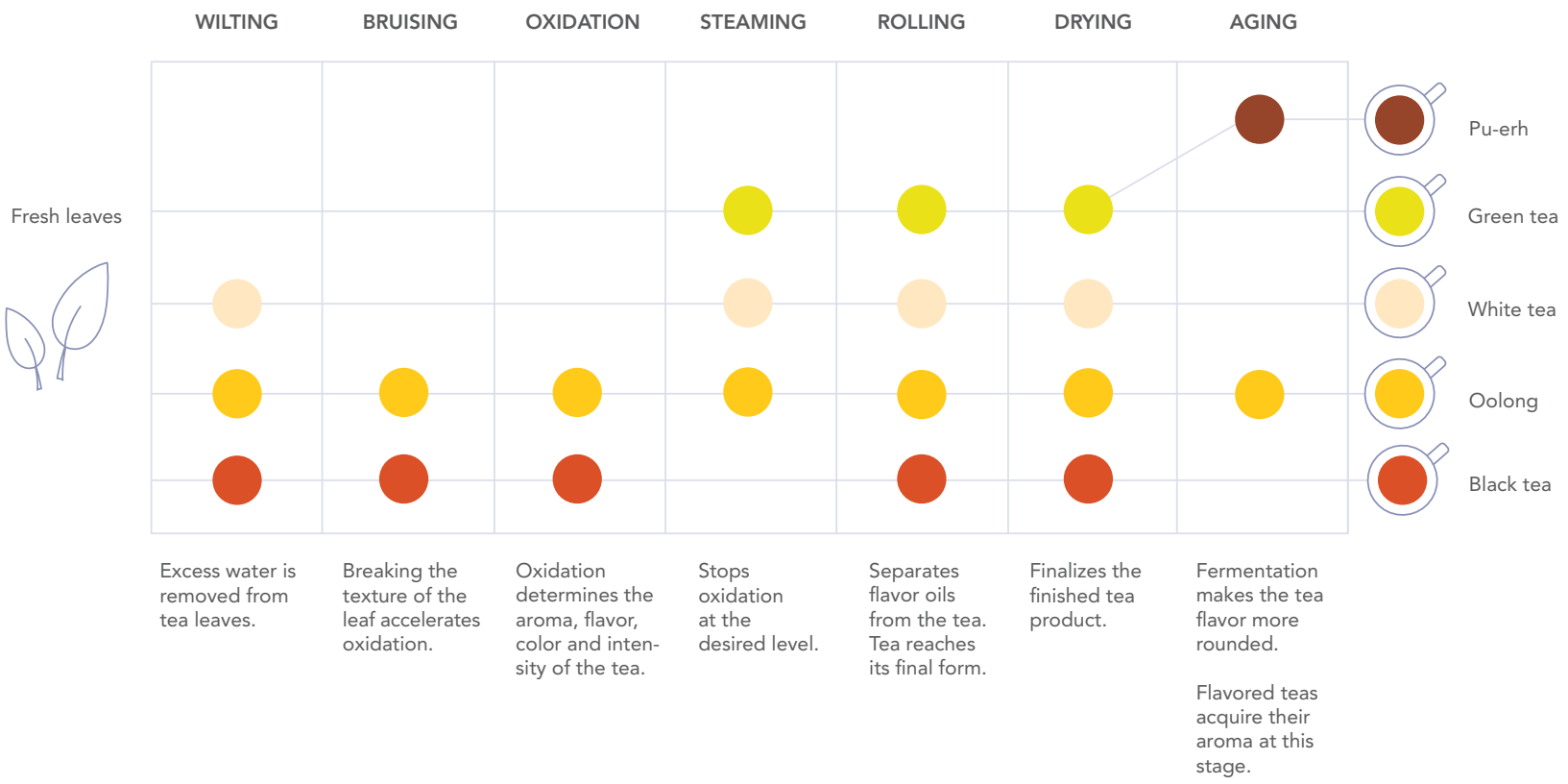
- Pu-erh tea after a high-fat meal (85–95 °C / 185–203 °F, 12 seconds to 2 minutes)
- Green tea with meals (60–80 °C / 140–176 °F, 1–2 minutes)
- Sencha, matcha, gyokuro
- Oolong tea when you need to concentrate (80–85 °C / 176–185 °F), 2–3 minutes)
- White tea (60–70 °C / 140–158 °F, 1–2 minutes)
- Yerba maté when working (60–70 °C / 140–158 °F, 3–5 minutes)
- Caffeine-free herbal tea in the evening

– Avoid:

- Bagged tea
- Prepared ice teas
- Black tea
- Using milk with tea (inhibits the health benefits of flavonoids)[515]

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TEA PROCESSING



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ALCOHOL

The highest consumption rates of alcohol seem to be concentrated in Europe. The highest rates can be seen in countries like Estonia, Belarus, Lithuania, the Czech Republic, Austria and Ireland, with each around 11–14 liters (3–6 gallons) per capita annually. Drinking per se and high-volume drinking are consistently more prevalent among men than women.

According to the World Health Organization, the use of alcohol is associated with at least 60 different illnesses. Health hazards are present even with short-term liberal use, but severe hazards become apparent particularly with long-term use. The main alcohol illnesses are alcohol dependency, alcohol poisoning, alcohol psychosis, alcoholic liver diseases and pancreatitis. In addition to these, the liberal consumption of alcohol causes neurological and psychiatric illnesses, hormonal and nutritional disorders, degeneration of the heart muscle, arrhythmia, cancer and blood diseases. As many as 6 % of all deaths are caused by alcohol. Alcohol-related causes of death are the single most significant factor in 15–64 year old men, ahead of coronary artery disease. Alcohol plays a role in a significant number of accidents.[516]

Based on a comprehensive demographic study report, the moderate use of alcohol (2 units of alcohol for men and 1 unit for women per day) in good company may reduce the risk of dementia and the impairment of cognitive functions. The study also found that heavy use (more than 3–5 units per day) increased the risk of dementia and impaired cognitive functions.[517]

RECIPE

HANGOVER CURE

- *3 dl (1 1/4 cups) coconut water*
- *1 avocado*
- *Juice from half a lemon*
- *Couple of broccoli buds*
- *300 mg red ginseng*
- *2–3 cm (1 inch) piece of ginger*
- *2 egg yolks*
- *1 tsp chlorella*
- *Sea salt and fenugreek, to taste*

Blend the ingredients in a blender.

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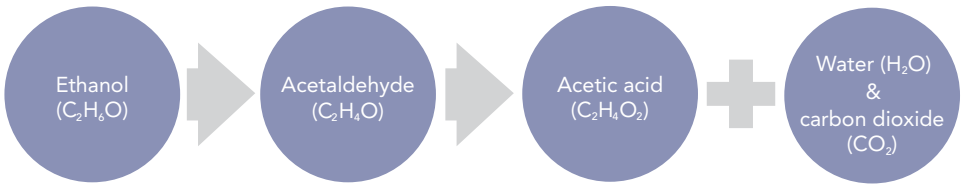
+ Favor:

- Total abstinence or consuming small amounts infrequently in good company
- Homemade tinctures
- Homemade herbal beer and alcoholic cider
- Clear liquor packaged in glass bottles (potato-based is preferable to grain-based)
  - Russian Standard Imperia
  - Russian Standard Platinum
- Gin, tequila and whiskey
- Champagne
- Biodynamic red wines (low tannin, no added sulfites)
- Natural wines
- Classic herbal beers (Healing Herbal Beers, Buhner)
- Sprite or equivalent lemon and lime mixer (accelerates the breakdown of acetaldehyde in the system)[518]

– Avoid:

- Lagers
- Colored liquors
- Alcoholic ciders sweetened with sugar
- The consumption of carbonated beverages mixed with alcohol (increases the absorption of alcohol)

THE BREAKDOWN OF ALCOHOL IN THE SYSTEM



Hangover symptoms are caused by acetaldehyde poisoning. The breakdown of acetaldehyde into harmless acetic acid requires glutathione tripeptide (glutamic acid, cysteine and glycine).

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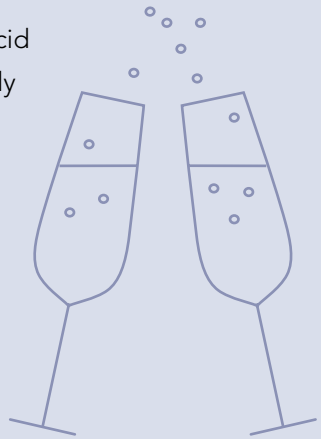
TIP

BEATING A HANGOVER

The suggestions are based on supporting natural glutathione levels, removing toxic substances and restoring nutrients depleted by alcohol.

Before use:

- Eat meat (particularly turkey) with turmeric and egg yolks (amino acids)
- 5–10 g (0.17–0.35 oz) chlorella
- Vitamin B1 and alpha lipoic acid
- 100 mg glutathione (preferably in a liposomal form)
- Milk thistle (silymarin) and fenugreek[519]



During:

- 500 mg vitamin C and 200 mg N-acetylcysteine (NAC) before each alcoholic drink
- 300 mg ginseng (accelerates the exit of acetaldehyde from the system)[520]
- A glass of water with each alcoholic drink

After:

- Vitamin B complex
- Electrolytes (unrefined sea salt and coconut water)
- Broccoli (sulforaphane eliminates toxic acetaldehyde from the body)[521]
- Fresh ginger (2–3 cm / 1-inch piece prevents nausea)

Before bed:

- 1–2 g (0.03–0.07 oz) activated charcoal (binds the toxins formed)

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03
EXERCISE

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"Obstacles don't have to stop you. If you run into a wall, don't turn around and give up. Figure out how to climb it, go through it, or work around it."

– Michael Jordan (b. 1963)

"The body is your temple. Keep it pure and clean for the soul to reside in."

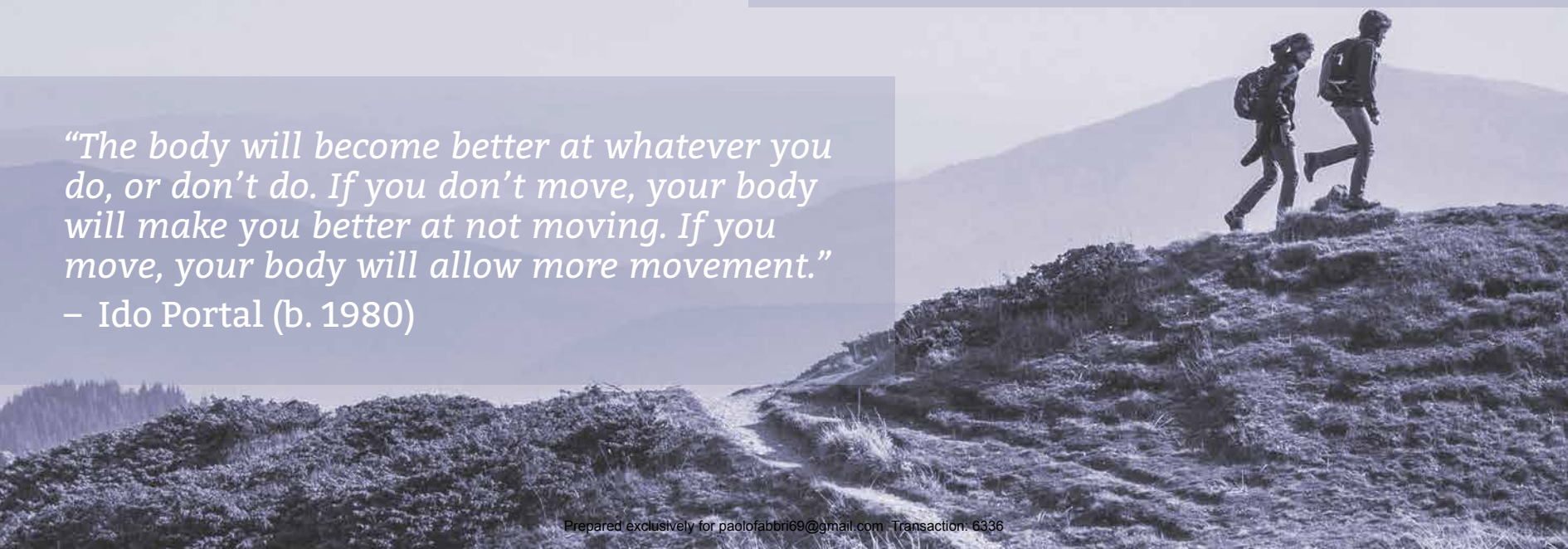
– B. K. S. Iyengar (1918–2014)

"Lack of activity destroys the good condition of every human being, while movement and methodical physical exercise save it and preserve it."

– Plato (427–347 BCE)

"The body will become better at whatever you do, or don't do. If you don't move, your body will make you better at not moving. If you move, your body will allow more movement."

– Ido Portal (b. 1980)



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"I GUESS I SHOULD EXERCISE MORE TO LOSE WEIGHT..."

Mark is severely overweight. According to his doctor, he is at high-risk of developing diabetes or hypertension. He has been prescribed at least 30 minutes of exercise three times per week. To lose weight, he should also avoid fatty foods, and eat less calories overall.

Mark has heard the same advice several times over the years but nothing seems to work. After intensively losing weight, he often gains it all back again.

Once again, Mark has decided to get a grip on himself and shape up. This time, he is in it for the long haul – after all, it's a question of health. He decides to eat less and exercise more. This includes an exercise regime that involves prolonged aerobic exercises every morning. He also makes a New Year's resolution to lose 10 kilos and to run a marathon with his workmates.

At first, everything seems to go as planned. Mark selects low-fat options at the supermarket and consumes several energy drinks when exercising. His efforts begin paying off – he loses weight rapidly and his fitness improves.

After a few months, however, something is not right: Mark sleeps restlessly, his joints ache, and he's consumed by constant hunger and fatigue. Despite exercising daily, his weight is no longer coming off.

Does such self-torture even make sense? Could it be that there's something not quite right about the advice "eat less, exercise more"? Or is Mark's willpower simply lacking?

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CHEETAH: THE PREDATOR OF THE SAVANNAH

"Have the will of the tiger, the speed of a cheetah and the heart of a lion"
– Kevin McCarty (b. 1972)

The archetype of graceful, strong, and fast movement in this book is the cheetah – the fastest land mammal in the world. The cheetah is a highly revered animal in Egyptian mythology: fast, strong, brave, and fearless.

The moving cheetah has been compared to a bow that produces a great deal of force. In addition to its well renowned speed, its agility and suppleness are the primary qualities for catching prey. The cheetah also has particularly large and strong internal organs to maintain a sufficient supply of oxygen. The cougar and the jaguar – close relatives to the cheetah – are also fast and efficient predators.

Humans can exercise speed, suppleness and strength like the cheetah. The Exercise section of the *Biohacker's Handbook* attempts to clearly describe functional exercises in various environments as well as boosting general energy levels. Additionally, the purpose of this section is to provide diverse tools for strength, speed, agility, and endurance training.



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EXERCISE AND HEALTH

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The importance of exercise to health and well-being was already known in Ancient Greece. Hippocrates (460–270 BCE) has been quoted: "Eating alone is not enough for health, there must also be exercise." During the Renaissance, the significance of the individual's own actions on his or her health became of interest.

Health was no longer in the hands of God alone. In his 1553 work, *Book of Bodily Exercise* Spanish doctor, Christóbal Méndez described exercise as "blessed medicine" for the health of individuals. This medical point of view became more and more prevalent entering the industrial era. In his 1769 book, *Domestic Medicine*, Scottish doctor, William Buchan indicated that exercise alone could prevent many illnesses that were difficult to treat. French doctor, Clement Tissot, on the other hand, highlighted the importance of incidental exercise. From the late 19th century exercise was introduced into school curricula.[1]

The significance of exercise to health and general well-being was understood rather early on. Proper scientific studies on the subject matter did not appear until the turn of the 20th century. *The American Journal of Physiology* was first published, and in 1920, physiology professor August Krogh won the Nobel Prize in medicine, having discovered the mechanism that regulates blood flow in the muscles. Research on the health benefits of exercise really took off in the 1950s when *The Lancet* published a groundbreaking study on the positive impact of exercise on the prevention of coronary heart disease.[2]

The World Health Organization (WHO) has created global recommendations on physical activity for health which are based on extensive research. For individuals aged between 18 and 64 physical activity includes recreational or leisure-time physical activity, transportation, occupational, household chores, games, sports or planned exercise, in the context of daily, family, and community activities.[3]

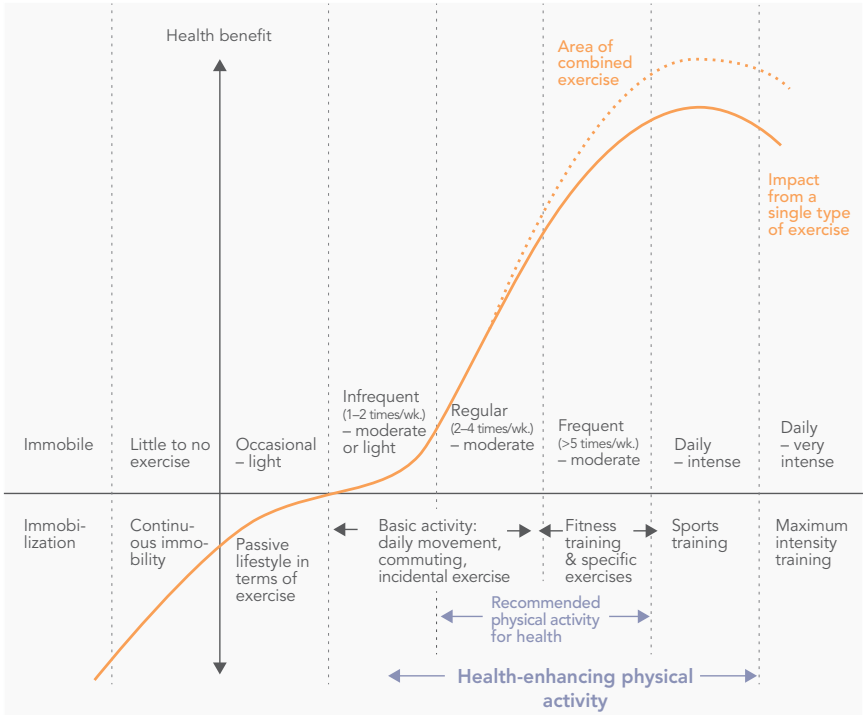
- Improve endurance fitness by exercising several days per week for a minimum combined duration of 2 hours 30 minutes (brisk exercise) or 1 hour 15 minutes (strenuous exercise)
- In addition, improve muscular fitness and proper form at least twice per week
- Additional health benefits may be achieved with five hours of endurance exercise per week.

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According to studies, the health benefits of regular exercise include the following:[4]

- Lowered risk of premature death
- Lowered risk of coronary heart disease
- Lowered risk of stroke
- Lowered risk of hypertension
- Lowered risk of type 2 diabetes
- Lowered risk of metabolic syndrome
- Lowered risk of colon cancer
- Lowered risk of breast cancer
- Prevention of weight gain
- General benefit in weight loss combined with reduced energy intake
- Improved condition of the cardiovascular and circulatory system as well as muscular fitness
- Improved bone density
- Prevention of falling
- Prevention of depression
- Improved cognitive functions

THE CUMULATIVE IMPACT OF EXERCISE ON HEALTH



Source: Vuori, I. & Taimela, S. & Kujala, U. (2005). Liikuntalääketiede. Duodecim: Helsinki.

Based on meta-analysis studies, the most effective way to encourage people to exercise is *behavioral intervention* rather than *cognitive intervention*.[5 6] In other words, people respond more easily to concrete experiences compared to intellectual facts. Examples of behavioral intervention include setting goals, self-monitoring and measuring, feedback systems, exercise prescriptions, and various challenges.

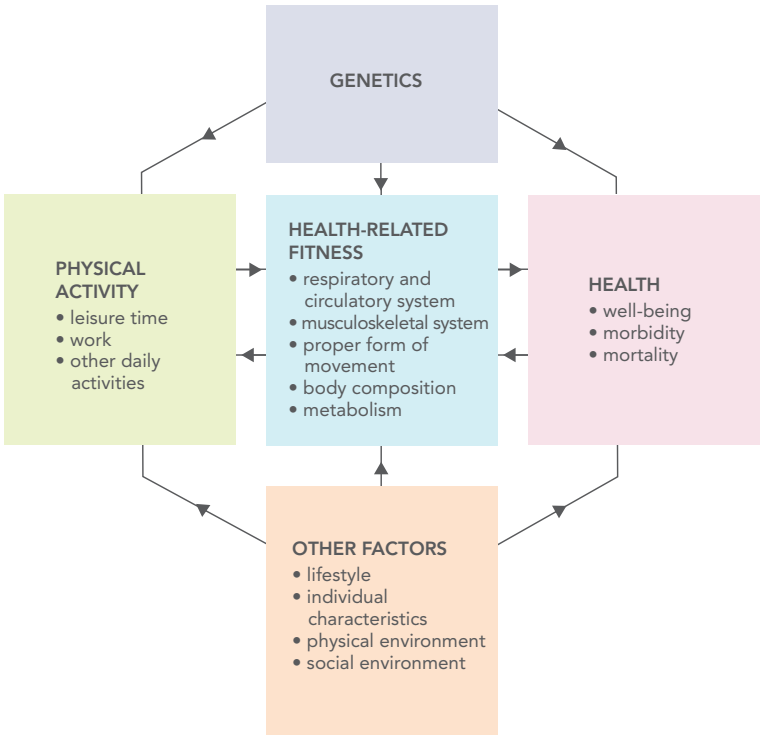
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EXERCISE AND THE BRAIN

As the saying goes, sound mind in a sound body. Most people are aware that exercise makes us feel better. Previously it was believed that this was due to physiological factors only. However, recent studies have found that exercise improves our brain function. According to the latest meta-analyses, exercise increases the amount of gray matter, particularly in areas crucial for memory functions such as the orbitofrontal cortex and the hippocampus.[7]

In today's technology-oriented world, we have become alienated from our natural need to move, hunt, and gather food. In terms of survival, immaterial things have replaced physical effort. It is tragic that it is precisely the lack of bodily exercise that makes us unable to deal with the challenges that cause an ever-growing amount of stress on our minds.

Of all the medication used to treat people, the share of psychiatric medication has also grown dramatically (see the Mind chapter of the *Biohacker's Handbook* for more details). In 2000, scientists at Duke University published a study that compared the effects of the antidepressant sertraline as well as exercise on cases of severe depression over the course of 10 months. Regular exercise was found to be more effective in treating depression compared to medication.[8]



EXERCISE–FITNESS–HEALTH

Source: Bouchard, C. & Shephard, R. (1994). *Physical Activity, Fitness and Health*. Oxford University Press.

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A comprehensive 2014 meta-analysis found physical exercise to have a significant positive impact on various levels of depression. Exercise is recommended as a treatment for mild or moderate depression.[9] According to meta-analyses, regular exercise also reduces stress which is a predisposing factor for various illnesses.[10] Aerobic exercise in particular has also been found to boost the production of endogenous cannabinoids (anandamide),[11] [12] opioids (beta-endorphin), and phenylethylamine.[13] These chemicals probably contribute to the pleasurable experience of *a runner's high*.

In his book *Spark – The Revolutionary New Science of Exercise and the Brain*, John J. Ratey, an associate clinical professor of psychiatry at Harvard Medical School, discusses in depth the impact of exercise on the brain and the mind.[14] According to Ratey, exercise has been found to increase the long-term potentiation of nerve cells, improving the ability to learn and memorize. Similarly, BDNF protein (Brain Derived Neurotrophic Factor) levels have been found to increase after physical activity. This has a positive impact on cognitive functions.[15] The most significant increase of BDNF in the blood was found after aerobic exercise and particularly high intensity activity.[16]

The effects of strength training on BDNF have been inconclusive.[17] [18] The positive impact of strength training on the brain function is mainly due to other mechanisms.[19] For elderly people in particular, performing strength training at least twice weekly increases the functional plasticity of the brain.[20] A study published in 2014 found that just one 20-minute strength training session significantly improves episodic memory.[21]

Several studies have found that exercise reduces the occurrence of neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease as well as assists in the treatment of these diseases.[22] [23] For example, dance has been used to significantly improve the motor skills and quality of life of patients suffering from Parkinson's disease.[24] The development of a child's brain, nervous system, and cognitive function to their full potential also requires regular and varied physical activity.[25] [26]

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THE INDIVIDUALITY OF EXERCISE

A basketball player more than two meters (6 ft 7 inches) in height is unlikely to do well in ski jumping. Conversely, a lean marathon runner will not be a successful weightlifter. Humankind represents a diversity of sizes, strengths and physical characteristics. It is therefore worthwhile to carefully consider the suitability of each type of exercise – what is my body suited for and what are my personal preferences?

There are individual differences in recovery, too. Generally speaking, women need more time to recover compared to men, and as we age the recovery period grows longer. Because of this, a customized training program and listening to one's own body are key in maintaining and developing the enjoyment of exercise. Aside from sex and age, other individual factors include one's previous fitness level, training background, and the development level of various physical characteristics.

THE SOCIAL DIMENSIONS OF EXERCISE

Regular exercise affects the social behavior of the individual. People who exercise regularly generally have healthier emotional lives and more confidence.[27] For children in particular, physical activity has been found to improve social skills.[28] Exercising in a group also invokes team spirit and may improve communication skills. It is fascinating to note that rowers, for example, have a higher tolerance of pain in a group setting than when training alone.[29] Indeed, team sports appear to beat individual sports in developing psychosocial skills and health.[30]

In addition to exercise, spectator sports have also been found to have health benefits. Intensive sports moments experienced and shared with others may strengthen social relationships.[31] The social impact of spectator sports is much greater for men compared to women. Many people also consider watching sports an aesthetic experience which, like art, may activate areas of the brain to do with aesthetic pleasure.[32]

NEVER STOP PLAYING

Exercise should not be thought of as a chore or a compulsory item to check off to promote health. Playful movement is normal and characteristic of children but adults often completely forget about it. We don’t stop playing because we grow old. We grow old because we stop playing.

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Exercise could be thought of as natural, playful movement that takes place throughout the day, without forced performances, grimacing, and exhaustion. The saying "grease the groove" (GTG)[33] refers to short, almost playful exercises conducted throughout the day that place significantly less strain on the nervous system whilst yielding results along with being fun. For example, you could do a few pull-ups each time you pass under a scaffold. You could also break up the working day with intermittent push-ups, squat jumps or dashes in the stairs. Lastly, nature and the outdoors offer endless possibilities.

72-year-old Stephen Jepson has taken the concept of playfulness in exercise and created a philosophy called *Never Leave the Playground*. Jepson rides a unicycle, balances, juggles, and walks a tightrope. His philosophy is constant movement regardless of the surroundings.[34]

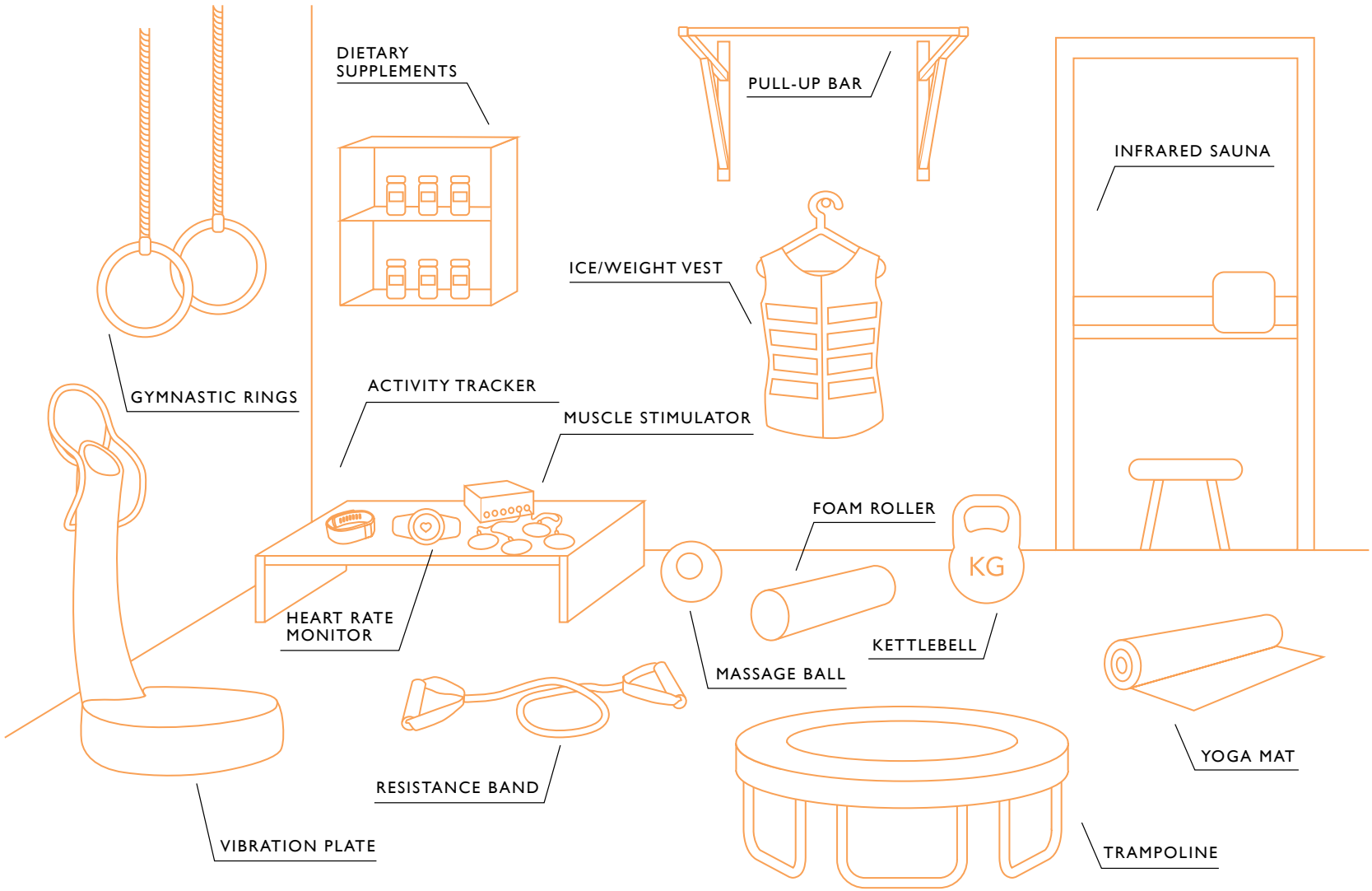


BIOHACKER'S EXERCISE MANIFESTO

1. Life is movement, movement is medicine.
2. Exercise in a regular and varied manner.
3. Train equally in strength, speed, agility, balance and endurance.
4. Increase everyday incidental exercise.
5. Utilize your body weight in training.
6. Exercise outdoors whenever possible.
7. Quality over quantity.
8. Exercise in good company.
9. Maintain the balance between exercise and rest.
10. Never stop playing.

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BIOHACKER'S GYM



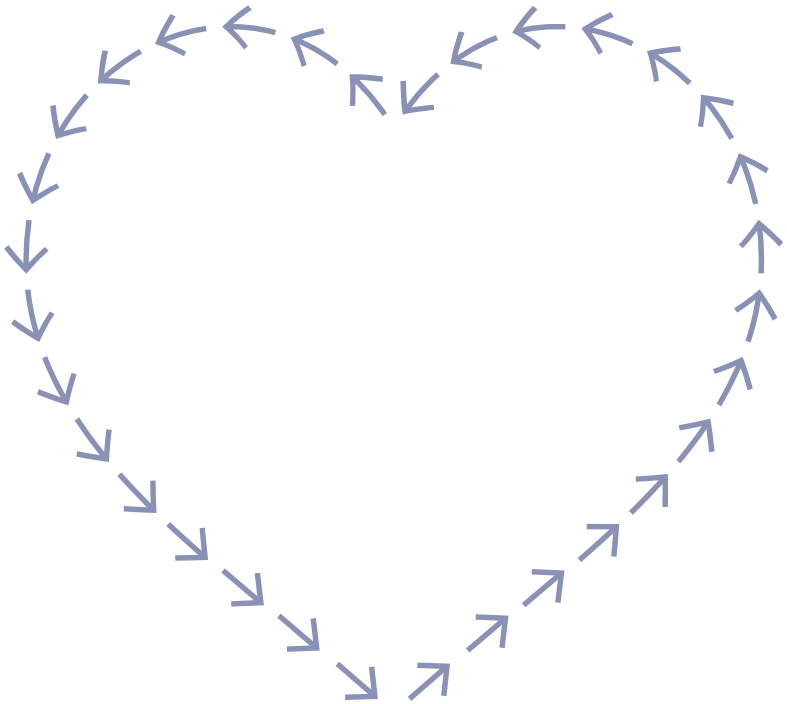
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ANATOMY AND PHYSIOLOGY

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The cardiovascular and circulatory system consists of the heart, arteries, veins, capillaries, and lymphatic vessels. Its function is to carry blood to various parts of the body. The heart acts like a pump, pushing blood from veins into arteries and capillaries. Biochemical reactions and substance exchange between blood and cells occur in capillaries from which "used" blood travels into the heart through veins. The vessels of the lymphatic system absorb the interstitial fluid from tissues back into veins.[35]

The purpose of the circulatory system is to deliver oxygen and nutrients to cells and to remove waste products from them. Hormones secreted by endocrine glands are also delivered throughout the body by the circulatory system. In addition, it serves as a part of the body's temperature control system.



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HEART

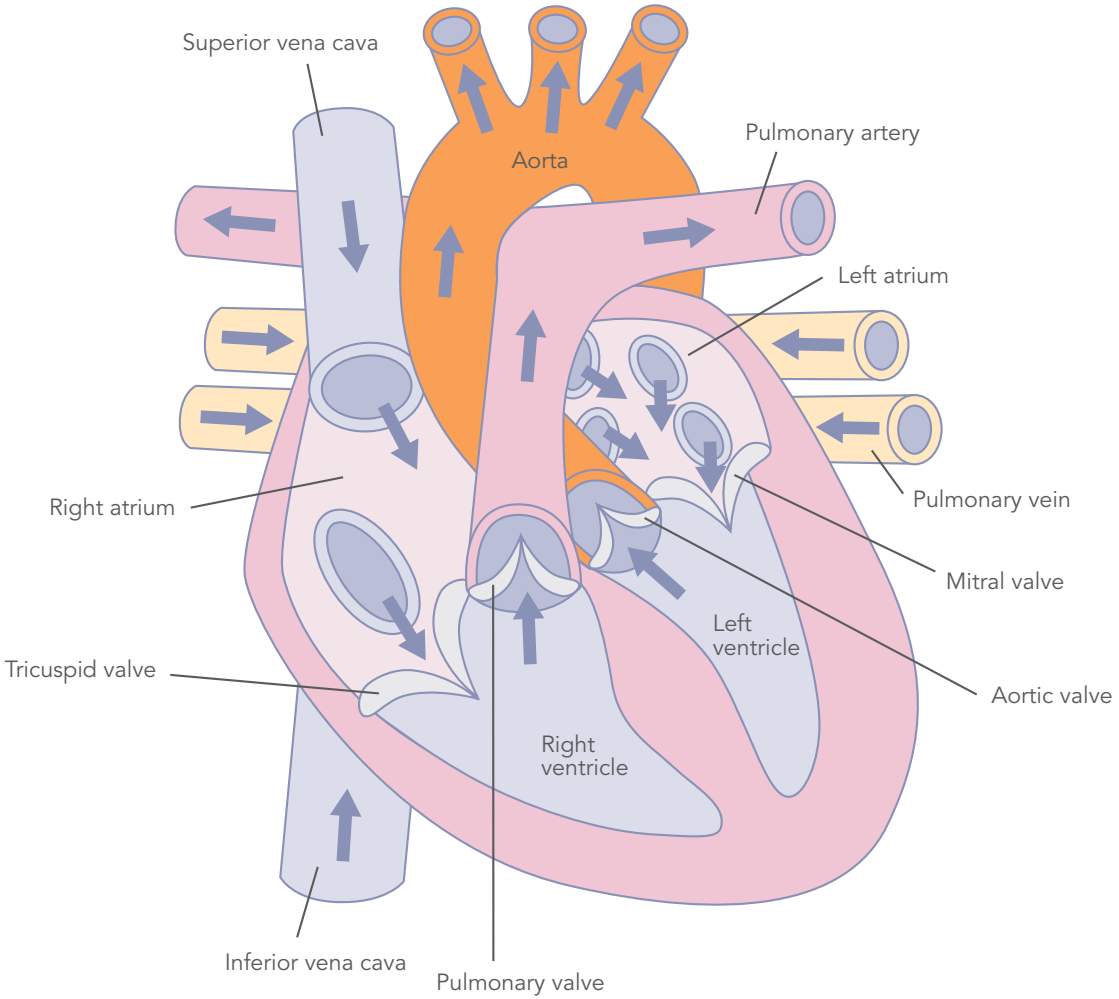
The heart is located inside the chest, in the mediastinum behind the sternum. The heart is formed of a muscular wall consisting of three layers, and inner cavities. The outermost layer (*pericardium*) is a double-walled sac around the heart. Between the layers of the sac, there is the pericardial cavity, filled with liquid. This reduces friction caused by the heart beating. The inner layer of the sac is attached to the middle layer of cardiac muscle tissue (*myocardium*). Conversely, the outer layer (*parietal pericardium*) is attached to the surrounding tissue. Inside the cardiac muscle, there is the endocarium layer, which is in direct contact with the blood that flows through the heart.[36]

The heart has four chambers: the right and left atrium and the right and left ventricle. In addition, there are four valves. Two of these are located between the atria and the ventricles (atrioventricular valves) and the other two between the ventricles and the arteries (semilunar valves). Blood from the body flows from the veins into the atria. From there, the blood moves into the ventricles and, as the heart contracts, into the arteries. Low-oxygen blood travels via the superior and inferior vena cava into the right atrium, from which it is pumped via the right ventricle into the lungs. Oxygenated blood returns from the lungs into the left atrium, from which it is pumped via the left ventricle throughout the body.

The heart has a separate circulatory system that secures its oxygen supply. It involves three coronary arteries (one on the right and two on the left) and their branches. Coronary arteries are attached to the base of the aorta where they receive blood rich in oxygen. A clot in a single artery branch may cause lack of oxygen in the cardiac muscle, leading to coronary thrombosis. The low-oxygen blood used by the cardiac muscle travels via the veins into the right atrium to be recycled.[37]

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PARTS OF THE HEART

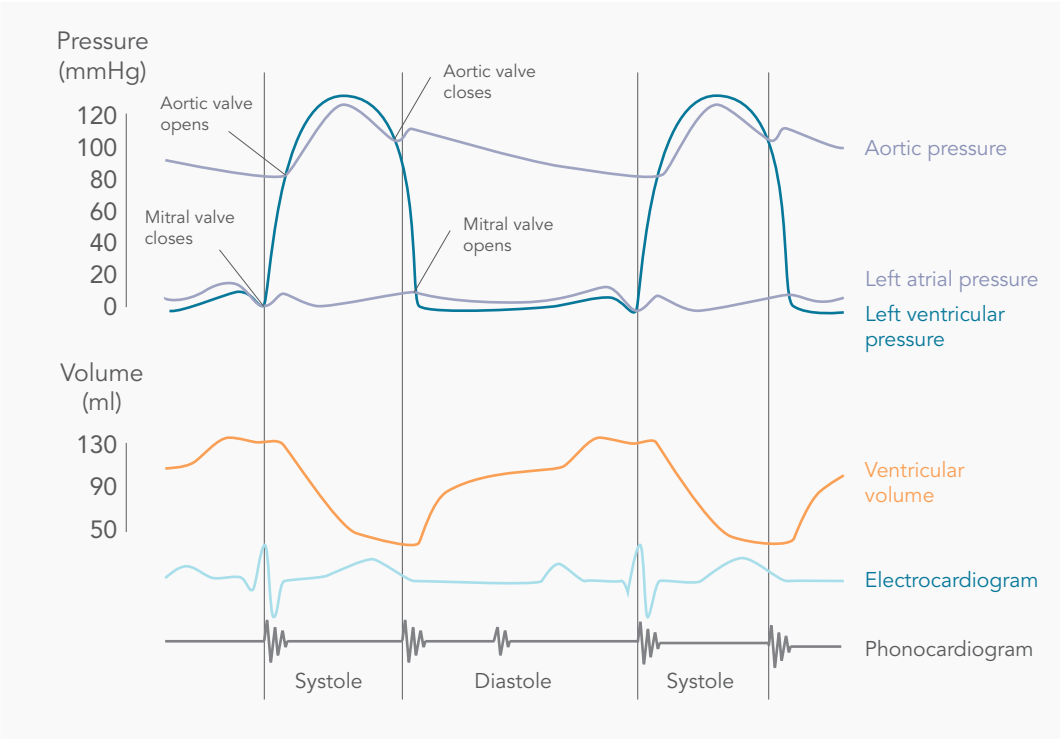


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CARDIAC FUNCTION

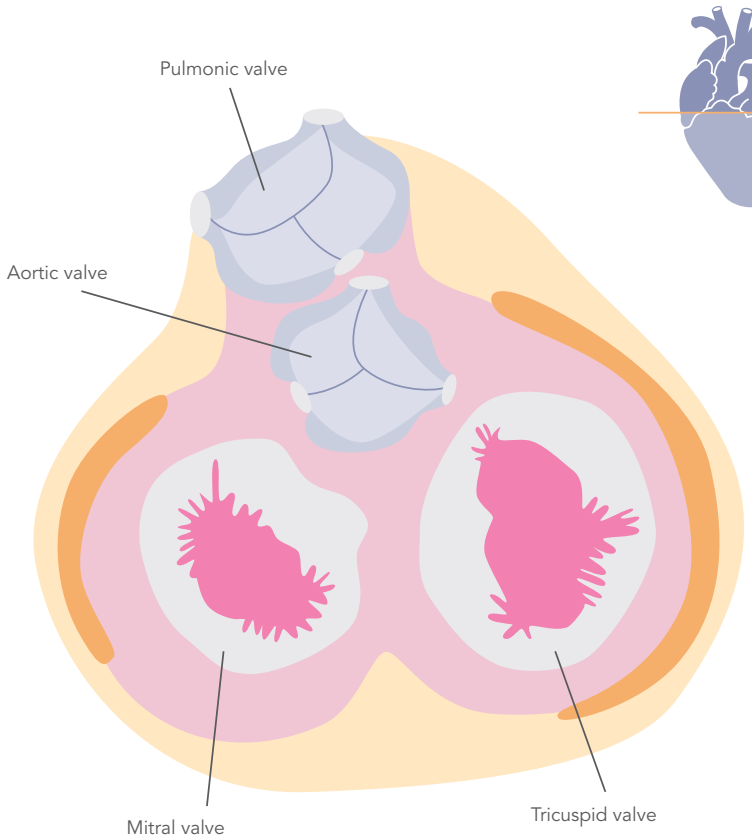
The function of the heart is both mechanical and electrical. Heart valves prevent the blood from flowing back into the atria from the ventricles. As blood flows into the atria, the atrioventricular valves remain closed until the ventricle muscles relax and the ventricles expands. As the pressure difference evens out, blood flows from the atria into the ventricles. This phase is called diastole (see the cross section image of the heart/ diastole on the following page). In the systole phase, the atrioventricular valves close due to pressure caused by blood, and the pressure in the ventricles increases. As the ventricles contract, the semilunar valves open and blood enters the aorta (left side) or the pulmonary artery (right side).

HEART FUNCTION CYCLE

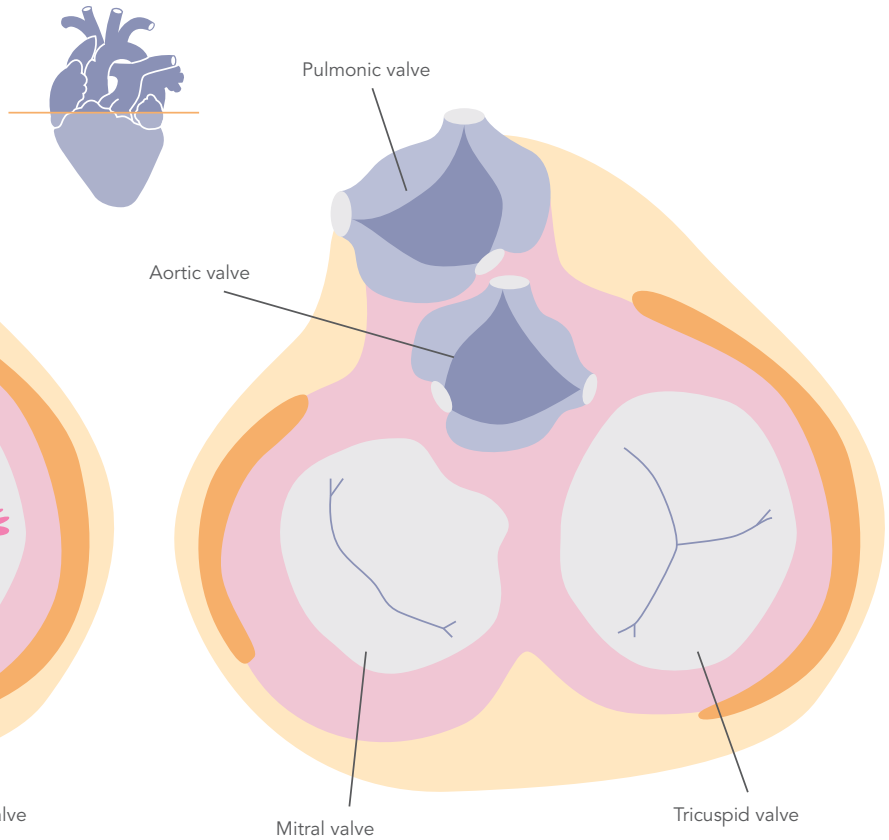


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CROSS SECTION OF THE HEART: DIASTOLE



CROSS SECTION OF THE HEART: SYSTOLE



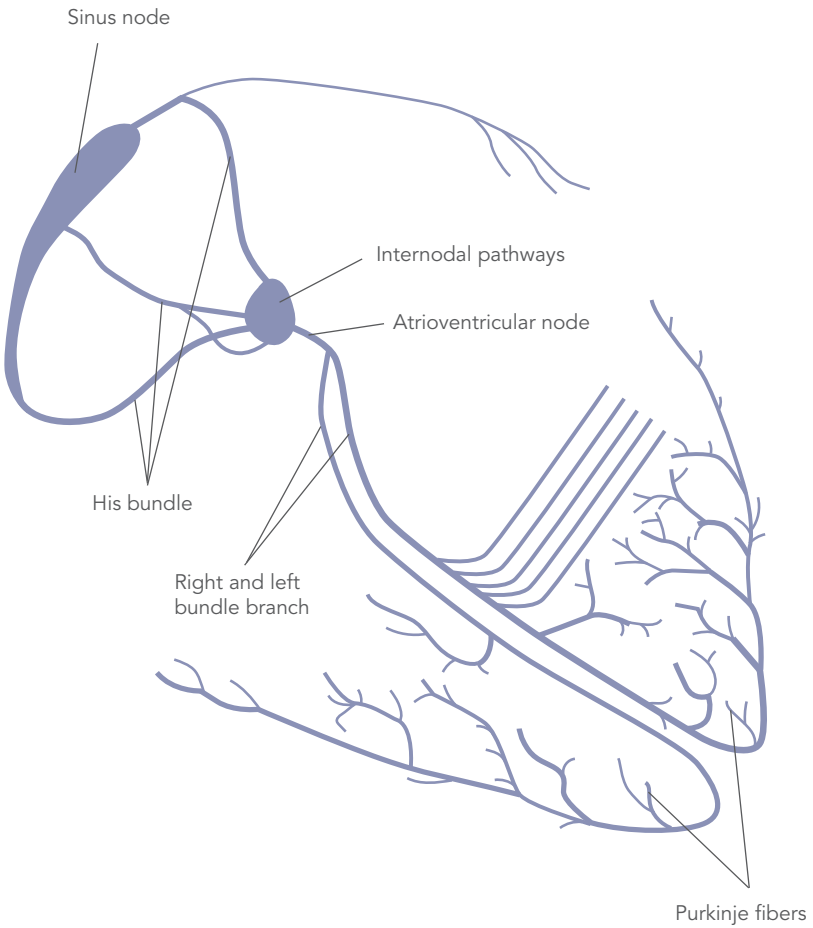
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CARDIAC CONDUCTION SYSTEM

The electrical function of the heart and the contracting thereof are governed by a system of specialized pacemaking cells. The system consists of the sinus node that initiates the heart contraction, atrioventricular node (AV node), internodal pathways, and His bundle and Purkinje fibers. The sinus node is a self-acting, tireless pacemaker from which the electrical impulse spreads via the internodal pathways to the AV node and on to the ventricles. The purpose of this ingenious system is to contract the heart efficiently and in a nearly symmetrical manner.

The electrical function of the pacemaking cells is governed by their sodium, potassium and calcium ion channels. Calcium has a particularly crucial role in the contraction of the cardiac muscle. The contraction involves three electrical phases: prepotential (before contraction), depolarization (during contraction) and repolarization (relaxation).[38]

ELECTRICAL CONDUCTION SYSTEM OF THE HEART



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REGULATION OF THE HEART FUNCTION

Heart rate is regulated by the autonomic nervous system as well as signals relayed by hormones. Signals that slow the heart rate (parasympathetic nervous system) are sent by the brainstem via the vagus nerve. Conversely, signals that increase the heart rate are sent by the nerve fibers of the sympathetic nervous system.

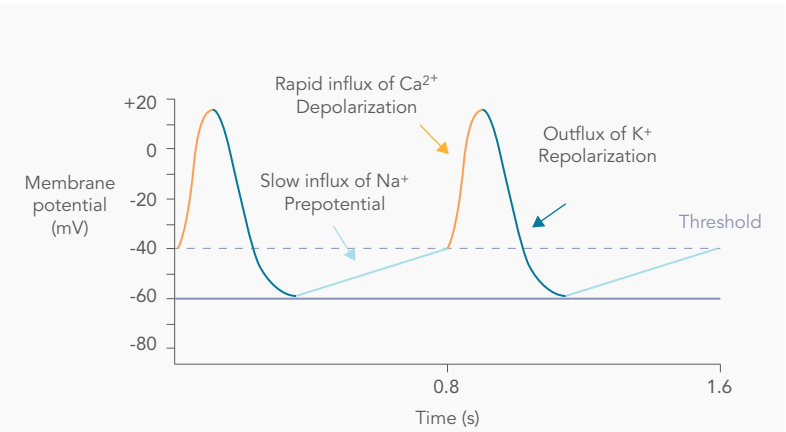
For example, neurotransmitters (adrenaline and noradrenaline) secreted by the adrenal gland medulla as a reaction to stress boost the activation of the sympathetic nervous system, increasing the heart rate. Relaxation activates parasympathetic nerve impulses and the heart rate slows down due to acetylcholine.[39]

Heart rate can be regulated through breathing: inhaling momentarily increases the heart rate whilst exhaling reduces it. This phenomenon is called *heart rate variability* (HRV).

Heart rate and blood pressure are also regulated by the baroreflex. For example, blood pressure in the upper torso and head increase when lying down, causing a signal to be sent to the brain via the baroreceptors in the neck and the aortic arch. The vasomotor center (center of neural circulatory control) located in the medulla oblongata of the brainstem sends a signal to the heart, reducing the heart rate and cardiac contractive force. Conversely, when standing up rapidly, the heart rate and cardiac contractive force increase.

Muscle contractions also increase the heart rate. Proprioceptors are sensory receptors located in muscles, joint capsules and tendons that assess the nature of movement. In turn, they are in touch with the vasomotor center. Increased proprioceptor activity increases the heart rate and circulation.

THE ELECTRICAL CONDUCTIVITY OF PACEMAKING CELLS AND CHANGES IN POTENTIAL IN THE CELL MEMBRANE



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FACTORS THAT *INCREASE* HEART RATE AND CARDIAC CONTRACTILITY:

CHANGE IN ACTIVITY OR LEVEL	RESULT
Nerves that increase heart rate	Noradrenaline released by cells
Baroreceptors	↓ Activity -> lower blood pressure
Proprioceptors	↑ Activity during exercise
Chemoreceptors	↓ Blood oxygen level ↑ Level of hydrogen ions, carbon dioxide and lactic acid in blood
Limbic system	Preparing for exercise, strong emotional reactions
Thyroid hormones	↑ Production of hormones T3 and T4
Calcium	↑ Ca2+ level
Potassium	↓ K+ level
Sodium	↓ Na+ level
Body temperature	↑ Body temperature
Nicotine, caffeine, stimulants	↑ Heart rate

FACTORS THAT *DECREASE* HEART RATE AND CARDIAC CONTRACTILITY:

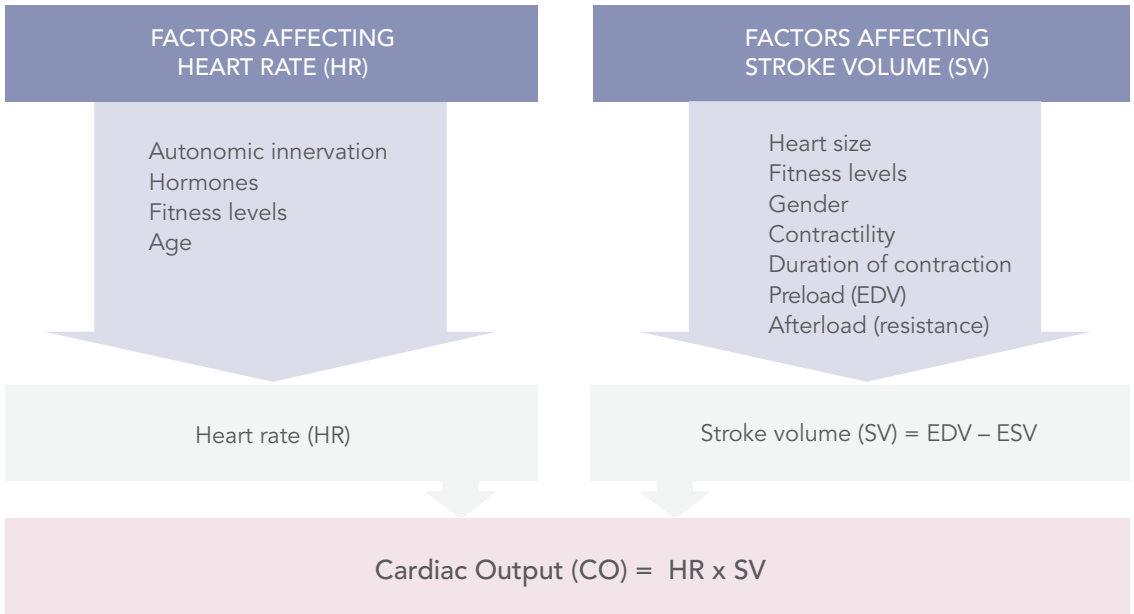
CHANGE IN ACTIVITY OR LEVEL	RESULT
Nerves that decrease heart rate (vagus nerve)	Acetylcholine released by cells
Baroreceptors	↑ Activity -> higher blood pressure
Proprioceptors	↓ Activity after exercise
Chemoreceptors	↑ Blood oxygen level ↓ Level of hydrogen ions, carbon dioxide and lactic acid in blood
Limbic system	Relaxation
Thyroid hormones	↓ Production of hormones T3 and T4
Calcium	↓ Ca2+ level
Potassium	↑ K+ level
Sodium	↑ Na+ level
Body temperature	↓ Body temperature
Theanine, taurine, relaxants	↓ Heart rate

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CARDIAC OUTPUT

Cardiac output refers to the volume of blood pumped by the heart in one minute. It is affected by the stroke volume as well as the heart rate, i.e. beats per minute. The stroke volume for a normal person weighing 70 kg (150 lbs) is approximately 70 ml (2.4 oz). Stroke volume may be significantly increased with physical training. The normal average heart rate is estimated to be 75 beats per minute (with a range of 60–100). From this, it can be deduced that the average cardiac output is 5.25 l/min (with a range of 4.0–8.0 l/min). In other words, on average, the heart pumps five liters (169 oz) of blood per minute.[40]

FACTORS AFFECTING CARDIAC OUTPUT

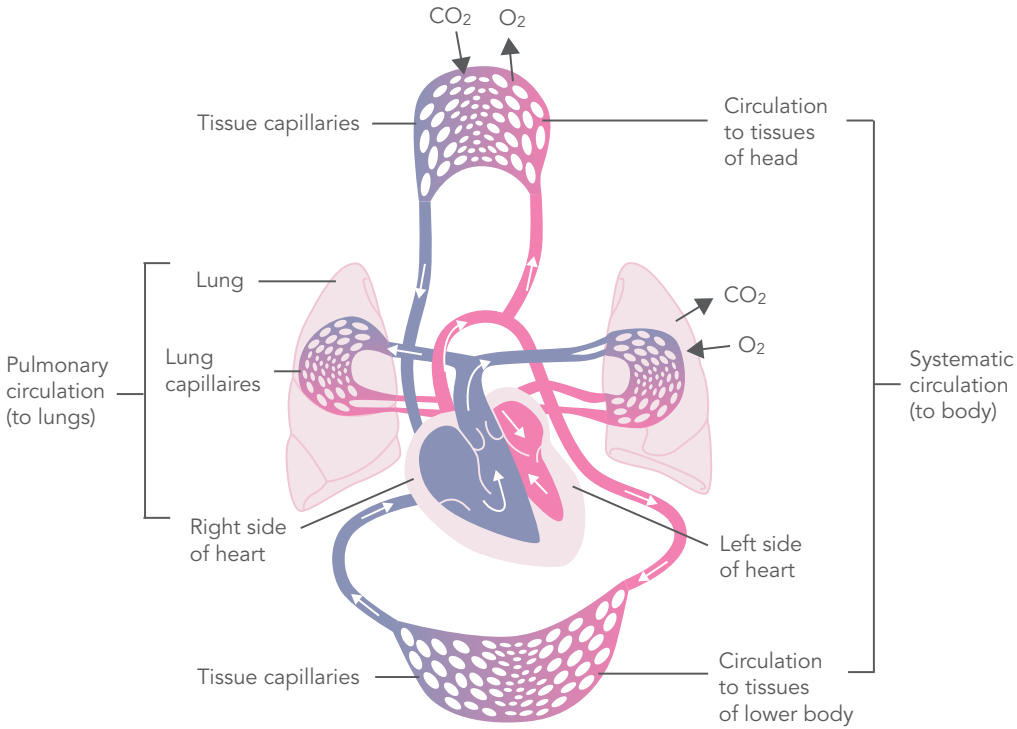


Source: The OpenStax CNX Project & Rice University. (2016)

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CIRCULATION

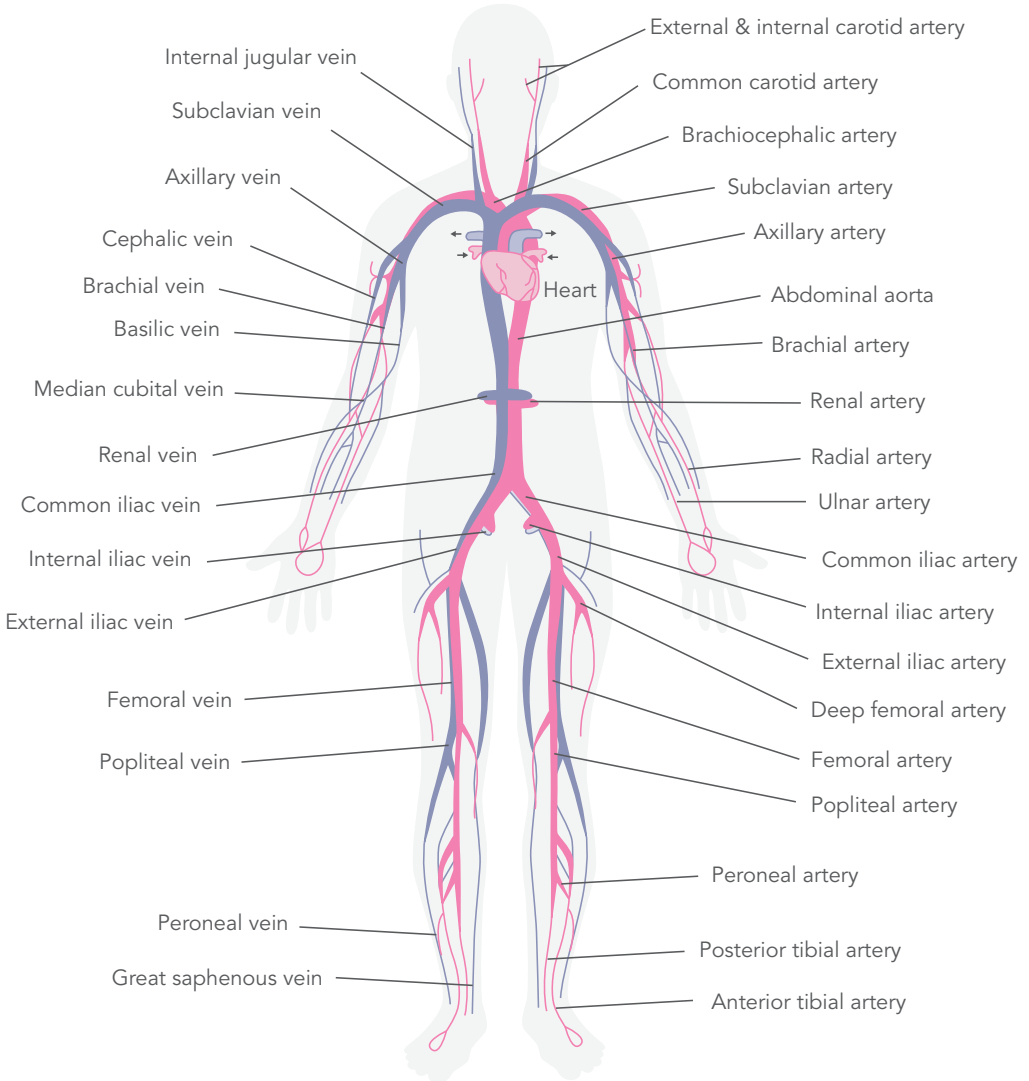
Circulation can be roughly divided into systemic circulation and pulmonary circulation. Systemic circulation involves the function of the left-hand side of the heart and its circulation. The left ventricle pumps oxygen-rich blood into the aorta and into the body. The spent blood returns to the right atrium via the superior and inferior vena cava. Conversely, pulmonary circulation involves the function of the right-hand side of the heart and its circulation. The right ventricle pumps spent blood rich in carbon dioxide into the lungs in where it is once again oxygenated. From the lungs, the blood travels via the pulmonary vein into the left atrium.



SYSTEMIC CIRCULATION AND PULMONARY CIRCULATION

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Circulation can also be divided into macrocirculation and microcirculation. As its name implies, macro-circulation covers the circulation within larger veins including major arteries and veins (see image). The purpose of macrocirculation is to deliver blood to internal organs and lead spent blood away to be recycled.



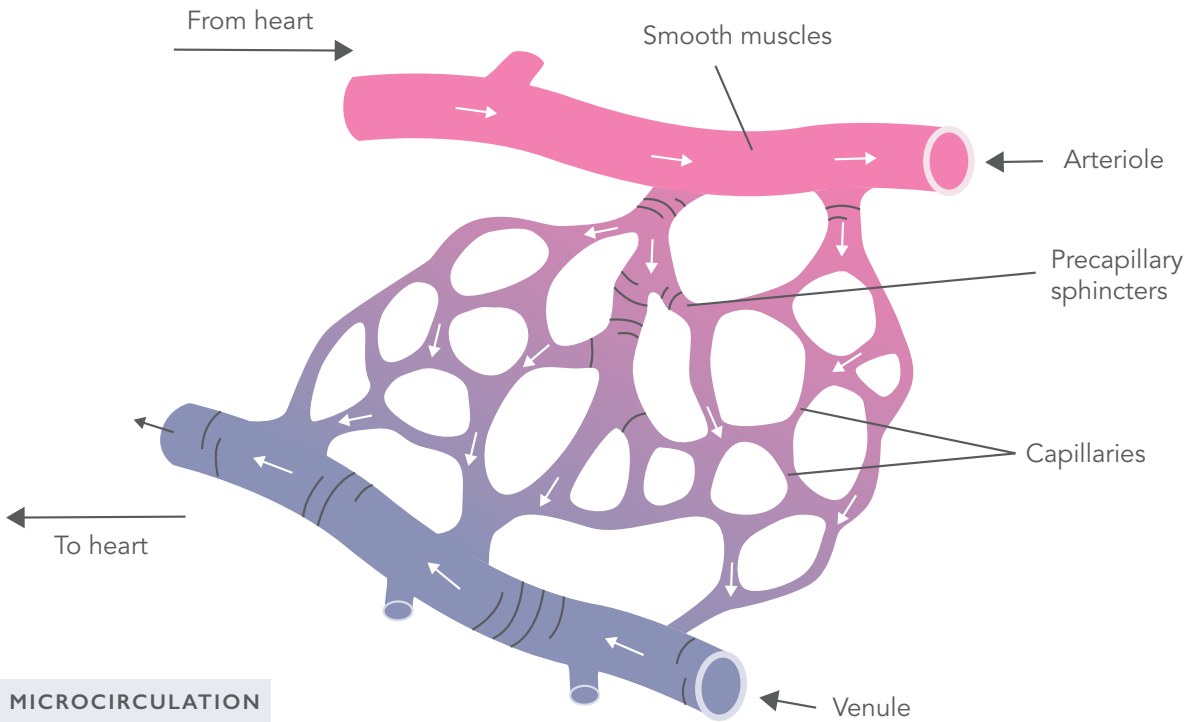
SYSTEMIC CIRCULATION

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MICROCIRCULATION

Microcirculation refers to the circulation within arterioles, capillaries and venules at tissue level. The main purpose of microcirculation is the delivery of oxygen and nutrients to tissues and the removal of carbon dioxide from tissues. It also acts as a very good regulator of blood flow and blood pressure.

Microcirculation has an important role in the inflammatory response of the body. Inflammation triggers an activation response in many circulatory cells (such as white blood cells and platelets), cells lining blood vessels (endothelial cells and blood flow regulating pericytes) and cells surrounding blood vessels (mast cells and phagocytic cells or macrophages). This is why inflammation often causes heat and swelling.[41]



MICROCIRCULATION

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The flow volume of the microcirculation remains constant regardless of pressure changes in the systemic circulation. This is due to the arteriole wall muscles contracting and relaxing according to various stimuli. The precise microcirculation system secures sufficient nutrient and oxygen delivery to the internal organs regardless of any changes taking place in the body.

There are many different mechanisms involved in the regulation of the microcirculation. These include metabolic, electrical, neural and mechanical (muscle-based) regulation. For example, venules provide feedback to arterioles about the metabolic state of tissues, and during exertion, the arterioles in the muscles expand to deliver more oxygen to the tissues.[42]

The efficiency and control of the microcirculation often deteriorate with age. Factors contributing to this include smoking, alcohol consumption, poor diet, stress, sleep deprivation, air pollution, environmental pollution and the lack of exercise.

CAPILLARY EXCHANGE

Capillaries are in direct contact with tissues, making biochemical exchange between interstitial fluid and blood possible.

Capillary walls are permeable enough for most substances in the blood to freely pass into the interstitial fluid.[43] Only proteins fail to pass though the capillary walls. This is why molecules attached to carrier proteins (such as hormones) are not effective at tissue level.

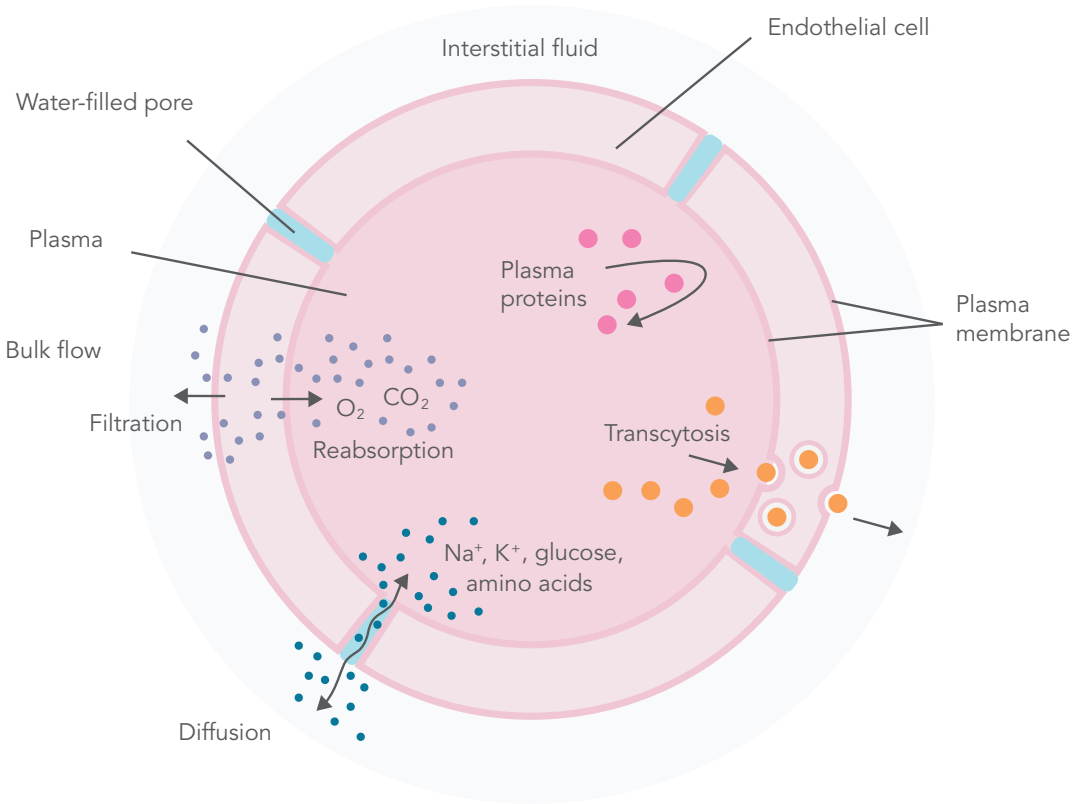
Three **metabolic mechanisms** are currently known: diffusion, bulk flow and transcytosis.

- **Diffusion** causes oxygen, glucose, amino acids, etc. to flow from capillaries into interstitial fluid. Metabolic waste flows from interstitial fluid back into capillaries.

- In **bulk flow**, the exchange occurs via small fat molecules. The flow of substances from the capillaries into the interstitial fluid is called filtration. Conversely, reabsorption refers to the flow of substances from the interstitial fluid into the circulation.

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• In **transcytosis**, large molecules such as proteins, hormones and immuno-globulins move into the interstitial fluid with the help of vesicles via the endothelial cells of the capillaries. The transfer occurs through exocytosis: the fluid sac surrounding the protein merges with the cell membrane, moving the protein into the interstitial fluid.



CAPILLARY EXCHANGE

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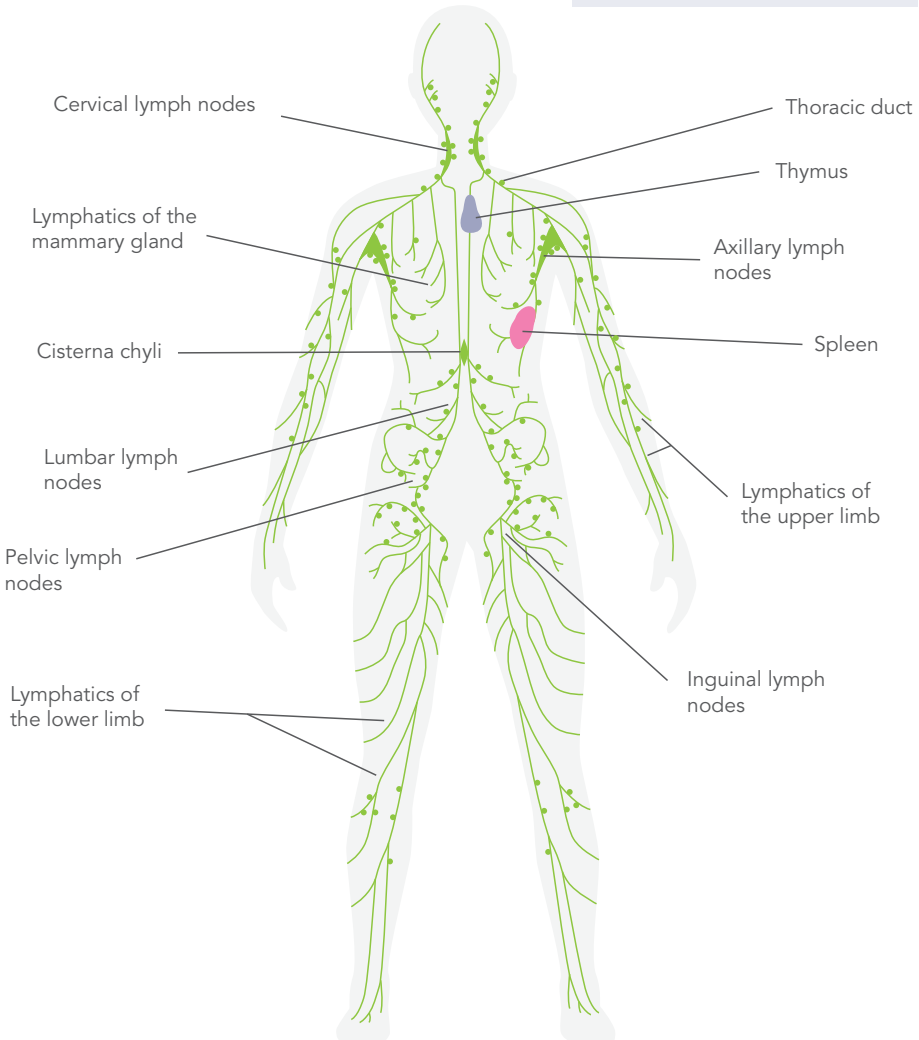
LYMPHATIC SYSTEM AND CIRCULATION

The lymphatic system is part of the circulation. It consists of a comprehensive network of lymphatic vessels, lymph nodes and other lymphoid tissues, the spleen and the thymus.

The lymphatic vessels circulate lymph, which has an important role in fluid balance regulation, immune system function, and carrying fatty acids. Lymphatic circulation returns the fluid absorbed from the microcirculation back into circulation. Lymphatic circulation also carries the fat absorbed from the intestine into circulation.[44]

For the circulation of lymph, moving the entire body is important. Unlike blood circulation, lymphatic circulation does not have a heart-like pump. Instead, lymph circulates with the help of voluntary muscles, respiratory movements and the smooth wall muscles of the lymphatic vessels.[45]

LYMPHATIC CIRCULATION



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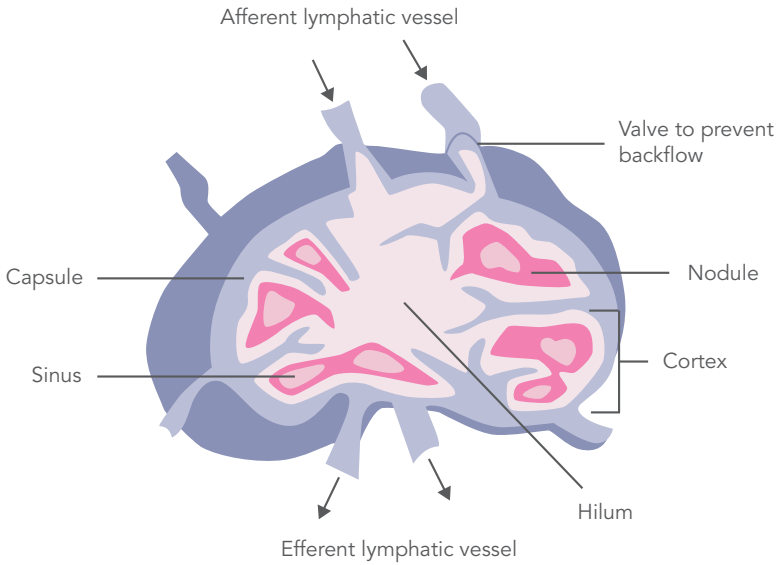
The consistency of lymph resembles that of blood plasma. It contains lymphocytes and a small amount of other white blood cells. In addition to these, lymph consists of metabolic and cellular waste, bacteria and proteins.

LYMPH NODES ARE THE QUIET WATCHMEN OF THE BODY

Lymphocytes are an important part of the immune system. They are produced in the bone marrow and matured either in the thymus (T cells) or the marrow (B cells). Mature lymphocytes move into the spleen, lymph nodes and other lymphoid tissues such as tonsils and adenoids, lymphoid tissue of the intestine, and the walls of respiratory and urinary tracts.[46]

An individual has approximately 500–600 lymph nodes, most of which are clustered in the intestine, armpits, neck, and groin. The size of lymph nodes can vary dramatically (diameter approximately 1–20 millimeters). The size varies due to infections, possible tumors in the body, etc.

