

## **Sleep and the rhythm of life: why we and other living things sleep & the powerful influence of the body clock**

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The human brain is a stunningly complex example of biological machinery, and it has a peculiar property. It shuts itself off from the outside world each and every day, for hours on end. Why? The answer to this question is often identified as a 'mystery'; a great unsolved problem in science in general, and biology in particular. To give you an example, the 125<sup>th</sup> anniversary of the magazine called *Science*, one of the most eminent research journals in the world, identified the top 125 most pressing scientific questions that remain unanswered. In that list were questions such as: *What is the universe made of? & Are we alone in the universe?* These are big-picture questions to be sure. Also included in the list were: *Why do we sleep? & Why do we dream?*

It is perhaps odd that in this day and age of great scientific discoveries that we do not seem to know the answer to these seemingly simple questions about sleep. It is, of course, possible that sleep has some property that is simply quite extraordinary and hard to fathom, and that this unidentified property has not been discovered, so sleep remains unexplained. Alternatively, it is also possible that sleep and dreaming don't have any extraordinary biological attributes at all; such that something has simply been missed in the science.

This presentation identifies that sleep does something for the human brain that is very simple yet elegant from the point of view of biology. This simple function of sleep explains why it exists in us and other living things. Before identifying why we and other living things sleep, however, let us first appreciate the diversity of sleep behaviours that are found on this planet.

Sleep occurs in a vast array of species, including (to name a few) worms, flies, cockroaches, scorpions, ants, bees, snails, crayfish, fish, birds and all mammals. Most animals (like us) sleep with their whole brain all

in one go. Some animals, however, sleep with half of their brain at a time so that they can maintain some degree of vigilance and conscious behaviour from the side of the brain that is awake, while the other side sleeps. After a period of time these animals then swap sides such that the side of the brain that was previously asleep wakes up, whereas the side that was previously awake goes to sleep. Such half-brain sleep occurs in birds as well as dolphins, whales, seals, sea lions and walruses. Interestingly, seals, sea lions and walruses can also switch between whole-brain sleep on land and half-brain sleep at sea. Some birds also vary their use of half-brain sleep. These birds can still detect approaching predators and thus respond quickly to a threat while simultaneously gaining the value of sleep for the half of the brain that is asleep at the time.

Other sleep strategies found in nature include shared sleep in herding grazing animals, like those that live on the open grasslands of Africa. Such animals sleep lightly in a group and are able to respond to predators in such an environment where safe and secure sleeping sites are not available. Shared sleep strategies with temporary sentinels that provide a degree of vigilance for the group have also been identified for human hunter-gather tribes. Some species can also reduce or suspend sleep for a period of time, without apparent detriment, for example migrating birds and newborn whales and dolphins. That the temporary absence of sleep in newborn whales and dolphins also occur in their mothers is astonishing. To conceive of a month without any sleep is difficult for our human mindset, and almost impossible to envision for anyone who has been a parent never mind how 'sleep deprived' they think they are. Such suspensions of sleep, however, are necessary for survival in migrating birds as they move to a more hospitable habitat, and for the mothers to protect their young in the case of newborn whales and dolphins.

Overall, these and other examples of varied sleep behaviour and strategies should not be viewed as simple quirks of nature. Such behaviours indicate that sleep serves some purpose in biology because different species have found various ways to achieve it.

All brains are organized by a set of three key principles that apply across nature, and sleep provides a powerful boost for each of these principles. Firstly, all brains are built to be rewired and flexible, and learning is a good example. Secondly, all brains are highly interconnected. Thirdly, brains allow the organisms that house them to navigate the 'fitness landscape'. This term is from the field of evolutionary biology and is explained in the presentation.

The genes that an organism is born with influence its initial starting position on the 'fitness landscape'. The genes of some members of a species may confer low fitness; hence there is a higher likelihood of death and extinction for those organisms. In contrast, those organisms with genes that confer higher fitness have a higher probability of survival and reproductive success. The fate of organisms whose genes confer intermediate fitness is less certain, and anything that boosts their fitness would also be strongly selected for by the process of evolution by natural selection. The concept of organisms 'navigating the fitness landscape' relates to individuals being able to find behavioral (or some other) solutions to help them survive in the savage garden of nature. The philosopher Daniel C. Dennett neatly illustrates the point with a statement from his outstanding book *Darwin's Dangerous Idea*: "*animals by dint of their own clever activities in the world ... hasten or guide the further evolution of their species*".

Flexible brains boost the ability of living things to navigate the fitness landscape as they can observe, learn and even teach each other effective solutions to survive and flourish in their conditions of existence. The first presentation concludes with a summary of how sleep boosts brain rewiring for flexible behavior and thus why sleep exists in nature throughout the animal kingdom.

The simple explanation of why sleep exists in us and other living things has deeper implications for the relationship between sleep and mental health. These we will touch upon in the lecture and likely the discussion.

The second lecture identifies a more ancient biological property shared by *all living things* on the planet – the '*circadian (daily) rhythm*'. The 2017 Nobel Prize was awarded for discovery of the mechanisms controlling circadian rhythms.

All living things - encompassing plants, fungi and animals, as well as bacteria and other ancient lifeforms (the '*archae*') - evolved a particularly important biological property: *to tell daily (24 hour) time*.

Exposure to natural sunlight is the single most powerful organizer of daily biological clocks in all organisms. The mechanisms behind this effect of natural light is identified in the lecture.

Our biological clocks are reset *daily* by natural light. This daily resetting is the root basis of *time-shifting*; a facet of biology that enables living things to predict the onset and offset of each day and the passing of the seasons, and to plan appropriately for the investment of time, effort and resources.

In humans, however, this effect of natural light and the ability to time-shift comes with a set of problems unique to our age and species.

Our biological clocks are 'tricked' by artificial light at night after the sun sets. This effect of artificial light tricks our brains to thinking we are in a different time zone to the one we are living in. Our brains can think we are on Vancouver time when we are in Toronto – causing '*social jet lag*' without going anywhere.

The presentation concludes by identifying that optimal sleep occurs when our preferred sleep-amounts and timing (our inherent 'sleepotype') is appropriately matched with our inherent daily biological clock (our 'chronotype' - such as being an early bird or night owl). This will be a fruitful topic for additional discussion especially as it relates to the pervasive problem of insomnia in modern society.