**Adaptive loss of REM sleep in the fur seal in seawater: insight to the function and biological role of REM sleep**

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Key features of sleep are recorded in all living organisms, from simple forms (e.g., worms) to humans. This implies that sleep serves an important, yet unknown, vital evolutionary function. 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 one another as much as they do from waking based on behavioral, brain activity, eye state and muscle tone features.

The majority of sleep studies reported that REM sleep deprivation leads to a REM rebound when the deprivation ceases. Therefore, a key finding has been that REM sleep is homeostatically regulated, i.e. just as food or water deprivation lead to increased eating when food or water is restored. Some evidence also suggests that periods of REM sleep deprivation for a week or more cause impaired performance, memory, 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 difficult to separate the effects of REM sleep loss from the stress of repeated awakening.

Studies of sleep in cetaceans revealed they have only one sleep state which is unihemispheric sleep (USWS), being unihemispheric waking at the same time. In spite of many years of effort, no evidence of REM sleep has been found in dolphins and whales yet. The semiaquatic northern fur seal (*Callorhinus ursinus*) is a unique subject for comparative sleep studies. This animal can live on land and in seawater. During the summer breading 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 (such as bilateral or bihemispheric SWS, immobility, regular breathing and REM sleep) and fully aquatic mode of sleep as shown by cetaceans (USWS, 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, it displays minimal or no REM rebound upon returning to land. Sleeping in seawater also make them to virtually eliminate bilateral SWS and have primarily USWS.

Our findings have several important implications for understanding the function and biological role of REM sleep. First, 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 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. Second, the fact 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 and have REM sleep daily needs to be reconciled with the idea that REM sleep is essential for maintaining cognitive functions. Third, the absence of REM sleep rebound after accumulating a profound deficit of REM sleep challenges the idea that REM sleep is homeostatically regulated. Our data are consistent with the hypothesis that REM sleep may serve to reverse the reduced brain temperature and metabolism effects of bilateral SWS or nonREM sleep, a state that is greatly reduced 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 bilateral SWS.