Several lymphatic vessels lead to the lymph node, bringing in lymph from the surrounding tissue. The medullary sinuses of the lymph node contain macrophages that consume foreign substances found in the lymph, particularly various pathogens. The function of the macrophages is a part of cell-mediated immunity. The medullary sinuses converge at the hilum where the lymph exits via lymphatic vessels to be used again.



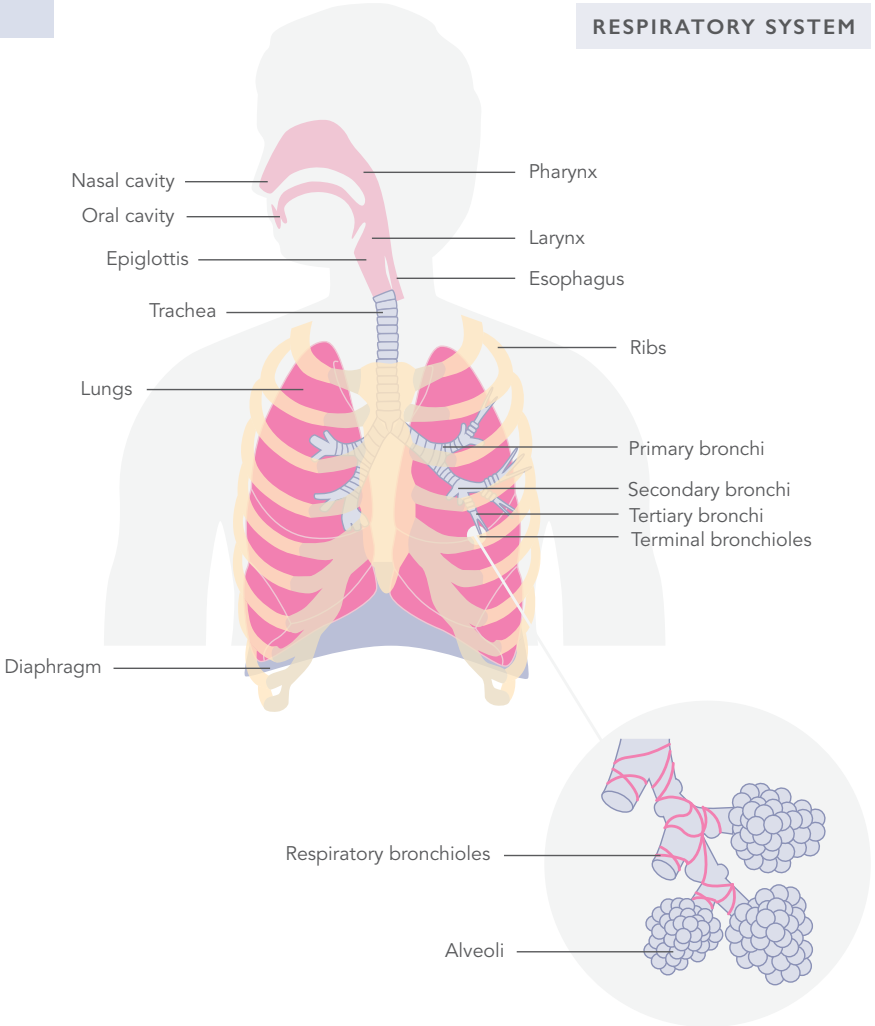
LYMPH NODE

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RESPIRATORY SYSTEM

The respiratory system consists of the organs and structures of the body that participate in respiration and gas exchange in the tissues. In addition to breathing, the respiratory system is involved in voice production (larynx, oral cavity), the regulation of the body's acid-base balance, and the removal of waste products.

The respiratory system is divided into the upper and lower respiratory tract. The upper respiratory tract includes the nasal cavity and paranasal sinuses, oral cavity, pharynx, and larynx. The lower respiratory tract includes the trachea, bronchi, and lungs. The physiological functions of the respiratory system are described on the following page.



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PART OF THE RESPIRATORY SYSTEM	PHYSIOLOGICAL FUNCTIONS
Nasal cavity	• Cilia, nasal hair and mucus purify inhaled air • Humidifying, heating or cooling air
Oral cavity	• Passing air into the trachea
Pharynx	• Fighting impurities • Contains a great deal of lymphatic tissue (including tongue, adenoids and tonsils)
Epiglottis	• Preventing food from entering the trachea
Larynx	• Connecting the pharynx and trachea, participating in voice production
Trachea	• Feeding air into the bronchi, mucus secretion
Lungs	• The largest and most important organs in the respiratory system • The right lung has three lobes, the left lung has two lobes • Gas exchange takes place in the alveoli
Bronchi	• Feeding air into the alveoli
Alveoli	• Gas exchange through diffusion (oxygen into the body, carbon dioxide out)
Pleural cavity	• Protecting the lungs, reducing friction caused by breathing • Pleural cavity normally has negative pressure which holds the lungs close to the thoracic wall
Diaphragm	• An important muscle of respiration • Expanding the thoracic cavity, enabling airflow into the lungs • On inhalation, the contraction of the diaphragm expands the thoracic cavity and by extension the lungs

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LUNGS

The lungs are the body's main respiratory organ. Humans have two lungs, one on each side of the body. The right lung consists of three lobes, while the left lung has only two. Each lung is fed by a main bronchus. These branch out into lesser bronchi.

The lungs are located in the chest cavity, on either side of the heart in front of the spine. On the front side, they are protected by the ribs. Below the lungs, there is the diaphragm, one of the main muscles of respiration.

The lungs are estimated to contain up to 2400 kilometers (1490 miles) of airways and approximately 400 million alveoli. Due to the enormous number of alveoli, the respiratory surface of an adult human measures 30–50 square meters.[47]

The lungs are surrounded by the pleural cavity which consists of two layers (parietal pleura and visceral pleura) and the fluid between these layers. Fluid exchange is controlled by the circulation in the intercostal arteries and the lymphatic system. Some illnesses (such as liver cirrhosis,[48] pulmonary embolism[49]) or trauma[50] may cause fluid (pleurisy) or air (pneumothorax) to collect in the lungs, making breathing difficult.

The lungs have a dedicated circulation in which low-oxygen blood is oxygenated for use by the body. Pulmonary circulation is discussed in more detail in the section "Circulation."

RESPIRATION AND THE ALVEOLI

Respiration refers to the mechanical and biochemical transfer of oxygen (O2) from the air into cells, and conversely, the transfer of carbon dioxide (CO2) from cells into the air. Cellular respiration is discussed in more detail in section "Metabolism – the cornerstone of energetic life."

Respiration is regulated by the respiratory center located in the medulla oblongata. Its functions are influenced by the levels of carbon dioxide, oxygen and hydrogen in the blood. This is called humoral regulation.[51] Corresponding nervous regulatory mechanisms include the mechanical movements of the chest, stimuli from the air entering the lungs, signals sent by proprioceptors, and changes in body temperature. Pain also has a significant effect on respiration.[52] Respiration may also be voluntarily regulated for example through hyperventilation (breathing very fast).

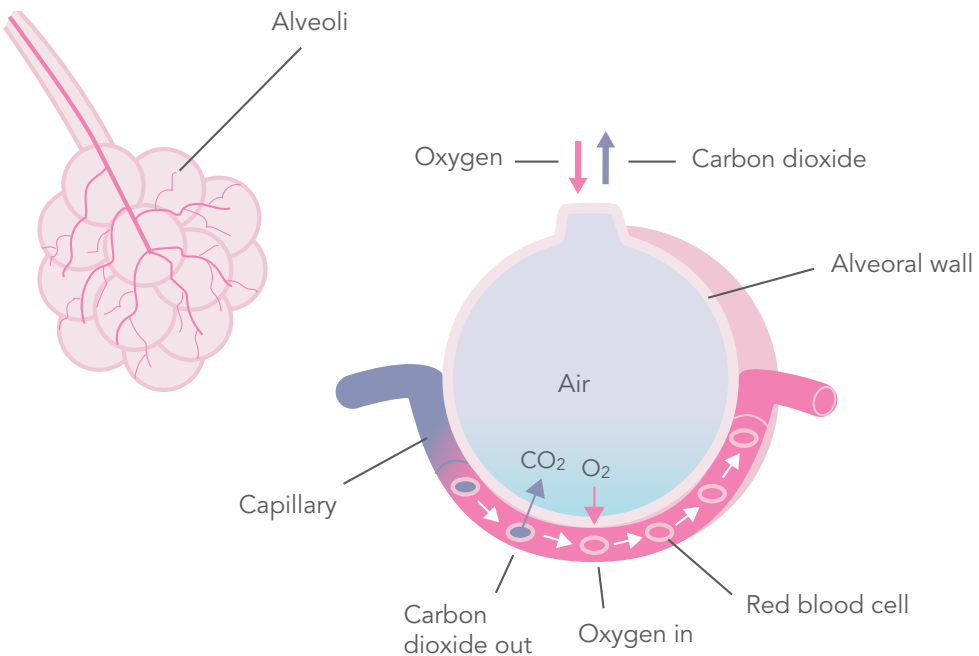
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The contraction and dilation of the bronchi is regulated by the autonomic nervous system. The sympathetic nervous system has a bronchodilatory effect (adrenaline and noradrenaline) by way of beta receptors. The corresponding bronchoconstrictory effect (acetylcholine) of the parasympathetic nervous system occurs by way of muscarinic receptors. Excessive contraction of the lungs occurs for example in connection with asthma, allergies and chronic obstructive pulmonary disease. Sometimes heavy physical activity may also contract the bronchi and cause exercise-induced asthma (particularly when the air is cold and dry).[53]

Mechanical human respiration can be divided into two parts: inhalation and expiration. Inhalation is always active, expiration is passive at rest. Inhalation is triggered by the diaphragm and outer external intercostal muscles that create a vacuum in the lungs, causing air to flow in. During activity, expiration is also active.

Respiration can be further divided into four breathing patterns: clavicular breathing, costal breathing, diaphragmatic breathing and deep breathing. Like other muscles, respiratory muscles may be properly exercised. Further information about this can be found in section "Breathing techniques."

ALVEOLAR GAS EXCHANGE



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Respiratory gas exchange takes place in the alveoli where oxygen binds with the hemoglobin of red blood cells. The oxygen saturation (SaO2 %) of hemoglobin depends on the partial pressure of oxygen and carbon dioxide in the tissue, temperature, blood pH and carbon monoxide. The oxygen saturation level may also fall due to an illness (chronic obstructive pulmonary disease or asthma).

Oxygen-saturated hemoglobin molecules are carried into other tissues where the oxygen is released for use by various organs. Conversely, the carbon dioxide molecules of the "spent" blood pass into the alveoli, through the airways, and out of the body.

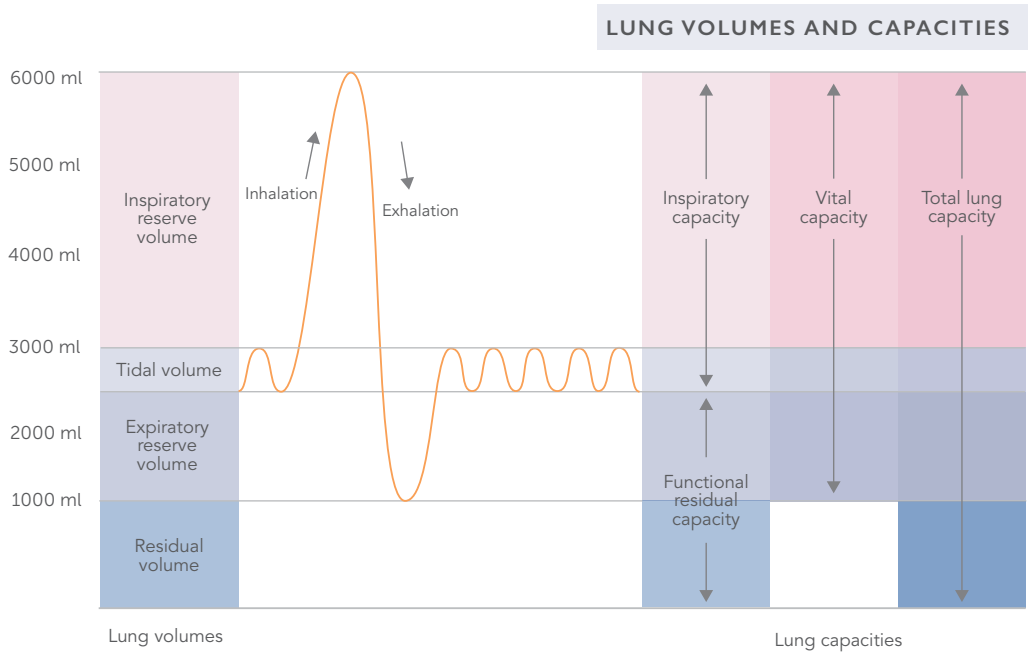
HEMOGLOBIN

Hemoglobin is an iron-rich protein molecule that binds oxygen. One hemoglobin molecule can bind four oxygen molecules.

Approximately one third of red blood cells consists of hemoglobin, giving it its characteristic red color. Blood hemoglobin is often used as the primary laboratory test to determine the level of iron in the body.

For men, the normal range of hemoglobin is 134–167 g/l (13.4–16.7 g/dL), for women it is 117–155 g/l (11.7–15.5 g/dL). Low hemoglobin leads to anemia that may cause various physical symptoms (such as fatigue, vertigo, breathlessness). Anemia may be caused by the lack of iron, vitamin B12 or folate, bone marrow disorders, bleeding or increased hemolysis of red blood cells.

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RESPIRATORY CAPACITY AND TIDAL VOLUME

Human beings breathe on average 12–20 times per minute. Those familiar with breathing exercises or meditation may have a significantly slower rate of breathing.[54] Adopting deep breathing techniques also reduces breathing frequency. When breathing normally, the tidal volume of a male person is approximately 500 ml (or 7 ml/kg of body mass). At maximal breathing capacity (such as during heavy physical exercise), this may reach 4–5 liters (or more in the case of athletes). Respiratory minute volume is the volume of air inhaled per minute at rest (approximately 6–7 liters).

Vital capacity (4.5 liters) is the combined sum volume of inspiratory reserve volume (3 liters), tidal volume (0.5 liters), and expiratory reserve volume (1 liter). In practice, this is the amount of air one breath can move.

The tidal volumes of females are approximately 20 percent smaller compared to those of males. Tidal volume is significantly affected by physical activity and other pastimes that exercise the respiratory system, such as singing.

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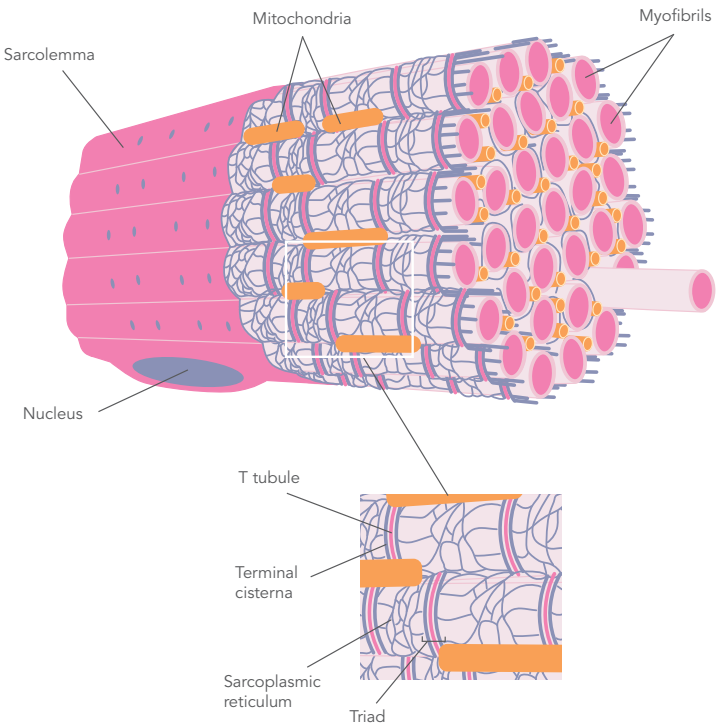
SKELETAL MUSCLES AND MOTOR CONTROL

The muscles attached to the skeleton form the majority of the body muscle mass. In addition to voluntary skeletal muscles, the body contains smooth muscle tissue. It can be found for example in the walls of the digestive tract, blood vessels, bladder and respiratory tracts. The function of smooth muscle tissue is regulated by the autonomic nervous system. It is therefore not voluntary.

An individual uses the skeletal muscles for movement and to control the fine motor movements of various body parts. Skeletal muscles consist of striated muscle fibers which are very large in size and contain multiple nuclei (genetic centers of the cell). The striated appearance of the muscle fibers is caused by repeating units called sarcomeres, the smallest functional units of muscle. The muscle fibers themselves consist of myosin and actin filaments (myofibril). During a muscle contraction, they slide over each other.[55]

The muscle contraction is triggered by an action potential transmitted by an alpha motor neuron (see section "Motor unit" below). The action potential spreads into the muscle fiber via T-tubules. From here, the signal spreads to the terminal cisternae of the sarcoplasmic reticulum, releasing calcium and eliciting the muscle contraction.

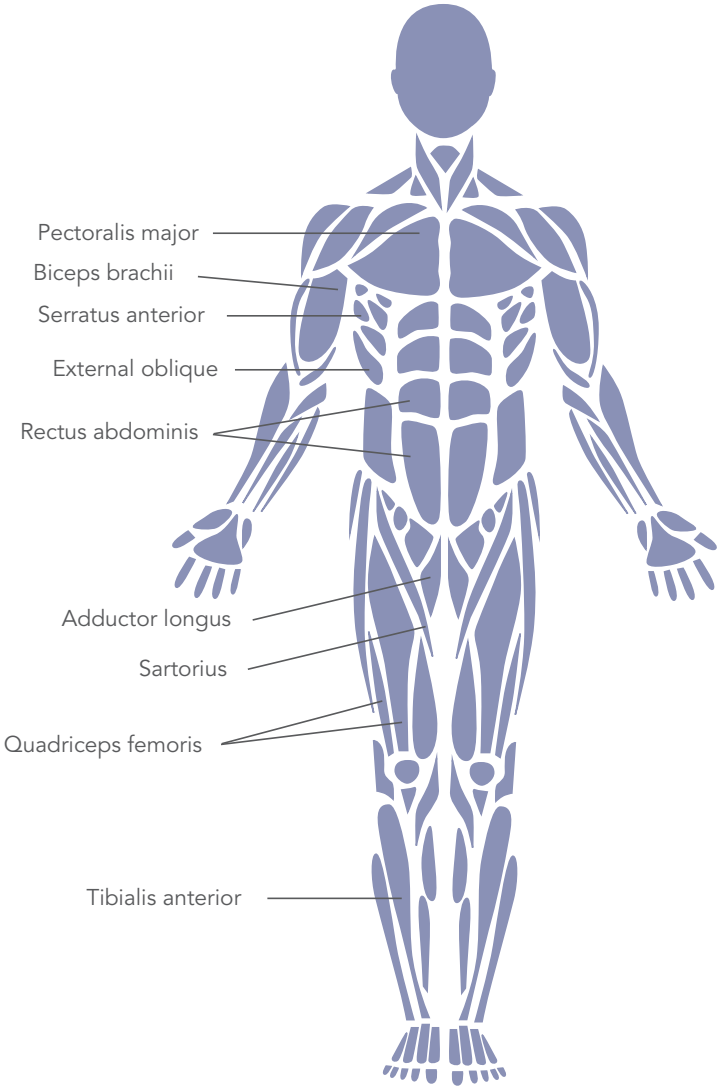
SKELETAL MUSCLE FIBER



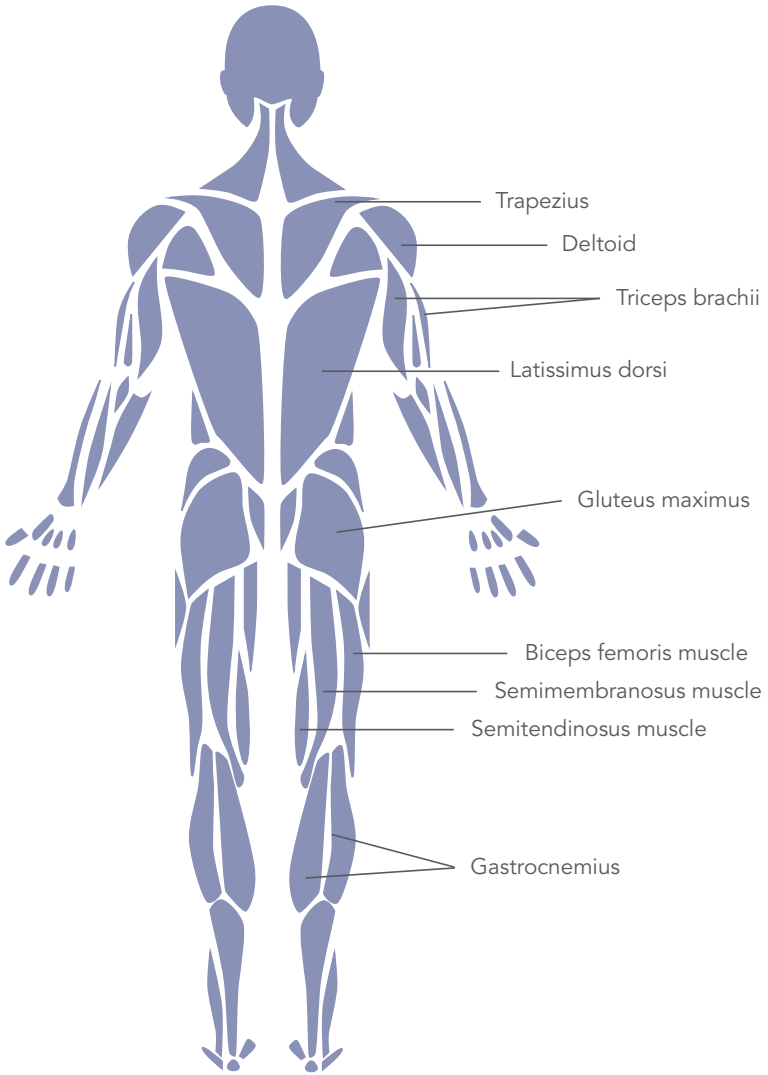
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Major skeletal muscles and their functions:

- Pectoralis major (adduction of shoulder joint, flexion of shoulder joint to 60 degrees)
- Biceps brachii (flexes the forearm at the elbow)
- Serratus anterior (pulling scapula forward, assists with lifting arm, assists with forceful inhalation)
- External oblique (supporting internal organs, assists with rotation of pelvis, assists with forceful expiration)
- Rectus abdominis (flexion of lumbar spine, supporting abdominal area, assists with defecation, assists with forceful expiration)
- Deltoid (abduction of arm, flexion of shoulder joint)
- Biceps femoris (extension of hip joint, flexion and outward rotation of knee joint)
- Semimembranosus (extension of hip joint, flexion and inward rotation of knee joint)
- Semitendinosus (extension of hip joint, flexion and inward rotation of knee joint)



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Major skeletal muscles and their functions:

- Trapezius (lifts the shoulder blade, braces the shoulder, draws the head back)
- Deltoid (raises the arm)
- Triceps brachii (extends the forearm at the elbow)
- Latissimus dorsi (rotates and draws the arm backward and toward the body)
- Gluteus maximus (extends and rotates the thigh outward when walking, running and climbing)
- Hamstring group: Biceps femoris muscle, Semimembranosus muscle and Semitendinosus muscle (draws thigh backward, flexes the knee)
- Gastrocnemius (bends the lower leg at the knee when walking, extends the foot when jumping)

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DID YOU KNOW

AN ALPHA MOTOR NEURON BRINGS CONTRACTION SIGNALS TO THE STRIATED MUSCLE FROM THE UPPER PARTS OF THE CENTRAL NERVOUS SYSTEM. IT TRANSMITS INFORMATION FROM THE CEREBELLUM, THE PRIMARY MOTOR CORTEX, AND THE MOTION AND ORIENTATION RECEPTORS OF THE INNER EAR. EACH STRIATED MUSCLE CELL IS CONNECTED TO A PRESYNAPTIC TERMINAL OF AN ALPHA MOTOR NEURON. THIS IS CALLED THE NEUROMUSCULAR JUNCTION. ACETYLCHOLINE ACTS AS THE NEURO-TRANSMITTER IN THE SYNAPSE.

MUSCLE CELL TYPES

There are three main types of human skeletal muscle cells: slow-contracting but high endurance type I cells and fast-contracting type IIA and IIX cells. Slow cells are activated during daily activities or endurance sports. Fast cells are activated only when explosive movement is required. Type I cells are active in aerobic conditions. Type IIA cells utilize both aerobic and anaerobic energy. They have both endurance and strength properties. Type IIX cells create a strong contraction but become fatigued very quickly. Latest studies have also specified other muscle cell types based on their properties: IC, IIC, IIAX, and IIXA.[56]

An individual's muscle cell type is largely determined by genetics. However, training may have some effect on it. The muscle cell type can be determined with a muscle biopsy. The distribution of muscle cell types also varies significantly between different muscles. For example, the quadriceps contain 50–70 % fast muscle cells whereas the soleus contains up to 90 % slow muscle cells (great for walking).[57]

Sports enthusiasts' muscle cell types are often distributed in a way that is favorable for their particular sport. For example, it is common for endurance athletes to have more type I muscle cells compared to the rest of the population. On the other hand, endurance sports may change the muscle cell type from fast to slow.[58] There has not been a clear indication of strength training having an effect on the proportion of slow to fast muscle cells. Strength training may have a slight effect on type IIA cells changing into faster IIX types.[59]

Individuals with the R allele of the ACTN3 gene usually do very well in sports requiring strength and speed.[60] Their muscle cell type distribution favors fast muscle cell types (IIA and IIX). A muscle biopsy of a world champion sprinter

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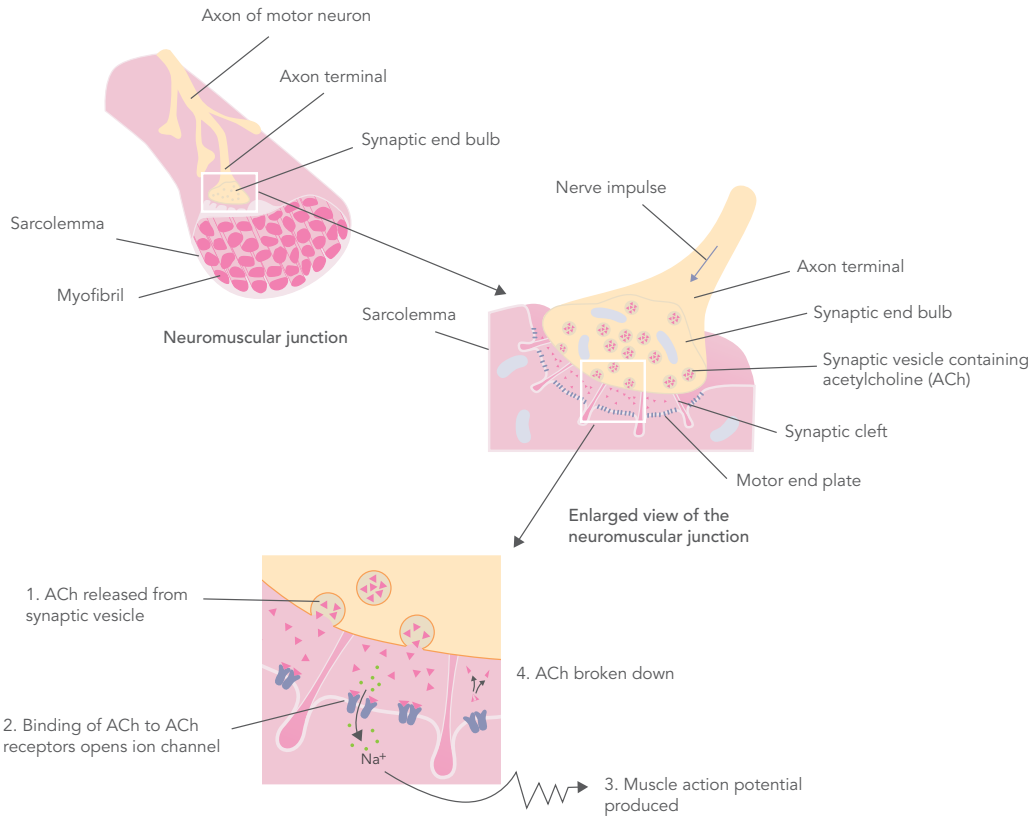
revealed an unusual muscle cell distribution: 71 % were fast muscle cells (the average distribution being almost the same in reverse).[61 62]

MOTOR UNIT

A functional neuromuscular entity is called a motor unit. It consists of an alpha motor neuron in the spinal cord, muscle units, and axon terminals to which the signal is being transmitted. The muscle cells of each motor unit are of the same type. The motor unit is the smallest motion-generating entity in the body.

The number of motor units in each muscle varies. The size of motor units is also variable. When precise motor control is required (for example, the fine motor function of the eye), the motor units are small. The motor units are larger in muscles where gross motor function is sufficient (such as abdominal muscles).[63]

NEUROMUSCULAR JUNCTION / AXON TERMINAL



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Motor units can be divided into groups based on the contractility and endurance of the muscle cells. Motor units are categorized into *slow-twitch* (S) or *fast-twitch* (F) units. Fast units are further divided into three groups: *fatigue-resistant* (FR), *fatigue-intermediate* (Fint) and *fatigable* (FF).[64] Motor units are also activated in this order based on the force required by the movement. The fastest motor units are activated in maximal movement such as changes of direction and jumps.[65]

MYOTENDINOUS JUNCTION

The connection point between muscle and tendon is called a *myotendinous junction*. The force generated by muscle contraction is transmitted via the tendon to the skeleton to be released for example as limb movement. The junction tendons consist of dense collagen fibers and fibrocytes (the main cell type of connective tissue). At the tendon end of the muscle, the muscle fibers become thinner and their filaments overlap with the collagen fibers of the tendon.[66]

Due to their structure, myotendinous junctions are prone to injury. In the event of muscle or tendon injury, the myotendinous junction is typically the first casualty.[67] Injuries to the myotendinous junction may be prevented by improving balance and body proprioseptics, strengthening collagen fibers and improving general muscular strength. Good joint mobility and thorough pre-exercise warm-ups also provide protection from injury.[68]

MUSCLE SPINDLE – A SENSORY RECEPTOR IN THE MUSCLE

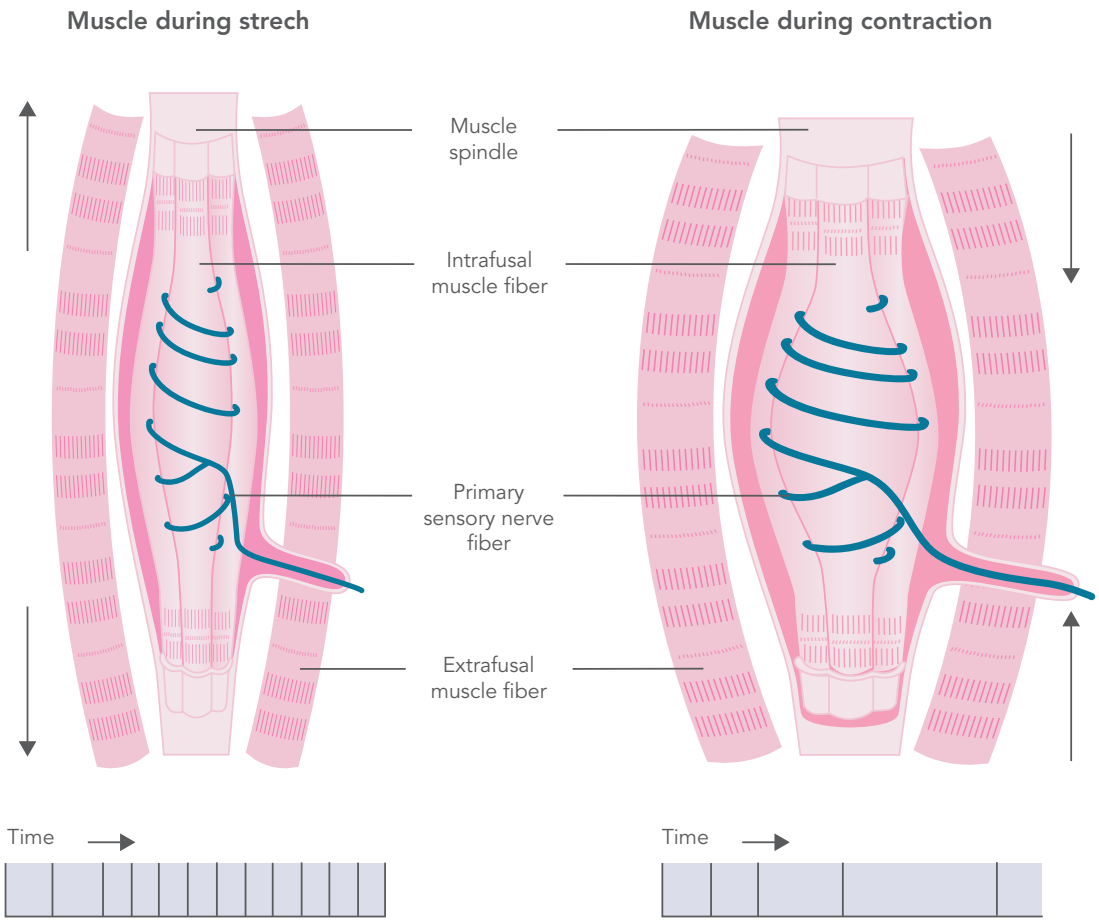
A muscle spindle is a sensory receptor (stretch receptor or proprioceptor) located within the muscle. It detects changes in the length of the muscle and transmits this information to the central nervous system.

A muscle spindle contains several sensory nerve terminals. Of these, type Ia nerve terminals (afferent) react to rapid changes in muscle length. Type II nerve terminals transmit information about the muscle length and activate other motor nerves. Structurally very thin type III and IV fibers transmit information about various sensations such as pain, changes in temperature and chemical sensations.[69]

Muscle spindles are plentiful in the neck area muscles which are important for adjusting the position of the head and the rest of the body. Facial muscles also contain plenty of muscle spindles which are consistent with the fine motor function requirements of facial movements and eating. For example, the number of motor spindles in the neck and face area is many times greater compared to that of the bicep.[70]

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MUSCLE SPINDLE DURING STRETCH AND CONTRACTION



a) Action potential frequency increases during stretch

b) Action potential frequency declines during contraction

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METABOLISM – THE CORNERSTONE OF ENERGETIC LIFE

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Metabolism is the continuous vital process of breaking down organic matter and forming new substances within the tissues of the body.

The word is derived from the Greek word *metabole* meaning "change." Indeed, the body is in a constant state of change.

The breakdown process is called catabolism whereas anabolism is the process by which living organisms synthesize new molecules. Metabolic reactions are affected by several reaction-accelerating body enzymes (biocatalysts). In addition, metabolism is regulated by hormones, various growth factors, vitamins, minerals, and the autonomic nervous system.[71]

Various chemical reactions form so-called metabolic pathways. Energy metabolism in particular is discussed in this section of the book. Metabolic pathways are crucial for the maintenance of homeostasis (the equilibrium of the body).

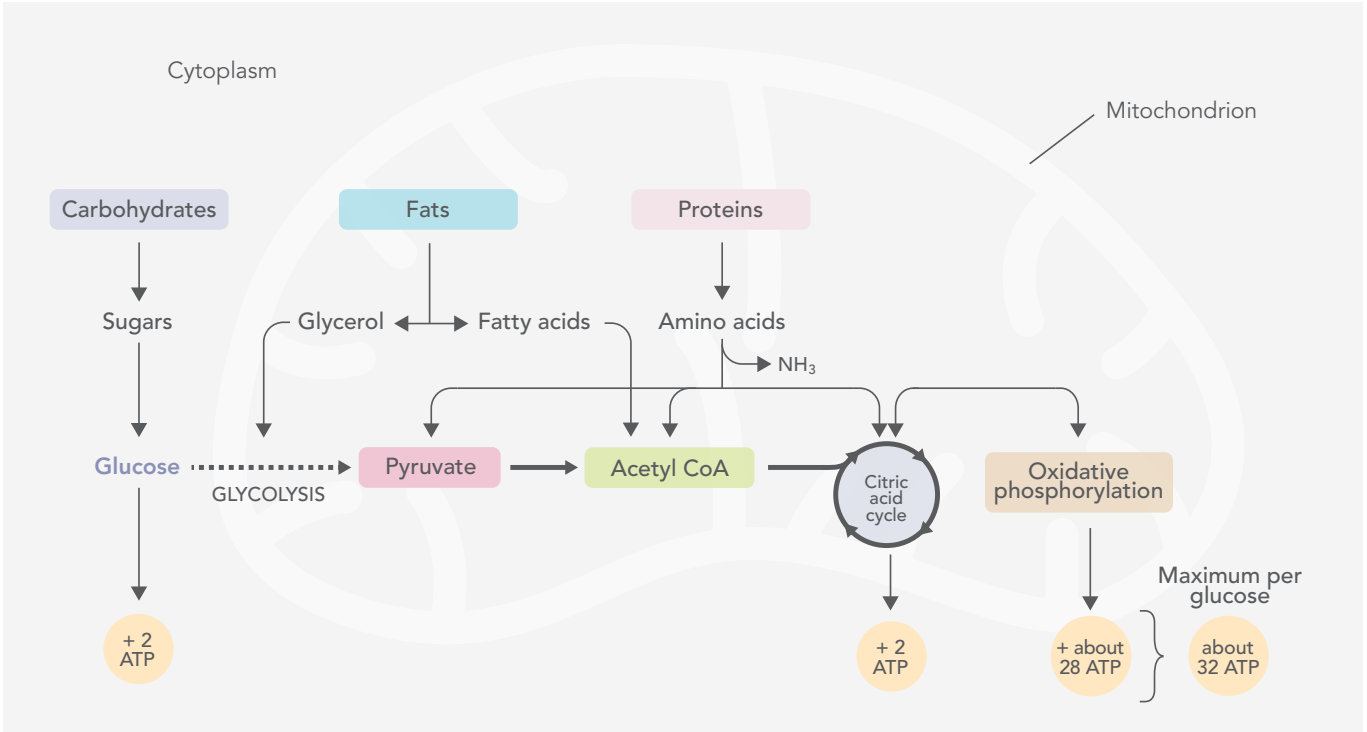
The long-term imbalance of metabolic pathways may lead to various metabolic disorders. Genetic hereditary enzyme dysfunctions may also cause innate metabolic disorders (for example, a mutation in the MTHFR gene may cause an increased level of homocysteine and therefore an increased risk of cerebrovascular disorders).[72]

Examples of metabolism include the breaking down of carbohydrates, proteins and fats into energy (the citric acid cycle), the removal of superfluous ammonia through urine (the urea cycle) and the breakdown and transfer of various chemicals. The metabolic pathway that was first discovered was glycolysis in which glucose is broken down into pyruvate supplying energy (ATP and NADH) to cells.[73]

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AEROBIC ENERGY SYSTEM

The aerobic (requiring oxygen) metabolic process is also called cellular respiration. The processes involved in the aerobic energy system (cellular respiration) are glycolysis, pyruvate oxidation, the citric acid cycle and the electron transport chain. In practice, various cascades use glucose and oxygen to produce ATP (adenosine triphosphate) that acts as an energy source. Byproducts of these processes include carbon dioxide and water.



AEROBIC CELLULAR RESPIRATION

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AEROBIC GLYCOLYSIS

The first metabolic phase, glycolysis, takes place in the cytoplasm. When glycolysis occurs under aerobic conditions, a glucose molecule is broken down into pyruvate, simultaneously producing two ATP molecules and two NADH molecules. Glycolysis also takes place under anaerobic conditions; however, the end result in this case is lactate, or lactic acid (see section "Anaerobic energy system").

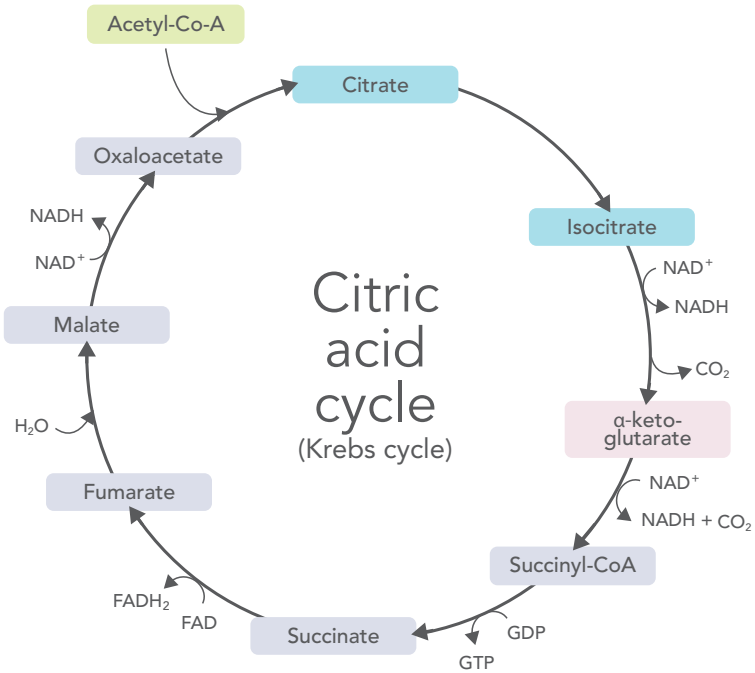
CITRIC ACID CYCLE

The citric acid cycle, or Krebs cycle (named after the Nobel prize winner Hans Adolf Krebs who discovered it), takes place in cell mitochondria.[74] The primary metabolic compound of the citric acid cycle is acetic acid (acetyl coenzyme A) produced from fatty acids, carbohydrates and proteins.[75]

The various reactions of the citric acid cycle (see image) form hydrogen ions and electrons which are then transferred to the inner mitochondrial membrane for oxidative phosphorylation (binding energy to ATP molecules through oxidation) and the electron transport chain. The reaction releases NADH and small amounts of ATP and carbon dioxide.

The citric acid cycle involves ten steps, each of them affected by B vitamins and certain minerals such as magnesium and iron as well as the liver's main antioxidant, glutathione. The reactions are inhibited by heavy metals such as mercury, arsenic and aluminum.

CITRIC ACID CYCLE



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Most of the energy generated during the citric acid cycle is captured by the energy-rich NADH molecules. For each acetyl coenzyme A molecule, three NADH molecules are generated and then used for energy in the reaction that follows (oxidative phosphorylation).

The regulation of the citric acid cycle is determined by the availability of various amino acids as well as feedback inhibition (for example, if too much NADH is produced, several enzymes of the citric acid cycle are inhibited, slowing down reactions).

Oxaloacetate acts as a compound used to fulfill a sudden need to produce energy (for instance, in the brain or muscles). Taking an oxaloacetate supplement may therefore be useful, and it may even boost the regeneration of mitochondria in the brain, reduce silent inflammation in the body and increase the number of nerve cells.[76]

To put it simply, the body incorporates ingenious systems that convert consumed food into electrons which are used as energy for various needs.

OXIDATIVE PHOSPHORYLATION

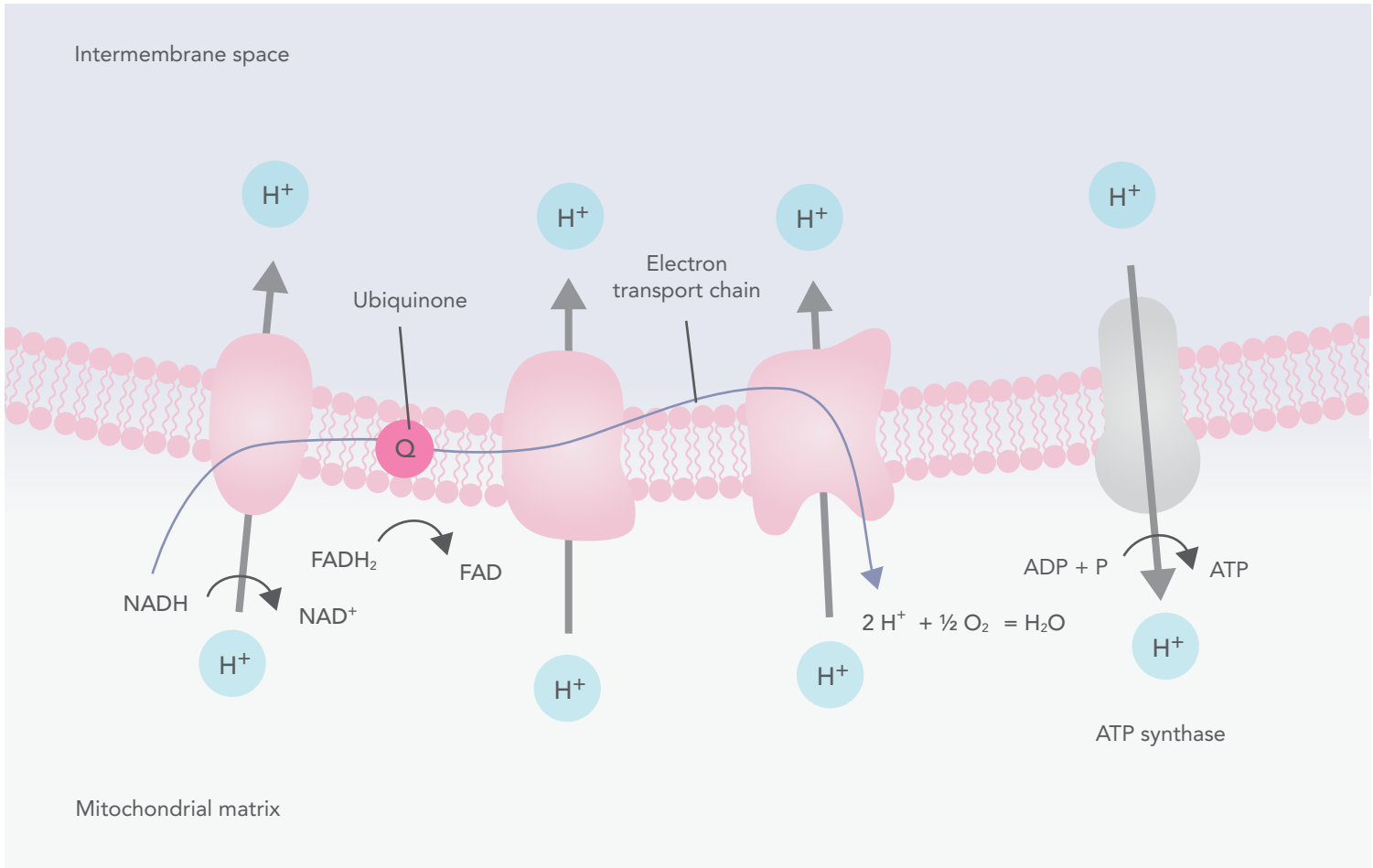
Oxidative phosphorylation consists of two parts: the electron transport chain and ATP synthase. Oxidative phosphorylation produces most of the energy generated in aerobic conditions (ATP). It is a continuation of the citric acid cycle.

In the electron transport chain, hydrogen ions (H+) are released into the mitochondrial intermembrane space. Through ATP synthase, the hydrogen ions released from the intermembrane space move back into the mitochondrion. Using the energy released in the process, ATP synthase converts the ADP used for energy into ATP again.

Ubiquinone (coenzyme Q10) acts as a contributor to the electron transport chain. It has been used for decades as a dietary supplement. Low cellular ubiquinone levels may be a predisposing factor for various illnesses due to insufficient aerobic energy production in the cells. In addition, the use of cholesterol medication (statins) has been found to be a contributive factor to ubiquinone deficiency.[77]

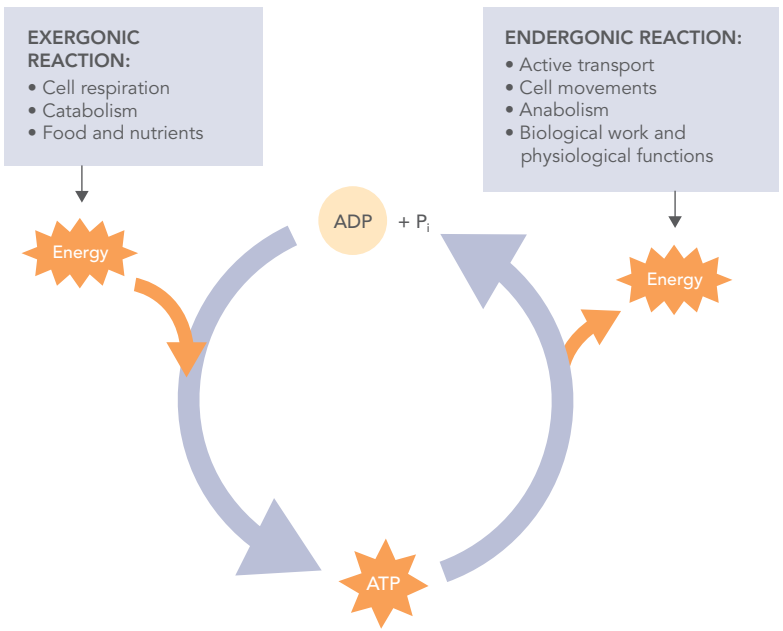
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ELECTRON TRANSPORT



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RECYCLING OF ATP



ATP

Adenosine triphosphate or ATP is one of the main compounds in the human energy metabolism. ATP molecules bind a great deal of energy which is released in cells by the ATPase enzyme. This releases both energy and a phosphate group that converts ATP into ADP. ATP is the sole energy source in the muscle cells. ATP is recycled hundreds of times in cells before it breaks down. Practically all living organisms use ATP for energy production.

BETA-OXIDATION OF FATTY ACIDS

Fatty acids broken down in the digestive system are used for energy in the mitochondria. In this reaction (called beta-oxidation), the fatty acids are activated by being bound to coenzyme A. The result is acetyl coenzyme A (see above) which is used for energy production in the citric acid cycle.[78]

The oxidation of long-chain fatty acids requires carnitine acyl transferases in which the fatty acids are transported from the cytoplasm into the mitochondrion. Such transfer of short- and medium-chain fatty acids into mitochondria is unnecessary as they move there by diffusion.

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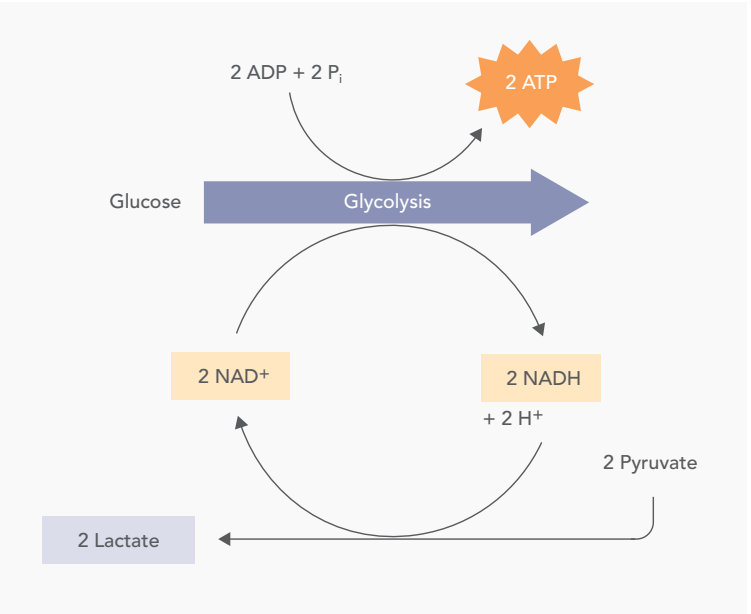
ANAEROBIC ENERGY SYSTEM

The term "anaerobic" refers to reactions that happen without oxygen present. The anaerobic energy system is needed in circumstances in which oxygen is not immediately available in the quantities required, for example during high-intensity sports activity. In the anaerobic energy system, ATP is produced by breaking down glucose polymers (glycogens) stored in muscles and the liver as well as by utilizing the free ATP molecules immediately available in the muscle cells.

ANAEROBIC GLYCOLYSIS

During anaerobic glycolysis, glucose is broken down into pyruvate which is then converted into lactic acid (lactate) during the lactic acid fermentation process. The lactic acid fermentation takes place when oxygen is not available for energy production.

ANAEROBIC GLYCOLYSIS



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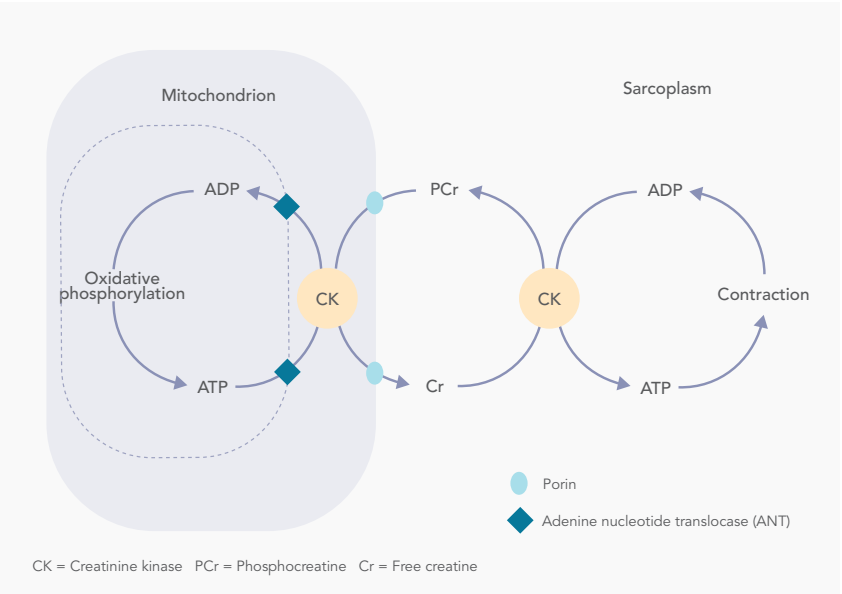
CREATINE PHOSPHATE SYSTEM

The creatine phosphate system is one of the main energy sources for muscles. It is estimated that approximately 95 % of the body's creatine is located in the skeletal muscles. Creatine phosphate (phosphocreatine) is synthesized in the liver from creatine and phosphate (from ATP; see above). Red meat is a source of creatine, and it can also be synthesized from amino acids (arginine and glysine).[79] Creatine is used as a dietary supplement (creatine monohydrate) as it significantly increases force generation in the skeletal muscles.[80]

Creatine is formed and recycled in the creatine phosphate shuttle (see image). The shuttle transports high-energy ATP molecule phosphate groups from mitochondria to myofibrils (muscle fibers), forming phosphocreatine (creatine phosphate) through creatine kinase. It is used by the muscles for fast energy production.

Unused creatine is transported by the same shuttle into mitochondria where it is synthesized into creatine phosphate. Used phosphocreatine forms creatinine which exits the body in urine via the kidneys.

When determining the filtering capability of the kidneys, it is useful to measure the blood creatinine level. The higher a person's muscle mass, the higher the volume of creatinine secreted. Because of this, the muscle creatine level and blood creatinine level of men are usually higher than those of women.



CREATINE PHOSPHATE SHUTTLE

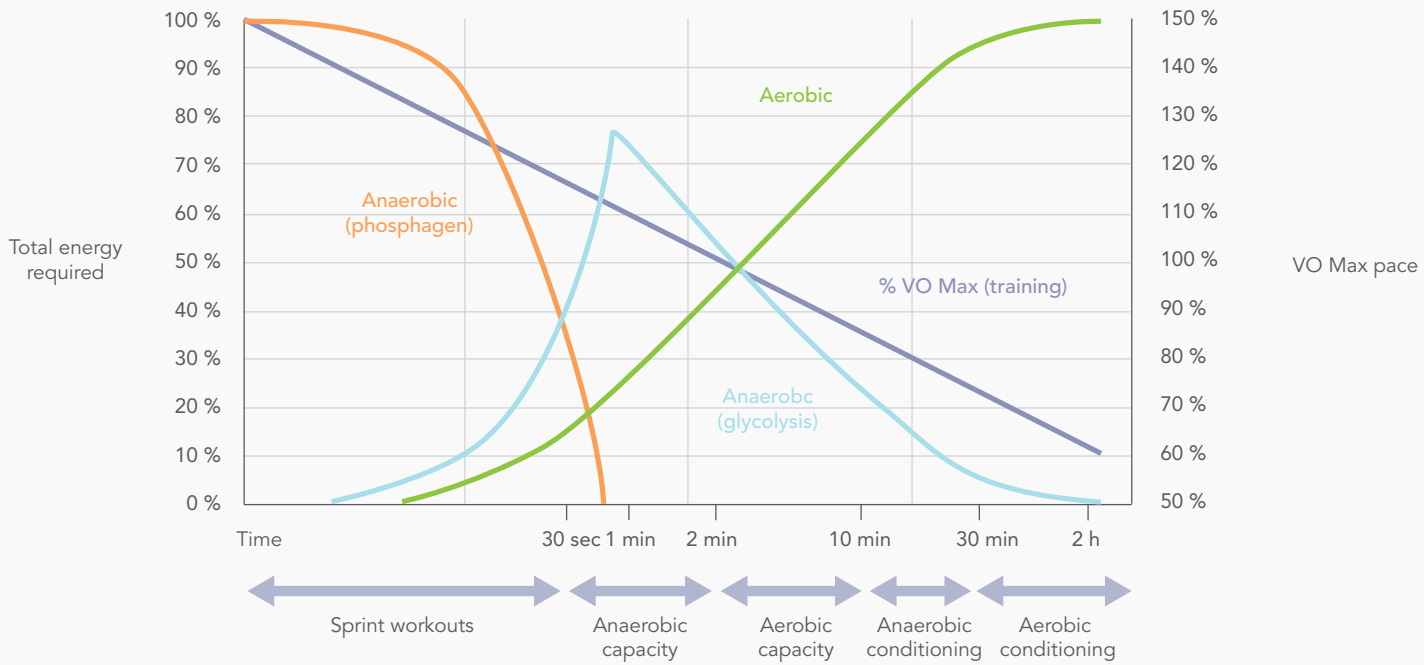
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ENERGY SYSTEMS AND THEIR FUNCTIONS

ENERGY SYSTEM	MECHANISM	ACTIVITY TYPE	APPROX. DURATION	BENEFITS	DRAWBACKS
Aerobic	Oxygen is metabolized to release energy	Low to moderate intensity	> 90 seconds	↑ heart function ↓ body fat	↓ muscle mass ↓ strength ↓ speed ↓ power
Anaerobic 1	ATP synthesized from creatine/phosphate to produce energy	Medium to high intensity	5–7 seconds	↑ heart function ↓ body fat ↑ muscle mass ↑ strength ↑ speed ↑ power	
Anaerobic 2	Glucose broken down for energy; causes fatigue	Medium to high intensity	7–90 seconds		

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THE ENERGY SYSTEMS DURING EXERCISE



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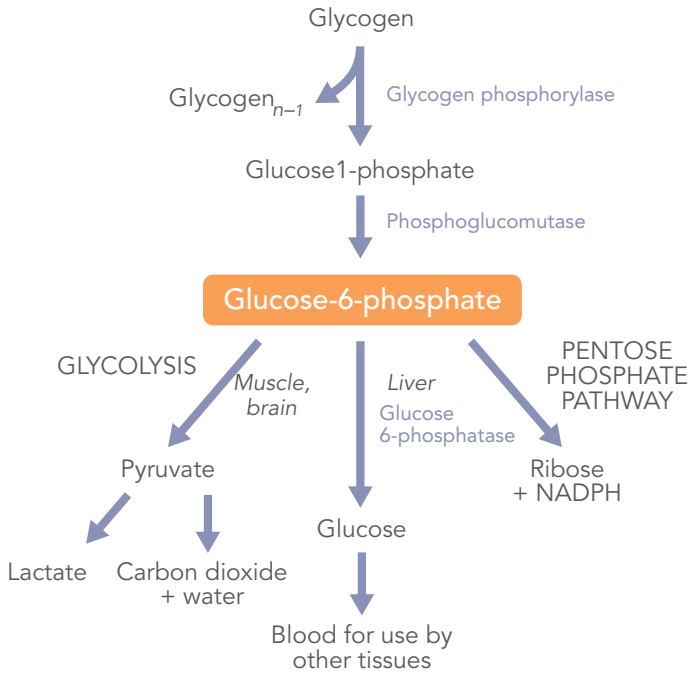
THE BODY'S MAIN ENERGY STORAGE SYSTEMS

The body utilizes two different types of energy storage. Energy-dense molecules such as glycogen (sugar) and triglycerides (fat) are stored in the liver, muscles and adipose tissue (fat; triglycerides only). Another important type of energy storage is comprised of the electrochemical ions located between cell membranes. Due to its complex nature, the latter is not covered by this book.

GLYCOGEN

Glycogen is a large-size molecule formed of several (up to 30,000) glucose molecules. Glycogen is stored in the liver (10 % of the weight), muscle cells (2 % of the weight) and, to a lesser extent, red blood cells.[81] In addition to glucose, glycogen binds triple the amount of water. Because of this, a person's body weight may fluctuate by several kilograms within a 24-hour period depending on the fill level of the glycogen reserves.

The glycogen storage in the liver acts as an energy reserve for the entire body's energy production needs, and those of the central nervous system in particular. The glycogen storage in the muscles is only used for the energy production of muscle cells. The amount of glycogen present is determined by physical exercise, the basal metabolic rate and eating habits.

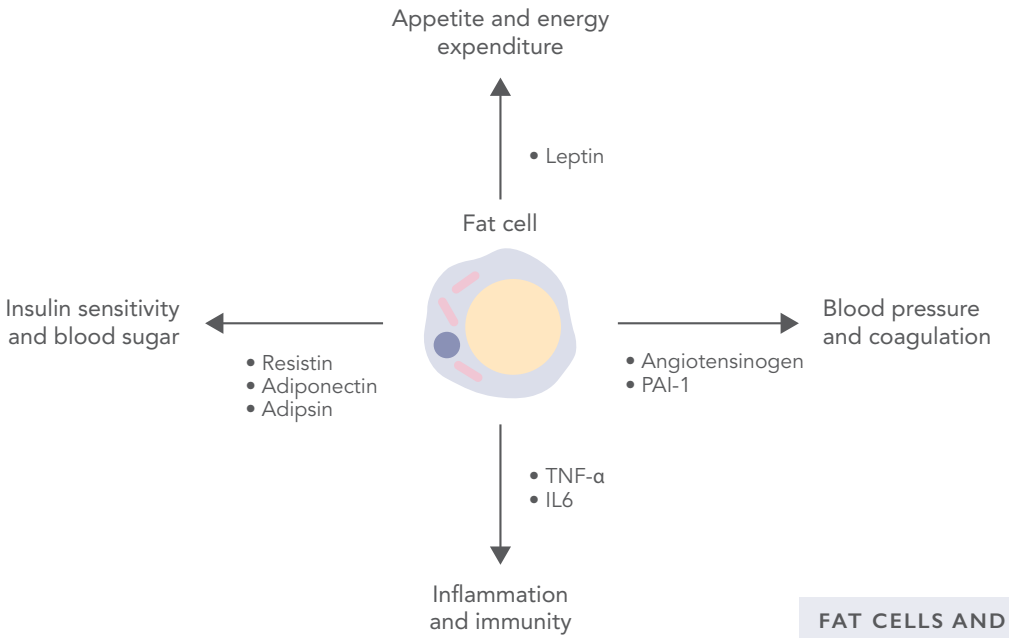


THE BREAKDOWN OF GLYCOGEN AND USING IT FOR ENERGY

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The glycogen reserves are especially important for the regulation of blood sugar between meals and during intensive exercise. Glucose may also be used for energy under anaerobic conditions. Conversely, fatty acids are broken down into energy only under aerobic conditions. The brain needs a steady level of glucose although it is able to utilize, for example, the ketone bodies produced by the liver during fasting.[82]

A metabolically active glycogen breakdown product is glucose 6-phosphate in which the glucose molecule binds with one phosphate group. It may be used for energy in a muscle under either aerobic or anaerobic conditions, utilized via the liver as glucose elsewhere in the body or converted into ribose and NADPH for use in various tissues (for example in the adrenal gland, red blood cells, mammary glands and the fat cells in the liver).[83]



FAT CELLS AND HORMONES

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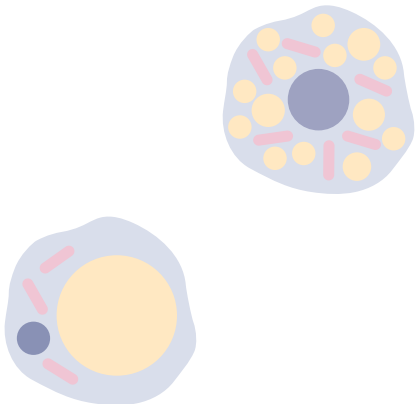
ADIPOSE TISSUE

Adipose tissue (fat) is the body's main long-term energy storage system. In addition to fat cells (adipocytes), it consists of connective tissue cells and vascular endothelial cells. Fat cells contain a lipid droplet consisting of triglycerides and glycerol. Adipose tissue is located under the skin (subcutaneous adipose tissue), in bone marrow, between muscles, around internal organs (visceral fat) and in the breast tissue. Visceral fat is particularly detrimental to health as it increases the risk of type 2 diabetes, coronary heart disease and various inflammatory diseases.[84]

Adipose tissue is also a hormonally active (endocrine) organ. Adipose tissue produces for example, leptin, adiponectin and resistin that regulate the energy metabolism and body weight.[85]

Adipose tissue is ever changing, storing or breaking down free fatty acids for use by the body. The process of breaking down adipose tissue into energy is called lipolysis. In lipolysis, triglycerides of the adipose tissue are oxidized by lipase and triglyceride lipase into free fatty acids and glycerol. Fatty acids are used for energy in the muscles, liver and heart; glycerol is mainly used in the liver.

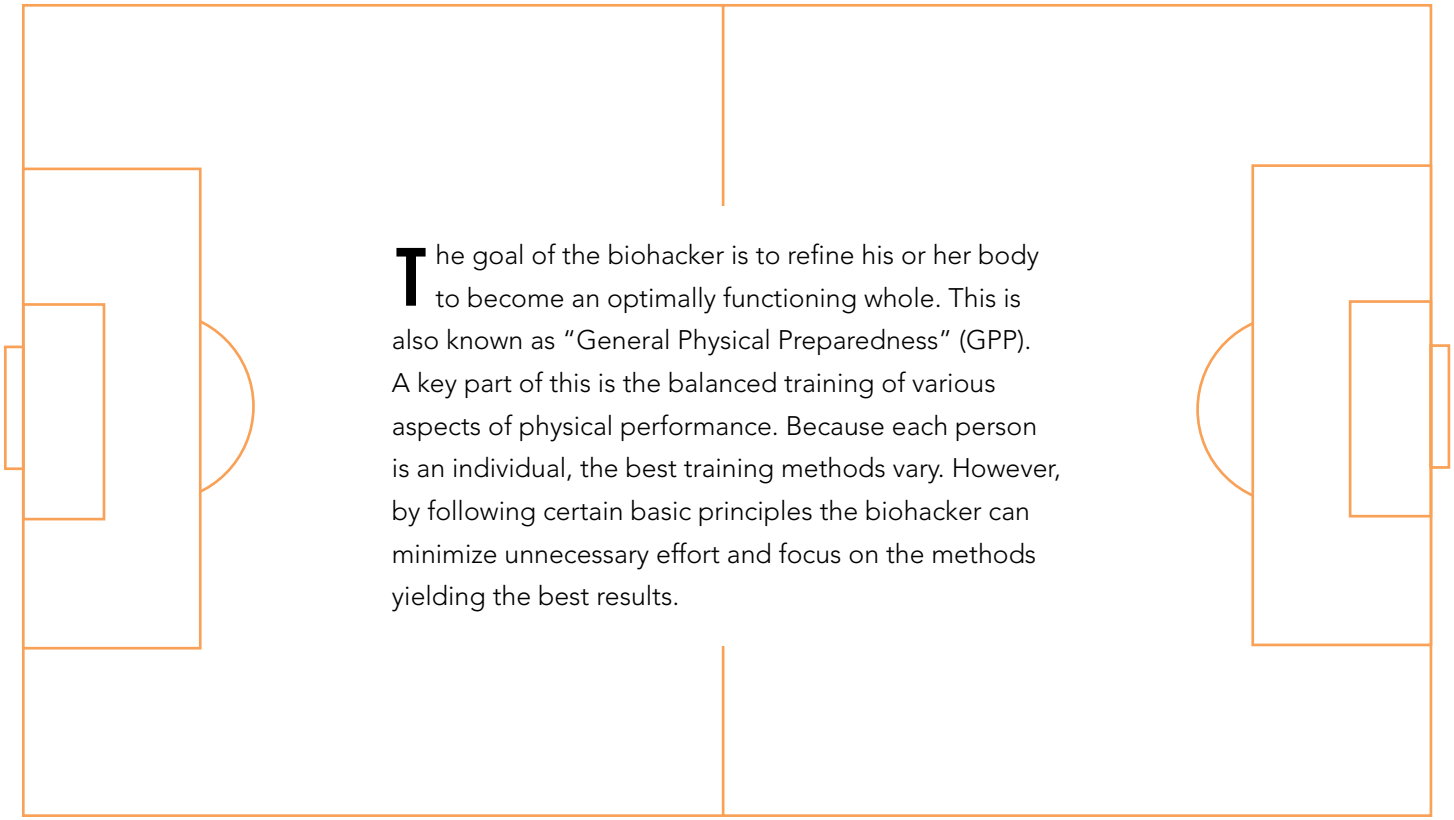
Conversely, insulin inhibits lipolysis. If the body's stored insulin levels are consistently elevated, the fatty acids circulating in the blood are stored in the adipose tissue. This is called lipogenesis. In particular, the secretion of insulin is stimulated by high blood sugar levels and a carbohydrate-rich diet.[86] An abundant protein intake also increases insulin secretion.[87]



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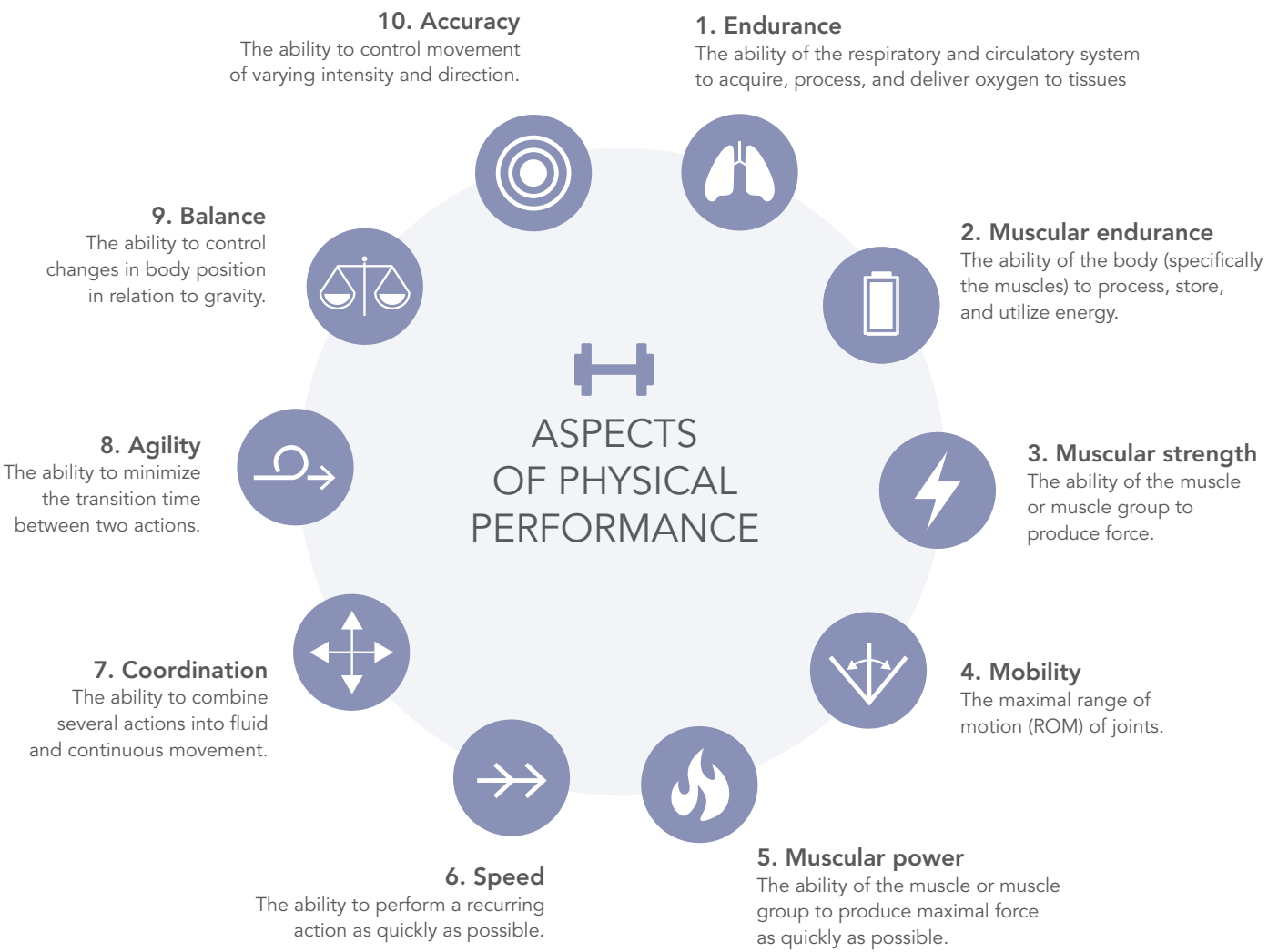
METHODS TO IMPROVE PHYSICAL PERFORMANCE

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The goal of the biohacker is to refine his or her body to become an optimally functioning whole. This is also known as "General Physical Preparedness" (GPP). A key part of this is the balanced training of various aspects of physical performance. Because each person is an individual, the best training methods vary. However, by following certain basic principles the biohacker can minimize unnecessary effort and focus on the methods yielding the best results.

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ENDURANCE EXERCISE

Endurance refers to the body's ability to withstand fatigue and remain active whilst under physical strain. Endurance depends largely on the performance of the respiratory and circulatory system as well as the energy management in the muscles, i.e. their ability to convert fat and carbohydrates into energy.[88] This is determined by the number of mitochondria, the number of capillaries in the muscles as well as various metabolic pathways (glycolysis, Krebs cycle and oxidative phosphorylation).

Endurance exercise is generally recommended as the basis of all healthy physical exercise. The recommendation is to exercise for at least 2 hours and 30 minutes per week (the common suggestion is five times per week, for at least 30 minutes each time).

Some activities considered to fall under endurance exercise include walking, cycling, swimming, hiking and even heavier house and yard work. The intensity varies depending on the individual's fitness level. To make significant developments in one's endurance fitness, it is usually necessary to include activities more arduous than walking, for example running, cross-country skiing, fast-paced cycling or various ball games. In terms of group exercise, various aerobics, dance, and cross-training classes are popular.

Endurance exercise can be divided into four types by the level of exertion involved: basic aerobic endurance, tempo endurance, maximal endurance and speed endurance. Endurance can also be divided into either aerobic or anaerobic exercise. In practice, basic aerobic endurance is the basis of all movement.

The boundary between basic endurance and tempo endurance is called the aerobic threshold. Similarly, the boundary between tempo endurance and maximal endurance is called the anaerobic threshold. Anaerobic (oxygen-free) energy production increases with the level of physical effort. The aerobic threshold is the level of effort at which anaerobic energy pathways start to be a significant part of energy production (usually under 70 % of the maximal heart rate).[89]

The anaerobic threshold is defined as the level of exercise intensity at which lactic acid builds up in the body faster than it can be cleared away by the heart, liver and striated muscles. For this reason, it is also sometimes called the lactate threshold (approximately 85–90 % of the maximal heart rate). Once the threshold has been surpassed, more

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lactic acid is produced in the muscles than can be removed, slowly leading to fatigue.[90] Both aerobic and anaerobic threshold may be increased by training. For example, runners want to increase their aerobic threshold because this will enable them to run faster for longer.

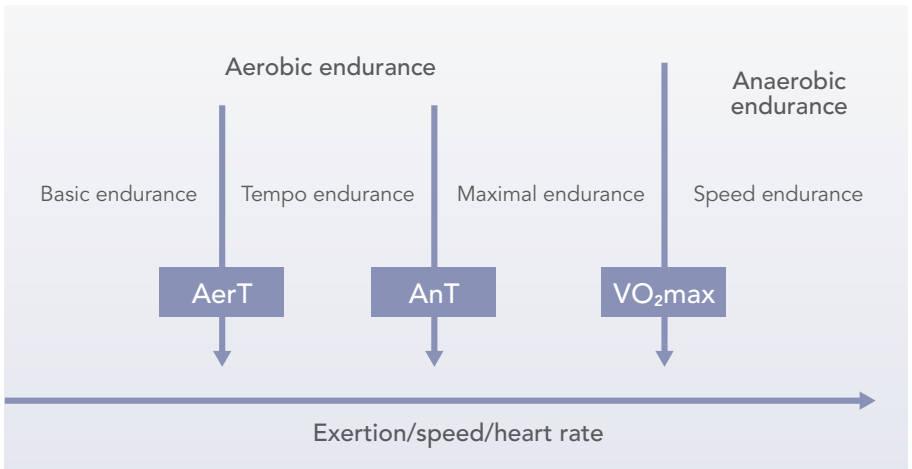
Maximal endurance refers to the level of intensity that ranges from the anaerobic threshold to the maximal aerobic exertion. It is determined by the maximal oxygen uptake (VO2max), the biomechanical power of the activity and the performance of the neuromuscular system.

