A World without Day or Night

While the rest of us can only dream of a life without clock-watching, for some 300 test subjects, this became reality. The subjects lived in an underground "sleep bunker" at the Max Planck Institute for Behavioral Physiology, some of them for weeks at a time, with no way of telling the time and only their internal clock to rely on. As early as the 1950s, the co-founders of chronobiology, Gustav Kramer and Jürgen Aschoff, began studying how this internal clock regulates our sleep-wake cycle.

The journey to the discovery of the internal clock begins with migratory birds: in the early 1950s, physiologist Gustav Kramer was studying bird migration at the Max Planck Institute for Marine Biology in Wilhelmshaven. His observations led him to conclude that the reason migratory birds are able to keep so precisely to their route lay in their ability to navigate using the sun. During this process, they continually compensate for the sun's movement using an internal mechanism – a mechanism that can be compared to a clock.

To prove that birds compensate for solar motion, Kramer observed a starling searching for food in a circular cage. He and his colleagues attached to the outside of the cage, at regular intervals, twelve identical feeders covered with a rubber film having a small slit for an opening. Early every morning, the researchers filled the feeder on the east side of the cage – and the starling quickly learned that food was located where the sun rose. However, even when Kramer put the food into the eastern feeder in the afternoon, the bird found it immediately, having taken the movement of the sun into account.

In another experiment inside a tent with a fixed light, the bird took the light to be the sun. Because it assumed that the sun moves, at other times of the day, it searched the other feeders for its food – but found it only mornings, since the food, as in the cage experiment, was hidden in the eastern feeder. After these experiments, there was hardly any doubt that an internal clock exists.

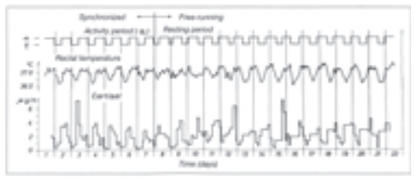
In 1958, Kramer was named head of a department at the new Max Planck Institute for Behavioral Physiology in Seewiesen. A year later, however, he lost his life in a tragic accident: he slipped and fell to his death while trying to catch wild rock pigeons in Calabria, believing them to be far better laboratory animals than starlings.

Rütger Wever analyzing the bodily functions of a subject in the sleep bunker.

But even after his death, the Max Planck Society continued the research into chronobiology begun by Kramer and his colleagues, mainly through the efforts of physician Jürgen Aschoff, who had also been appointed to the new Max Planck Institute for Behavioral Physiology in 1958, as head of the department of Biological Rhythms and Behavior located just a few kilometers from Seewiesen in Erling-Andechs. Aschoff had already conducted research in this area. In his research on mice and chaffinches, he discovered a rule that now bears his name. According to Aschoff's rule, "the active period of diurnal animals becomes shorter and that of nocturnal animals becomes longer than 24 hours if the intensity of the light they are exposed to is increased." The internal clock can thus be reset by light.

These findings led him to ask how the biological clock that governs our daily rhythms behaves under laboratory conditions. Our body temperature, for example, follows a daily rhythm: it is highest in the evening and lowest in the morning. All organs and bodily functions have similar rhythms: the rate at which tissue cells divide, the potassium and calcium content of urine, the precision and speed with which we solve mathematical problems – there is always a daily maximum and minimum.

Aschoff decided to utilize a soundproof bunker used by the military in World War II to create such controlled conditions. In 1963, he made the bunker into an experimental station for test subjects who were to live in it for three to four weeks, totally isolated from the outside world. It was just a stopgap solution, but the results were so encouraging that, in 1964, a more advanced facility was designed and built. It comprised a comfortable living and sleeping area, a shower, a toilet and a small kitchen in which the subjects could prepare their own meals.



Living according to your own personal rhythm: Sleep-wake patterns shift in the sleep bunker, as do body temperature fluctuations (middle) and cortisol peaks (bottom).

