BIOLOGICAL RHYTHMS

Specification: Biological rhythms: circadian, infradian and ultradian and the difference between these rhythms. The effect of endogenous pacemakers and exogenous zeitgebers on the sleep/wake cycle.

WHAT YOU NEED TO KNOW
1. Outline examples of, and evaluate circadian rhythms, with research support.
2. Outline examples of, and evaluate the role of endogenous pacemakers and exogenous zeitgebers.
3. Outline examples of, and evaluate infradian and/or ultradian rhythms

KEY TERMS	DEFINITIONS
Biological Rhythms	Biological rhythms are cyclical patterns within biological systems that have evolved in response to environmental influences, e.g. day and night. There are two key factors that govern biological rhythms: endogenous pacemakers (internal), the body's biological clocks, and exogenous zeitgebers (external), which are changes in the environment.
Circadian	One biological rhythm is the 24-hour circadian rhythm (often known as the 'body clock'), which is reset by levels of light. The word circadian is from the Latin 'circa' which means 'about', and 'dian', which means 'day'. Examples of circadian rhythms include the sleep-wave cycle and body temperature.
Infradian	Another important biological rhythm is infradian rhythms, which last longer than 24 hours and can be weekly, monthly or annually. A monthly infradian rhythm is the female menstrual cycle, which is regulated by hormones that either promote ovulation or stimulate the uterus for fertilisation.
Ultradian	Ultradian rhythms last less than 24 hours and can be found in the pattern of human sleep. This cycle alternates between REM (rapid eye movement) and NREM (non-rapid movement) sleep and consists of five stages. The cycle starts at light sleep, progressing to deep sleep and then into REM sleep, where brain waves speed up and dreaming occurs. This repeats itself about every 90 minutes throughout the night and a person can experience up to five complete sleep cycles each night.
Endogenous Pacemakers	Endogenous pacemakers are internal mechanisms that govern biological rhythms, in particular the circadian sleep/wake cycle. Although endogenous pacemakers are internal biological clocks, they can be altered and affected by the environment. The most important

	endogenous pacemaker is the suprachiasmatic nucleus, which is closely linked to the pineal gland, both of which are influential in maintaining the circadian sleep-wake cycle.
Exogenous Zeitgebers	Exogenous zeitgebers influence biological rhythms. These can be described as environmental events that are responsible for resetting the biological clock of an organism. They can include social cues, such as meal times and social activities, but the most important zeitgeber is light, which is responsible for resetting the body clock each day, keeping it on a 24-hour cycle.

Introduction

Biological rhythms are cyclical patterns within biological systems that have evolved in response to environmental influences, e.g. day and night. There are two key factors that govern biological rhythms: **endogenous pacemakers** (internal factors), the body's biological clocks, and **exogenous zeitgebers** (external factors), which are changes in the environment.

Exam Hint: For each of the biological rhythms (circadian, infradian and ultradian) it is important you that you can define the term and provide at least one example.

1. Circadian Rhythms

One biological rhythm is the 24-hour **circadian rhythm** (often known as the 'body clock'), which is reset by levels of light. The word circadian is from the Latin 'circa' which means 'about', and 'dian', which means 'day'.

The **sleep-wake cycle** is an example of a circadian rhythm, which dictates when humans and animals should be asleep and awake. Light provides the primary input to this system, acting as the external cue for sleeping or waking. Light is first detected by the eye, which then sends messages concerning the level of brightness to the **suprachiasmatic nuclei (SCN)**. The SCN then uses this information to coordinate the activity of the entire circadian system. Sleeping and wakefulness are not determined by the circadian rhythm alone, but also by **homoeostasis**. When an individual has been awake for a long time, homeostasis tells the body that there is a need for sleep because of energy consumption. This homeostatic drive for sleep increases throughout the day, reaching its maximum in the late evening, when most people fall asleep.