The indicative threshold values can be determined using the Karvonen formula:

(Maximal heart rate – resting heart rate) x desired heart rate zone between 60–90 % + resting heart rate
For example (189 – 50) x 0.7 + 50 = 147 (the estimated aerobic threshold for a 35-year-old individual with a resting heart rate of 50 bpm).

The most accurate[91] method of estimating the maximal heart rate (HRmax) is to use the following formula:
211 – 0.64 x age in years (for example 211 – 0.64 x 35 = 189)

ENDURANCE TYPES AND THRESHOLDS



AerT = Aerobic threshold
AnT = Anaerobic threshold

Source: Keskinen, K. & Häkkinen, K. & Kallinen, M. (2007). *Kuntotestauksen käsikirja*. Finnish Society of Sports Science. 2nd print.

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THE BASIC PRINCIPLES OF ENDURANCE TRAINING

The main goal of endurance training is to increase the body's ability to perform prolonged exercises ranging in duration from a few minutes to several hours. Typical sports include walking, running, cycling, cross-country skiing, swimming and hiking.

Developing endurance usually requires training at least three times per week, for 30 to 60 minutes at a time. Utilizing heart rate zones and training with a heart rate monitor can be useful. However, this is not strictly necessary – the method helps you recognize various heart rate zones and their physiological impact on endurance training.

Key factors in endurance exercise:

- The majority of endurance training takes place in the basic endurance zone (approx. 70–80 % of the training session). This develops basic endurance in general and cardiac output in particular (see section "Heart – Cardiac output").
- Focus on technique training
- Training should be progressive in nature and there should be sufficient time reserved for recovery
- High intensity interval training (HIIT) is particularly effective for increasing the number of mitochondria and the maximal oxygen uptake (VO2max)[92 93] (see section "HIIT" for more information)
- Perform various interval exercises in the tempo and maximal endurance zones
  - Short intervals (HIIT); 15–45 second exercise intervals, rest for 15 seconds to 3 minutes
  - Long intervals; 3–8 minute exercise intervals, rest for 1 minute to 4 minutes
  - Incremental intervals; 8–20 minute exercise intervals, varying rest intervals. The intensity is even lower than in the long interval training
- Strength training increases the effectiveness of endurance exercise and improves performance[94]
- Perform restorative exercises and avoid overtraining

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HEART RATE ZONES AND LACTATE LEVELS FOR ENDURANCE TRAINING

HEART RATE ZONE	% OF LACTATE THRESHOLD	INTENSITY (% OF HRMAX)	DESCRIPTION
Zone 1 / Basic endurance 1 Goal: Recovery, warm up and cool down Energy system: Aerobic (oxidative)	70–76 %	50–60 %	Light aerobic exercise may facilitate recovery by boosting circulation (removing inflammatory agents) and the secretion of growth hormones. For example, walking a dog, hiking, light swimming, yard work, yoga, etc.
Zone 2 / Basic endurance 2 Goal: Endurance Energy system: Aerobic (oxidative)	77–85 %	60–70 %	Training in this heart rate zone is mainly beneficial for slow muscle cells and the improvement of basic endurance. Energy utilized mainly from the adipose tissue. The foundation of endurance training is laid in this heart rate zone.
Zone 3 / Tempo endurance 1 Goal: Muscular endurance Energy systems: Aerobic (oxidative) & glycolytic	86–95 %	70–80 %	Increases exertion and improves aerobic power. For example, walking uphill will raise the heart rate to this level. Breathing is heavy but steady. Significant consumption of energy reserves; there is a risk of overtraining in this heart rate zone.

Source: Greenfield, B. (2014). *Beyond Training. Mastering Endurance, Health & Life.* Victory Belt Publishing.

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HEART RATE ZONE	% OF LACTATE THRESHOLD	INTENSITY (% OF HRMAX)	DESCRIPTION
Zone 4 / Tempo endurance 2 Goal: Muscular endurance, lactic acid tolerance, speed Energy systems: Aerobic (oxidative) & glycolytic	96–103 %	80–90 %	Training in this heart rate zone takes place on either side of the lactate threshold and improves lactate tolerance. Breathing is heavy and laborious. Training in this heart rate zone improves fast muscle cells and recovery. Particularly useful in interval training (2:1 to 1:3 ratio of exertion to recovery).
Zone 5 / Maximal endurance Goal: Speed maintenance, development in exercise technique and economy, the effective removal of lactic acid Energy systems: Glycolytic, creatine phosphate	104 %–max	90–100 %	Exertion always exceeds the lactate threshold. Very exhausting and arduous. Suitable for short interval exercises. Usually requires a longer recovery period.
Beyond Zone 5 Goal: Explosive speed, power Energy systems: Creatine phosphate (glycolytic when duration exceeds 5 seconds)	Max		Improves strength, explosive speed and fast muscle cells. Performed as short explosive intervals (ratio of exertion to recovery is 1:4 to 1:10). For example powerlifting, weight training, and plyometric training.

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A SIMPLE AND EFFECTIVE ENDURANCE TRAINING PROGRAM:

- Exercises to be completed 3 times per week
- Program duration 8–12 weeks
- The exercises are divided into two parts:
  - Endurance training to increase oxygen uptake (days 1 & 3)
  - Incremental intervals (day 2)
- Total duration of each training session is 30–40 minutes
- Each exercise includes warm up and cool down sections
- In addition to the basic exercises you may walk as much as you wish
- The program may also be applied, for example, to cross-country skiing, cycling or swimming

Mon	Tue	Wed	Thu	Fri	Sat	Sun
Endurance training		Incremental intervals		Endurance training		

x 8–12 weeks

Days 1 & 3:

- 5–10 minute warm up (heart rate zones 1–2); the goal is to activate the circulation and nervous system (no shortness of breath)
- Actual training (four intervals of 4 minutes each):
  - Increase exertion incrementally for 1–2 minutes (severe shortness of breath, no lactic acid) and continue at this level for the remaining 2–3 minutes of the interval (heart rate zone 4). After the interval you should feel like you could easily have continued for another minute at the same exertion level (there may be some lactic acid at this point but it will be removed during the recovery period).
  - 2–3 minute recovery period after the interval, heart rate between zones 1–2 (breathing returns to normal). Depending on the fitness level, this may mean jogging or walking.
  - Repeat the interval four times
- Approx. 5 minute cool down (heart rate zones 1–2); breathing returns to normal, you are able to speak in complete sentences

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Day 2:

- 5–10 minute warm up (heart rate zones 1–2); the goal is to activate the circulation and nervous system (no shortness of breath)
- Actual training (three intervals of 8 minutes each, incremental intervals):
  - Increase exertion incrementally for 1–2 minutes (severe shortness of breath, no lactic acid) and continue at this level for the remaining 6–7 minutes of the interval (heart rate zone 3). After the interval you should feel like you could easily have continued for another minute at the same exertion level (there should be no lactic acid present).
  - 1–2-minute recovery period after the interval, heart rate between zones 1–2 (breathing returns to normal). Depending on the fitness level, this may mean jogging or walking.
  - Repeat the interval three times
- Approx. 5 minute cool down (heart rate zones 1–2); breathing returns to normal, you are able to speak in complete sentences

HOW TO UTILIZE HEART RATE ZONES IN TRAINING?

- If your endurance fitness level is good but you get fatigued as soon as your muscles start producing lactic acid, you should add intervals in heart rate zone 4
- If intervals pose no problem but you get fatigued during prolonged exercises performed at a steady pace, you should add exercises in heart rate zone 2 and intervals in zone 3
- If you can't sprint to the finish at the end of a 5 kilometer run, you should add intervals in heart rate zone 5 (maximal endurance)
- If your body is slow to recover, add exercises in heart rate zone 1

WHAT ARE THE COMMON PITFALLS OF ENDURANCE TRAINING?

- Training at the same intensity level and heart rate zone time after time
- Training at the same pace time after time
- Training too hard on lighter training days or vice versa

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THE BENEFITS OF ENDURANCE EXERCISE

Endurance exercise has both functional and structural benefits. Structural changes include increases in heart volume and muscular strength, lung volume, number of mitochondria and microvasculature. Functional changes include lower blood pressure at rest, lower resting heart rate, increased heart stroke volume and cardiac output, and improved oxygen uptake.[95]

Endurance exercise is known to have a positive impact on anxiety and depression, balancing stress and the treatment and prevention of numerous chronic illnesses (see section "Exercise and health" for more information).

It is also known to reduce the risk of cardiovascular diseases. It appears that to achieve these benefits, just three months of moderate training (2–3 hours per week) is required, after which further benefits are limited even if there is an increase in the amount or intensity of training.[96] Moderate exercise (MET <6) seems to be the best predictor of longevity and general good health.[97]

DID YOU KNOW

MET STANDS FOR METABOLIC EQUIVALENT. IT REPRESENTS THE INCREASED ENERGY EXPENDITURE CAUSED BY PHYSICAL ACTIVITY COMPARED TO THE AMOUNT OF ENERGY USED AT REST. ONE MET UNIT IS EQUIVALENT OF THE OXYGEN CONSUMPTION OF THE BASAL METABOLIC RATE. FOR EXAMPLE, EVERYDAY ACTIVITIES SUCH AS EATING, WASHING AND WRITING HAVE A MET VALUE OF 2, I.E. BASAL METABOLIC RATE TIMES TWO. BRISK WALKING REPRESENTS A MET VALUE OF 5.

THE POTENTIAL DISADVANTAGES OF ENDURANCE EXERCISE

Excessive and extreme endurance exercise may cause various health problems. In particular, cardiac remodeling and increased arrhythmia are potential problems for people who participate in marathon running, ultra running, long-distance cycling or ironman training.[98,99] It appears that the risk of coronary heart disease and the occurrence of atherosclerosis are also higher than usual for marathon runners.[100,101]

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THE STRENUOUSNESS OF VARIOUS ACTIVITIES IN MET UNITS

ACTIVITY	MET
Sleeping	0.9
Sitting	1
Washing	2
Light housework	2
Yard work	3
Chopping wood	6
Construction site	5–7
Walking 6 km/h (3.7 mph)	4–5
Running 8 km/h (5 mph)	8
Basketball	6–8
Strenuous rowing	12
Cycling 27–30 km/h (16–19 mph)	12
Running 15 km/h (9.3 mph)	15
Hard competitive endurance performance	17–

Source: Ainsworth, B. et al. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise* 32 (9 Suppl): S498–504.

Those participating in endurance exercise (running in particular) are also more likely to have repetitive strain injuries compared to people doing other types of exercise. These injuries include various knee and ankle injuries, repetitive strain injuries of the Achilles tendon or the foot and even strain fractures of the legs. It has been estimated that the cause of the high injury rate is excessive training and insufficient rest and recovery.[102]

A comprehensive survey study found long periods of walking to be a safer alternative to running whilst achieving the same health benefits (lower blood pressure, improved blood lipid levels and lower risk of diabetes).[103]

Endurance exercise impairs the development of muscle mass and muscular strength (the reverse however does not apply) which should be taken into consideration if these are the main exercise goals. The deterioration of strength and muscle mass is proportional to the amount of endurance training performed – the more endurance training one undertakes, the harder it is to develop muscle mass and strength.[104]

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STRENGTH TRAINING

Physical strength refers to a person's ability to generate force, or resistance, that one can apply to a given task. In practice, physical strength is determined by two factors: the cross-sectional area of a muscle as well as muscle fiber volume and their contractile intensity.[105] On the other hand, a person may be strong even if their cross-sectional muscle area is not large[106] because force generation hinges on the ability of the nervous system to command, recruit and organize the muscle fibers more effectively.[107] [108] The strength of connective tissues such as tendons and fibrous tissues also affects the ability of the muscles to generate force. A good example of this is the biomechanics of the Achilles tendon.[109]

The muscle cell type distribution of an individual significantly affects his or her ability to generate force (see section "Muscle cell types"). The force generation ability is also affected by the individual's sex, age, hormonal balance, nervous system function, general health, and nutritional status.

The strength training of muscles (and the nervous system) means training with the objective of increasing force generation and usually also muscle mass. Muscular strength training is commonly referred to as gym training, weight training or resistance training.[110] The maximal force generation ability is commonly measured in terms of a one-repetition maximum (1RM) (for example a squat).



THE BASIC PRINCIPLES OF STRENGTH TRAINING

To develop muscular strength it is usually necessary to exercise the major muscle groups at least twice per week for at least 20 minutes at a time. Studies have typically included training programs of 5–15 different exercises. There are 1–4 sets per exercise, each set consisting of 8–15 repetitions.

Key factors in strength training:

- Perform the exercises using correct technique and form
- Favor multi-joint exercises (such as deadlift, front squat, back squat, pull-up, bench press, dip, shoulder press, etc.) over single-joint exercises (such as bicep curl, leg extension) as the latter do not bring any significant additional benefits (strength and muscular mass)[111] [112]

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- Progressively increase weight between exercises; start for example with 60–70 % of the maximal performance capacity
- Progressively increase exercise volume, i.e. the number of sets or repetitions
- Vary the tempo and time under tension (TUT)
- Get sufficient rest and vary the length of recovery periods
- Reduce the training load every 3–4 weeks
- Change up your training program every 1–3 months

Special techniques and methods are discussed later in this book.

Maximal strength:
The best way to develop maximal strength is by completing sets of 1–5 repetitions reaching 85–100 % of the one-repetition maximum (1RM). Maximal strength is considered to be the basis of all other strength properties. The most effective set/repetition pattern is 3–5 x 3 (three to five sets of three repetitions each). Rest for 3–5 minutes between sets.

Speed strength and explosive strength:
The best way to develop speed and explosiveness is to lift sub-maximal (40–80 % 1RM) loads in several sets. The most effective set/repetition pattern is 7–9 x 3. Rest for 1–3 minutes between sets. The development of speed strength also requires maximal strength training.

Muscle growth (hypertrophy):
The best way to promote muscle growth is to introduce mechanical and metabolic stress. For muscle growth, perform sets of 8–12 repetitions with medium weights (65–85 % 1RM). The most effective set/repetition pattern is 3–5 x 8–10. Rest for 60–90 seconds between sets. Sets are often repeated to exhaustion.

Strength endurance:
To develop strength endurance, perform sets of 12 or more repetitions with significantly sub-maximal loads (20–70 % 1RM). In addition to developing strength endurance, this type of training can boost recovery after other strength training. The most effective set/repetition pattern is 3 x 15–20. Rest for 30–60 seconds between sets.

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TIME UNDER TENSION (TUT)[113]

Time under tension (TUT) refers to the time that the muscle or muscle group is under strain during one set. Each exercise can be divided into three phases: eccentric (lengthening), concentric (shortening) and pause. For example, when performing a squat, 2 seconds down, 1 second in the lower position and 2 seconds up is equivalent of 5 seconds of TUT. If one set includes ten repetitions of five seconds each, the TUT value is 50 seconds.

Varying the TUT duration can impact different energy systems (ATP, creatine phosphate and anaerobic glycolysis). The number of repetitions alone is not all there is to training as a repetition can be performed fast or more slowly. A set of slower repetitions of longer TUT duration performed to exhaustion is more effective for stimulating muscle growth than a faster set (for example, 8 repetitions of either 2 or 8 seconds of TUT; the end result is 16 seconds of TUT vs. 48 seconds).[114]

Maximal strength and speed strength: 5–10 seconds of TUT
Basic muscular strength: 10–30 seconds of TUT
Hypertrophy (muscle growth): 30–60 seconds of TUT
Strength endurance: More than 60 seconds of TUT

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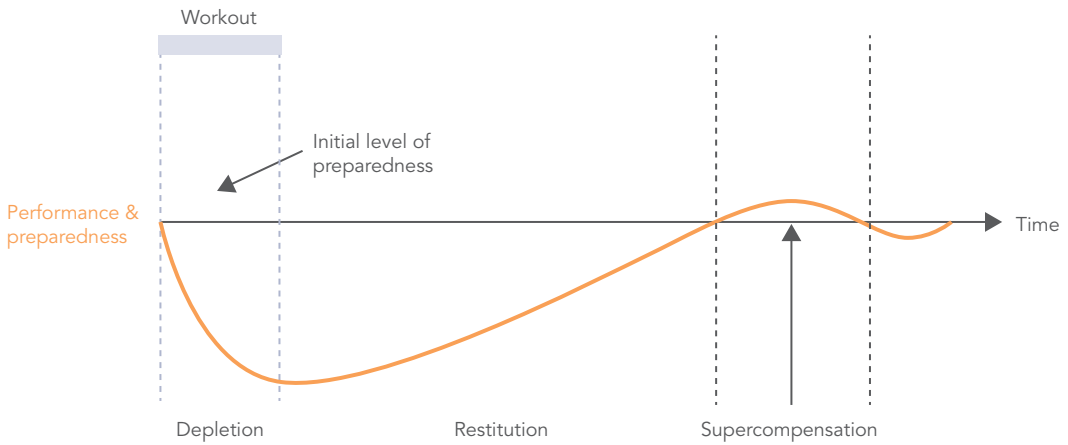
RECOVERY: THE SUPERCOMPENSATION THEORY

Supercompensation is one of the oldest adaptation theories used widely in traditional muscle strength training and bodybuilding. The core concept of supercompensation is that training consumes common resources, biochemical cascades, energy reserves and the nervous system. The extent varies depending on the load and intensity of the workout. Therefore, training represents a catabolic activity (breakdown of tissue).

The body needs rest, hydration and nutrition to bounce back from the catabolic state. If the recovery (anabolic state) is optimal, the body becomes stronger and more powerful by the time of the next workout (see image 1).

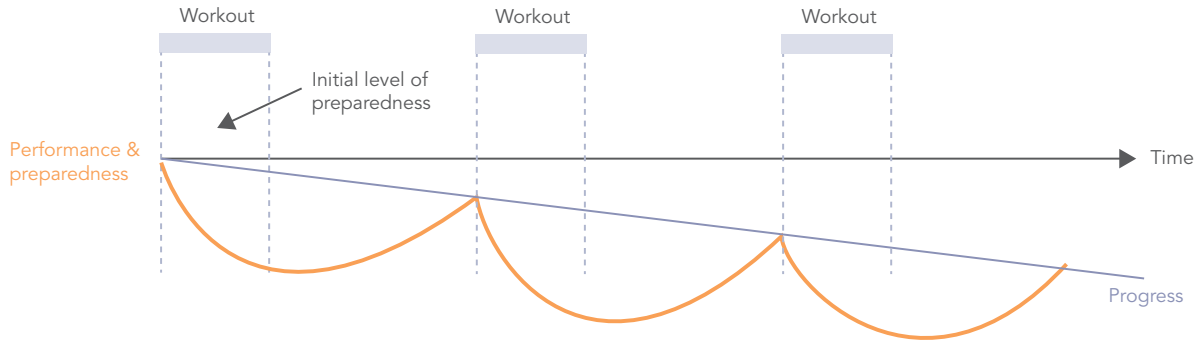
If the rest period is too short, the next workout will consume even more of the body's resources. Over time, this can lead to overtraining. If the rest period is too long, the achieved progress may be lost (see image 2). Temporary overload may be utilized, for example, by training on several subsequent days and then resting for a longer period of time. According to the theory, there is a greater supercompensation effect in this case, provided that the nutrition and rest are sufficient (see image 3).

IMAGE 1: SUPERCOMPENSATION AND PERFORMANCE LEVEL

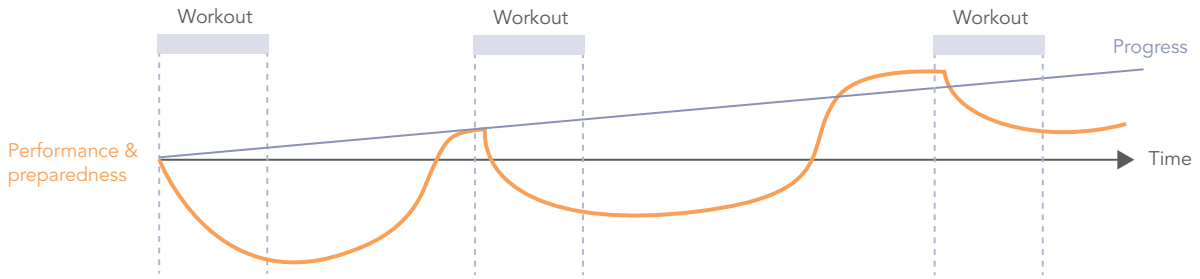


Source for figures 1–3: Zatsiorsky, V. & Kraemer, W. (2006). *Science and Practice of Strength Training* (2nd edition). Champaign, Illinois: Human Kinetics Publishers.

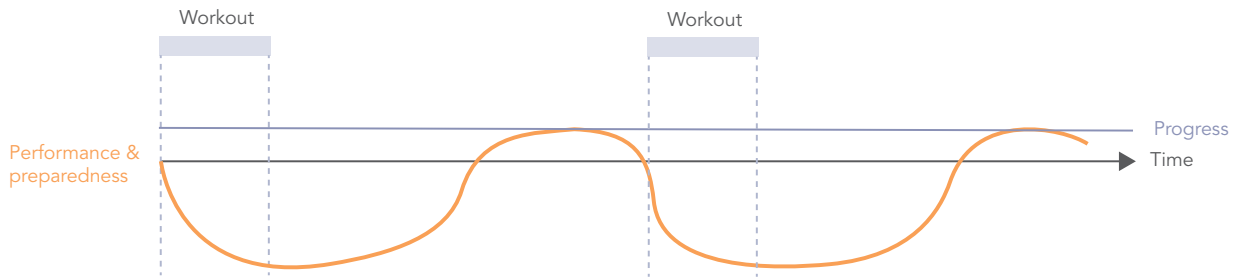
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The intervals are too short and the individual's performance level is consistently falling due to accrued fatigue.



The intervals are optimal – the next workout always takes place during the supercompensation phase.

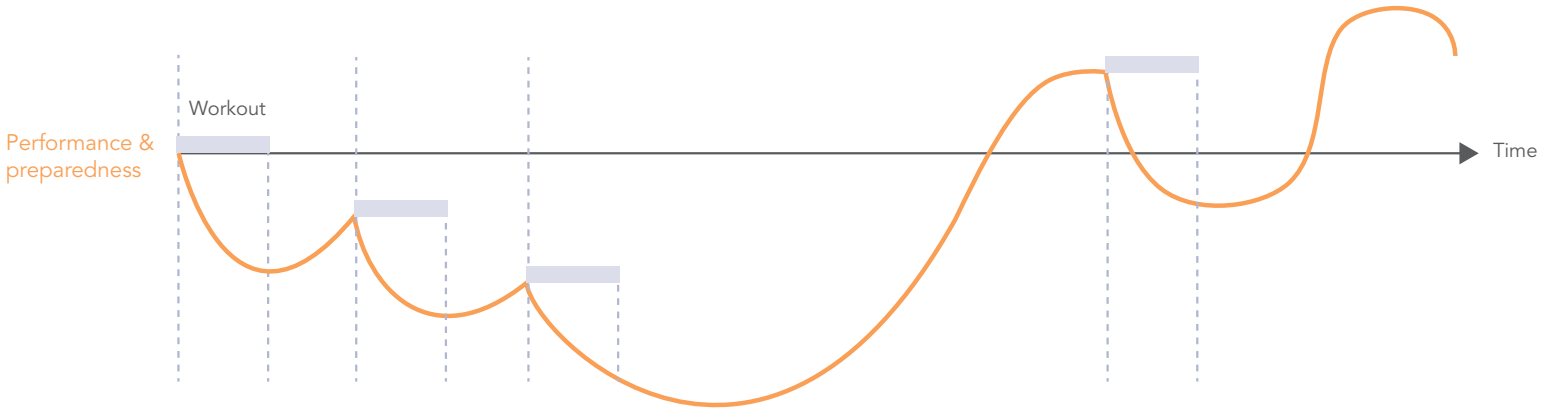


The intervals are too long and the desired training effect is not achieved.

IMAGE 2: SUPERCOMPENSATION IN THREE DIFFERENT SCENARIOS

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IMAGE 3: TRAINING MICROCYCLE WITH SUPERCOMPENSATION



The rest intervals of the first three workouts are too short for full recovery, causing fatigue to accrue. The recovery period between the third and fourth workout is longer and optimal for this situation. In this case, the supercompensation effect is even greater.

THE FITNESS-FATIGUE THEORY

The fitness-fatigue theory is a more sophisticated version of the supercompensation theory. It has recently gained more support, and indeed, the theory has a stronger scientific basis.[115]

The core concept of the theory is the so-called preparedness that fluctuates over time. There are two integral components to preparedness: slow- and fast-changing factors. The term "physical fitness" represents a very slow-changing state that depends on the individual's preparedness. Things such as temporary psychological stress or a sudden illness have an effect on preparedness.

According to the theory, the immediate effects of training are fitness and fatigue. The end result is defined as the sum of positive and negative factors. For example, the training regimen can lead to moderate fitness but with prolonged effectiveness (such as 72 hours). Conversely, the fatigue caused may be significant but shorter in terms of duration (such as 24 hours).

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A well-designed training program takes into account fatigue in relation to physical fitness when planning the timing of the next training session.

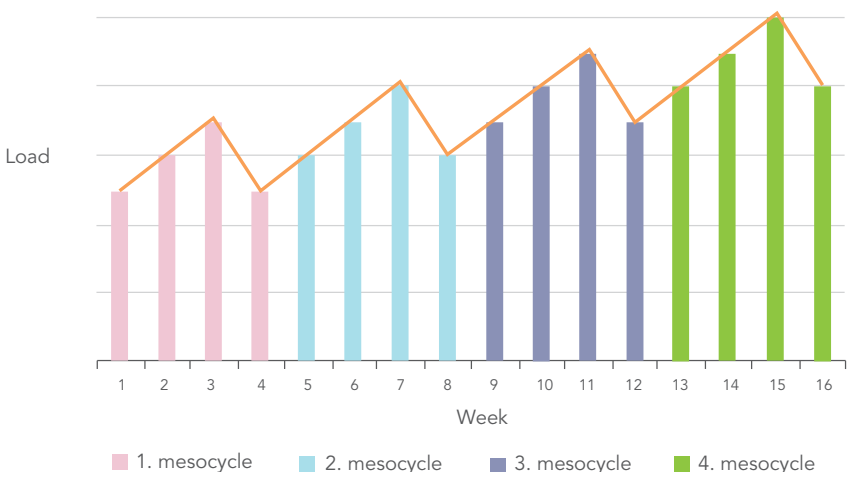
TRAINING PERIODIZATION

Training periodization means varying the training volume and intensity so that the optimal performance level is achieved while avoiding overtraining. Periodization is used to split a longer workout into shorter training cycles of various lengths.[116]

Many types of sports require numerous properties, the concurrent training of which may not be practical or possible. Using different training cycles for the desired properties is a key part of well-planned training.

- **Microcycle** (typically 1 week / 2–14 days)
  - Refers to one training cycle, for example, a one-week training period
- **Mesocycle** (2–12 weeks)
  - For example, a 3:1 paradigm where the training is incremental in intensity for 3 weeks and then lighter for one week
  - Several mesocycles may be repeated back to back
- **Macrocycle** (2–12 months)
  - A typical athlete macrocycle includes the training season, the competition season, and the transitional phase of the competition season
  - Macrocycles can also be divided into mesocycles that emphasize various properties (for example, swimming, running and cycling for triathlon training, or weight-lifting, gymnastics, and metabolic conditioning for crossfit training)

A CLASSIC 3:1 PERIODIZATION PARADIGM. EVERY FOURTH WEEK IS LIGHTER (FOURTH MICROCYCLE)



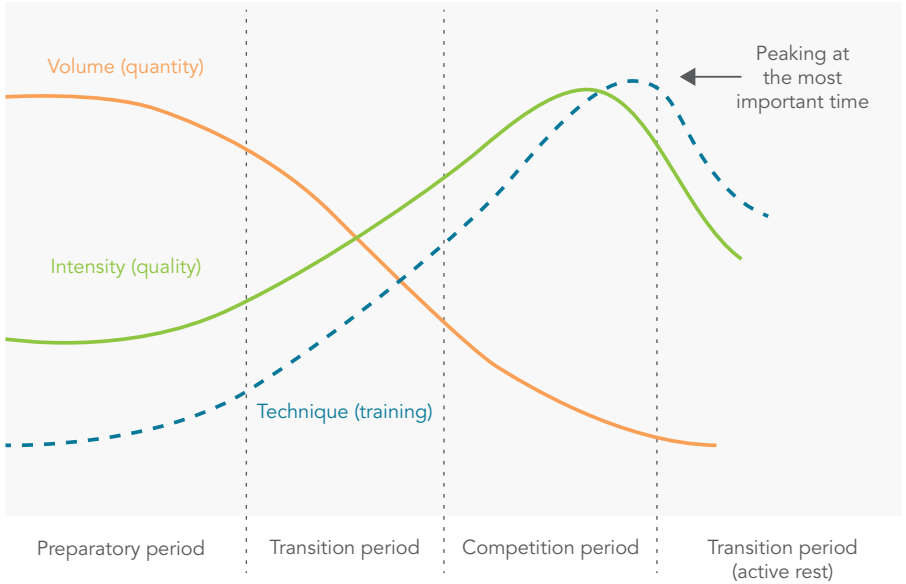
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Zatsiorsky and Kraemer (2006) describe the periodization of traditional training as the reconciliation of conflicting goals. During the process, the current importance of each training aspect as well as long-term goals are assessed.[117]

Alongside traditional periodization, there is also the method of non-linear periodization. For example, one microcycle (5–9 days) of strength training may include speed, basic and maximal strength exercises. The non-linear model provides more variety within a microcycle, for example, in terms of lighter days or weeks.

According to a study published in 2015, the most effective method for even experienced strength trainers is one in which both the load and the number of repetitions varies from one training session to another. Scientists believe that the reason behind the effectiveness of this type of training is that the changes in intensity and volume inhibit the habituation effect. The duration of the study was 6 weeks, i.e. one mesocycle.[118]

TRAINING PERIODIZATION AND MACROCYCLES



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STARTING STRENGTH PROGRAM[119]

- Exercise to be completed 3 times per week
- Program duration approx. 3 months
- Each training session is 30–40 minutes long
- The program consists of two exercises to be completed on alternating days (for example, MON exercise 1, WED exercise 2, FRI exercise 3, etc.)

Exercise 1:

- Back squat 3 x 5
- Bench press 3 x 5
- Deadlift 2 x 5

Exercise 2:

- Back squat 3 x 5
- Shoulder press with a bar 3 x 5
- Bent-over row 3 x 5

Warm-up sets before the actual work sets:

- 10 x 25 % of the work set (for example, if the work set is 100 kg (220 lbs), the first warm-up set is 25 kg (50 lbs))
- 6 x 50 % of the work set
- 3 x 75 % of the work set

Progression:

- Begin training with weights that are light enough for you to complete each repetition with proper form
- Add 2.5 kg (5.5 lbs) of weight each session (squat and deadlift); for other exercises add weight every other session
- Add weight until you can no longer complete three sets of five repetitions each; at this point reduce the set weights to what they were 2–3 weeks ago and slowly begin adding weight again.

THE HEALTH BENEFITS OF STRENGTH TRAINING

Strength training is associated with a lowered risk of metabolic syndrome,[120] hypertension[121] and cardiovascular diseases.[122] Conversely, reduced muscular strength increases the risk of metabolic syndrome and the associated chronic illnesses.[123] A study published in 2015 found that strength training may also reduce the metabolic and cardiovascular health risks caused by excess weight (BMI 27–30) to the same level as for individuals of normal weight.[124]

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Regular strength training strengthens bones,[125] increases muscle mass and muscular strength,[126] helps in weight management,[127] improves muscular endurance[128] and reduces the occurrence of musculoskeletal ailments.[129] Regular strength training is also associated with increased life expectancy.[130] [131]

Strength training may significantly slow down the age-related loss of muscle mass (sarcopenia).[132] [133] In many illnesses muscle atrophy (cachexia) is a risk factor for premature death.[134] For example, as many as 25 % of cancer patients die of cachexia[135]

The effects of strength training on the brain and mind are discussed in the "Exercise and the brain" section of the Exercise chapter.

THE POTENTIAL DISADVANTAGES OF STRENGTH TRAINING

There are potential health risks associated with strength training. Training using poor technique and excessive loads may cause repetitive strain injuries. Adverse effects of strength training reported in various studies include strains, muscle cramps, joint pains, and in extreme cases, ruptured muscles or bone fractures.

Prolonged strength training performed using poor technique can cause ailments like spondylolysis (stress fracture of the pars interarticularis of the vertebral arch), spinal disc herniation and spondylolisthesis (the displacement of a vertebral bone).[136] Young people and older adults are particularly susceptible to these injuries. On the other hand, strength training performed with care and proper form also prevents many types of injury.[137] Elderly people in particular benefit from strength training as it may prevent injuries related to slipping and falling.[138]

SPECIAL TECHNIQUES IN STRENGTH TRAINING: ISOMETRIC TRAINING

Isometric training means exercising muscles in such a way that the length of the muscle remains constant. In practice, this means performing the exercise in a static position and joint angle. The word "isometric" is derived from the Greek words *isos* ("equal") and *metron* ("measure" or "distance"). Isometric training can be divided into overcoming isometrics (maximal exertion against an immovable object) and yielding isometrics (prolonged exertion against the resistance of an additional weight or individual body weight).

Isometric exercises may be used to promote recovery from injury, for example, in individuals with painful osteoarthritis in the knee.[139] In 2014, Mayo Clinic published a meta-

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analysis indicating that isometric training performed at a fairly light intensity is effective in lowering blood pressure – even more so than aerobic exercise or other weight training.[140]

Isometric training has been found to increase strength and muscle mass.[141] [142] However, isometric training only strengthens the muscle at the joint angle used (max. 10–20 degrees to either side). Dynamic muscular training strengthens the muscles throughout the entire range of motion.

BASIC PRINCIPLES OF ISOMETRIC TRAINING:

- Use maximal muscle contractions
- The set length is 1–10 seconds (increases maximal strength)
- The set length is 45–60 seconds (increases muscle mass)
- Use three different joint angles per exercise
- Rest between sets using a ratio of 1:10 (for example, 3 seconds of exercise, 30 seconds of rest)
- Isometric exercises may be performed alongside dynamic exercises (the recommendation is to perform explosive exercises followed by isometric exercises)
- Isometric exercises may be performed at the beginning or end of the training session. This way they activate the neuromuscular system in preparation for strength and speed exercises

Sample exercise – maximal strength:

- Deadlift (+ 125 % 1RM): 6 sets x 6-second maximal lift
- The bar must be heavy enough to not move at all
- Maximal muscle tension throughout the whole body

Sample exercise – muscle mass and strength endurance:

- Superset for biceps (3–4 sets)
  - Bicep curl with a bar x 8 repetitions (30-second recovery)
  - Isometric bicep tension at a 125-degree joint angle x 45 seconds

ECCENTRIC QUASI-ISOMETRIC TRAINING (EQI)

EQI is a special technique that may prevent muscle injuries (stretching elastic components and strengthening tendons).[143] The EQI technique can also be used to increase force generation at all joint angles.[144] Eccentric refers to the lengthening of muscles as they contract; quasi-isometric means movement that is extremely slow, almost static. A sample exercise for EQI is a static push-up in the lower position with hands on blocks. As the muscles become fatigued, the position gradually becomes lower until the chest touches the floor. This combines the isometric exercise and the eccentric muscle contraction and lengthening.

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Sample exercises for EQI training:

- EQI – Push-up with hands on blocks
- EQI – Dip with parallel bars
- EQI – Lunge (feet on blocks)
- EQI – Single-leg squat (hind leg on block)
- EQI – Pull-up

PERFORMANCE CATEGORIES OF MULTI-JOINT EQI EXERCISES (LUNGE AND PUSH-UP ON BLOCK)

TIME	CLASSIFICATION
Under 60 seconds	Weak
60–90 seconds	Below average
90–150 seconds	Average
150–240 seconds	Above average
Over 240 seconds	Excellent

Source: Thibaudeau, C. (2014)

SUPER-SLOW REPETITIONS

A strength exercise may be performed at an extremely slow pace to gain various benefits at the cellular level, such as growth of the satellite cells and the nuclei of muscle cells.[145] The duration of eccentric (inhibitive) and concentric (facilitative) phases of super slow repetitions may be adjusted to suit various patterns.

The physiological response caused by exercise varies. The production of lactate in particular increases during prolonged repetitions (more than 60 seconds).[146] Super-slow repetitions appear to be more effective than conventional training in improving the strength of individuals over 50 years of age.[147]

Super-slow training has its drawbacks: for example, the weak development of maximal strength and the lesser metabolic impact on energy expenditure and fat burning in particular.[148]

SUPER-SLOW ECCENTRIC REPETITIONS

Studies indicate that the most effective way to utilize super-slow repetitions is to only use them in the eccentric (muscle lengthening) phase (for example, a 4–14-second lowering movement during a bench press exercise, depending on the load).

The super-slow lowering phase is combined with a fast concentric (contracting) lifting phase that is performed

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using explosive strength. This can also be called tempo training where the duration of the eccentric phase, pause, concentric phase and isometric phase is noted down (for example, 40X0 = a 4-second lowering phase followed immediately by an explosive lifting phase). Super-slow eccentric repetitions are an excellent technique for maximal muscle growth and tendon strengthening.[149 150]

LOAD (% OF 1RM)	DURATION OF ECCENTRIC PHASE	NUMBER OF REPEATS PER SET
60 %	14 seconds	3
65 %	12 seconds	3
70 %	10 seconds	2
75 %	8 seconds	2
80 %	6 seconds	1
85 %	4 seconds	1

NEGATIVE REPETITIONS

A negative repetition refers to the eccentric phase of the exercise without a concentric phase to follow it (for example, just a slow lowering phase of a bench press exercise). Because there is no concentric phase, it is possible to use a significantly heavier maximal load (1RM) for negative repetitions. Negative repetitions usually require the help of another person (or several people) so that the exercise can be performed safely.

When using supramaximal loads (> 1 RM; 100–130 %), the duration of the eccentric phase depends on the load:

- 10 seconds (110–115 % 1RM)
- 8 seconds (115–120 % 1RM)
- 6 seconds (120–125 % 1RM)
- 4 seconds (125–130 % 1RM)

Only one repetition is performed with 3–10 sets depending on the objectives. Negative repetitions place extreme strain on the central nervous system. They should therefore be performed sparingly. When used correctly, these techniques can be very effective for developing maximal force generation and muscle growth.[151 152]

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HIGH INTENSITY INTERVAL TRAINING (HIIT)

High intensity training became popular among body-builders in the 1970s when sports equipment pioneer Arthur Jones (1926–2007) developed a method to counter long, lower intensity exercises. The idea was to complete short sets at maximal intensity with short rest periods. Jones also developed the Nautilus exercise machines and published articles (*the Nautilus Bulletin*) on strength training and muscle growth.[153]

High intensity interval training has become a natural continuation of the interval methods used by endurance athletes. High intensity interval training has been in use for a long time in sports that are interval-like by nature, such as soccer, basketball and American football.

HIIT is defined as very high intensity exercises (85–95 % of maximum heart rate) completed in interval form, i.e. alternating action and rest. The intensity of the rest phase is usually 60–70 % of maximum heart rate. The length and number of the intervals vary widely depending on the training method. A typical example includes 30 seconds of action followed by 30 seconds of rest, repeated 8 to 10 times. Many studies involve observing a significantly longer interval cycle (for example, 4 minutes of action, followed by 3 minutes of active rest – repeated 4 times).

By varying the length of the action phase (from 10 seconds to several minutes), it is possible to develop the body's various energy systems (see section "Metabolism"). However, there doesn't appear to be a link between the length of the rest phase and the biochemical effects of the exercise on muscle cells (lactate, ATP, creatine phosphate and H+).[154] This suggests that the benefits of varying the length of the rest intervals can be explained by other factors (neurological, hormonal and cardiovascular changes).[155]

In particular, HIIT develops the cardiovascular and circulatory system, maximal oxygen uptake,[156] insulin sensitivity and sugar metabolism[157] as well as lactate tolerance.[158] HIIT is also an effective form of exercise for weight loss and burning fat.[159] In the comprehensive Harvard Alumni Health study (2000), in comparison to lighter forms of exercise, a link was found between HIIT and a lower risk of mortality.[160]

HIIT has been found to increase the size and number of mitochondria in muscle cells. In addition, HIIT significantly increases the volume of oxidative enzymes in the muscles (see section "Metabolism – Citric acid cycle").[161]

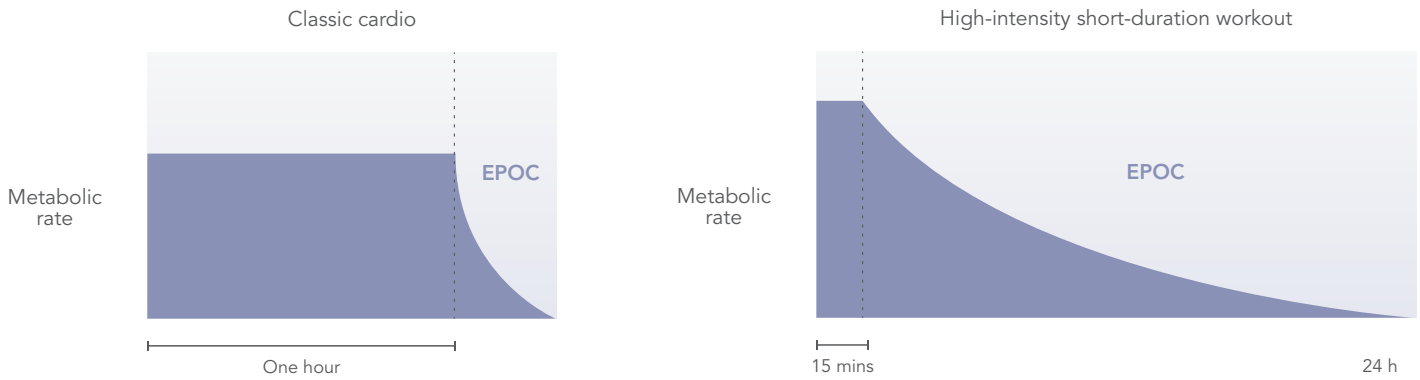
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HIIT VS. PROLONGED ENDURANCE TRAINING

According to a meta-analysis published in 2015, HIIT is more effective than conventional lighter-impact training for lowering the risk of cardiovascular diseases and generally improving vascular performance.[162]

A meta-analysis published in 2014 found HIIT, when compared to constant prolonged exercise, to be significantly more effective in improving the performance of the cardiovascular and circulatory system, particularly in individuals suffering from metabolic syndrome.[163]

Compared to prolonged endurance training, HIIT is also a more effective method for developing maximal oxygen uptake[164] and burning fat.[165 166] The excess post-exercise oxygen consumption (EPOC) and 24-hour energy expenditure after a HIIT session are significantly higher than that of a constant endurance training session.[167 168]



EXCESS POST-EXERCISE OXYGEN CONSUMPTION (EPOC)

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THE TABATA METHOD

The Tabata method is based on a 1996 study of Olympic-level speed skaters, published by professor Izumi Tabata.[169] The study compared high intensity interval training to training performed at a constant pace.

The HIIT group completed a 10-minute warm-up before the interval training which included eight 20-second sets of extremely high intensity (170 % VO2max / 85 rpm on a stationary bike) alternated with 10-second rest intervals. The actual workout was therefore only 4 minutes in length. There was a short post-workout cool-down phase.

The control group exercised for an hour on the stationary bike at a constant pace (70 % VO2max). Both groups trained 5 times per week for 6 weeks. The training intensity was increased in both groups in accordance with improvements in fitness and oxygen uptake.

The Tabata group's improvements in maximal oxygen uptake (VO2max) were higher than those of the control group (7 ml/min per kg vs. 5 ml/min per kg). The anaerobic capacity of the Tabata group also improved 28 % compared to the baseline, whereas the control group showed no improvements at all. The Tabata group also spent significantly less time training than the control group.

Having gained popularity in recent years, Crossfit training applies the Tabata method on bodyweight and strength exercises. However, it is unlikely that Crossfit will produce the same extreme intensity (VO2max 170 %) as the traditional Tabata method, mostly due to the overbearing muscle fatigue. The Tabata method is best combined with simple exercises that effectively increase the heart rate and anaerobic load, such as cycling, running, cross-country skiing and indoor rowing.

Training instructions:

- Warm up for 5–10 minutes (stationary bike, rowing machine, running)
- Complete 8 sets as follows.
  - 20 seconds of action (very high intensity / maximum heart rate)
  - 10 seconds of rest
- Follow with a short cool-down and recovery phase
- As your performance improves, increase the resistance on the stationary bike or rowing machine

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- We recommend completing 1 to 3 workouts per week depending on the volume and intensity of other training completed

THE GIBALA METHOD

The Gibala method is based on a 2010 study conducted on students, published by Martin Gibala, a doctor of physiology. The goal of the study was to determine the effect of high intensity (100 % VO2max) interval training on general performance using a method that is safer and of slightly lower intensity than the Tabata method.

The study continued for two weeks during which six stationary bike workouts were completed. Each workout included a 3-minute warm-up phase followed by the interval phase: 60 seconds of action followed by 75 seconds of rest, repeated 8–12 times. There was no control group involved in the study. Gibala found out that this method achieved the same oxygen uptake benefits as 5 hours of constant pace endurance training per week. The method also significantly increased the force generation capability of muscle cells and improved sugar metabolism.[170]

Training instructions:

- Warm up for 5–10 minutes (stationary bike, rowing machine, running)
- Complete 8 sets as follows:
  - 60 seconds of action (between tempo and maximal endurance)
  - 75 seconds of rest / light action (cycling, walking, light rowing)
- Follow with a short cool-down and recovery phase
- As you improve, you may increase the number of sets to 12

SPRINT INTERVAL TRAINING (SIT)

Many HIIT exercises with typical alternating action and rest cycles are called sprint interval training. This section discusses sprint interval training performed by running and its positive effects on the cardiovascular and metabolic performance.

Sprint interval training may significantly increase the levels of myokinase and creatine phosphokinase enzymes in muscle cells as well as boost the activity of glycolytic enzymes. The enzyme activity of the mitochondria in

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muscle cells is also significantly increased. This means that the training improves the aerobic (oxygen present) and anaerobic (oxygen not present) energy expenditure of muscle cells (see section "Metabolism" for more information).

SIT may also increase the cross-sectional muscle area and is likely to change the muscle cell type distribution to contain more of the fast IIA cells (see section "Muscle cell types" for more information).[171] Sprint interval training has also been found to significantly increase the levels of growth hormones and testosterone (anabolic effects, i.e. related to muscle growth and increased strength).[172] [173]

A study published in 2011 found that a 6-week period of sprint interval training (4–6 x 30 seconds of running) significantly improved aerobic performance and oxygen uptake (as much as the control group that ran for 30–60 minutes at a constant pace). However, spring interval training did not improve cardiac output.[174]

Training instructions:

- The sprint may be completed on a level surface or slightly uphill (easier on the knees)
- Warm up by jogging for 5–10 minutes and performing a few sharp accelerations while running
- Complete 4–6 sets as follows:
  – Run 200 meters at 85–95 % of maximum exertion
  – Rest/walk for 3–4 minutes
- Slowly increase the number of sets from four to six
- We recommend completing 1–3 workouts per week depending on the volume and intensity of other training

HIGH INTENSITY INTERVAL RESISTANCE TRAINING (HIRT)

Strength training is also compatible with short recovery periods and high intensity. This is called high intensity interval resistance training (HIRT). Typically, strength training conducted at high intensity involves long recovery periods (3–5 minutes) between sets to maintain the best possible performance in each set. On the other hand, shorter recovery periods (20–60 seconds) are more effective for increasing the levels of growth hormones and improving muscular endurance.[175]

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According to studies, HIRT significantly increases excess post-exercise oxygen consumption (EPOC) and raises the basal metabolic rate slightly compared to conventional strength training.[176] A crossfit-type HIRT program appears to be able to lower the body fat percentage efficiently and improve maximal oxygen uptake.[177]

Training instructions:

- Always complete a full-body workout
- Use exercises that work the major muscle groups
- 5–15 repetitions per exercise
- 3–4 supersets per workout
- Warm up for 10–15 minutes before the actual workout
- Complete the workout 48–72 hours after the previous workout to ensure recovery
- You can also use a basic barbell and weights that make it simple to complete various supersets and barbell complexes

Sample workout:

1. Superset 1 (8–10 minutes without breaks)
   a. Deadlift (20 % 1RM) x 10
   b. Clap push-up x 5
   c. Pull-up with overhand grip x 5
   d. Ab wheel (knees on the ground) x 6–10
2. Superset 2 (8–10 minutes without breaks)
   a. Jump squat x 5
   b. Pull-up with underhand grip x 5
   c. Bench press (20 % 1RM) x 10
   d. Knee lift to elbows (hanging on a bar) x 6
3. Superset 3 (8–10 minutes)
   a. Bulgarian lunge x 5 / leg
   b. Inverted row on a bar or rings x 10
   c. Push-up x 10
   d. V-ups x 8

Perform the exercises of each superset without breaks and continue for 8–10 minutes (if you are hit with muscle fatigue and are unable to continue with the repetitions, take a short break). Take a 3-minute break before the next superset.

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GYMNASTICS

Besides running and wrestling, gymnastics is one of the original forms of exercise. The word is derived from the Greek word *gymnos* meaning "naked" or "clean." In Ancient Greece gymnasts naturally exercised in the nude. As a form of exercise, gymnastics was particularly popular in the army as it prepared the bodies of the warriors for battle.

These days, gymnastics is a sport that has been divided into various forms such as artistic gymnastics and rhythmic gymnastics.

The goal of gymnastics is to improve physical strength, coordination, balance, agility, muscular endurance and flexibility. From the biohacker's viewpoint, the top priority is to train a well-functioning body using simple gymnastic exercises. Artistic gymnastics is a particularly useful source for exercises performed on rings, parallel bars, a horizontal bar or a pull-up bar.

When started from an early age, gymnastics develops motor skills, general fitness and cognitive and social skills.[178]

Gymnastics also develops the ability to adopt full body movement sequences, spatial awareness and the ability to adapt to various kinesthetic stimuli.



BASIC PRINCIPLES OF GYMNASTIC TRAINING

One of the main physiological factors in gymnastics is the greatest possible force generation in relation to body weight. Great muscle mass alone will not ensure success in gymnastics. Moving one's body requires great relative strength. For young and healthy individuals, the correlation between muscle thickness and maximal strength is usually 0.5–0.7 in the lower limbs and just 0.23 in the upper limbs.[179]

Even more so than strength, skill training is of utmost importance in gymnastics. Without sufficient skills, it is impossible to perform gymnastic movements. However, they also require sufficient strength. Strength and skill develop hand in hand.

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Below we have listed basic gymnastic movements categorized by difficulty level. If you are a beginner at gymnastics, try the easiest movements beginning with the basics. The most efficient method to learn the movements is under the guidance of a coach. There are good instructions and video clips available for each of the movements on the Gymnastics WOD website.[180]

Gymnastics movements – easy:

- Forward/backward roll
- Bridge
- Hollow rock / hollow hold
- Superman / superman rock
- Pull-up (with bar or rings)
- Ring row
- Broad jump
- Box jump
- Burpee
- Squat
- Hip shoots
- L-sit
- Hanging on a bar (active and passive / different grip variations)
- Push-up (different variations)

Gymnastics movements – medium difficulty:

- Cartwheel
- Headstand
- Handstand (against a wall or without a wall)
- Handstand walk
- Dip (with parallel bars or rings)
- Rope climb (different variations)
- Toes to bar (T2B)
- Tuck up
- V-up

Gymnastics movements – difficult:

- Handstand push-up
- Muscle-up (with bar or rings)
- Front lever (different variations)
- Back lever (different variations)
- Iron cross (different variations)
- German hang
- Swings on parallel bars
- Kip

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A test program to start gymnastics training:

- Hollow body hold
  - The goal is to maintain the position for 60 seconds
- Arch body hold / superman
  - The goal is to maintain the position for 60 seconds
- Bent-arm chin hang
  - The goal is to maintain the position for 60 seconds
- Standing pike stretch
  - The goal is to place hands behind legs while maintaining weight on toes

A gymnastics program on rings to improve mobility and strength:

- Program duration 3 months
- The same workout is repeated 2–3 times per week while increasing the difficulty level
- All exercises are completed slowly and carefully with technique as the priority (see videos on this topic on the additional information page)

Sample workout:

- Warm-up with the rings for approx. 10 minutes (shoulder mobility exercises and joint activation)
- Actual strength exercises:
  - Top position hold 3 x 5–10 seconds
  - Ring dip 3 x 3–5 repetitions
  - Reverse row sit back 3 x 3 repetitions
  - Tuck/L-sit 3 x 5–10 seconds
  - Chin-up/pull-up 3 x 1–3 repetitions, also tighten your buttocks and thighs (full body exercise)

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KETTLEBELL TRAINING

A kettlebell is an iron or steel ball equipped with a handle. Training involves ballistic exercises that improve strength, speed, balance and endurance. It provides a hard workout for the hamstrings, pelvis, lower back, shoulders, arms and the entire core. It is crucial to follow proper form.

The history of kettlebell training goes back to 18th-century Russia where the sport originates. The kettlebell or *girya* was popular especially amongst farmers and later used for exercise in the Soviet army. In the 1940s, kettlebell training was refined as a sport called Girevoy Sport. The sport includes lifts similar to weight lifting such as jerking and snatching. Both sports involve lifting as many repetitions as possible within a 10-minute period.

The Russian swing, a simple kettlebell exercise, has been found to develop maximal and explosive strength in the lower body.[181] In addition, an interval-type kettlebell swing routine (alternating 30 seconds of action and 30 seconds of rest for 12 minutes) causes a positive hormonal response typical of strength training (increased post-workout levels of testosterone and growth hormone).[182] The swing exercises have also been found to improve endurance and maximal oxygen uptake.[183]



BASIC PRINCIPLES OF KETTLEBELL TRAINING

As with other technique-based athletic sports, you should familiarize yourself with the basics of kettlebell training before attempting the exercises. The basic techniques can be learned quickly. You should progress in the movements according to their difficulty level. The weight of the kettlebell should be increased incrementally. If you have shoulder or back problems, kettlebell training may not be a good form of exercise for you as it places a lot of strain on these areas.

Kettlebell movements – easy:

- Russian swing
- American swing
- Deadlift using kettlebells
- One-arm kettlebell row
- Goblet squat (holding the kettlebell in front of the chest)

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- Shoulder press using a kettlebell
- Abdominal crunch holding a kettlebell with straight arms
- Farmer's carry using kettlebells
- Slingshot (well suited for warm-ups)
- Halo (well suited for warm-ups)
- Russian twist

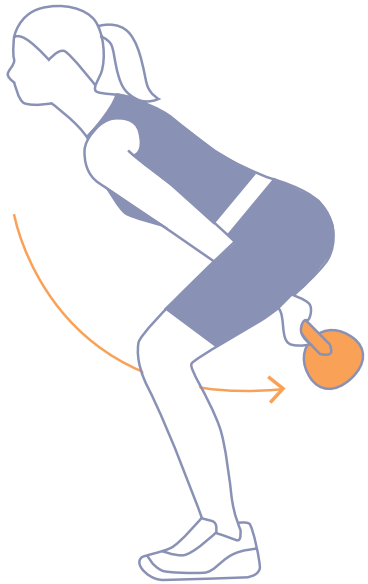
Kettlebell movements – medium difficulty:

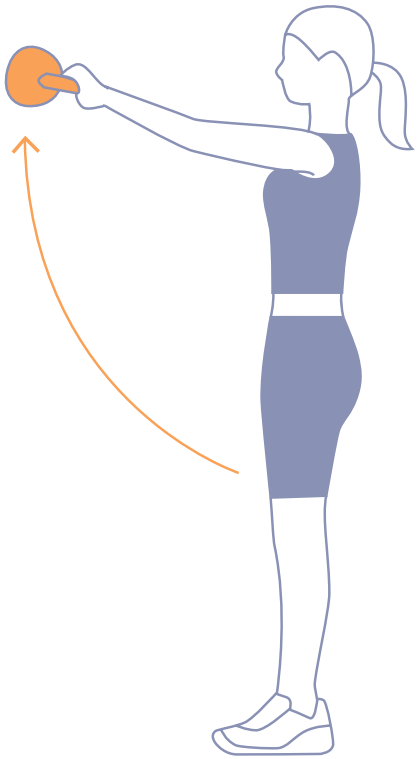
- Single leg deadlift using kettlebells
- Turkish sit-up
- One hand kettlebell swing
- Push-up on kettlebells
- Walking lunges, holding kettlebells in hands or on the lap
- Lateral squat using kettlebell
- Floor press using kettlebells
- Push press using kettlebells

Kettlebell movements – difficult:

- Turkish get-up
- Front squat with two kettlebells
- Clean using one or two kettlebells
- Jerk using one or two kettlebells
- Snatch using a kettlebell

- Thruster using kettlebells
- Floor press in bridge position using kettlebells
- Overhead squat using one or two kettlebells
- Sots press using kettlebells
- Pistol squat using kettlebells





RUSSIAN SWING

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A simple kettlebell training program:

- Program duration 2–3 months
- Duration of each training session is 30 to 40 minutes
- The same exercise is repeated 3 times per week
- Increase the weight of the kettlebell as training progresses (example starting weights 4–8 kg or 8–18 lbs for women, 12–16 kg or 26–35 lbs for men)
- Training is completed in circuit format, i.e. moving from one exercise to the next taking a 30–60-second break

Sample workout:

- Warm-up for 5–10 min (slingshot and halo, also light jogging, indoor rowing or burpees)
- Actual training:
  - Russian swing 3 x 20-30 repetitions
  - Bent-over row 3 x 15 repetitions on each side
  - Goblet squat 3 x 15 repetitions
  - Abdominal crunch 3 x 15 repetitions
  - Shoulder press 3 x 10 repetitions on each side
  - Deadlift 3 x 10–15 repetitions (2 kettlebells)
  - Around the world 3 x 20 repetitions

SECRET SERVICE SNATCH TEST (SSST)

- The test is designed for more advanced kettlebell enthusiasts
- The test is completed using a kettlebell weighing 24 kg (men) or 12 kg (women)
- The time allowed is 10 minutes during which as many snatches as possible should be performed
- You may lower the kettlebell to the ground at any point
- Right and left hands can be alternated at will (for example, 10 repetitions with the right hand followed by 10 repetitions with the left, etc.)
- An excellent result and "the entry requirement to the Secret Service" is 200 repetitions or more

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NATURAL MOVEMENT

"To treat deep sadness, go in nature. To find yourself, go in nature. To experience peace and happiness, go in nature. As often as you can." – Erwan Le Corre (b. 1971)

Natural movement refers to inherent types of human movement in various environments. However, many modern-day knowledge workers are alienated from nature and mostly spend their time sitting in front of a computer or lying on a couch. Many others torment themselves at the gym using all kinds of machines yet are unable to climb a tree or lift a heavy rock off the ground. Navigating uneven terrain may also be difficult for inexperienced modern individuals.

George Hébert (1875–1957), a physical educator for the French Navy, was the first modern physical skills instructor with a training philosophy involving natural movement. His motto was "Être fort pour être utile" ("Be strong to be useful"). Hébert was particularly inspired by the natural strength, flexibility, endurance and agility of African natives. Some sources suggest that Hébert was also strongly inspired by the coaching style of Spaniard Francisco Amorós (1770–1848) as well as his book "*Manuel d'éducation physique, gymnastique et morale*".[184]

Hébert's *La méthode naturelle* develops human beings' natural physical properties in a varied manner. As a result, a person can walk, run, jump, move on all fours, climb, balance, throw and pick up objects, defend themselves and swim with ease.

After having studied the methods of Hébert and Amorós, in 2008 Frenchman Erwan Le Corre (b. 1971) developed natural movement into a sport, MovNat. Compared to natural movement as referred to by Hébert, MovNat is more systematic and based on scientific research.[185] A pilot study published in 2015 found that MovNat-type movement requiring high-level proprioception (such as climbing) improves working memory.[186]



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PARKOUR

"*Obstacles are found everywhere, and in overcoming them we nourish ourselves.*" – David Belle (b. 1973)

The history of parkour is similar to that of natural movement: both originated in France and focused on the use of the body in various environments. Parkour was developed as a sport in the 1980s in France and the suburbs of Paris in particular. It was largely developed by Raymond Belle (b. 1939) and later his son David Belle (s. 1973) as well as the developer of free running, Sébastien Foucan (b. 1974). As a training method, parkour is reminiscent of the military obstacle course (*parcours du combattant*) which in turn was developed by natural movement pioneer Georges Héber.[187]

Parkour strives for moving as efficiently as possible and navigating various terrains – usually in an urban setting. Parkour movements include running, climbing, hanging, swinging, leaping, jumping, rolling and moving on all fours. The philosophy of David Belle however has more to do with the attitude held rather than individual physical movements. Indeed, the sport is about the art of moving.

There are a few established parkour movements. These include the vault (clearing an obstacle by jumping or catching) and the roll (rolling after having cleared an obstacle and landed). As its name implies, the precision jump refers to a precise jump landing on various surfaces. Sometimes the jump lands on the wall after which it is followed by gripping and hanging by the arms. This is called the cat leap.

A few scientific studies have been conducted on parkour. Parkour significantly improves jumping abilities and various muscle skills. According to one study, the practitioners of parkour performed better than gymnasts in drop jumps and straight jumps.[188] Roll landing, typical of parkour, is more efficient and less stressful on the joints compared to the conventional method of landing used in gymnastics.[189]

There is a risk of injury associated with parkour, particularly in relation to landing after a jump or fall. However, compared to many other types of sports, the risk of injury is not necessarily any greater.[190]

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A BEGINNER'S PARKOUR TRAINING PROGRAM:

- You can complete the exercises as often as you wish
- The exercises prepare you for actual parkour training

Exercises:

- Deep bodyweight squat
  - Start by spending a total of 1 minute per day in the squatting position
  - Increase the time by one minute per day until you spend 30 minutes per day in the squatting position after a month
  - Deep squatting improves the mobility of the ankles, back and pelvis
- Hanging on a bar (passive)
  - Start by hanging for a total of 15 seconds per day and increase the time incrementally until after a month you spend seven and a half minutes per day hanging
  - Hanging improves shoulder mobility and strength
- Wall support
  - Start with a few seconds at a time until you can remain in the active position for 30 seconds
  - Wall support improves upper body and core strength and control
- Walking on all fours (same as natural movement)
  - You can practice this daily in various environments
  - It improves fitness and the technique of movement
- Jogging, sprints and jumps
  - Start lightly by doing these a few times a week in a time frame of 15–30 minutes
  - Improving basic fitness is an important part of parkour training as it enables the individual to progress to more difficult movements
  - It is easy to combine jogging with light jumps and leaps

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BODYWEIGHT TRAINING

The philosophy behind bodyweight training is similar to that of natural movement and parkour: "the world is my gym." The workouts do not require any equipment or a specific location as your own body acts as the resistance. Bodyweight training uses many of the training elements of gymnastics (see section "Gymnastics"). However, in practice a pull-up bar, wall bars and a dip station are necessary to complete various exercises.

The focus of bodyweight training is to improve strength, balance, endurance and mobility. If the main goal is increased strength, bodyweight training should be combined with strength training done with weights.

In bodyweight training, the intensity level is increased by completing more difficult versions of each exercise (unlike strength training where heavier weights are introduced to increase the workload). Increasing the number of repetitions or sets is used for both strength training and bodyweight training.

Typically, the bodyweight training exercises are divided into four categories – this is also used in bodybuilding:

- Pushing exercises (such as push-ups)
- Pulling exercises (such as pull-ups)
- Core exercises (such as planks)
- Lower body exercises (such as squats)

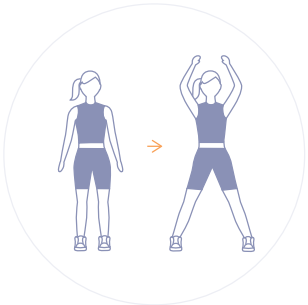
Many bodyweight exercises not only work specific muscle groups but also develop certain functional muscle-tendon-fascia lines.[191] Many people use the term "functional training" in connection with bodyweight training as it creates an image of usefulness in daily life. Functional training appears not to bring any added benefits to the functionality of the body compared to strength training.[192] The most effective strategy is to combine strength training and bodyweight training which complement each other.

Bodyweight training may cause muscular imbalance if the lower body is not separately trained using weights. Imbalance may occur in the upper body if the focus is on vertical exercises (pull-ups and other pulling exercises) and horizontal exercises (row exercises) are neglected.

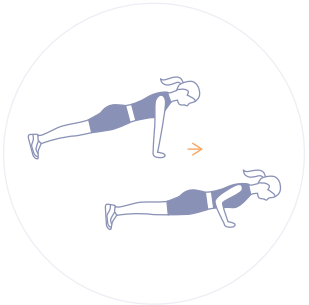
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COMMON BODYWEIGHT EXERCISES

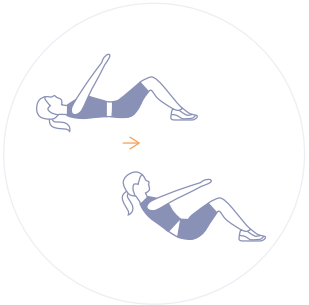
JUMPING JACK



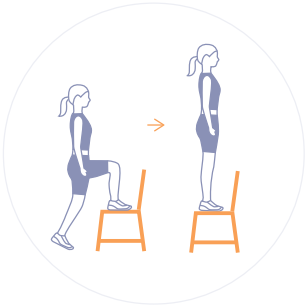
PUSH-UP



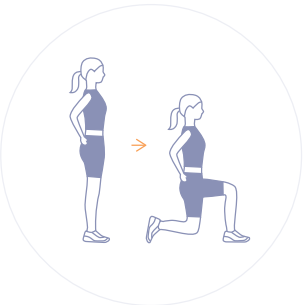
SIT-UP



STEP-UP ONTO CHAIR



LUNGE



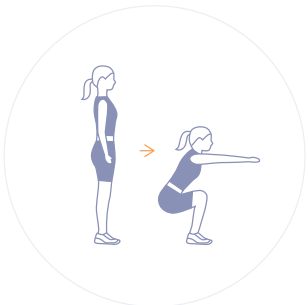
TRICEP DIP ON CHAIR



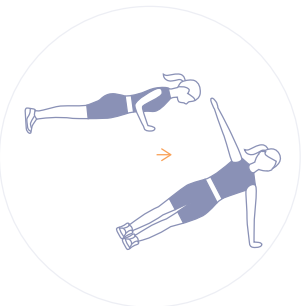
HIGH KNEES RUNNING IN PLACE



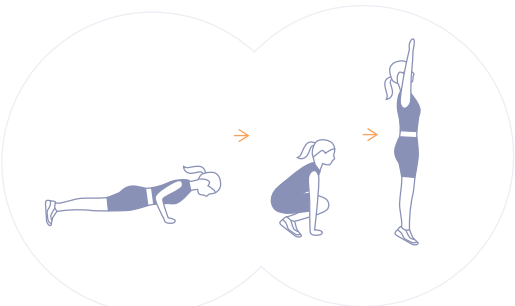
SQUAT



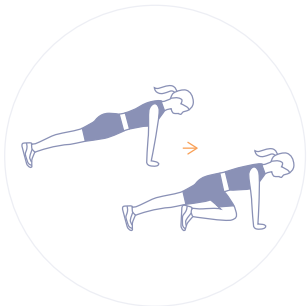
PUSH-UP AND ROTATION



BURPEE



MOUNTAIN CLIMBER



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A full-body bodyweight workout – sample program:

- Program duration is one month, after which you may change to more difficult variations of the exercises; for example squat > Bulgarian lunge > pistol squat
- Workout to be completed 2–3 times per week
- When switching programs, do a lighter switchover week (for example after 4 weeks of training)
- The program follows a circuit training pattern where there is a 60–90-second recovery break after each exercise
- Exercises:
  - Bodyweight squat 3 x 8–10
  - Pull-up 3 x 6–8
  - Pelvic lift 3 x 12–15
  - Dip using a bench or parallel bars 3 x 6–8
  - Bodyweight row 3 x 12–15
  - Push-up 3 x 12–15

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MOBILITY TRAINING

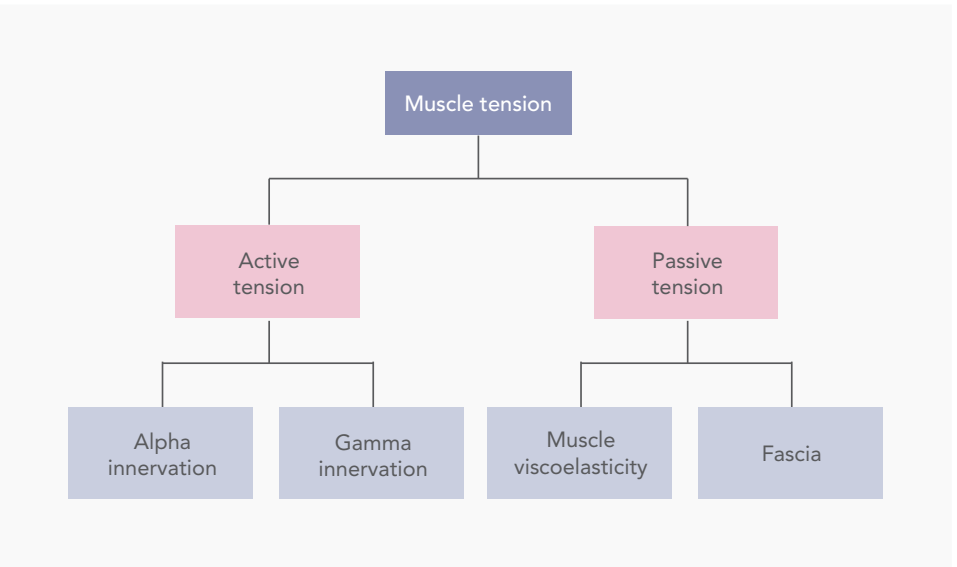
Mobility refers to the ability to move the limbs and body through various ranges of motion without pain. A reduced range of motion of a joint indicates impaired mobility. Mobility (flexibility) is a basic physical characteristic and, in practice, the basis of general physical ability. Children are a great example of normal mobility and flexibility. The modern-life tendency to sit down to work that starts at school reduces natural mobility.

Optimal mobility is crucial for the maintenance of good posture and the prevention of incorrect positions and injuries during exercise. By improving mobility, it is possible to also significantly improve the effectiveness and economy of various exercises. For the elderly, mobility has an important role in the prevention of slipping and falling as well as accidents.[193]

Mobility can be divided into active and passive mobility. Active mobility refers to the range of motion caused by the use of muscles, whereas passive mobility refers to the range of motion caused by an external force (such as another person or gravity).

Professionals who measure the range of motion of various joints include physiotherapists, occupational therapists, physiatrists and orthopaedists.[194] The functional range of motion and body control can be examined using for example the Functional Movement Screen (FMS) tests.[195] They are used by trained coaches and therapists.

FACTORS AFFECTING MUSCLE TENSION AND STIFFNESS



Source: Page, P. (2012). Current concepts in muscle stretching for exercise and rehabilitation. *International Journal of Sports Physical Therapy* 7 (1): 109–119.

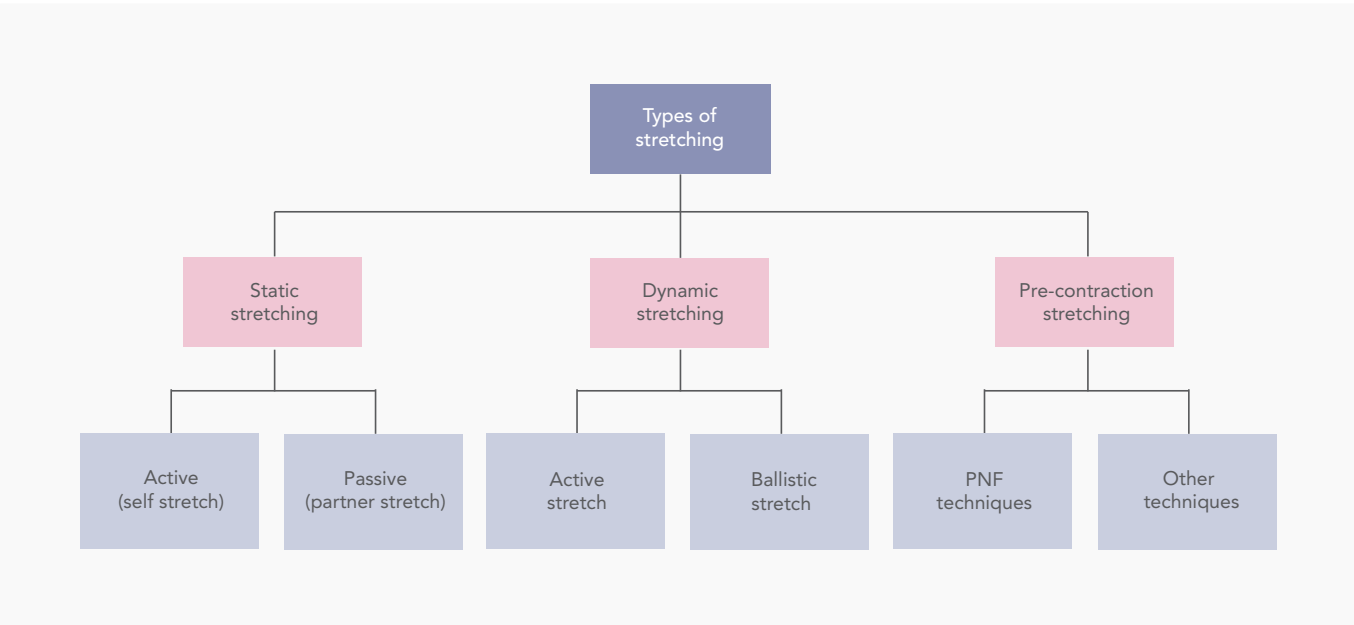
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STRETCHING

Stretching can be divided roughly into three categories based on the desired duration: short dynamic stretching, medium-length stretching and long static stretching. In addition, stretching is categorized based on its type into static, dynamic and pre-contraction stretching where the muscle to be stretched is first contracted and then stretched. Other techniques have been developed around this (see the table on the below).[196]

Medium-length stretching (15–30 seconds)[197] has been found to significantly increase the range of motion of joints.[198] It should only be completed after a workout as static stretching completed before a workout impairs the force generation capability of muscles.[199]

MUSCLE STRETCHING TECHNIQUES

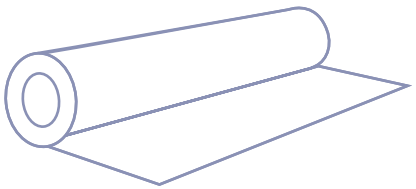


Source: Page, P. (2012). Current concepts in muscle stretching for exercise and rehabilitation. *International Journal of Sports Physical Therapy* 7 (1): 109–119.

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According to the latest research, long passive stretches (over 30 seconds) are harmful: they impair the strength and speed properties of muscles and potentially predispose them to injury. The cause is likely to be both neural[200] and mechanical.[201]

The *Biohacker's Handbook* principally recommends dynamic, short stretches[202] as well as special techniques such as MET (muscle energy technique)[203] and PNF (proprioceptive neuromuscular facilitation stretching).[204] The MET and PNF techniques usually require the support of a knowledgeable therapist (such as an osteopath, chiropractor or physiotherapist) to complete the exercises.



DYNAMIC STRETCHING PROGRAM:

- The exercises may be completed before each workout
- Before dynamic exercises you can warm up for example by skipping a rope, using an indoor rowing machine or doing star jumps
- The set is repeated 2–3 times

Exercises:

1. Hand walks for 10 meters
2. Leg swings to front, back and sides (15 repetitions in each direction)
3. Lunges, twisting the torso toward the squatting leg (10 repetitions per leg)
4. Scorpion (10 repetitions in each direction)
5. Knee to chest walking stretch (10 repetitions per leg)
6. Upper arm rotations individually and with both hands together (10 repetitions in each direction)
7. Upper arm swings to the sides and front (total of 30 repetitions)
8. Clavicle press and twist (10 repetitions on each side)

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MUSCLE ENERGY TECHNIQUE (MET)

The MET method uses active movement as part of mobilization. MET is used by many individuals who practice manual therapy. MET may also be used independently, for example by stretching and contracting the thigh muscle using the wall for support. Initially, the muscle is stretched gently (20 % of maximal muscle tension) after which it is stretched further against the therapist's hand or for example, a wall. The stretch is increased incrementally by repeating this action three times, always stretching the muscle slightly further.

