The Science of Sleep: Understanding Circadian Rhythms and Their Impact on Health

Specific aim:

Circadian rhythms are biological processes that regulate sleep and other vital functions in humans. These rhythms, discovered through historical experiments such as those by Jean-Jacques d'Ortous de Mairan and Nathaniel Kleitman, are not strictly 24-hour cycles and can vary between individuals. Circadian rhythms influence sleep patterns, attention, energy levels, digestion, and metabolic processes, such as insulin sensitivity and hormone regulation.

Future research directions can involve studying the variations in circadian rhythms among different populations, including those with sleep disorders, to identify crucial genetic and environmental factors. Utilizing advanced neuroimaging techniques like fMRI to map brain activity during various sleep stages can enhance our understanding of sleep regulation. Additionally, developing wearable devices to monitor sleep patterns can aid in self-managing sleep health. Understanding the relationship between circadian rhythms and metabolic functions can lead to improved treatments and promote a healthier lifestyle.

Background:

The Primary question about sleep in the history of science is “Do plants sleep?”.

In 1729, a French geophysicist named Jean-Jacques d'Ortous de Mairan noted that Mimosa pudica, the shy plant, opens its leaves at sunrise and closes them when the sun sets. He started an experiment in which he isolated this plant from sunlight completely and began observing its behavior. What he noticed was a revolution, a great discovery. He noticed that the plant continued to open its leaves at sunrise and closed them when the sun set. This discovery suggested that the plant has circadian rhythms.

In 1938, When Professor Nathaniel Kleitman asked if humans have circadian rhythms like plants, he decided to go with his assistant to Mammoth Cave in the state of Kentucky, which is considered one of the deepest caves in the entire world to the point that sunlight does not reach it. They took food, some equipment, and beds. 32 days were enough to discovered that humans have circadian rhythms. They noticed that they slept at the time they were used to sleeping and woke up at the time they were used to waking up. This experiment confirmed that every human has their wake-up system, also the biological clock is not 24 hours. Professor Nathaniel and his assistant noticed that they had a sleep period of 9 hours and a waking period of 16 hours in one day, making their biological clock 25 hours. On another day they had a sleep period of 8 hours and a waking period of 15 hours, making their biological clock 23 hours.

The biological clock is not only responsible for sleeping and waking times, but it also regulates vital processes while awaking, such as attention, energy, and digestion. The biological clock has peaks and troughs as shown in Figure 1. When it is at its peak, human body will be fully focused, have high energy, and exhibit high brain activity. When it is at its trough, the body will experience lethargy.

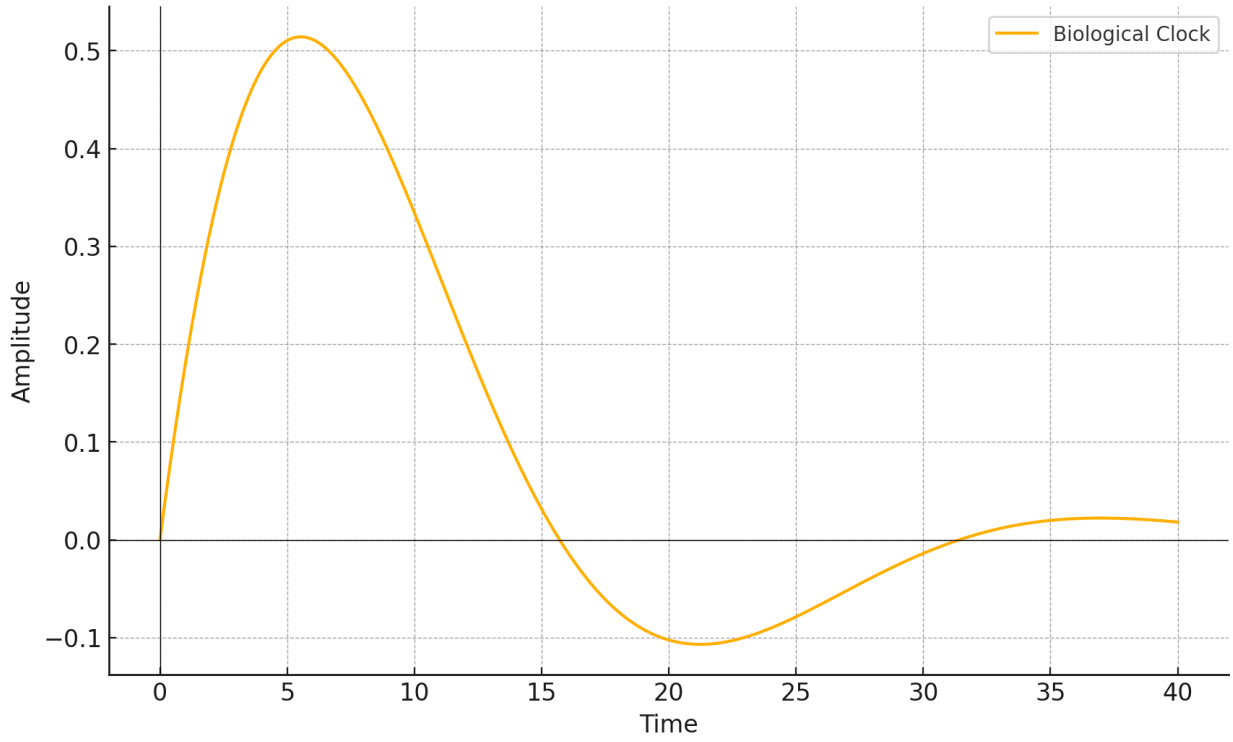

Figure 1 shows the peak and trough of the biological clock.

