

ENLIGHTEN YOUR CLOCK

How your body tells time



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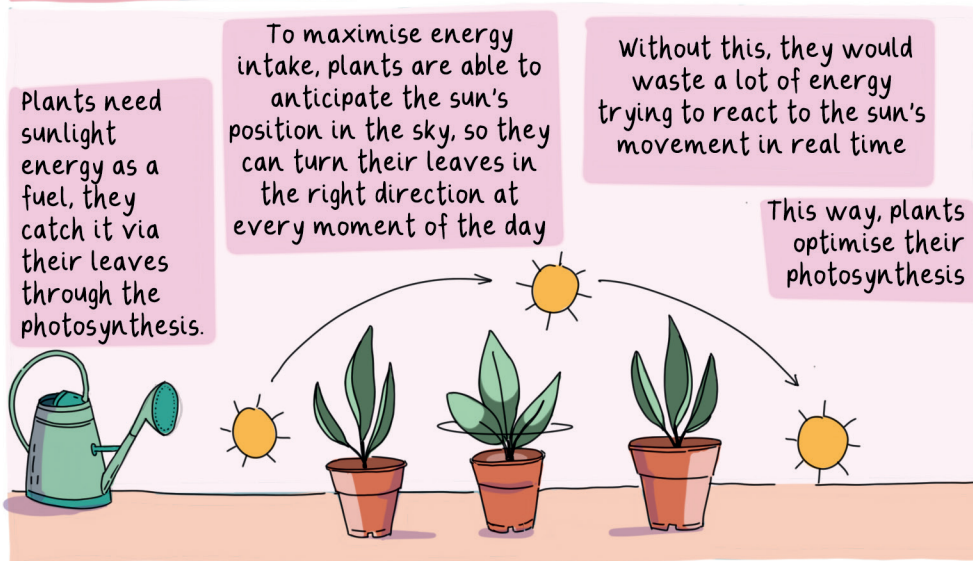
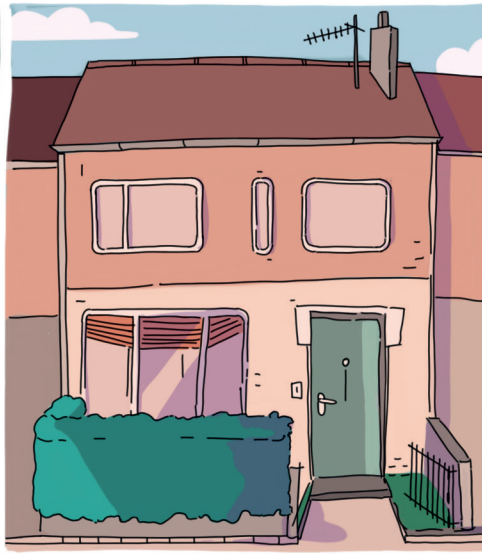
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Good morning



Your circadian clock

Like plants, your body works on a 24h cycle, based on a day period, which is determined by the Earth's rotation of 24h on its own axis

This 24 hours cycle is brought about by the circadian rhythm, a rhythm generated inside your brain affecting the body

"circa" : about
"diem" : a day

Each of your cells and organs have a clock

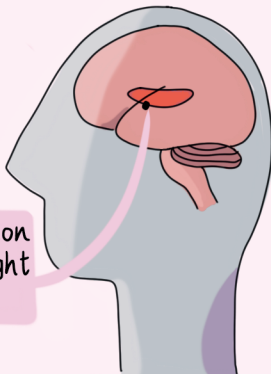
If all of them were working independently, that would be a mess. Thus, a central circadian clock, also called the circadian pacemaker, coordinates them

Like the conductor of an orchestra, it synchronises all the clocks of your body to a uniform internal time.

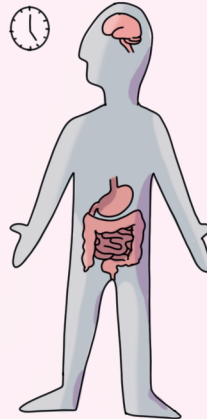


The conductor giving the rhythm in your body is a structure of the brain: the SCN, for suprachiasmatic nucleus.

A tiny collection of neurons right in there



The circadian clock generated by the SCN impacts on many processes. It regulates performance and immunity. It could also may be involved in appetite...



But the most important function controlled by your circadian clock is your SLEEP-WAKE CYCLE



Just like this plant, your body knows what time it is and when it's time to sleep.

I didn't even know I was capable of that
But where does the info come from?

Well, this is all made possible by ...



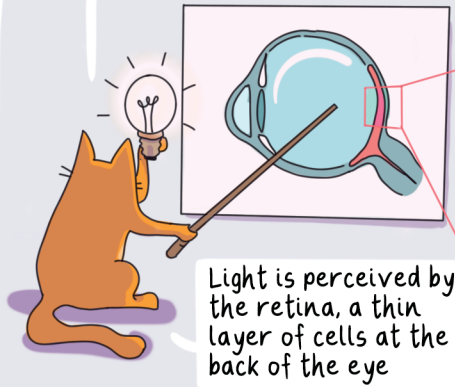
Sensing and perceiving light

Since the internal biological rhythm your body sets is not a perfect 24h, we need a way where all our internal clocks can get on the same rhythm

