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Neurobiology

The adjustable REM sleep in Fur Seals

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ABSTRACT
Semiaquatic fur seals have little or no REM sleep when in water for 2 weeks. Upon coming back to the land-life they return to have normally about 80 min of REM sleep a day. Such a unique ability to turn REM sleep on and off leads us to better understand its biological role.

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Key features of sleep such as behavioral quiescence, reduced responsiveness to external stimuli and characteristic posture are recorded in all living organisms, from simple forms like jellyfish to humans. This implies that sleep serves an important, yet unknown, vital evolutionary function. However, sleep is unambiguously differentiated into two states only in land mammals and birds. These two states include slow-wave sleep (SWS) and rapid eye movement (REM) sleep. They differ from each other, as well as from the waking state, in terms of behavioral, brain activity, eye state and muscle tone features. In fact, during REM sleep the brain is active but the animal cannot move due to strong muscle suppression.

So far, the majority of sleep studies report that lack of REM sleep- as a consequence of repeated awakenings- leads to an increase of the REM sleep time (so called REM rebound). Therefore, a key finding has been that REM sleep is homeostatically regulated, i.e. just as food or water deprivation leads to increased eating when food or water is once again available. Some evidence also suggests that periods of lack of REM sleep for a week or more cause impaired behavior, memory deficit, physiological dysfunction, and eventual death. However, the vast majority of these data were collected in the laboratory setup when animal and human subjects were forced to wake up hundreds of times a day,

disrupting their normal behavior of physiological processes. Under these conditions, it is hard to know what is caused due to REM sleep loss and what is caused by the stress of being awakened repeatedly.

Studies of sleep in cetaceans- a group of aquatic mammals- revealed that they have only one sleep state which is defined as unihemispheric sleep. It implies that sleep involves only one half of the brain while the other one remains awake. In spite of many years of effort, no evidence of REM sleep has been found in dolphins and whales yet.

The northern fur seal (Callorhinus ursinus) is a great model for studying sleep. This animal can live on land and in seawater. During the summer breeding seasons, they alternate between periods of staying on land with short foraging trips to the ocean. During the winter migratory season, northern fur seals migrate more than 2000 km to the wintering grounds and remain pelagic for up to 10 months before going back to land. The challenges for sleep on land and in water are different for the air-breathing warm-blooded animal. Moving from land to seawater, the fur seal switches between the typical terrestrial type of sleep (bihemispheric slow-wave sleep, immobility, regular breathing and REM sleep) and fully aquatic mode of sleep as shown by cetaceans (unihemispheric sleep, sleep in motion, interrupted pattern of breathing and apparent absence of REM sleep). Like no other animal, the fur seal provides an opportunity to examine the plasticity of sleep when responding to different ecological demands.

We have examined the key features of sleep in fur seals when on land and in seawater. We found that although fur seals have on average 80 min of REM sleep a day when on land, they have little or no REM sleep (less than 3 min) when in seawater for as long as 2 weeks. After this nearly complete elimination of REM, the fur seals have minimal or no REM rebound upon returning to land.

Our findings have several important implications for understanding the function and biological role of REM sleep.

Firstly, we observed the ability of the fur seal to “naturally” eliminate or substantially reduce the amounts of REM sleep for days or weeks in seawater when ecological conditions change and it questions the idea that REM sleep is vitally needed. Thus, giving up REM sleep in water appears to be more beneficial for the fur seal than having REM sleep to fulfill some yet unknown vital function, unless REM sleep serves different functions in different animals. There is some evidence that fur seals can have a reduced amount of REM sleep for up to 1-2 months. However, what happens to REM sleep when they are aquatic for 6-10 months is unknown and should be a subject for future studies.

Secondly, we observed that REM sleep in the fur seal is eliminated at a time when the animal requires high levels of alertness, performance, learning, and motor activity to navigate, locate prey, and avoid predators compared to when the seal is resting on land. In fact, on land the fur seal has daily REM sleep, which could be reconciled with the idea that REM sleep is essential for maintaining cognitive functions.

Thirdly, the absence of REM sleep rebound in fur seals after accumulating a profound deficit of REM sleep in seawater life challenges the idea that REM sleep is homeostatically regulated. Our data are consistent with the hypothesis that REM sleep may serve to reverse a reduced brain temperature and metabolic effects of bihemispheric slow-wave sleep or non-REM sleep, a state that is greatly decreased when the fur seal is in the seawater. This may explain the absence of REM sleep in the dolphin and other cetaceans that don’t have bihemispheric slow-wave sleep.