PHOTOS: MPS

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... Real biological rhythms persist under constant conditions [...] and are not simply induced by light or darkness [...]. Many subjects have already spent time in such constant conditions: the Max Planck Institute for Behavioral Physiology alone has data on some 150 people who have spent a long time [...] shut away from natural light in experimental facilities. ...

The only connection to the outside world was two doors with a tiny room between them. Only one door could be opened at a time, and the room contained a refrigerator for temporarily keeping urine samples, as well as a store of food – including the obligatory beer from the local Andechs brewery. The researchers restocked the food-store at different times of day to ensure that the subjects could not use the restocking time as a way of working out what time of day it was. There were no clocks or watches in the bunker, the subjects having handed theirs over before entering. Nor was there a radio or television, just a solitary record player, which the more resourceful subjects used to time their egg cooking: a record took three minutes from beginning to end, just the right amount of time to boil an egg. The test persons were asked to maintain a structure to their days, eating three meals a day at normal intervals, not taking any naps, and taking various psychological tests. The researchers evaluated all the data of their activities and physiological reactions outside the bunker, for example the regular rectal temperature measurements, the amount of urine they passed and its potassium/calcium content, as well as the results of periodic requests that the test subjects estimate how long they thought twenty or sixty seconds was.

Rütger Wever accompanies a test subject on her journey into timelessness. Students liked to use the period of isolation in the sleep bunker as a chance to cram for exams.

The first test subject was Jürgen Aschoff himself, who wanted to find out firsthand how it felt to be totally timeless. He later reported that, in the first few days, he was extremely curious to know what time it really was. However, he gradually lost all interest in it and found it quite comfortable to live in a timeless environment.

Over the first two years, 25 subjects stayed in the bunker and were monitored. The researchers noted that the majority of them woke up slightly later every day. Their average days were no longer 24 hours, but soon lengthened to between 24.7 and 25.2 hours. However, this length then remained constant, and their bodily functions basically followed this new rhythm. As this rhythm does not correspond to conventional day and night, it is called the circadian rhythm (lat. circa = approximate, dies = day).

The fact that this rhythm continued while the subjects were in the bunker was an important indication of the existence of an internal clock that controls our daily rhythms. And the fact that each test person developed their own circadian rhythm also supported this theory. If the rhythms had been the same for all the subjects, the researchers could not have ruled out an unknown external periodic event that was having a biological effect on the subjects.

The bunker research ceased in the early 1980s, and of some 300 monitored subjects (only 4 left the bunker early), one type of subject proved extremely interesting. The researchers discovered this unique subject type while they were observing a student who had agreed to spend several weeks in the bunker. He maintained that this would be sufficient time for him to prepare for his exams, which were scheduled for immediately after the experiment. However, when the agreed period was over and the researchers opened the doors of the bunker, the student protested vehemently: they were deceiving him, he claimed, the agreed time period was not yet over, and he was therefore nowhere near finished with his studying.

How could this have happened? The test subject's sleep-wake rhythm had spun completely out of control and was no longer approximately 24 hours, but almost 33, without the student realizing it. He believed that he had completed a day's work in around 14 hours, while in fact it had taken him 20. However, his bodily functions gave no indication of this disruption; they had maintained their circadian rhythm. The researchers thus concluded that humans have at least two independent biological clocks that are normally synchronized – but that are out of sync in some people. Incidentally, the Andechs-based researchers were able to solve the exam-studying issue: they contacted the examiner, explained the situation and agreed on a new date for the student.

For the test subject, time had passed too quickly. For others, however, it passed far too slowly, as was the case for an editor from the Max Planck Society's press office who took part in an experiment under more difficult conditions: for the entirety of his three-day confinement, he was not allowed to carry out any type of activity. No reading materials, no record player and no writing materials – the researchers had even removed all the paper clips from the bunker. His life consisted solely of sleeping, lying, sitting, eating, smoking a pipe and drinking mineral water or orange juice (there was no alcohol, tea or coffee). The subject had expressed the desire to experience total timelessness one time, but he was soon utterly fed up with it. He lost all concept of time, ultimately just waiting for the "end of the experiment" signal that would rescue him – a situation he described as grueling.

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