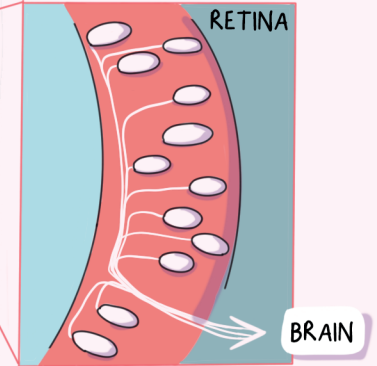


And light helps to synchronise our central circadian clock with our environment

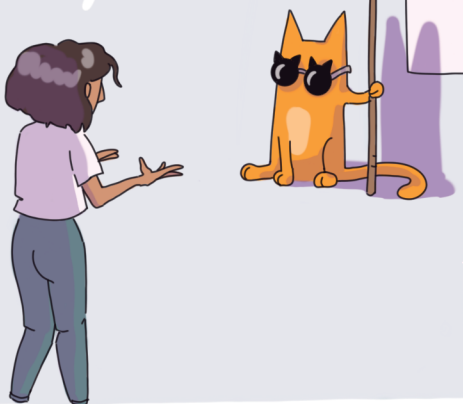
Here is half a cross-section of an eye



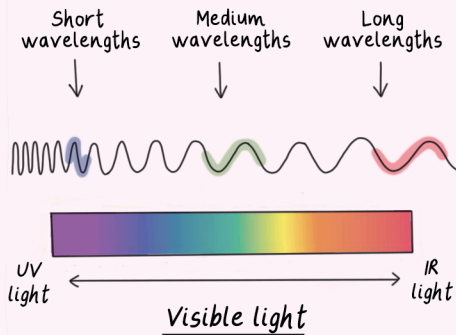
The retina consists of many cells able to detect wavelengths of light, and send light information to the brain, for vision for example



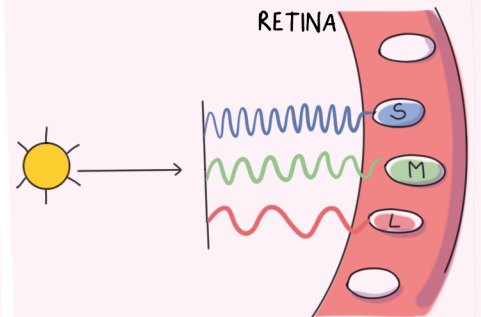
Wait, "light wavelengths"? What's that?



Visible light is a range of wavelengths between Ultraviolet (UV) light and Infrared (IR) light...



... and colour vision is possible thanks to the cones: a type of light-detecting cells. There are 3 types of cones, each sensing one range of wavelengths: short (S), medium (M), and long (L)



This is how colour vision works, but it's a bit different from the way in which you sense the light that synchronises your circadian clock to sunrise and sunset.

Another type of light sensitive cell exists for this purpose*: Its job is to send light signals to the circadian clock in the SCN



These cells are sensitive to short-wavelength light, which appears violet, blue and cyan to us.



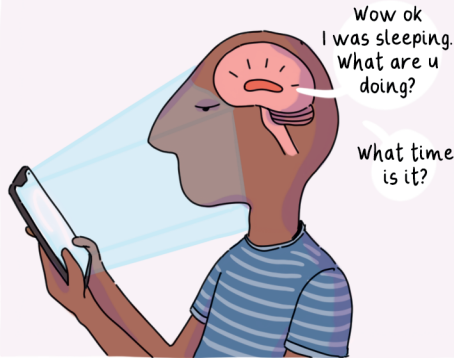
* Neuroscientists call them the ipRGCs: intrinsically photosensitive retinal ganglion cells

Rhythms in the evening

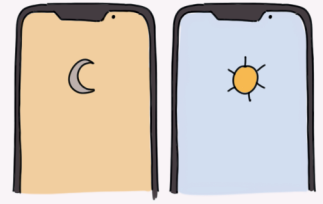
The cells responsible for circadian rhythms are sensitive to blue light

If you activate these cells with artificial light during night time, your circadian clock will be stimulated like it's day time.

That's why you should avoid bright light emitted from smartphones and computers, which activates your light-sensitive cells and makes you keep going.



This wrong-timing- stimulation can lead to disruption of the circadian rhythm and hence to sleep problems, such as insomnia.



That's why turning your screens to a night mode (less blue light) or just reducing the brightness can avoid stimulating your circadian clock at the wrong time.

Ok I see. So in order not to shift our rhythms, we shouldn't send a daytime signal with bright light to our circadian system during the night

That's it. Of course other factors can make it more difficult for you to fall asleep

For instance, the arousal driven by exciting content you see on instagram can also delay your falling asleep.

Does this only happen with the light from a smartphone?

What?

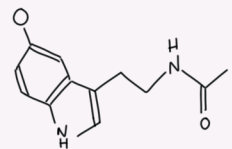
The circadian clock shifting and holding up my sleep

No, bright evening lighting can do so as well

How?



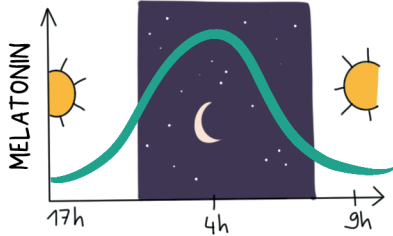
When night comes, the brain — under the influence of the SCN and its clock — secretes a substance called MELATONIN. The hormone of darkness.



This molecule signals to the body that it's nighttime, leading to changes in your body (e.g., a decrease in body temperature)

Melatonin secretion and its suppression by light

In normal conditions, melatonin is synthesised during the night...



...but it is not produced throughout the day

In diurnal animals, melatonin is a signal for sleep.