Compared to conventional manipulation and manual handling techniques, MET produces a stronger neurological relaxation response and circulatory response.[205] Because of this, it is suitable for the treatment of painful muscle tension caused by oxygen deficiency.

Types of exercise to improve mobility and flexibility:

- Yoga (different variations, particularly ashtanga and hatha)
- Pilates
- Fustra (particularly for neck and back pain)
- Tai Chi
- Mobility training

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BREATHING TECHNIQUES

Studies on mammals have found that the respiratory rate of each species (i.e. the number of breaths taken per minute) is in proportion to its lifespan. The higher the respiratory rate, the shorter the lifespan. For example, the respiratory rate of a mouse varies between 60 and 230 times per minute and its expected lifespan is 1.5–3 years. On the other hand, the respiratory rate of a whale is 3–5 times per minute and its expected lifespan is well over 100 years. The average normal respiratory rate of human beings is 12–20 times per minute. On the other hand, the physical size of the species appears to have some impact on the expected lifespan, at least in the case of mammals (mouse vs. human being vs. whale).[206]

Various breathing techniques and for example, deep breathing may significantly reduce the respiratory rate and at the same time boost the respiratory minute volume (see section "Respiratory system") as well as reduce oxidative stress in the body.[207] [208] Increased constant oxidative stress due to nutrition, environment or other factors increases the respiratory rate and may accelerate the aging process.[209]

THE WIM HOF METHOD

Dutchman Wim Hof (b. 1959) – also known as The Iceman – has developed a method to control his autonomic nervous system and immune system.[210] Hof is famous for his numerous world records, for example having sat in an ice bath for two hours. He climbed Mount Kilimanjaro in three days wearing only a pair of shorts. He also ran a marathon in Finland at a temperature of –20°C (–4°F).

Hof's method utilizes the Tummo meditation and a breathing technique known as *Pranayama*. A controlled study on humans has been published on the Hof method. The test subjects were able to regulate their sympathetic nervous system and immune system using exercises developed by Hof. After having received a bacterial toxin injection, individuals who had practiced the method had fewer flu-like symptoms compared to the control group, a higher adrenaline level in the blood and a more constant level of stress hormones in the blood. The study also found that individuals who had practiced the method had a lower level of pro-inflammatory cytokines (TNF-α, IL-6, IL-8) whereas their anti-inflammatory cytokine levels (IL-10) were higher than in the control group.[211]

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Follow these steps:

1. Sit comfortably with a straight back, eyes closed (the exercise should be completed immediately after waking up, with an empty stomach)

2. Warm-up exercise:
   a. Breathe in slowly while expanding the diaphragm
   b. Breathe out and deflate your lungs as much as possible
   c. Repeat the breathing cycle 15 times

3. Power breathing exercises
   a. Imagine blowing up a balloon; breathe in through the nose and breathe out through the mouth producing short but powerful bursts of air
   b. Close your eyes and repeat this 30 times until you feel slightly dizzy and tingly

4. Body scanning
   a. During the power breathing exercise, scan your body from head to toe and feel which body parts are in need of energy and which parts have a surplus of it
   b. Using your thoughts, send warmth and energy to the parts where these are not flowing
   c. Feel the negative energy exit your body as it fills with warmth

5. Holding your breath
   a. After 30 quick breathing cycles, draw your lungs full and then deflate them as much as possible
   b. Relax and feel the oxygen fill your entire body
   c. Hold your breath until you feel the need to gasp for air

6. Restorative breathing
   a. Draw your lungs full and feel your diaphragm expand
   b. Relax the entire abdominal area (solar plexus)
   c. Hold your breath for 15 seconds while drawing your chin close to the chest
   d. Scan your body with your mind and identify any remaining blockages
   e. In your mind, direct energy to these parts

This is one exercise cycle. Repeat the exercise 2–3 times. As you progress, you may extend the exercise to cover six cycles. End the exercise by relaxing for 5 minutes while scanning your body.

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INTERMITTENT HYPOXIA TRAINING

Intermittent hypoxia training (IHT) was used and studied in Russia and Ukraine at the turn of the 1940s, particularly on athletes. IHT is used for example, when an athlete moves to a higher altitude with thinner air. Hypoxia means the reduced oxygen supply of the body.

IHT has been used under research conditions in barochambers that allow the regulation of the partial pressure of oxygen and carbon dioxide. However, the use of barochambers involves potential side effects.[212]

Hypoxia training may be implemented anywhere by holding one's breath (*kumbhaka pranayama*) using interval sequences.[213] [214] Another option is to use a specific mask which lowers the oxygen saturation of the airflow and increases lung ventilation. The mask, specifically designed for training use, increases the carbon dioxide level of the airflow (hypercapnia) which, aside from oxygen deficiency, has performance-boosting physiological effects.[215] [216]

IHT increases the plasticity of the respiratory system as well as strength by increasing the number of growth factors in the respiratory tract motoneurons.[217] Additionally, IHT may increase endurance during athletic performances.[218] Properly practiced IHT is also likely to improve the oxygen uptake of tissues and the function of the immune system as well as boost the production of antioxidants in the body.[219] Notice: do not practice hypoxia training if you have any medical conditions such as asthma, COPD, cardiovascular disease or other chronic diseases without first consulting your doctor.

Train as follows:

- Practice holding your breath while keeping your face in cold water for as long as possible. Repeat this five times with three stabilizing breaths between the exercises (see section "Cold thermogenesis")
- Hyperventilate (breathe rapidly) and then hold your breath for as long as possible; repeat this 5 times
  - Hyperventilating increases the time you can spend holding your breath as it removes carbon dioxide from your blood
- Do swimming exercises in cool water
  - Hold your breath while swimming a length of 25 meters; stabilize your breathing and then repeat the swimming interval for a total of 10 times

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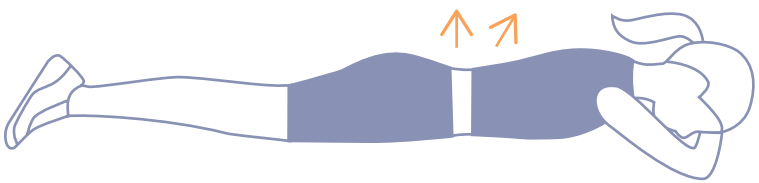
CROCODILE BREATHING

Crocodile breathing is thus named due to the position and breathing technique typical of crocodiles. Crocodile breathing trains the diaphragm, the body's main respiratory muscle. Deep abdominal breathing exercises may activate the parasympathetic nervous system and reduce stress. Abdominal breathing may also reduce post-workout oxidative stress and accelerate the recovery process.[220]

Follow these steps:

- Lie prone on the floor with your hands under your forehead, backs of the hands facing up
- Using your diaphragm, breathe deeply through your nose into your abdomen
- You are breathing correctly when your lower back rises up and your sides expand when breathing in
- Start with 20 breaths and increase the number incrementally until you reach one hundred
- You can use the pace of 1:2 here, i.e. breathing out takes twice as long as breathing in (for example, 4 seconds in and 8 seconds out)

CROCODILE BREATHING



COMBINING BREATHING AND MOVEMENT

Many traditional types of exercise such as yoga and oriental martial arts combine breathing and movement into one fluid action. Of course, breathing has a central role in many sports that require strength and exertion such as high jumping, weightlifting, powerlifting and many throwing events of track and field. In fact, all sports rely heavily on optimal and proper breathing. On the other hand, when singing and dancing, optimal breathing is linked to the sound and movement created.

Activities that combine breathing and movement include various types of yoga, qigong, various martial arts and tai chi. All of these are well suited for exercising the connection between the body and breathing.

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Tai chi was originally developed as a battle skill in China in the 16th and 17th centuries. Today tai chi is a form of exercise in which breathing and movement are used to achieve harmony between the body and mind.

Each tai chi movement collects, stores and releases energy. The movements are performed so that each movement ends as the next begins – just like breathing. First, the movement opens up and the lungs fill up – just like a bow drawing an arrow. Then the movement closes down and the lungs deflate – just like the arrow flying off the bow.

An important focal point in tai chi is *dantian*, a center located three finger widths below the belly button. It can be thought of as the abdominal enteric nervous system, our second brain. Breathing attempts to gather so-called chi energy into this center. Using breathing exercises, it is possible to develop a strong center that combines pelvic floor muscles with some of the body's stronger muscles.

A SIMPLE DANTIAN BREATHING EXERCISE:

- Stand with your feet in line with your pelvis
- Bend the knees so that they barely cover the toes (riding position)
- Push the pelvis to the front, straightening the spine
- Lower your shoulders toward the front, draw your chin in slightly and straighten the neck so that it is a continuation of the spine
- Place one hand above the belly button and the other below it
- Place your tongue against the palate and breathe slowly through the nose
- Breathe in slowly using the diaphragm while relaxing the pelvic floor muscles
- Breathe out slowly using the diaphragm while gently tensing the pelvic muscles so that the pelvic floor moves toward the belly button by approximately one centimeter
- Repeat the breathing exercise. Feel chi fill your center.

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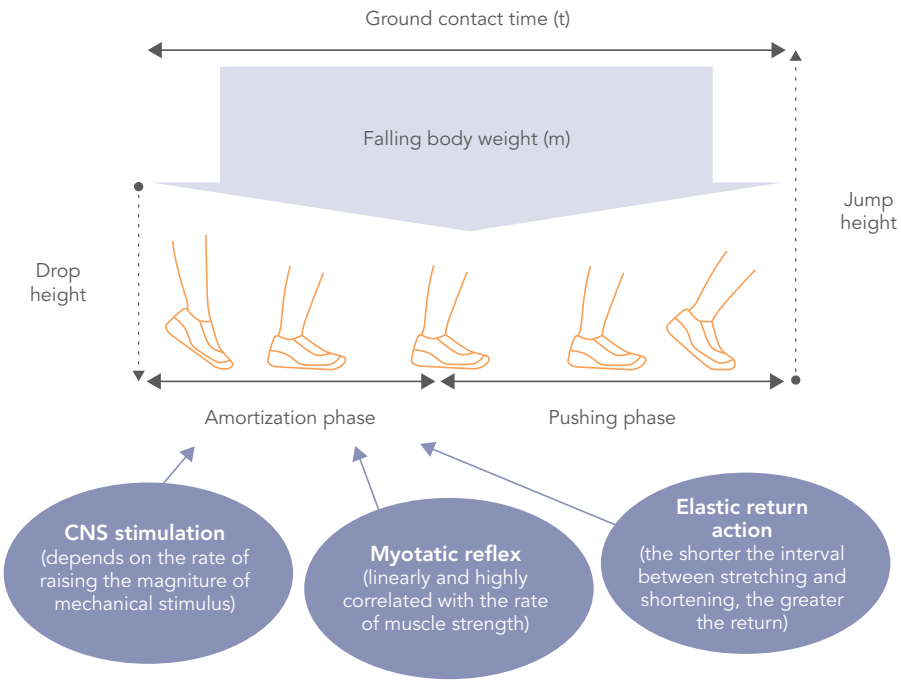
PLYOMETRIC TRAINING

Plyometric training involves a quick muscle stretch followed by a very quick contraction. Leap and jump exercises are commonly associated with plyometric training although explosive plyometric exercises (such as throws) can be used for the upper body as well.

Plyometric training was developed in the Soviet Union in late 1950s to help high jumpers achieve better results especially during winter training. Scientist Yuri Verkhoshansky analyzed high jumpers using biomechanics and found that the momentary force of their jumps was up to 300 kg (660 lbs). Verkhoshansky used this information to develop drop jumps that improved the high jumpers' explosive strength.

In 1968, Verkhoshansky named plyometric training "the shock method" which reflects the use of elastic energy in force generation.[221] In the 1980s, the training method was renamed "plyometrics" in the United States after athlete Fred Wilt and coach Michael Yessis analyzed the warm-up exercises of Soviet athletes before track and field competitions.

THE BIOMECHANICS OF DROP JUMPS



Source: Verkhoshansky, J. (1968).

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BASIC PRINCIPLES OF PLYOMETRIC TRAINING

The goal of plyometric training is to develop explosive speed of motion, activate many muscle fibers in a short period of time and utilize the elastic energy stored in tendons.[222] Plyometric training improves strength, muscular power, speed, coordination and general athletic performance.[223 224 225 226 227] Plyometric training is also useful for the prevention of osteoporosis[228] and improving bone density, particularly in young people.[229]

Jumping strength is best developed by combining several techniques such as the squat jump, countermovement jump and drop jump. Using additional weights has not been found to be of extra benefit.[230]

Start plyometric training by studying and practicing the movements and techniques. The difficulty level and pace of progression should be modified for the individual's background, sex, age, fitness level and any previous history of plyometric training.[231]

When starting plyometrics, start with the easiest jumps. Drop jumps put a strain on joints and muscles and should be left until later. It is a good idea for a beginner to start practicing the jump exercises in water due to its ability to reduce impact. This is a particularly suitable technique for overweight individuals.[232]

If you're also including strength or endurance exercises in the workout, always perform the plyometric exercises first. The nervous system is then able to perform the exercises in an explosive manner.

Plyometric training is particularly useful for individuals participating in sports requiring speed strength. The training also benefits for example, endurance athletes and exercisers as it reduces the contact time between the ground and the foot which in turn improves the efficiency of running.[233]

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A PLYOMETRIC TRAINING PROGRAM THAT DEVELOPS JUMPING STRENGTH:

- Split the training program into phases so that the nervous system may be prepared for the more advanced exercises
- A progressive program reduces the risk of injury
- Always warm up your muscles with care before the actual exercises
- Take a break of 2–4 minutes between sets (the closer to maximal the performance, the longer the rest break)

Landing practice and preparing the muscles (phase 1):

- Squat 3 x 10
- Drop from standing position to jump landing position 3 x 6
- Jump squat 3 x 6 (from semi-squat position)
- Hold in jump landing position (semi-squat) 3 x 30 sec
- Hip thrust on the floor 3 x 12

Complete the program two times per week for 2–3 weeks.

Preparatory jumps and jumping practice (phase 2):

- Jump upward with both feet (swinging arms) 3 x 6
- Jump forward with both feet (swinging arms) 3 x 5 (30 seconds of rest between repetitions)
- Jump upward with one foot (jumping and landing on the same foot) 3 x 3/foot
- Jump forward with one foot (jumping and landing on the same foot) 3 x 3/foot

Complete the program 2 times per week for 3 weeks. The exercises are done in a submaximal manner.

Leaping and jumping practice (phase 3):

- High jump with both feet 3 x 5 (30 seconds of rest between individual jumps)
- Long jump with both feet 3 x 5 (30 seconds of rest between individual jumps)
- Jump onto box (find a suitable height for yourself) 3 x 5 (30 seconds of rest between individual jumps)
- Single foot long jump, landing on both feet 3 x 3 / foot (30 seconds of rest between individual leaps)

Complete two workouts per week for 2–3 weeks. Complete the workouts separately from any other training you do.

Perform the exercises in a maximal manner, i.e. jumping as high or as far as possible.

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Performing leap and jump sets while increasing volume (phase 4):

- High jump with both feet 5 x 5 (perform the jumps back-to-back)
- Long jump with both feet 5 x 5 (perform the jumps back-to-back)
- Jump onto box 3 x 5 (30 seconds of rest between individual jumps)
- Jump over a hurdle with both feet 3 x 5 (five jumps over five consecutive hurdles; find a suitable height for yourself)
- Lateral leaps (i.e. skater leaps) 3 x 6

Complete two workouts per week for 3 weeks. Complete the workouts separately from other training. Perform the exercises in a maximal manner. Rest for 3–4 minutes between sets.

Alternate leaping practice (phase 5):

Practicing alternate leaps requires advanced general strength and excellent coordination skills. It is important to jump as high as possible while moving forward. Therefore, do not allow the ground to just hit your feet – jump off it like a spring.

- Alternate leaps forward 3–5 x 25–50 meters
- Lateral leaps with minimal ground contact 5 x 3–5/foot
- Double leaps alternating the side (left+left, right+right, left+left...) 3–5 x 25–50 meters

Increase incrementally the number of leaps and the distance covered. Complete 2–3 workouts per week for 3–4 weeks.

Drop jumping practice (phase 6):

Drop jumps are the toughest exercises on the nervous system. Because of this, the recovery period is slightly longer than with other types of jumps. The initial depth of drop jumps should be approximately 40 centimeters. Increase the depth incrementally to 75 centimeters. When completing a drop jump, you step down from a platform and jump up as quickly as possible.

- Drop jumps with both feet 3–5 x 5–10 (30 seconds of rest between jumps)
- Drop jumps with a single foot 3–5 x 3–5/foot (30 seconds of rest between jumps)

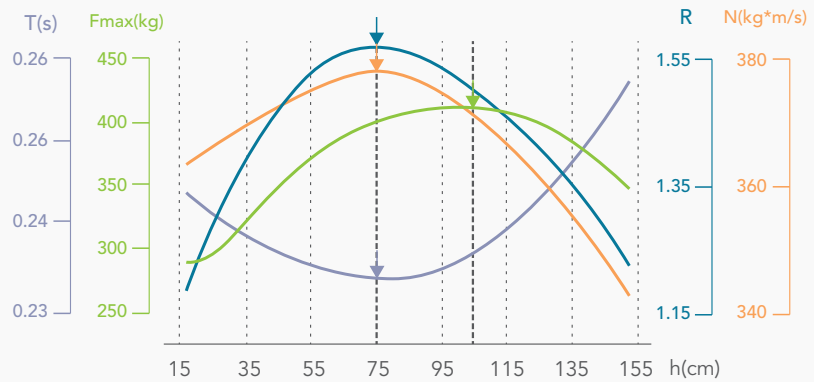
Increase the number of jumps incrementally by adding sets or increasing set lengths. Complete two workouts per week for 2–3 weeks.

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Plyometric exercises for the upper body:

Upper body plyometric training may improve for example, ball throwing speed and mechanics and the muscular power and speed of the upper body.[234]

- Explosive push-ups
  - Drop push-ups
  - Clap push-ups
  - Flying push-ups
  - Push-ups with lateral movement
  - Push-ups onto a medicine ball and off
  - Explosive push-ups using a BOSU ball
- Explosive pull-ups
  - Clap pull-ups
  - Kipping pull-ups
  - Hand release pull-ups (explosive push, release grip momentarily in the top position)
- Medicine ball throwing exercises
  - Overhead throw
  - Rotational throw
  - Upward throw
  - Forward pass
  - Single-hand throw variations
- Overhead slam
- Plyometric variations of bench press etc.



T(s) = Contact to the ground Fmax(kg) = Maximal force generation
R = Responsiveness factor N(kg*m/s) = Maximal power
(H/h = Depth of drop jump / drop height

Conclusions:

1) Explosive strength is best developed using a drop height of 75 cm.
2) Maximal force is best developed using a drop height of 110 cm.

THE EFFECT OF DROP HEIGHT ON FORCE GENERATION

Source: Verkhoshansky, J. (1968).

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VISUALIZATION TRAINING

Ice hockey legend Wayne Gretzky believed in the power of visualization. In his mind, he practiced a single performance more than 10,000 times. He described that it was as if an electric shock ran along his spine when the scene was finally actualized in a game.[235]

IDEOMOTOR TRAINING

Ideomotor training refers to the act of visualization before an athletic performance. The term ideo means thought and motor means muscle activation. To be more precise, ideomotor training means picturing the athletic performance in one's mind while performing micromovements (small movements that resemble larger ones). The concept of ideomotor training is not new – German philosopher and psychologist Johann Fredrich Herbart (1776–1841) suggested as early as 1825 that each action of movement is preceded by a visualization of that movement.[236] Scientists from various fields (from cognitive psychology to robotics) have proven that the complex movements of human beings are governed by basic action concepts (BACs).[237]

Visualization training has been found to activate the same neural networks and nerve routes in the brain as actual physical training. Athletes participating in both ideomotor training and physical training have been proven to achieve better results compared to those participating in either physical or visualization training.[238]

MIRROR NEURONS IN VISUALIZATION TRAINING

Mirror neurons located in the premotoric part of the brain are an important factor in visualization training.[239] They are activated when the individual is watching a set of motions to be learned.[240] The mirror neuron activity and the mimicry of the action in the brain continue even if the individual does not see the entire performance. Indeed, it has been found that the mirror neurons of the primary motor cortex conclude and predict the future trajectories and intentions of other individuals.[241] The significance of mirror neurons in team sports is immense as they activate 400–500 milliseconds before the opponent's next move. The anticipation may also occur erroneously, for example, due to diversion tactics.

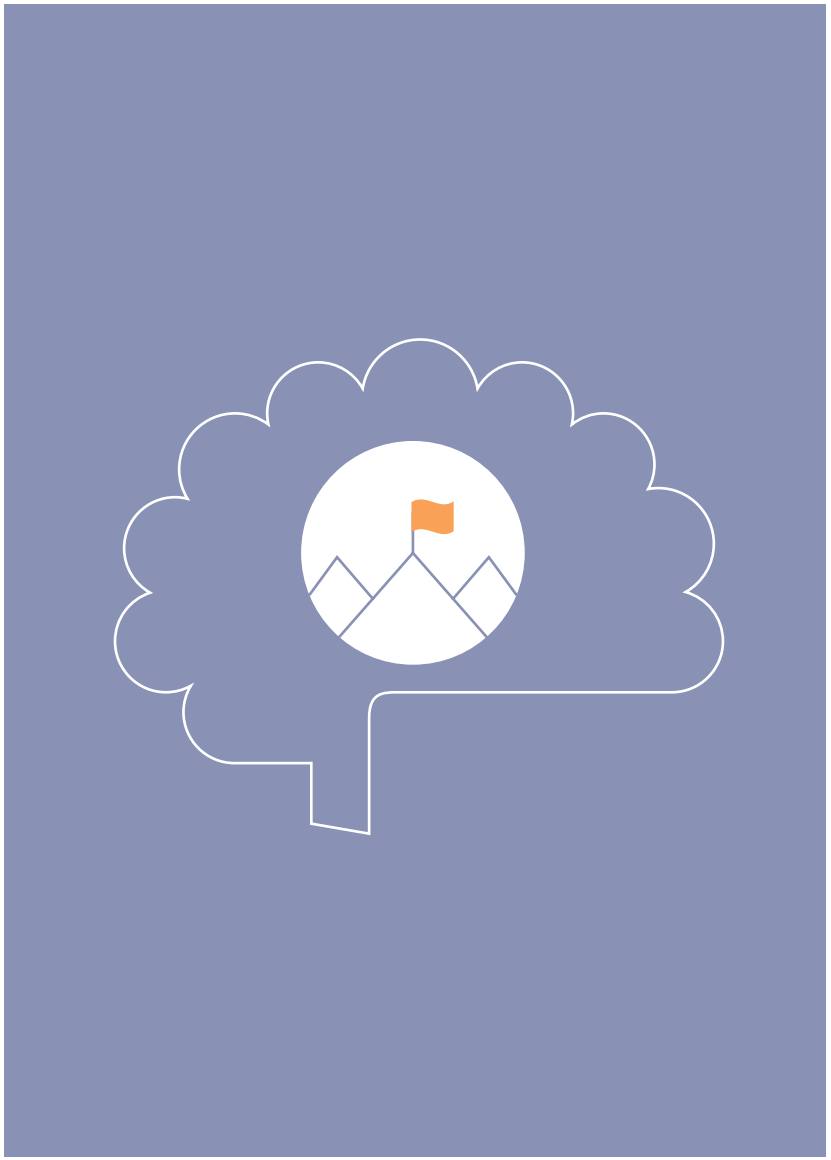
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A SIMPLE VISUALIZATION EXERCISE TO BOOST ATHLETIC PERFORMANCE:

For best results, complete the exercise several times a day for 5–15 minutes at a time.

1. Close your eyes and breathe deeply for a minute (5 seconds in and 5 seconds out, 5:5)
2. Scan your entire body from head to toe (continue breathing at the pace of 5:5)
3. Mentally focus on a successful performance; see yourself succeeding (external perspective)
4. Focus internally on the performance, walk through the movement or set of motions while performing small imitative micromovements (internal perspective)
5. Talk to yourself either out loud or inside your head using a positive tone: "I will be successful in my performance. I will score this goal."
6. Avoid negative images and thoughts

Immediately before the performance, clear your mind for 5 seconds and walk through the successful performance in your mind. Then actualize the movements (for example, in golf, tennis, weightlifting, gymnastics, powerlifting, throws, and kicks).



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HYDRATION

A human being can survive without food for extended periods of time but as little as 3–5 days without fluids is likely to lead to death. Similarly, during and after exercise, the sufficient intake of fluids is of utmost importance. The body is only able to absorb a relatively small amount of fluid under exertion. This volume varies from 300 to 1200 milliliters per hour.[242]

As little as two percent dehydration of body mass may be harmful, particularly in relation to aerobic performance. As the level of dehydration increases, so does the risk of injury. Anaerobic performance and muscular strength have been found to remain unaffected at a slightly higher dehydration level. For example, dehydration of 3–4 % is not necessarily of significant harm.

Fluid intake should be initiated at the beginning of the workout. The general rule is to drink 0.1–0.2 liters at 15–20-minute intervals throughout the workout. Hydration is also crucial for recovery from exercise. For example, dehydration impairs the production of testosterone after both strength training[243] and endurance training.[244] Thus, the most important ingredient in any post-workout recovery drink is water.

According to official guidelines one should drink a minimum of 1–1.5 liters of water per day, preferably 2–3 liters depending on daily activity level and air temperature.[245] In addition, the daily fluid intake should be increased by at least a liter per each hour of exercise. The elderly should also drink more fluids due to the impaired ability of their kidneys to filter urine.[246]

Exaggerated fluid intake during exercise is not recommended. Excessive hydration and its side effect of salt/sodium loss (hyponatremia) may be more harmful than insufficient fluid intake. The daily water requirement is approximately 3.5 liters for men and 2.5 liters for women.[247] It is surprising how much of this water we get from food (particularly vegetables, fruits and berries that have a high water content).

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DRINKING DURING EXERCISE

At a minimum, a sports drink should contain sodium (salt). Commercial sports drinks often contain other electrolytes besides sodium although studies have found sodium to be the most important one. The amount of sodium needed varies significantly based on weather conditions, the length of the exercise session, and individual factors. There should be 0.5–1.5 g of sodium per one liter of sports drink.

Regular physical exercise boosts sweating[248] and thus improves the body's thermoregulation capacity. The endurance-impairing effect of dehydration becomes obvious with climbing air temperature, particularly in individuals who do little exercise. Conversely, dehydration has little effect on the performance of endurance exercises when the weather is cool or cold.[249]

THE EFFECTS OF DEHYDRATION ON PERFORMANCE

It appears that a dehydration level of more than 2–3 % may impair motor skills, ability,[250] alertness, decision-making capability, attentiveness,[251] perception, concentration[252] and the subjective feeling of energy.[253] Insufficient hydration may also impair performance due to psychological effects.[254] For example, drinking more fluids than the sense of thirst indicates does not appear to bring any extra benefits in many situations even if it leads to decreased dehydration.[255]

A simple indicator of sufficient hydration is the color and volume of urine. Light yellow urine and a large urinary volume indicate that the body's fluid balance is sufficient. Conversely, dark colored urine and a small urinary volume are indicative of dehydration.[256] On the other hand, urine that is completely colorless indicates that the fluid intake is too large in volume or too rapid.

URINARY COLOR CHART FOR HYDRATION ASSESSMENT



Source: International Olympic Committee 2012 (adapted color chart)

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INSTRUCTIONS FOR ACQUIRING OPTIMAL FLUID BALANCE:

- The sensation of thirst and the color of urine are simple indicators for monitoring fluid balance
- Drink a minimum of 2 liters of pure water per day
- You may add flavors and potentially hydration-improving components to the water (such as salt, honey, lemon) or use other fluids available (including sports drinks, coconut water, birch sap, freshly pressed vegetable juices, various types of tea)
- A balanced consistency is easily achieved by combining various component properties. For example, adding sodium (salt) to coconut water which is naturally rich in potassium (2 g/l) improves the hydration capacity of the drink.[257]
- A good sports drink contains carbohydrates (6–8 %) and sodium (0.5–1 %). In addition, a small amount of protein (1–2 %) and electrolytes (Mg, K, Ca) may be useful. Carbohydrate intake is not relevant in terms of performance if the exercise lasts less than an hour and if a person is fully keto-adapted and mostly burning fat for energy (in aerobic exercise).
- A drink containing sodium is often perceived to taste more pleasant than plain water, increasing the likelihood of consumption.[258] It may be a good idea to add a pinch of high-quality salt to the fluid if you often suffer from dehydration.



HYDRATION DRINK: COCONUT WATER

Coconut water is rich in minerals such as calcium, magnesium and zinc as well as electrolytes, potassium in particular. Adding the right amount of salt (sodium) makes the ratio of electrolytes isotonic, further improving fluid absorption. Add some lemon juice and you have fresh lemonade that hydrates the body naturally without any artificial additives.

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COLD THERMOGENESIS

Rapid temperature changes have several health benefits. Cold thermogenesis and the heat generation induced by it may boost metabolism and circulation and activate brown adipose tissue (BAT) found in the back of the neck and the upper back.[259] The purpose of the brown adipose tissue is to quickly generate heat. To do this, the brown adipose tissue burns conventional white adipose tissue. The activation of brown adipose tissue also increases the use of glucose in the energy metabolism of cells.[260] Regular exposure to cold may increase the amount of brown adipose tissue and thus further boost these processes. Therefore, cold thermogenesis may help in weight management, reduce the tendency to feel cold and improve cold tolerance.[261]

Feeling cold is a sign of the body temperature falling. The shivering reflex causes muscle cells to vibrate which generates heat. This reflex is regulated by the hypothalamus. Cold thermogenesis activates the sympathetic nervous system. It constricts blood vessels in the hands, feet and layers of skin to protect vital functions from the cold.[262] Hypothermia occurs when the body temperature drops below 35°C (95°F). This happens when an unaccustomed person spends approximately 15–30 minutes in water of 0–5°C (32–41°F). Loss of consciousness follows when the body temperature drops below 30°C (86°F).

World record holder Lewis Pugh (who swam for more than 30 minutes in water of 0–5°C/32–41°F) says he used cold thermogenesis to prepare for the ordeal.[263] Dutch "Ice Man" Wim Hof ran a marathon in Lapland at the temperature of –20°C (–4°F) wearing a pair of shorts. He also broke the world record after submerging himself in ice water for nearly two hours. According to researchers, Wim Hof is able to consciously control his autonomic nervous system, increase the level of cortisol and reduce inflammatory markers.[264]

PRACTICING COLD THERMOGENESIS

A nerve located in the face (specifically the trigeminal nerve which is linked to the vagus nerve) is especially sensitive to cold. By practicing cold thermogenesis using your face, you are improving your whole body's ability to withstand cold.

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What is needed? Ice cubes, a bucket or other open container, a thermometer and a timer.

- Drink a glass of cold water before each practice session
- Fill the container with cold water and add the ice cubes
- Measure the temperature and check that it is approximately 5–10°C (41–50°F)
- Set the timer for 30 seconds
- Close your eyes, draw your lungs full of air and push your head into the cold water
- Stay submerged while holding your breath for 30 seconds
- Breathe deeply for at least a minute before the next repetition to ensure that the carbon dioxide exits your lungs fully
- Repeat three times every evening

When 30 seconds feels too easy, increase the time according to your progression. We do not recommend holding your breath beyond 90 seconds even though the world record is 11 minutes without auxiliary oxygen. Similarly, we do not recommend this to those suffering from hypertension, slow heart rate (less than 40 beats per minute) or cardiovascular diseases. If you encounter arrhythmia, frostbite, dizziness or you lose consciousness, stop practicing immediately.

The following may be helpful:

- In addition to a cold shock, cold exposure on the face causes a *diving reflex* which lowers the heart rate (*bradycardia*). The lower your heart rate, the slower your consumption of oxygen. This is a natural reaction for most mammals. To facilitate lowering your heart rate, take deep, calm breaths before the exercise. Fill no more than 80 % of your lungs with air so that you can relax your whole body. The objective is to consume as little of the oxygen available as possible.



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- Direct your attention elsewhere from the need to breathe
- Meditating or imagining fish underwater may by helpful
- Remember that if you remain calm and feel no pain, you are far from losing consciousness. It depends largely on your willpower.
- If water gets up your nose, maintain slight tension in your nostrils or hold them closed with your fingers
- Thermogenic plants that promote heat generation (such as green tea, coffee, ginger or chili) may help if consumed before the exercise[265]
- Adaptogens (such as rhodiola rosea, ginseng, cordyceps or ashwagandha) may increase the ability to tolerate the stress caused by the cold shock. In studies conducted by the United States army, tyrosine (found, for example, in spirulina, fish, turkey and egg whites) was found to increase the ability to act during cold exposure.[266]

It is possible to practice cold thermogenesis further using an ice vest, a cold shower or a cold pool for up to 20 minutes at a time or until the surface temperature of the body reaches 10°C (50°F). Take precautions to protect yourself from frostbite and cover your head, fingers and toes if necessary.

According to the latest studies, cold thermogenesis is unwise immediately following an intensive strength training workout. Cold thermogenesis performed immediately after a workout may even prevent the beneficial effects of strength training on muscle growth and blood vessel development.[267] This is due to the immediate post-workout cold exposure preventing the hormetic stress, or hormesis, brought on by the strength workout.[268] Appropriate hormesis results in increased anatomical and physiological strength. Therefore, we recommend waiting for at least two hours after a strength training workout before a prolonged cold thermogenesis. Cold thermogenesis that results in shivering and shaking may also increase muscle growth by stimulating the secretion of irisin.[269] [270]

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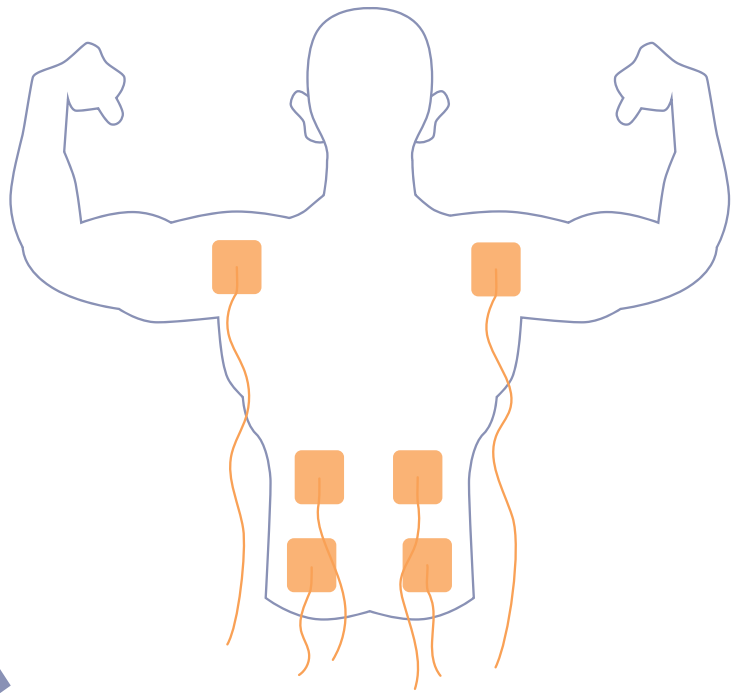
ELECTRICAL MUSCLE STIMULATION

Neuromuscular electrical stimulation (NMES) involves using electrodes to deliver electrical impulses directly to muscle tissue. The most widely studied application of NMES is the activation of the quadriceps muscle during exercise. Similar to resistance training, NMES appears to cause muscle deterioration followed by an anabolic (muscle repairing) phase. This is the basis for the potential muscle building and force generation increasing effects of the method.[271] The recommendation is to combine NMES with strength training[272] as the muscle fiber activation provided by NMES is not complete or always in the correct sequence.[273]

NMES is not a new discovery – Soviet sports scientists studied and utilized electrical stimulation as early as the 1960s.[274] Dr. Yakov Kots has claimed to be able to increase the force generation of top athletes by as much as 40 percent using electrical muscle stimulation. However, these claims have not been fully scientifically proven.

A study published in 1989 combined Olympic-level weightlifting training with the NMES method. The results were impressive: within a week, the test subject was able to increase the front squat lift load by 20 kg (44 lbs). This is an extremely significant improvement in such a short time.[275] Similar results were later achieved using more extensive data.[276]

The tests conducted on athletes have inspired the application of neuromuscular electrical stimulation to physical rehabilitation therapy. As such, it has been established as an effective method of treatment.[277]



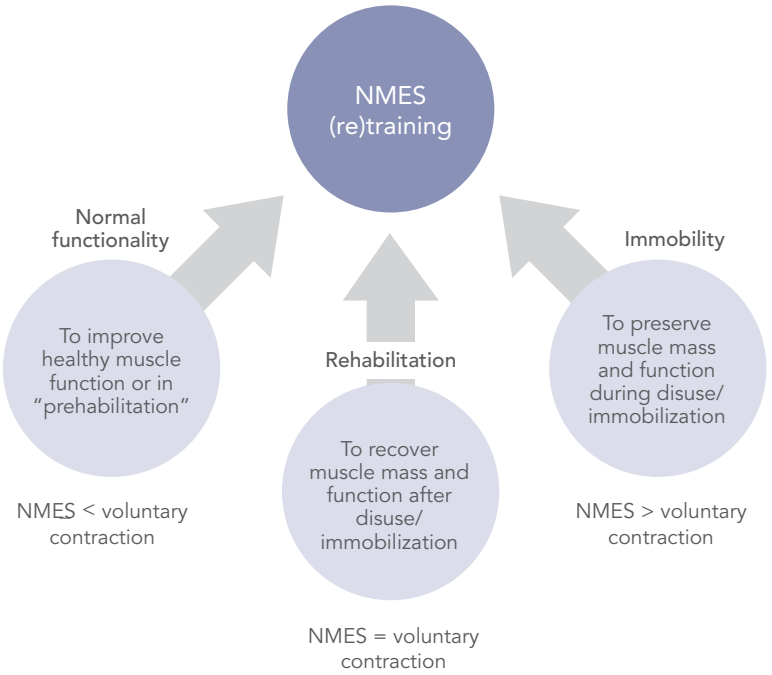
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For example, the NMES method is used in the rehabilitation of individuals recovering from a stroke.[278]

Many NMES devices feature various protocols for different types of muscle exercises (endurance, strength, speed), to correct muscular imbalances or to decrease muscle atrophy. The NMES method is also suitable for use during recovery from exercise as long as the frequency and intensity settings used are strong but comfortable.[279] In addition, it is possible to "massage" muscles using long contractions (3–10 seconds). NMES has also been found to improve local circulation.[280]

The effective activation of the motor units depends on factors including the progressive increase of the electric current intensity, variations in muscle length, and the positioning of the electrodes.[281] To maximize muscle tension, the recommendation is to use 100–400 microsecond biphasic rectangular pulses at the frequency of 50–100 Hz conducted using the highest tolerable electric current.[282] However, training should be initialized in a slow and incremental manner to minimize adverse effects and excessive muscle fatigue. When applied and used incorrectly, the NMES method may be harmful to muscles. Excessive use may be a predisposing factor for rhabdomyolysis (muscle breakdown).[283]

EFFECTIVENESS AND USES OF NMES TRAINING[284]



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NMES AND STRENGTH TRAINING – EXAMPLE PROGRAM:

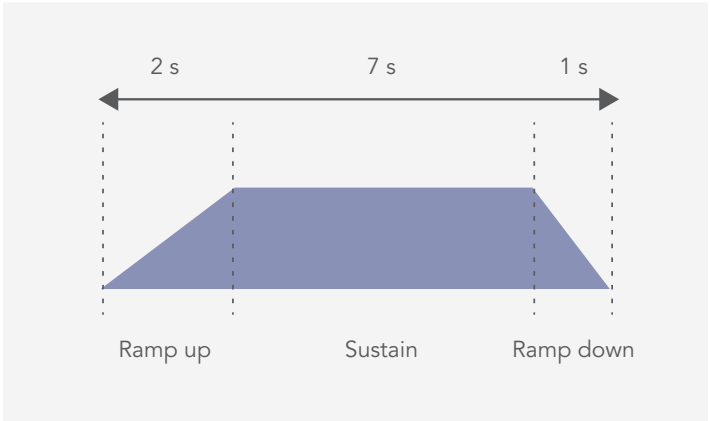
- The goal of the program is the maximal growth of the quadriceps muscles
- Program duration is 3 weeks during which 6 exercises are completed (2 per week)
- Add weights in a progressive manner (see section "Strength training" for more information)
- The strength training exercise is combined with the electrical stimulation (NMES) of the quadriceps muscles
- Attach the electrodes to each thigh according to the instructions provided with the device
- Select the quadriceps program on your device
- NB! If there is obvious disparity between the quadriceps muscles you may use electrical stimulation only on the weaker muscle to correct the difference.

Exercise:

- Back squat 4 x 10
- Leg press 3 x 10
- Prone hamstring curl 3 x 10

NMES program:

- 2500 Hz burst AC (biphasic pulse waveform)
- Frequency 50 Hz
- Duty cycle 1:2, e.g. a 6.66 ms contraction followed by a 13.32 ms pause
- Pulse width 400 microseconds



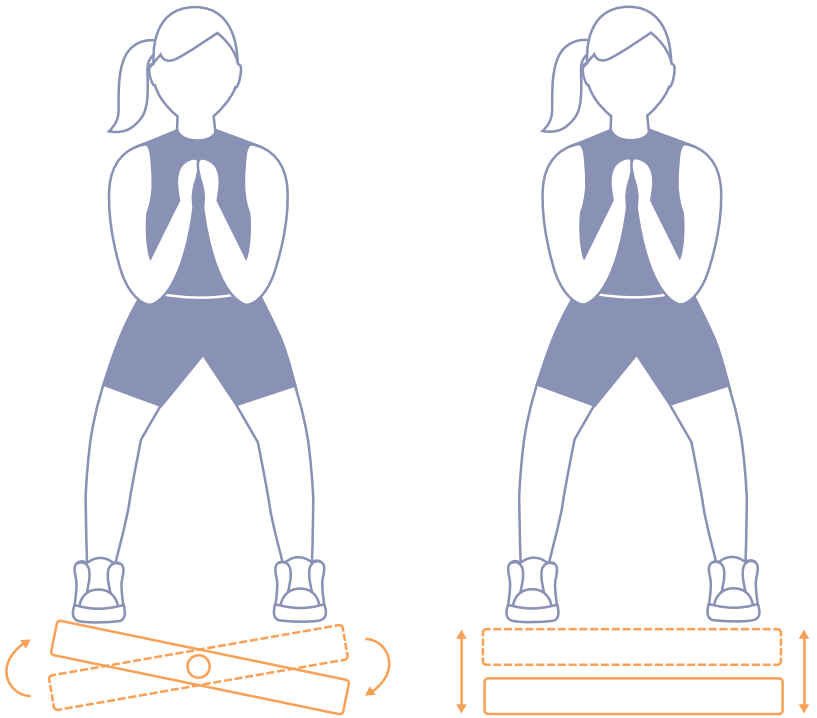
NMES STIMULATION DIAGRAM

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WHOLE-BODY VIBRATION

The whole-body vibration (WBV) training method is a neuromuscular method based on the tonic vibration reflex.[285] It involves the use of a whole-body vibration plate that produces vertical or rotational vibration (see image). Usually the individual stands or performs bodyweight exercises on the device. It is used to improve muscular strength, balance, and bone density.

Vibration training boosts lymphatic and peripheral circulation[286] and improves proprioception (the sense of position and motion).[287] Improvements in bone density have been found in post-menopausal women.[288] Indeed, the clearest health benefits have been generally recorded for individuals of advanced age.[289] The WBV method may also be used by individuals suffering from fibromyalgia to improve balance and reduce pain and fatigue.[290]



TWO DIFFERENT PLATFORM TYPES OF WBV DEVICES

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Factors in vibration training:

- Vibration frequency
- Vibration amplitude
- Type of exercise (dynamic/static, duration and intensity)
- Type of vibration platform (vertical or rotational)

The frequency of rotational (oscillating) vibration is slightly lower than that of vertical vibration (26–30 Hz vs. 35–50 Hz). It also requires higher amplitude (2–4 mm vs. 6–10 mm).

In an EMG test, the best muscle response was achieved with a frequency of 35–45 Hz and an amplitude of 4 millimeters (vertical vibration).[291] A submaximal (50 % 1RM) squat exercise conducted using added weights significantly increases the energy expenditure and training intensity compared to the same exercise performed without vibration.[292] A study on obese individuals found that WBV training combined with a calorie-restricted diet (–600 kcal) reduces harmful visceral adipose tissue (fat tissue around internal organs) more effectively than aerobic exercise and/or calorie restriction alone.[293]

tip

WORKING DAY

The WBV device can be used for invigoration during short breaks within the working day. At the same time, you get exercise which is physiologically equivalent to a significantly longer walk. Standing on the WBV for 2 minutes may also temporarily improve cognitive performance.[294]

A study published in 2000 indicates that a static deep squat exercise combined with vibration training boosts the levels of testosterone and growth hormones in men immediately after the exercise. It also reduces the level of cortisol. The individuals studied also demonstrated increased jumping strength after the exercise compared to before.[295] A study published in 2015 also found that a static deep squat combined with moderate added weights (30 % of body weight) significantly improved the post-exercise jumping strength and speed.[296] The training methods of each of the two studies are described on the following page.

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According to a comprehensive meta-analysis study (2015), vibration training improves general neuromuscular performance. However, for athletes, vibration training is not sufficient to improve sport-specific performance.[297] According to recent studies, vibration training may be used by athletes, for example, during warm-up to increase jumping strength and speed.[298] Vibration training may also reduce delayed onset muscle soreness (DOMS) which is particularly common after resistance training.[299]

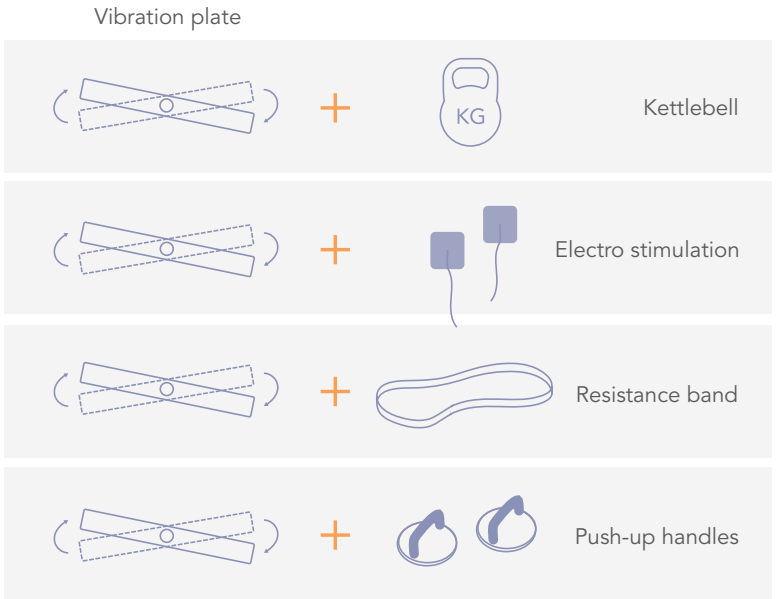
Training protocol 1 (Bosco et al. 2000):

- Repeat the exercise 2–4 times per week
- Hold the squat position for 60 seconds, then rest for 60 seconds
  - repeat 5 times, then rest for 6 minutes
  - repeat once more, i.e. 5 times 60 seconds of action followed by 60 seconds of rest
- A vertical WBV device was used in the study (vibration frequency 26 Hz, amplitude 4 mm)

Training protocol 2 (Pojskic et al. 2015):

- Repeat the exercise 2–3 times per week before other training that requires strength and explosiveness
- The exercise is completed in a static squat position (knees at a 90 to 100 degree angle)
- Place a barbell on your shoulders and add a total of 30 % of your bodyweight onto it (for example, 30 kg if you weight 100 kg)
- Maintain the squat position for 60 seconds, then rest for 30 seconds – repeat this 5 times
- A vertical WBV device was used in the study (vibration frequency 50 Hz, amplitude 4 mm)

PRACTICE IDEAS



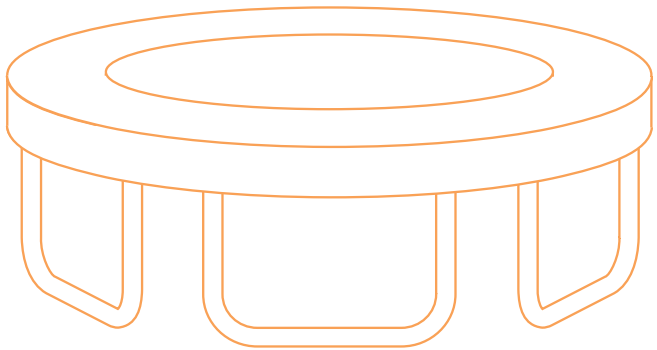
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REBOUNDING

Rebounding (exercising on a miniature trampoline) has become trendy in recent years among health-conscious individuals, either as exercise completed during the working day or as part of a varied exercise regime. Jumping on a miniature trampoline for just a few minutes significantly improves lymphatic and blood circulation and oxygen uptake.[300]

Public awareness of rebounding was increased in the 1980s after a well-known study by NASA which compared the physiological effects of running and trampoline jumping. The study had a small sample set (8 people) but the methodology was sound. It found trampoline jumping to be a significantly safer form of exercise than running (in terms of strain on joints and tissues). At the acceleration of less than 4G, oxygen consumption was at times twice that of running on a treadmill while the biomechanical stress was identical.[301] Such studies have not been conducted on miniature trampolines.

Effective exercises on a miniature trampoline include jumping, jumping jacks, running in place, skipping on one foot and jumping while maintaining various static positions. A particularly good setting for a miniature trampoline is at the office where work duties can alternate with pleasant bouts of jumping. Jumping on a miniature trampoline combines childlike playfulness with whole-body exercise.



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SAUNA AND HEAT EXPOSURE

There are two general types of sauna: traditional sauna and infrared sauna. Sauna baths, loved by most Finns, are an example of a rapid temperature change to which our internal thermostat reacts in a way that is beneficial for health. Traditional sauna boosts the production of growth hormone,[302] improves metabolism, and increases oxygen uptake. Taking a sauna bath has been found to have a positive impact on the performance of endurance athletes.[303] Sauna can also reduce joint pain and improve joint mobility[304] as well as ease the symptoms of individuals suffering from tension headaches.[305]

A link has been found between regular sauna baths (2–3 times per week) and a significantly lower risk of cardiac arrest and coronary heart disease. The more frequent and prolonged the sauna sessions, the greater the health benefit.[306] Taking regular sauna baths also reduces the likelihood of catching a cold.[307] The Finnish saying "sauna is the poor man's doctor" is exceptionally accurate. Combining a sauna bath with ice swimming is a Nordic tradition, the health benefits of which many swear by and are justified by science.

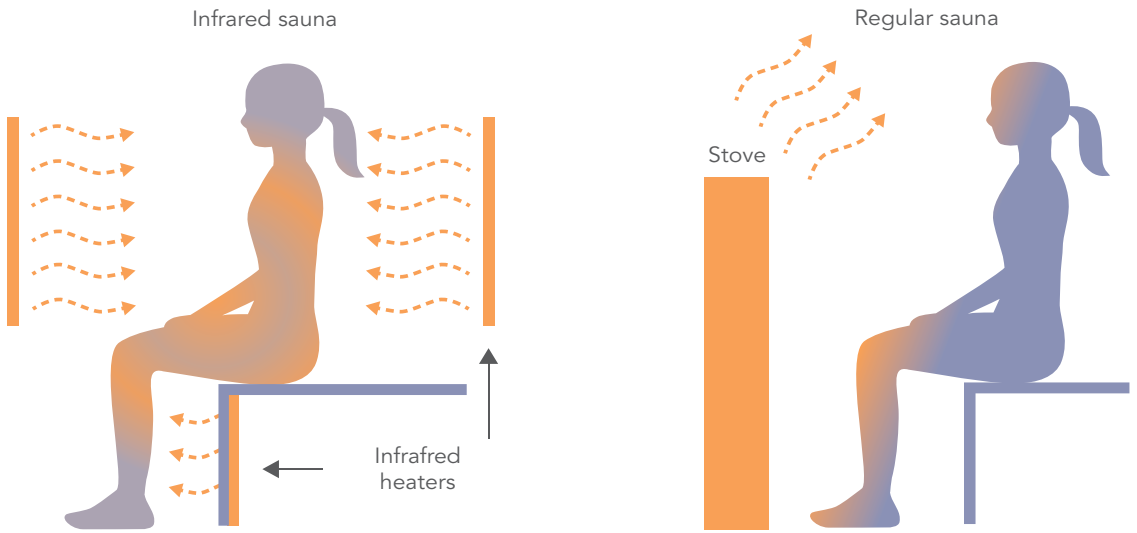
The effects of taking a sauna bath are similar to those of physical exercise.[308] It produces heat-shock proteins (HSPs) that may have positive effects on muscle growth.[309] Spending time in a hot sauna also appears to increase insulin sensitivity which is beneficial for weight loss and diabetes prevention.[310]

Recipes for a proper sauna bath:

- Stay in the sauna for a minimum of 15 minutes at a time
- Two 20-minute sauna sessions in more than 80 degrees Celsius (176 Fahrenheit) with a 30-minute cooling break in between may increase the production of growth hormone 2–5-fold (the hotter the temperature, the greater the growth hormone production)
- Two one-hour sauna sessions per day may increase growth hormone levels up to 16-fold[311]
- Spend 15–30 minutes in the sauna followed by 5–10 minutes in a cold shower – when done 2–3 hours before bedtime, this will significantly improve sleep quality
- To maximize recovery and muscle growth, spend a minimum of 30 minutes in the sauna after exercise

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COMPARISON OF SAUNA TYPES



INFRARED SAUNA

Infrared saunas use infrared radiation which heats body tissues directly instead of air. The frequency of the radiation emitted by infrared saunas is 3–12 μm which falls under what is called far-infrared (FIR). Far-infrared has been found to have tissue-level effects particularly on the mitochondria respiratory chain in the cell energy production process and the blood supply of tissues by dilating blood vessels and improving circulation.[312]

In the past 10 years, many gyms and beauty salons have introduced infrared saunas alongside traditional saunas. An increasing number of people also install infrared saunas in their homes to enjoy the health benefits. In Western countries, infrared saunas are usually heated to approximately 40–50 degrees Celsius (104–122 Fahrenheit) at which point sweating begins in 15–20 minutes.

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In Japan, the properties of the infrared sauna are used for Waon therapy in which the sauna is heated to 60 degrees Celsius (140 Fahrenheit). Patients sit in the sauna for 15 minutes after which they are wrapped in heated blankets for 30 minutes more. Waon therapy is used particularly for patients suffering from heart failure in effort to increase stroke volume, cardiac output, and ejection fraction (see section "Cardiovascular and circulatory system").[313] [314] According to studies, Waon therapy significantly reduces cardiac deaths and issues caused by heart failure.[315]

Other health benefits of the infrared sauna:

- Reduces oxidative stress in the body[316]
- Speeds up recovery from exercise[317]
- May reduce short- and long-term pain[318] [319] [320]
- May promote the detoxification of the body[321] through increased microcirculation[322] and deep sweating caused by infrared radiation
- May be used as a treatment for chronic fatigue syndrome as it can significantly ease the symptoms (Waon therapy)[323]

THE INFRARED SAUNA & NIACIN PROTOCOL

This guide is adapted from the detoxification program used in the removal of toxins contributing to the Gulf War syndrome.[324] The protocol has also been used in firefighter detoxification programs. Most toxins (including DDT, PCB and many pesticides and heavy metals) are stored in the adipose tissue. An individual's toxin load is proportional to their body weight which forms one of the risk factors associated with excess weight.[325]

According to a study published in 1990, the adipose tissues of Yugoslavian electronics factory workers contained toxin levels 140 times greater than those found in their blood. After a detoxification program, the toxin levels in the adipose tissues decreased on average by 30 %.[326]

A key factor in the program is niacin (vitamin B3) whose effect is based on rebound lipolysis.[327] This means that the niacin releases a large volume of fatty acids and toxins from fat cells in a delayed manner, approximately 2–3 hours after consumption. Initially niacin inhibits lipolysis. In liver cells, niacin promotes fat beta-oxidation and inhibits the synthesis of fatty acids (lipogenesis). This may affect the treatment of fatty liver disease (see section "Metabolism" for more information).[328]

Combining the protocol with exercise boosts circulation and by extension, the detoxification process. Conversely, infrared sauna improves microcirculation which in turn,

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boosts the circulation of toxins in blood and their removal from the body through sweating.

In its common form (*nicotinic acid*), niacin causes a flush reaction caused by severe dilation of blood vessels. This can be avoided by using a slowly absorbed form of niacin (*inositol hexanicotinate*).

- Start with a 500 mg dose of slowly absorbed niacin and wait 20 minutes before doing any exercise
  - You may increase the dose by 500–1000 mg per week (maximum dose described in the original detoxification protocol is 5000 mg)
- Move briskly for 20–30 minutes (the objective is to raise the body temperature and to increase lymphatic and blood circulation)
- After exercise, enter a preheated infrared sauna (minimum 40 degrees Celsius or 104 Fahrenheit) for 15–60 minutes (the longer the better)
- While in the sauna, you may consume coconut water or other mineral-rich fluids to prevent dehydration and to replace the minerals lost through sweating
- At the end of the sauna session, take 2–5 activated charcoal capsules that bind the toxins secreted in the intestine – they will exit the body with feces
- Start the protocol with caution and moderation if you are aware that your body has accumulated a great deal of toxins or if your body fat percentage is high
- The process of the toxins exiting your body may cause detox symptoms which will pass
- Have your liver function values checked 2 weeks after starting the protocol and again 2 weeks after that
- The maximum duration of the protocol is 30 days during which it is recommended to consume plenty of minerals and healthy fats (see the *Biohacker's Handbook* section "Nutrition")
- Complete the protocol 2–3 times per week. If you want fast results, you may complete the protocol daily after testing it a few times
- If you suffer from any chronic illnesses, discuss the treatment protocol with your doctor

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MEASURING EXERCISE AND PHYSICAL PERFORMANCE

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Individual physical performance and athletic level may be measured by focusing on specific areas.

The main areas include:

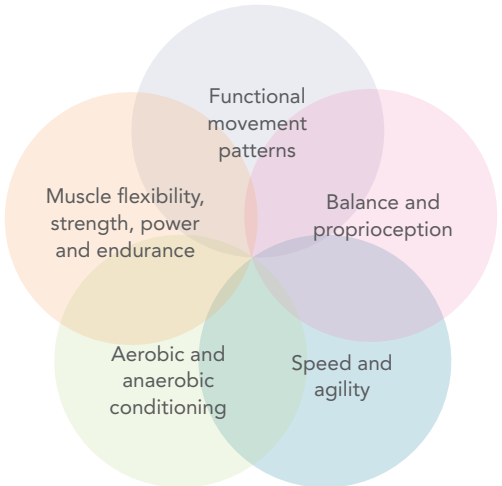
- Energy production – aerobic and anaerobic processes
- Neuromuscular system function – muscular strength and maximal force generation, speed strength and explosiveness, strength endurance
- Mobility, agility and coordination
- Recovery

Current views indicate that assessing and measuring exercise and physical performance in the Western world first started with army tests developed for cadets. The first version of the Army Physical Fitness Test was developed in 1858. In 1920, all soldiers were widely assessed in a 100-yard run, long jump, wall climb, hand grenade toss and obstacle course.[329]

In East Asian cultures and the martial arts integral to them, progress assessment has been conducted through so-called belt examinations or tests. Belt tests were adopted in judo as early as the 1880s. Karate belt tests were introduced in 1924.

For the biohacker, various tests provide an opportunity to comprehensively assess one's physical development. Tests are helpful in assessing fitness and performance as well as planning a suitable exercise regime. Today, various technological aids and wearable applications make it possible to comprehensively assess physical performance and its various areas.

THE MAIN TESTING AREAS



Source: Manske, R. & Reiman, M. (2013). Functional Performance Testing for Power and Return to Sports. *Sports Health* 5 (3): 244–250.

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TESTS THAT MEASURE AEROBIC FITNESS AND OXYGEN UPTAKE

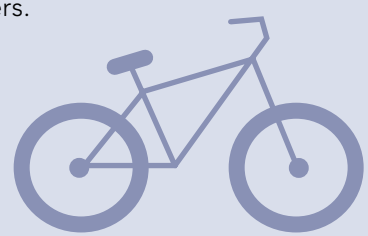
Measuring and testing athletes began after the first official Olympic games (1886). The first bicycle ergometer was built in Denmark in 1910. The concept of maximal oxygen uptake was developed in 1920 by physiologist Archibald Hill (1886–1977).[330] However, it was not until the 1960s that comprehensive studies regarding maximal oxygen uptake testing were published.[331] [332] The concept of anaerobic threshold (see section "Endurance exercise") was adopted by the scientific community after a study published in 1964.[333]

UKK WALK TEST

The scientifically validated UKK walk test was developed in Finland in the early 1990s for the purpose of measuring endurance fitness, i.e. the performance of the respiratory and circulatory system.[334] The walk test is intended especially for the study of the physical fitness of middle-aged people. However, it can also be applied to other age brackets or overweight individuals.[335] [336]

OXYGEN UPTAKE

Oxygen uptake refers to the ability of the respiratory and circulatory system to transport oxygen and the ability of the muscles to use it for energy production. Maximal oxygen uptake (VO2 max) refers to the oxygen uptake occurring under extreme stress. The terms oxygen uptake and oxygen consumption are often used interchangeably. Maximal oxygen uptake is expressed either as an absolute value (liters per minute) or more commonly as a relative value of liters per minute per kilogram of bodyweight (ml/kg/min). Oxygen uptake is indicative of endurance fitness which can be improved with regular endurance or interval training. The highest maximal oxygen uptake values have been measured for cyclists and skiers.



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The test involves walking 2 kilometers on a level surface as fast as possible. A fitness index is then calculated based on the time spent walking, the heart rate at the end of the test, body mass index, and sex. The test subject's maximal oxygen uptake is estimated based on the test results. Adequate accuracy is achieved when the heart rate at the end of the test is at least 80 % of maximum heart rate.[337] The test is not generally recommended for individuals of very high fitness levels as it is not sufficiently strenuous in these cases.[338]

The UKK walk test formula for estimating maximal oxygen uptake: The result is VO2max (ml/min/kg)

Men:
184.9 – 4.65 x (time in minutes) – 0.22 x (heartbeat) – 0.26 x (age) – 1.05 x (BMI)

Women:
116.2 – 2.98 x (time in minutes) – 0.11 x (heartbeat) – 0.14 x (age) – 0.39 x (BMI)

EXAMPLES OF OXYGEN UPTAKE

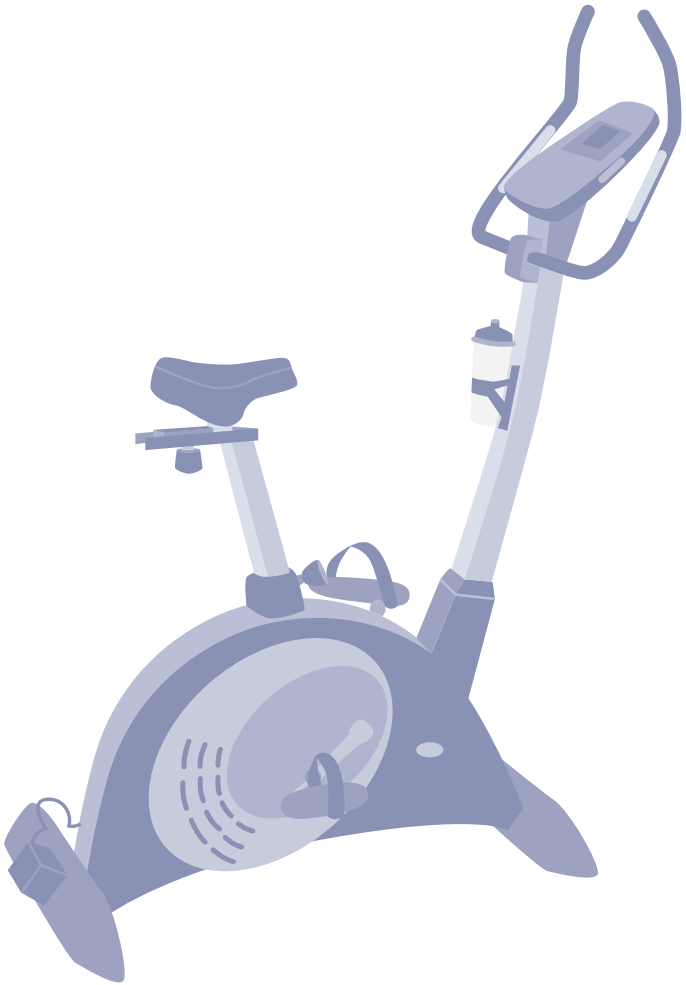
	OXYGEN UPTAKE ML/MIN/KG	MET VALUE
Top endurance athlete, male	80–90	22–26
Top endurance athlete, female	70–80	20–23
Physically active individual, 10 km run in 40 mins	60	17
Physically active individual, 10 km run in 60 mins	40	11
Physically inactive individual, gets winded by taking the stairs	25	7

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CLINICAL EXERCISE STRESS TEST USING A BICYCLE

A clinical exercise stress test (exercise ECG) is usually conducted using a stationary bicycle (exercise ergometer) under the supervision of a doctor. The test is offered by many medical clinics. Stress tests are also often conducted to study potential cardiovascular diseases. It is particularly common when diagnosing coronary heart disease. For the biohacker, a clinical exercise stress test using a bicycle is a good means of measuring aerobic fitness and anaerobic force generation, as long as the test is performed to absolute exhaustion.

Arterial blood oxygen level and lung function may also be measured during the test. Athletes usually undergo more comprehensive testing, i.e. running spiroergometry (see paragraph below). The doctor may interrupt the stress test if something unusual is detected in the symptoms, electrocardiogram, blood pressure, blood oxygen saturation, or other variables.[339]



BICYCLE ERGOMETER

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The exercise stress test is usually initialized with low resistance (40 W for women, 50 W for men). The test is typically conducted with three-minute intervals between additions to resistance. For women, the increments in resistance are 40 W each, for men they are 50 W each. The pace is usually 60–70 rpm. Perceived exertion is assessed during the exercise stress test using the Borg scale (see image). The objective of the exercise stress test is to achieve the perceived exertion rating of 90 % of maximum within 6–12 minutes by increasing the resistance level. For individuals of very high fitness, the time required may be significantly longer. Maximal oxygen uptake may be estimated based on the test results. However, for athletes, the accuracy is not sufficient when the performance is submaximal.[340 341]

THE BORG SCALE

	Perceived exertion	Suitability	Monitor breathing
6			
7	extremely light		normal rate of breathing
8	very light		
9			
10	light	suitable for all	deeper breathing (able to hold conversation)
11			
12			
13	somewhat strenuous	suitable for physically active individuals	out of breath (difficult to hold conversation)
14			
15	strenuous		
16			
17	very strenuous	suitable for physically very active individuals and athletes from time to time	panting (impossible to hold conversation)
18			
19	extremely strenuous		
20			

Source: Sovijärvi, A. (2012). Spiroergometria. In: *Kliinisen fysiologian perusteet*. Helsinki: Kustannus Oy Duodecim.

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RUNNING SPIROERGOMETRY

Spiroergometry is the extended version of the clinical exercise stress test, intended especially for athletes. It is conducted using either a bicycle ergometer or treadmill. In addition to the analytical methods of the clinical exercise stress test, this test involves measuring respiratory gases and the tidal volume.The test allows for the direct measurement of oxygen consumption and carbon dioxide production and therefore the anaerobic threshold. The more comprehensive version can also involve measuring the lactic acid level in arterial blood. The test subject pedals the bicycleergometer or runs on the treadmill, with incremental increases to resistance, either to submaximal or complete exhaustion. The respiratory gases are measured using a mask secured to the test subject's face.

ENDURANCE FITNESS CLASSIFICATIONS BASED ON OXYGEN UPTAKE (WOMEN) (ML/MIN/KG)

AGE	WEAK	POOR	FAIR	AVERAGE	GOOD	VERY GOOD	EXCELLENT
20–24	under 27	27–31	32–36	37–41	42–46	47–51	over 51
25–29	under 26	26–30	31–35	36–40	41–44	45–49	over 49
30–34	under 25	25–29	30–33	34–37	38–42	43–46	over 46
35–39	under 24	24–27	28–31	32–35	36–40	41–44	over 44
40–44	under 22	22–25	26–29	30–33	34–37	38–41	over 41
45–49	under 21	21–23	24–27	28–31	32–35	36–38	over 38
50–54	under 19	19–22	23–25	26–29	30–32	33–36	over 36
55–59	under 18	18–20	21–23	24–27	28–30	31–33	over 33
60–65	under 16	16–18	19–21	22–24	25–27	28–30	over 30

Source: Shvartz, E. & Reibold, R. (1990). Aerobic fitness norms for males and females aged 6 to 75 years: a review. *Aviation Space and Environmental Medicine* 61 (1): 3–11. Review.

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Spiroergometry can accurately determine an individual's maximal oxygen consumption (oxygen uptake) and anaerobic threshold. This is the point where carbon dioxide production begins to increase compared to oxygen consumption and lactic acid begins to form in the blood. At the same time, the breathlessness level is significantly increased (see sections "Metabolism" and "Endurance training"). Spiroergometry is the golden standard when it comes to studying performance-impairing factors related to respiration, the cardiovascular system, metabolism, etc. The spiroergometry test is also widely used to assess an individual's ability to work.[342]

ENDURANCE FITNESS CLASSIFICATIONS BASED ON OXYGEN UPTAKE (MEN) (ML/MIN/KG)

AGE	WEAK	POOR	FAIR	AVERAGE	GOOD	VERY GOOD	EXCELLENT
20–24	under 32	32–37	38–43	44–50	51–56	57–62	over 62
25–29	under 31	31–35	36–42	43–48	49–53	54–59	over 59
30–34	under 29	29–34	35–40	41–45	46–51	52–56	over 56
35–39	under 28	28–32	33–38	39–43	44–48	49–54	over 54
40–44	under 26	26–31	32–35	36–41	42–46	47–51	over 51
45–49	under 25	25–29	30–34	35–39	40–43	44–48	over 48
50–54	under 24	24–27	28–32	33–36	37–41	42–46	over 46
55–59	under 22	22–26	27–30	31–34	35–39	40–43	over 43
60–65	under 21	21–24	25–28	29–32	33–36	37–40	over 40

Source: Shvartz, E. & Reibold, R. (1990). Aerobic fitness norms for males and females aged 6 to 75 years: a review. *Aviation Space and Environmental Medicine* 61 (1): 3–11. Review.

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COOPER TEST

The Cooper test, developed by Dr. Kenneth H. Cooper in 1968 for the United States army, is used for the assessment of maximal endurance. It involves running as far as possible in 12 minutes. According to studies, a strong correlation exists between the Cooper test results and maximal oxygen uptake.[343] The test is best suited for runners as it utilizes running economy and technique.

The Cooper test results of Finnish army conscripts have been recorded since 1975. Compared to the peak year of 1980 (when the average result was 2760 m), men's endurance fitness as measured by the Cooper test has declined by more than 300 meters in 30 years. A comparable dip has not been detected in muscular fitness.[344]

COOPER TEST FITNESS CLASSIFICATIONS

AGE		EXCELLENT	GOOD	AVERAGE	POOR	WEAK
17–20	m f	over 3000 m over 2300 m	2700–3000 m 2100–2300 m	2500–2699 m 1800–2099 m	2300–2499 m 1700–1799 m	under 2300 m under 1700 m
20–29	m f	over 2800 m over 2700 m	2400–2800 m 2200–2700 m	2200–2399 m 1800–2199 m	1600–2199 m 1500–1799 m	under 1600 m under 1500 m
30–39	m f	over 2700 m over 2500 m	2300–2700 m 2000–2500 m	1900–2299 m 1700–1999 m	1500–1899 m 1400–1699 m	under 1500 m under 1400 m
40–49	m f	over 2500 m over 2300 m	2100–2500 m 1900–2300 m	1700–2099 m 1500–1899 m	1400–1699 m 1200–1499 m	under 1400 m under 1200 m
50+	m f	over 2400 m over 2200 m	2000–2400 m 1700–2200 m	1600–1999 m 1400–1699 m	1300–1599 m 1100–1399 m	under 1300 m under 1100 m

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TESTS THAT MEASURE ANAEROBIC FITNESS

Tests that measure anaerobic fitness may be divided into studies that measure anaerobic power and those that measure anaerobic capacity. The measuring process and results of anaerobic power tests are significantly affected by the test subject's motivation and pain tolerance. For example, a competitive situation often yields significantly higher test results. A test conducted in a group setting also affects motivation and by extension the results.[345]

The easiest way to study anaerobic capacity is to conduct a short cycling test completed using maximal power. Anaerobic capacity is affected by the phosphocreatine and lactate utilization properties of the muscles (see section "Metabolism"). The link between the oxygen debt accrued during exercise and anaerobic capacity has previously been studied but the results have been imprecise with weak correlation findings. The golden standard of measuring anaerobic capacity and peak power is the Wingate test.

WINGATE TEST

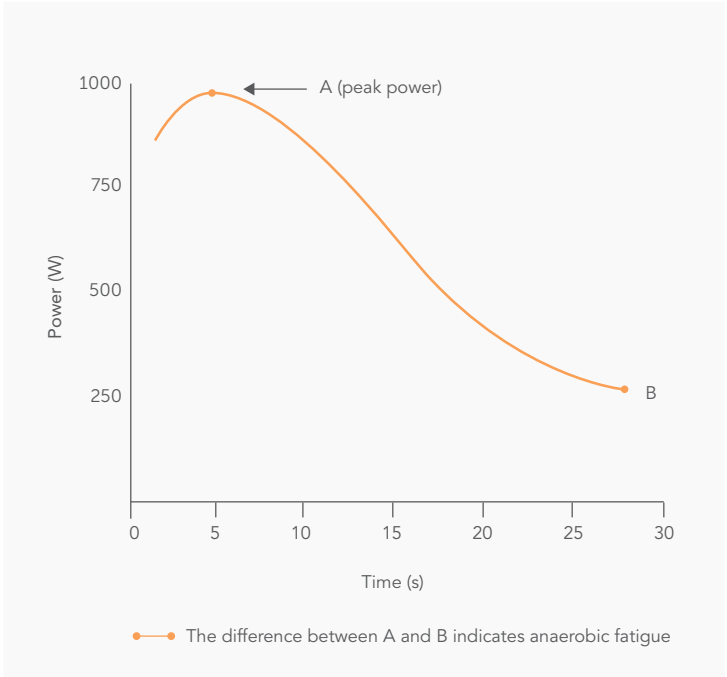
The Wingate anaerobic test (WAnT), developed in 1974 by the Wingate Institute (Netanya, Israel), is a bicycle ergometer test that measures anaerobic capacity. After a few decades and many revisions, the Wingate test has been established as the golden standard of testing anaerobic capacity.[346]

The Wingate test involves a 5 to 10-minute low-power warm-up followed by 30 seconds of pedaling completed using maximal power and a standardized load. Wingate applications that are longer than 30 seconds (for example, 60 seconds or 120 seconds) also test aerobic metabolism.[347] The interval method is also used for training and improving both aerobic and anaerobic performance (see section "HIIT training" for more information).[348] According to studies, the Wingate test should be performed in the afternoon or evening as the peak power is significantly lower in the morning.[349]

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Measurable quantities:

- Peak power (PP)
  - Power produced in the first 5 seconds (W)
- Relative peak power (RPP)
  - Peak power proportional to body weight
- Anaerobic fatigue (AF)
  - Percentage of power lost by the end of the test vs. the starting peak power
  - Indicative of lactic acid tolerance – the higher the percentage, the lower the lactic acid tolerance level
- Anaerobic capacity (AC)
  - Total amount of work performed during the test



EXAMPLE RESULT OF THE WINGATE TEST

MART TEST

The MART test (Maximal Anaerobic Running Test), developed in the late 1980s, is intended especially for runners. It is used to test properties related to speed endurance. However, it can also be applied to various other sports, particularly ball sports.[350] In practice, several assistants are required during the test for measuring and timing. Because of this, the test is difficult to complete without expert help. However, a stripped-down version of the test may be independently completed using a heart rate monitor and a treadmill.

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The original test protocol involves running 8–12 sprints of 20 seconds each on a treadmill with a 3-degree angle and an increasing speed. The recovery period between the sprints is 100 seconds. The speed setting of the treadmill is increased by 1.4 km/h (0.87 mph) per each sprint. The starting speed is determined by the test subject's fitness level.

