FUNCTIONS OF SLEEP, INCLUDING RESTORATION AND EVOLUTIONARY ACCOUNTS

Sleep is found throughout the animal kingdom, but it is hard to recognise in reptiles/cold-blooded animals. The human need for sleep is recognised in all cultures and across all time periods. For example, reference to sleep can be seen in Mesopotamian legends, in anthropological accounts of Aboriginal rituals, and in writings relating to war and religion. Because of our apparent need for sleep, it is likely that it serves some important function(s).

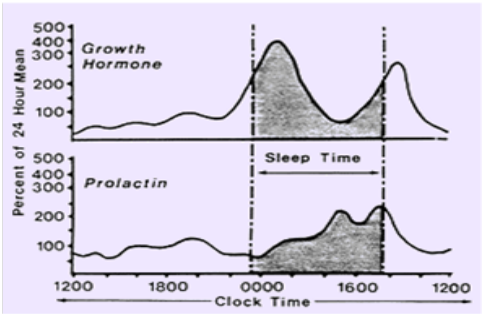
As we noted in the elsewhere, one way of studying the functions of sleep is to deprive people of it, either totally or partially, and see what the consequences of this deprivation are. So, don't be surprised if some of the studies we looked at in Disrupting Biological Rhythms reappear here!

Restoration theory of the functions of Stage 4 sleep

The most well known restoration theory of sleep function is that proposed by **Oswald (1966, 1980)**. According to Oswald, **stage 3 & 4** sleep has 3 main functions:

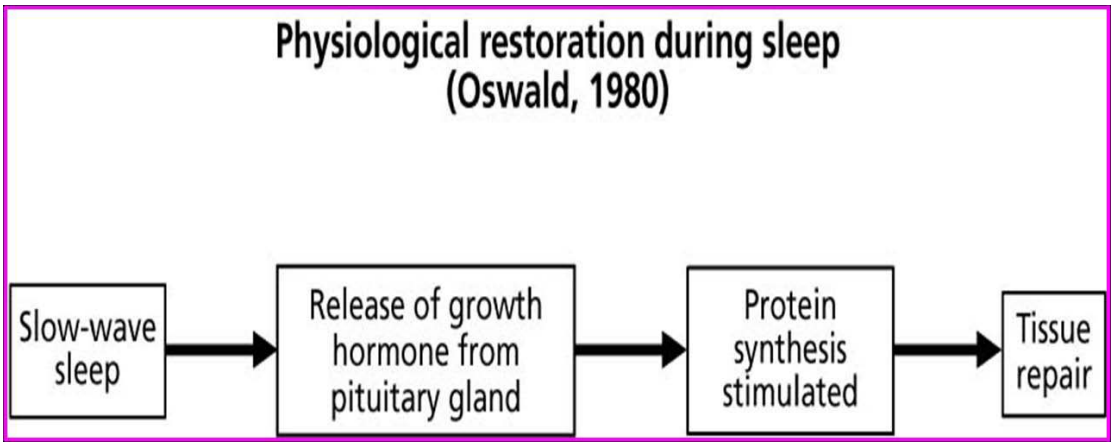
- To restore depleted energy resources
- To eliminate waste products from muscles
- To recover physical abilities

What Oswald is arguing is that the functions of stage 3 and 4 sleep ('deep sleep') is to *repair the damage done to the body during the waking day*. Oswald bases his theory on a number of findings. For example, research has shown that the pituitary gland releases **growth hormone** during stage 4 sleep. This is important in tissue growth and red blood cell formation (i.e. the growth process).



Growth hormone is released during Stage 4 sleep

It has also been found that cell repair occurs during stage 4 sleep through a process called **protein synthesis** (for which growth hormone is necessary: see above). More recent research suggests that neurotransmitter levels increase during stage 4 sleep, as though the brain is trying to replenish the 'stocks' that were used up during the waking day. This might also happen during REM sleep (see later).



Evaluation of restoration theory of Stage 4 sleep

One finding which is consistent with Oswalds' theory is that people spend longer in Stage 4 sleep following strenuous physical activity. For example, **Shapiro et al (1981)** found that people who had competed in an ultra-marathon, a running race of 57 miles, slept an hour and a half longer than they normally did for two nights following the race. Stage 4 sleep occupied a much greater proportion of their total sleep time (about 45%) than normal (about 25%). The increase in Stage 4 sleep was achieved at the cost of reduced REM sleep.