In nocturnal animals, melatonin is still secreted during the night but it is a signal for activity



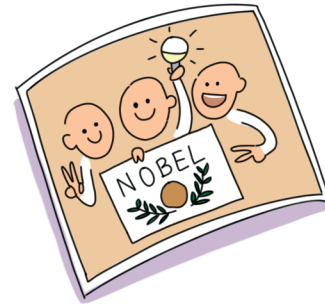
→ melatonin has different effects depending on the species

But the light environment has been subject to many changes for humans since the arrival of artificial light during the 19th century



With artificial light and our indoor lifestyle, light doesn't stop with the sunset

Bright light can reduce night time secretion of melatonin depending on the light environment and the kind of light bulb used (LED, incandescent, fluorescent)



In 2014, the Physics Nobel Prize was awarded for the invention of blue LEDs, which paved the way to making white-light with energy-saving LED light sources

So light in the environment contains blue light

Blue light stimulates circadian cells in the retina

Circadian cells acts on the SCN and suppress melatonin secretion (just like in daylight)

This can lead to circadian disruption and sleep disturbances



All my light comes from LED lights ...

Don't panic, you can just dim your lights in the evening

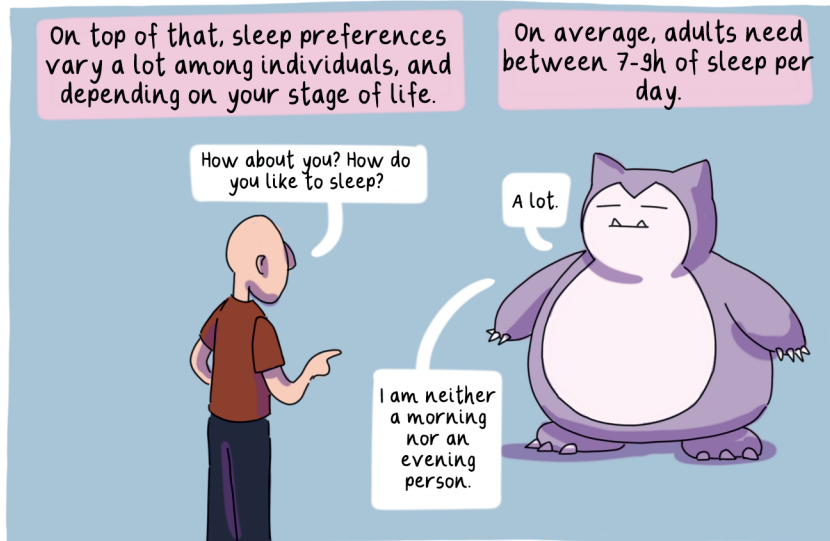
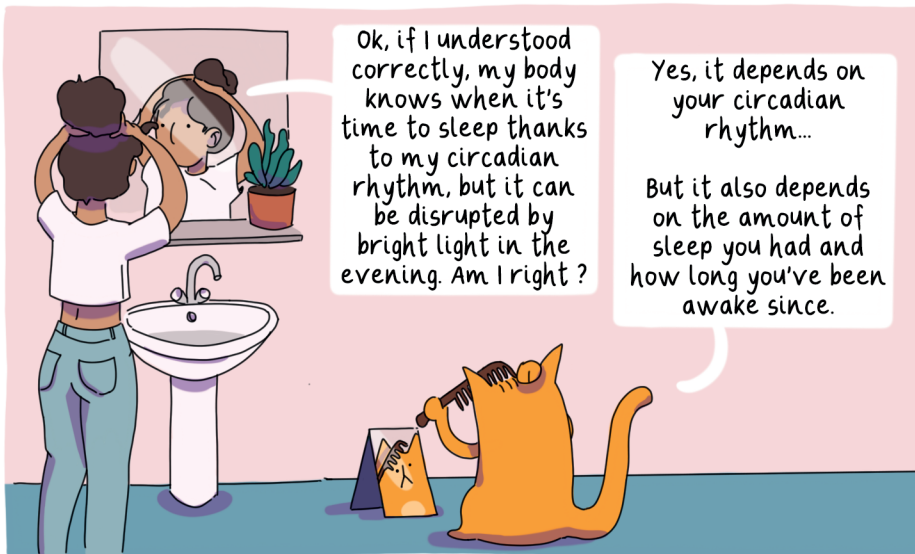
Plus, all humans aren't equally sensitive to melatonin suppression by indoor lights

But for people having sleep problems, getting less bright light at night can be helpful for better sleep!



*Light-emitting diodes

Chronotype and sleep timing preferences



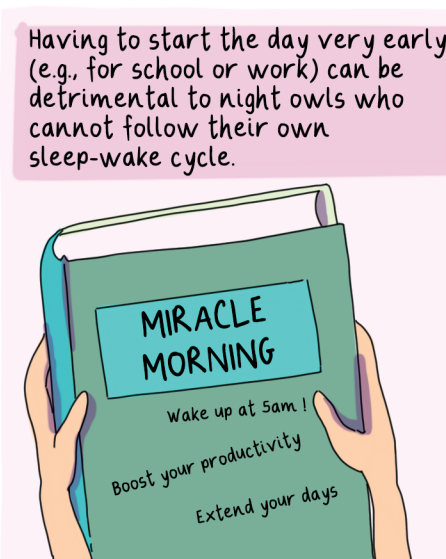
The circadian clock starts working before you are born.

Rhythms are stabilized in childhood.

Then during puberty, it shifts to evening preference, with ongoing changes in sex hormones and behaviour (staying up late, exposure to evening lights). This can cause troubles for teenagers who must get up early for school.

Eveningness tends to peak in the earlier twenties and then drifts towards more and more morningness with aging.

Boy that was fast



Circadian rhythms shifting and consequences

Well, there's a relationship between sleep disorders and mood disorders for sure.

Like depression?

Yes, for instance

Mood disorders are often associated with sleep troubles

Circadian disruption induced via jet lag and shift work tend to exacerbate mood disorder symptoms in susceptible individuals

Night shift workers are more vulnerable to sleep trouble, irritability, depression and difficulties in maintaining personal relationships

This is fine

That's rough! Is there anything they can do?