Body temperature is another circadian rhythm. Human body temperature is at its lowest in the early hours of the morning (36^{o}C at 4:30 am) and at its highest in the early evening (38^{o}C at 6 pm). Sleep typically occurs when the core temperature starts to drop, and the body temperature starts to rise towards the end of a sleep cycle promoting feelings of alertness first thing in the morning.

Evaluating Circadian Rhythms

- **Research Support:** Research has been conducted to investigate circadian rhythms and the effect of external cues like light on this system. **Siffre (1975)** found that the absence of external cues significantly altered his circadian rhythm: When he returned from an underground stay with no clocks or light, he believed the date to be a month earlier than it was. This suggests that his 24-hour sleep-wake cycle was increased by the lack of external cues, making him believe one day was longer than it was, and leading to his thinking that fewer days had passed.
  - Siffre's case study has been the subject of criticism. As the researcher and sole participant in his case study, there are severe issues with generalisability. However, further research by **Aschoff & Weber (1962)** provides additional support for Siffre's findings. Aschoff & Weber

studied participants living in a bunker. The bunker had no windows and only artificial light, which the participants were free to turn on and off as they pleased. Aschoff & Weber found that the participants settled into a longer sleep/wake cycle of between 25-27 hours. These results, along with Siffre's findings, suggest that humans use natural light (exogenous zeitgebers) to regulate a 24-hour circadian sleep-wake cycle, demonstrating the importance of light for this circadian rhythm.

- **Individual Differences:** However, it is important to note the differences between individuals when it comes to circadian cycles. **Duffy et al. (2001)** found that 'morning people' prefer to rise and go to bed early (about 6 am and 10 pm) whereas 'evening people' prefer to wake and go to bed later (about 10 am and 1 am). This demonstrates that there may be innate individual differences in circadian rhythms, which suggests that researchers should focus on these differences during investigations.

- Additionally, it has been suggested that temperature may be more important than light in determining circadian rhythms. **Buhr et al. (2010)** found that fluctuations in temperature set the timing of cells in the body and caused tissues and organs to become active or inactive. Buhr claimed that information about light levels is transformed into neural messages that set the body's temperature. Body temperature fluctuates on a 24-hour circadian rhythm and even small changes in it can send a powerful signal to our body clocks. This shows that circadian rhythms are controlled and affected by several different factors, and suggests that a more holistic approach to research might be preferable.

2. Endogenous Pacemakers & Exogenous Zeitgebers

Biological rhythms are regulated by **endogenous pacemakers,** which are the body's internal biological clocks, and **exogenous zeitgebers**, which are external cues, including light, that help to regulate the internal biological clocks.

Exam Hint: It's important to note that endogenous pacemakers and exogenous zeitgebers interact with one another to control and fine-tune biological rhythms and therefore it is necessary to consider these concepts together.

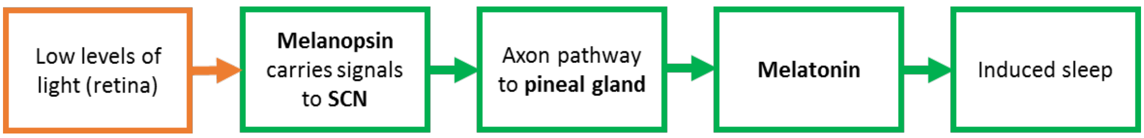
Endogenous Pacemakers

Endogenous pacemakers are internal mechanisms that govern biological rhythms, in particular, the circadian sleep-wake cycle. Although endogenous pacemakers are internal biological clocks, they can be altered and affected by the environment. For example, although the circadian sleep-wave cycle will continue to function without natural cues from light, research suggests that light is required to reset the cycle every 24 hours. (See Siffre and Aschoff & Weber, above)

The most important endogenous pacemaker is the **suprachiasmatic nucleus,** which is closely linked to the **pineal gland,** both of which are influential in maintaining the circadian sleep/wake cycle.

