THE BIOLOGICAL CLOCK

What is the biological clock?

Earth has rotated on itself since the beginning of time, long before the emergence of life. That rotation is the source of the 24-hour day-night cycle. All life-forms living on Earth, including bacteria, plants, animals and humans, have evolved under that 24-hour cycle, and all of them possess a biological clock that helps them adjust to the day-night cycle.

In humans, the central biological clock is located in the brain, specifically in the hypothalamus, a site dedicated to physiological regulation. Within that strategic location, the biological clock acts as an orchestra conductor, giving the rhythm to all bodily functions. This is an essential role, because bodily functions need to occur at the right time of day to fulfill their purpose. The biological clock also ensures an internal temporal organization, preventing the simultaneous occurrence of incompatible functions.

The rhythm of our biological clock is endogenous, meaning that it is generated by the clock itself, by the action of specific genes called “clock genes”. This endogenous rhythm has a period of about 24 hours. For this reason, this rhythm is called “circadian”, from the Latin words “circa” (about) and “dies” (a day).

In addition to the main biological clock, there are many secondary biological clocks located in most organs of the body, including the skin, the heart, the liver, the kidneys, etc. All of these clocks harmonize the global physiological and psychological functioning of the body.

The influence of the biological clock on sleep and wakefulness

To regulate the alternation between the states of sleep and wakefulness, the biological clock works in collaboration with an equilibrium mechanism called the “homeostatic process”. The homeostatic process adjusts wakefulness levels according to sleep needs: wakefulness is high after a good night of sleep, but decreases progressively as the duration of time awake increases. For its part, the biological clock determines when the brain’s wakefulness signals are strong or weak, within the 24-hour cycle.

In humans, the biological clock is set to support maximal wakefulness during the day and continuous sleep during the night. So, wakefulness signals are weak in the morning because we are rested after a night of sleep and we don’t need additional stimulation to stay awake. During the day, the wakefulness signals promoted by the biological clock increase progressively to reach maximal strength about two hours before our habitual bedtime. These signals counterbalance the increasing need to sleep in order to maintain stable alertness levels for all our waking time. After bedtime, the wakefulness signals decrease to very low levels, allowing for many consecutive hours of sleep.

The effects of light on the biological clock

The rhythm produced by the biological clock varies from one person to another. The duration or period of the rhythm is about 24.2 hours on average in humans. So, our biological clock needs a daily adjustment to stay synchronized with the 24-hour day-night cycle of the environment. The main cue used by the biological clock to synchronize its rhythm to the day-night cycle is the timing of light and darkness.

Our eyes are necessary not only to see the world around us, but also to inform our central biological clock of the presence of light. For this purpose, we have some special retinal cells that connect directly to the biological clock. These special cells have a high sensitivity to blue light, the colour of the sky on a cloudless day. On the other hand, these cells are essentially blind to yellowish-orange light, such as the light of a campfire.

The biological clock reacts differently to light according to the time of day. In general, it reacts to morning light by shortening its rhythm, which has the consequence of making all body rhythms occur earlier. Exposure to morning light is important for people having an internal rhythm longer than 24 hours as it prevents their rhythms from shifting later and later. On the contrary, light exposure in the evening lengthens the rhythm of the internal clock and delays all rhythms to a later time. So, exposure to light in the evening, especially to the blue light emitted by electronic devices, tends to delay our rhythms, including our sleep-wake rhythm, to a later time.

After a sudden time change, such as after a plane flight across many time zones, the biological clock finds itself desynchronized with the new day-night cycle. The clock will resynchronize progressively, if the traveler is exposed to the light-dark cycle of the new environment. The resetting of the main biological clock usually takes a few days, about one day per time zone. However, the secondary clocks located in the various organs of the body do not all resynchronize at the same rate. As a result, there is a transition period during which the clocks have different rhythms, causing all kinds of discomforts such as digestive problems, headaches, and irritability, all symptoms known as being part of the “jet lag syndrome”.

Should we adjust the biological clock of night workers?

When starting a series of night shifts, the worker’s biological clock is desynchronized with the sleep-wake cycle imposed by the work schedule. In contrast to the jet lag situation, the light-dark cycle associated with day and night does not change. Therefore, the biological clock is not exposed to the light-dark signals necessary to make an adjustment to the new sleep-wake cycle.

Without an adjustment, the biological clock does not send any wakefulness signals during the night, when the worker is at work. Furthermore, the internal clock continues to send strong wakefulness signals during the day, when the night worker is trying to sleep. Then, for the night worker, the biological clock becomes a major source of insomnia during the day and of drowsiness during the night.

It is possible to adjust the night worker’s biological clock, using exposure to light and darkness at the right time. Experimental studies have demonstrated that it is possible to completely change the internal time of the biological clock in 2-3 days, especially when using bright light exposure at specific times carefully chosen. But is it really the best solution for night workers?

Obviously, there are advantages to adjusting the internal clock to the sleep-wake cycle imposed by the night work schedule. Once adjusted, the biological clock will help the night worker perform better at work during the night and ensure more good-quality sleep during the day. With a well-adjusted clock, digestion and mood are better, and the general feeling of well-being is improved.

The main disadvantage is that the internal clock needs a few days to adjust, even when using appropriate light and dark exposures. And the period of adjustment is even longer for most of the secondary clocks. During this adjustment period, the main internal clock is unstable and the secondary clocks all have different rhythms. According to current knowledge, such an internal circadian disruption, mostly when repeated, could have very harmful consequences in the long term, leading to increased risk of cancer, and metabolic disorders such as diabetes, and cardiovascular disorders.

A complete adjustment of the biological clock may therefore be appropriate for workers having the same schedule for long periods of time. For example, this is the case for workers on remote oil rigs who keep the same night schedule for weeks at a time. But most night workers rarely work more than 4 or 5 nights in a row. They would not benefit from a full adjustment of their biological clocks because they usually don’t want to continue to be up at night on their days off. Furthermore, many night workers have a rotating day-night shift work schedule. In trying to re-adjust each time they have a day off or a day shift, the workers will maintain their circadian clocks in a permanent state of instability.

The current consensus is rather, to aim for a partial adjustment of the night workers’ clocks. This way, they are not completely adapted to day or night work, but they are never completely desynchronized either. This is a compromise, but it has the major advantage of ensuring that their biological clocks are more stable. This is why it is recommended to adopt as many routine habits as possible, in spite of the schedule changes. Notably, keeping similar meal times helps to maintain cohesion in the secondary biological clocks.

In conclusion...

Night work is a big challenge for both our main and secondary biological clocks. They will adjust better if we carefully choose the best times to sleep and to expose ourselves to light, and if we install some regularity in our daily life habits. Our biological clocks will then be able to correctly fulfill their role and help us to stay in good health.