The best they can do is to ensure that they take naps at the right time, and avoid being exposed to bright lights at certain points during their shift.

Although it's important for night shift workers to be aware of the risks of their job.

Similar symptoms have been observed in jet-lag shiftings of regular travellers.

And fun fact: It is generally worse travelling from West to East.

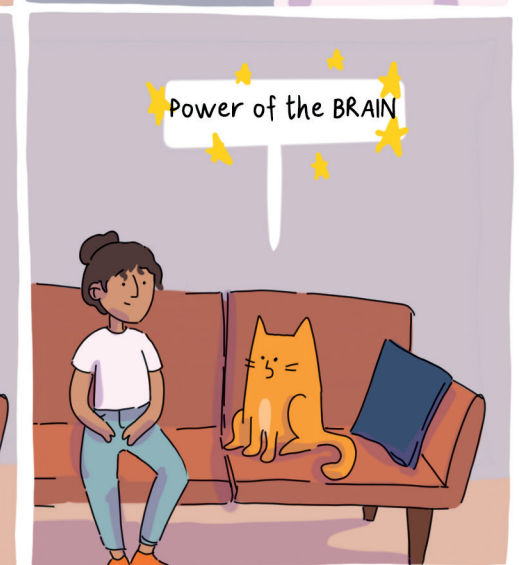
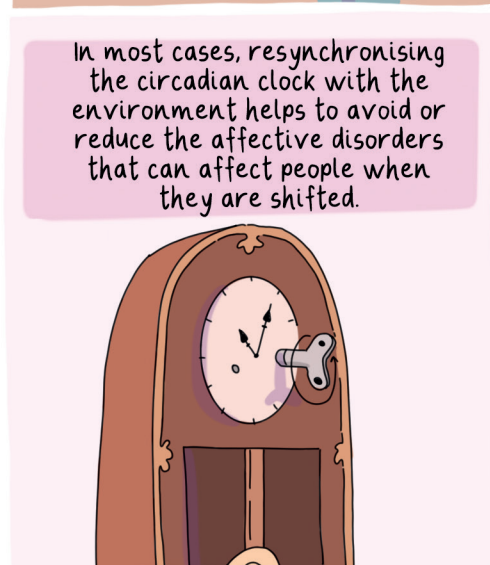
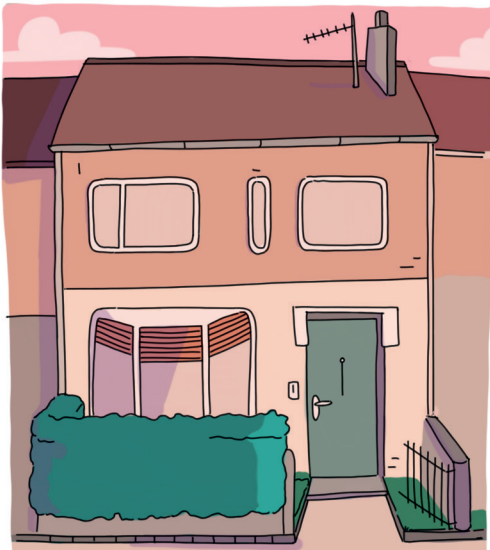
Go visit Europe they said

But did you know that a big part of the population is affected by something called 'social jet-lag'?

Keep your energy for this evening, I am already late

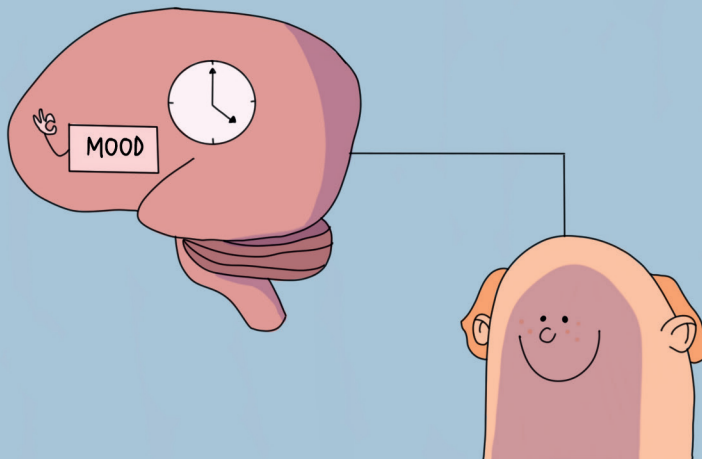
phase shifted like you would say lmao

Social jetlag

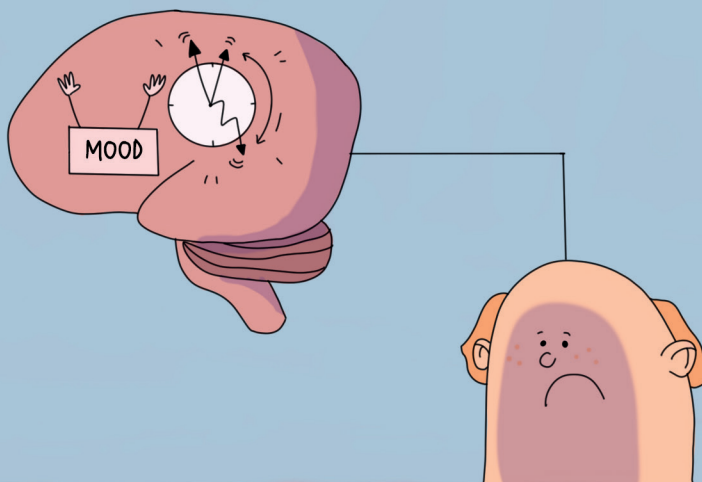


The relationship between sleep and mood

The neural brain region associated with mood (secreting especially serotonin and dopamine) is under circadian clock regulation



which means that if you disrupt your circadian clock, it is reasonable to expect troubles such as depression or anxiety.