The **suprachiasmatic nucleus (SCN),** which lies in the **hypothalamus**, is the main endogenous pacemaker (or master clock). It controls other biological rhythms, as it links to other areas of the brain responsible for sleep and arousal. The SCN also receives information about light levels (an exogenous zeitgeber) from the optic nerve, which sets the circadian rhythm so that it is in synchronisation with the outside world, e.g. day and night.

The SNC sends signals to the **pineal gland**, which leads to an increase in the production of melatonin at night, helping to induce sleep. The SCN and pineal glands work together as endogenous pacemakers; however, their activity is responsive to the external cue of light. Put simply:



Exogenous Zeitgebers

As outlined above, exogenous zeitgebers influence biological rhythms: these can be described as environmental events that are responsible for resetting the biological clock of an organism. They can include **social cues** such as meal times and social activities, but the most important zeitgeber is **light**, which is responsible for resetting the body clock each day, keeping it on a 24-hour cycle.

The SNC contains receptors that are sensitive to light and this external cue is used to synchronise the body's internal organs and glands. **Melanopsin,** which is a protein in the eye, is sensitive to light and carries the signals to the SCN to set the 24-hour daily body cycle. In addition, social cues, such as mealtimes, can also act as zeitgebers and humans can compensate for the lack of natural light, by using social cues instead.

Evaluating Endogenous Pacemakers & Exogenous Zeitgebers

- The importance of the SCN has been demonstrated in research. **Morgan (1955)** bred hamsters so that they had circadian rhythms of 20 hours rather than 24. SCN neurons from these abnormal hamsters were transplanted into the brains of normal hamsters, which subsequently displayed the same abnormal circadian rhythm of 20 hours, showing that the transplanted SCN had imposed its pattern onto the hamsters. This research demonstrates the significance of the SCN and how endogenous pacemakers are important for biological circadian rhythms.
    - However, this research is flawed because of its use of hamsters. Humans would respond very differently to manipulations of their biological rhythms, not only because we are different biologically, but also because of the vast differences between environmental contexts. This makes research carried out on other animals unable to explain the role of endogenous pacemakers in the biological processes of humans.

- There is research support for the role of melanopsin. **Skene and Arendt (2007)** claimed that the majority of blind people who still have some light perception have normal circadian rhythms whereas those without any light perception show abnormal circadian rhythms. This demonstrates the importance of exogenous zeitgebers as a biological mechanism and their impact on biological circadian rhythms.

- There is further research support for the role of exogenous zeitgebers. When **Siffre** (see above) returned from an underground stay with no clocks or light, he believed the date to be a month earlier than it was. This suggests that his 24-hour sleep-wake cycle was increased by the lack of external cues, making him believe one day was longer than it was. This highlights the impact of external factors on bodily rhythms.

- Despite all the research support for the role of endogenous pacemakers and exogenous zeitgebers, the argument could still be considered **biologically reductionist.** For example, the behaviourist approach would suggest that bodily rhythms are influenced by other people and social norms, i.e. sleep occurs when it is dark because that is the social norm and it wouldn't be socially acceptable for a person to conduct their daily routines during the night. The research discussed here could be criticised for being **reductionist** as it only considers a singular biological mechanism and fails to consider the other widely divergent viewpoints.

3. Infradian Rhythms & Ultradian Rhythms

Infradian Rhythms

Another important biological rhythm is the **infradian rhythm. Infradian rhythms** last longer than 24 hours and can be weekly, monthly or annually.

A monthly infradian rhythm is the **female menstrual cycle,** which is regulated by hormones that either promote ovulation or stimulate the uterus for fertilisation. Ovulation occurs roughly halfway through the cycle when oestrogen levels are at their highest, and usually lasts for 16-32 hours. After the ovulatory phase, progesterone levels increase in preparation for the possible implantation of an embryo in the uterus. It is also important to note that although the usual menstrual cycle is around 28 days, there is considerable variation, with some women experiencing a short cycle of 23 days and others experiencing longer cycles of up to 36 days.