Digestive processes are active when the biological clock is at its peak, and they become inactive when the biological clock is at its trough.

If the biological clock is at its peak, your internal temperature is high. Conversely, at its trough, the temperature is low, preparing human body for sleep. This explains the feel of hotness when trying to sleep at a different time than usual. Drinking cold water, lowering the temperature of AC, or taking a shower could help decreasing the internal temperature, which aids in falling asleep.

Regarding the question of "Who sets the biological clock?" Matthew Walker identifies a nucleus called the suprachiasmatic nucleus. This nucleus is located above the intersection of the optic nerves from the right and left eyes, as shown in Figure 2.

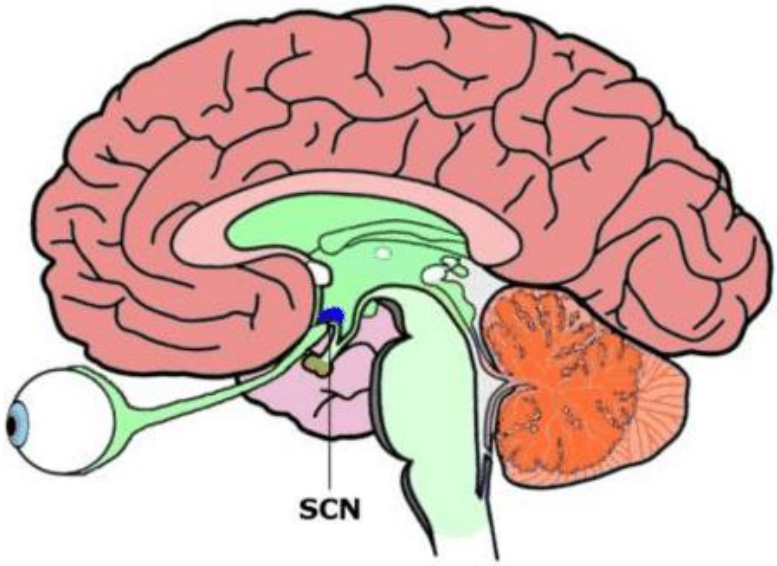

Figure 2 shows the location of SCN (Supra Junctional Nucleus).

In conclusion, the study of sleep and circadian rhythms has revealed that these biological processes control not only sleep but also vital functions like attention, energy, and digestion. Observations from Jean-Jacques d'Ortous de Mairan's work with Mimosa pudica to Nathaniel Kleitman's experiments in Mammoth Cave demonstrate the presence of circadian rhythms in both plants and humans. These rhythms affect our internal temperature and overall functioning, emphasizing the importance of regular sleep patterns. The suprachiasmatic nucleus, identified by Matthew Walker, plays a crucial role in regulating this clock. Understanding and

respecting our natural rhythms is essential for maintaining health, enhancing productivity, and improving quality of life.

Future directions:

Studying changes in circadian rhythms among different people, including those with sleep disorders, can show crucial genetic and environmental factors. By studying groups, researchers can identify how lifestyle variations impact sleep patterns. For example, shift workers often face disruptions in sleep, dizziness, and stress due to irregular hours, highlighting the impact of environmental factors. Understanding these variations can lead to modified treatments, promoting better sleep health for individuals.

Using advanced neuroimaging techniques like fMRI to map brain activity during various sleep stages is crucial for understanding sleep regulation. These methods allow researchers to identify key brain regions involved in different sleep phases, such as the hypothalamus and brainstem. By observing these areas in real-time, scientists can uncover how they work together to initiate and maintain sleep. This knowledge aids in understanding sleep disorders and developing targeted treatments, ultimately enhancing sleep health.

Developing wearable devices that monitor sleep patterns is essential for self-managing sleep health. These devices use sensors to track metrics such as sleep stages, heart rate, and movement. By providing real-time feedback, they help users understand and improve their sleep quality. Advanced algorithms can detect issues like sleep apnea and irregular sleep patterns, alerting users to take corrective actions. This technology enables proactive management of sleep health.

Circadian rhythms influence the body's metabolic rate. Research shows that metabolic rate can vary throughout the day, often being higher in the morning and lower at night. This variation can affect how efficiently the body processes calories and nutrients. Circadian rhythms also affect insulin sensitivity, which is the body's ability to respond to insulin. Insulin sensitivity tends to be higher in the morning and decreases throughout the day. Disruptions to these rhythms, such as those caused by irregular sleep patterns or shift work, can lead to impaired glucose metabolism and increase the risk of type 2 diabetes. Hormones that regulate

metabolism, such as leptin and ghrelin, are influenced by circadian rhythms. By exploring this relationship more deeply, we can improve our method to living a healthier life.

Resources:

1. Palotti, J., Pérez-Auli, E., & Menéndez, M. (2018). Ambulatory assessment of human circadian phase and related sleep disorders from heart rate variability and other non-invasive physiological measurements. ResearchGate.
2. Walker, M. (2017). *Why we sleep: Unlocking the power of sleep and dreams*. Scribner.