Ok, this explains mental troubles that night shift workers and long-distance regular travellers can have.



..but what about sleep disturbances themselves?

I still don't know why I can't sleep at night



Do you know how sleep works?

No, tell me Mr Know-It-All



Sleep phases and dreams

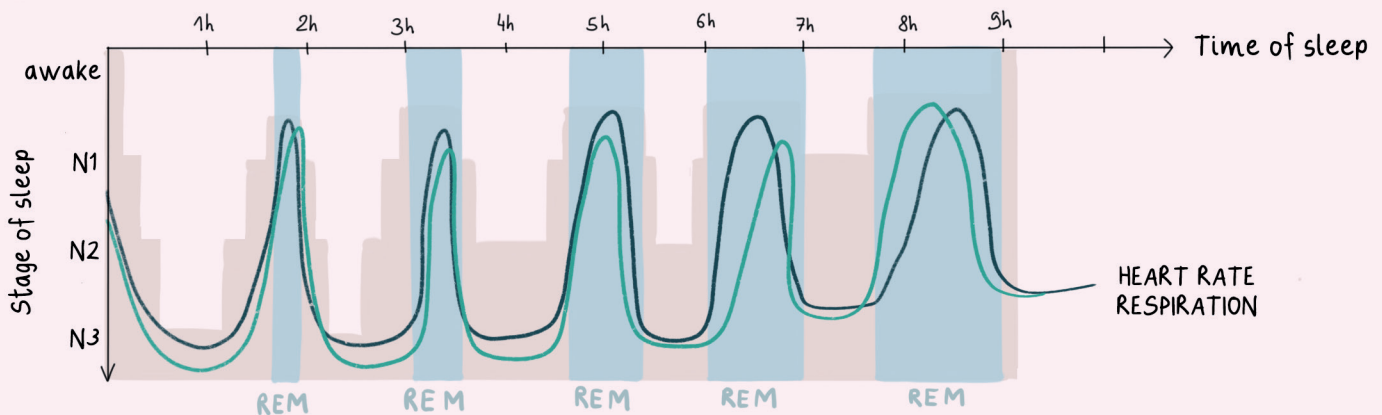
For centuries people thought that sleep was a uniform passive state of rest. Nowadays, scientists are better at studying sleep. The approach used to record sleep activity, called polysomnography, is also used to diagnose some sleep disorders for instance. It consists of the patient spending nights in a sleep laboratory. Thanks to this technique, sleep can be understood better!



Ready for a good night of sleep

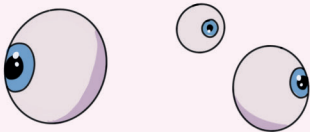


By studying sleep, scientists have discovered that sleep oscillates between different states: stages N1, N2, N3 and Rapid Eye Movement (REM). Our respiration and heart rate (and others) vary depending on the phase we are in.



REM (rapid eye movement) is a phase also called paradoxical sleep. Your eyes are making large movements behind your eyelid.

creepy

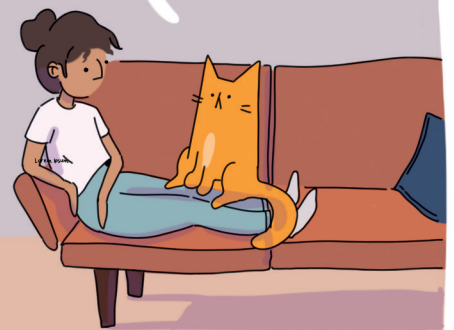


Humans have 5 or 6 REM phases per night. Scientists suggest that this stage of sleep would promote learning functions.

REM-phase is when the dreams occur, especially the most bizarre ones. When you remember your dreams when you wake up, it's very probable you were in REM-sleep.

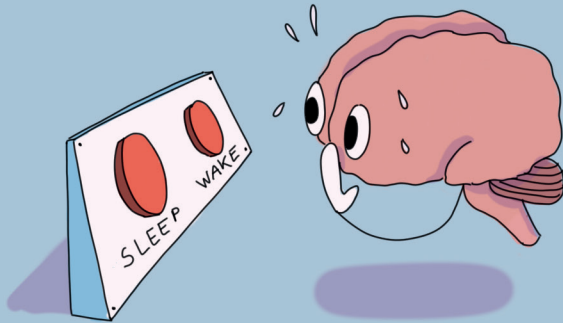


Now that you have understood what REM is, it is easier to understand pathologies like narcolepsy

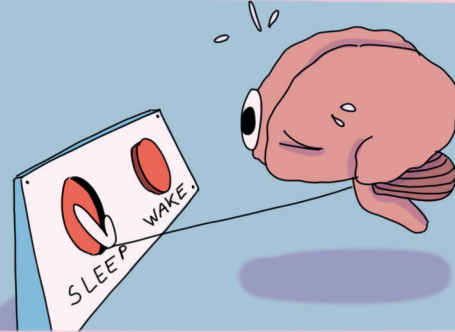


Narcolepsy and insomnia

Narcolepsy affects the brain's ability to control the sleep-wake cycle.