A later version of the test is suitable for the running track. It involves running 10 x 150 meters (492 ft) (with a recovery period of 100 seconds) at an increasing speed.[351] Jumps are performed before, after, and during the test. A jump performed five minutes after the recovery period gives a rough estimate of the recovery speed of the muscles. In addition, the blood lactate level is determined 40 seconds after the end of each sprint. The lactate level is also determined before and after the test.[352]

RAST TEST

RAST (Running Based Anaerobic Sprint Test) was developed at the University of Wolverhampton. Its properties are similar to those of the Wingate test.[353] According to the developer of the test, RAST is more readily applicable to sports that involve running.[354] It is also easier to complete without additional equipment (such as a bicycle ergometer and measuring devices). Today, it is widely used in ball sports (basketball in particular) to measure lactic acid tolerance levels.[355]

The RAST test involves running 35 meters (114 ft) six times as fast as possible. There is a 10-second break after each 35-meter sprint. Each sprint is timed to the one hundredth of a second.

The power of each sprint can be calculated using this formula:

Power = Bodyweight x Distance^2 / Time^3

Other quantities are calculated as in the Wingate test.
Peak power = The power of the fastest (usually first) sprint
Minimum power = The power of the slowest (usually last) sprint

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TESTS THAT MEASURE MOBILITY AND BODY CONTROL

The conventional method of measuring mobility and general control of the body involves using single one-way mobility tests. Physiatrists, orthopedists and physiotherapists measure specific joint angles particularly after surgery. A joint deviating from the normal range of movement (ROM) should indeed be rehabilitated so that normal function may be resumed.

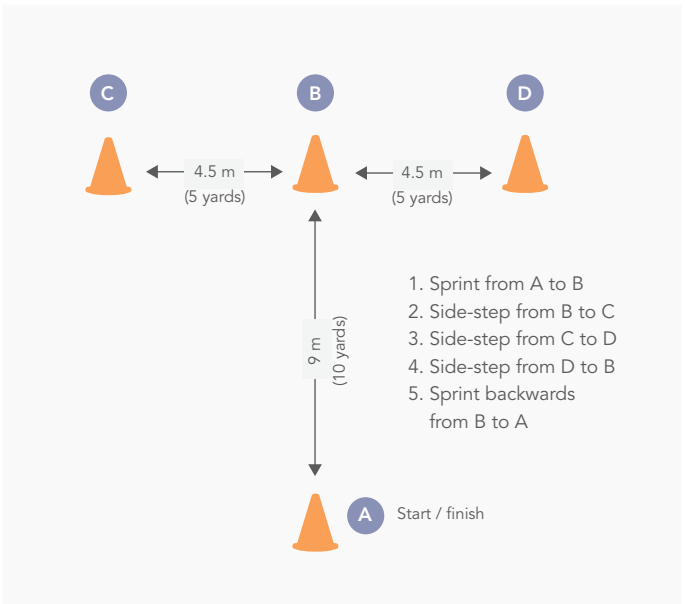
The main areas where mobility should be measured are the spine, hip, shoulder, knee, and ankle joint. A joint may be measured either passively with the help of an assistant or actively by extending a movement to the extreme position. A useful exercise for assessing general mobility is the overhead squat completed with a barbell.[356]

Home tests for measuring mobility:

- Forward bend test
- Shoulder mobility test
- SLR test (Straight Leg Rise)
- Lateral flexion test

Tests that measure body control and agility:

- Balance test on one foot (> 30 seconds is a good result)
- Y balance test
- Balance beam test
- Zigzag sprint
- Shuttle run test
- Throwing a tennis ball at a wall (from 2–3 meters or 7–10 ft) with one hand and catching it with the other hand
- Agility T-test (image below)



AGILITY T-TEST

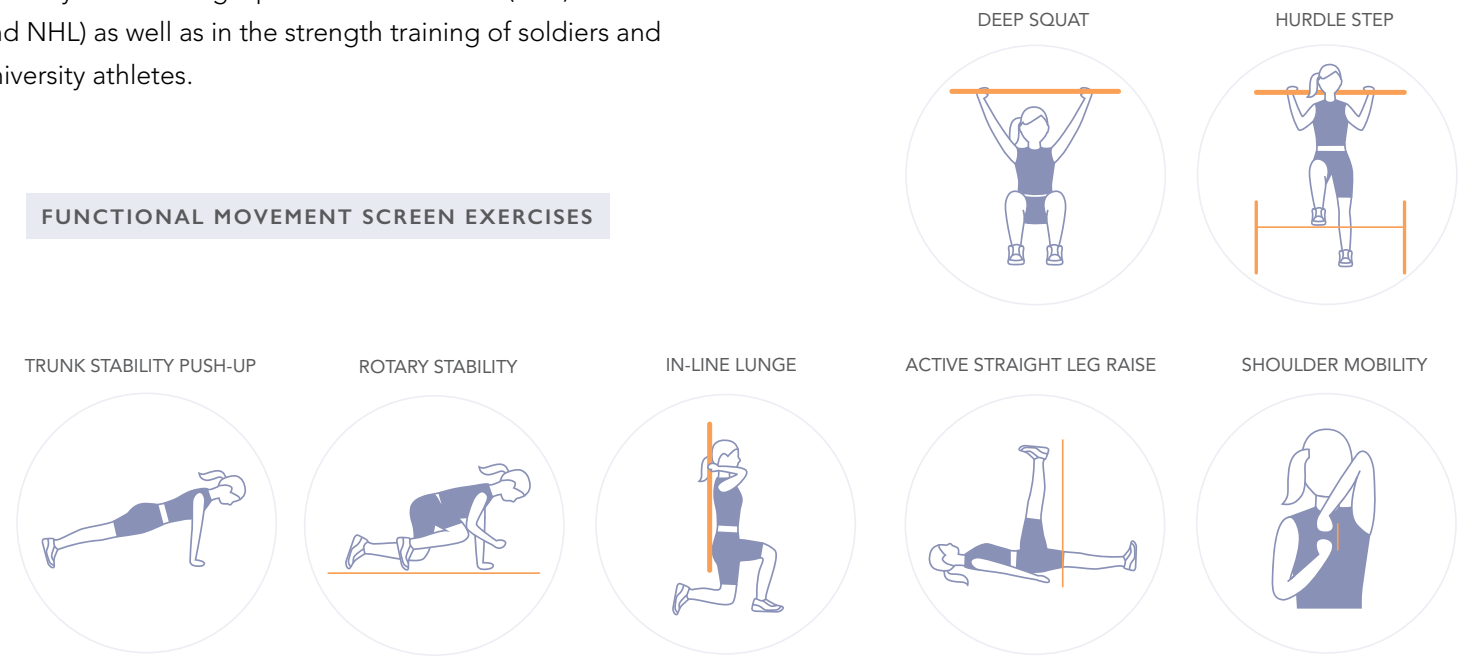
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FUNCTIONAL MOVEMENT SCREEN (FMS)

Functional Movement Screen (FMS) is the biohacker's choice when it comes to measuring mobility and body control. FMS is a set of seven exercises developed by Gray Cook, an American physiotherapist who specializes in strength training and body movement. The motivation behind developing the test was to create a battery of means to determine the limitations and problems associated with fundamental movement patterns.[357] [358] The FMS test is widely used amongst professional athletes (NFL, NBA and NHL) as well as in the strength training of soldiers and university athletes.

The FMS test assesses the mobility and balance of the body. The FMS test requires a specially trained instructor.[359] According to studies, the differences in interpretation from one tester to another are minimal, making the test reliable even if various instructors are used.[360] A poor FMS test result (lower than 14) correlates strongly with a higher risk of injury.[361]

FUNCTIONAL MOVEMENT SCREEN EXERCISES



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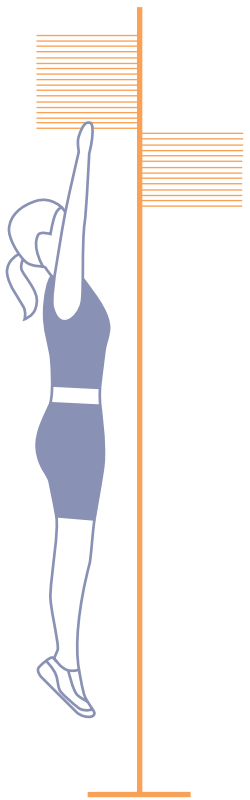
TESTS THAT MEASURE MUSCULAR STRENGTH

There are hundreds of tests available for measuring muscular strength. This section discusses the most widely used and studied tests that are also scientifically validated. Conventional maximal strength tests used outside a laboratory setting include the deadlift, bench press, back squat and shoulder press.[362] [363] Upper body strength endurance may be measured, for example, by using the maximal repetition count of pull-ups or push-ups. A link has been found between upper body maximal strength and strength endurance. For the lower body, strength endurance is affected more by maximal aerobic capacity than maximal strength.[364]

The muscular fitness tests used in the army mainly assess muscle strength endurance (maximal repetitions within 60 seconds performing sit-ups, push-ups, back extensions and pull-ups) as well as the relative speed strength of the lower body (standing long jump). However, the results can vary greatly depending on the techniques used. The U.S. Army uses the official and validated Army Physical Fitness Test (APFT) which is used to assess the muscular strength, endurance and cardiovascular performance of each soldier.[365]

VERTICAL JUMP

The vertical jump is one of the most accurate tests used for measuring the explosive strength of the lower limbs.[366] Indeed, the vertical jump has a strong correlation with the maximal speed strength of the lower body.[367] A good result for men is 60 cm (24 inches) and for women 50 cm (19.5 inches). Improving the result by ten centimeters (4 inches) usually requires a significant amount of practice. Vertical jumps of up to 122 cm (48 inches) have been officially measured for top athletes. One of these is basketball legend Michael Jordan.



Usually a vertical jump is performed either with both feet, stepping into the jump with one foot, or leading with one foot after a running start. The standing reach height of the test subject is first measured against a wall or a measuring stick. At the highest point of the jump, the test subject touches the wall or measuring stick (leaving for instance a magnesium powder mark).

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The difference between the standing reach height and the jump height is calculated, yielding the vertical jump result.[368] More advanced measuring stations use infrared laser for measuring. The best way to improve vertical jump results is plyometric training (see section "Plyometric training").[369]

VERTICAL JUMP RESULT CLASSIFICATIONS

EVALUATION	MEN (CM)	WOMEN (CM)
Excellent	> 70	> 60
Very good	61–70	51–60
Above average	51–60	41–50
Average	41–50	31–40
Below average	31–40	21–30
Poor	22–30	11–20
Weak	< 22	< 11

STANDING LONG JUMP

The standing long jump measures the explosive strength and elasticity of the body.[370] Completing the test requires no specific equipment or preparation. The measuring process is also easy. This makes the test very useful, even at home.

In terms of history, the standing long jump was an Olympic event until 1912 and a competitive sport until the 1970s. The official world record is 3.73 m (12 ft 2¾ in) from 2015. The standing long jump is a common fitness test in the armed forces around the world. Many professional sports also use the standing long jump as a testing method before the start of each season.

The result of the standing long jump is largely determined by the goal line selected by the individual. A study revealed that this external approach yielded better results than the internal approach of focusing on extending the knees as quickly as possible.[371]

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STANDING LONG JUMP RESULT CLASSIFICATIONS

EVALUATION	MEN (CM)	WOMEN (CM)
Excellent	> 250	> 200
Very good	241–250	191–200
Above average	231–240	181–190
Average	221–230	171–180
Below average	211–220	161–170
Poor	191–210	141–160
Weak	< 191	< 141

THE MARGARIA-KALAMEN POWER TEST

The Margaria-Kalamen power test, also commonly known as the step test, measures the strength and power of the lower limbs.[372] The test involves a six-meter run followed by running up a set of stairs as fast as possible while only stepping on every third step (the corresponding 3rd, 6th and 9th steps are marked). Each step is 17.8 cm (7 in) tall. The test measures the time spent ascending from the 3rd step to the 9th step. A modified version of the Margaria-Kalamen test is used in American football: in this version, the athlete runs up 20 steps, stepping only on every fourth step.[373]

The test may be completed independently using a stopwatch. However, the recommendation is to use an automatic measuring system which includes pressure-detecting mats on the 3rd and 9th step and a digital timing system. The power produced by the test subject is calculated using the following formula:

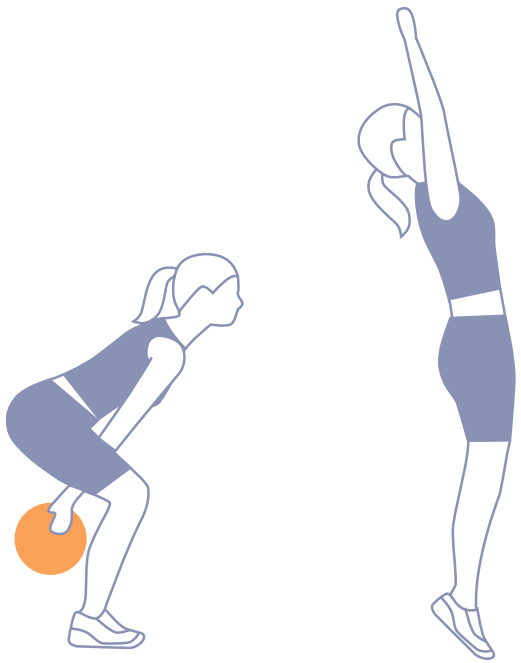
$$P = \frac{gmh}{t}$$

P = power
m = the mass of the athlete
h = the vertical height between the third and ninth steps
t = the time between stepping on the third and ninth steps
g = acceleration due to gravity (9,81m/s²)

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MEDICINE BALL THROW

A backward medicine ball throw is one of the easiest ways to measure the explosive force generation of the whole body and the upper body in particular. Throwing a medicine ball takes little practice – according to a study, 5–6 throws are required to reach the maximal result.[374]



In terms of explosive force, the medicine ball overhead throw appears to be comparable to the countermovement vertical jump. According to a study, bodyweight is directly proportional to the throw distance.[375]

In the test, a medicine ball weighing either two kilos (4.4 lb) (women and young people) or three kilos (6.6 lb) (men) is used. The medicine ball overhead throw may also be used as a training method. In this case, the weight of the ball can be greater (for example, 6 kg or 13.2 lb).

MEDICINE BALL SIDE THROW

The medicine ball side throw measures the explosive force of the core and upper body, particularly for men.[376] EMG studies have indicated that for right-handed people, the left side external abdominal oblique muscle in particular is strongly activated compared to other core muscles (see section "Skeletal muscles and motor control").[377] The test also appears to be comparable to the 1RM bench press.

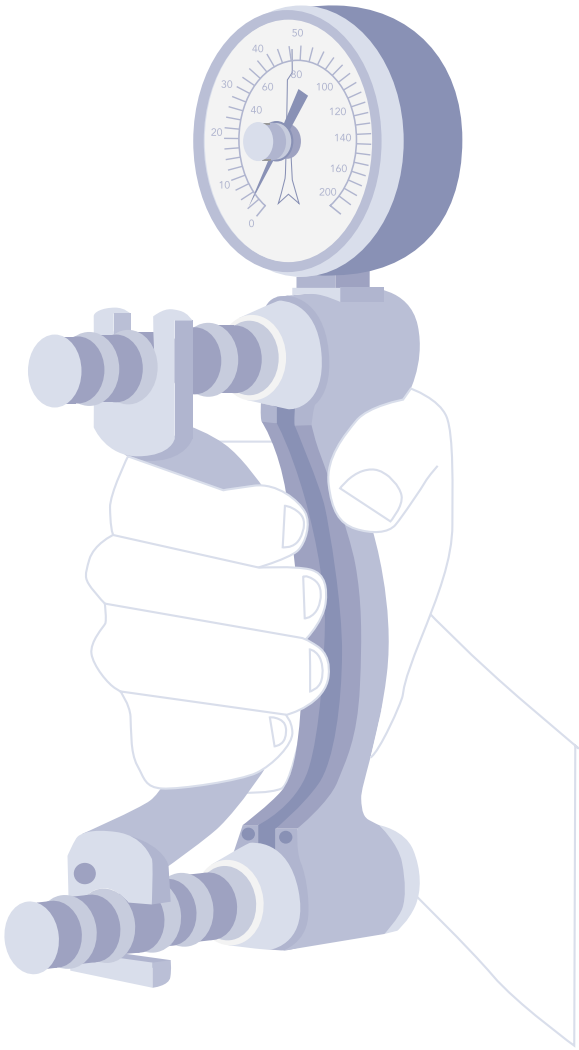
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HAND GRIP STRENGTH TEST

The hand grip strength test is one of the oldest muscular strength tests. It was used in the U.S. army as early as 1880. The correlation between hand grip strength and general fitness and even normal growth was discovered as early as the 1950s.[378] A dynamometer was developed in 1954 for measuring hand grip strength. Today, it is known as the Jamar/Saehan hand dynamometer. Other types of dynamometers also exist, including the Metitur Good Strength device.

For the hand grip strength test, various population- and device-specific reference values are available. The Finnish reference values are based on the Health 2000 study (see image on the next page). European and American reference values are similar to the findings of Health 2000 study.[379] The hand grip strength test helps assess and predict functional decline in old age and general muscular strength.[380] In middle-aged individuals, good hand grip strength may indicate protection from geriatric immobility and predict a longer life expectancy.[381]

The actual test is performed seated with back support. The upper arm is placed alongside the body and the elbow is at a 90-degree angle. The wrist is in a neutral position. The grip test is completed using the dominant hand, with



DYNAMOMETER

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the maximal grip lasting 3–5 seconds. It is repeated 2–3 times. The best result is recorded.

Hand grip strength may be improved using special hand grip exercise devices (various resistances), by lifting heavy objects or simply by hanging down. Hand grip strength is of critical importance in many strength-based exercises such as pull-ups, deadlifts, and carrying and picking up objects – not to mention climbing.[382] In absolute terms, the best hand grip strength results are achieved when the arm is straight (vs. the 90-degree angle used in the test).[383] The hand grip strength test may also be used to monitor the recovery process by comparing the test result to the result of the previous day.

HAND GRIP STRENGTH TEST REFERENCE VALUES BY AGE GROUP (KG)

FITNESS LEVEL		30–39	40–49	50–59	60–69	70–79	80+
Well below average	f m	under 27.1 under 45.8	under 26.0 under 45.8	under 23.6 under 41.8	under 20.1 under 37.3	under 15.8 under 28.6	under 11.3 under 20.3
Below average	f m	27.1–30.2 45.8–50.9	26.0–29.4 45.8–50.9	23.6–27.3 41.8–47.0	20.1–23.6 37.3–42.5	15.8–19.6 28.6–33.4	11.3–14.6 20.3–24.6
Average result	f m	30.3–32.9 51.0–55.4	29.5–32.2 51.0–55.2	27.4–30.3 47.1–51.8	23.7–26.6 42.6–46.5	19.7–22.6 33.5–38.9	14.7–17.4 24.7–30.9
Above average	f m	33.0–36.0 55.5–61.4	32.3–35.6 55.3–60.0	30.4–33.3 51.9–56.8	26.7–29.5 46.6–51.5	22.7–26.0 39.0–43.3	17.5–21.0 31.0–34.8
Well above average	f m	36.1 or over 61.5 or over	35.7 or over 60.5 or over	33.4 or over 56.9 or over	29.6 or over 51.6 or over	26.1 or over 43.4 or over	21.1 or over 34.9 or over

Source: Health 2000 study.

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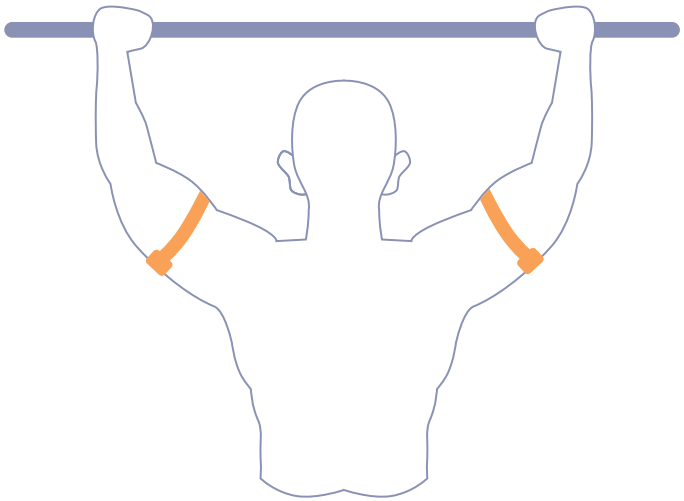
ELECTROMYOGRAPHY

Electromyography (EMG) measures the electrical activity in the muscle. In medicine, EMG is typically used to examine muscle and nerve damage. The first documented EMG measurement was taken as early as 1666 with an electric eel. The first successful measurement of human muscle activity took place in 1890 when French physiologist Étienne-Jules Marey (1830–1904) managed to record electric muscle activation on paper. The term "electromyography" was coined.

It was not until the early 1980s that it became possible to measure multiple muscle activations at once, kick starting the era of medical EMG use. The past decade has seen the appearance of the surface EMG (sEMG) which is of interest to the biohacker. It can produce precise measurements of muscle cell activation and fatigue patterns.[384 385 386] The most recent EMG applications include wearable biometric clothes that measure the heart rate and energy consumption in addition to muscle activation.

The benefits of sEMG for a physically active individual:

- Measures the activation level and force generation of the muscle
- Measures muscle fatigue
- Measures the activation of different muscle cell types (fast vs. slow)
- Measures the timing of muscle activation in relation to the movement
- May help correct muscular imbalance and lateral differences



EMG DEVICE

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MEASURING RECOVERY

The changes in the body caused by exercise only become beneficial with sufficient recovery time. Excess physical (and mental) stress and insufficient recovery time can easily lead to overreaching. On the other hand, if the objective is to develop various physiological properties, temporary overreaching is necessary as long as it is paired with sufficient recovery time.[387] Recovery assessment is therefore important, particularly when it comes to individuals with training goals.

Objective tools for monitoring recovery:

- Heart rate variability (HRV)
- Resting heart rate
  - Distinct increases in the resting heart rate are indicative of impaired recovery speed
- Heart rate recovery after exercise – X percent in Z minutes
- Bodyweight
  - Rapid loss may be indicative of excess fluid loss
- Reaction time test
  - Slower reactions are indicative of the impaired recovery speed of the nervous system
- RESTQ-Sport questionnaire for athletes[388]
- Mood (POMS questionnaire)[389]
- Orthostatic test

Subjective tools for monitoring recovery:

- Sleep quantity and quality
- Appetite
- Severity and duration of muscle soreness (DOMS)
- General energy level
- Measuring the sensitivity of the nervous system, for example, jump testing to a specific height
- General well-being

Factors affecting recovery:

- The amount and intensity of exercise
- General nutritional state (food quantity and quality)
- General health and illnesses
- Sleep quantity and quality
- Rest and relaxation
- Muscle care
- Various medications
- Alcohol use
- Jet lag
- High altitude
- Adapting to a new climate
- Work-related stress factors
- Social stress factors
- Emotional stress factors

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OVERTRAINING SYNDROME

Overtraining syndrome (OTS) is a medically recognized state,[390] in which the body has been under more stress than it has been able to recover from.[391] Overtraining is not just an athlete issue – it may apply to any physically active individual whose lifestyle includes several long-term stressors. According to various estimates, 15–60 % of athletes suffer from a prolonged overtraining syndrome during their careers. Endurance running athletes are particularly susceptible to overtraining.[392 393] An individual with overtraining experience often becomes sensitive to the effects of overexertion. Symptoms may appear after just one training session performed at an excessive exertion level.

The chronic overtraining syndrome is preceded by functional and intentional periods of excessive training. As the state of stress becomes prolonged, excessive training without sufficient rest may lead to overtraining.

SYMPTOMS ASSOCIATED WITH THE OVERTRAINING SYNDROME

PARASYMPATHETIC ALTERATIONS: MORE COMMON IN AEROBIC SPORTS (ENDURANCE TRAINING)	SYMPATHETIC ALTERATIONS: MORE COMMON IN ANAEROBIC SPORTS (HIIT, WEIGHT TRAINING)	OTHER SYMPTOMS
• Fatigue • Depression • Bradycardia (slow heart rate) • Lack of motivation	• Insomnia • Irritability • Agitation • Tachycardia (rapid heart beat) • Hypertension • Restlessness	• Anorexia • Weight loss • Lack of mental concentration • Heavy, sore , stiff muscles • Anxiety • Awakening unrefreshed

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TERMINOLOGY RELATED TO EXCESSIVE TRAINING AND OVERTRAINING

TERM	DEFINITION	PERFORMANCE DECREMENT	OUTCOME
Functional overreaching	Increased training leading to a temporary performance decrement and with improved performance after rest.	Days to weeks	Positive (supercompensation)
Nonfunctional overreaching	Intense training leading to a longer performance decrement but with full recovery after rest; accompanied by increased psychologic and/or neuro-endocrinologic symptons.	Weeks to months	Negative (due to symptoms and loss of training time)
Overtraining syndrome	Intense training leading to a long term (at least two months) performance decrement, with more severe symptomatology and maladapted physiology. Addional stressor not explained by other disease.	Months	Negative (due to symptoms and possible end to athletic career)

Source: Kreher, J. & Schwartz, J. (2012). Overtraining Syndrome: A Practical Guide. *Sports Health* 4 (2): 128–138.

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VARIOUS HYPOTHESES FOR THE CAUSE OF OVERTRAINING:[394]

- Glycogen hypothesis
  - Low glycogen reserves (manifests as muscle fatigue and heavy legs)
  - May be a result of increased cytokine secretion
- Central nervous system fatigue hypothesis
  - Crucial factor being serotonin and its dysregulation
- Glutamine hypothesis
  - Low glutamine levels in the food and body are a predisposing factor for infections and fatigue
- Oxidative stress hypothesis
  - People who exercise excessively suffer from a high level of oxidative stress which is a predisposing factor for silent inflammation, muscle fatigue, and muscle soreness
  - However, whether the oxidative stress is a cause or effect of overtraining is not clear
- Autonomic nervous system hypothesis
  - Imbalance of the sympathetic and parasympathetic nervous systems
  - Changes are evident in the heart rate variability analysis (HRV)
- Hypothalamus hypothesis
  - Changes in the HPA axis (hypothalamic–pituitary–adrenal axis) and HPG axis (hypothalamic–pituitary–gonadal axis) affect the levels of cortisol, ACTH, testosterone and other hormones in the body
  - Typical finding is a low ratio of testosterone to cortisol
- Cytokine hypothesis
  - Continuous hard training and insufficient rest create a chronic state of inflammation and a cytokine storm (IL-1b, IL-6, TNF-alpha)
  - High levels of cytokine in the body may cause decreased appetite, sleep disorders, depression, and general feeling of illness

The causes of overtraining are complex. None of the hypotheses mentioned above can fully explain all aspects of overtraining syndrome. Researchers suspect that many factors are involved. Overtraining syndrome also manifests differently in different people. Overtraining can be prevented by adjusting the exercise load according to one's mood (POMS questionnaire). A low mood indicates a lower exercise amount/load.[395]

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FACTORS THAT PROMOTE THE ONSET OF OVERTRAINING SYNDROME:

- Increased training load without adequate rest
- Lack of diversity in exercise
- Excessive competing
- Trouble sleeping
- Low energy intake from food, micronutrient deficiency
- Social and emotional stress factors (family, work, relationships)
- Previous illness
- Exposure to high altitudes
- Heatstroke
- Severe physical impact or shock, particularly in the head area

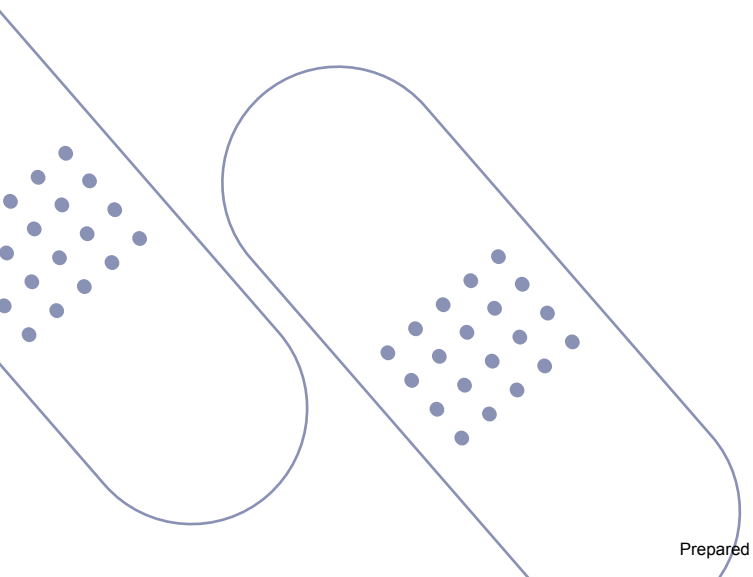
There are laboratory tests that may be utilized to diagnose the overtraining syndrome. However, no universal recommendations can be given. If overtraining is suspected, you should contact a specialist and have at least the following tests taken:[396]

- Immunological markers to check the state of the immune system (see the *Biohacker's Handbook: Invincible Immunity* for more details)
- Cortisol and testosterone and their ratio
  - Additional saliva-based 24-hour analysis (cortisol and DHEA)
  - From the urine, cortisol metabolites, the ratio of cortisol to cortisone in particular (increases significantly upon overtraining)[397]
- Thyroid hormones (TSH, T4V, T3V, rT3 and autoimmune antibodies if needed)
- Creatine kinase (reflects the breakdown of muscle cells)
- Iron balance (ferritin, transferrin saturation, serum iron and transferrin)
- Oxidative stress (FRAS test)
- Energy metabolism and mitochondria function as well as general nutritional state
  - Amino acids
  - Fatty acids
  - Organic acids
  - Vitamins and minerals
  - Oxidative stress
  - Citric acid cycle
  - Methylation

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TOOLS FOR RECOVERY AND REHABILITATION FROM SPORTS INJURY

- Pulsed electromagnetic field therapy[398]
  - Nerve injuries in limbs[399]
  - Muscle injuries and other soft tissue injuries[400]
  - Tenosynovitis[401 402]
  - Fractured bones[403]
  - Osteoarthritis[404 405]
  - DOMS (delayed onset muscle soreness)[406]
- Low level laser therapy (LLLT) and near-infrared therapy
  - Repetitive stress injuries and strains[407]
  - Acute and chronic neck pain[408]
  - Joint pain[409]
  - Shoulder and rotator cuff complaints[410]
  - Recovery from exercise[411]
- Peristaltic pulse dynamic compression (PPDC)
  - May alleviate muscle pain and speed up recovery[412]
  - May improve the mobility and flexibility of lower limbs[413]
- Compression clothing
  - May speed up recovery from exercise[414]
- Voodoo Floss Band
  - May alleviate muscle and joint pain and improve joint mobility[415]
- Kinesio taping
  - May help treat pain caused by musculoskeletal injury during exercise; may also prevent further injury of previously injured muscles/joints[416 417]
- Foam rolling / self-myofascial release
  - May improve joint range of motion and muscle performance and speed up recovery[418]



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GENETIC TESTS

Genetics has a significant impact on athletic ability and an individual's suitability for specific sports. It is estimated that more than 200 individual genes affect physical performance. Of these, more than 20 genetic variants have been associated with elite athletic ability.[419] [420] Genetic tests are here to stay. This also benefits an average active individual.

It is important to realize that regardless of what one's individual genetic profile looks like, all athletic properties (oxygen uptake, lactic acid tolerance, muscular strength and speed, recovery, etc.) can be improved (epigenetics). However, in terms of selecting a specific sport, it may be interesting and useful to have genetic data available. This way you can focus on training in a way that is optimal to your body.



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ACE

The ACE gene and its I/D polymorphism was the first genetic factor to be associated with human athletic performance.[421] The ACE gene regulates the angiotensin-1-converting enzyme. It affects the regulation of things such as blood pressure, fluid balance, red blood cell synthesis, tissue oxidation and the aerobic efficiency of muscles. The ACE I/I genotype is strongly associated with endurance properties whereas the D/D genotype is associated with strength and speed properties.[422]

ACTN3

The ACTN3 gene regulates the function of the alpha-actinin-3 protein. Alpha-actinin-3 is a protein that binds fast muscle cells (IIA and IIX) together. The polymorphism rs1815739 of this gene (RR genotype/R577X) is associated with improved speed properties of the muscle cells. This polymorphism is present especially in elite weightlifters and sprinters.[423] Conversely, the XX genotype of the same polymorphism is more often found in endurance athletes, although according to studies the association is quite weak. According to studies, the R577X variant of the ACTN3 gene is the genetic variant most strongly linked to athletic properties.[424]

MCT1

The MCT1 gene regulates the monocarboxylate transporter 1 protein which has an important function in the transportation of lactate (lactic acid) to muscle cells for oxidation. The polymorphism rs1049434 of this gene (AA genotype/A1470T) is associated with fast lactate transportation. It is found particularly often in endurance athletes. The AA genotype indicates the slower onset of muscle fatigue and faster recovery.[425] Conversely, the TT genotype is more often found in athletes who practice sports in which speed and strength are required.[426]

PPARGC1A

The PPARGC1A gene regulates the mitochondrial biogenesis and general function. It works together with the PPAR-γ nuclear receptor and participates in the regulation of sugar and fat metabolism.[427] Endurance exercise in particular activates the PPARGC1A gene.[428] The polymorphism rs8192678 of this gene (AA genotype/Gly482) is associated with excellent endurance fitness and the improvement of the anaerobic threshold in European men.[429] [430]

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ADRB (1,2,3)

Beta 1, 2 and 3 adrenergic receptors regulate the heart function and adipose tissue metabolism.

- The ADRB1 gene regulates the function of the beta-1-adrenergic receptor. The polymorphism rs1801252 (CC genotype/49Gly) and haplotype 49Gly:Arg389 of this gene are associated with improved athletic performance.[431]
- The ADRB2 gene regulates the function of the beta-2-adrenergic receptor. The polymorphisms Gly16Arg and Glu27Gln of this gene are found in athletes. In particular, genotypes Gly16 (GG) and Glu27 (GG) and haplotype Gly16:Glu27 are associated with strength athletics and improved strength properties.[432]
- The ADRB3 gene regulates the function of the beta-3-adrenergic receptor. The polymorphism rs4994 of this gene (AC genotype/Trp64Arg) is significantly more often found in top endurance athletes.[433]

COL5A1

The COL5A1 gene regulates the collagen alpha-1(V) chain which is associated with flexibility. A link has been found between flexibility and running economy in endurance sports. The polymorphism BstUI RFLP of this gene (rs12722 / TT genotype) is associated with good performance in endurance running.[434] [435]

IL-6

The IL-6 gene regulates interleukin 6 which acts both as a pro-inflammatory cytokine and an anti-inflammatory myokine (boosts muscle growth). IL-6 is secreted in response to muscle contractions in exercise.[436] [437] The polymorphism rs1800795 of the IL-6-174 G/C gene (GG genotype) is associated with positive strength and speed properties in European athletes.[438] [439]

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04
WORK

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"A person who never made a mistake never tried anything new."
– Albert Einstein (1879–1955)

"It's generally a waste of time to study productivity unless you have inspiring goals that demand rapid implementation."
– Steve Pavlina (b. 1971)

"Nothing is particularly hard if you divide it into small jobs."
– Henry Ford (1863–1947)

"'I'm too busy' just means 'I can't say no to the unimportant'."
– Robin Sharma (b. 1965)

"Efficiency is doing things right; effectiveness is doing the right things."
– Peter Drucker (1909–2005)

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"I'LL JUST TAKE A QUICK NAP BEFORE THE NEXT MEETING..."

Tim is a successful serial entrepreneur with no set working hours – he is on duty around the clock. Last night he got back from a business trip to Amsterdam around 2 AM. According to his calendar, the next meeting is at 8 AM at a nearby café. He can't miss it, even if that means only four hours of sleep. After a successful meeting, Tim lets out a sigh of relief – time for a quick nap before the next meeting at lunchtime.

Somewhere in the distance a phone is ringing. Still sleep deprived, Tim is awakened by a voice: "Hey Tim, are you coming to the meeting? I've tried to call you a couple of times now. It's 12:30 and the customer has been waiting for half an hour..." Tim jumps up, grabs a salad from the supermarket downstairs and rushes to the city branch in a taxi. It's 12:50 PM when embarrassed Tim finally greets his customer: "My apologies, I was just resting my eyes for a minute and… you know how it is."

This is not the first time Tim is late for a meeting. There is no relief in sight – his calendar shows that the next three weeks are going to be just as hectic. The last holiday he took was two years ago. Chronic sleep deprivation has become the norm over the past several years. Sometimes Tim is so tired he has trouble remembering the names of his employees.

Back problems, poor posture and other musculoskeletal ailments are ever-present in Tim's daily life. His breakfast consists of black coffee and a painkiller or two. At the end of the work day, he relaxes by enjoying a pint of beer with other workaholics. The quality and methods of Tim's work are in urgent need of improvement – but how? Tim seems to be trapped in a vicious cycle. Which will fail first, the body or the mind?

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ANT: THE PILLAR OF THE ECOSYSTEM

"Learn from the ants – how a tiny heart is big enough to love, help and care about another living existence."
– Munia Khan (b. 1981)

The archetype of the industrious worker in this book is the ant. A species older than dinosaurs, this insect is family-oriented and co-operative – in other words, eusocial. Ants have spread to nearly every corner of the world, the exceptions being polar glaciers and certain islands. There are more than 12,000 species of ants worldwide.

Worker ants gather food, clean the nest, care for the queen and generally oversee the functions of the colony. According to the latest research however, only 3 % of workers work continuously, and a quarter never work at all.[1] Some scientists believe that these ants are either too young or too old to work, while others suggest that they are too ill or need rest. The same study also found that 70 % of workers spend half the time idling. Wise old ants know what they are doing: work should not only be a constant struggle, rather it should also involve controlled amounts of rest and relaxation.



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MEANINGFUL WORK

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Enjoying or loathing one's daily work is of critical importance in terms of an individual's holistic well-being. Enjoying one's work is associated with significantly better health, particularly mental health.[2] Many people work under constant pressure to produce growth and development, causing more harm than good. Burnouts are particularly common in workplaces where the employees' happiness levels are poor and stress levels excessive.

Many company healthcare services are swamped with burnt out employees. According to a large study in 2012, 27.8 % of working US adults and an alarming 37.9 % of US physicians have had symptoms of burnout. According to the same study 23.2 % US working adults are dissatisfied with work-life balance, while 40.2 % of physicians have the same issue. Compared with high school graduates, individuals with MD or DO degree are at increased risk for burnout.[3] It is interesting to note that burnouts are more common in individuals under 40 years of age compared to those over 40.[4]

Burnouts are assessed using a survey form (MBI-GS or BBI-15) and observing changes in the general life situation and health. However, there are no universal criteria for a burnout diagnosis.

Predisposing factors for burnout include excessively high expectations of oneself and one's work, poor stress tolerance and coping mechanisms as well as a strong sense of duty. Other predisposing factors include vaguely defined duties, a lack of self-direction and a socially strained work environment.[5]



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To evaluate how well you are coping at work, ask yourself these key questions:

- Has your work made you cynical or critical?
- Do you find you have to drag yourself to work and it's hard to get the day started when you get there?
- Do your colleagues, customers or employers annoy you?
- Has your patience worn thin at work?
- Do you suffer from low energy levels at work?
- Do you find work disappointing?
- Do you use food, drugs or alcohol to feel better or to numb unpleasant feelings?
- Have you noticed changes in your sleeping patterns or appetite?
- Do you suffer from "unexplained" headaches, backaches or other physiological ailments?

Source: Mayo Clinic.

If you responded in the affirmative to more than one question, you should discuss coping strategies with your employer or a health care professional. It is also worth checking your general state of health.

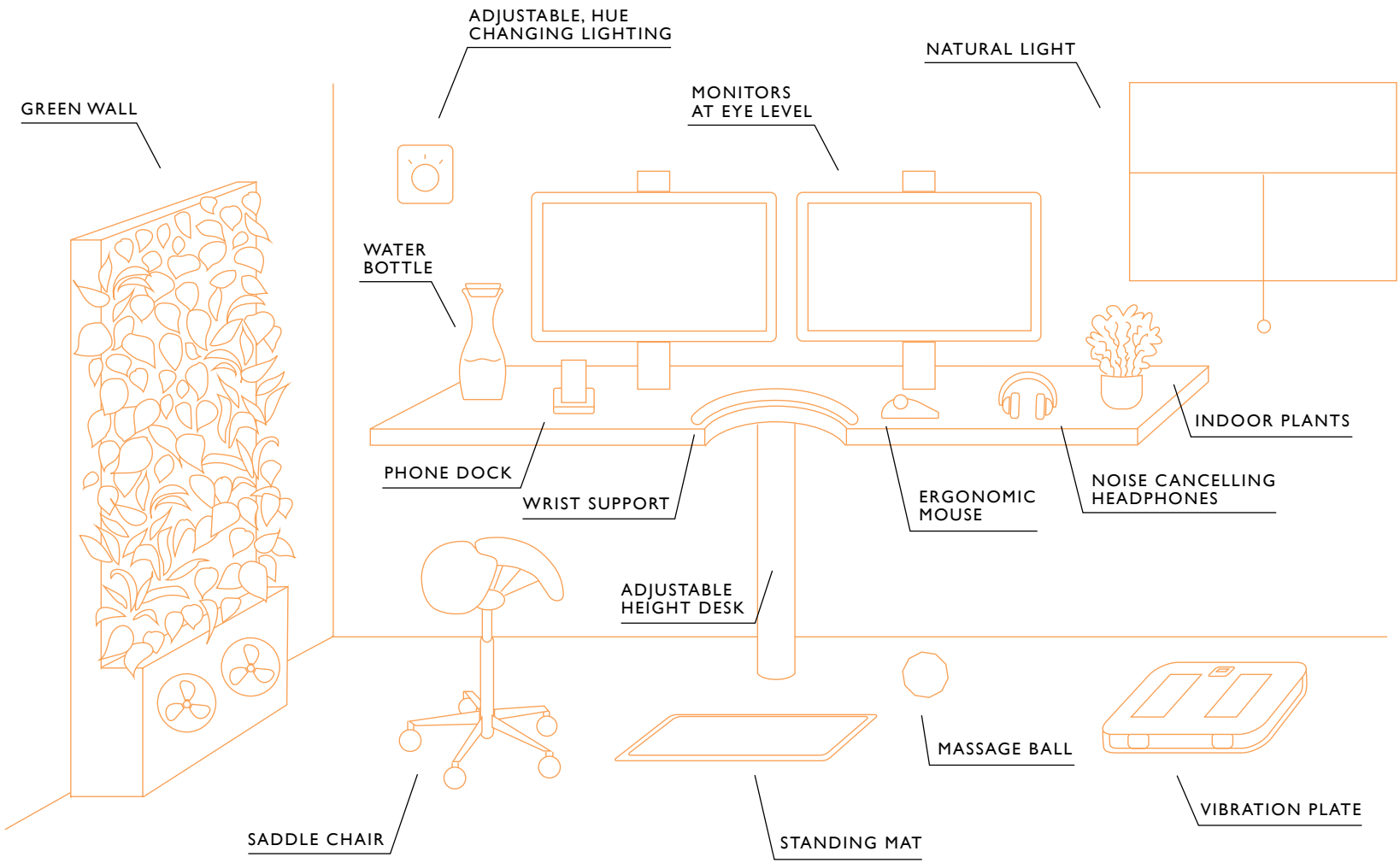


Biohacker's work manifestO

1. Your work should be genuinely enjoyable and meaningful to you.
2. Aim for self-directed freedom at work, for example regarding working hours.
3. Seek a positive and supportive atmosphere and a pleasant work environment.
4. Don't live to work, work to enrich your life.
5. Quality over quantity. Impact over efficiency.
6. Allow yourself enough time for rest and recovery.
7. Take regular breaks and use them to get up and move.
8. One half of your working time should be about producing an output while the other half should be spent on input – making connections and learning new things.
9. Research and select the best tools for repetitive tasks.
10. Pay attention to posture, ergonomics and working positions.

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PHYSIOLOGICAL SYSTEMS THAT AFFECT THE WORKING DAY

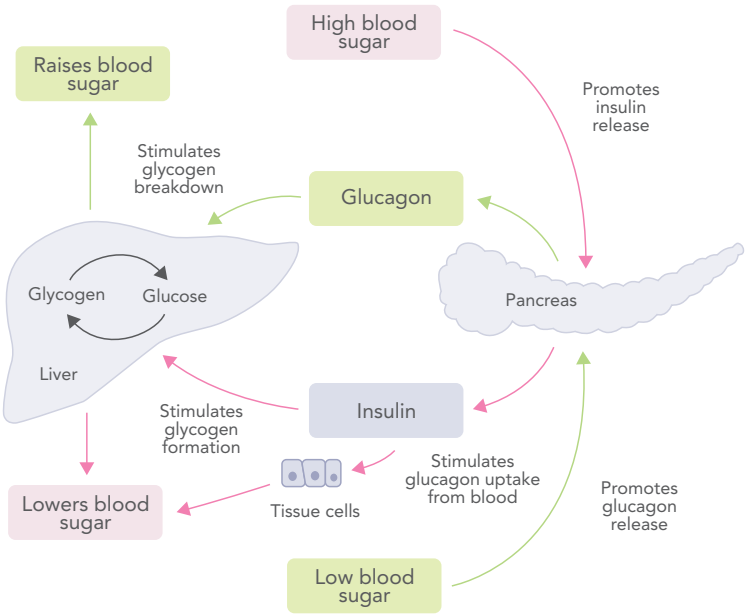
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The main physiological mechanism affecting the stability and general state of alertness during the working day is the regulation of blood sugar. Maintaining a stable level of blood sugar by refraining from overeating, continuous snacking and frequent meals is key to productivity and clarity of mind.

Constant spikes and crashes in blood sugar are a significant factor in mood swings. Hypoglycemia (low blood sugar) in particular can cause anxiety, irritability and edginess,[6] usually preceded by a significant drop in cognitive performance.[7] Conversely, for diabetics, a high level of blood sugar is associated with impaired cognitive performance and negative moods.[8] Blood sugar can reach a low level even in healthy individuals, for example due to prolonged exercise or fasting.[9] [10]

The activation of hunger signals is not necessarily preceded by a hypoglycemic (physiologically low) blood sugar level – usually the sensation of hunger and the urge to eat are triggered by a rapid decrease in blood sugar.[11] Thus, maintaining a constant level of blood sugar reduces hunger pangs and helps achieve a stable state of alertness throughout the working day.

REGULATING BLOOD SUGAR

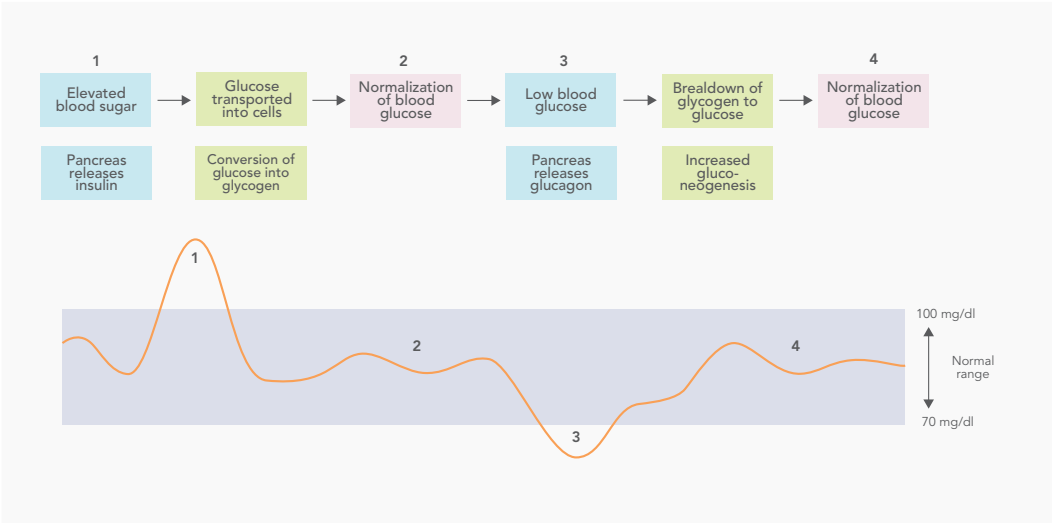


Source: Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

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REGULATING BLOOD SUGAR

Source: The McGraw-Hill Companies, Inc.



HORMONES INVOLVED IN BLOOD SUGAR REGULATION

The body's blood sugar regulation mechanism is a very sophisticated system which involves several hormones secreted by internal organs (see the table on the following pages).[12] The blood sugar level is regulated by a negative feedback system – this system seeks to bring the body into a state of systemic homeostasis, i.e. a state of equilibrium.[13]

When the blood sugar level is high, pulsations of hormones such as insulin are secreted into the circulation, lowering the blood sugar level.[14] Conversely, when the blood sugar level is low, glucagon and other hormones are secreted into the circulation to raise the blood sugar level.

Systemic blood sugar level monitoring takes place in the beta cells of the islets of Lagerhans in the pancreas[15] as well as in the glucose sensing neurons of the hypothalamus in the brain.[16]

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HORMONES INVOLVED IN BLOOD SUGAR REGULATION

HORMONE	IMPACT ON BLOOD SUGAR	SECRETED BY	METABOLIC EFFECT
Insulin	Lowers	Pancreatic beta cells	• Increases glucose absorption and storage (glycogen or fatty acids) • Increases the synthesis of fatty acids and proteins • Inhibits the breakdown of proteins and fatty acids
Glucagon	Raises	Pancreatic alpha cells	• Promotes the breakdown of glycogen into glucose • Promotes gluconeogenesis
Somatostatin	Raises	Pancreatic delta cells	• Inhibits the local release of glucagon from alpha cells • Inhibits the secretion of insulin and pituitary hormones
Cortisol	Raises	Adrenal cortex	• Promotes gluconeogenesis • Acts as an insulin antagonist (receptor blocker)
Adrenaline	Raises	Adrenal medulla	• Promotes the breakdown of glycogen into glucose • Promotes the release of fatty acids from fat cells

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HORMONES INVOLVED IN BLOOD SUGAR REGULATION

HORMONE	IMPACT ON BLOOD SUGAR	SECRETED BY	METABOLIC EFFECT
Thyroxine	Raises	Thyroid	• Promotes the breakdown of glycogen into glucose • Increases sugar absorption from the small intestine
ACTH	Raises	Anterior pituitary gland	• Increases the release of cortisol • Promotes the release of fatty acids from adipose tissue
Amylin	Lowers	Pancreatic beta cells	• Curbs the emptying of the stomach • Inhibits spikes in blood sugar
Glucagon-like peptide 1 (GLP-1)	Lowers	L cells in the small intestine	• Stimulates insulin secretion • Inhibits glucagon secretion • Decreases appetite
Gastric inhibitory peptide (GIP)	Lowers	K cells in the small intestine	• Promotes insulin secretion • Inhibits stomach acid secretion
Growth hormone	Raises	Anterior pituitary gland	• Acts as an insulin antagonist (receptor blocker)

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GLYCOLYSIS

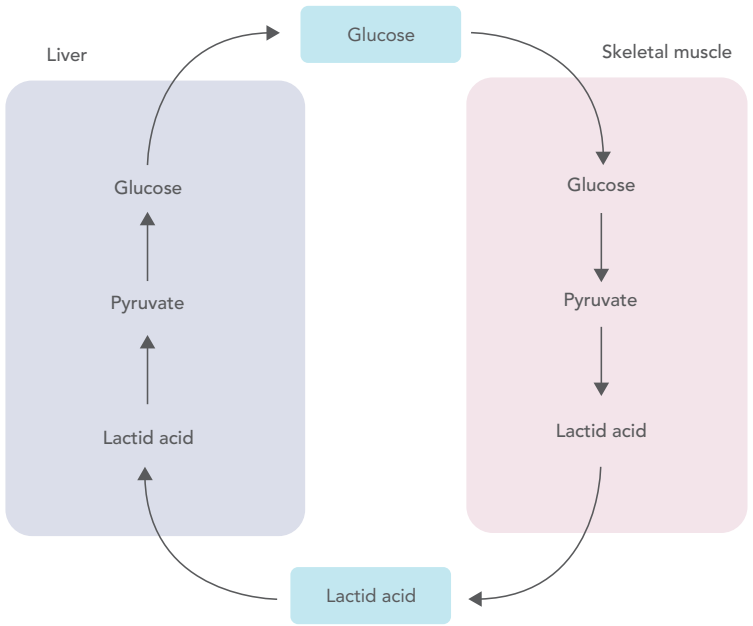
Glycolysis is a simple part of the glucose metabolism in which glucose is broken down into pyruvate or lactate. In addition to energy production, glycolysis regulates the secretion of insulin and is linked to glucose-stimulated insulin secretion in the pancreatic beta cells. In such cases, there is significantly increased secretion of the glucokinase enzyme which breaks down glucose into glucose-6-phosphate. Due to glucokinase activity being strongly linked to blood glucose levels and hence insulin secretion, glucokinase is considered the main blood sugar level sensor.[17]

GLUCONEOGENESIS

Gluconeogenesis is a metabolic process in which glucose is produced from lactic acid, glycerol, alanine and glutamine. Gluconeogenesis is activated particularly when the diet is lacking in carbohydrates. It also allows the body to stabilize the blood sugar level in the event that it becomes excessively low.

Gluconeogenesis takes place primarily in the liver (alanine) and the renal capsules (glutamine)[18] and, according to the latest studies, also in the intestine (particularly the small intestine).[19 20]

GLUCONEOGENESIS IN THE LIVER (FROM LACTIC ACID)



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Gluconeogenesis is activated when a person is in a starvation mode, following a low-carbohydrate diet, performing intensive exercise or fasting. Most of the biochemical reactions of gluconeogenesis are reversed compared to those of glycolysis.[21] The enzymatic reactions of gluconeogenesis are regulated by the hormone glucagon secreted by the pancreas.

FOODS AND SUPPLEMENTS THAT HELP REGULATE BLOOD SUGAR LEVELS

The effects of various foods on blood sugar have conventionally been described using the glycemic index (GI). It represents the change in blood sugar caused by the food compared to a reference value (glucose solution). Conversely, the glycemic load (GL) indicates the total effect the meal has on blood sugar. The concepts of GI and GL were originally developed for diabetics. There has also been attempts to apply them to the treatment of other health problems (such as cancer and heart diseases) with conflicting results. The GI and GL have been criticized for not considering individual variation and insulin response triggered by food. Also, the glycemic response triggered by a meal consisting of various ingredients cannot be reliably estimated.[22]

However, an insulin index has been developed to best represent the effect of food on the secretion of insulin.[23] So far the insulin index has received little attention although it appears to be of use to type 1 diabetics who have previously been accustomed to estimating and counting the amount of dietary carbohydrates.[24] The satiety score can be used along with the insulin index. It represents the sensation of satiety yielded by a specific food. For example, potatoes have a high insulin index of 121, however, their satiety score is also very high at 323 (see the table on the following pages for more information).[25]

A low GI diet is often recommended for individuals focused on weight loss. However, the glycemic index alone appears to have little impact on weight loss compared to other diets of the same calorie content.[26]

According to studies, a diet with a consistently high glycemic load is associated with a higher level of silent inflammation.[27] [28] Conversely the Mediterranean diet with a low glycemic load is quite effective in reducing obesity, insulin resistance, high blood pressure and high cholesterol, at least in women suffering from metabolic syndrome according to one study.[29]

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THE GLYCEMIC INDEX, INSULIN INDEX AND SATIETY SCORE OF VARIOUS FOODS

FOOD	GLYCEMIC INDEX	INSULIN INDEX	SATIETY SCORE
Oatmeal	60 ± 12	40 ± 4	209
Rice cereal	70 ± 9	66 ± 5	116
White bread (wheat) / reference value	100 ± 0	100 ± 0	100
French fries	71 ± 16	74 ± 12	116
Brown rice	104 ± 18	62 ± 11	132
White rice	110 ± 15	79 ± 12	138
Wholegrain bread	97 ± 17	96 ± 12	157
Potato	141 ± 35	121 ± 11	323
Pasta	46 ± 10	40 ± 5	119
Eggs	42 ± 16	31 ± 6	150

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THE GLYCEMIC INDEX, INSULIN INDEX AND SATIETY SCORE OF VARIOUS FOODS

FOOD	GLYCEMIC INDEX	INSULIN INDEX	SATIETY SCORE
Cheese	55 ± 18	45 ± 13	146
Beef	21 ± 8	51 ± 16	176
Lentils	62 ± 22	58 ± 12	133
Fish	28 ± 13	59 ± 18	225
Cooked beans	114 ± 18	120 ± 19	168
Apple	50 ± 6	59 ± 4	197
Banana	79 ± 10	81 ± 5	118
Yoghurt	62 ± 15	115 ± 13	88
Ice cream	70 ± 19	89 ± 13	96
Potato chips	52 ± 9	61 ± 14	91
Donut	63 ± 12	74 ± 9	68

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A diet of foods with a fairly low glycemic load and insulin index represents the preferred option for both health and mental alertness. Foods with a high insulin index should be consumed after exercise to replenish the glycogen reserves in the muscles and liver with insulin.

The spike in blood sugar caused by a meal may be balanced with various foods and supplements (see the following chapters). In Western countries, cinnamon is typically added to sweet desserts and baked goods that significantly raise blood sugar levels. In China, medicinal fungi and herbs are included in the diet due to their blood sugar balancing properties. The Ayurvedic medicine of India incorporates several herbs to balance blood sugar, such as *Gymnema sylvestre*. The Hindi word "gurmar" means "sugar destroyer".[30]

REGULATING BLOOD SUGAR WITH FOOD

Cinnamon is a spice derived from plants of the genus *Cinnamomum*. Cinnamon sold in Europe is usually Chinese (cassia) cinnamon (*Cinnamomum cassia, Cinnamomum aromaticum*) that contains coumarin which is toxic to the liver and kidneys when consumed in large quantities (see the Nutrition chapter of *the Biohacker's Handbook* for more information).

There are numerous varieties of cinnamon in the world with significant variation in the coumarin content. Consuming cinnamon as tea is a traditional way to use it. This method also significantly reduces coumarin intake. The toxicity of coumarin varies between individuals. It is linked to the ability of the genetic variant CYP2A6 to act as part of the liver's cytochrome P450 system.[31]

The properties of cinnamon that help regulate blood sugar and insulin sensitivity are strongly linked to its high chromium content as well as the effects of polyphenols and volatile polymers.[32] Depending on the study design and dose used, cinnamon lowers the fasting blood sugar levels by 10–29 %.[33] A typical recommended daily amount is 1–6 grams.[34] When deciding on the amount to use, it is recommended you consider your genetic background (CYP2A6 polymorphism), goals and any potential interactions with medicinal products.

The effects of many performance-boosting herbs and so-called smart drugs are often also associated with blood sugar regulation. For example, according to a meta-analysis from 2014, ginseng root has been found to help lower fasting blood sugar levels.[35]

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Foods and spices that help balance blood sugar:

- Cinnamon
- Bilberry
- Garlic
- Sour cherry
- Apple cider vinegar
- Coffee
- Chia
- Caraway
- Ginger
- Shiitake mushroom
- Lemon
- Turmeric
- Cacao (and dark chocolate)

Supplements and remedies that help balance blood sugar:

- Chromium
- Vitamin D
- Alpha lipoic acid
- Reishi
- Maitake
- Chaga
- Cordyceps
- Psyllium
- MCT oil
- Gymnema sylvestre
- Bitter melon
- Prickly pear cactus
- Fenugreek
- Purslane
- Banaba leaf
- Milk thistle
- Resveratrol
- Magnesium
- Panax ginseng
- Berberine
- Green tea
- Coriander
- Vanadyl sulfate

THE EFFECT OF COFFEE ON BLOOD SUGAR REGULATION

Long-term studies have found a link between coffee consumption and higher insulin sensitivity as well as a lowered risk of developing type 2 diabetes (see section "Coffee" in the Nutrition chapter of *the Biohacker's Handbook* for more information). Despite these findings, coffee may acutely decrease insulin sensitivity and raise blood sugar levels in individuals unaccustomed to caffeine.[36]

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The changes in blood sugar regulation caused by coffee are most probably due to caffeine.[37] Decaffeinated coffee has not been found to cause a similar swing in blood sugar levels. It appears that regular coffee consumption also reduces the effects of coffee on blood sugar.[38]

Individuals with a point mutation in the CYP1A2 gene (variant 164A>C) break down caffeine significantly slower compared to the general population. This is also linked to the blood sugar swings caused by coffee as well as higher levels of fasting blood sugar, particularly in individuals with high blood pressure.[39]

SLEEP AND BLOOD SUGAR REGULATION

Blood sugar levels fall steadily when fasting during waking hours. Conversely, blood sugar levels usually remain constant during sleep.[40] This is due to the blood sugar level initially rising by approximately 20 % at the beginning of the sleep cycle and then slowly falling to a normal level. These observations indicate that the utilization of glucose for energy is decreased during sleep.[41] During non-REM sleep, the glucose metabolism of the brain decreases by 11 %.[42] Conversely, glucose metabolism is increased during REM sleep and when awake.[43]

DID YOU KNOW

MELATONIN PRODUCTION, TRIGGERED BY SUNDOWN, AFFECTS BLOOD SUGAR REGULATION AND INDUCES DROWSINESS. MELATONIN RECEPTORS ARE LOCATED IN THE BRAIN AND THE PANCREAS. THE PANCREATIC RECEPTORS CAUSE INSULIN PRODUCTION TO DECREASE OVERNIGHT WHILE MAINTAINING THE LEVEL OF BLOOD SUGAR. NIGHT-TIME EATING IS ASSOCIATED WITH AN INCREASED RISK OF DIABETES. INDIVIDUALS WITH THE GG GENOTYPE OF THE MTNR1B GENE ARE EXCEPTIONALLY SENSITIVE TO THE EFFECTS OF MELATONIN.[44] THEY SHOULD AVOID EATING AT NIGHT AND EVEN EARLY IN THE MORNING.

Sleep deprivation has a significant impact on blood sugar regulation. Being severely deprived of sleep (four hours of sleep per night) for as little as one week impairs the use of glucose for energy and raises fasting blood sugar. It is also a predisposing factor for sugar metabolism disorders (pre-diabetes).[45] According to a study, individuals who sleep less than 6.5 hours per night have up to 40 % lower insulin sensitivity compared to those who get a normal amount (7–8 hours) of sleep per night.[46] Impaired insulin sensitivity

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is a predisposing factor for blood sugar swings, obesity and type 2 diabetes. According to a meta-analysis published in 2015, for blood sugar regulation and diabetes prevention, the optimal amount of daily sleep is 7–8 hours. It is worth noting that excess sleep may also impair blood sugar regulation.[47]

Sleep deprivation also interferes with the sensation of hunger by affecting the secretion of leptin and ghrelin. According to a study conducted on young men, insufficient sleep (4 hours) on just two consecutive nights decreased the level of the satiety hormone leptin by 18 % and increased the level of the hunger hormone ghrelin by 28 %. Individuals experiencing sleep deprivation reported a significant (24 %) increase in appetite, particularly for sweet, salty or starchy foods.[48] More comprehensive population studies have also yielded comparable results.[49 50]

INTERMITTENT FASTING

Intermittent fasting means fasting for a significant portion of the day (for example 16 hours) and consuming the daily food intake during the remaining eating window (for example 8 hours). The simplest way to implement this is to extend the overnight fast by skipping breakfast[51] and enjoying the first meal of the day in the afternoon.

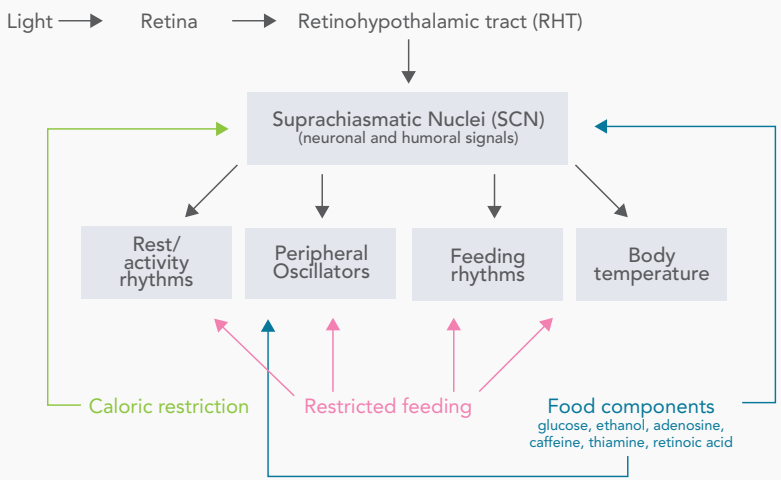
The concept of intermittent fasting counters the trend of "six small meals a day" promoted by the food industry and fitness culture of today. Grazing is often rationalized with claims of activating the metabolism and making weight management easier. However, no scientific basis has been found for such claims.[52 53] In fact, the basal metabolic rate (BMR) increases slightly after a 36-hour fast – it is only after 72 hours that the BMR begins to slowly decrease.[54] Intermittent fasting is helpful in achieving the desired calorie restriction[55] when the goal is removing waste products from the body (autophagy) or weight loss. Improvements in the regulation of sugar metabolism have also been reported in conjunction with intermittent fasting.[56]

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According to one study, there were no significant differences in the energy expenditure of individuals who ate frequently (6 times per day) compared to those who ate more infrequently (2 times per day). The same study found that those who fasted in the morning naturally ate slightly less overall and also consumed a slightly smaller amount of carbohydrates.[57]

From an evolutionary perspective, human beings evolved to eat when there is food available (usually in the evening) – the rest of the time was spent acquiring the food (in the morning and during the day).

REGULATION OF THE SUPRACHIASMATIC NUCLEUS



The effects of nutrition, light and other signals on the rhythmic functions of the body.

Source: Froy, O. (2007). The relationship between nutrition and circadian rhythms in mammals. *Frontiers in Neuroendocrinology* 28 (2–3): 61–71. Review.

In practice, intermittent fasting works well as it allows for the consumption of satisfying meals during the eating window while maintaining a moderate overall energy intake. For example, the consumption of food (particularly carbohydrates) in the evening significantly reduces the levels of stress hormones and promotes sleep[58] as well as stabilizing the secretion of leptin, ghrelin and adiponectin (burning fat).[59] Consuming meals later in the evening also activates the parasympathetic nervous system, calming the body and making it easier to fall asleep.

Intermittent fasting (and calorie restriction) may also be used to balance the function of the suprachiasmatic nucleus (SCN) that regulates the circadian rhythm of the body. The primary factor in SCN regulation is light (particularly sunlight).[60]

Intermittent fasting (or fasting in general) is not generally recommended for individuals who are under 18 years of age, pregnant, breastfeeding, severely fatigued or suffering from the chronic fatigue syndrome.

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Water, tea, coffee and mineral water are often consumed to maintain fluid balance when fasting. Low-energy green juices are also a good option as they contain essential micronutrients (see recipes on the following page). Highly active or athletic people may also consume essential amino acids (EAA) or branched chain amino acids (BCAA) in tablet or powder form to maximize recovery.[61]

There are various methods of intermittent fasting:

- Fasting for 24 hours 1–2 times per week ("Eat Stop Eat")
- Fasting for 20 hours followed by a 4-hour eating window ("The Warrior Diet")
- Fasting for 36 hours followed by a 12-hour eating window ("The Alternate Day Fast")
- Fasting for 16 hours followed by an 8-hour eating window ("Leangains")
- Fasting for 18 hours (fatty coffee allowed) followed by a 6-hour eating window ("Bulletproof Intermittent Fasting")

Health benefits of fasting/intermittent fasting:[62]

- May extend lifespan by slowing down the aging process
- May reduce the risk of developing metabolic and chronic diseases such as
  - Cancer
  - Diabetes
  - Metabolic syndrome
  - Arthritis
  - Neurodegenerative diseases (such as Alzheimer's disease)
- May improve insulin sensitivity and lower blood pressure
- May reduce oxidative stress in the body
- May improve the hormonal balance of the body

THE BIOHACKER'S GUIDE TO INTERMITTENT FASTING

Each of the authors of *the Biohacker's Handbook* has his own pattern for intermittent fasting that has evolved over various experiments.

Here is a sample pattern for a person who is physically active and works at the office:

- Fasting overnight and delaying the first meal as much as possible (usually until sometime between 3 PM and 6 PM depending on the timing of the previous meal)
- While fasting, drink plenty of fluids such as mineral water (rich in minerals, delays hunger)
- Hunger may be further delayed before the first meal by consuming an apple which is rich in fiber and relatively low energy (< 50 kcal) – consuming a cucumber may also delay hunger (negligible calorie intake)
- Consider the following low-carbohydrate drink recipes (next page):

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FRESHLY PRESSED GREEN JUICE

- *2 cucumbers*
- *4 celery stalks*
- *1 lemon*
- *5 cm (2-inch) piece of fresh ginger*
- *2 tbsp cold-pressed olive oil or vegetable oil blend*
- *1 tbsp green powder (wheatgrass, chlorella, spirulina etc.)*
- *¼ tsp salt*
- *also green drink powders mixed with lemon, salt and water*

ANTI-INFLAMMATORY SOUP

- *2 cups bone broth*
- *5 cm (2-inch) piece of fresh turmeric*
- *5 g medicinal fungi extract powder (reishi, chaga etc.)*
- *6 garlic cloves*
- *3 tbsp apple cider vinegar*
- *1 tbsp ghee*
- *1 tsp black pepper*
- *¼ tsp salt*

THE BIOHACKER'S PROTEIN-RICH FATTY COFFEE

- *1.25–2 cups coffee made with freshly ground beans (see section "Coffee" in the Nutrition chapter of the Biohacker's Handbook)*
- *4 tbsp hydrolyzed collagen protein*
- *1 tsp grass-fed butter*
- *1–2 tbsp MCT oil or caprylic acid*
- *1/2 tsp vanilla*

The coffee is kept in a thermos and consumed over an extended period of time (4–5 hours). When consumed slowly, the brew can balance blood sugar levels without interfering with the ketogenic effects of fasting. The optional collagen protein introduces a suitable amount of amino acids into the circulation without breaking the fast. In addition, the coffee significantly increases satiety and delays hunger.



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- The first meal should consist mainly of protein, fibrous vegetables and fat, and a small amount of carbohydrates (if desired)
- The second (and last) meal, consumed between 8 PM and 11 PM, should include plenty of carbohydrates as well as suitable amounts of fat and protein – when consumed close to bedtime it can help optimize sleep
- Physical exercise is often timed either at the end of the fasting period in the afternoon or after the first meal later in the evening

KETOSIS

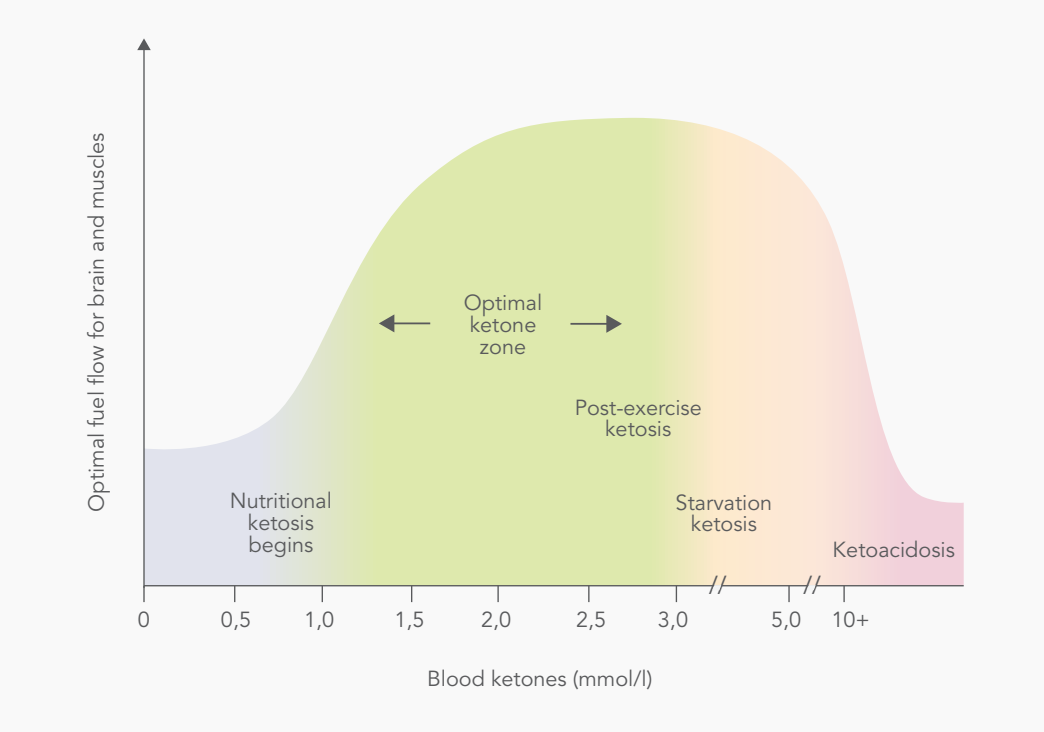
Ketosis refers to the metabolic state in which ketone bodies (and not glucose) form the body's primary energy source. Ketosis takes place when the consumption of carbohydrates has been repeatedly restricted to less than 50 grams per day or the overall energy consumed is less than 800 kcal per day (very low calorie diet or VLCD).[63] [64] If metabolism is functioning normally, the body is in a mild state of ketosis after a night's sleep (8 hours). The slow onset of ketosis after fasting is also directly proportional to abdominal obesity. The more obese the individual, the slower the onset of ketosis.[65]

KETONE BODY LEVELS IN THE BLOOD	KETOSIS STATE OF THE BODY
< 0.2	No ketosis
0.2–0.5	Mild ketosis
0.5–3.0	Ketosis caused by food consumption
2.5–3.5	Post-exercise ketosis
3.0–6.0	Ketosis caused by starvation
15–25	Ketoacidosis

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PHASES OF KETOSIS

Source: Phinney & Volek (2011).



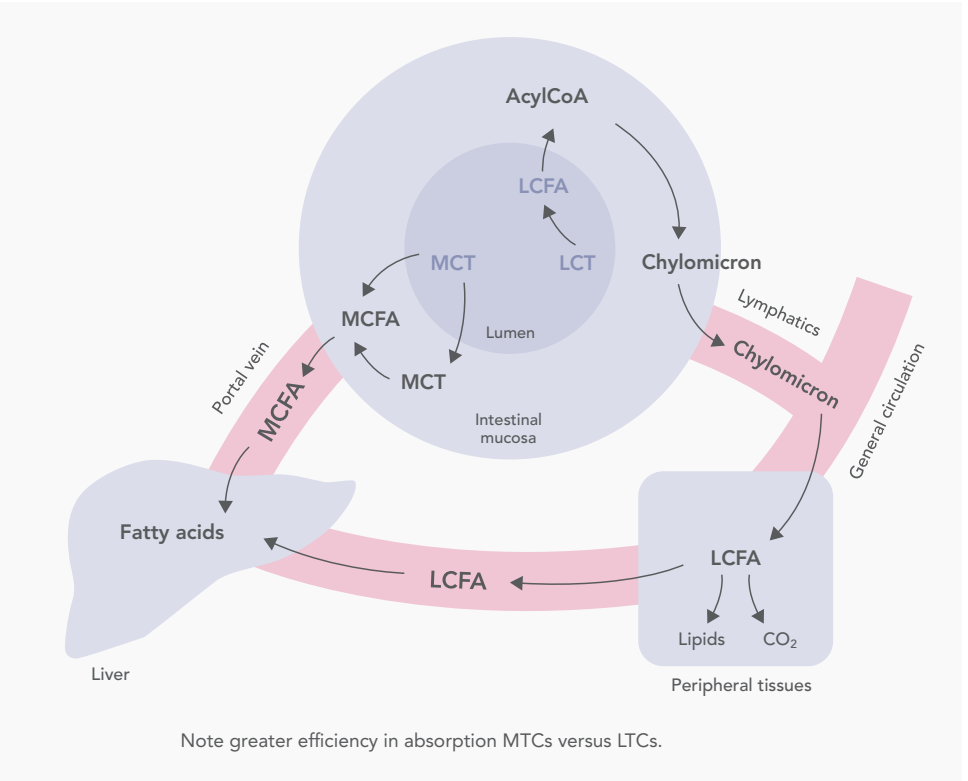
Ketosis is induced incrementally after 3–4 days of low calorie intake, fasting or limited carbohydrate intake, once the body's glucose stores (glycogen in the liver and muscles) are depleted. The activation of ketosis is a normal body reaction to secure the energy supply of the central nervous system and the brain when no glucose is available.[66 67]

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The onset of ketosis may be accelerated by consuming medium-chain fatty acids (MCT oil).[68] Compared to long-chain fatty acids, MCT fatty acids are rapidly used for energy due to being readily absorbed (see image). MCT fatty acids also quickly move into the mitochondria and unlike long-chain fatty acids, they do not require carnitine to oxidize fats. Ketosis may also be induced after intensive and prolonged exercise, particularly if only a small amount of carbohydrates was consumed before such exercise.[69]

Fasting or restricting the consumption of carbohydrates lowers insulin levels in the circulation while increasing the levels of glucagon and adrenaline.[70] This leads to the release of free fatty acids and glycerol (beta-oxidation) into the circulation. Oxidized fatty acids and glycerol form into acetyl coenzyme A which in turn enters the citric acid cycle in the mitochondria (see section "Metabolism – the Cornerstone of Energetic Life" in the Exercise chapter of *the Biohacker's Handbook* for more information).