Extension: A second example of an infradian rhythm is related to the seasons. Research has found seasonal variation in mood, where some people become depressed in the winter, which is known as ***seasonal affective disorder (SAD).*** *SAD is an infradian rhythm that is governed by a yearly cycle. Psychologists claim that* ***melatonin,*** *which is secreted by the* ***pineal gland*** *during the night, is partly responsible. The lack of light during the winter months results in a longer period of melatonin secretion, which has been linked to the depressive symptoms.*

Exam Hint: While it is logical to assume that infradian rhythms, in particular the menstrual cycle, are governed by internal factors (endogenous pacemakers) such as hormonal changes, research suggests that these infradian rhythms are heavily influenced by exogenous zeitgebers.

Evaluating Infradian Rhythms

- Research suggests that the menstrual cycle is, to some extent, governed by exogenous zeitgebers (external factors). **Reinberg (1967)** examined a woman who spent three months in a cave with only a small lamp to provide light. Reinberg noted that her menstrual cycle shortened from the usual 28 days to 25.7 days. This result suggests that the lack of light (an exogenous zeitgeber) in the cave affected her menstrual cycle, and therefore this demonstrates the effect of external factors on infradian rhythms.

- There is further evidence to suggest that exogenous zeitgebers can affect infradian rhythms. **Russell et al. (1980)** found that female menstrual cycles became synchronised with other females through odour exposure.

In one study, sweat samples from one group of women were rubbed onto the upper lip of another group. Despite the fact that the two groups were separate, their menstrual cycles synchronised. This suggests that the synchronisation of menstrual cycles can be affected by pheromones, which have an effect on people nearby rather than on the person producing them. These findings indicate that external factors must be taken into consideration when investigating infradian rhythms and that perhaps a more holistic approach should be taken, as opposed to a reductionist approach that considers only endogenous influences.

- Evolutionary psychologists claim that the synchronised menstrual cycle provides an evolutionary advantage for groups of women, as the synchronisation of pregnancies means that childcare can be shared among multiple mothers who have children at the same time.

- There is research to suggest that infradian rhythms such as the menstrual cycle are also important regulators of behaviour. **Penton-Volk et al. (1999)** found that woman expressed a preference for feminised faces at the least fertile stage of their menstrual cycle, and for a more masculine face at their most fertile point. These findings indicate that women's sexual behaviour is motivated by their infradian rhythms, highlighting the importance of studying infradian rhythms in relation to human behaviour.

- *Finally, evidence supports the role of melatonin in SAD.* ***Terman (1988)*** *found that the rate of SAD is more common in Northern countries where the winter nights are longer. For example, Terman found that SAD affects roughly 10% of people living in New Hampshire (a northern part of the US) and only 2% of residents in southern Florida. These results suggest that SAD is in part affected by light (exogenous zeitgeber) that results in increased levels of melatonin.*

Ultradian Rhythms

Ultradian rhythms last fewer than 24 hours and can be found in the pattern of human sleep. This cycle alternates between REM (rapid eye movement) and NREM (non-rapid movement) sleep and consists of five stages. The cycle starts at light sleep, progressing to deep sleep and then REM sleep, where brain waves speed up and dreaming occurs. This repeats itself about every 90 minutes throughout the night.

A complete sleep cycle goes through the four stages of NREM sleep before entering REM (Stage 5) and then repeating. Research using EEG has highlighted distinct brain waves patterns during the different stages of sleep.