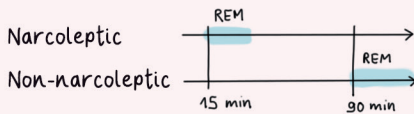


This condition can impair people's lives due to excessive daytime sleepiness (which can cause accidents and result in poor performance at school/work)

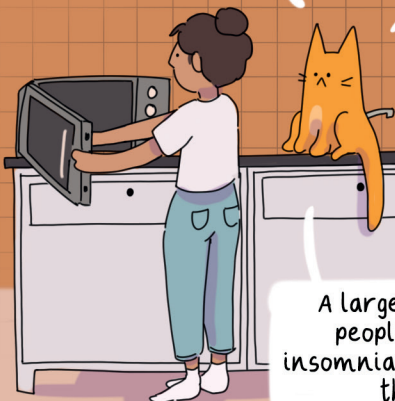


The main hypothesis explaining narcolepsy is a lack of hypocretin in the brain, a protein that promotes wakefulness and regulates REM-sleep

In addition to having trouble staying awake, people with narcolepsy have REM sleep at abnormal times (within 15 minutes of falling asleep compared to 90 minutes)



In fact, chronic insomnia is usually linked to other troubles



It is often linked to other mental health conditions (stress, anxiety, depression, PTSD*, drugs), but it can also be linked to Alzheimers, epilepsy or chronic pain.



*PTSD: Post-traumatic stress disorder

Good habits to support your circadian clock and sleep-wake cycle

In sleep medicine, chronic insomnias can be treated by cognitive behavioural therapies.

Even if you don't have any medical problems like insomnia, many small things can be done to improve sleep.

It is important to keep good habits for your circadian cycle. It can really make a big difference to your sleep quality!

Keep a regular time to go to bed, not to be shifted.

Try not to ignore a feeling of being sleepy; it is a window of opportunity to sleep.

Avoid going to bed with a full or empty stomach

CRAP

Avoid bright and blue light after dusk

Spend a lot of time outside during daytime hours (in particular in the morning) and have a bath of light

Speaking of which, you should also take care of adjusting nutrition to circadian timing

It is no longer a good time to eat the soup

You should give it to me

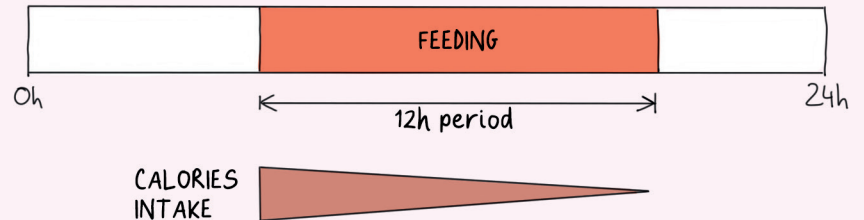
Be aware of the stimulant effect of substances like caffeine, tea, alcohol and nicotine

Nutrition and exercise in circadian rhythms

Your body is better at digesting food during the day: the metabolism is optimised that way



It is recommended to eat during a 12h period or less per day (e.g. from 7am to 7pm or from 8am to 8pm).



And humans should also eat most of their calories during the first part of the day.

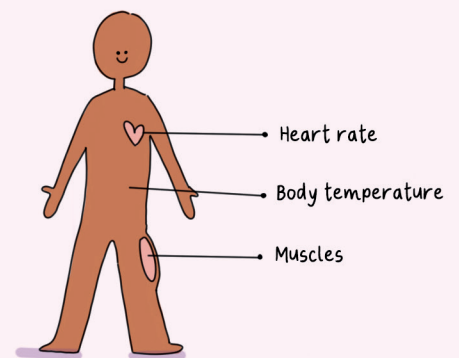


Eating times follow a circadian rhythmicity..



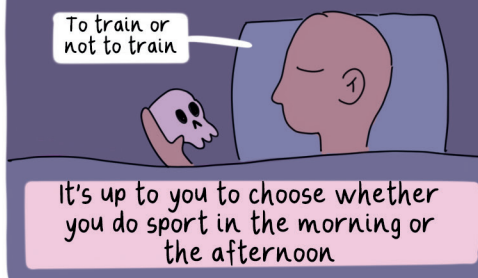
...same goes for the moments you exercise

Indeed, many aspects of exercise show time-dependent effects:



Studies have shown that performance for the same exercise is higher in the afternoon than in the morning.

But people who exercise in the morning show an increase in energy expenditure on the following days.



No risk for me, I'm not doing any exercise



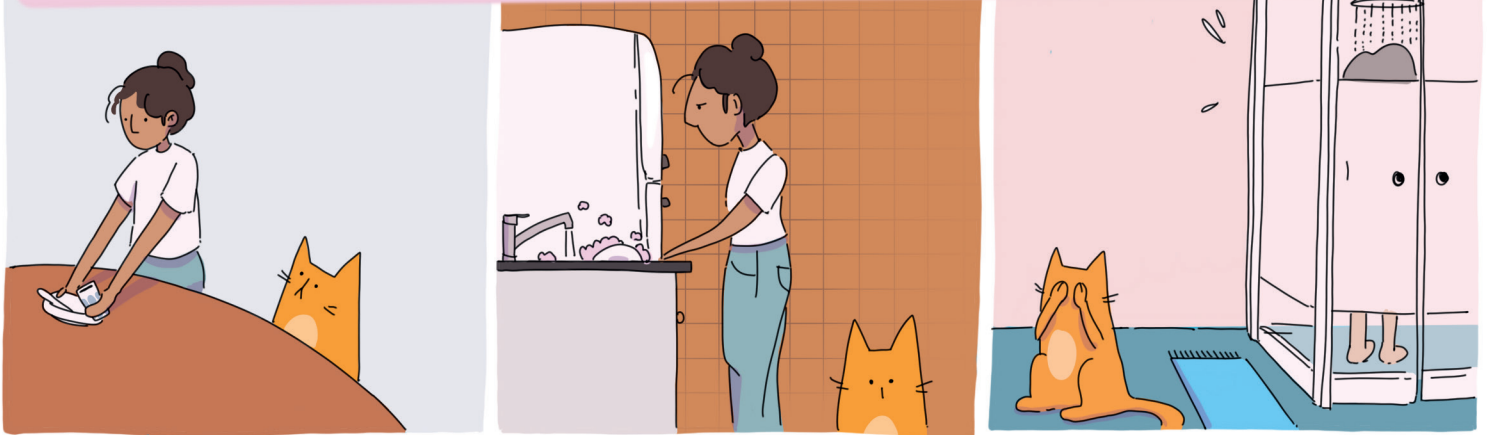
But at least, I think I understood the biological clock and the circadian system.

