Feeling sleepy? Maybe your brain's too full

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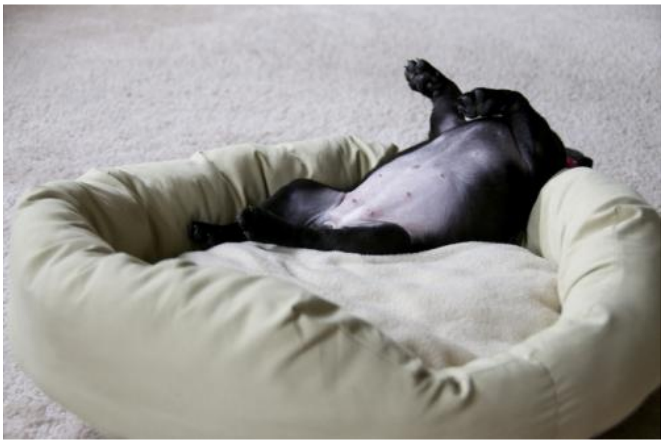

The question of why animals risk the vulnerability that comes with not being conscious for hours has led to many theories. Credit: billfromesm/Flickr

Sleep is an essential state of the brain but why do animals risk the vulnerability that comes with not being conscious for hours? What happens in the brain during sleep that's so vital for life?

Numerous theories for why we sleep have been proposed, and they all agree that sleep plays an important restorative function. But rather than being a passive state as previously thought, we now know sleep is a very active and dynamic process.

Since that realisation, theories about the function of sleep describe its role differently – to consolidate memories perhaps, or to flush out toxins and waste matter, or generally reorganise the vast amount of information gathered throughout wakefulness to filter out irrelevant information.

The mechanics of sleep

There are two processes that regulate the cycle of sleep and wakefulness. The first relates to the timing of when you sleep and are awake. It uses the brain region known as the suprachiasmatic nucleus in the hypothelamus, which acts as a "master clock".

The other relates to the build-up of sleep need (sleep pressure), which depends on the amount of time you've been awake. This keeps your body functioning in sync with the external world (driven by sunlight), and allows you to sleep during the night and be awake during the day.

Generally, as we reach late evening, the pressure to sleep becomes high enough for the brain to initiate sleep through various brain regions including the hypothalamus. Together, these brain regions initiate sleep through molecular messengers called neurotransmitters.

Once you're asleep, the brain becomes relatively disconnected from the external environment (and this is why sleep is so mysterious in evolutionary terms, because we are completely vulnerable during these hours).

Based on electrical brain activity, sleep is divided into two states, rapid eye movement (REM) sleep and non-REM sleep. These cycle roughly every 90 minutes, with four or more cycles per night.

Non-REM sleep is divided into light stages of sleep (stage one and two) and deeper or slow-wave sleep (stage three and four). REM sleep is the stage of sleep during which we dream.

Sleep and brain plasticity

When you're awake, your brain has to constantly deal with incoming information from the ever-changing environment and respond appropriately to different situations.

Due to the incredible flexibility, learning, and memory capacity of our brains (brain plasticity), we quickly learn things that are important to daily function, while filtering out redundant information.

Brain plasticity is the result of a variety of processes that broadly lead to increases or decreases in the number and strength of the connections between brain cells (neurons). It also results from the establishment of new connections between neural circuits shaped by learning and memory experiences of wakefulness.

Although REM sleep is associated with dreaming and has been linked with memory consolidation, the details of its functional role and significance are unclear.

In recent years, the slow-wave sleep that occurs during non-REM sleep has received a lot of research attention because it's thought to play an important role in brain plasticity, learning, and memory.

And it's this kind of sleep that forms the basis of an elegant theory of sleep function called called the synaptic homeostasis hypothesis. The core point of the theory, according to the researchers who proposed it is that sleep is "the price we pay for plasticity".

A new theory

According to the synaptic homeostasis hypothesis, brain plasticity mostly takes place when we're awake and taking in new information from the environment. Functionally important information that's relevant to our daily function and survival prompts brain changes that lead to an overall increase in the strength and number of neural connections (synapses) in the brain as a whole.

But this increase cannot be sustained forever because higher synaptic strength requires lots of energy, cellular resources, and space. So the system becomes inefficient and signalling between neurons becomes more erratic, reducing the capacity for learning and memory.

This is where sleep comes in – it puts the brain into an "offline" state during which the synaptic strength accumulated during wakefulness can be surveyed through spontaneous electrical activity. And it ensures the process is uninterrupted by the external environment.

The process returns the system back to a more sustainable, baseline level while, at the same time, keeping a trace of important learning and memory information.

The hypothesis says slow-wave sleep plays a major role in achieving synaptic homeostasis or "renormalisation" by creating an environment that facilitates returning synaptic strength to a normal level.

Criticism and strength

The synaptic homeostasis hypothesis theory is supported by a growing amount of research evidence including molecular, cellular, genetic, animal and human studies.

Its critics says the theory may be too simplistic because it fails to offer more detailed neural mechanisms by which the described brain effects are achieved. But this lack of focus on detailed mechanisms also makes the theory attractive because it suggests a more universal and general function for sleep.

This function is to maintain neuronal balance by returning synaptic strength accumulated through wakefulness to inefficient levels, back to normal levels so your brain can optimise learning and memory capacity when you're awake.

Source: The Conversation