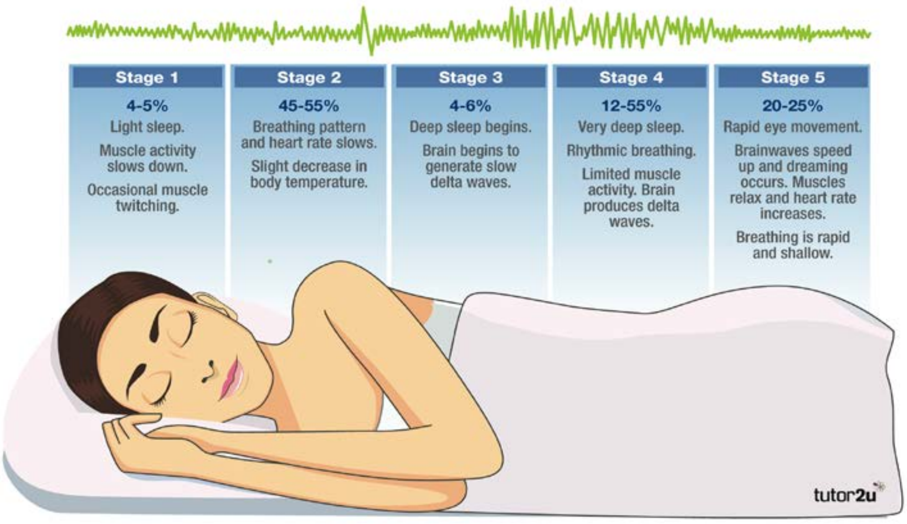
1. Stages 1 and 2 are 'light sleep' stages. During these stages brainwave patterns become slower and more rhythmic, starting with **alpha** waves progress to **theta** waves.

2. Stages 3 and 4 are 'deep sleep' or slow wave sleep stages, where it is difficult to wake someone up. This stage is associated with slower **delta** waves.

3. Finally, Stage 5 is REM (or dream) sleep. Here is the body is paralysed (to stop the person acting out their dream) and brain activity resembles that of an awake person.

On average, the entire cycle repeats every 90 minutes and a person can experience up to five full cycles in a night.

Exam Hint: When providing an example of an ultradian rhythm, answers should explicitly mention that the cycle occurs more than once every 24 hours. Furthermore, specific details in relation to the distinctive characteristics of the different stages are required to demonstrate understanding.



Extension: Another ultradian rhythm is appetite or meal patterns in humans. Most humans eat three meals a day and appetite rises and falls because of food consumption.

Evaluating Ultradian Rhythms

- **Individual Differences:** The problem with studying sleep cycles is the differences observed in people, which make investigating patterns difficult. **Tucker et al. (2007)** found significant differences between participants in terms of the duration of each stage, particularly stages 3 and 4 (just before REM sleep). This demonstrates that there may be innate individual differences in ultradian rhythms, which means that it is worth focusing on these differences during investigations into sleep cycles.
    - In addition, this study was carried out in a controlled lab setting, which meant that the differences in the sleep patterns could not be attributed to situational factors, but only to biological differences between participants. While this study provide convincing support for the role of innate biological factors and ultradian rhythms, psychologists should examine other situational factors that may also play a role.

- Additionally, the way in which such research is conducted may tell us little about ultradian rhythms in humans. When investigating sleep patterns, participants must be subjected to a specific level of control and be attached to monitors that measure such rhythms. This may be invasive for the participant, leading them to sleep in a way that does not represent their ordinary sleep cycle. This makes investigating ultradian rhythms, such as the sleep cycle, extremely difficult as their lack of **ecological validity** could lead to false conclusions being drawn.

- An interesting case study indicates the flexibility of ultradian rhythms. **Randy Gardener** remained awake for 264 hours. While he experienced numerous problems such as blurred vision and disorganised speech, he coped rather well with the massive sleep loss. After this experience, Randy slept for just 15 hours and over several nights he recovered only 25% of his lost sleep. Interestingly, he recovered 70% of Stage 4 sleep, 50% of his REM sleep, and very little of the other stages. These results highlight the large degree of flexibility in terms of the different stages within the sleep cycle and the variable nature of this ultradian rhythm.