I'll try to summarise to be sure



Conclusion

I have understood that.. many aspects of my behaviour and well-being are influenced by my circadian rhythm. The latter is synchronised on a day period. During the night, my brain secretes melatonin which helps me sleep, but if I expose myself to bright light during the evening, it can stop melatonin secretion.



Um, I have my own sleep preference: I'm definitely not a morning lark. Also if I don't respect my natural cycle, it can shift my circadian clock, and can cause mental health problems. This shifting happens for night shift workers and with jet lag.



And now I have some tips to get a better night's sleep, according to my circadian clock!

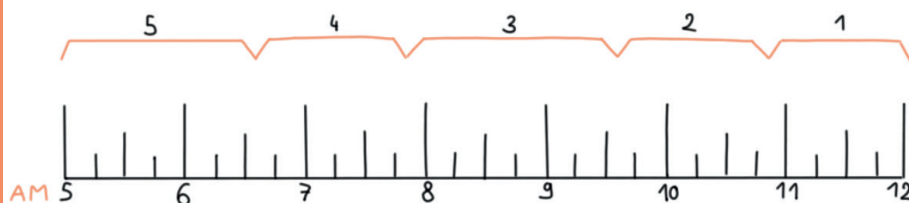


Test yourself: Are you a morning lark or a night owl?

Score your points from each question

1

Considering only your own «feeling beat» rhythm, at what time would you get up if you were entirely free to plan your day?



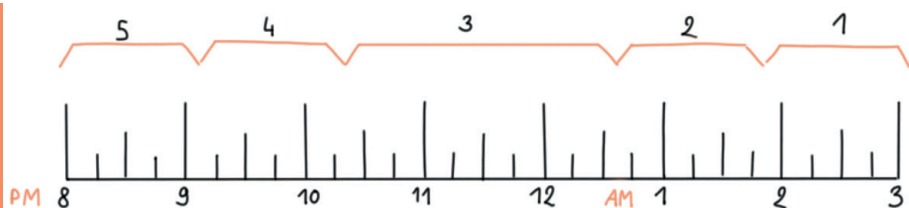
2

During the first half hour after having woken in the morning, how tired do you feel?

Very tired 1
Fairly tired 2
Fairly refreshed 3
Very refreshed 4

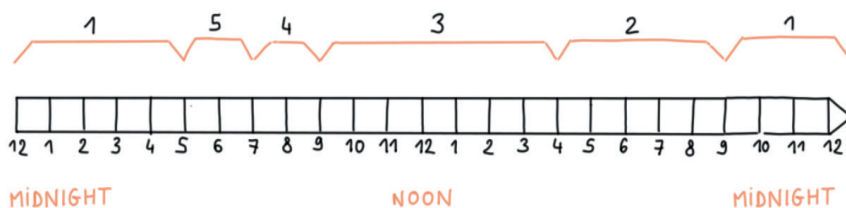
3

At what time in the evening do you feel tired and as a result in need of sleep?



4

At what time of the day do you think that you reach your «feeling best» peak?



5

One hears about «morning» and «evening» types of people. Which ONE of these types do you consider yourself to be?

Definitely a «morning» type 6
Rather more a «morning» than an «evening» type 4
Rather more a «evening» than a «morning» type 2
Definitely a «evening» type 0

Results

On the basis of the range of the direct total score, we can divide people, approximately, into five groups based on their score.

If you want to do the full questionnaire and get specific advice depending on your chronotype, visit this website:
<https://chronotype-self-test.info/index.php?>

Score

22-25 Definitely Morning Type
18-21 Moderately Morning Type
12-17 Neither Type
8-11 Moderately Evening Type
4-7 Definitely Evening Type

Further information

If you have found this book interesting and would like to learn more, here are some interesting

How to sleep better:

📄 More details about clinical conditions and sleep in general

<https://www.mentalhealth.org.uk/publications/how-sleep-better>

📄 Here you will find more details about many topics (Do I have insomnia?/Am I getting enough sleep?/The causes of snoring, etc.)

<https://www.thensf.org/sleep-health-topics/>

📄 More information and support for children, adults and professional

<https://thesleepcharity.org.uk/information-support/>

Insomnia:

📺 What causes insomnia? Dan Kwartler – TED-Ed

A well explained video about insomnia

<https://youtu.be/j5Sl8Ly17k8>

📄 7 healthy tips for a better night's sleep

https://blog.ed.ted.com/2016/08/23/7-healthy-tips-for-a-better-nights-sleep/?utm_source=youtube&utm_medium=social&utm_campaign=insomnia

Sleep in teenagers:

📺 The Teen Sleep Hub

A series of videos about anxiety, social media, peer pressure, and their relation to sleep

<https://teensleephub.org.uk/>

📄 SCRAMS

Teenagers are not lazy!

https://scrams.sphsu.gla.ac.uk/?page_id=213

📄 Sleep Scotland

A guide entitled "Sleep support for adolescents" is available here:

<https://www.sleepscotland.org/education/teen-zone/>

If you think your sleep troubles could be linked with anxiety or depression, here are some useful resources to find help:

📄 A centralised website with a lot of information about mental health

<https://youngminds.org.uk/find-help/conditions/depression/>

✉ Whatever you're going through, you can contact the Samaritans for support.