THE ABSORPTION AND DELIVERY OF FATTY ACIDS IN THE BODY



Note greater efficiency in absorption MTCs versus LTCs.

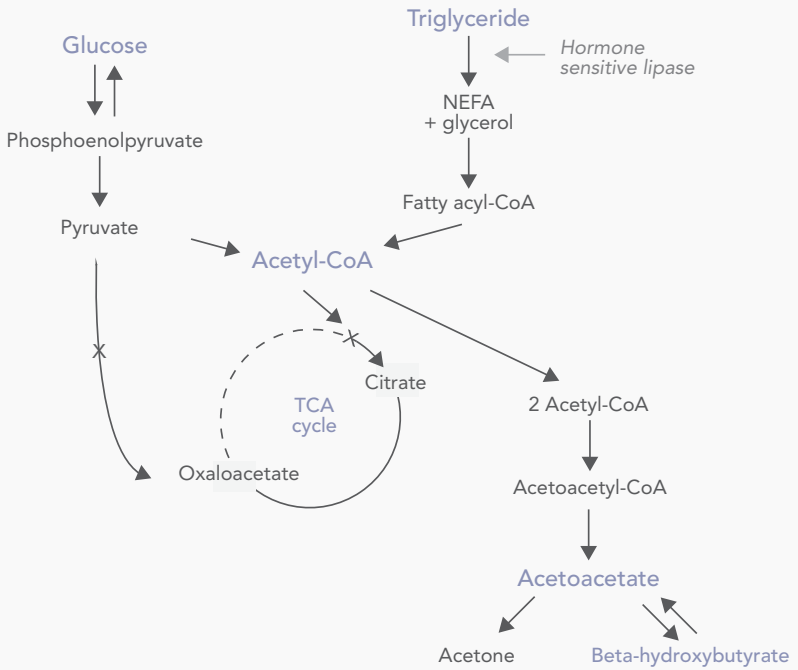
Source: Ward, D. & English, J. (2013). Medium chain triglycerides (MCTs). Beneficial effects on energy, atherosclerosis and aging. *Nutrition Review.*

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The production of ketone bodies is activated by the excessive production of acetyl coenzyme A. The process is activated when the malate has been used for gluconeogenesis and there is an insufficient amount of oxaloacetate available for the normal citric acid cycle (compared to a situation in which carbohydrates are continuously available). Acetyl coenzyme A is used to form acetoacetate and beta-hydroxybutyrate (BHB), the primary ketone body (see image).[71]

The ketone bodies produced by the liver are released into the circulation and delivered into the mitochondria of the brain, internal organs and muscles for use in energy production (ATP). BHB is restored to acetyl coenzyme A which is utilized in the citric acid cycle.[72]

THE BIOCHEMICAL REGULATION OF KETOSIS



During high rates of fatty acid oxidation, primarily in the liver, large amounts of acetyl-CoA are generated. These exceed the capacity of the TCA cycle, and one result is the synthesis of ketone bodies.

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Insufficient research exists to assess the safety of prolonged ketosis. So far the most extensive study conducted on a continuous ketogenic diet took place over 56 weeks. Health benefits were detected at least for overweight individuals.[73] From an evolutionary standpoint, it is not typical for human beings to remain in continuous ketosis for extended periods of time. Rather, after fasting or food acquisition, the energy deficit is normally corrected.

Studies conducted on rats indicate that ketosis increases the biogenesis (volume and quantity) of mitochondria and boosts the production of ATP, particularly in the brain.[74] This may explain why individuals in a state of ketosis often report significant improvements in their attention span and mental agility.

Potential health benefits of ketosis:[75]

- An effective weight loss method, particularly in the short term
- An effective method in the treatment of epilepsy
- May reduce the risk of cardiovascular diseases
- May reduce the risk of developing type 2 diabetes; may be helpful during treatment
- May help treat acne
- May be helpful in the adjuvant therapy for cancer
- May help treat polycystic ovary syndrome
- May help treat degenerative neurological diseases (such as Alzheimer's and Parkinson's diseases)

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REGULATING BLOOD PRESSURE

Blood pressure represents the pressure present in the arteries that lead blood away from the heart. Systolic pressure indicates the pressure during heart contraction, whereas diastolic pressure indicates the pressure while the heart is at rest (see section "Cardiac function" in the Exercise chapter of *the Biohacker's Handbook* for more information). Blood pressure continuously varies depending on the environment as well as individual reactions. Normal physiological mechanisms (such as the autonomic nervous system and kidneys) ensure that blood pressure is as functional and stable as possible in all situations.

Physiological factors that affect blood pressure include the pumping action of the heart, the density (viscosity) of the blood, the fluid volume present in the circulation and the peripheral vascular resistance. The latter includes structural changes (such as calcification) in the veins, as well as growth in the muscular layer of the veins due to increased pressure.

These factors may form a vicious cycle as the elevated blood pressure causes arteries to thicken, causing the blood pressure to increase further. Peripheral vascular resistance may also rise with increased sensitivity to vasoconstrictors. This may be caused for example by the continuous hyper-activity of the sympathetic nervous system (chronic stress).[76]

Along with the regulation of blood sugar, maintaining a relatively stable blood pressure (normal daily variation considered) is one of the primary factors in maintaining mental alertness. A sudden increase or drop in blood pressure may cause a variety of symptoms such as dizziness, fatigue, blurred vision, headache, increased heart rate, sweating or nausea. Momentary exertion at the gym or during exercise may cause a significant increase in blood pressure. Being nervous may also cause a temporary increase in blood pressure (for example the so-called "white coat syndrome").[77]

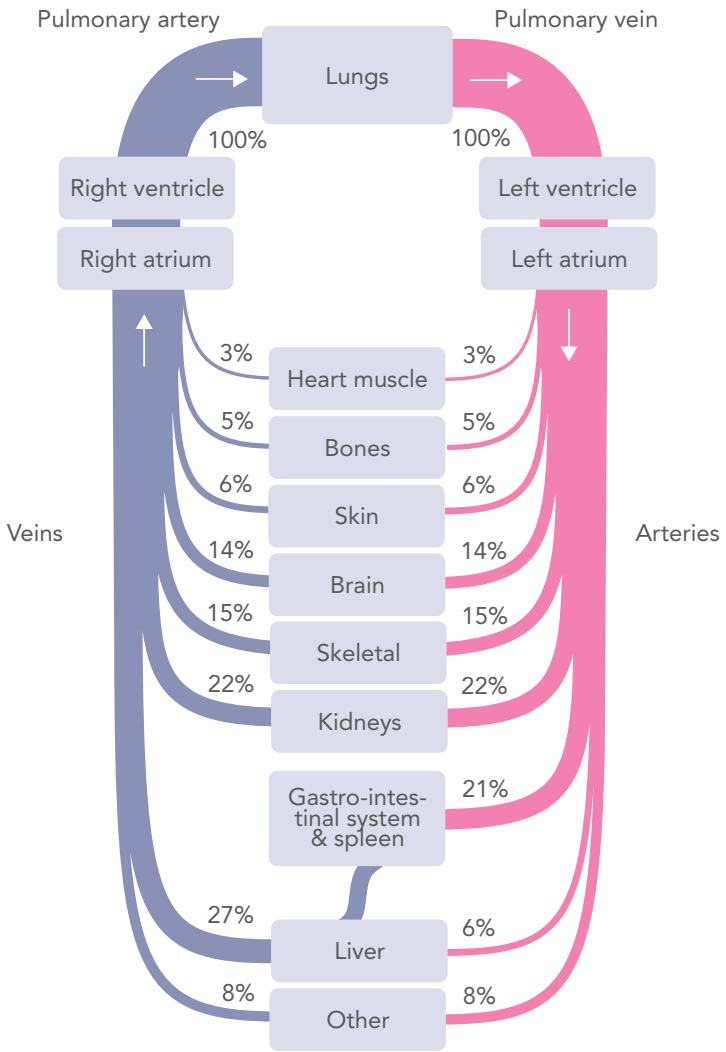
Another example is orthostatic hypotension (plummeting blood pressure) which is usually seen in the elderly. It involves a significant drop in blood pressure (systolic over 20 mmHg and/or diastolic over 10 mmHg) within three minutes of standing up. One of the main causes of orthostatic hypotension is Parkinson's disease and other dysregulation of the autonomic nervous system. However,

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it can also be caused by a low sodium diet, dehydration or hormonal problems (for example disorders involving the thyroid or the adrenal gland); it can also occur after a meal (postprandial hypotension). Alcohol and various drugs may also cause orthostatic hypotension.[78] [79]

REGULATION MECHANISMS

The regulation of blood pressure involves a variety of mechanisms. These include local (microcirculation), neural (neural regulation) and chemical factors that regulate the fluid balance of the body (humoral regulation). Other factors affecting the regulation of blood pressure include venous valves, muscle contractions and breathing (see the Exercise chapter of *the Biohacker's Handbook* for more information). To put it simply, the regulation of blood pressure is the sum of blood flow in various tissues as per their metabolic needs (see attached image).



DISTRIBUTION OF CARDIAC OUTPUT

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FACTORS AND METHODS INVOLVED IN BLOOD PRESSURE

HIGHER BLOOD PRESSURE	LOWER BLOOD PRESSURE
Stress[80]	Meditation and breathing exercises[81]
Activation of the sympathetic nervous system	Activation of the parasympathetic nervous system
Caffeine (no significant effect if consumed in coffee)[82]	Theanine[83]
Talking[84] and noise[85]	Silence and music[86]
Alcohol (more than one unit per day)[87]	Tea[88]
Many painkillers, antidepressants and contraceptive pills[89]	Acupuncture[90]
Office space and urban environment	Nature and forest ("forest bathing")[91]

HIGHER BLOOD PRESSURE	LOWER BLOOD PRESSURE
Evening (physiological phenomenon)	Morning (physiological phenomenon)
Excess weight[92]	Weight loss
Physically passive lifestyle	Physical activity[93]
High amount of fructose in diet (> 70 g / day)[94]	Low amount of fructose in diet (< 25 g / day)
"Junk food"[95]	Mediterranean diet[96] and paleolithic diet[97]
Sodium and chloride (NaCl, refined table salt and hidden salt)[98]	Magnesium, calcium and potassium; appropriate salt intake (mineral salt)[99]
Low level of vitamin D in blood[100]	Optimal level of vitamin D in blood
Artificial office lighting and over-illumination[101]	Sunlight (UVA radiation)[102]

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MEMORY FUNCTIONS

"Neurons that fire together wire together."
– Donald Hebb (1904–1985)

The word "memory" is derived from the name *Mnemosyne*, the Ancient Greek god of memory. Memory function has been studied for more than a century, yet it remains one of the greatest unsolved mysteries of biology. Spanish professor of neuroanatomy and 1906 Nobel laureate Santiago Ramón y Cajal (1852–1934) discovered the neuron (nerve cell) and developed interest in the connections that exist between such cells.[103]

It is estimated that the brain contains 10–100 billion nerve cells, each of them forming 1,000–10,000 synaptic connections with other cells. In theory, the brain could therefore store more than 100 trillion bits (100 terabits) of information. According to the latest estimate, its capacity could be up to 10 times that, i.e. one petabit.[104]

The workings of the mind and brain are often compared to a computer that processes information and stores it in memory. However, describing a biological organism



using mechanical metaphors can never be more than partially correct (see "Brain metaphors" on the following page). Many scientists today believe that the brain cannot be thought of as a mere machine that spews out zeros and ones.

Memory refers to the process of encoding, storing and retrieving information. The aspects of memory are usually referred to as sensory memory, short-term working memory and long-term memory. In some cases, short-term memory and working memory are separated into distinct memory systems, although they frequently work together.[105]

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The areas of the brain related to memory function in particular are the hippocampus, cortex, amygdala, basal ganglia, mammillary bodies and cerebellum (see section "The Structure and Functions of the Brain" in the Mind chapter of *the Biohacker's Handbook* for more information on the anatomy). The hippocampus is activated during declarative learning (see long-term memory on the following page) whereas the activation of the amygdala is associated with emotional memory.[106]

The hippocampus is crucial in processing and storing memories. It receives impulses from various parts of the cortex and forwards them to other areas of the brain. Hippocampus activity typically produces theta waves that are visible on an EEG. They are particularly frequent during REM sleep.[107] In addition to sleeping, hippocampus activity can be boosted with meditative exercises.[108] [109]

BRAIN METAPHORS[110]

The metaphors used for the human brain have become more and more advanced with the progress of technological development. For example, in the 3rd century AD when hydraulic pumps were all the rage, the brain was compared to a machine in which various liquids flow under pressure.

In the 16th century, French philosopher René Descartes described man as a complex machine. This comparison was based on the idea that thinking consists of small mechanical movements in the brain. When advancements were made in electricity and chemistry in the 1700's, it was thought that the functions of the brain were mostly due to various electrochemical reactions.

With the invention of the computer in the mid-1900's, the current concept emerged describing the brain as a computer that processes and stores information in the memory.

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ENGRAM

An engram forms when a specific nerve impulse travels repeatedly on the same nerve route. This brings about a biophysical and biochemical change. A recurring nerve impulse occurring between neurons is referred to as long-term potentiation (LTP). Instead of being stored in a specific location in the brain, engrams are distributed throughout the cortex.[111] The more complex the task, the more comprehensively the brain works to form the engram. The development of engrams is possible due to the plasticity of nerve cells, i.e. their ability to adjust to new stimuli.[112]

LONG-TERM MEMORY

Long-term memory forms a fairly stable and permanent storage unit for memory material. Information is moved from the working memory to the long-term memory if the information has either been processed in depth, repeated or associated with intense emotions.

Long-term memory is divided into two parts: declarative memory[113] which processes information, semantics and events; and procedural memory which processes skills that have previously been practiced and learnt. The procedural memory of individuals suffering from Alzheimer's disease is generally more functional and efficient compared to their declarative memory.[114] Conversely, individuals suffering from Parkinson's disease experience significant deterioration in both declarative and procedural memory.[115]

Canadian psychologist and neuroscientist Endel Tulving (b. 1927) divides long-term memory into episodic memory and semantic memory:

- **Episodic memory** stores all experiences and events that are strongly associated with the formation of personality and identity.[116]
- **Semantic memory** stores concrete information about various subjects, objects and concepts.[117]

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According to recent studies, these two aspects of long-term memory are strongly dependent on and linked to each other.[118]

Sufficient quality and amount of sleep has been found to significantly improve both procedural and declarative memory. REM sleep and deep sleep are particularly important for the purpose of strengthening engrams. Insufficient REM sleep is associated with poor spatial skills. As we age, the amount of deep sleep is reduced which may have a deteriorating effect on memory.[119]

LONG-TERM POTENTIATION (LTP) AND LONG-TERM DEPRESSION (LTD)

Long-term potentiation (LTP) is the most studied characteristic associated with the plasticity and memory function of nerve cells. LTP refers to the strong and frequent initial activation of certain synapses which later brings about the strengthening of such neuron pathways in certain parts of the brain (for example the hippocampus). When this neuron pathway is reactivated, for example by a sensory stimulus or thought, long-term potentiation ensures that the information previously stored is easily retrievable.[120]

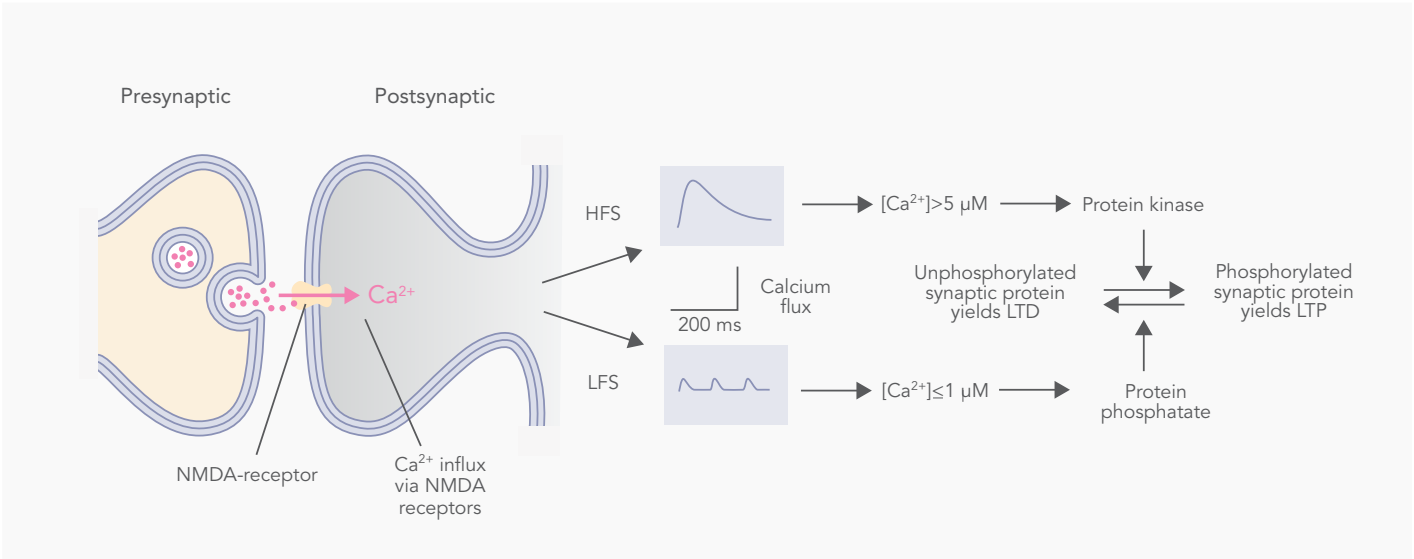
Various nerve cell molecules such as the NMDA receptor and calcium contribute to LTP. In fact, they are necessary for LTP to work. Other link mechanisms include the muscarinic acetylcholine receptor, nitric oxide synthase (NOS), dopamine receptor and glutamate receptor.

LTP occurs in two phases after the induction (high frequency nerve cell stimulation). In the early phase (expression), synapses become sensitized to impulses and increase the number of receptors. In the late phase, the repeated impulses induce protein synthesis in the cell. Thus there are long-term effects at the cell and gene level (see image on the next page).

The opposite of LTP is long-term depression (LTD) in which the intensity of signals is reduced. This prevents the synapses from being overloaded and maintains the stability of the brain and the entire central nervous system.[121] This regulation occurs by either increasing (LTP) or reducing (LTD) the number of NMDA receptors.[122] The mechanism is equivalent to the hormonal negative feedback system. LTD also plays an important role in erasing old engrams.[123]

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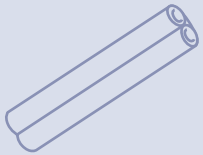
THE REGULATION OF LONG-TERM POTENTIATION AND DEPRESSION IN NEURONS



Methods and nutrients that contribute to long-term potentiation (LTP) and brain plasticity:

- Caffeine[124]
- tDCS (transcranial direct-current stimulation)[125]
- rTMS (repetitive transcranial magnetic stimulation)[126]
- Nicotine[127 128 129]
- Meditation[130 131 132 133]
- Racetams (prescription drugs) such as piracetam[134]
- Magnesium (especially magnesium threonate)[135 136]
- Forskolin[137 138]

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CINNAMON AS A MEMORY AID

According to a recent study (2016) conducted on mice, consuming cinnamon may improve memory function and brain plasticity in individuals with learning difficulties.[139] Other studies conducted on rodents indicate that cinnamon slows down the deterioration of cognitive skills[140] and improves the functional abilities of individuals suffering from Parkinson's disease.[141] It is possible that the future will see similar effects detected in humans.

SENSORY MEMORY

Sensory memory stores short-term memory data until a conceptual interpretation has been completed (approximately half a second; close to 3 seconds in echoic memory). Sensory memory is sizable in capacity, meaning that sensory information of various types can be processed simultaneously. Sensory memory is mostly automated and not under conscious control.

A sensory memory engram forms even when the individual is not paying attention to the sensation. Conversely, the long-term storage of a sensation requires conscious attention and the activation of long-term working memory.[142]

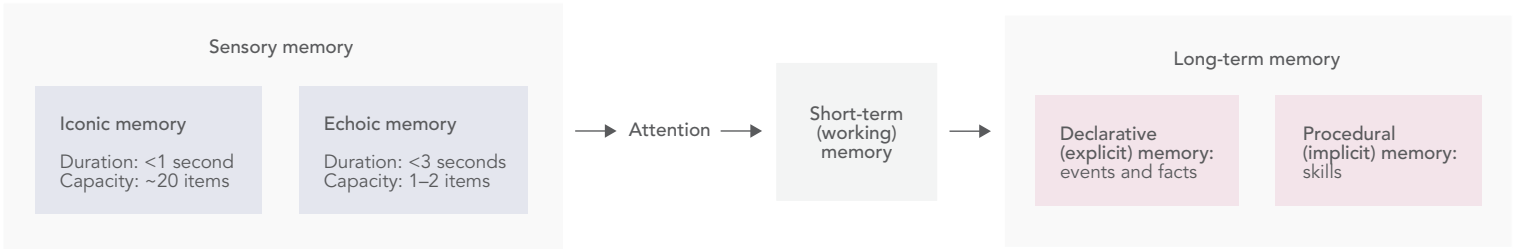
The location of the information stored depends on the sensory system. For example, visual information is stored in iconic memory and auditory information in echoic memory. Each sensory system has its own memory.

SHORT-TERM WORKING MEMORY

As its name implies, working memory represents the information storage currently in use for work or other activities. It is activated when the individual is making deductions, thinking, studying, solving problems or retrieving information from long-term memory for immediate use.

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THE OPERATIONAL CHAIN OF MEMORY



Working memory is also essential to the decision-making process (see section "Decision-making" for more information). Working memory can be divided into verbal and nonverbal (visuospatial) working memory based on the content processed.[143]

Working memory may be distinguished from short-term memory using neural subsystems. When working memory is functioning, the dorsolateral prefrontal cortex activates. It is not active when memory information is not being processed (i.e. when the information has not been moved to working memory).

THEORIES OF WORKING MEMORY FUNCTION

There are several theories regarding working memory function. One of the most frequently cited theories is Baddeley's model of working memory (1974).[144] It has been widely criticized for its complexity – yet it has proven useful when studying working memory.

Engle's two-part memory model is a more simple explanation of working memory function. It divides working memory into two parts: primary and secondary memory. Primary memory maintains the information being used while secondary memory retrieves information from elsewhere in memory.

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According to Engle's model, individual differences in memory function can be explained by the ability to stay focused on information, the ability to ignore the stimuli that interfere with one's concentration and the ability to retrieve information from long-term memory.[145] This explanation has gained a great deal of support: scientifically speaking, the simpler explanation is also the most likely (the Occam's razor principle).

Working memory functions are supported by inhibitory control which helps maintain concentration and prevents humans from reacting to all stimuli and thoughts present. Inhibitory control is a crucial factor in the ability to focus on a single matter at hand when the ability to block inner and outer distractions is necessary.[146] For example, meditating has been found to curb wandering thoughts and to improve concentration.[147] [148]

THE CAPACITY OF WORKING MEMORY

According to American psychologist George Miller (1920–2012), the capacity of working memory is estimated to be between 5 and 9 information chunks (the average being seven). He arrived at the figure seven in the 1950s while studying people's ability to repeat back sequences of digits. More recently, it has been claimed that the real figure is four information chunks (3–5). This is currently considered to be the most precise estimate of the capacity of working memory.[150]

According to the interference theory, one's ability to memorize is significantly affected if the number of memory items grow in relation to the time available for each information chunk. The more there is to remember within a short span of time, the more these new items interfere with the processing of previous items.[151] The capacity of working memory can also be compromised during stress and anxiety.[152] [153]

The duration of working memory is estimated to be less than 20 seconds. However, it is possible to extend this time by repeating the items to be memorized.[154]

THE ANATOMY AND PHYSIOLOGY OF WORKING MEMORY

Brain scans have made it possible to study the anatomy and physiology of memory functions. Working memory function is believed to take place mainly in the dorsolateral (processing of memorized information) and ventrolateral (maintenance of memorized information) areas of the prefrontal cortex.[155]

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However, it is not restricted to just these areas – many studies indicate that working memory function also occurs in the cerebral cortex.[156] It has been shown that working memory involving verbal functions and remembering objects predominantly activates the left side of the brain whereas spatial coordination predominantly activates the right side.[157]

Working memory activates various circuits depending on the task at hand. Focusing one's attention on something specific also activates various areas of the brain. For example, when one concentrates on something particularly important, this activates the left and right posterior parietal cortex, the ventromedial prefrontal cortex and the left inferior parietal lobule of the brain.[158] Transcranial direct-current stimulation (tDCS) of these areas may improve working memory.

Working memory function also varies based on sex. A comprehensive meta-analysis suggests that working memory activates limbic (such as hippocampus) and prefrontal areas of the brain in women and parietal areas in men significantly more than vice versa (see section "The Structure and Functions of the Brain" in the Mind chapter of *the Biohacker's Handbook* for more information).[159]

Conducting working memory exercises has been found to increase the number of dopamine receptors (DRD1) in the prefrontal cortex and temporal lobe.[160] According to studies, the neurotransmitters crucial for working memory function are dopamine, noradrenaline and acetylcholine (see section "Neurotransmitters" in the Mind chapter for more information).[161] Excessive or insufficient production of these neurotransmitters impairs the function of the prefrontal brain and, in particular, the dynamic network connectivity (DNC). Disruptions in DNC function are associated with various cognitive disorders.[162]

EFFECTIVE METHODS FOR DEVELOPING WORKING MEMORY:

- Meditation (see above)
- The so-called "brain training" programs may help develop working memory although there is conflicting research[163] [164]
- Regular physical activity helps to maintain proper working memory[165]

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- High intensity maximal or interval training[166 167] (especially four hours after a learning process)[168]
- Barefoot running[169]
- Yoga[170 171]
- Listening to tonal (harmonious) music[172] – fast classical music in a major key activates working memory and boosts processing speed particularly in the elderly (the Vivaldi effect)[173 174]
- Transcranial direct-current stimulation (tDCS) (see section "Technologies for the Mind" in the Mind chapter for more information)[175]
- Dual N-Back training may improve working memory (controversial findings)[176 177]
- Creatine monohydrate[178 179]
- Caffeine and theanine[180]
- Panax ginseng and Bacopa monnieri[181]
- Nicotine[182]
- L-tyrosine[183 184]
- Turmeric[185] and curcumin[186]
- Phosphatidylserine[187]



REACTION TIME

Studies on visual reaction time (VRT) indicate that it can also be trained. A shorter VRT is associated with more effective learning and better motor performance.[188] An auditory (hearing-based) reaction time has been found to be shorter than its visual counterpart.[189] This may explain why some individuals learn more effectively by listening rather than reading.[190] A study conducted on medical students indicates that men have a shorter reaction time compared to women. The same study also found exercise to significantly improve reaction time.[191]

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WORK ERGONOMICS AND METHODS FOR WORKING BETTER

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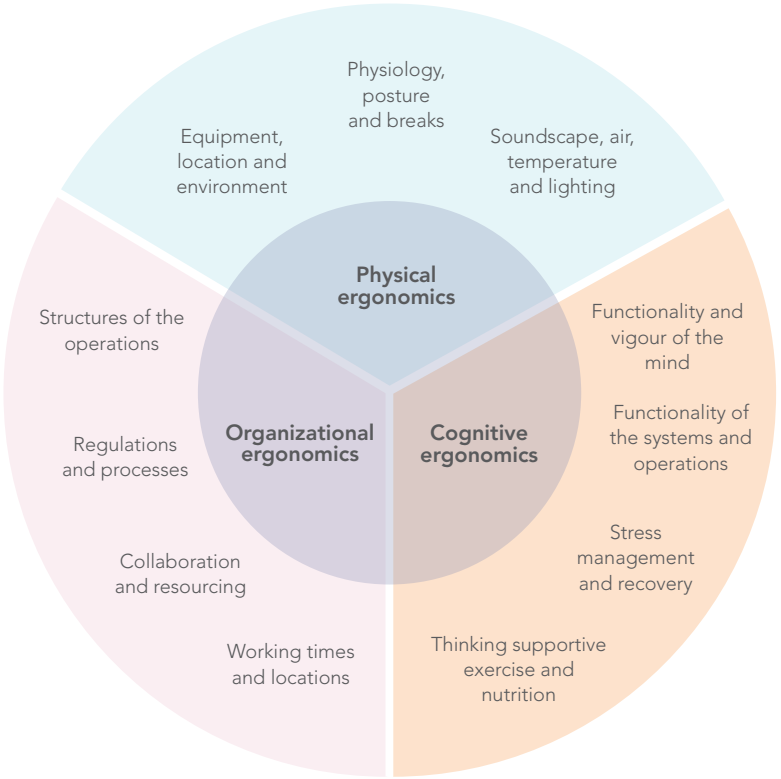


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The term "ergonomics" is derived from the Greek words ἔργον (*érgon*, work) and νομός (*nomós*, sharing). The concept and the idea behind ergonomics are rooted in the relationship between labor and economy. The need to optimize ergonomics is thousands of years old. The key question is: how to make people and tools function as efficiently and safely as possible?

Ergonomics is not just about tools or posture. Ergonomics may be divided into physical, cognitive and organizational ergonomics (see image). Going deeper, neuro-ergonomics utilizes knowledge of the human brain and neural function when designing user interfaces and systems.

Ergonomic thinking and design highlights efficiency, functionality and accessibility. The goal is to minimize physical, psychological and social strain. The goal of ergonomics is to maintain the ability to work and function as long as possible. Such optimization is a key part of the biohacker's way of assessing not only work itself but also the best possible way of working.



ASPECTS OF ERGONOMICS

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ERGONOMICS AND BACK PAIN

"You are as old as your spine."
– Chinese proverb

According to the 2012 National Health Statistics Reports as many as 54.5 % of U.S. adults had a musculoskeletal pain disorder. Nearly half of the reported problems were lower back pain and a quarter was neck related pain.[192]

Back pain has become more common, especially in the age bracket of 30–54. For some, back pain turns chronic and may linger for years. It is estimated that approximately 90% of back complaints lack a clear medical cause. The causes behind back pain are varied; these include poor work ergonomics, excessive workloads, stress, psychological disorders and emotional problems.[193]

Talking into a cell phone, browsing social media and typing messages, in particular, frequently cause us to assume unnatural positions. Many people use their phones in a position where the cervical spine is bent forward. Holding one's head at a 60-degree angle places the equivalent of a 60-pound (27 kg) weight on the cervical spine (see image on the following page).[194]

Over the years, this may cause significant deterioration of the cervical spine alongside other musculoskeletal ailments. In fact, children as young as 7 have been found to have changes in the cervical spine caused by the typical "text neck".

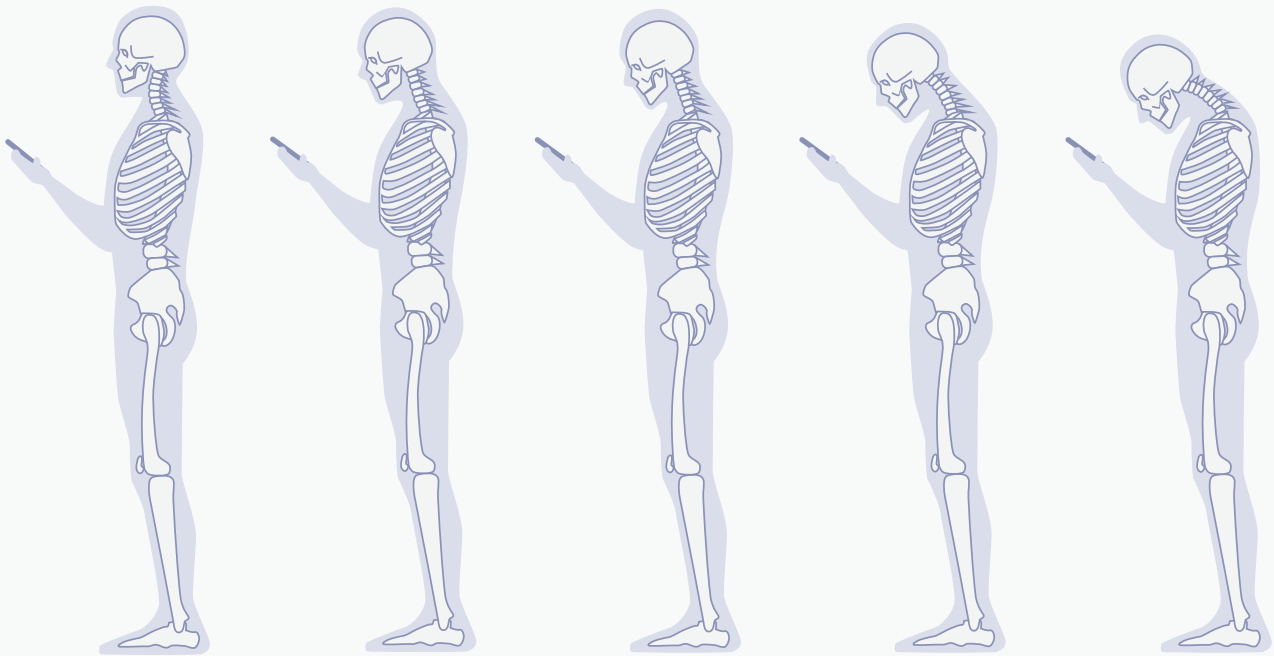
The Forward Head Posture (FHP) may also cause disorders in the function of the central nervous system.[195] Poor cervical spine posture may also cause pressure in the carotid arteries and thus impair the circulation in the brain,[196] causing the brain to have less oxygen at its disposal and therefore, impairing cognitive function.

Implement the following changes to optimize ergonomics when using a cell phone:

- Instead of typing, use voice control
- Avoid using a cell phone for extended periods of time
- Avoid browsing the internet and reading emails using the phone
- To rebalance after using a cell phone, straighten your neck, relax your shoulders, twist your thumbs upwards and breathe deeply
- Pay continuous attention to good posture and optimize the position in which you use your phone. Prop your elbows against your body and lift the phone to eye level.

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THE RATIO OF NECK POSTURE AND WEIGHT LOAD ON THE CERVICAL SPINE



Position	Neutral	15 degrees	30 degrees	45 degrees	60 degrees
Force to cervical spine	4–5 kg 9–11 lbs	12 kg 26 lbs	18 kg 40 lbs	22 kg 49 lbs	27 kg 60 lbs

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THE SIGNIFICANCE OF POSTURE IN WORKING LIFE

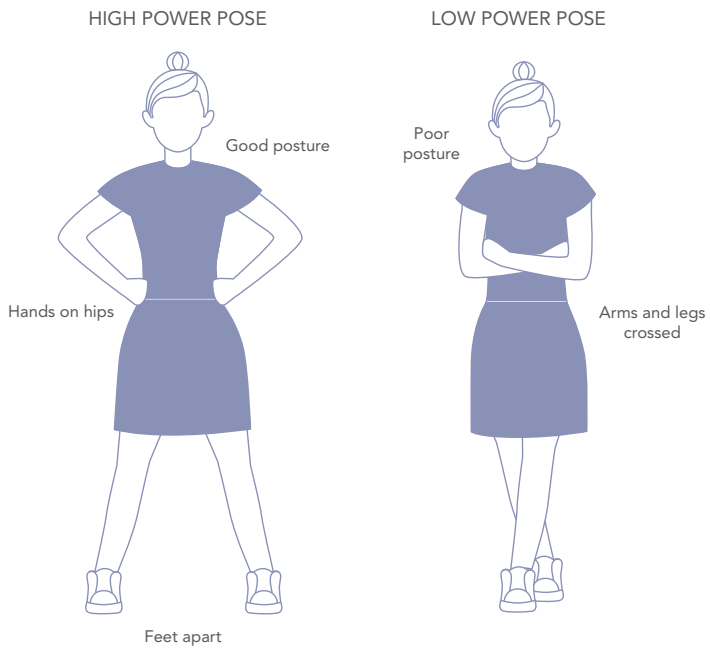
Body positions have been found to impact the formation of people's opinions. A typical example of this is nodding to signify agreement or shaking one's head when disagreeing.[197] An interesting finding in relation to body positions indicates that hugging oneself may reduce the perceived level of physical pain.[198]

Body positions are also linked to the feeling of power. So-called power positions are associated with higher levels of self-confidence and eloquence. According to a small study (42 test subjects) published in 2011, power positions may raise the level of testosterone and reduce the level of cortisol in the circulation. The effect the body position had on the hormone levels was apparent after just two minutes.

However, a more comprehensive study (200 test subjects) published four years later did not find a link between power positions and changes in hormonal levels. Instead, a perceived experience of power was associated with power positions. The study design varied slightly between these two studies which may help explain the differences in the findings regarding hormones.[199]

When conversing with another person, body positions communicate one's level of interest and establishes the perception of a shared experience. For example, if the upper bodies of both parties are aligned but the lower bodies are pointing in different directions, it is likely that at least one party is not interested in the conversation. Conversely, an open body position from the feet upward is a sign of genuine interest.[200]

Pay attention to your body position and sensations when you meet new people, negotiate, receive feedback or perform in front of an audience.



HIGH AND LOW POWER POSES

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SITTING AND THE LACK OF PHYSICAL ACTIVITY

Societal change, industrialization and urbanization have changed the natural patterns of human movement. Unlike in previous times, exercise as part of labor is now rare and affects few of today's knowledge workers. Starting from childhood, we are taught to sit still and be quiet. This is detrimental to the postural development of a growing child and may cause musculoskeletal disorders.

According to a large study conducted in the U.S. in 2017 a middle-aged or older adult sits on average for 11.4 hours per day. Previous studies of adults have found daily sitting time to average just nine hours per day. Those who sat in stretches less than 30 minutes had a 55 % lower risk of death compared to those who sat for more than 30 minutes at a stretch.[201]

In recent years, the health risks associated with sitting have been widely discussed in the media. It has been claimed that sitting too much is even more dangerous than smoking. Indeed, excessive sitting may increase the risk of cardiovascular diseases, metabolic syndrome, type 2 diabetes and various types of cancer (the last observed only in women). [202] [203] [204]

The lack of physical activity is one of the singular key factors in comprehensive follow-up studies and meta-analyses regarding all-cause mortality.[205] [206] A low level of physical activity and excessive sitting have a domino effect that undermines health in many ways. For example, it has been found to contribute to sleep impairment.[207]

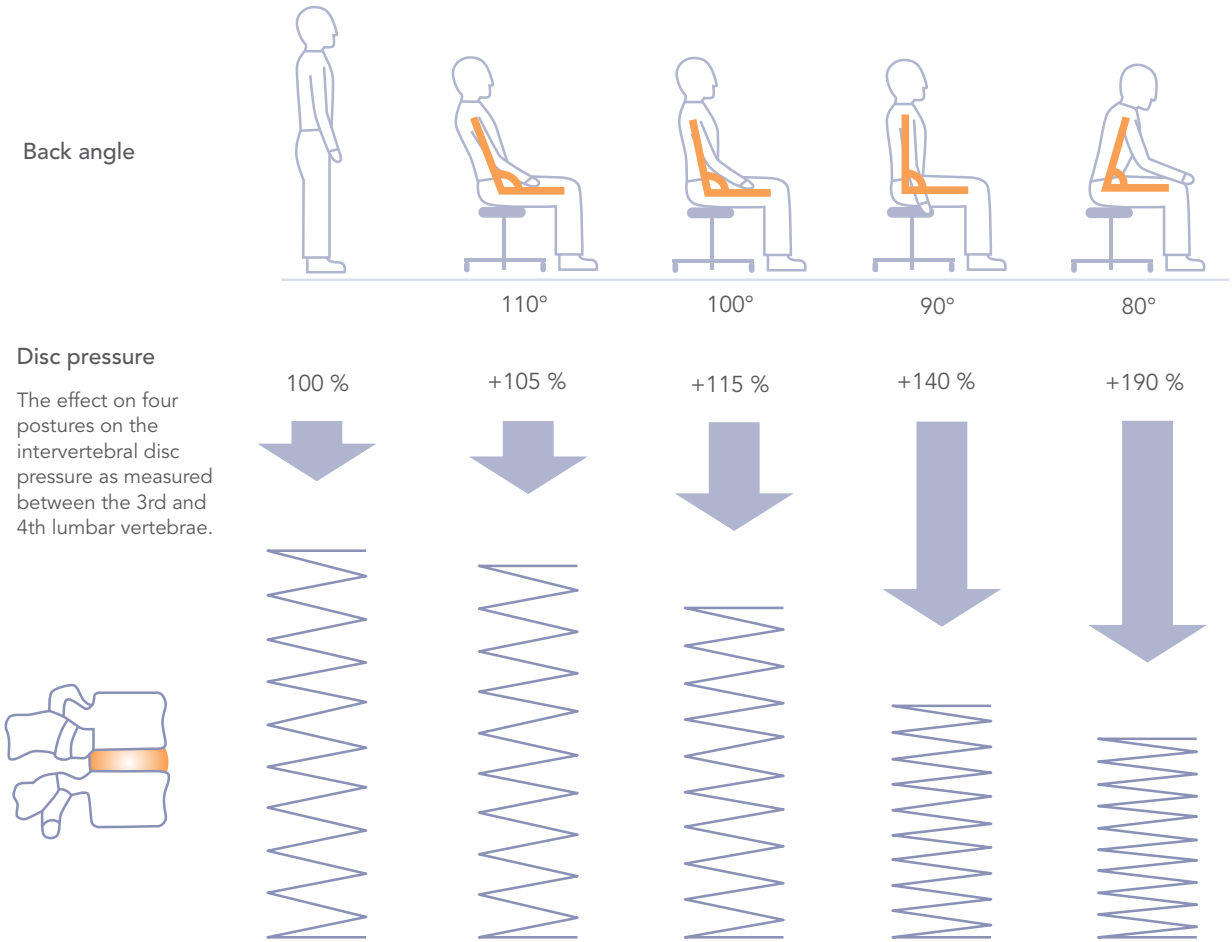
SITTING AND THE CIRCULATION

A feather-light press on the back of your hand can block a blood vessel. This is a good reminder of the delicacy of the veins. At work, we sit on our backside and genitals which is unfavorable for both the circulatory and nervous systems. When seated, the weight of the upper body squashes a large number of nerves and blood vessels in the thighs, buttocks, pelvic and genital areas.

A good seat supports the upper body by the ischia instead of the muscles. The rear edge of the male pubic bone is located directly below the pelvis. To prevent the pubic bone from squashing crucial nerves and blood vessels in the genital area, men tend to unconsciously tilt their pelvis backwards when sitting. As a result, the vertebrae of the lower back settle into a position that may cause deterioration of the lumbar spine.[208] [209]

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THE EFFECT OF BODY POSITION ON INTERVERTEBRAL DISC PRESSURE



Source: Hedman, T. & Fernie, G. (1997). Mechanical response of the lumbar spine to seated postural loads. *Spine* 22 (7): 734–743.

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Many women are used to sitting with their legs crossed. Prolonged, this position impairs circulation and increases health risks. In individuals suffering from hypertension, sitting cross-legged causes a significant rise in blood pressure.[210]

The biohacker's solution for minimizing the risks of sitting includes the following:

- Keep a sitting diary or wear an activity tracker to reduce the time spent sitting
- Do more work standing up and actively vary your working positions over the course of the day
- Use an application that reminds of short and long breaks from computer use
- If you do sedentary work, incorporate active movement into your breaks (e.g. jumping jacks, squats, push-ups or trampoline jumping – a vibration plate is also a feasible solution)
- When seated, use an adjustable saddle chair (see section "Saddle chairs and sitting," below)
- Move around when talking on the phone and schedule walking meetings whenever possible

SADDLE CHAIRS AND SITTING

A two-part saddle chair is the least harmful type of seat in terms of the function of the genital area. Circulation is significantly improved when loose trousers are worn (perhaps forgoing underwear) with the two-part saddle chair.

For men, sitting on a two-part saddle chair does not cause pressure at the base of the penis, unlike a conventional saddle chair or regular chair. There is less pressure on the pudendale nerve leading to the genitals, as well as on the pudendal vein and artery. Men also tend to spread their legs to relieve the feeling of pressure in the testicles.

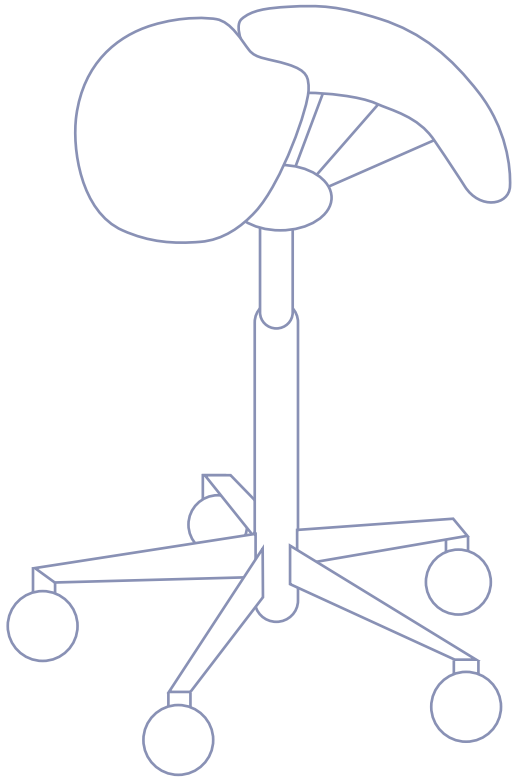
It should be noted that clothes that are excessively tight keep the testicles too close to the warm body. Increased temperature is detrimental to sperm quality. A two-part saddle chair lowers the testicular temperature to the optimal level of 33 degrees Celsius (94.1 degrees Fahrenheit) whereas sitting on a conventional chair often causes the testicular temperature to rise to body temperature, i.e. approximately 37 degrees Celsius (98.6 degrees Fahrenheit).

In male cyclists, the drastic pressure on the tissue covering the pubic bone has been found to cause erectile dysfunction, impotence and testicular cancer.[211] [212] Even in women, cycling causes damage to the external genital organs, leading to reduced tactile sensitivity in the area.[213] Similar problems may occur in horseback riders and individuals using a conventional (one-part) saddle chair.

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A two-part saddle chair encourages both men and women to tilt their pelvis forward without the uncomfortable feeling of pressure on the pubic bone and genitals. This helps them maintain natural lordosis, the ideal posture of the spine.[214] A two-part saddle chair effectively reduces pressure on the genital area and maintains a safe angle (135 degrees) between the thighs and the upper body.[215]

The gap in the middle of the chair also prevents pressure forming within the pelvis and the organs located in the pelvic area.[216] Prolonged sitting places constant pressure on the bladder, ovaries, uterus, vagina, prostate and rectum, causing further strain on these organs.



Further ergonomic solutions can be found in the bonus materials of the handbook

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STANDING AT WORK

Public awareness of standing desks increased between 2005 and 2018 as the health risks of sitting were studied and discussed more widely. Today, various types of standing desks and even desks equipped with treadmills may be found at furniture stores for moderate prices. Standing desks facilitate working ergonomically while standing up. The lymphatic and blood circulation is improved and the calorie expenditure is increased. At the same time, one avoids the health problems caused by sitting. According to a meta-analysis published in 2014, walking desks in particular improved the levels of HDL cholesterol and post-meal blood sugar.[217]

If you have previously spent the whole working day sitting, the general recommendation is to make the change to the standing position incrementally. A good start is to stand half the time – for example, you could stand for 30 minutes, followed by 30 minutes of sitting. Increase the proportion of standing incrementally until you stand (or walk) for most of the work day. Listen to your body – excessive standing can also cause physiological problems.

TIP

STAND PROPERLY

Point your toes straight and plant your entire feet firmly on the ground. At the same time, tighten your buttocks slightly and activate your abdominal muscles to maintain a stable and controlled position. Consciously practicing this position makes standing pleasant and more stable.

Try the following exercises when using a standing desk:

- Roll your shoulders in both directions
- Stand on one foot
- Perform squats or stay in a squatting position for a moment
- Do push-ups, pull-ups, jumping jacks or burpees throughout the day
- Place one foot temporarily on a platform

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- Move spontaneously (e.g. by changing the standing position or rotating joints)
- Do plank exercises to make standing easier
- Do kettlebell swings once per hour
- Occasionally use a bar stool or a saddle chair
- Shake and pat various parts of your body
- Massage the soles of your feet using a massage ball (e.g. an ice ball)
- Jump on a miniature trampoline or stand on a vibration plate once per hour
- Use a computer application that forces you to take breaks

Health benefits associated with standing:

- Reduces the risk of developing obesity[218] [219]
- May improve blood sugar regulation[220]
- May reduce the risk of cardiovascular diseases and diabetes[221]
- May reduce perceived fatigue and the tendency to suffer from back pain[222]
- May improve mood and energy levels and reduce neck pain[223]
- May extend lifespan[224]

ANTI-FATIGUE MATS

Anti-fatigue mats are flexible and adaptable mats that are suitable for standing on at work. They force one to perform micromovements that improve balance and proprioception. Anti-fatigue mats also prevent the lower back pain sometimes caused by standing,[225] as well as leg fatigue and swelling.[226] In addition to anti-fatigue mats, there are many board-type products available that improve balance and body control.

WALKING DESK

In the United States, professor Seth Roberts (1953–2014) inspired many health gurus to adopt a light and portable walking desk as early as 1996. Nathan Edelson, the original developer of the idea, had already published studies on the topic in the late 1980s.[227] [228] It was not until 20 years later that the first walking desk became available for purchase.

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The user of a walking desk walks at a slow phase, typically 2–3 km/h (1.25–2 mph) while working on the computer. The speed may be increased slightly during a conversation or a telephone call, for example. One can easily walk up to 10 kilometers (6 miles) over the course of a working day.

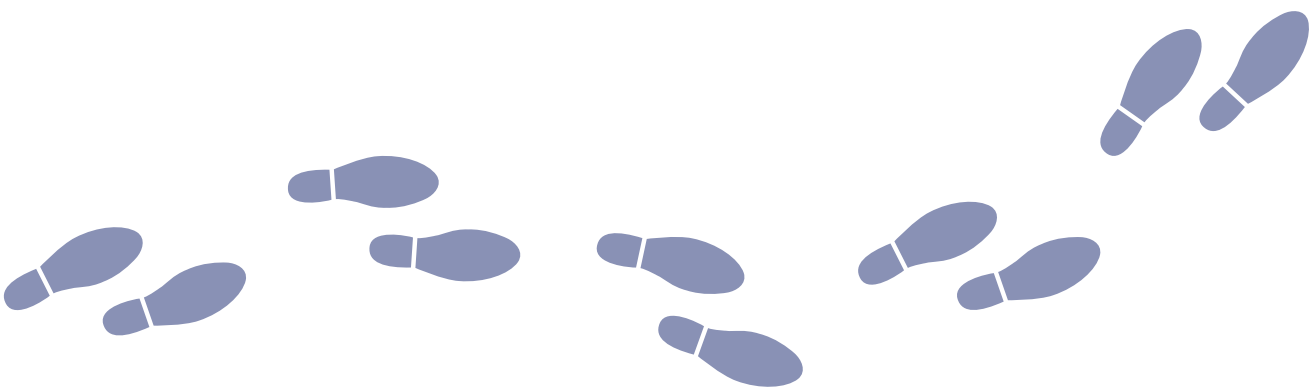
The treadmill of the walking desk should be set at a slight incline (1–3 degrees). This activates the gluteal muscles which are utilized in all jumping movements.

The walking desk helps increase the day-to-day activity level and the daily energy expenditure, likely leading to easier weight management, particularly for overweight individuals.[229 230]

Walking is associated with numerous health benefits (see the Exercise chapter of *the Biohacker's Handbook* for more information).

Recommendations for walking more during the working day:

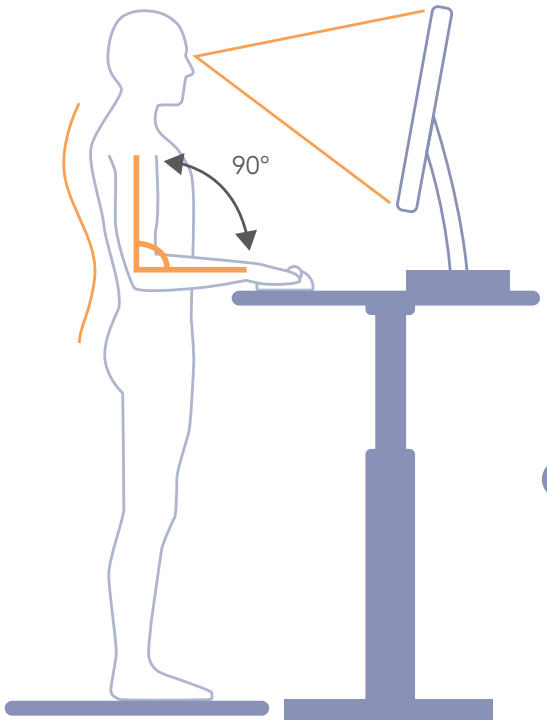
- Use a walking desk
- Schedule walking meetings whenever possible
- Take the stairs instead of the elevator
- Walk whenever you are on the phone
- Read articles or listen to interviews on a portable reader while walking
- Bonus: walk barefoot on uneven terrain



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PROPER WORK ERGONOMICS

1. Head and neck are balanced, and in-line with the torso.
2. Shoulders are relaxed.
3. Elbows are close to the body and bent between 90 and 120 degrees. Desktop height should be adjusted accordingly.
4. Monitor should be around 50–70 cm (20–28 inches) from the face, and slightly tilted back.
5. Top of the monitor is at or just below eye level so the user does not have to tilt the head up or bend the neck down.
6. Wrists and hands are straight, in-line, and roughly parallel to the floor.



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TAKING BREAKS AND ELIMINATING DISTRACTIONS

"All of humanity's problems stem from man's inability to sit quietly in a room alone."
– Blaise Pascal (1623–1662)

Taking breaks during the work day is important for the maintenance of energy levels and mental agility. The mind can only process 5–9 things at any one time (Miller's Law).[231] The fewer disruptive stimuli there are, the easier it is to get on with things and produce results.[232] Developing routines, improving concentration, minimizing external factors and consciously calming one's mind all facilitate carrying out and completing various tasks.

COGNITIVE ERGONOMICS AND ROUTINES

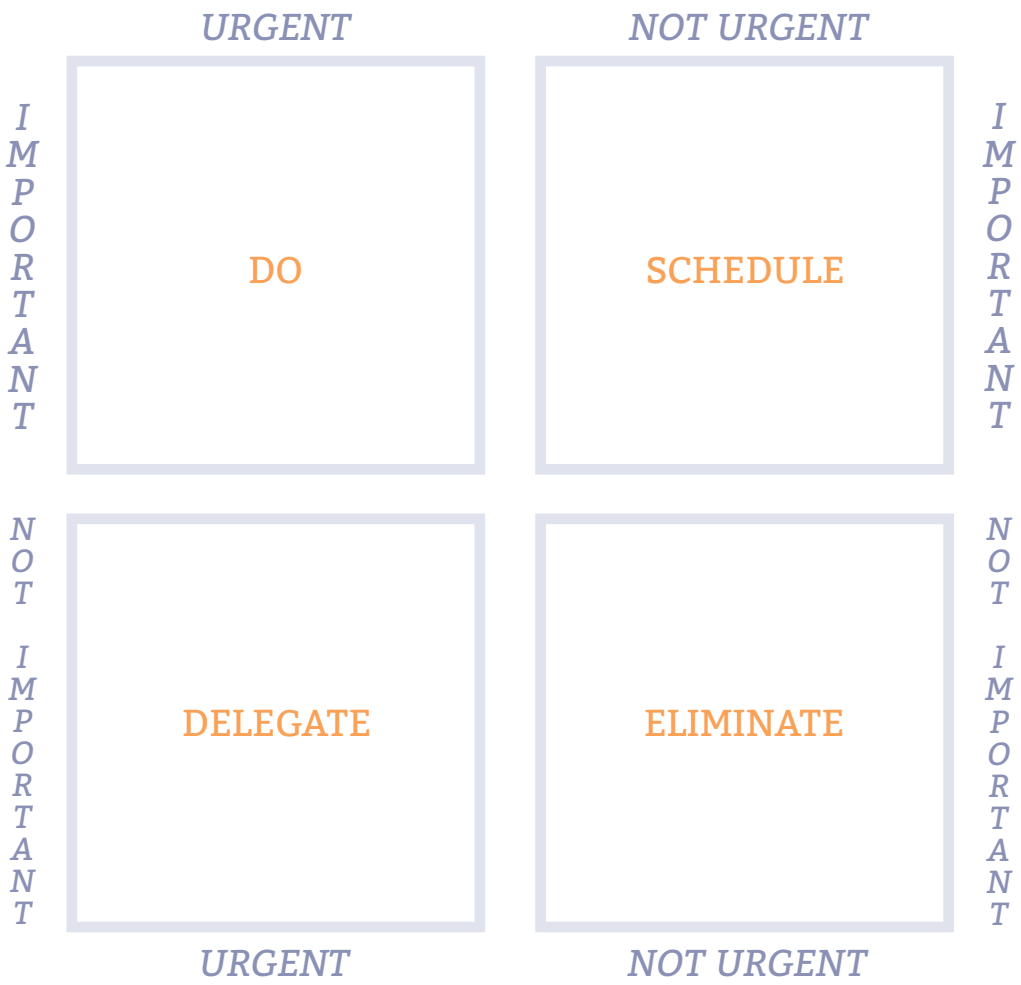
Planned habitual routines help concentration and improve the ability to make day-to-day decisions. The former U.S. President Dwight Eisenhower once said that what's important is rarely urgent and what's urgent is rarely important. President Eisenhower incorporated this principle into his time management method (see "the Eisenhower Matrix" on the following page).

Try these cognitive ergonomics tools:

- Setting the day's main goals in the morning (1–3 goals)
- Not-To-Do lists
- Splitting a large project into smaller tasks
- Automating and outsourcing repetitive tasks
- Creating a recurring task list (to establish routines and habits)
- Using an interval timer with preset phases for routines
- Utilizing time management methods (such as GTD or Pomodoro)
- Taking regular breaks and microbreaks while working
- Tidying the work station before and after working
- Writing down in the evening the tasks that preoccupy the mind

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THE EISENHOWER MATRIX



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CONCENTRATION

The law of concentration: 1 x 1 = 1 vs. 0.5 x 0.5 = 0.25

Several studies indicate that humans are not good at multi-tasking.[233] Switching between tasks is stressful and may reduce productivity by up to 40 %.[234] Typically people are able to concentrate and focus on one thing (e.g. a lecture or a text) for approximately 10–25 minutes. In the flow zone (see section "Flow"), this time may be several times that, even hours. Concentrating on a single thing improves productivity.

Follow these steps:

- Plan task completion based on time (e.g. scheduling telephone calls and emails at a specific time and not throughout the day)
- Plan task completion based on context (e.g. completing certain tasks at the work station, on the go, on the phone, while commuting, etc.)
- Specify a different function for each device (e.g. work on the computer, entertainment on the tablet and social contacts on the phone)
- Schedule the tasks that require concentration
- Block the use of distracting applications when you intend to concentrate on one

Tasks requiring a higher level of concentration activate the sympathetic nervous system, which may trigger physiological effects such as the dilation of pupils.[235] The dilation is directly proportionate to the demands of the task at hand – when working on a less demanding task, the pupils become smaller. In future, it will be possible to use eye-tracking software to create user interfaces that adapt to the user's ability to receive information.[236]

OPTIMIZING EXTERNAL FACTORS

External factors may distract you away from the matter you are focusing on. On the other hand, external stimuli may also improve our ability to concentrate. According to a study, the work of a California office worker is interrupted as often as once every three minutes. Interruptions also cause excess stress and burnouts.[237]

Follow these steps:

- Disable email and instant messaging notification sounds
- Block the use of social media applications
- Disconnect the internet when the tasks do not require it
- Minimize excess noise, e.g. by using noise-canceling headphones
- Optimize air temperature, oxygen level, purity and humidity (see the Sleep chapter of *the Biohacker's Handbook* for more information)

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- Use optimal, indirect full-spectrum light that is similar to daylight
- Minimize unnecessary human contact that impairs your ability to work

INDOOR AIR QUALITY

In terms of external factors, creating an optimal indoor climate is the single most important factor in improving the working conditions of knowledge workers. We spend more than 90 % of our time indoors and breathe in 12–15 kg (26–33 lbs) of indoor air per day. According to studies, indoor air can be 2–5 times (and sometimes up to 100 times) more polluted than fresh outdoor air.[238] Poor indoor air quality is a predisposing factor for respiratory infections, poisoning, chronic obstructive pulmonary disease, cardiovascular diseases, lung cancer and asthma.[239] Considering the fact that for example in Finland more people are killed annually by fine particles than car accidents (1800 vs. 300), improving indoor air quality is a top priority for health.[240]

Unpurified indoor air contains various types of impurities such as fine particles (including mold and dust) and harmful gases (including chemicals from surface treatment agents, detergents, exhaust fumes and smoking).[241] In an office environment, the indoor air quality is often undermined for example by old computers[242] and printers. IT devices release volatile organic compounds (VOC) and ultrafine particles which may be harmful to health.[243] [244] Furniture paints and protective agents may also release volatile organic compounds.[245]

Studies suggest that poor indoor air quality has a significant impact on cognitive abilities and alertness. Poor indoor air quality may indeed make us dumber: according to a study conducted on test subjects, the individuals tested received significantly lower cognitive test results when tested in a poorly-ventilated building.[246]

OPTIMAL AIR QUALITY:

- Carbon dioxide content (CO2): < 625 ppm
- Humidity: 35–65 %
- Temperature: 19 °C (66 °F)
- VOC content: < 150 ppb
- Particle count: < 12.5 µg/m3

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Actions for improving indoor air quality:

- Wipe off dust on a regular basis
- Refrain from smoking indoors
- An induction cooktop is preferable to gas or wood in terms of air quality
- Swap detergents for the safest alternatives possible, such as vinegar
- Favor unscented detergents and personal hygiene products
- If necessary, have the indoor air quality analyzed
- Ventilate your home frequently (20 min per day)
- Purchase an air purifier
- Purchase an air freshener that increases air humidity
- Use ozone treatments to remove unpleasant odors
- Purchase an ionizer that spreads ions into the air, trapping negatively charged particles
- Purchase plants that purify indoor air. The following plants are recommended by NASA:[247]
  - Snake plant
  - Barberton daisy
  - Chrysanthemums
  - Peace lily
- Renovate your home to incorporate breathable and natural building materials

CALMING THE MIND

Use the following tools to calm your mind:

- Music
  - Classical music
  - Calming ambient sounds
  - Nature sounds
  - Solfeggio frequencies
  - Binaural beats and isochronic tones
- Scents and aromatherapy
  - Lavender, rosemary, lemon, jasmine, cedarwood, peppermint, chamomile
  - Frankincense incense
- Spike mat
  - Boosts oxytocin and endorphins (improves mood)
- Yoga, massage and stretching
  - Boosts circulation throughout the body and the brain
- Minimizing sensory stimuli (sensory deprivation)
  - Isolation tank
  - Silence exercises (see section "Mind and body balance through meditation" in the Mind chapter of *the Biohacker's Handbook* for more information)
  - Deep breathing (see sections "Breathing techniques" and "Breathing – they key to controlling the nervous system" in the Mind and Exercise chapters of *the Biohacker's Handbook* for more information)

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DECISION-MAKING

"If it's not a hell yes, it's a no."
– Derek Sivers (b. 1969)

Decision-making is a cognitive process where a choice is made between several options. Decision-making can be examined from the perspective of the individual's values and needs. These values, on the other hand, are determined by the individual's world view.

The decision-making process is a continuum integrated into stimuli from the surrounding environment. The more environmental stimuli there are, the more decisions (conscious or unconscious) must be made each day. Dutch psychologist Ap Dijksterhuis (b. 1968) is the father of the Unconscious Thought Theory. According to his theory, most of the decisions requiring complex reasoning are unconscious (subconscious).[248]

The conscious mind usually makes the decisions regarding simpler matters. If the rational, conscious mind were forced to analyze the pros and cons of every decision, we would very quickly become fatigued.[249]

According to research, the decisions made by the unconscious mind may be clearer and better than those made by the conscious mind.[250] However, not all scientists agree.[251] In some cases, the decision-making process of the conscious mind may be simpler than that of the unconscious mind.[252] Sometimes people are paralyzed by the multitudes of options available and unable to make decisions. This is called analysis paralysis.

It might also – at least in part – be called information overload, which is often considered a downside of today's information-centric society. Having too much information available may reduce the probability of an actual decision being made.[253] Fatigue and confusion may also be the end result of what is known as decision fatigue. In such cases, the capacity of the brain and mind to make decisions is exceeded.[254] [255]

$$1+1=2$$

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INDIVIDUAL DECISION-MAKING PROCESSES

Decision-making and drawing conclusions hinge on the information available at the time, the time available and the individual's processing ability. According to a study conducted in the 1950s by Nobel laureate, sociologist and psychologist Herbert A. Simon (1916–2001), maximizers always attempt to achieve an optimal result whereas satisficers try to find a solution that is good enough.[256] Simon studied chess players and found that the masters who had had more practice saw the game board in a different way compared to the others.

Renowned psychoanalyst Sigmund Freud (1856–1938) used the metaphor of a horse and rider in connection with decision-making to point out the conflict between emotional impulses (horse) and reason (rider).[257] The ability to make a decision between emotion and reason often determines whether the individual procrastinates or reaches a decision.

From the biohacker's viewpoint, the decision-making process is of utmost importance. An individual's decision-making process often involves prejudices and outright illusions that may influence the outcome. They are also called cognitive biases, or tendencies to think in a particular way.[258] For example, an individual often prioritizes things based on how easy they are to remember or how they feel. Recurring media coverage usually also affects this. Cognitive biases and heuristics (such as intuitive decisions and "common sense") may have an impact for example on medical treatment choices.[259]

Cognitive biases include the following:

- Selective perception
- Confirmation bias
- False-consensus effect
- Cognitive inertia (the inability to see perspectives other than one's own)
- Conservatism bias
- Information bias
- Recency illusion
- Clustering illusion
- Bandwagon effect
- Blind-spot spot
- Anchoring (attachment to first source of information)
- Cognitive ease/strain
  - Susceptibility to believe claims expressed with simpler words
- Priming (suggestions that direct the attention to information repeated later on)
- Intuitive heuristics (choosing the easiest solution to a difficult problem)

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Cognitive biases may also affect physical behavior. Psychologist John Bargh asked students at New York University to form four-word sentences using the five words provided. One group was given words associated with old age, such as Florida, forgetful, gray, bald and wrinkle. After the exercise, these students walked more slowly compared to the students who were given words that were not associated with aging.[260]

Fighting cognitive biases requires deeper information processing. Psychologist Daniel Gilbert developed a theory based on the thoughts of philosopher Baruch Spinoza (1632–1677) that suggest that deeming something false begins with first pretending to believe it. This often happens automatically. For example, "dolphins are pink" triggers a momentary acceptance of the statement, followed by an intuitive denial based on previous experience. Studying the statement further may reveal that there indeed is a pink species of dolphins (*inia geoffrensis*) living in the Amazon. Only by processing the statement thoroughly can it be proven true or false. In other words, a deeper analysis of the statement requires simultaneously processing conflicting information.[261]

Nobel laureate and psychologist Daniel Kahneman, who specializes in decision-making and behavioral sciences, writes in his book *Thinking, Fast and Slow* (2011) about two distinct systems through which individuals usually form their opinion:[262]

- System 1: fast, automatic, emotional, stereotypical, subconscious
- System 2: slow, analytical, logical, calculating, conscious

According to Kahneman, we spend most of the time with our behavior and decision-making being controlled by System 1. System 2 requires more effort and activating it consumes more energy.

There are several decision-making models involving deeper processing. One of these is the GOFER model, developed in the 1980s, which is taught to adolescents.

The GOFER model involves five steps of decision-making:

1. Goals
2. Options
3. Facts
4. Effects
5. Review

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Another example is the DECIDE model, developed for managers in health care. It consists of six steps:[263]

1. Defining the problem
2. Establishing the criteria
3. Considering all the alternatives
4. Identifying the best alternative
5. Developing and implementing an action plan
6. Establishing and monitoring the solution

The decision-making process suitable for knowledge work or studying reflects the various models created by scientists, many of which are very similar:[264] [265]

1. Identify the decision you want to make
2. Gather the information necessary for the decision
3. Identify various alternatives
4. Weigh and assess the evidence associated with the alternatives
5. Make a selection between the alternatives
6. Act per the decision made
7. Review the decision and its significance – is there a need for a new decision?

THE EFFECTS OF PERSONALITY AND EMOTIONAL LIFE ON DECISION-MAKING

Decision-making may also be affected by the individual's personality as well as typical thinking and behavioral patterns.[266] The individual's emotional state also has an impact on decision-making. Overall, experiencing various emotions is helpful in decision-making: often decisions must be made in uncertain situations in which the choices are not clear.

The somatic marker hypothesis is based on this.[267] The theory involves the impact of emotions on decision-making from the viewpoint of neurobiology. According to the hypothesis, various emotions create physical feelings that potentially distort decision-making in favor of rewards, for example.[268]

Loewenstein and Lerner (2003) assign emotions two-fold roles in decision-making: anticipating specific future emotions and being experienced directly during the decision-making process.[269]

People who "live in the moment" are more likely to make decisions based on their current emotional state. People who focus on the past or the future are more likely to make decisions based on a similar, previously experienced

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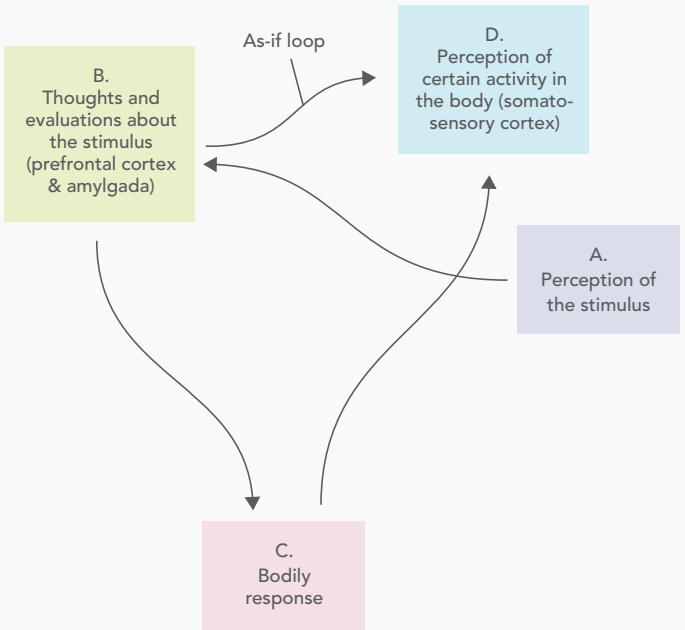
emotion or an imagined potential emotion. A decision made in the spur of a moment may indeed be very irrational and disruptive to rational, optimal decision-making.

Conversely, the classification devised by Pfister and Böhm (2008) is based on various roles that reflect emotions in decision-making.[270] They include:

- Providing information (positive and negative emotions; often arise directly from the options being considered)
- Improving speed (emotions that encourage fast decision-making; often triggered by hate or fear)
- Assessing relevance (emotions that help decide whether the decision is relevant; e.g. regret or disappointment)
- Enhancing commitment (emotions that involve moral sentiments and the sense of community; such as guilt or love)

Another noteworthy factor is the so-called emotional memory[271] which has unconscious influence on every decision made. It is possible to become conscious of this by monitoring your own mind and identifying any repeating patterns.

THE DAMASIO SOMATIC MARKER HYPOTHESIS



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OPTIMIZING READING AND LEARNING

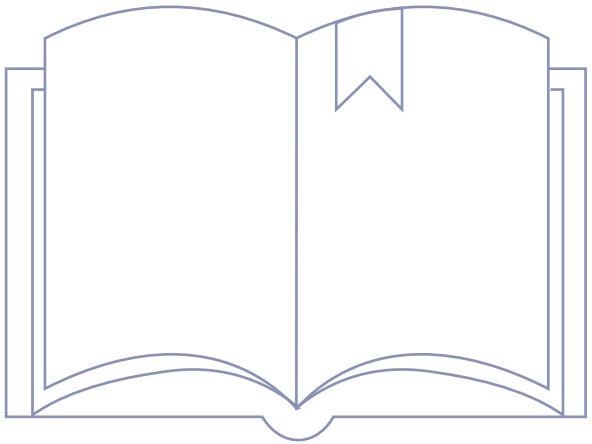
Reading, learning and concentration are most efficient in 25-minute cycles. This observation is based on the Pomodoro technique, devised by Francesco Cirillo in the late 1980's. The technique is named after a timer shaped like a tomato (pomodoro in Italian).[272]

There should be frequent short breaks as the memory function works best at the beginning and end of each session. During the middle, it is often harder to focus. Why do you think rock stars start and end their concerts with loud bangs and pyrotechnics? They know that people tend to remember only the beginning and the end (see section "Memory functions" for more information).

The best readers also know how to take breaks to recharge. While on a break, enjoy refreshments (such as biohacker drinks) to stabilize your blood sugar level. See also section "Efficient napping" in the Sleep chapter of *the Biohacker's Handbook*.

Consider these factors for efficient reading:

- The importance of proper light (full-spectrum light or natural light improves reading efficiency)
- If you read on a computer, using 2–3 monitors increases efficiency
- Optimize the light output of the computer screen
- Maximize your reading speed by identifying the optimal recognition point (ORP). It is usually located slightly to the left of the middle of each word.[273] See the bonus information page (Spritz applications) for more information.



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When you start reading, do the following:

- Set the correct reading position
  - When you wish to speed read, sit at a table and place the book at a 45-degree angle
- Review the table of contents
- Quickly preview and leaf through the book
  - Images, tables, graphics and special sections
- Read efficiently, avoiding unnecessary eye movements (focus your eyes at the middle of the line)
- Using a pen or the reader's highlighting functionality, underline or highlight important content so that you can easily review it
- Take a photo of the underlined sections or cut them on a computer and paste them into a new notes document
- Review the underlined sections several times and reduce the reading speed for each iteration
- In terms of learning, writing notes manually is more effective than typing them on a computer[274]

Keep the following goals in mind:

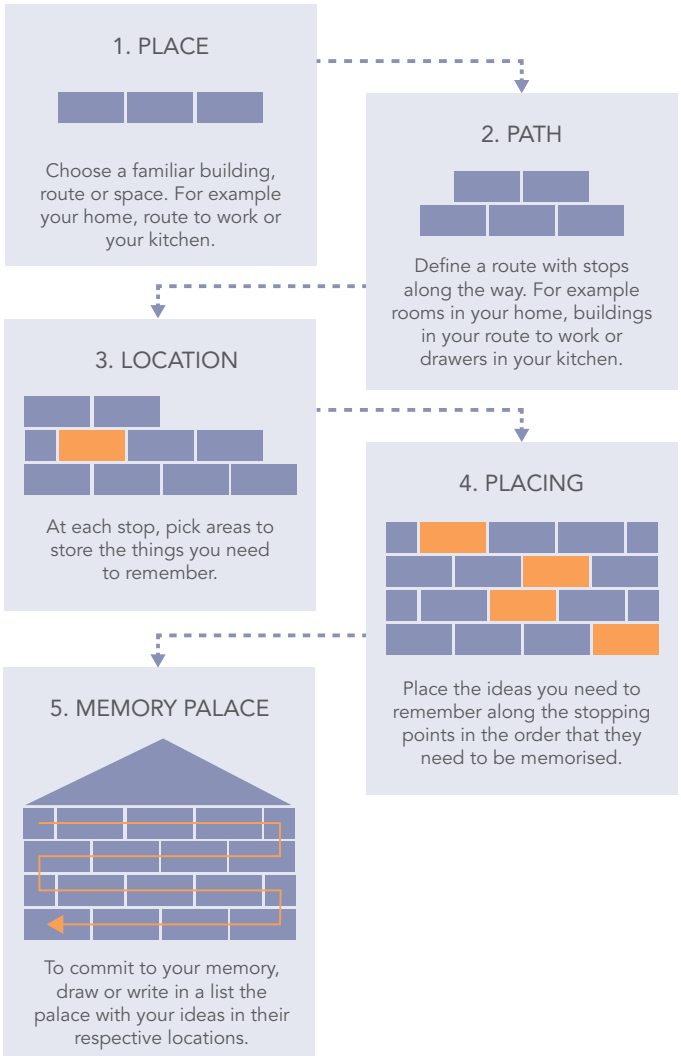
- Why am I reading this?
  - Never read anything without a clearly defined goal
  - Most people read everything at the same speed because they lack a clear reason for reading
- What do I want to take away from this?
  - A fast reader adjusts his/her reading speed according to the goal and the text at hand
  - Setting a goal only takes a second but it may save hours of your time

After reading and studying:

- Visualize what you just learned and connect it to the larger visual whole. You may utilize for example the Memory Palace technique in which you split your body or house into ten points. Visualize connecting the things you have learned to various points in a specific order.
- To help remember the numbers, create an item for each number in your mind. Learn the numbers by recalling the items in a specific order.
- Take a nap. It increases the likelihood of remembering.
- Review your notes every few weeks. Repetition increases the volume of gray matter in the brain which is associated with information processing.[275]
- Try to teach what you learned to someone else. If you cannot find a suitable subject, write an article or make a video of the subject matter. 50 % of the time should be spent consuming (e.g. reading) and the other 50 % producing (e.g. writing).