Possible Exam Questions

1. **Short Answer Question:** Outline one or more examples of circadian rhythms. (4 marks)

2. **Short Answer Question:** Outline one or more examples of ultradian rhythms. (4 marks)

*Exam Hint: Students often lose marks on short answer questions by not **focusing** their response. The most accessible example for this question is the alternation between NREM and REM sleep. However, top mark answers need to provide details of this alternation, including the number of episodes per night and the distinctive characteristics of each stage. Another example could include meal patterns in humans. Some students confuse ultradian and infradian rhythms and claim that temperature and the sleep/wake cycle is an example of ultradian, which is incorrect.*

3. **Short Answer Question:** Outline one or more examples of infradian rhythms. (4 marks)

4. **Short Answer Question:** Outline what research into circadian rhythms has found. (4 marks)

5. **Short Answer Question:** Outline what research into ultradian/infradian rhythms has found. (4 marks)

6. **Short Answer Question:** What is meant by the terms endogenous pacemakers and exogenous zeitgebers. (4 marks)

7. **Application:** John is an electrician and has just started a new job where he works shifts. He works 4 day shifts, then has 4 days off, and then works 4 night shifts. After working night shifts, John finds it difficult to sleep during the day and becomes very frustrated. **Using your knowledge of endogenous pacemakers and exogenous zeitgebers, explain John's experiences. (4 marks)**

8. **Essay**: Outline and evaluate circadian rhythms. (16 marks)

9. **Essay**: Outline and evaluate infradian and/or ultradian rhythms. (16 marks)

10. **Essay:** Discuss research into the disruption of biological rhythms. (16 marks)

Exam Hint: You can answer this question by considering the effects of shift work on mood, physical illness and productivity; the beneficial effects of altering shift work patterns; and the effects of jet lag on physical health.

11. **Essay:** Discuss the consequences of disrupting biological rhythms. (16 marks)

Exam Hint: While this question may appear similar to the above, the focus of this question needs to be on 'the consequences' of disruption and not just a descriptive outline of the research.

12. **Essay**: Outline and evaluate the effect of endogenous pacemakers and exogenous zeitgebers on the sleep-wake cycle. (16 marks)

Extension: Disruption of Biological Rhythms

*One of the more difficult sample questions is to discuss the **consequences** of disrupting biological rhythms and this section will focus on a different area that examines the disruption in the sleep-wake cycle for people who work at night (shift workers).*

People who work at night (shift work) often experience symptoms similar to jet lag. This is because the person's work schedule (exogenous zeitgeber) is at odds with their circadian sleep-wave cycle, which is governed by powerful biological factors (endogenous pacemakers). Not surprisingly, people who work shift work often feel sleepy at work and suffer from insomnia at home.

There are numerous **consequences** for people who work shifts, including:

- **Sleep Deprivation:** People who work at night and have to sleep during the day often experience difficulties in sleeping. This is because their biological clocks (endogenous pacemakers) do not adjust completely. Furthermore, the daytime is associated with significantly more noise and other disturbances that can also affect sleep.
    - Research suggests that daytime sleep is shorter than night-time sleep. **Tilley and Wilkinson (1982)** suggest that REM is particularly affected and this reduction in sleep results in sleep deprivation, which produces lower levels of energy and reduces alertness during the night time (awake period).

- **Heart Disease:** There is a relationship between shift work and heart disease.
    - **Knutsson (1986)** found that people who worked shift patterns for more than 15 years were significantly more likely to develop heart disease. This research highlights the negative health consequences of disrupting biological rhythms, in particular the sleep-wake cycle. However, it is worth noting that these findings are purely correlational and while the findings might indicate a link between the disruption of biological rhythms and heart disease, other factors may also play a significant role. For example, it may be that jobs that require night time working are inherently more stressful and it is the stress that is the major factor and not the shift work.

- **Social Consequences:** Another issue that people who work shift patterns experience is social disruption. People who work hours that are at odds with the hours worked by their family and friends find it difficult to spend quality time with significant others.

- **Practical Applications:** While the research above highlights a series of negative consequences associated with disrupting biological rhythms, **Czeisler et al. (1982)** used research on shift work to improve the health and performance of shift workers. They found that by using a phase system to make shift changes slower, workers reported increased satisfaction and increase productivity. This suggests that the negative impact of disrupting biological rhythms can be overcome by slowly introduce people to night work.