<https://www.samaritans.org/>

Phone (from UK): 116 123

Email: jo@samaritans.org

✉ Offers confidential advice and support for young people struggling with suicidal thoughts.

<https://www.papyrus-uk.org/>

Phone (from UK): 0800 068 4141

Text: 07860039967

Email: pat@papyrus-uk.org

✉ Childline

If you're under 19 you can confidentially call, chat online or email about any problem big or small.

<https://www.childline.org.uk/>

Phone (from UK): 0800 1111

Disclaimer: This book does not replace medical advice or diagnosis. Please contact your health provider if you are concerned.



Bibliography

- (1) Manoogian, E. N. C.; Chaix, A.; Panda, S. When to Eat: The Importance of Eating Patterns in Health and Disease. *J Biol Rhythms* 2019, 34 (6), 579–581. <https://doi.org/10.1177/0748730419892105>.
- (2) Kuula, L.; Gradisar, M.; Martinmäki, K.; Richardson, C.; Bonnar, D.; Bartel, K.; Lang, C.; Leinonen, L.; Pesonen, A. K. Using Big Data to Explore Worldwide Trends in Objective Sleep in the Transition to Adulthood. *Sleep Med* 2019, 62, 69–76. <https://doi.org/10.1016/j.sleep.2019.07.024>.
- (3) Chaix, A.; Panda, S. Timing Tweaks Exercise. *Nat Rev Endocrinol* 2019, 15 (8), 440–441. <https://doi.org/10.1038/s41574-019-0229-z>.
- (4) Borbély, A. A.; Daan, S.; Wirz-Justice, A.; Deboer, T. The Two-Process Model of Sleep Regulation: A Reappraisal. *J Sleep Res* 2016, 25 (2), 131–143. <https://doi.org/10.1111/jsr.12371>.
- (5) James, S. M.; Honn, K. A.; Gaddameedhi, S.; Van Dongen, H. P. A. Shift Work: Disrupted Circadian Rhythms and Sleep—Implications for Health and Well-Being. *Curr Sleep Medicine Rep* 2017, 3 (2), 104–112. <https://doi.org/10.1007/s40675-017-0071-6>.
- (6) Eiser, A. S. Physiology and Psychology of Dreams. *Semin Neurol* 2005, 25 (01), 97–105. <https://doi.org/10.1055/s-2005-867078>.
- (7) National Institute of Neurological Disorders and Stroke. Narcolepsy, 2020. <https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/fact-Sheets/Narcolepsy-Fact-Sheet>
- (8) Spitschan, M. Melanopsin Contributions to Non-Visual and Visual Function. *Curr Opin Behav Sci* 2019, 30, 67–72. <https://doi.org/10.1016/j.cobeha.2019.06.004>.
- (9) Brown, T. M. Melanopic Illuminance Defines the Magnitude of Human Circadian Light Responses under a Wide Range of Conditions. *J Pineal Res* 2020, 69 (1). <https://doi.org/10.1111/jpi.12655>.
- (10) Lucas, R. J.; Peirson, S. N.; Berson, D. M.; Brown, T. M.; Cooper, H. M.; Czeisler, C. A.; Figueiro, M. G.; Gamlin, P. D.; Lockley, S. W.; O'Hagan, J. B.; Price, L. L. A.; Provencio, I.; Skene, D. J.; Brainard, G. C. Measuring and Using Light in the Melanopsin Age. *Trends Neurosci* 2014, 37 (1), 1–9. <https://doi.org/10.1016/j.tins.2013.10.004>.
- (11) Lewy, A.; Wehr, T.; Goodwin, F.; Newsome, D.; Markey, S. Light Suppresses Melatonin Secretion in Humans. *Science* 1980, 210 (4475), 1267–1269. <https://doi.org/10.1126/science.7434030>.
- (12) Vetter, C.; Phillips, A. J. K.; Silva, A.; Lockley, S. W.; Glickman, G. Light Me up? Why, When, and How Much Light We Need. *J Biol Rhythms* 2019, 34 (6), 573–575. <https://doi.org/10.1177/0748730419892111>.
- (13) Hastings, M. H.; Maywood, E. S.; Brancaccio, M. Generation of Circadian Rhythms in the Suprachiasmatic Nucleus. *Nat Rev Neurosci* 2018, 19 (8), 453–469. <https://doi.org/10.1038/s41583-018-0026-z>.
- (14) Cain, S. W.; McGlashan, E. M.; Vidafar, P.; Mustafovska, J.; Curran, S. P. N.; Wang, X.; Mohamed, A.; Kalavally, V.; Phillips, A. J. K. Evening Home Lighting Adversely Impacts the Circadian System and Sleep. *Sci Rep* 2020, 10 (1), 19110. <https://doi.org/10.1038/s41598-020-75622-4>.
- (15) Blume, C.; Garbazza, C.; Spitschan, M. Effects of Light on Human Circadian Rhythms, Sleep and Mood. *Somnologie* 2019, 23 (3), 147–156. <https://doi.org/10.1007/s11818-019-00215-x>.
- (16) Stockman, A. Cone Fundamentals and CIE Standards. *Curr Opin Behav Sci* 2019, 30, 87–93. <https://doi.org/10.1016/j.cobeha.2019.06.005>.
- (17) Allen, A. E. Circadian Rhythms in the Blind. *Curr Opin Behav Sci* 2019, 30, 73–79. <https://doi.org/10.1016/j.cobeha.2019.06.003>.
- (18) Walker, W. H.; Walton, J. C.; DeVries, A. C.; Nelson, R. J. Circadian Rhythm Disruption and Mental Health. *Transl Psychiatry* 2020, 10 (1), 28. <https://doi.org/10.1038/s41398-020-0694-0>.

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