Similarly, research shows that more time is spent in Stage 4 sleep when we are younger, because our need for growth hormone is greater. We spend much less time in Stage 4 sleep in old age, presumably because we no longer need growth hormone.

Empson (1989) found that disruption of Stage 4 sleep in healthy people produces symptoms similar to those experienced by fibrositis sufferers. This is interesting, because fibrositis sufferers are known to experience a chronic lack of Stage 4 sleep. Since fibrositis is a disorder which causes acute inflammation of the back muscles and their sheaths, this is consistent with Oswald's view that sleep serves a restorative function.

Finally, research shows that deprivation of Stage 4 sleep leads to a 'rebound effect', presumably because of the need to 'catch up' on lost repair time. If Stage 4 sleep did not serve any functions, there would be no need to 'catch up' on missed time spent in it.

However, Oswald's theory is weakened by the fact that, as **Huber-Weidman** suggests, we can go for a lengthy period (at least five nights) without sleep, and suffer little damage to our physiological systems. Likewise, taking the wakefulness drug *Modafinil* doesn't seem to lead to any adverse effects nor does it lead to a rebound effect.

Other research has contradicted Shapiro et al's findings, and shown that physical activity increases stage 4 sleep onset, but does *not* increase its duration. In fact, there is even evidence to suggest that a *lack of exercise* doesn't lead to us sleeping less or to a change in our sleep cycles. **Ryback & Lewis (1971)** studied healthy individuals who were asked to spend six weeks in bed doing nothing! Their sleep patterns remained the same, despite the lack of a need for physical restoration to take place. In connection with this, the giant sloth's behaviour is also difficult for Oswald to explain. It expends very little energy, and yet it sleeps for 20 hours a day!

Finally, research shows that insomniacs suffer from far more psychological problems than healthy people, and that we generally sleep more during periods of stress. These findings would suggest that sleep may serve a *psychological restoration* function as well as the *physical restoration* function proposed by Oswald.

Despite the above weaknesses, a lot of psychologists agree with Oswald's theory, so much so that the following distinction is commonly made:

- **Optional sleep** (stages 1 & 2) which we *can* go without
- **Core sleep** (stages 3 & 4 and REM) which we *can't* go without

Restoration theory of REM sleep

Remember that in studies of *partial sleep deprivation*, participants are woken whenever they enter a particular stage of sleep. They are then told to go back to sleep, until they enter that stage again, when they are woken again. This continues throughout the night, and deprives them of a

single stage of sleep. The stage of sleep that has been most extensively investigated in this way is REM, and there are two important findings.

First, following REM sleep deprivation, people spend longer in it when allowed to sleep normally (i.e. people typically show a *rebound effect*). Second, when deprived of REM on successive nights, people show a REM *starvation effect* (i.e. the brain makes an ever increasing number of attempts to try and have REM sleep).

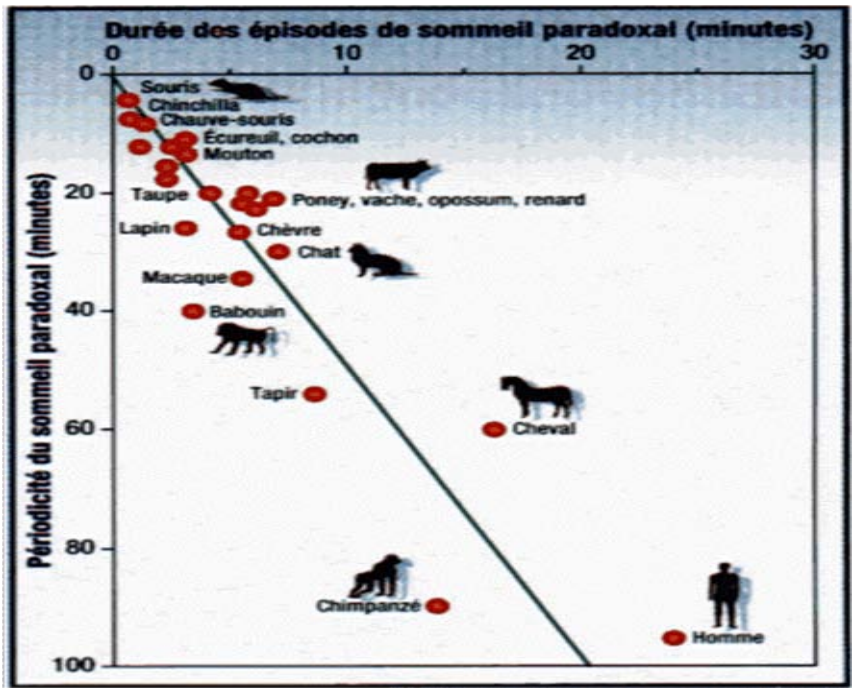
One way in which we can deprive ourselves of REM without being in a sleep laboratory is through drinking *alcohol*. Alcohol suppresses REM without affecting NREM sleep. When people abstain from alcohol, they also experience a rebound effect. REM deprivation also affects our anxiety levels. People who experience anxiety during the waking day but sleep normally, show lower levels of anxiety than people who are REM deprived.