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EXAMPLE OF THE MEMORY PALACE TECHNIQUE



UPGRADE YOUR COMMON BEHAVIOR PATTERNS ON A COMPUTER

- Maintain emotions that encourage activity: identify the thoughts that lead you to the state of concentration or the inability to concentrate
- *Solve et coagula* – focus and divide your energy depending on the situation
- Utilize specialized time tracking programs and identify the behavior patterns that undermine your time management, as well as their root causes. Repetitive routines often create a sense of rush, anxiety and frustration.
- Use two separate computer desktops, both equipped with a wallpaper modified especially to improve project management.
- Limit your availability. After an interruption, it may take up to 45 minutes to return to a state of concentration. Up to a quarter of the working day may be taken up by such interruptions. If you work in an open plan office, place a clock on your desk to indicate the time at which you may next be disturbed.

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FLOW

"You know that what you need to do is possible to do, even though difficult, and sense of time disappears. You forget yourself. You feel part of something larger."
– Mihály Csíkszentmihályi (b. 1934)

Flow is a term coined by Hungarian-born psychologist Mihály Csíkszentmihályi (b. 1934) to describe the mental state of being in harmony with the information processed by the consciousness as well as one's own goals. It is a time of peak emotion and performance. Flow is also called the optimal experience. A person experiencing flow is so focused on one singular thing that everything else is shut outside the consciousness.

Many top athletes have described experiencing flow or being in "the Zone" during record-breaking athletic performances.[276] Scientists have determined that the state of flow involves a temporary decrease in activity in the frontal area of the brain. As a result, the neurons of the basal ganglia light up with greater efficiency (see section "The Structure and Functions of the Brain" in the Mind chapter of *the Biohacker's Handbook* for more information).

DID YOU KNOW

THE OPPOSITE OF FLOW IS PSYCHOLOGICAL ENTROPY, MEANING A DISARRAY OF THE HUMAN CONSCIOUSNESS. IN THIS STATE, THE INFORMATION PROCESSED BY THE CONSCIOUSNESS CONFLICTS WITH THE INTENTIONS. IN PSYCHOLOGICAL ENTROPY, THE FOCUS IS ON THE IRRELEVANT, MAKING IT DIFFICULT TO FULFILL THESE INTENTIONS.

Thus, the analytical part of the brain is put on hold while the creative sensorimotor parts take center stage.[277]

The top priority for work efficiency is to conjure up inspiration. Flow is the result of continuously doing the things that make us feel meaningful and cause us to push the limits of our skills.

According to author Steven Kotler, the kindlers of flow (or triggers) can be divided into four categories: psychological factors, environmental factors, social factors and creative factors.

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Psychological triggers include:

- Concentrating intensively on one task at a time without interruptions
- A clear goal or objective
- Immediate feedback that facilitates improving performance in real-time
- The optimal ratio between challenge and skills (challenge slightly higher than skills)

Environmental triggers include:

- Potential serious consequences of failure (e.g. in a survival situation)
- A rich environment with plenty of new factors, surprises and uncertainty
- A deep state of embodiment

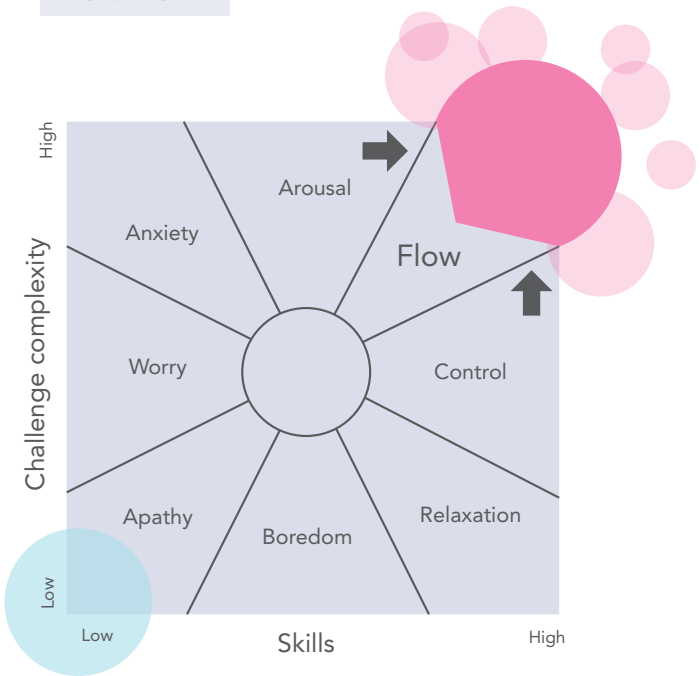
Social triggers include:

- A deeply shared state of concentration, e.g. in team sports
- Clear goals shared by the group
- Effective communication amongst the group
- A shared common factor (such as a language)
- A shared skill level and group participation
- A risk associated with the task boosts motivation and creativity
- The feeling of control regarding the task (the combination of autonomy and competence)
- The ability to be present and listen
- Being open to new experiences and able to say "yes"

Creative triggers include:

- Identifying repeating patterns (such as color, shape, data, movement, sound, concepts, risks, failure, etc.)
- Taking a risk and having the courage to present new ideas

FLOW MODEL



Source: Csíkszentmihályi (2004).

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TRAVEL

Make traveling as easy as possible by eliminating stress, jet lag and the need to carry luggage. A minimalist attitude makes traveling significantly simpler. Only pack the necessary hand luggage.

The packing list of a knowledge worker:

- Waterproof backpack or shoulder bag (max. 55 cm x 35 cm x 20 cm / 21.5" x 14" x 8")
- Vacuum or compression bags to minimize the space required for clothes
- 1 l (1 quart) zip-lock bag for liquids
- Transparent 30–100 ml (1–3.4 fl oz) containers and bottles for liquid cosmetics, dietary supplements and food; make sure they fit into the zip-lock bag (leave the original packaging at home and only pack the necessary amounts or buy them at the destination)
- A cable lock to deter bag theft in public spaces, transportation, hotel, etc.
- An RFID-blocking wallet for cards and passport
- Ballpoint pen
- Chopsticks or spork
- Adapters for various electric plugs (depending on the destination) and the necessary cables (USB, phone chargers, etc.) in a protective pouch
- Antibacterial and wrinkle resistant underwear and t-shirts (easy to wash out in a hotel room sink), two of each
- Second pair of trousers or a skirt if the trip is longer than a week
- Sunglasses or blue light blocking glasses in a lightweight case
- Lightweight sneakers that are also suitable for sports
- For men: shorts that double as swimwear
- Smartphone and/or tablet replaces a camera, travel guides, books, maps, etc.
- Sleeping mask and earplugs (airplane version) or noise cancelling headphones
- Cable ties, elastic bands, etc. to tie cables together
- Black electrical tape to cover LEDs in the hotel room
- Lightweight rain poncho or a small umbrella
- Lightweight thermos for coffee, tea and water
- Lightweight day bag

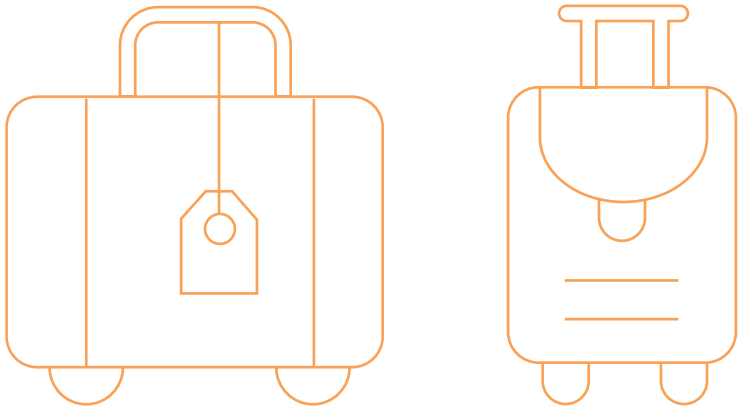
Wear a long-sleeve shirt, jacket and a hat, if applicable. Roll your clothes to minimize wrinkling. Favor dark colored clothes that are easy to combine and do not show stains.

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Airport survival guide:

- Always check in online the day before the flight
- Do not check bags to avoid stress and standing in queues
- Place your jewelry and belt in your bag in anticipation of the security check
- Acquire an elite-level frequent flyer card – you get a fast track security check and may be able to get some rest in the business lounge
- Only fill your water bottle after the security check
- Secure the network connection on all of your devices using a VPN
- When the screen tells you to go to the gate, note that the actual boarding time is still usually several minutes away. When boarding is underway, instead of standing in the line, sit down and do something useful. Often the boarding process takes at least 10 minutes.
- Pack your own snacks or fast to avoid low-quality food
- If possible, choose a special meal – you will be served first and often the food is fresher as well
- Go to the toilet before boarding
- Wait to exchange currency at your destination (the exchange rate in-town is usually better)
- Purchase roaming or local SIM card for your phone

American biohacker Tim Ferriss popularized the term *travel caching*: if you visit the same destination frequently, don't bother carrying luggage. Arrange with a hotel or a local friend to store your stuff in an assigned place. Various services or self-service storage units and safe-deposit boxes are also good solutions here. Another alternative to carrying luggage is to send a bag to the destination in advance via a freight company. These methods eliminate the need to carry luggage and the risk of it getting lost.



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FLYING

Flying is stressful for the body, particularly longer flights that cross several time zones. Other stress factors associated with flying include noise, ionizing radiation exposure, poor air quality and toxins, low-quality food onboard, unfamiliar people, jet lag and lack of sleep.

According to the Civil Aviation Authority (CAA), the air onboard many airplanes has been found to have significant amounts of tricresyl phosphate (TCP) which is classified as a neurotoxin.[278] The following types of aircraft have been reported as particularly suspect in regards to tricresyl phosphate: Aerospace 146, Boeing 757, Airbus A319 and Embraer 145.[279] The term "aerotoxic syndrome" is used to refer to the health hazards and symptoms caused by the air quality and potential toxins onboard. However, the syndrome is currently not officially recognized in aviation medicine.[280] Using an activated carbon protective mask may be beneficial when flying in the aircraft types where air impurities have been found.

A significant stress factor is the fear of flying (aerophobia/aviophobia) which is at least partially linked to the fear of losing control. According to various estimates and studies, 20-40 % of people suffer from degree of aerophobia at some point in their lives. Approximately 7–8 % of people do not fly at all because of this.[281]

It is possible to conquer the fear of flying through cognitive-behavioral psychotherapy or hypnosis. Learning to control the fear is also possible.[282] Statistically speaking, the fear of flying is entirely irrational as the risk of dying in an aircraft accident is approximately 1:14 000 000.[283]

Frequent flyers (cabin crew in particular) are exposed to cosmic radiation. Frequent radiation has been found to cause chromosome translocation in aircraft pilots. This may represent a predisposing factor for cancer (particularly leukemia and melanoma) and may cause infertility.[284 285 286] Infrequent flyers are exposed to a comparatively small radiation dose – for comparison, the radiation dose produced by a chest X-ray (0.1 mSv) is fivefold compared to that of a return flight across Europe (20 µSv).[287]



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Measures for minimizing radiation exposure caused by flying:

- Animal tests indicate that taking a large dose of anti-oxidants (such as glutathione, astaxanthin, selenium, vitamin E, coenzyme Q10, NAC, vitamin C and alpha lipoic acid) before flying reduces the oxidative stress caused by radiation[288 289 290 291]
- Animal tests indicate that taking a large dose of omega-3 fatty acids (particularly DHA) before flying prevents inflammation caused by UVB radiation[292] and reduces oxidative stress in the brain[293]
- Animal tests indicate that taking fairly large doses of chlorella (500 mg/kg) and/or spirulina (60 mg/kg) before flying may provide protection from gamma radiation[294 295]
- The regular consumption of potassium iodide, including before flying, protects the thyroid from radioactive iodide[296]
- Speed up the exit of radioactive toxins from the intestine using activated charcoal and zeolite[297 298]
- Avoid flying between 8 AM and 5 PM. The best time to fly is at night as radiation exposure is significantly lower when the sun is not visible.
- Ask for a pat-down instead of a radioactive body scan (particularly in the United States)

RECOVERING FROM JET LAG

Jet lag refers to a disruption in the regulation of an individual's internal clock and circadian rhythm. Jet lag causes a disruption in the regulation of an individual's sleeping pattern. It occurs particularly in the elderly. Jet lag occurs when a person travels through several (usually more than three) time zones. The greater the time difference, the worse the jet lag. The day cycle of our internal clock is slightly longer than 24 hours (24 h 11 min)[299] which makes it generally easier to travel east to west than in the opposite direction.

The symptoms are caused by a conflict between the sleep-wake cycle and other cycles occurring in the body (such as the hormonal cycle). In addition to sleep disruptions, jet lag may cause symptoms such as fatigue, nausea, intestinal complaints, dizziness, headaches, swelling, irritability and general deterioration in performance.[300]

According to an international review conducted in 1994, up to 90 % of flight attendants suffer from fatigue associated with jet lag for five days after long-haul flights, and 94 % report having experienced impaired sleep quality and a lack of energy.[301] Constant changes in the circadian rhythm and the exposure to jet lag may be a predisposing factor for impaired cognitive functions, mood disorders, sleep problems and even heart disease, metabolic disorders and cancer.[302 303 304]

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FLYING EAST TO WEST

Adjusting to the time difference is easier when flying east to west as extending one's internal day cycle is easier than shortening it. For example, when flying from Europe to the East Coast of the United States, the time difference is between five to seven hours. When flying east to west, the sleep-wake cycle adjusts to the new time in increments of 2–3 hours per day. Highly adaptable individuals may be able to adjust fully within a couple of days.[305]

Therefore sleeping on an overnight flight from Europe to New York is not advised – the best strategy is to stay awake and go to bed immediately upon arrival at the destination late at night (e.g. when it's 6 AM in Paris and 10 PM in New York).



FLYING WEST TO EAST

When traveling west to east, the best strategy is to start adjusting one's sleeping pattern before departure by going to bed a few hours earlier than normal. This makes it easier to fall asleep on the plane. Eastward flights (e.g. from New York to Helsinki) often depart in the afternoon or evening and arrive in the morning. In such cases, it is advisable to sleep on the plane (see section "Sleeping on an airplane" in the Sleep chapter of *the Biohacker's Handbook*). At the destination, immediate sunlight exposure and exercise may facilitate adjusting to the new rhythm. They have also been found to be effective in syncing the circadian rhythm.

To minimize jet lag, avoid:

- Alcohol
- Sleeping pills
- Caffeine and chocolate for 5–8 h before bedtime
- Poorly timed sunlight (during evening or night-time hours in the destination time zone)

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To minimize jet lag, try:

- Adequate and appropriate mineral-rich hydration (minimum 60 fl oz/pound of body weight/day)
  – Special trick: soaked chia seeds or cucumber
- Fasting or intermittent fasting (14–24 hours before the first meal in the destination time zone). It is recommended you do this for approximately a week before departure to give the body time to adjust to fasting.[307] [308]
- If you are not sleeping during the flight, get up and move. This boosts lymphatic and blood circulation.
- Wearing compression socks or trousers during the flight improves circulation and reduces swelling
- Exercising in the sun at the destination (if arriving in the morning or afternoon). Bodyweight training and/or walking is recommended.[309] [310]
- Grounding immediately upon arrival at the destination (e.g. by walking barefoot in the grass or sand; swimming is also a good option). This helps the body recover from the stress caused by the flight (may reduce inflammation, boost circulation and reduce stress levels).[311] [312]
- 50 mg pycnogenol three times daily for a total of seven days. Start two days before flying.[313]

DID YOU KNOW

FOR TWO DAYS BEFORE FLYING WEST TO EAST, USE BRIGHT LIGHT THERAPY AT THE TIME WHEN YOU WANT TO WAKE UP AT THE DESTINATION. FOR EXAMPLE, IF THE TIME DIFFERENCE IS 8 HOURS AND YOU WANT TO WAKE UP AT 8 AM, USE A BRIGHT THERAPY LIGHT FOR TWO HOURS JUST BEFORE BEDTIME. THIS WILL HELP ADJUST TO THE NEW CIRCADIAN RHYTHM MORE RAPIDLY.[306]

- Take melatonin at the appropriate time (when it is evening at the destination)[314] – the dose depends on the genotype of the MTNR1B gene which affects melatonin metabolism. If you are of the GG genotype, take just 10 % of the normal dose (e.g. 0.3 mg vs. 3 mg). Do not eat anything for 8 hours after taking melatonin.[315]
- Do not go to sleep immediately upon arrival (unless it is evening or night-time at the destination). Try to stay awake until night-time. If you must sleep, take a short 20- to 40-minute nap. Sleeping for several hours during the day makes it more difficult to adjust to the new time zone.



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HOTEL ROOM OPTIMIZATION

Staying in various hotels and hotel rooms is a fundamental part of traveling. For many CEOs, it is not unusual to have up to 100 travel days per year. A few basic factors can significantly improve your hotel room stay, particularly in terms of sleep and air quality.

Many hotels use strong detergents for cleaning. This undermines the air quality. Carpets collect dust and moisture which is also not ideal in terms of air quality. Avoid carpeted hotel rooms whenever possible. Also, try to book a hotel in a quiet area to minimize noise concerns.

Follow these steps:

- Ensure the room is smoke-free
- When checking in, ask about the possibility of a late checkout and the cost of an upgrade to a better room
- Ask for the hygiene products that you don't carry with you
- Place the "do not disturb" sign on the door to avoid being disturbed by the housekeeping or uninvited visitors. Never use the "please service my room" sign – it signals to potential burglars that you're not in.
- The light switch card reader usually takes any card, so you can keep the electricity on at all times
- Air the room immediately (continue airing until unpleasant smells have dissipated)
- Switch air conditioning on. Set the temperature at a suitably cool level to promote a lowered body temperature before bedtime.
- Consider carrying a travel-sized ionizer and/or air humidifier
- Switch off all LED lights, particularly blue ones (e.g. TV, clock radio and other devices in the hotel room). If switching them off is not possible, cover the lights with black electrical tape.
- Take the hotel room telephone off the hook so that you are not woken up by it ringing (e.g. due to a wrong number)
- Before bedtime, draw the window curtains to darken the room completely. If necessary, use clothes pegs or trouser hanger clips to hold the curtains together.
- Remove all brochures and flyers from view – place them in a drawer, for example. This is to avoid unnecessary temptations and distractions.
- Check the room and the toilet in particular for signs of mold (dark spots). If you detect mold, ask to change rooms.
- Check the mattress for bugs (rare but occasionally possible)
- Bring your own tea and/or coffee. Use the room kettle.

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MONITORING AND MEASURING THE WORK ENVIRONMENT AND WAYS OF WORKING

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Ways of working can be measured using various methods. Monitoring the factors and physiological systems contributing to work efficiency is now possible thanks to trackers and applications made available to consumers. The monitoring and measuring methods related to the mind and memory are discussed in the Mind chapter of *the Biohacker's Handbook*. Topics concerning sleep are discussed in the Sleep chapter.

Measurable factors related to wellbeing at work and optimizing work efficiency include:

- Sitting, standing, walking and running (time and distance)
- Posture (hours per day maintaining good posture)
- Heart rate and blood pressure throughout the day (heart rate, systolic and diastolic pressure)
- Blood sugar (mmol/L and mg/dL)
- Indoor air quality (VOC, fine particles, carbon dioxide, humidity)
- Lighting (lumens)
- Noise (decibels)
- Temperature (Celsius or Fahrenheit)
- Mood
- Innervation (e.g. reaction time)
- Tests measuring cognitive performance
- Breaks (amount of rest, exercise)
- Time spent using a computer (efficient working, studying, interaction, wasted time)
- Time spent on the phone (minutes per day)
- Stress and recovery – heart rate variability (HRV)
- Sleep quality (deep sleep, REM sleep, total hours slept, wakeups)

What's worth measuring depends on what is being worked on and the skills being developed. Overall, for office-based work it is more relevant in terms of health to measure the proportion of standing time to sitting time than to count steps. Indoor air quality is more useful than noise or lighting. By monitoring one's nervous system function and cognitive performance, the biohacker is able to pinpoint the part of the day during which he/she is at his/her most efficient to perform various tasks. Blood sugar measurements may yield information about fatigue-inducing blood sugar swings and facilitate adjustments to eating habits to make them more balanced. Measuring mood, stress and recovery are of interest to many looking to fine-tune one's personal workload. The time spent using a computer in relation to the time spent using a cell phone or sleeping may in itself speak volumes about one's sleep-wake cycle.

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MEASURING HEART RATE VARIABILITY (HRV)

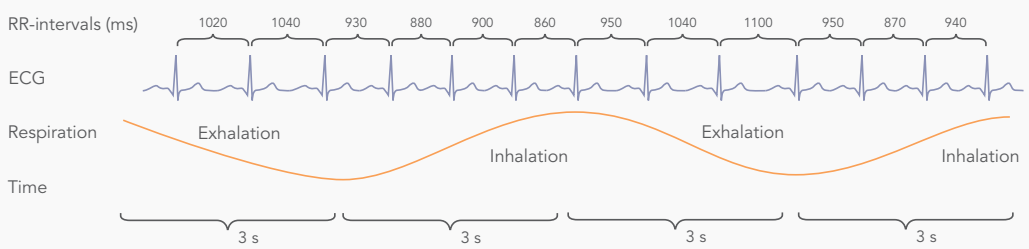
Heart rate variability (HRV) is a normal physiological phenomenon. Heart rate is not constant. The interval between heart beats varies based on factors such as breathing (respiratory sinus arrhythmia, see image). On inhalation, the frequency is usually slightly higher (sympathetic reflex) while on exhalation (parasympathetic reflex) it is lower. The range of HRV is a good indicator of the functional state and dynamics of the autonomic nervous system, as well as heart-brain interactions.[316]

HRV increases when the body is in recovery or the individual is relaxing. Conversely, it decreases when the body is under strain (such as under stress). HRV can change significantly depending on the situation. HRV variability peaks in young adults (15–39 years of age) and begins to taper off as we get older.[317]

Factors affecting heart rate variability:[318]

- Breathing (see above)
- The reactions and functional state of the autonomic nervous system
- Stress reactions
- Hormonal reactions
- Relaxation
- Metabolic processes
- Physical activity (exercise and recovery)
- Movements and changes in posture
- Thinking and emotional reactions (general psychological stress)
- Alcohol use and nutrition

HEART RATE VARIABILITY



Heart rate increases and thus the time between successive RR-intervals gets shorter during inhalation and longer during exhalation. This fluctation in the time between the successive RR-intervals is called heart rate variability (HRV).

Source: Firstbeat Technologies Ltd (2014).

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Measuring HRV over 3–7 days is an excellent way to examine the stress caused by the work day and other activities, recovery during the work day and recovery overnight. HRV may also be measured using various sensors that can be worn or placed under the bed sheets to monitor long-term recovery (see the bonus information page for device and application recommendations).

EMOTIONS AND HEART RATE VARIABILITY

Negative emotions (such as frustration, anger, anxiety and worry) reduce HRV and cause irregular variation in heart rate. Conversely, positive emotions (such as gratefulness, joy and love) increase HRV and regular sine waves (coherence).[319]

HEART RATE VARIATION IN TWO EMOTIONAL STATES



Source: HeartMath, Inc.

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MEASURING SITTING, STANDING AND PHYSICAL ACTIVITY

In the past decade, the market has been flooded with various activity trackers and measuring devices. Before activity trackers, pedometers were used to count steps. Three-axis accelerometers have been used for research purposes for some time now.

These days many smartphones feature a step counter. Some devices have the capability to count the stairs and stories climbed. Compared to actual pedometers, the problem with accelerometers is often the way the steps are registered – the figures are optimistic and the recommended 10,000 step daily result is too easily achieved. External activity-tracking accessories such as bracelets, jewelry and watches have been designed for use with popular phone models. Some activity trackers have a continuous heart rate monitoring feature.

A comprehensive systematic analysis published in 2007 found that the use of step counters was associated with a significantly higher level of physical activity as well as lower body mass index and blood pressure.[320] According to the study, the use of step counters increased the level of physical activity by nearly 30 %. Conversely, a review published in 2014 found that one third of those who purchased an activity tracker stopped using it within six months.[321] According to a statistic published in 2017, 10 percent of people in the United States had used an activity tracker or another wearable fitness device (measuring activity, calorie expenditure and sleep quality) in 2016. The highest wearable fitness device adoption rate was in Spain with 16 %. For example in Japan, only 4 % of the population used a fitness tracker in 2016.[322]

The main benefit of activity trackers is that they encourage people to move – get up periodically and take the stairs instead of the elevator. Some trackers have a vibration feature to warn the wearer of excessive sitting. Some trackers can measure and calculate sitting and standing as distinct categories, making it possible to improve daily activity levels.

STEP COUNT AND ACTIVITY LEVEL IN ADULTS[323]

Passive	< 5 000 steps per day
Low activity	5 000–7 499 steps per day
Moderate activity	7 500–9 999 steps per day
Good activity	10 000–12 499 steps per day
Very good activity	12 500+ steps per day

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MEASURING AND MONITORING BLOOD PRESSURE

Measuring blood pressure is one of the oldest and most common types of health measurements taken at a clinic and/or at home. A comprehensive meta-analysis found a connection between low (although not excessively low) blood pressure and reduced mortality and a lower risk of cardiovascular diseases.[324]

According to an exceptionally comprehensive meta-analysis (61 studies, more than one million adults) published in *The Lancet* in 2002, the optimal blood pressure is 115/75 mmHg or under.[325] Studies examining the blood pressure levels of forager-horticulturalists have found that even aging does not significantly raise the average blood pressure (110–115/70 mmHg) amongst the members of these tribes.[326 327]

Blood pressure monitors are widely available for purchase at various price points. Some monitors store the measurement data in the cloud. These provide an excellent, easy-to-use tool for people who wish to frequently monitor their blood pressure level.

Tips for purchasing a blood pressure monitor:

- Usually a higher-price monitor is also better quality
- Favor monitors that do not beep (this may cause anxiety and result in a higher blood pressure reading)
- Favor monitors that store the measurement data in the memory where it is readily accessible or transferable to another device or the cloud
- Favor clinically validated blood pressure monitors; measurements taken from the arm are more accurate than those taken from the wrist[328 329]

Category	Systolic/upper, mmHg	Diastolic/lower, mmHg
Low blood pressure	< 90	< 60
Normal	**90–119**	**60–79**
Prehypertension	120–139	80–89
High blood pressure (hypertension) stage 1	140–159	90–99
High blood pressure (hypertension) stage 2	160–179	> 100
Hypertensive crisis	> 180	> 110

BLOOD PRESSURE TABLE FOR ADULTS

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MEASURING AND MONITORING BLOOD SUGAR LEVELS

A constant blood sugar level is one of the key factors for the maintenance of good performance levels and mental alertness. For diabetics, monitoring blood sugar levels is vital for health. Monitoring one's own blood sugar may also be useful for people who are not diabetic – such as curious biohackers who are keen to find out what factors in nutrition and lifestyle have an effect on performance and mental alertness.

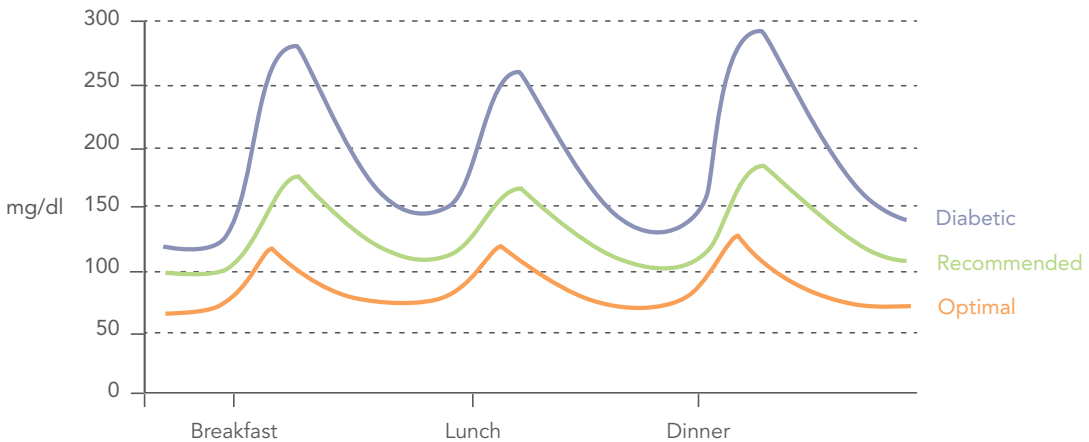
Blood sugar test strips were introduced in the 1970s. They were soon followed by devices that gave a blood sugar value using the test strips. Today, it is possible to take a quick fingertip sample and have a device analyze it almost instantaneously. Peripheral devices and applications designed for measuring blood sugar are also available for smartphones.

Diabetics might now use monitors placed under the skin that take nearly continuous blood sugar measurements (e.g. every five minutes). These monitors warn the user when the results are too low or too high or when sudden swings in blood sugar are detected.[330] It is possible to collect long-term blood sugar data using such devices.

The latest advancement is a device that uses laser (mid-wavelength infrared) to measure blood sugar without requiring a needle prick. According to a study conducted by the developers, the accuracy of the device is 84 % compared to a blood test.[331] Various nanotechnology-based devices are also in development.

Blood sugar measuring methods under development:[332]

- Contact lenses that measure blood sugar levels[333]
- Infrared and ultrasound devices



VARIATIONS IN BLOOD SUGAR LEVELS

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- Raman spectroscopy
- Single-use nanobiosensors (blood sugar analysis from saliva)[334] and implants (blood sugar analysis from blood)[335]
- Affinity sensors that take measurements optically[336]

INTERPRETING BLOOD SUGAR MEASUREMENTS

The following recommended values are based on several studies. They can be used to determine optimal estimates of the lowest possible risk of developing diabetes, cardiovascular diseases, metabolic syndrome, etc.[337 338 339 340 341 342 343 344]

The immediately preceding food intake should be taken into consideration when measuring blood sugar values. For example, individuals who follow a low-carbohydrate diet usually have a lowered tolerance of sugar which may cause high measurement values after a high-carbohydrate meal. This should be taken into consideration when conducting an oral glucose challenge test in a laboratory setting. The recommended adjustment period is four days before the test, during which a minimum of 150 g of carbohydrates per day should be consumed.

- **Fasting blood sugar** (fasting plasma glucose, FPG)
  - Normal: 4–6 mmol/L or 72–108 mg/dL
  - Optimal: 4.0–5.3 mmol/L or 72–95 mg/dL (Life Extension Foundation recommends 4.0–4.7 mmol/L or 72–85 mg/dL)[345]
- **Glycated hemoglobin** (HbA1C)
  - Normal: 20–42 mmol/L / 4.0 % – 6.0 %
  - Optimal: 20–34 mmol/L / 4.0 % – 5.3 %
  - Disruptive factors may include anemia (excessively low result) or dehydration (excessively high result)
- **Oral glucose tolerance test** (OGTT)
  - Values taken: fasting blood sugar and blood sugar 1 hour and 2 hours after the glucose challenge (75 g)
  - Normal value at 1 hour: < 10.0 mmol/L or 180 mg/dL Optimal value: < 7.8 mmol/L or 140 mg/dL
  - Normal value at 2 hours: < 8.6 mmol/L or 155 mg/dL Optimal value: < 6.7 mmol/L or 121 mg/dL
- **Measuring blood sugar levels** at 1 hour and 2 hours after a meal
- **Self-monitoring blood sugar levels** during a 24-hour period (note that the margin of error when using a monitor intended for home use is approximately 10 %)
  - Fasting blood sugar after fasting for 12 hours
  - Blood sugar immediately before lunch
  - Blood sugar one hour after lunch (optimal value < 7.8 mmol/L) or 140 mg/dL
  - Blood sugar 2 hours after lunch (optimal value < 6.7 mmol/L) or 121 mg/dL
  - Blood sugar 3 hours after lunch (optimal value < 5.3 mmol/L) or 95 mg/dL

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GENETIC TESTS

In this section, we briefly discuss the genetic factors that impact the systems discussed in the Work chapter (blood sugar, blood pressure and memory). Genes involved in blood sugar regulation are discussed in the Nutrition and Exercise chapters of the book. These genes include ACE, PPARGC1A, TCF7L2 and PPRG2.

As advancements are made in gene research, new genes that are involved e.g. in blood pressure regulation are constantly discovered. A 2014 meta-analysis studied the genetic makeup of more than 87,000 Europeans. As a result, 11 new genes involved in blood pressure regulation were identified. Scientists believe that this may influence the way new hypertension drugs and therapies are developed in the futuren.[346]

The following genes are involved in the regulation of blood sugar:

MC4R

The MC4R gene regulates the function of the type 4 melanocortin receptor. The receptor binds an alpha-melanocyte-stimulating hormone (α-MSH) which affects the amount of food consumed. The CC genotype of polymorphism rs17782312 of this gene is associated with an increased risk of metabolic syndrome.[347]

IRS1

The IRS1 gene regulates insulin receptor substrate 1 (IRS1), one of the key proteins to transmit the metabolic signals of insulin. Studies on IRS1 point mutation and polymorphisms are partially conflicting; however, there are clear links between the impact of diet on insulin regulation in various genotypes. The GA genotype of polymorphism G972R (rs1801278) of this gene is associated with insulin resistance, particularly when combined with a diet high in salt. There is also an increased risk of diabetes when hypertension has previously been established.[348]

The GG genotype of polymorphism rs7578326 and the TT genotype of polymorphism rs2943641 of the IRS1 gene are associated with a lowered risk of insulin resistance, type 2 diabetes and metabolic syndrome. The risk was significantly lower when the proportion of saturated fat to carbohydrates in the diet was low (< 0.25). In addition, a study conducted on the population of Puerto Rico found that carriers of the G allele of the polymorphism rs7578326 of the IRS1 gene had a lowered risk of metabolic syndrome when the dietary intake of monounsaturated fatty acids was below average.[349]

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CRP

The CRP gene regulates the function of the C-reactive protein which is the key marker of acute inflammation. It is used for example to predict the development of cardiovascular diseases. The GG genotype of polymorphism -732A/G of this gene significantly improved the insulin sensitivity triggered by physical exercise.[350]

LIPC

The LIPC gene regulates the function of hepatic lipase which hydrolyzes the triglycerides and phospholipids in lipoproteins. It converts IDL (intermediate density lipoprotein) molecules into LDL molecules. The TT genotype of polymorphism -514C/T of this gene is associated with a significantly increased blood sugar level 2 hours after an oral glucose challenge test, as well as increased fasting insulin levels and cholesterol values (total cholesterol, HDL and triglycerides). However, a negative impact on insulin resistance was not detected.[351] The GG genotype of polymorphism G-250A of this gene is associated with an increased risk of type 2 diabetes.[352]

VDR

The VDR gene regulates the function of the vitamin D receptor. These receptors are present in every cell of the body which reflects the importance of vitamin D at the cellular level. The FF genotype of polymorphism Fok1 of this gene is associated with impaired insulin sensitivity and an increased risk of type 2 diabetes.[353] This genotype reacts well to taking vitamin D as a dietary supplement which lowers the risk of developing insulin resistance.[354] According to a study conducted on young men, the BB genotype of polymorphism Bsm1 of the VDR gene is associated with higher fasting blood sugar levels (< 5.55 mmol/L or 100 mg/dL). However, this was not detected in the men of this genotype who were physically very active.[355]

ADIPOQ/APM1

The ADIPOQ or APM1 gene regulates the function of the adiponectin hormone. It is involved in the oxidization of fatty acids, glucose metabolism, insulin sensitivity and the regulation of energy metabolism. Studies have found a link between obesity and a low level of adiponectin in the circulation. The TT genotype of polymorphism +457>G (rs2241766) and the GG genotype of polymorphism +276G>T (rs266729) of this gene are associated with significantly lowered adiponectin levels and increased insulin resistance. The TG haplotype of these two polymorphisms has the strongest link to insulin resistance.[356] For women in particular, the GA genotype of polymorphism

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G-11391A of this gene (and the previously mentioned GG genotype of polymorphism +45T>G) are associated with raised adiponectin levels and developing hyperglycaemia during the three-year follow-up period.[357] Dietary changes (increasing the intake of vegetables and substituting low GI options for high GI carbohydrates) and walking regularly are effective in lowering adiponectin levels in overweight carriers of the polymorphisms of this gene (see above). However, this effect has not been detected in individuals with normal body weight.[358]

The following genes are involved in the regulation of blood pressure:

AGT

The AGT gene regulates the function of the angiotensinogen. Angiotensinogen is a protein produced in the liver that converts renin into angiotensin I. This is part of the RAA system that regulates blood pressure. The TT genotype of polymorphism M235T of this gene is associated with high diastolic blood pressure in men[359] but a lowered risk of hypertension in women.[360] The effect of the genotype on blood pressure depends on the origin and sex of the population.

ATP6AP2

The ATP6AP2, or (pro)renin receptor gene, regulates the function of the renin receptor. It promotes the conversion of angiotensinogen into angiotensin I. Animal tests indicate that point mutations (SNP) in this gene may be a predisposing factor for the development of hypertension.[361] Carriers of the C allele of polymorphism IVS5+169C>T of this gene had lower blood pressure compared to carriers of the T allele. This was also associated with a lower level of aldosterone in the circulation.[362]

CYP11B2

The CYP11B2 gene regulates the function of the aldosterone synthase enzyme which is involved in the biosynthesis of the hormone aldosterone. Aldosterone, or the salt hormone, regulates the salt balance and blood pressure in the body. The CC genotype of polymorphism C-344T of this gene is associated with a slightly lowered risk of hypertension compared to the TT genotype.[363]

According to a study conducted on Japanese men, the CT and TT genotypes of the same polymorphism were associated with a risk of hypertension if the individual's diet was high in salt.[364]

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VEGF

The VEGF gene regulates the function of the vascular endothelial growth factors (VEGF) in the blood vessels. These growth factors are activated for example after injury or intense physical exercise. Significantly raised levels of VEGF have been found in the blood plasma of individuals who suffer from hypertension. Polymorphisms 634G>C (C allele) and 936C>T (T allele) of this gene are significantly more common in individuals who suffer from hypertension.[365]

NOS (1,2,3)

The NOS genes regulate nitric oxide synthases (1, 2 and 3). These enzymes catalyze the production of nitric oxide from arginine. Nitric oxide is involved in many physiological phenomena in the body, such as the dilation of blood vessels. The insufficient availability of nitric oxide in the inner membrane of blood vessels (endothelium) is a predisposing factor for hypertension.[366]

The CC genotype of polymorphism rs3782218 of the NOS1 gene is associated with an increased risk of hypertension and coronary heart disease. The AT genotype of polymorphism rs2255929 of the NOS2 gene is associated with a slightly increased risk of hypertension whereas the CC genotype of polymorphism rs3918227 of the NOS3 gene is associated with a significantly increased risk of hypertension.[367]

The following genes are involved in the memory function:

COMT & ANKK1

The COMT gene regulates the function of the catechol-O-methyltransferase enzyme which breaks down catecholamines such as dopamine in the prefrontal area of the brain. Conversely, the DRD2/ANKK1 gene cluster affects the density of the dopamine receptors in the striatum. Polymorphism rs4680 (Met/ Met) of the COMT gene and polymorphism Taq-Ia (A1+) of the DRD2/ANKK1 gene are associated with improved visual working memory. This is fundamentally linked to the delayed exit of dopamine from the prefrontal area of the brain.[368]

CACNA1C

The CACNA1C gene regulates the alpha 1C subunit of the L-type calcium channel (CaV1.2). Calcium channels play a key role in the conversion of electrical activity into biochemical events in nerve cells. Polymorphism rs1006737 of this gene is associated with impaired working memory in healthy individuals, but not in those suffering from bipolar disorder.[369] The same polymorphism is associated with impaired learning in healthy individuals.[370]

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BDNF

The BDNF gene regulates the function of the brain derived neurotrophic factor (BDNF). BDNF is a growth factor that facilitates the specialization of new nerve cells and the survival of existing nerve cells. It has a key role in the memory function, particularly in the hippocampus and the cortex.[371] The Val/Val genotype of polymorphism rs6265 (Val66Met) of this gene is associated with improved auto-biographical memory in elderly individuals that are physically active.[372]

OXTR

The OXTR gene regulates the function of the oxytocin receptor. Oxytocin has an important function in developing emotional attachment, face memory and the ability to distinguish facial expressions. The polymorphism rs237887 of this gene (A/A genotype) is associated with impaired face memory and sociability.[373] Conversely, the G/G genotype is associated with increased sociability and attachment.[374]

GRIN2B

The GRIN2B (or NR2B) gene regulates the function of subunit 2 of the NMDA receptor. The NMDA receptor is one of the key neurotransmitter receptors in the brain. Its function is particularly associated with long-term potentiation (memory and learning). The CC genotype of polymorphism rs7301328 (C366G) of this gene is associated with impaired verbal memory (e.g. when remembering a list of words read out loud).[375]

ADRA2B

The ADRA2B gene regulates the function of the alpha-2b adrenergic receptor. The deletion variant of this gene, in which three glutamic acids (SNPs rs28365031, rs29000568 and rs4066772) are deleted from the receptor-coding gene, is associated with improved emotional memory[376] and the improved ability to notice the negative aspects of a situation.[377]

GCR

The GCR gene regulates the function of the glucocorticoid receptor (GR) in the cells. The stress hormone cortisol and other glucocorticoids bind to the glucocorticoid receptor. The density of these receptors is particularly high in the prefrontal area of the brain. The G allele of polymorphism rs6198 (the 9-beta A3669G genotype) of this gene is associated with an improved reaction time in women but not in men.[378]

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REBALANCING BLOOD SUGAR

BLOOD SUGAR BALANCING COCKTAIL

To be consumed approx. 30 minutes before a high-carbohydrate meal:

- *100–300 mg alpha lipoic acid*
- *50–100 mg chromium*
- *500–1000 mg berberine*
- *200–400 mg EGCG (green tea extract)*
- *50 mg resveratrol*
- *100 mg magnesium malate*



BLOOD SUGAR REBALANCING SMOOTHIE

- *1–2 tbsp apple cider vinegar (look for a product with sediment at the bottom of the bottle)*
- *1–2 tsp cinnamon*
- *1–2 dL (½–1 cup) blueberries*
- *2 small garden apples*
- *2 cm (1-inch) piece ginger*
- *1 tbsp chia seeds (soaked)*
- *1 tsp turmeric powder*
- *1–2 tsp raw honey*
- *1 tbsp MCT oil or virgin coconut oil*
- *a pinch of unrefined sea salt*
- *3–4 dL (1.25–1.75 cups) spring water or purified water*

Cut up an apple, remove the core. Peel and cut up a piece of ginger. Place all ingredients in a blender and blend until smooth. Sip slowly.

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THE ALCHEMIST'S POWER POTION

- *6 dL (2.5 cups) hot spring water*
- *1 tsp fungus powder extract (you can use a mixture)*
- *1 tsp ginseng root powder*
- *2 tbsp raw cocoa powder*
- *1 handful cashew nuts*
- *1 tbsp raw honey*
- *1 tbsp cold-pressed virgin coconut oil*
- *1/2 tsp vanilla powder*
- *1/4 tsp chili or cayenne pepper powder*
- *a pinch of unrefined sea salt*

Blend the ingredients in a blender.

Try these as powdered extracts:

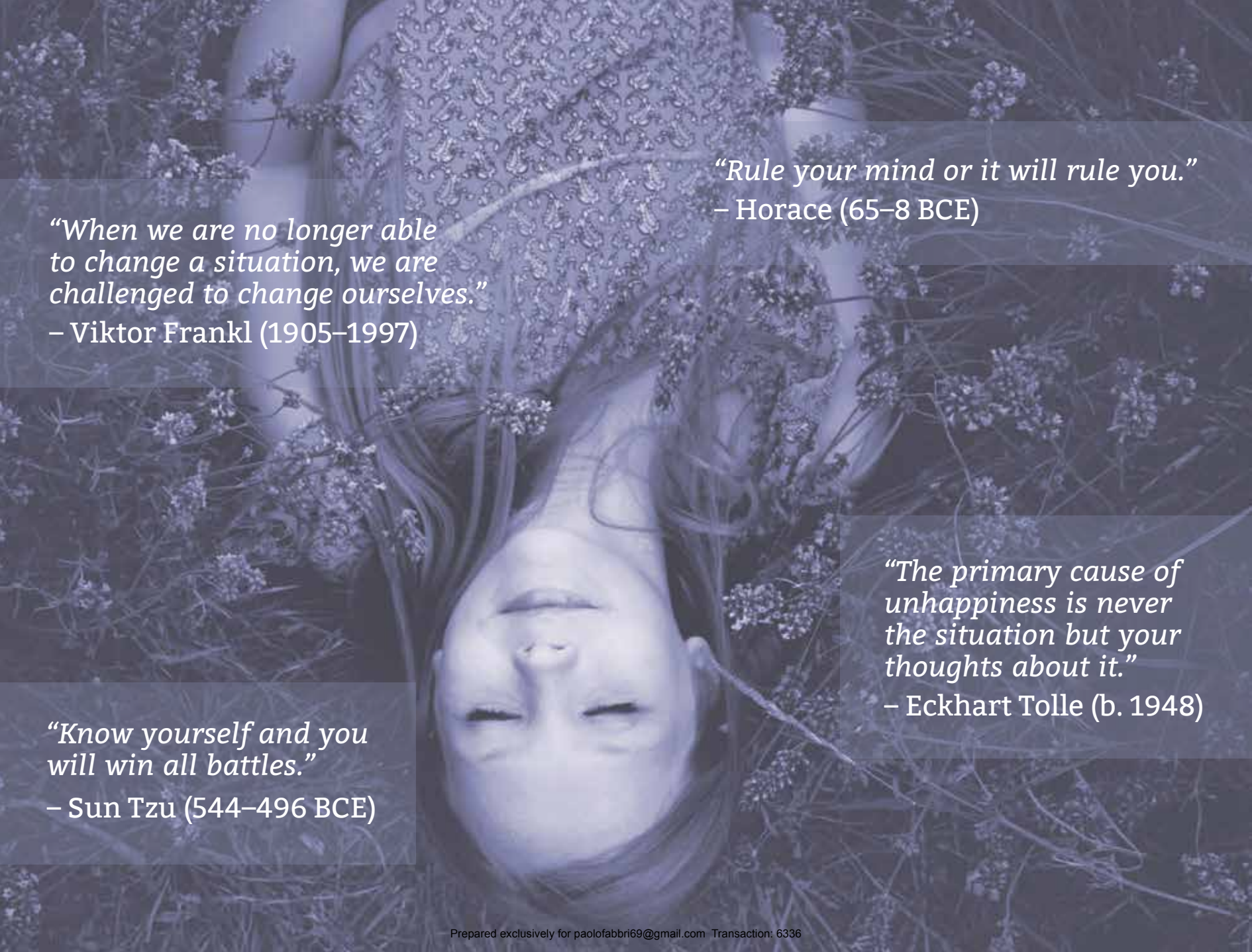
– reishi
– cordyceps
– lion's mane
– chaga
– maitake
– shiitake
– himematsutake



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05 MIND

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"When we are no longer able to change a situation, we are challenged to change ourselves."
– Viktor Frankl (1905–1997)

"Rule your mind or it will rule you."
– Horace (65–8 BCE)

"The primary cause of unhappiness is never the situation but your thoughts about it."
– Eckhart Tolle (b. 1948)

"Know yourself and you will win all battles."
– Sun Tzu (544–496 BCE)

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"I CAN'T GET A MOMENT OF PEACE FROM THE CONSTANT CHATTER IN MY MIND..."

Lisa's problem is a common one: continuous thought pollution occupying the mind and causing energy drainage. She sometimes feels it is hard to get peace from her own thoughts. Indeed, it is not uncommon to feel like a prisoner inside one's own mind. Lisa's hyperactive mind and negative thoughts are troublesome in several ways: falling asleep is difficult, she struggles to listen to others, and her job is full of interruptions, task-switching and constant multitasking.

Lisa consults a physician to help her with the issues she's experiencing. In the end, she is "diagnosed" with stress and moderate depression – even though the doctor didn't have time to discuss Lisa's emotional life at all. The treatment options available are limited to sedatives and antidepressants.

Dissatisfied with this, Lisa decides to seek help elsewhere. With the help of books and websites, she begins to get to know her own mind. She finds an introductory course on meditation, recommended by several people in her social circle. Lisa is wondering whether meditation might be the key to managing the endless flood of thoughts.

Could it be possible to curb the stream of thoughts and change the way she reacts to external factors? This approach feels strange and at odds with everything she has learned before: ever since she was a child, she was taught to be constantly active, curious and to keep her mind busy. After forty years of struggle, Lisa feels it's time to take a different approach.

The first few meditation sessions prove difficult. Even a second feels too long to concentrate only on observing one's thoughts and sensations. Lisa quickly finds herself drifting into her own dream world... until the instructor's voice interrupts her daydreaming and returns her focus on observing the breath.

The road to a serene mind is as challenging as learning to walk as a baby. After a couple of sessions and home exercises, Lisa is able to maintain mental focus and clarity for up to ten minutes. For the first time in a long time, Lisa is hopeful that she will be able to get her thoughts and life under control.

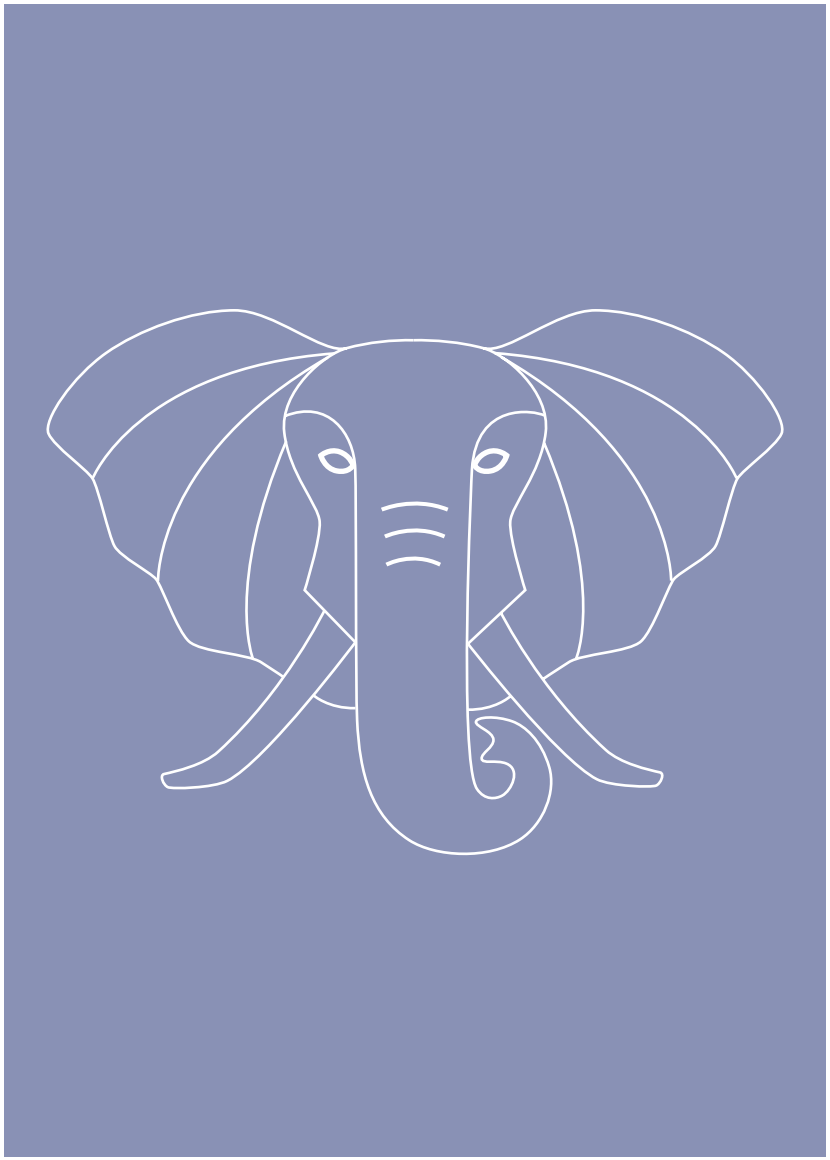
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TAME YOUR MENTAL ELEPHANT

"If you want to change people's minds,
you've got to talk to their elephants."
– sosial psychologist Jonathan Haidt (b. 1963)

One of the most revered Hindu deities is Ganesha: a man with a big round belly, four hands, and the head of an elephant. Ganesha is known as the remover of obstacles and the Hindu god of wisdom, luck and intelligence. Ganesha is also portrayed in Buddhism as Vināyaka.

In his book, *The Happiness Hypothesis*, American psychologist Jonathan Haidt uses the elephant as a metaphor for the mind.[1] Taming the elephant is the key to developing oneself and getting the mind under control. In the metaphor, the rider of the elephant represents the conscious mind while the elephant represents the subconscious mind. The rider cannot control the elephant by brute force – control can only be attained by becoming its servant.



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I THINK – THEREFORE I AM?

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"I think, therefore I am." Most readers will undoubtedly recognize this famous phrase by philosopher René Descartes (1596–1650). The French philosopher, mathematician, author, and scientist was the most well-known rationalist of the early 17th century. According to Descartes, all sensory experiences should be treated with suspicion and the rational mind should be the primary source of information. For rationalists, thinking and the rational mind are all that exists. Taken to the extreme, rationalism leads to solipsism, the belief that only one's own perceptions and thoughts of reality are certain.[2]

Psychology studies the human consciousness and its manifestation in behavior. Psychology and the study of the psyche have fascinating historical roots. Psychology branched out as a distinct science in the 19th century. German philosopher, psychologist and physicist Gustav Fechner (1801–1887) devised a law according to which the psychological sensation is proportional to the logarithm of the material stimulus (S = K log I); this branch of psychology, later named psychophysics, helped establish the scientific nature of the field amongst psychologists.

After Fechner, psychology took great leaps thanks to scientists such as William James (1842–1910), the American father of psychology, and James Mark Baldwin (1861–1934), a pioneer in experimental psychology. Their thinking combined "ancient wisdom and knowledge" with the perennial philosophy (Latin: *philosophia perennis*). They viewed reality through a scientific and analytical lens whilst also considering spiritual viewpoints and religious experiences.

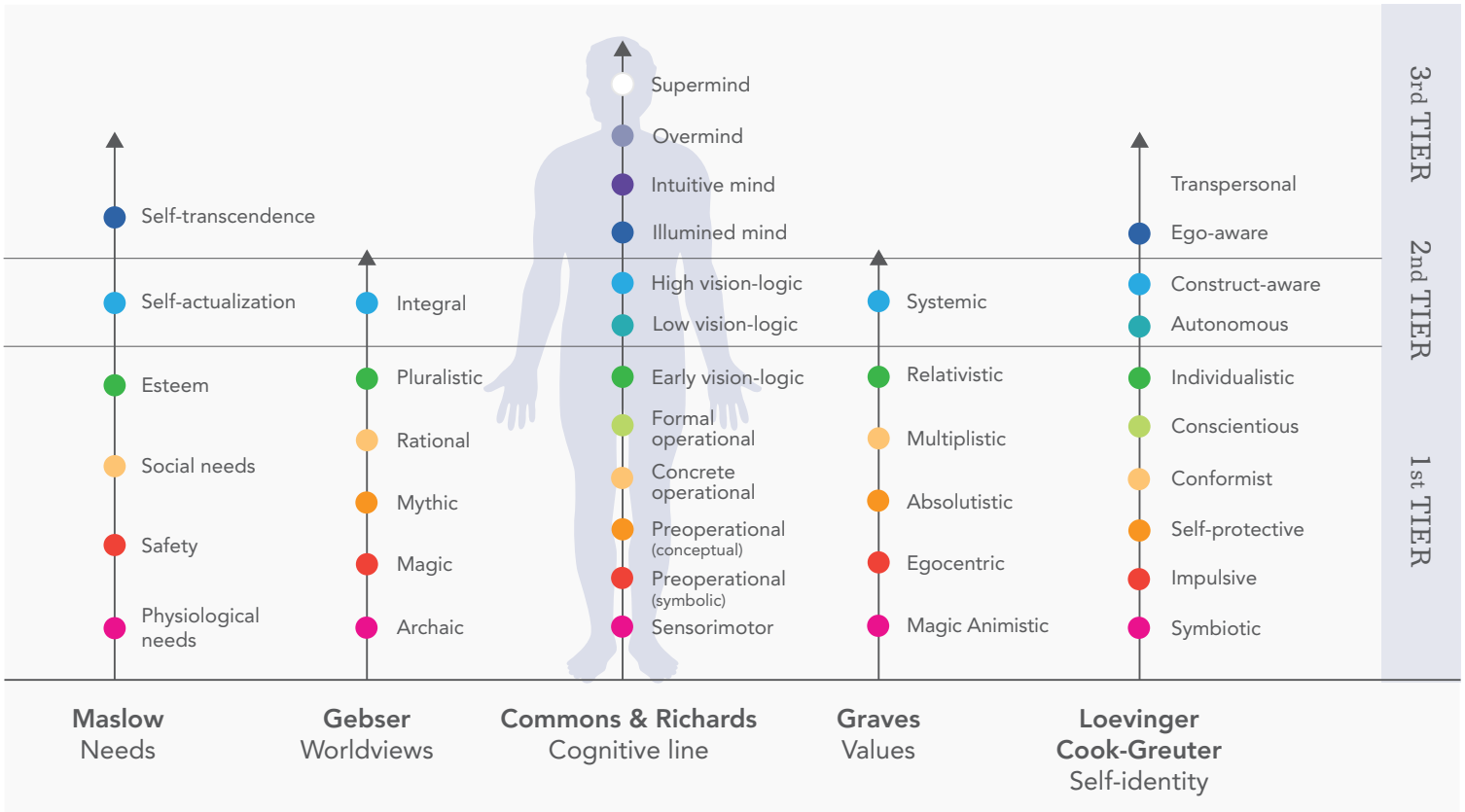
Ken Wilber, a well-known philosopher and the developer of the integral theory and integral psychology, divides consciousness into functions, structures, states, modes and development.

ACCORDING TO WILBER:

- **The functions of consciousness** include perception, desire, will and acts
- **The structures of consciousness** include body, mind, soul and spirit
- **The states of consciousness** include waking, dreaming, sleeping and altered states
- **The modes of consciousness** include aesthetic, moral and scientific
- **The developmental stages of consciousness** include prepersonal, personal and transpersonal as well as subconscious, self-conscious and superconscious[3]

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SYNTHESIS OF DEVELOPMENTAL THEORIES (WILBER)



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In his synthesis Wilber combines the research of scientists such as Carl Jung, Sigmund Freud, Jean Gebser, Jean Piaget, Robert Kegan, Albert Maslow and Susanne Cook-Greuter under a single frame of reference. This makes it possible to study the consciousness, ego, world view and identity from a developmental viewpoint.

The various aspects of human development are not linear – development takes place in multiple directions at once. This means that it is impossible to identify distinct developmental steps. Development may take place horizontally or vertically (*translation vs. transformation*). According to Wilber, development that takes place in adulthood is usually horizontal, i.e. going deeper into the existing framework and developmental level. This may mean for example learning new skills, methods or facts whilst the general psychological frame of reference remains unchanged.

Based on her research, developmental psychologist Susanne Cook-Greuter devised a model of the levels of ego development called the *action logic model*.[4] In this model, each level of development forms a distinct systemic entity.

In the Cook-Greuter model, each level of development (*action logic*) consists of three primary dimensions: doing (*behavioral*), being (*affective*) and thinking (*cognitive*). The levels of developments in Cook-Greuter's model are divided into nine action-logics. Her Leadership Development Framework provides one possible account of how individuals navigate the straits of human existence by using navigational lore, common sense, increasingly complex maps, algorithms, and intuition (see pictures on the next page).

In the model Cook-Greuter describes that self-awareness seems to expand in a regular pattern from ignorance to mature wisdom through a sequence of increasingly complex perspectives on the self and others. Based on her research from the 1990s and 2000s, most of the adult population in the US are at Expert Stage (36.5 %), while in the highest stages (Magician & Ironist) encompass only 2 % of the population.[5]

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MAPPING THE SELF-AWARENESS FROM BIRTH TO EGO-TRANSCENDENCE

Infant, Stage 1
(Symbiotic: E1)



Confused, autistic; preverbal

Impulsive, Stage 2
(Impulsive: E2)



1st person perspective
Rudimentary, physical self-labeling, basic dichotomies

Opportunist, Stage 2/3
(Self-protective: E3 (Δ))



Self-discription in terms of own wishes; dichotomous thinking, self-serving

Rule-oriented (Δ/3)



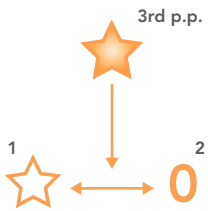
2nd person perspective
Single visible external feature; Beginning comparisons

Diplomat, Stage 3 (Conformist: E4)



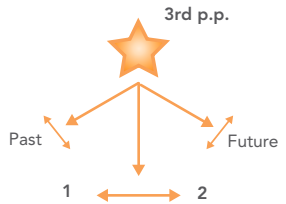
Several external features; vital stats, membership self; rudimentary internal states; concrete operations

Expert, Stage 3/4 (Self-conscious: E5)



3rd person perspective
Clusters of external attributes, simple traits, beginning introspection; beginning separate self-identity; abstract operations

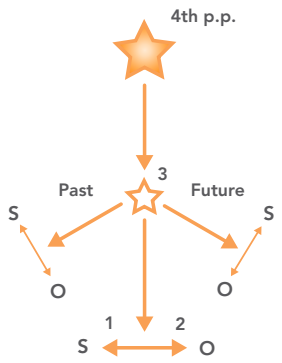
Achiever, Stage 4 (Conscientious: E6)



Expanded 3rd person perspective
Self a system of roles and clusters of traits; independent self, prototype personality; recent past and present, linear causality -> Formal operations

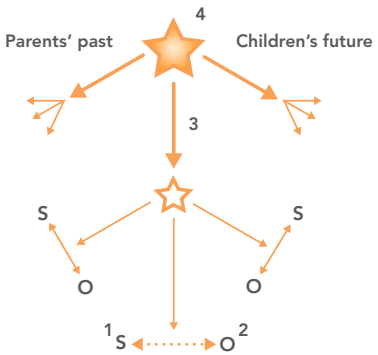
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The Individualist, Stage 4/5



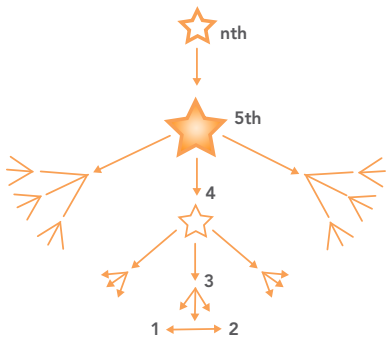
4th p. perspective

The Strategist, Stage 5



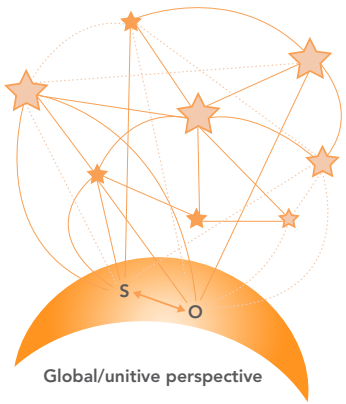
4th p. perspective expanded

The Magician, Stage 5/6



5th to nth p. perspective

The Ironist, Stage 6



Global/unitive perspective

Source: Cook-Greuter, S. (2002). A detailed description of the development of nine action logics in the leadership development framework: Adapted from ego development theory.

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Robert Kegan, a developmental psychologist from Harvard, has devoted his career to studying human meaning-making – a process of making sense of experience through problem solving. In his book, *In Over Our Heads* (1994), Kegan explains the five orders of consciousness in terms of human development. Each of the fiver orders synthesizes three lines of development: processing of things, inter-personal communication and self-actualization. With each order of consciousness, a person creates a wider and more complex understanding of him/herself and their surroundings.

The key principle described is known as Kegan's "Subject-Object Theory". It offers remarkable insight into the actual mechanics of transformation, both psychologically and spiritually. The subject of one stage becomes the object of the subject of the next stage. This process describes the process of both "vertical growth" through psychological stages of consciousness and "horizontal growth" through states of awareness and awakening.[6]

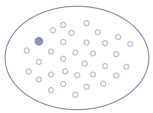
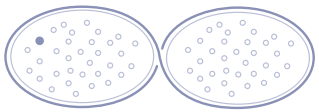
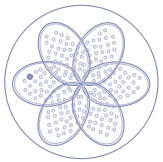
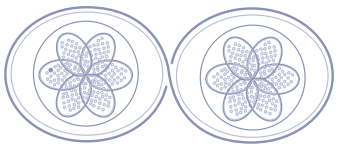
Subject = elements of our knowing or organizing that we are identified with, tied to, fused with, or embedded in.
Object = Elements of our knowing or organizng that we can reflect on, handle, look at, be responsible for, relate to each other, take control of, internalize, assimilate, or otherwise act upon.

From the biohacker's viewpoint, it is useful to assess one's current level of development regarding factors such as the consciousness, self-identity, emotions, kinesthesis (movement), senses, values and world view.

Indeed, the biohacker is also a "nooshacker" (cf. bioshpere vs. noosphere; the Greek word *noos* means wisdom and the mind).

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ROBERT KEGAN'S FIVE ORDERS OF MIND, SUBJECT/OBJECT DIFFERENTIATIONS AND STRUCTURES OF MEANING-MAKING

Developmental Stage/ Order of Mind (typical ages)	**What can be seen as an *object*** (the content of one's knowing)	**What one is *subject* to** (the structure of one's knowing)	**Underlaying Structure of Meaning-Making**
1st Order: Impulsive Mind (~2–6 years old)	One's reflexes	One's impulses, perceptions	Single point
2nd Order: Instrumental Mind (~6 years old through adolescence)	One's impulses, perceptions	One's needs, interests, desires	Categories 
3rd Order: Socialized Mind (post-adolescence)	One's needs, interests, desires	Interpersonal relationships, mutuality	Across categories 
4th Order: Self-Authoring Mind (variable, if achieved)	Interpersonal relationships, mutuality	Self-authorship, identity, ideology	Systemic 
5th Order: Self-Transforming Mind (typically >~40, if achieved)	Self-authorship, identity, ideology	The dialectic between ideologies	System of systems 

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THE STRUCTURE AND FUNCTIONS OF THE BRAIN

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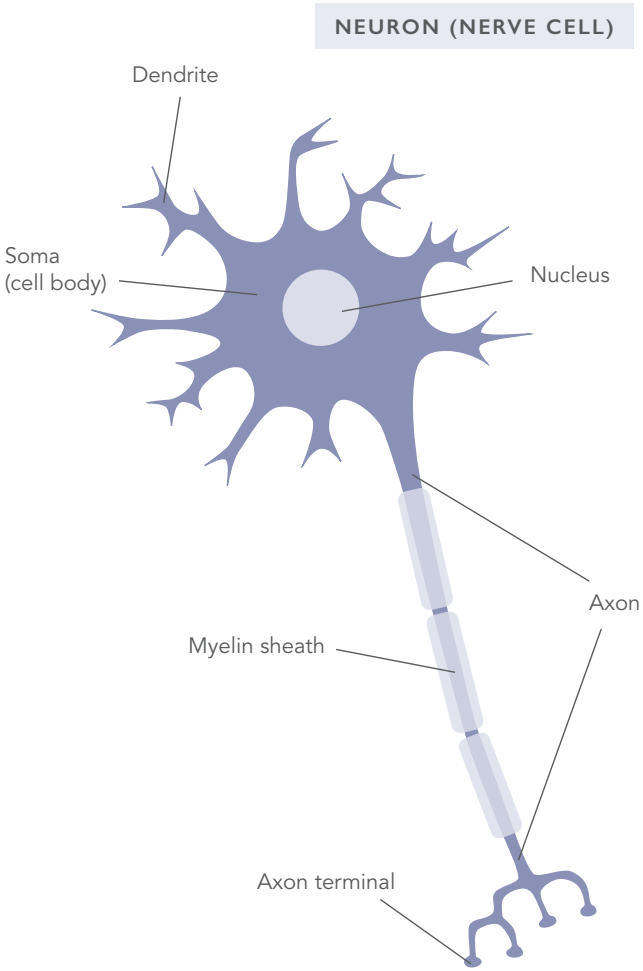
It is important for the biohacker to understand the basic structure and physiological mechanisms of the brain. The techniques outlined below are used to influence these aspects.

The brain is an organ located inside the skull. It receives, stores, processes and produces information. This is done by approximately 100 billion neurons, the axons of which form an integrated network.

The functions of the brain neurons include the following:[7]

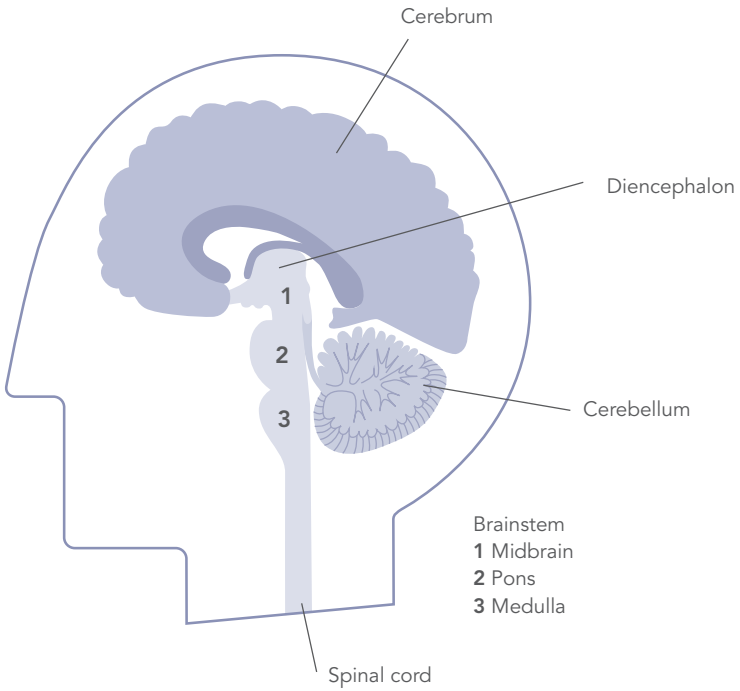
- Receiving impulses from other cells
- Assessing the information provided by the impulses and transmitting it onward
- Acting as independent oscillators
- Storing information about the robustness of the connections between cells

In addition to neurons, the brain contains a large number of glial cells[8] and other support structures such as blood vessels, membranes and fluid-filled cavities.[9]



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THE STRUCTURE OF THE BRAIN



CENTRAL NERVOUS SYSTEM

The central nervous system consists of the spinal cord, brainstem, cerebellum and cerebrum. The central nervous system receives information via the peripheral nervous system. Action commands are also transmitted from the brain to muscles, internal organs and endocrine glands via the peripheral nervous system.

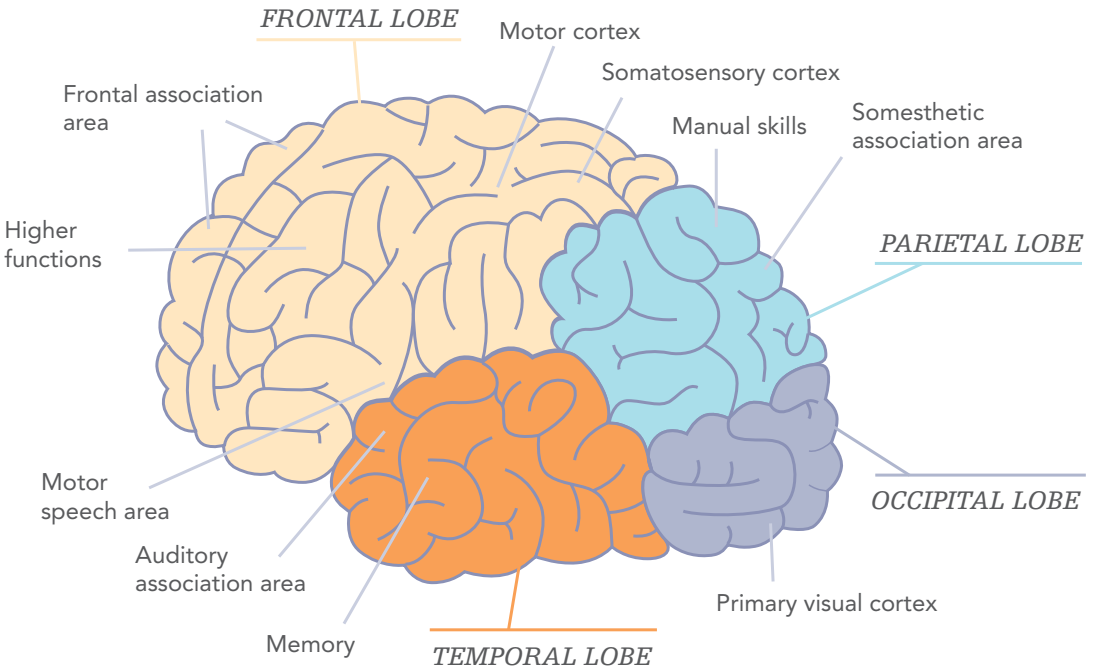
Voluntary activity is mostly controlled by the cerebrum. Other parts of the brain such as the cerebellum appear to function involuntarily and complete the actions commanded by the cerebrum. The cerebellum assesses delays accurately[10] and plays a crucial part in performing and coordinating previously learned series of movements (such as swimming).[11] The cerebellum is connected to the back of the brainstem by the cerebellar peduncles. The brainstem hosts connections between different parts of the brain, sensory and motor nerve routes, and various types of nuclei that regulate unconscious vital body functions (such as breathing).

The brainstem consists of the diencephalon, midbrain, pons and medulla. The diencephalon is the home of the hypothalamus which regulates endocrine functions and the thalamus through which signals sent by the senses are transmitted to the cortex (except the sense of smell). The spinal cord contains neurons controlling automatic functions and nerve routes for controlling muscles, tactile sensations, as well as various reflexes (such as pain).[12]

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CEREBRAL HEMISPHERES

Scientists have studied the role each part of the brain takes in performing various functions. For example, neurobiologist Roger W. Sperry won the Nobel Prize in 1981 for his research on the changes caused by damage to the corpus callosum which connects the cerebral hemispheres. Based on his findings, Sperry proposed that the left hemisphere is responsible for linguistic functions. This is the basis for the persistent notion of layman psychology that the left hemisphere is responsible for logical thinking whilst the right hemisphere is responsible for creative thinking. Since then, such simplified distinction has been debunked.



PARTS OF THE BRAIN

In the light of current knowledge, both hemispheres function with equal efficiency, although in certain situations one hemisphere may be more active than the other. Based on observations made from brain scans, the right hemisphere regulates the functions of the left side of the body and vice versa.[13]

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The right and left hemisphere consist of the cortex, white matter and basal ganglia. These are clusters of neurons connected to the movement-controlling parts of the cortex as well as the cerebellum. The cortex is divided into four lobes across each hemisphere: at the front, there is the frontal lobe, followed by the parietal lobe. Below the parietal lobe there is the temporal lobe. The occipital lobe is located at the back of the brain. The cortex is divided into several areas, each with their own function and unique tissue structure.[14]

Different parts of the cortex are interconnected via axon clusters. The hemispheres are connected by the corpus callosum through which approximately 200 million axons travel.[15] Einstein's corpus callosum was known to have very robust connections which may help explain his extraordinary abilities.[16]

According to studies, the connection between the hemispheres may be enhanced through exercise, meditation, neurofeedback,[17] playing musical instruments[18] or acupuncture.[19]

The brain and the entire central nervous system communicate with the environment via 12 cranial nerves and 31 spinal nerves. Upon entering the brain, sensory information is first received by the primary cortex from which the edited information is transmitted to the adjacent cortical areas for processing. The primary areas send abundant feedback signals to the thalamus, as do the higher areas to the primary areas. As interpretations depend on sensory information, the observation may vary significantly based on the focus of attention.