This has led Oswald to propose that REM sleep also serves an important function. Whilst stage 4 sleep serves to *physically* restore us, Oswald argues that the function of REM sleep is to *'psychologically restore'* us. Oswald argues that purpose of REM sleep is to:

- replenish brain processes and repair the brain
- consolidate learning and memory
- enable us to dream

Oswald also bases this theory on a number of observations. First, people spend longer in REM following brain trauma induced by, for example, a drug overdose or by ECT. According to Oswald, this is the brain attempting to repair the damage that has been done to it. Research also indicates that *protein synthesis*, which (as noted previously) is important in cell manufacture and growth, occurs at its greatest levels in REM sleep. And it turns out that protein synthesis is a vital component in consolidating long-term memory.

Once again Oswald's theory is supported by several research findings. For example, REM sleep is less likely to occur in species whose behaviour is genetically determined. So, the more a species depends on learning for its behavioural repertoire, the more REM sleep it has:



Species whose behaviour is genetically determined spend less time in REM

As we have seen previously, the amount of time spent in REM sleep is not the same across the lifespan. The amount of time spent in REM sleep is greatest in infancy and least in old age. This is consistent with Oswald's theory – infants have a much greater need to consolidate learning and memory than do people in old age.

Oswald's theory is also supported by studies which show that if people are experimentally deprived of REM sleep, they show impaired memory. **Empson & Clarke (1970)** gave participants unusual phrases to try and remember just before bedtime. They were then given a memory test about them the next morning. Those deprived of REM sleep remembered less than those who were woken up the same number of times during the night, but not during REM sleep. Research typically shows a deficit of around 15% in REM-deprived sleepers.

Finally Oswald's theory would predict that a longer time would be spent in REM sleep when learning is taking place, and memories needed to be consolidated. Studies show that this is true in non-humans and humans, and that the increase in time spent in REM sleep is greatest during the steepest part of the learning curve.

This person is trying to learn how to adapt to a gross distortion in her visual world. According to Oswald, she should spend longer in REM sleep while learning takes place

However, as with his theory of the functions of stages 3 and 4 sleep, it is also possible to criticise Oswald's theory of the functions of REM sleep. Although some studies have shown memory deficits following REM sleep deprivation, others have not. For example, anti-depressant drugs suppress REM sleep, and people who take them may deprive themselves of REM sleep for months or even years. However, research studies show no impairment in learning and memory.

Other drugs, such as alcohol, also suppress REM sleep. However, whilst abstaining from alcohol produces an REM rebound effect, people do not experience this when they stop taking anti-depressant drugs. We know that anti-depressant drugs cause increases in the levels of *serotonin* and *noradrenaline*. So, the function of REM sleep might actually be to restore neurotransmitter levels - because anti-depressant drugs increase neurotransmitter levels, there would be no need for REM and no need for a rebound effect.

Therefore, if we were deprived of REM sleep, our serotonin and noradrenaline levels would drop, and this would cause problems with the behavioural functions they are involved in such as perception, memory and attention (which is what research shows). Total sleep deprivation would have similar effects, because REM sleep is also lost under these conditions. This suggests that REM sleep might serve a restorative function, even if it is *not exactly* what Oswald proposes.

A second problem for Oswald's restoration theory comes from studies of sleep in *non-humans*. Cold-blooded reptiles do not have REM sleep, and yet they are capable of learning. Also, there are wide differences in how long non-humans sleep for, and there doesn't seem to be a correlation between how long a non-human sleeps for and how much restoration it needs. So perhaps sleep occurs for reasons other than restoration…

Evolutionary explanations of the functions of sleep

Evolutionary theories of the function of sleep argue that it ***evolved*** to aid survival back in prehistoric times. Certainly, some non-human animals go to extraordinary lengths in order to sleep. For example, domino fish sleep surrounded by a stinging anemone to which, over time, they have become immune.

One way in which sleep might help us survive is because it forces us to *conserve energy* at times when it would be inefficient for us to be awake. In this sense, sleep is like *hibernation*. This **'energy conservation hypothesis'** is supported by two observations. First, mammalian body temperature drops by 1-2 degrees during sleep. Second, many animals increase their sleeping time when food is scarce.

However, research shows that in humans, 8 hours sleep saves as little energy as that contained in a cup of milk! This is a long time to be doing nothing to save only a very small amount of energy!

This has led **Meddis (1979)** to propose an alternative evolutionary theory. He points out that whilst mammalian physiology does not differ greatly, the time that mammals spend asleep does, and that how long an animal

sleeps for is related to whether it is a *predator* or a *prey* species. This is called the '**safety needs hypothesis**'.

For example, lions sleep for 20 hours a day whereas giraffes only sleep for 5 minutes a day. According to Meddis, prey species sleep for shorter periods of time because they *cannot afford to be immobile* for long periods of time. However, predator species *can afford to be immobile* for long periods of time (who is going to attack them?) and this is why they sleep for long periods of time.

According to the comedian Woody Allen, "the lamb will lie down with the lion, but the lamb won't be getting much sleep." Meddis' theory explains why.

However, Meddis' theory is contradicted by the finding that some prey species *do* sleep for long periods. For example, the dormouse, sleeps for around 15 hours and takes 30 minutes to become alert after waking up). To explain this, Meddis says that if an animal is a *prey* species, then sleeping (keeping quiet) is an adaptive behaviour.

This is because the animal would be at less risk from its predators when it didn't have to engage in behaviours that were necessary for its survival such as feeding. In species that depend upon vision, it would be especially sensible for them to sleep during darkness. The problem with this explanation is that it is non-falsifiable (and therefore non-scientific, much like horoscopes).

To overcome this, Meddis says that how long an animal sleeps for is also related to its ***metabolic needs***. The short-tailed shrew, for example, must eat round the clock or die because of its high metabolic rate. It therefore spends very little time asleep. However, squirrels have a high metabolic rate sleep for long periods in order to conserve energy, so this

inconsistent with the claim that animals with a high metabolic rate spend little time asleep.

As well as these criticisms, there are several other points we can make that weaken Meddis' theory:

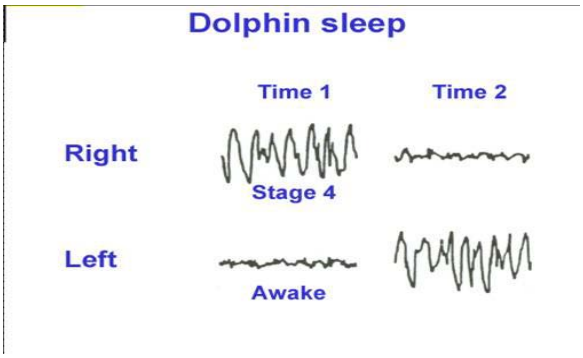
- There are other ways to avoid predation that are much less risky than sleeping (e.g. just being inactive or 'playing possum')

- Prey species might simply sleep for only short periods because it takes them longer to obtain sufficient food (e.g. horses spend a large part of the day grazing on low quality grass, whilst a fox can quickly catch nutrient rich meat)

- Sleep times may just be a function of an animal's *ecological niche* (the little brown bat sleeps for 20 hours a day and is only active when the flies it eats become active for 4 hours a day)

One final weakness in Meddis's theory is that sleep is found in species that would be better off without it, and yet those species go to extreme lengths in order to be able to sleep. For example, aquatic mammals such as dolphins are air breathers. However, they do spend a lot of time underwater. Because they breathe air, it would be dangerous for them to sleep underwater (they would either drown or suffocate).

The *bottle-nosed dolphin's* solution to this problem is very elegant. It 'switches off' one hemisphere at a time. This allows one (or other) hemisphere to be alert all the time while the other 'catches up' on its sleep. During these periods of '*unilateral sleep*', the dolphin continues to come up to the surface to breathe, so its sleep is not characterised by complete motor paralysis.



Unilateral sleep in the bottle-nosed dolphin

The dolphin's dramatic behaviour is a powerful argument in favour of the view that, just as in humans, sleep has evolved because it has an important *function*. Perhaps it is the restorative function proposed in Oswald's theory…