It is important to note that conscious interpretation of sensory information requires pre-existing memory information.[20 21] Processes leading to motor reactions and decision-making occur in the association areas of the parietal and frontal lobes. However, sensory information is also processed in the frontal lobe (in the frontal association area).[22] For example, well-targeted electrostimulation in these areas may well improve both motor and cognitive processes as well as memory[23] which is of particular interest to the bio-hacker (see section "Transcranial direct-current stimulation (tDCS)" for more information).

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THE AREAS OF THE BRAIN AND THEIR FUNCTIONS

An entire series of books could be written about the complex structure of the brain. This part only discusses the areas of the brain that are key to the contents of the *Biohacker's Handbook*.



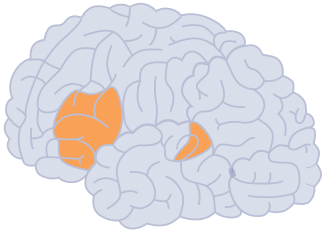
PARIETAL LOBE

The association areas of the parietal lobe connect various sensory experiences. They are located in the area around the visual, tactile and auditory cortices.

Primary neurotransmitter: acetylcholine

Functions:

- Compiling the information provided by various senses[24]
- Compiling the information provided by the field of vision with information regarding the positioning of the eyes, head and body[25]
- Connecting intentions and the environment before decision-making[26]



AREAS CONTROLLING SPEECH AND THE LANGUAGE CENTERS OF THE BRAIN

The areas of the brain associated with speech and language control consist of Broca's area[27] and Wernicke's area.[28]

Functions of Broca's area:

- Forming speech
- Combining words into sentences and assigning meaning to them
- Recognizing gestures in association with speech[29]

Functions of Wernicke's area:[30]

- Expressing speech and assigning meaning to it
- Understanding and repeating speech
- Reading and writing
- Expressing thoughts

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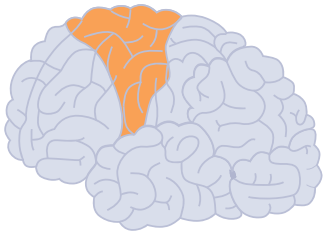
PREFRONTAL CORTEX

Together with the limbic system, the prefrontal cortex is one of the key areas of the brain for emotions and decision-making. It is located at the front of the brain and connected to the limbic system.

Primary neurotransmitters:[31] dopamine and noradrenaline, glutamate and serotonin (see section "Neurotransmitters" for more information).

Functions:[32]

- Controlling the limbic system
- Directing and maintaining focus
- Assessing and analyzing situations
- Controlling and assessing activity, learning from previous experiences
- Expressing emotions and empathy
- Regulating short term memory



MOTOR CORTEX

The motor cortex is the main control center of all body movement. It is located behind the orbitofrontal cortex. It consists of the primary motor cortex and the premotor cortex.

Primary neurotransmitters: acetylcholine and GABA (gamma-aminobutyric acid)

Functions:

- Controlling body movements
- Coordinating voluntary movements such as those of the muscles in the body and limbs
  - The premotor cortex plays a crucial part particularly in performing complex movements[33]
  - Mirror neurons facilitate imitating another person's gestures[34]
- Maintaining posture
- Regulating the internal reflexes of the cortex

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LIMBIC SYSTEM

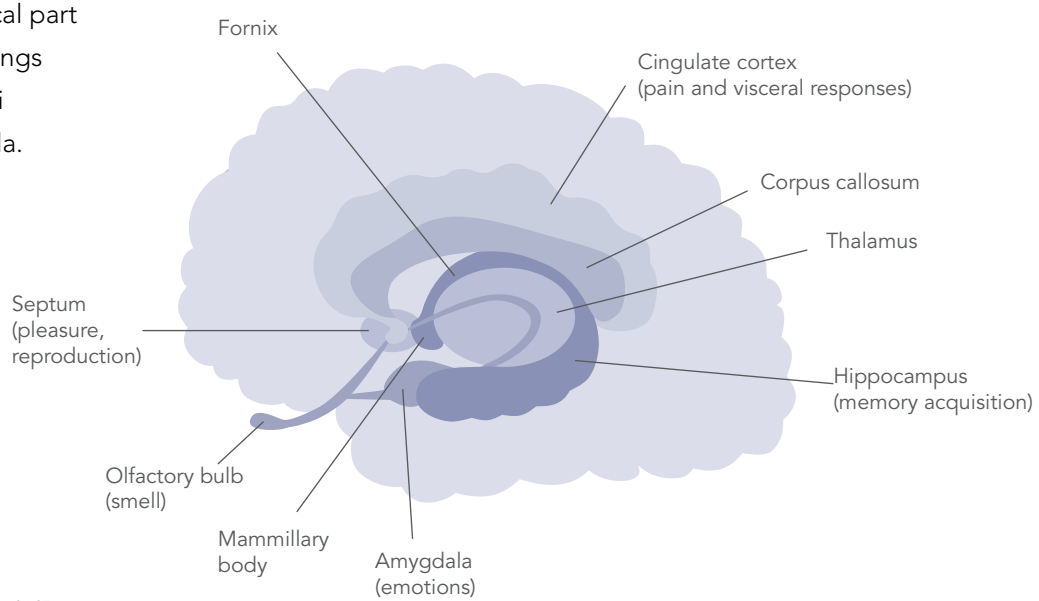
The limbic system is the regulation center of feelings and emotions. It is located in the central and front parts of the cerebrum. It forms a link between the brainstem and the cortical parts. The cortical part consists of the outer and inner rings. The rings connect to cortical groups of neuron nuclei such as the hippocampus and the amygdala.

Principal neurotransmitters:
noradrenaline, dopamine, serotonin and glutamate

Functions:

- Regulating emotional life
- Regulating eating and drinking
- Fear and "fight or flight" reactions[35]
- Memory regulation and comparative assessment (particularly the hippocampus)[36 37]
- Storing memories of how easy or difficult learning something was in the pastt[38]

LIMBIC SYSTEM



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METHODS FOR UPGRADING YOUR MIND

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There are more individuals suffering from mental health issues today than ever before. Population studies conducted in Western countries have found that 20–29 % of the adult population suffered from a diagnosed mental health issue within the year immediately preceding.[39]

The use of antidepressants has increased significantly. From 1999 to 2012, the percentage of Americans on antidepressants increased from 6.8 % to 13 %, according to a report published by the Journal of the American Medical Association (JAMA)[40] and the trend seems to be rising. Antidepressant users are most likely to be women and older adults.[41] In Germany, antidepressant use had risen 46 % in just four years. In Spain and Portugal, it rose about 20 % during the same period.[42]

Statistically, the use of antidepressants has increased faster than the rate of diagnosed mental health disorders. In other words, it is now extremely common to treat various symptoms with antidepressant medication. Antidepressants are prescribed not only for depression but also for eating disorders, panic disorders, anxiety and menopausal problems, for example. However, studies indicate that antidepressants do not cure illnesses and may only alleviate the symptoms.[43] They are also rarely more effective compared to a placebo.[44]

DID YOU KNOW

NEARLY ONE IN FIVE (44.7 MILLION IN 2016) U.S. ADULTS LIVES WITH A MENTAL ILLNESS.*

Studies conducted on antidepressants are not without their problems, either. For example, studies have been left unpublished in cases where the drug caused significant adverse effects to test subjects or where the desired evidence of the drug's effectiveness was not acquired.[45]

The use of psychiatric medication often also involves serious side effects, particularly in the case of antipsychotic drugs. The list of adverse side effects is long: susceptibility to infections, fatigue, loss of cognitive function, cerebro-vascular disorders, hypotension, aggressiveness, lethargy, restlessness, nausea, intestinal bleeding, weight gain, swelling, suicidality and a number of other serious side effects.

Antidepressants may be helpful in some cases; however, like sleeping pills, they should not be the primary treatment option. Before you start popping "happy pills", you should be aware that it is often possible to improve the balance and flexibility of the mind using various other methods. This book outlines several methods for observing, analyzing and developing one's mind.

*Source: National Institute of Mental Health.

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MIND AND BODY BALANCE THROUGH MEDITATION

Meditation – as a term, word or exercise – means different things to different people. The dictionary definition states that meditation refers to certain methods of exercising the mind or attempting to achieve certain states of consciousness (Oxford, Cambridge). Meditation could also be described as introspection where the practitioner observers his/her thoughts and feelings.

Meditation has been a traditional part of various spiritual and religious practices, particularly in convents and monasteries. Eastern meditation traditions and mystical movements are thousands of years old. Examples of these include Buddhism in its many forms, Hinduism, Taoism and Islam.[46] Meditation traditions also developed amongst some early cultures and first nations (such as the Eskimo, Native Americans and Bushmen). In the past century, the Western world has seen various movements involving the development of consciousness skills. Of these, Transcendental Meditation (TM) is the most widely studied.



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Since the 1950s, hundreds of studies have been published on meditation. The most recent ones that involve brain imaging and EEG have rectified some of the methodological errors of earlier studies and deepened our understanding of the health benefits of meditation.

A comprehensive meta-analysis study published in 2012[47] covered 163 studies on the psychological effects of meditation. As many as 595 studies had to be excluded due to methodological issues. The most robust psychological effects have been reported in relation to emotional factors and human relationships.

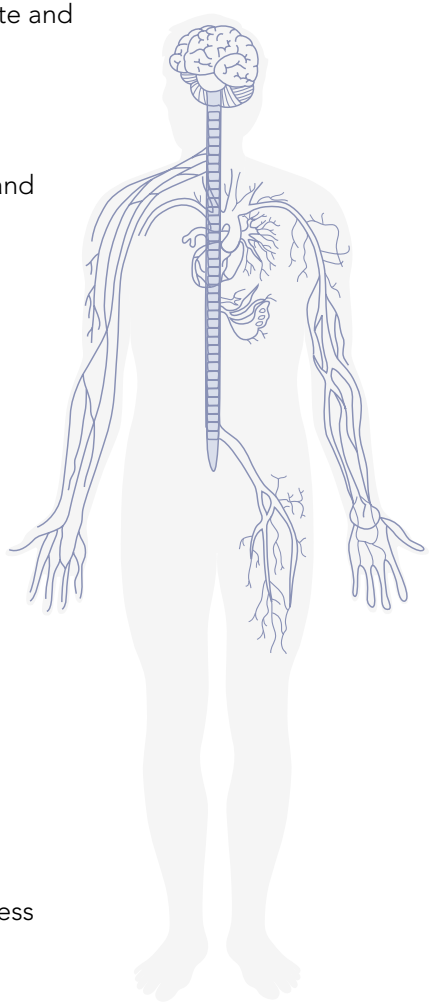
Slightly less robust effects have been observed in individuals' ability to concentrate as well as their cognitive functions. It should be noted that different meditation techniques produce different results. For example, the impact of Transcendental Meditation on cognitive skills is different compared to that of mindfulness techniques.[48]

PSYCHOLOGICAL EFFECTS

- Higher stress tolerance and lower stress levels[49 50 51 52]
- Finding it easier to forgive[53]
- Reduced anxiety and depression[54 55 56 57 58]
- Improved ability to concentrate and better control of emotions[59]
- Improved memory[60]
- Increased empathy[61]
- Improved cognitive function and intelligence[62 63 64]

PHYSIOLOGICAL EFFECTS

- Lower blood pressure and resting heart rate as well as reduced physiological stress[65]
- Lower levels of cortisol in the blood[66]
- Reduced chronic pain and the sensation of pain[67 68]
- Improved immunity[69]
- Reduced oxidative stress in the body[70]
- Increased alpha and theta waves in the brain[71 72]
- Increased brain plasticity[73]
- Slowing down the aging process of the brain[74] and improving cerebral blood flow[75 76]



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COMPARISON OF VARIOUS MEDITATION STYLES AND THEIR PHYSIOLOGICAL EFFECTS

MEDITATON	FOCUS OF ATTENTION	BRAIN AREAS	EEG
Tibetan Buddhist meditation	Focus on compassion and loving kindness	Increased activity in the left frontal lobe and the thalamus. Decreased activity in the parietal lobe (orientation and eyesight).	Increased activity in the 40 Hz frequency range (indicates concentration)
Vipassana, mindfulness, zazen	Observation, for example observing one's breathing	Increased connectivity in the right frontal lobe (attention) and sensations such as the insular cortex (taste), right parietal lobe (touch) and right temporal lobe (sound).	Activity in the left frontal lobe
Transcendental meditation	Mantra	Increased activity in the frontal lobe and the parietal lobe. Decreased activity in the striatum and the thalamus.	Increased uniformity of the frontal lobe alpha waves

Source: Travis, F. (2006, 2009, 2010)

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BREATHING – THE KEY TO CONTROLLING THE NERVOUS SYSTEM

Breathing and the regulation thereof have a great impact on the function of the autonomic nervous system. Deep breathing exercises are especially effective in reducing stress and tension. Extended exhalation effectively activates the parasympathetic nervous system which is linked for example to increased relaxation and recovery as well as lowered heart rate and blood pressure.[77]

The physiology of breathing and the breathing techniques associated with physical exercise are discussed in more detail in the Exercise chapter of the *Biohacker's Handbook*.

PRANAYAMA TECHNIQUES

Prāṇāyāma is a Sanskrit word which means extended breathing or expansion of the life force. The pranayama breathing techniques are a core part of practicing yoga together with other techniques such as various asanas (positions). Pranayama is based on the philosophy of the Yoga Sutras of Patanjali (400 CE).[78]

Pranayama breathing techniques can be used to improve stress tolerance and operational control,[79] parasympathetic nervous system function[80] and respiratory capacity[81 82] as well as to reduce blood pressure and oxygen consumption.[83]

THE BREATH OF FIRE (BHASTRIKĀ)

The breath of fire is a vigorous breathing technique in which the movements of the diaphragm are used to breathe in and out through the nose. The traditional bhastrika technique involves repeating the breath sequence 10–100 times, then drawing the lungs full of air and holding one's breath for as long as possible. This is followed by an exhalation through the mouth as slowly as possible, completing one bhastrika cycle. The cycles may be repeated as many times as is desired.

The breath of fire increases the oxygen saturation in the blood and improves the function of the respiratory system (particularly the diaphragm). The breath of fire balances the sympathetic and parasympathetic nervous systems. It also has a positive impact on the immune system function.[84 85]

The breath of fire may also be completed very slowly (6 breaths per minute), taking 4 seconds to inhale and 6 seconds to exhale. A five-minute exercise can be effective in lowering blood pressure and activating the parasympathetic nervous system.[86]

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A 10-second breathing exercise for stress relief

The breath of fire may also be utilized for quick stress relief.

- Bring your hands in front of your chest and push your palms together
- Breathe vigorously in and out through the mouth for 10 seconds utilizing your diaphragm
- Visualize stress leaving your body and fill your mind with positive thoughts
- Take a deep breath in and exhale completely after a ten-second breath of fire

THE RELAXING BREATH (VISAMA VṚTTI)

The Relaxing Breath technique, developed by Dr. Andrew Weil, is based on the vishama-vṛitti technique of the pranayama which utilizes uneven breathing patterns (for example 4–7–8). The figures refer to the ratio of inhalation, retaining the breath and exhalation as counted in the mind.

When treating his patients, Dr. Weil noticed that this breathing pattern was very effective in calming the nervous system and facilitating falling asleep. This breathing technique may also be used to alleviate stress and remove carbon dioxide from the body.[87]

Follow these steps:

- Breathe out through the mouth, making a hissing sound
- Close your mouth and breathe in through the nose whilst counting to four in your mind
- Hold your breath and count to seven
- Completely exhale, making a hissing sound whilst counting to eight in your mind
- Repeat the breathing cycle at least three times (and as many times as you wish)
- Complete the exercise at least twice per day

ALTERNATE NOSTRIL BREATHING

Alternate nostril breathing is one of the most common pranayama breathing techniques used in Western countries. Nādī Shodhana is Sanskrit and means the purification of energy channels. Indeed, alternate nostril breathing is used in yoga to balance the body and mind.

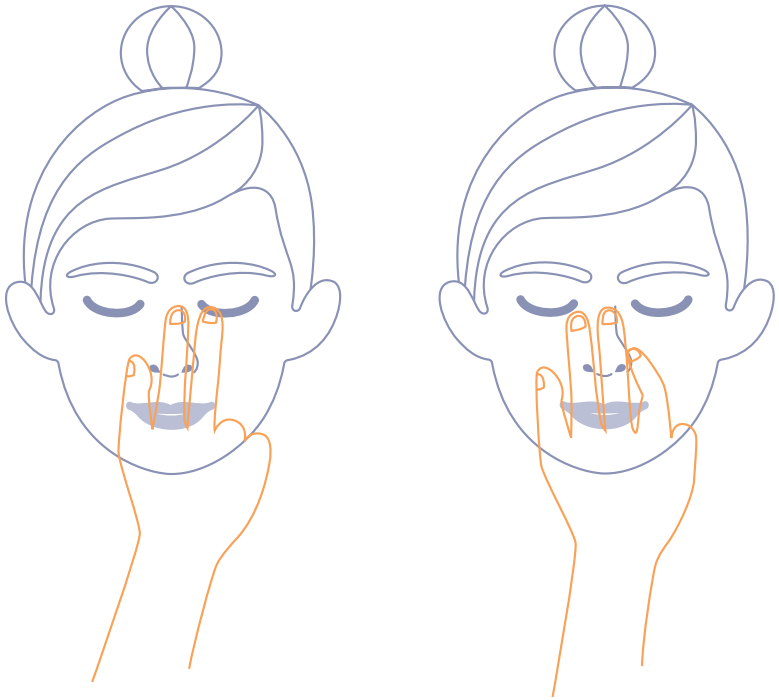
When practiced regularly, alternate nostril breathing can lower blood pressure, respiratory rate and resting heart rate[88] as well as improve heart rate variability (HRV)[89] and balance the function of the autonomic nervous system[90] by boosting the activity of the vagus nerve.[91]

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Follow these steps:

- Sit in a comfortable position with your back straight
- Place the left hand on the left knee and raise the right hand in front of the face
- Point the index and middle fingers of the right hand directly at the forehead, touching it
- Place the thumb by the right nostril and the ring finger by the left nostril
- The exercise:
  - Close the right nostril using the thumb and inhale slowly
  - After inhaling, release the right nostril and close the left nostril using the ring finger
  - Exhale slowly through the right nostril
  - Inhale through the right nostril, release the left nostril, and close the right nostril
  - Exhale through the left nostril
  - This completes one cycle of alternate nostril breathing; continue as directed for 10 minutes
- Alternatively, you may breathe through the left nostril for half the time and through the right nostril for the other half, one nostril at a time (for example 5 minutes + 5 minutes)

FINGER POSITIONING FOR ALTERNATE NOSTRIL BREATHING



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ONE-MINUTE BREATH (KUNDALINI YOGA)

More advanced breathing enthusiasts may test their lung capacity and the strength of their respiratory muscles using the one-minute breathing cycle. The one-minute breath technique is used for example in kundalini yoga to exercise the mind and develop intuition. This breathing technique and the associated meditation may also have hemisphere-integrating effects[92] through the corpus callosum and the medial gyrus.[93]

- Stand up straight or sit in a chair with your back straight and chest out
- First practice deep breathing by inhaling for 5 seconds and exhaling for 5 seconds for a period of a few minutes; this is a preparatory exercise
- Inhale for 20 seconds, first drawing air into the lower part of the lungs, then the middle and finally the top part
- Hold your breath for 20 seconds
- Exhale for 20 seconds, first releasing air from the top part of the lungs, then the middle and finally the lower part
- Repeat three times, gradually working up to 30 times
- If 20 seconds feels too long, start with 5 seconds, then 10 seconds and finally 20 seconds

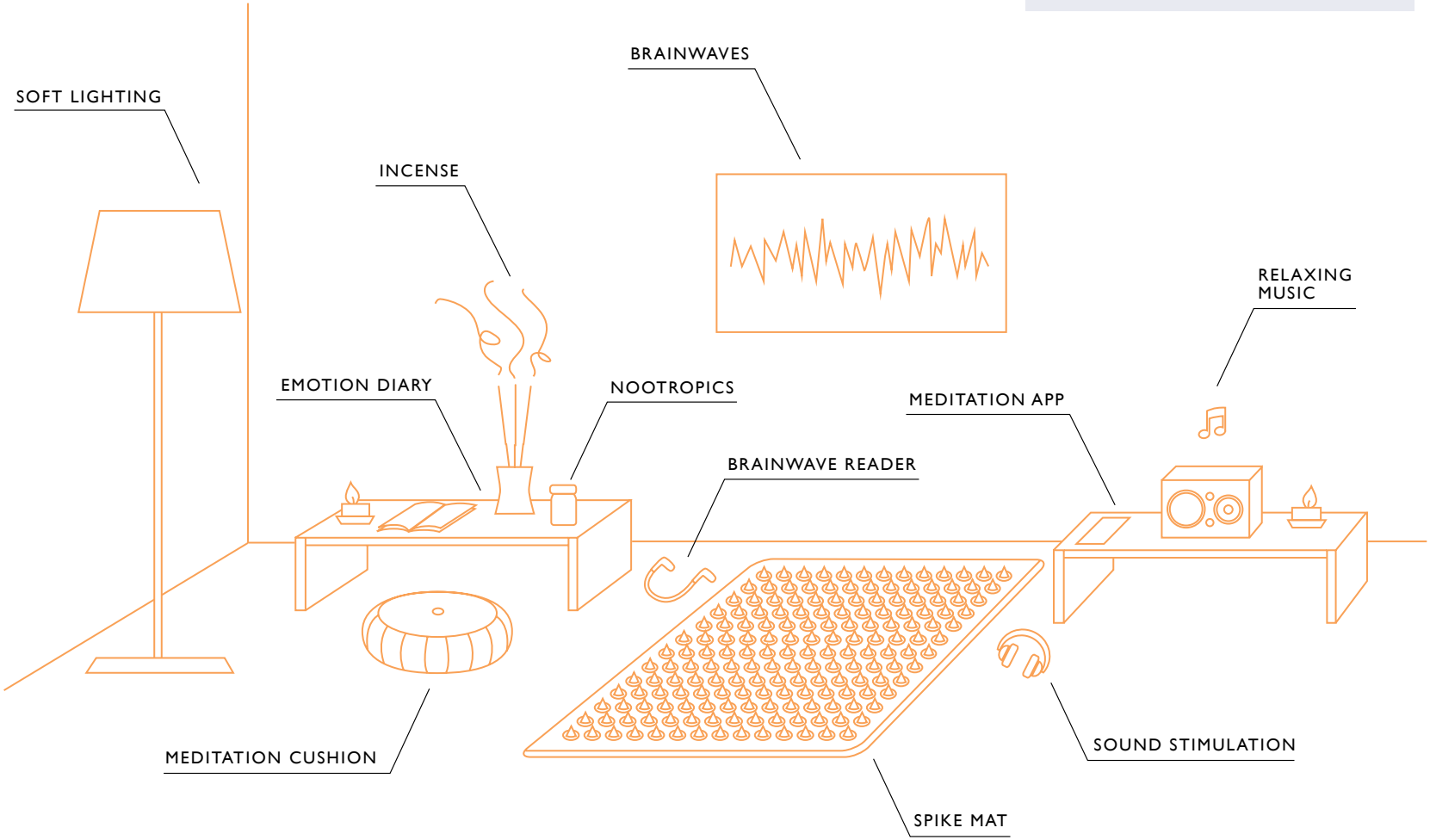
DEEP BREATHING EXERCISE (UJJAYI PRĀṆĀYĀMA)

Follow these steps:

- Inhale through the nose calmly and slowly, listening to the hum of your breathing. Fill your lungs completely.
- Exhale through the nose very calmly, listening to the hum of your breathing. If you wish, you can contract the epiglottis muscle slightly to increase the hum of the breathing in the throat. This helps make the breathing even calmer, deeper and longer.
- The longer and calmer your breaths are the better. However, do not try too hard, you should not get winded.
- If you get winded, stop the exercise. Next time lighten the exercise.
- Start with 10 cycles. You may increase the number of cycles as you become more advanced.

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BIOHACKER'S MEDITATION ROOM



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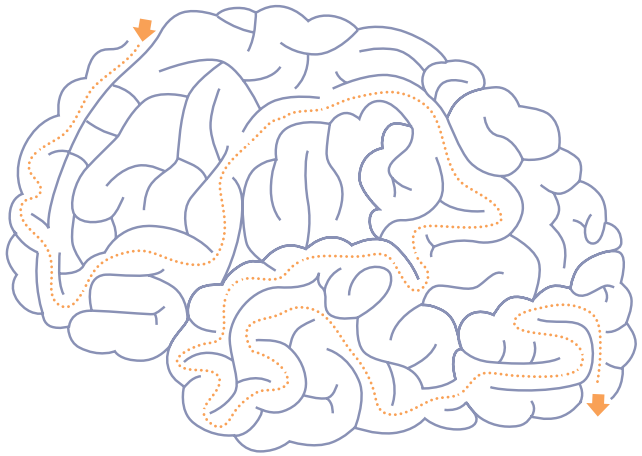
TECHNOLOGIES FOR THE MIND

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Is it possible to alter the structure of the brain? Can you take your consciousness to the next developmental level? Is it even possible to change your personality? These questions arouse conflicting emotions. Indeed, they are not indisputable even on a practical level.

It was previously thought that altering the brain to any significant extent was not possible, certainly not in adulthood. For almost a century the consensus was that brain cells could not regenerate. Since then, these claims have been proven to be myths.[94]

Great advances have been made in brain research in recent years. Instead of anatomical examinations of the brain, scientists now use new methods to learn about brain functions in real time, for example by using functional MRI (fMRI). Today, the best means of measuring brain activity and the interaction between different areas of the brain, in addition to the electroencephalogram (EEG) and quantified electroencephalogram (qEEG), is magnetoencephalography (MEG) which is used for imaging the magnetic fields created by the electrical activity in the brain. These methods have revealed that the brain is in a constant state of flux. The observed neuroplasticity has shown that the brain is capable of significant anatomical changes when required.[95]



Neurofeedback is a form of biofeedback which utilizes real-time feedback provided by the senses on the electrical activity of the brain (EEG). At the same time, the test subject uses the feedback received to influence his/her brain function, for example through a computer game. The idea behind neurofeedback is that successful gameplay is rewarding for the brain and it teaches the brain to act a certain way. In other words, the brain is capable of regulating its electrical activity upon feedback. Neurofeedback has been used to improve concentration, alleviate stress and treat various illnesses such as ADHD, depression, anxiety, chronic pain and epilepsy.[96 97]

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TRANSCRANIAL DIRECT-CURRENT STIMULATION (TDCS)

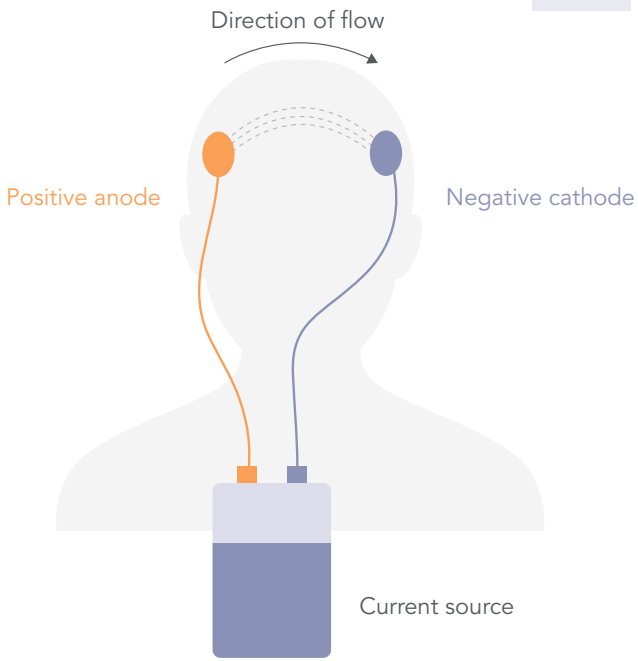
In 1801 Italian physicist Giovanni Aldini successfully cured Luigi Lanzarini of depression with electrical current conducted to the brain using a liquid battery called the voltaic pile, invented only the year prior by another physicist, Alessandro Volta.[98]

Transcranial direct-current stimulation (tDCS) uses a low-voltage direct current conducted to the scalp using two surface electrodes. The stimulation affects the activity of the nervous system for up to several hours post-stimulation.[99]

It is possible to choose a target area to be stimulated. Some of the reported and studied targets for stimulation include linguistic and mathematic intelligence, the ability to focus, problem-solving, memory and coordination.[100] The down-side of stimulating particular areas of the brain is the reported decline in other cognitive functions. For example, when stimulating the posterior parietal association area (see "The Structure of the Brain"), numerical learning is improved but the activation of the subconscious mind is impaired.[101]

According to the research conducted in the past 10 years, electrical stimulation is quite safe without any particular risks[102] or side effects.[103] According to recent studies, electrical stimulation may be helpful in improving self control (or slowing down the automatic response),[104] in the rehabilitation of the brain after a stroke[105 106 107] and the treatment of depression.[108 109 110]

TDCS



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RECORDING EMOTIONS

EMOTION DIARY

A functional way to identify and analyze one's own emotions is to keep a diary. Keeping an emotion diary and creative writing improve both emotional and physical health, for example by reducing stress and depressive thoughts.[111]

Recording emotions is very easy thanks to smartphone apps. In addition to recording your current emotional state, you can add various keywords, images and scales to the entries that may be used in statistical analyses. Emotion diary is also a great method for integrating gratitude practices with diary journaling.

RECOGNIZING FACIAL EXPRESSIONS

The concept of identifying emotions from facial expressions has been present in psychological literature for more than 50 years.[112] The validated method[113] involves using specially-developed computer programs that study real-time changes in facial expressions.

HEART RATE VARIABILITY (HRV)

Heart rate variability can be used to assess stress caused by emotional reactions. An extremely stressed person is often also anxious, highly strung or fearful. Heart Rate Variability is addressed more deeply in the Exercise chapter of the *Biohacker's Handbook*.

GALVANIC SKIN RESPONSE SENSOR

Analyzing emotions using a galvanic skin response sensor is one of the oldest methods. Lie detectors are partially based on this technology in addition to other methods (such as heart rate, respiratory rate and blood pressure). The sensor detects changes in electrical conductivity caused by changes in the circulation of the skin.

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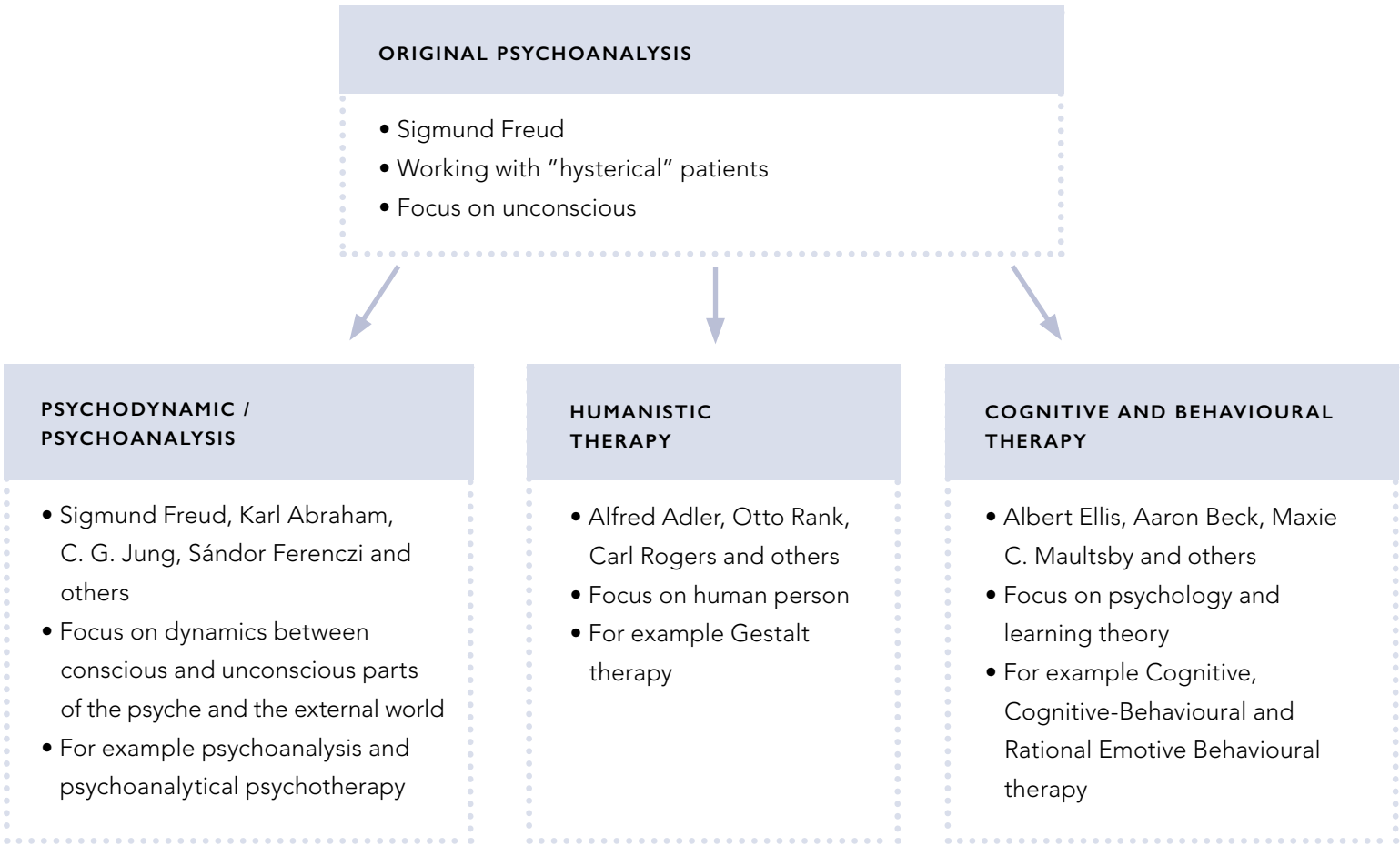
DIFFERENT FORMS OF THERAPY

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A single best form of therapy or psychological treatment does not exist – the ideal choice depends on the individual's development, current state and future goals. Many forms of psychotherapy involve processing repressed emotions stemming from the developmental stages of childhood as well as problematic thinking patterns.

Freud's psychotherapy model among other therapy models have been developed further in the 21st century on the basis of the modern conflict theory, which focuses on various emotional symptoms.[114] Cognitive psychotherapy on the other hand deals with unhelpful thinking patterns that undermine the individual's wellbeing, as well as the connections between such thinking patterns and difficult events, emotions and behavioral patterns. Cognitive psychotherapy has a strong theoretical and scientific basis. It is the most widely studied form of psychotherapy, particularly in relation to psychosocial situations.[115] However, it has been found to be of limited use in the treatment of severe psychiatric illnesses.[116]

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Other forms of therapy include inter alia hypnotherapy, Gestalt therapy and solution-focused therapy. For example, it is possible to gain access to subconscious processes through hypnosis and thus reduce unnecessary worries, troubles and fears. The use of hypnosis and hypnotherapy in treating various illnesses has been widely studied.[117] Comprehensive meta-analyses and reviews have found it to be effective in treating illnesses such as irritable bowel syndrome,[118 119] depression,[120] migraines[121] and possibly also the pain associated with fibromyalgia.[122]

Typically, patients seek psychotherapy due to anxiety, depression or various neuroses. However, psychotherapy can be beneficial even if the individual does not suffer from psychiatric problems.

The following forms of therapy may enhance your understanding of cognitive distortions, various types of beliefs and negative thought patterns:[123]

CBT
(COGNITIVE-BEHAVIORAL PSYCHOTHERAPY)

- Problem focused and action oriented
- Well suited for the treatment of anxiety or depression

DBT
(DIALECTICAL BEHAVIOR THERAPY)

- Facilitates changing harmful patterns of behavior by identifying the thoughts and emotions that trigger these patterns
- Well suited for the treatment of addiction

REBT
(RATIONAL EMOTIVE BEHAVIOR THERAPY)

- Aims at clearing the obstacles in thinking that sustain the problem
- Well suited for changing distorted or irrational beliefs

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NEUROTRANSMITTERS

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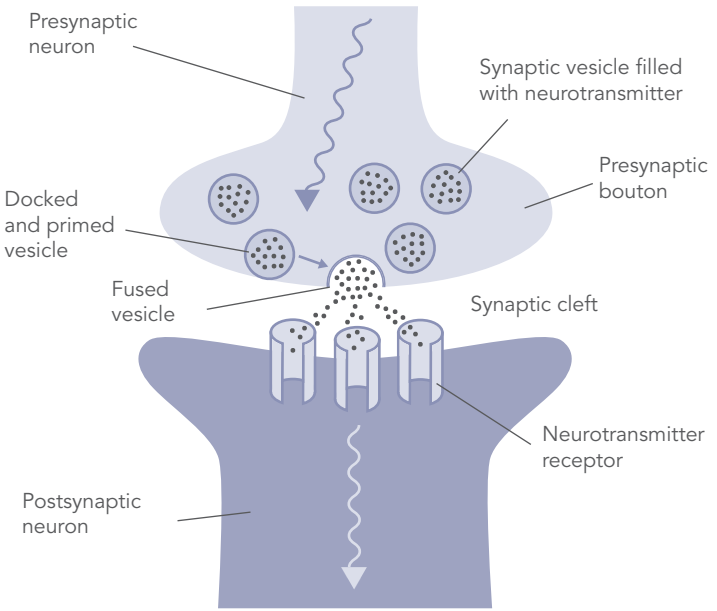
Modern neuroscience is based on the study of the structure of neurons and the nervous system. The neuroanatomical studies conducted by Santiago Ramón y Cajal (1852–1934) laid the foundation for the neuron theory that suggested that the nervous system consists of distinct neurons. It was not until the 1950s that this theory could be confirmed with the help of an electron microscope: the neurons were indeed distinct, connected to each other via synapses.

Neurotransmitters are messenger molecules that transmit, boost and (if necessary) block signals between neurons. In addition to neurotransmitters, the brain contains large numbers of various neuropeptides (messenger molecules affecting the functions of the nervous system).

Neurotransmitters are bundled into blisters (vesicles) that move from one neuron to another via interfaces (synapses).[124] The effect of the neurotransmitter may manifest quickly or slowly depending on the transmission mechanism.[125]

Nutrients are crucial for the production of neurotransmitters. Many neurotransmitters are formed from the amino acids found in food. Nutrient deficiency in itself may therefore cause neurochemical problems such as learning and attention difficulties, depression and other psychological disorders.

THE FUNCTION OF THE NEURON SYNAPSE



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KEY NEUROTRANSMITTER SYSTEMS

Neurotransmitters impact our thoughts and feelings.[126] A neurotransmitter imbalance may manifest as various psychological disorders. The balance between the main neurotransmitters (serotonin, dopamine, GABA and acetyl-choline) can be subjectively assessed using the indicative personality type test developed by American physician Eric R. Braverman (see the end of this chapter).[127]

The levels of neurotransmitters (noradrenaline, dopamine, serotonin) can be measured in practice by testing for the metabolic products of these in the blood or urine. A prime example of studying the neurotransmitter balance involves measuring organic acids in urine which provides insight into the general neurotransmitter balance of the body.[128] It should be noted however that significant neurotransmitter release occurs in the intestine[129] and the test does not differentiate the neurotransmitters originating from the central nervous system. There are methods of measuring the central nervous system neurotransmitters directly, but their availability is limited.[130]

AMINO ACIDS AS NEUROTRANSMITTERS

AMINO ACID	FUNCTION	HIGHEST CONCENTRATION
Alanine	Inhibitory, calming	Seaweed, gelatin, egg, turkey, beef
Aspartic acid	Stimulatory	Soy protein isolate, halibut, egg white, asparagus
GABA	Inhibitory, calming	Fermented foods, tea, tomato, mackerel
Glutamic acid	Stimulatory	Soy protein isolate, soy sauce, cottage cheese, flaxseed
Glycine	Inhibitory, calming	Gelatin, pork, beef, offal
Taurine	Inhibitory, calming	Mackerel, chicken liver, crayfish, fish, lamb

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THE ANATOMY AND PHYSIOLOGY OF NEUROTRANSMITTERS

NEURO-TRANSMITTER	MAIN FUNCTION	LOCATION	RECEPTORS	NOTES
Serotonin	Intestinal movements, mood, appetite, sleep, muscle control	Intestine, central nervous system	5-HT (various subgroups)	Most antidepressants function by regulating serotonin
Dopamine	Reward system, cognition, voluntary movements, arousal, executive functions	Hypothalamus, midbrain	D_1–D_5	Imbalance causes Parkinson's disease
Acetylcholine	Muscle control, memory, sensations	Nerve-muscle interaction, central nervous system	Nicotine receptor, muscarinic receptors	The most common neuro-transmitter. Alzheimer's disease damages acetyl-choline pathways which in turn causes dementia.
GABA	Inhibits neuron function in the central nervous system, regulatory immune responses	The entire brain, various peripheral tissues	$GABA_a$ & $GABA_b$	GABA deficiency is common in sufferers of depression and anxiety

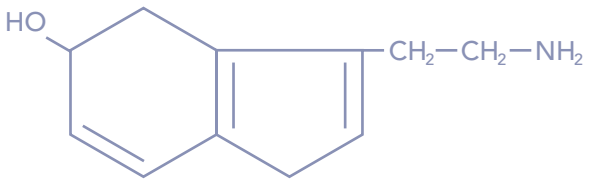
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SEROTONIN

Serotonin is a monoamine neurotransmitter of the brain (and the intestine). Serotonin is biochemically derived from tryptophan. Approximately 90 % of serotonin is located in the intestine where it regulates intestinal movements.[131] The rest is formed in the serotonin-producing neurons of the central nervous system. Serotonin has several physiological effects on mood, appetite, sleep, memory and learning. There are numerous serotonin receptors in various organs. The most well-known of these are the 5-HT_1 and 5-HT_2 receptor families.

HIGH LEVELS

At worst, excessively high levels of serotonin in the body can lead to a life-threatening serotonin syndrome.[132] This usually becomes apparent through the problematic combined effects of drugs that affect the serotonin system. Symptoms of the syndrome can include restlessness, diarrhea, elevated body temperature, nausea and elevated blood pressure.



THE CHEMICAL FORMULA OF SEROTONIN

Synthesis:



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Typical problems caused by serotonin deficiency include anxiety, depression and obsessive-compulsive disorders. Intestinal problems include constipation and slow intestinal movements.[133] Dietary changes can help rectify serotonin deficiency.

SEROTONIN BOOSTERS

Calsium	500–1000 mg
Fish oil	500–2000 mg
5-HTP	100–400 mg
Magnesium	200–600 mg
Melatonin (at night)	0.1–2 mg
Passionflower	200–1000 mg
Pyridoxine (Vitamin B6)	5–50 mg
SAM-e	50–200 mg
St John's wort	200–600 mg
Tryptophan	500–2000 mg
Zinc	15–45 mg

FOODS THAT BOOST SEROTONIN PRODUCTION

- Fruits and vegetables
  - Banana
  - Kiwi fruit
  - Plum
  - Papaya
  - Date
  - Tomato
- Animal products
  - Turkey and chicken
  - Various types of fish
  - Eggs
  - Cheese
- Nuts and seeds
  - Cacao
  - Almond
  - Sesame seeds









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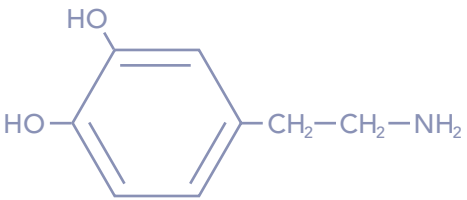
DOPAMINE

Dopamine is a brain neurotransmitter of the catecholamine and phenethylamine families. Dopamine is biochemically synthesized from tyrosine and DOPA. The brain contains several different dopamine systems, most of which involve rewarding and motivating behavior patterns.[134] It is therefore not surprising that dopamine-boosting drugs and stimulants such as cocaine, amphetamine, alcohol and nicotine are addictive. Other dopamine systems involve motor control and hormone secretion.

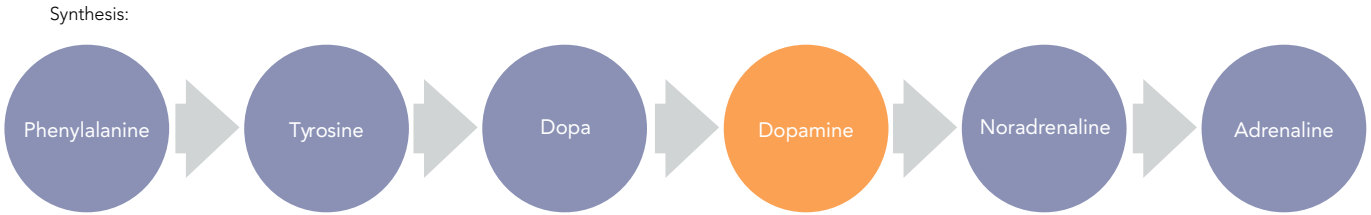
Dopamine dysregulation is a significant part of some illnesses such as Parkinson's disease, schizophrenia, ADHD and restless legs syndrome.[135] Besides the brain and central nervous system, dopamine affects other parts of the body including the digestive system, blood vessels and immune system.[136]

HIGH LEVELS

Excessively high levels of dopamine in the body can lead to dopamine dysregulation syndrome.[137] In addition to those suffering from schizophrenia, the syndrome has been found in Parkinson's disease sufferers who have taken excessively high doses of L-DOPA. Symptoms of the dysregulation syndrome include pathological gambling, hypersexuality, compulsive eating and aggressiveness.



THE CHEMICAL FORMULA OF DOPAMINE



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Dopamine impacts the dopamine-producing neurons of which there are approximately 400,000 in the human brain.[138] The effects on motivation and cognition in particular are significant. It is notable that both excessively low and excessively high levels of dopamine have a memory-impairing effect.[139] Like serotonin, there are several dopamine receptors. Of these, D_1-D_5 receptors have been the most widely studied and are considered the most significant. The number of D_1 receptors far outweigh all other dopamine receptors.

Typical problems caused by dopamine deficiency include mood swings, depression, social withdrawal, poor observation skills, chronic fatigue and low levels of physical energy.[140]

DOPAMINE BOOSTERS

Phenylalanine	500–2000 mg
Tyrosine	500–2000 mg
Methionine	250–1000 mg
Rhodiola rosea	50–200 mg
Pyridoxine	5–50 mg
B-complex	25–100 mg
Phosphatidylserine	50–200 mg
Maidenhair tree (Ginkgo Biloba)	50–100 mg

FOODS THAT BOOST DOPAMINE PRODUCTION

- Vegetables and fruits
  - Avocado
  - Banana
- Animal products
  - Turkey and chicken
  - Cottage cheese and ricotta cheese
  - Eggs
  - Pork
  - Duck
- Nuts and seeds
  - Walnut
  - Almond
  - Mucuna pruriens
  - Sesame seeds
  - Pumpkin seeds

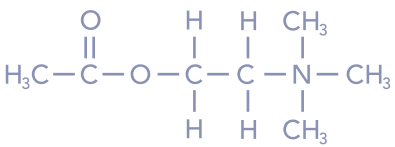


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ACETYLCHOLINE

Acetylcholine is an ester of acetate and choline. Acetylcholine activates the muscles and triggers muscle contractions via nicotine receptors. Acetylcholine acts as a brain plasticity and memory neurotransmitter via muscarinic receptors in the central nervous system and the brain.[141] For example, Alzheimer's disease involves severe cholinergic (acetylcholine-producing) disorders.

Acetylcholine has a crucial role in the reception of various external stimuli as well as observation skills. Based on studies conducted on animals, these include somatosensory (tactile),[142] auditory[143] and visual stimuli.[144]



THE CHEMICAL FORMULA OF ACETYLCHOLINE

HIGH LEVELS

Excessively high levels of acetylcholine in the body can lead to a cholinergic crisis.[145] This is often caused by a malfunction in the acetylcholine-degrading enzyme due to nerve gas (sarin), organophosphate poisoning or an overdose of the acetylcholinesterase drug. Symptoms of a cholinergic crisis include muscle paralysis, severe difficulty in breathing as well as increased sweating and saliva production.

Synthesis:



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Acetylcholine also affects the transmission of sensory information from the thalamus to certain parts of the cortex.[146]

As acetylcholine regulates brain "speed" and the frequency of electrical signals, insufficient acetylcholine levels may cause memory problems, slowness of movement, mood swings, learning difficulties and difficulties in abstract thinking.[147]

ACETYLCHOLINE BOOSTERS

Choline	100–500 mg
Phosphatidylcholine	500–2000 mg
Phosphatidylserine	50–200 mg
Acetyl-L-carnitine	250–1000 mg
DHA (docosahexaenoic acid)	200–1000 mg
Thiamine (Vitamin B1)	25–100 mg
Pantothenic acid (Vitamin B5)	25–100 mg
Methylcobalamin (Vitamin B12)	100–500 mg
Taurine	250–1000 mg
Maidenhair tree (Ginkgo Biloba)	50–100 mg
Korean Ginseng	100–500 mg

FOODS THAT BOOST ACETYLCHOLINE PRODUCTION

- Vegetables and fruits
  - Broccoli
  - Brussels sprout
  - Cucumber
  - Lettuce
  - Zucchini
- Animal products
  - Eggs (especially the yolk)
  - Cow's liver and lamb's liver
  - Beef
  - Pork
  - Yoghurt
  - Shrimp
  - Salmon and other oily fish
- Nuts and seeds
  - Pine nuts
  - Almond
  - Hazelnut
  - Macadamia nut





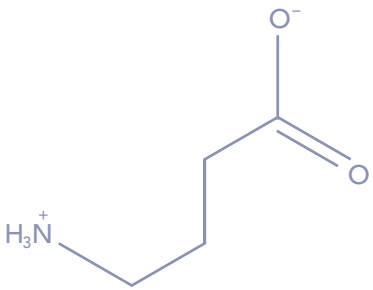




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GABA

GABA or gamma-aminobutyric acid is the main inhibitory neurotransmitter of the nervous system. GABA production takes place throughout the brain. It affects the frequency of calming theta brain waves. GABA does not pass the blood-brain barrier – instead, it is synthesized in the brain from glutamic acid with the help of active form of vitamin B6 (pyridoxal-5-phosphate).[148] Conversely, GABA breaks down into glutamate which is a stimulatory neurotransmitter.



THE CHEMICAL FORMULA OF GABA

HIGH LEVELS

Excessive levels of GABA in the body can cause many kinds of neurological and psychiatric symptoms. These include memory loss, restlessness, convulsions, hallucinations and impaired cognitive functions. Excessive levels of GABA are most commonly caused by an overdose of the GABA reuptake inhibitor drugs.[149]

Synthesis:



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There are two categories of GABA receptors: a and b. $GABA_a$ receptors are affected for example, by the calming derivatives of the diazepam drug. Alcohol predominantly affects $GABA_b$ receptors as well as the experience of pain.[150] The role of the GABA neurotransmitter is particularly important in the developing brain of a child.[151] [152]

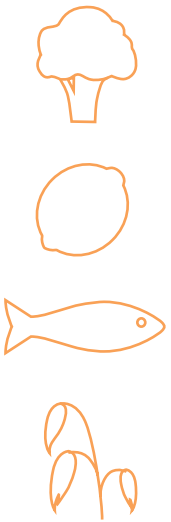
Individuals suffering from GABA deficiency often experience problems with stress tolerance, anxiety, depression, feelings of guilt as well as obsessive-compulsive disorders.[153]

GABA BOOSTERS

Inositol	500–2000 mg
GABA	100–1000 mg
Glutamic acid	250–1000 mg
Melatonin (at night)	0.1–2 mg
Thiamine (Vitamin B1)	200–600 mg
Niacinamide (Vitamin B3)	25–500 mg
Pyridoxine	5–50 mg
Valerian	100–500 mg
Passionflower	200–1000 mg

FOODS THAT BOOST GABA PRODUCTION

- Vegetables and fruits
  - Banana
  - Broccoli
  - Oranges and other citrus fruit
  - Spinach
- Animal products
  - Cow's liver
  - Mackerel
  - Halibut
- Nuts, seeds and grains
  - Almond
  - Walnut
  - Dark rice and rice bran
  - Oat

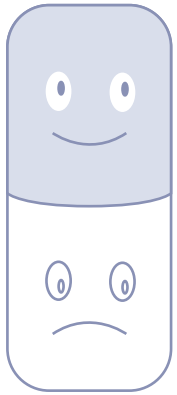


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SUMMARY OF NEUROTRANSMITTERS

The pharmaceutical industry has conducted intensive and long-standing research and development involving the neurotransmitter systems. Many neurological and psychiatric illnesses are thought to be caused by an imbalance in the neurotransmitter systems (for example, the monoamine hypothesis)[154] which has led to the development of drugs that alter the levels of various neurotransmitters in the body.

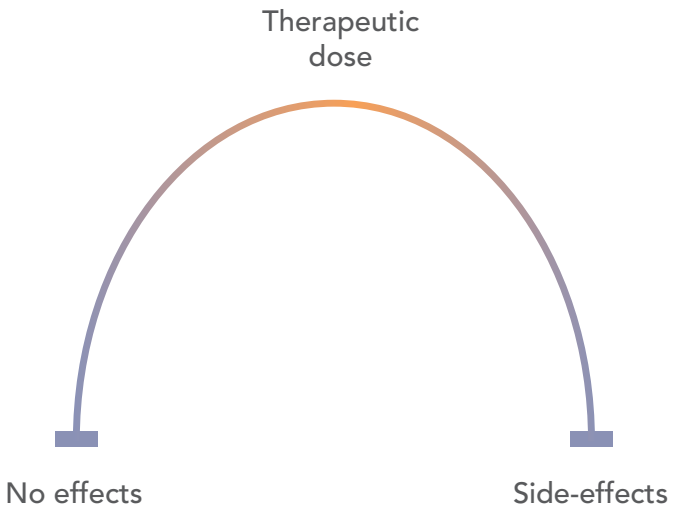
Examples of these include the SSRI drugs used for depression (serotonin), anxiety-suppressing derivatives of diazepam (GABA), cholinesterase blockers that act as muscle relaxants and alleviate the symptoms of Alzheimer's disease (acetylcholine) and antipsychotic drugs also used in the treatment of Parkinson's disease (dopamine). What these drugs have in common is their direct impact on the receptors of each neurotransmitter system throughout the body, which can easily lead to the development of side effects. Individual variation in human metabolism (for example, the genetic variations of the CYP450 system in the liver) present challenges for the use of medication.[155]



Medical intervention at the synthesis stage of the neurotransmitter can minimize unnecessary side effects by supporting the body's internal regulation mechanism. For example, instead of stimulating the dopamine receptor directly (L-DOPA and dopamine), it is significantly safer to stimulate the early stages of dopamine synthesis (phenylalanine and tyrosine). When dealing with neurotransmitter synthesis, it is crucial to identify the so-called rate limiting step. For example, in the case of dopamine, this step involves the conversion of tyrosine by tyrosine hydroxylase to L-DOPA and on to dopamine.[156]

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When determining your own neurotransmitter balance using questionnaires and laboratory tests, you can utilize the results to fine-tune your diet, dietary supplements, exercise and other factors that affect the brain.[157] Indeed, such activity could be called intelligent biohacking which is based on self-assessment and the correction of perceived imbalances.



DOSE-RESPONSE RELATIONSHIP

It should be noted that with neurotransmitters, the correct therapeutic dosage is rarely "the more the better". For example, both excessively low and excessively high levels of dopamine impair the working memory function.[158]

Everyone has their own personal optimal neurotransmitter balance. After conducting the tests, further personal experimentation is required. It is worth pointing out that the direct impact on neurotransmitters does not automatically bring happiness, serenity, focus or joy into your life. The mind is a complex entity that requires a comprehensive approach (for example, through meditation, psychotherapy and other methods outlined in this book).

More about neurotransmitters in the bonus materials:

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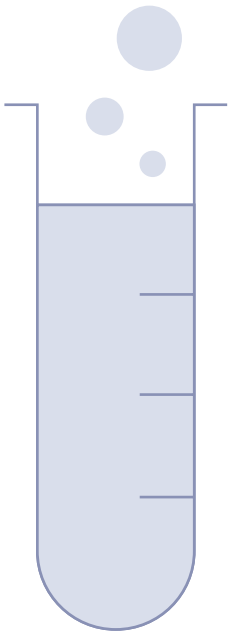
NOOTROPICS

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Throughout history, humankind has sought various tools to regulate the hormonal reactions, performance and alertness of the human body. One of the most interesting prospects involves boosting brain performance, cognitive function and memory using various substances and medicinal plants.

In 1964, Romanian psychologist and chemist Corneliu E. Giurgea (1923–1995) developed a chemical compound which he named piracetam. Giurgea found that this new chemical compound affected brain neurons, boosted their blood flow and increased oxygen consumption.

A few years later, Giurgea devised the term *nootropic*, meaning smart drug (derived from the Ancient Greek words *noos*, meaning mind, and *tropos*, meaning turning or aligning).[159] Nootropics have been found to improve memory and mood as well as to enhance alertness.[160] They should not be confused with simple cognitive enhancers as nootropics are often also neuroprotective and generally well-tolerated.[161]



Giurgea devised criteria for labeling a substance a nootropic:[162]

1. Enhances learning and memory
2. Enhances learning under disruptive conditions (for example, when there's a lack of oxygen)
3. Protects the brain against physical or chemical injuries
4. Strengthens the regulative mechanisms of the brain
5. Free from the pharmacological effects typical of psychotropic drugs, significant side effects and toxicity

Pharmacologist V. Skondia developed a more specific medical definition for nootropics:[163]

1. No effects on blood pressure or heart rate
2. No effects on EEG
3. Able to pass through the blood-brain barrier
4. Minimal side effects
5. Increases metabolism in the brain
6. Clinical studies must show enhanced brain function

This book does not discuss pharmaceutical nootropics such as racetams. Instead, we focus on dietary supplements and medicinal plants. Adaptogenic herbs are described in detail in the forthcoming *Biohacker's Stressbook*.

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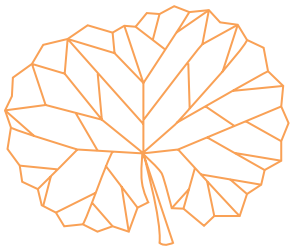
NOOTROPICS

Acetyl-L-carnitine (ALCAR)

- Protects the brain from damage, acts as an antioxidant[164]
- Enhances cognitive functions and the function of mitochondria[165]
- Reduces mental fatigue and improves concentration especially in people with chronic fatigue[166]
- Improves overall cognition in the elderly[167]

Alpha lipoic acid (ALA)

- Protects the brain and mitochondria from damage[168]



Water hyssop (Bacopa monnieri)

- Enhances memory[169]
- Enhances cognitive functions[170] such as attention speed[171]

CDP-choline (citicoline)

- Prevents memory deterioration[172] and enhances memory and learning[173]
- Improves attentional performance[174]

DHA (omega-3 fatty acid)

- Enhances memory and reaction time[175]
- Slows down the aging of the brain and enhances learning[176]
- Increases cerebral blood flow[177] [178]

Phosphatidylserine

- Enhances memory[179] and prevents memory deterioration[180]
- In children, it alleviates ADHD symptoms and enhances short term memory[181]
- Curbs the production of cortisol under strain and speeds up recovery from physical strain[182]

Carnosine

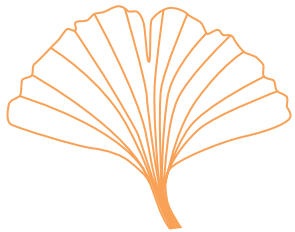
- Neuroprotective;[183] protects the brain against oxidative stress[184]
- Tests conducted on rats found it to boost the production of GABA in the brain[185]
- May slow down the aging of the brain[186]

Caffeine (coffee, tea)

- Enhances long term memory[187]
- Prevents dementia[188]
- When consumed together with theanine, it comprehensively enhances cognitive functions[189]

Choline

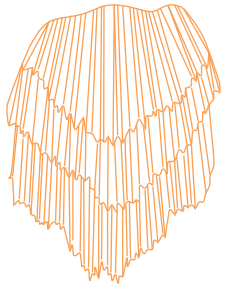
- Enhances cognitive performance[190]



Maidenhair tree (Ginkgo biloba)

- May enhance memory and observation skills due to improved cerebral blood flow[191]

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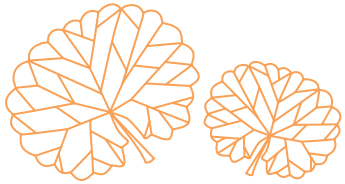
Creatine (monohydrate)

- Enhances general brain performance[192]
- May improve short-term memory and intelligence of stressed individuals and/or healthy individuals with the biggest potential of aging[193]

Tyrosine

- A precursor of dopamine and noradrenaline
- Building blocks for thyroid hormones
- Several studies have found improvements in mood, cognition and physical performance under stress, fatigue[194] and sleep deprivation[195 196]
- Decreases cortisol levels when under acute stress[197]

Gotu kola



- Neuroprotective[198]
- May reduce anxiety and reactions to loud noises[199]

Theanine

- Able to pass through the blood-brain barrier and thus has a direct impact on the brain
- Enhances memory and observation skills[200] when consumed together with green tea
- Increases the frequency of alpha waves in the brain;[201] enhances observation skills and cognitive functions when consumed together with caffeine[202]

Lion's mane

- Stimulates the synthesis of nerve growth factor (BDNF) in the brain[203]
- Enhances cognitive functions in individuals with mild deterioration of cognitive skills[204]
- May reduce depression and anxiety[205]

Oxaloacetate

- Imitates calorie restrictions in the diet which in turn has an anti-aging effect[206]
- Neuroprotective, i.e. protects the brain against damage[207 208]



COMBINATION OF CAFFEINE + THEANINE

- Enhances concentration skills[209 210]
- Enhances alertness and the ability to efficiently switch between tasks[211]

Ingredients:

- *100 mg caffeine (one cup of coffee)*
- *200 mg theanine*

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BIOHACKER'S BRAIN BOOSTER DRINKS

CHOCOLOVE CHAI CHAGA BOOM

- *6 dl (2 1/2 cups) strong chaga-golden root tea, brewed with spring water or filtered tap water*
- *1 dl (1/3 cup) raw cashew nuts*
- *4 tbsp raw cocoa powder*
- *1 tbsp maca powder*
- *1 tsp powdered reishi extract*
- *2–3 cm (1-inch) fresh ginger*
- *1/2 dl (1/5 cup) chia seeds, soaked*
- *1 tsp ceylon cinnamon*
- *1 tsp cardamom*
- *1 tsp bourbon vanilla*
- *1/2 tsp unrefined sea salt*
- *1 tbsp raw honey*

Pour a liter (4 cups) of spring water in a saucepan. Add 1 tbsp chaga powder and 1 tsp golden root. Brew for 30–60 minutes until the liquid is dark in color. Add water if needed during the process to account for evaporation.

Strain the warm liquid into a blender and add the remaining ingredients. Blend for 30 seconds and enjoy. The beverage gives you energy, warms the body and offers a stimulating effect in a pleasant and consistent manner whilst providing a large number of nutrients. This elixir has properties that support the immune system[212] and the function of the cardiovascular system.[213]



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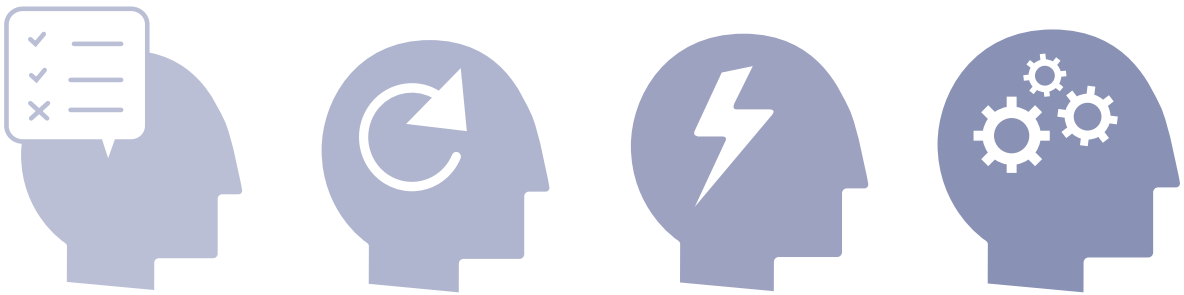
BIOHACKER'S BRAIN BOOSTER DRINKS

YERBA MATÉ MIND MAGIC

- *5 dl (2 cups) spring water*
- *15 g Yerba maté powder*
- *1 tbsp MCT oil or virgin coconut oil*
- *juice of half a lemon*
- *pinch of cayenne pepper*
- *optional: 1–2 tsp powdered herbal extracts (such as siberian gingseng, gotu gola, goji, ashwagandha)*

Heat water to 80–90°C (175–195°F). Place 2–4 heaped tablespoons of Yerba maté powder in a teapot and pour hot water over it. Brew for 5–10 minutes. Strain the liquid and pour it into a blender. Add the remaining ingredients and blend at full speed for 20–30 seconds.

Yerba maté contains several stimulatory xanthines that can be found in coffee (caffeine), tea (theophylline) and cacao (theobromine).[214] In addition to stimulating the mind, the beverage may improve your mood,[215] balance your cholesterol levels and reduce inflammation[216] as well as help regulate your blood sugar levels.[217]



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MEASURING MIND FUNCTION

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Mind function can be measured from several different viewpoints using various methods.

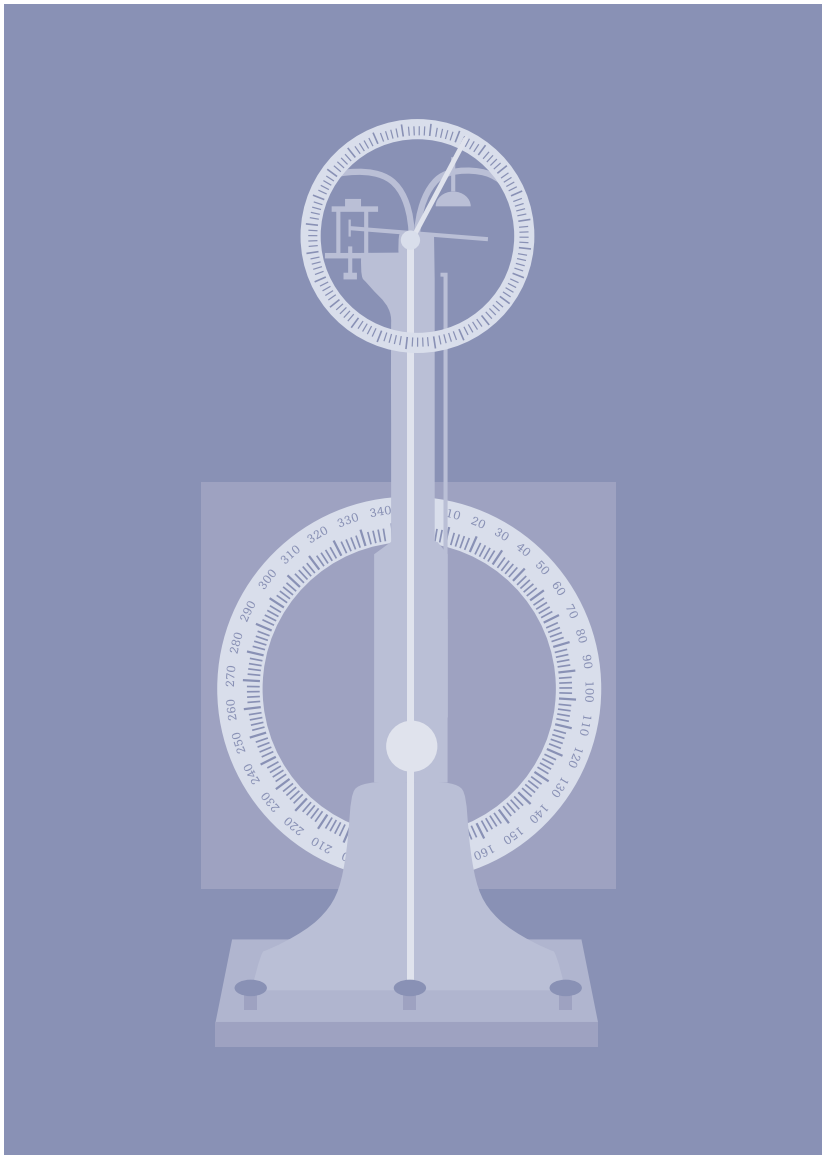
These include:

- Cognitive and neuropsychological tests (see the further reading page for more information)
- EEG
- Cerebral blood flow studies
- Brain imaging

In 1862, German Wilhelm Wundt (1832–1920) attempted to measure the speed of thought by studying the difference between the perceived position of a pendulum and its actual position.[218] Seventeen years later, Wundt invented a reaction time meter that had the test subject press a button upon perceiving a certain type of sound or light. This method continues to be used by some psychological studies.[219]

Cognitive tests in the book's bonus materials:

biohack.to/mind



WUNDT'S PENDULUM

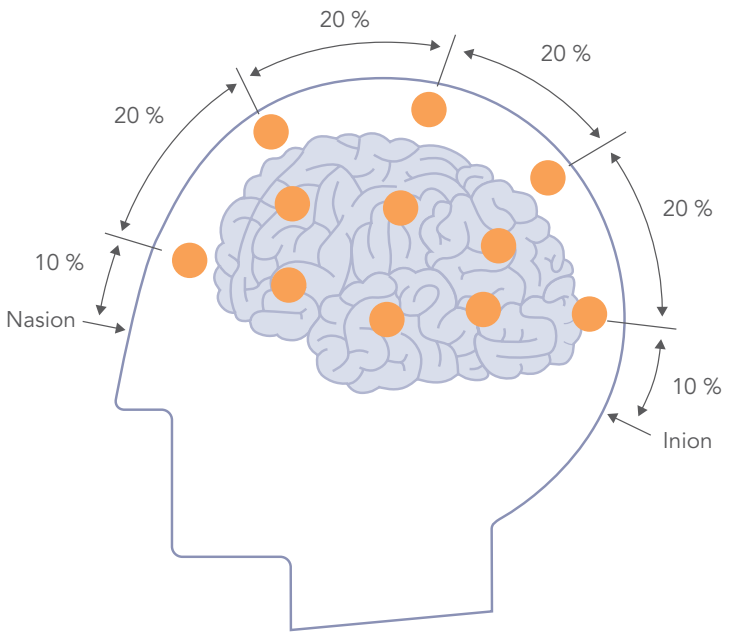
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INTERPRETING AN EEG

The history of the electroencephalogram (EEG) takes us back to the beginning of the 20th century when British physician Richard Caton presented in the esteemed *British Medical Journal* his study on the electrical characteristics of rabbit and monkey brains.[220] Around the same time, Polish physiologist Adolf Beck published his study on rhythmic oscillations in the brains of rabbits and dogs. The first proper EEG was recorded in 1924 by German physiologist Hans Berger.[221]

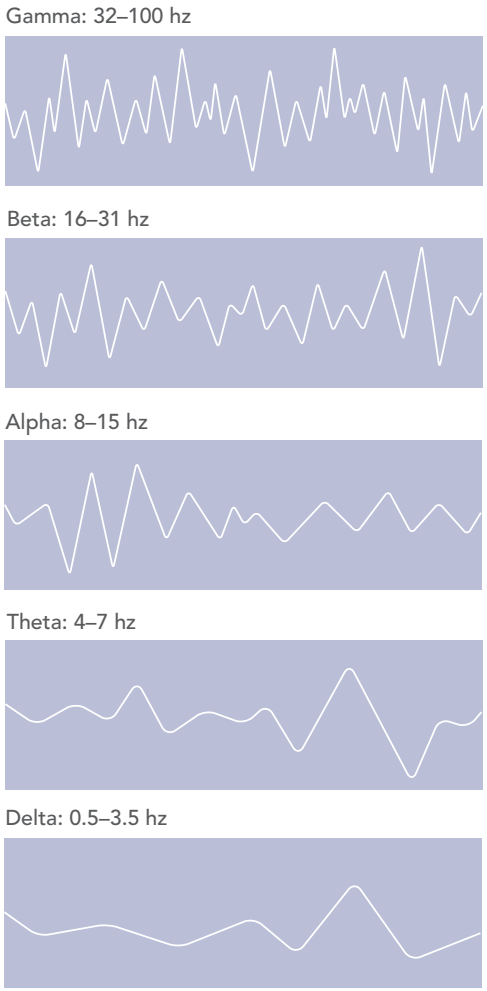
The electrical activity of the brain involves billions of electrically charged (polarized) neurons. Changes in the EEG indicate neuron activity (transport proteins of the cell membrane pump ions in and out of the cell).

When conducting an EEG study, electrodes are attached to the scalp to measure electrical activity. This method is typically used to diagnose various neurological complaints, migraines, ADHD and disorders such as epilepsy and insomnia. The EEG can be used together with brain imaging studies to yield more accurate data of brain activity.[222]



THE 10–20 SYSTEM OF ELECTRODE PLACEMENT

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The frequency range recorded by an EEG is approximately 1–50 Hz. For example, the EEG of a meditating person may note a signal of roughly ten oscillations per second. This so-called alpha rhythm features alpha waves of approximately 10 Hz (8–15 Hz). A beta rhythm refers to a higher EEG frequency (16–31 Hz). This is typical when the individual is awake with a high level of brain activity. Slower theta (4–7 Hz) and delta rhythms (0.5–3.5 Hz) can be seen when the individual is in a meditative state or in various phases of sleep, particularly during deep sleep (delta).

Gamma waves involve oscillations at the frequency range of 32–100 Hz, with the most typical frequency being 40 Hz. The gamma rhythm is associated with attention and concentration[223] as well as transcendental meditation.[224] In addition, very high frequency gamma waves may be perceived during lucid dreams.[225]

EEG devices intended for consumer use are available. These usually incorporate various cognitive exercise programs. The EEG can be used for example to monitor changes in various states of consciousness as well as to develop concentration. Brain function can be further altered when combined with biofeedback.

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QUANTITATIVE EEG & NEUROFEEDBACK TRAINING

Quantitative EEG (qEEG) is a snapshot or a visual map of the brain that allows a specifically tailored neurofeedback protocol to be developed for each individual's personal needs and desired outcomes. Therefore, it is also referred to as *brain mapping*, topographic EEG or brain electrical activity mapping (BEAM).[226] Quantitative EEG uses significantly more surface electrodes than a standard EEG for gathering data from over 24 areas of the brain. The gathered data is turned into colorful data visualizations representing the EEG activity of particular brain areas.[227]

qEEG provides information for example, about unusual across EEG frequencies (speed, power, and distribution), connectivity patterns, and how the brain changes its state. The recording is compared to a database of thousands of typical brains to find unusual patterns.

To explore different aspects of human cognition and possible cognitive disorders, the qEEG can be cautiously used by a skilled neurophysiologist to improve the analysis and possible interpretation flaws. According to studies, qEEG can be used in encephalopathies, delirium, learning disabilities, attention disorders, mood disorders and dementia.[228] Especially in ADHD, qEEG is seemingly useful in detecting ADHD by observing theta/beta ratio trait.[229]

Nowadays, qEEG measurement can be combined with neurofeedback training (qEEG-guided Neurofeedback; qNF) to improve attention, mood, focus, self-regulation and self-control as well as sleep, energy production, stress, anxiety and so on. A key focus of qNF is precisely tailoring the neurofeedback protocol based on the individual EEG baseline and symptom status of the client as determined by the qEEG. This is done in conjunction with clinical history and prevailing symptoms. For example, if the qEEG indicates an excess of a beta frequency and the presenting symptoms are expected with that pattern (i.e., anxiety), the protocol would be designed to decrease the amplitude of that beta frequency.[230]

Neurofeedback training combined with qEEG is based on the brain's constant reorganisation due to neuroplasticity. Repeated firing of neurons produces greater efficiency, interconnectivity, and synchronization. New learning happens quickly, in a few minutes, but creating new neurons and connections takes weeks.

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CONCLUSION

"To know thyself is the beginning of wisdom."
– Socrates (around 470–399 A.D.)

After finishing the book, your next question may be "what's next?"

A deeper understanding of the physiological systems described in this book and the techniques used in association with them helps us perceive how various tools and methods can improve human performance, well-being and health in practice. Only by studying your own situation are you able to identify the 20 % contribution into your well-being that yields 80 % of the results.

At best, a good theory is only a hypothesis. Only by acting as your own guinea-pig are you able to find out what works for you, and what doesn't. Do not hesitate to refer to professional help in addition to literature. It is worth listening to health care professionals, nutritionists, personal trainers, psychotherapists and other wellness experts on your journey towards better performance, well-being and health.

The further reading pages of this book will guide you in learning more about biohacking. These include references, video and audio clips and discussions in each section of the book. You will also find recommendations for services, books, mobile apps, devices, dietary supplements and other products. *Biohacker's Handbook* together with Biohacker Center organizes online courses, lectures, seminars such as the Biohacker Summit, retreats, webinars and webinars and publishes the Biohacker's Podcast for those interested in holistic well-being.

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