3b. Sleep importance - Circadian & Ultradian Rhythms

Characteristics and patterns of sleep:

Biological rhythms: periodic fluctuations/cyclic changes in bodily functions or activities that repeat themselves through time in the same order.

- e.g. body temperature, blood pressure, blood sugar level, secretion of certain hormones, mental alertness and the sleep–wake cycle.

Circadian rhythms: involves changes in bodily functions or activities that occur as part of a cycle with a duration of about 24 hours.

Sleep-wake cycle:

- Light is the main environmental cue that influences the sleep–wake cycle.
- An area of the hypothalamus called the suprachiasmatic nucleus (SCN) is the 'master' biological clock that regulates the timing and activity of the sleep–wake cycle.
- The SCN receives information about the amount of incoming light from the eyes and adjusts our sleep–wake cycle accordingly.
- It does so by sending neuronal messages to the nearby pineal gland to secrete more or less of the hormone melatonin into the blood.

Melatonin and the suprachiasmatic nucleus:

- The amount of melatonin present in the blood is associated with alertness. Higher melatonin levels are associated with greater drowsiness and vice versa.

- When there is less light, such as after sunset, the SCN signals the pineal gland to produce and secrete more melatonin, which will make us drowsy and induce sleepiness.
- Melatonin levels in the blood stay elevated all through the night, then fall back to low daytime levels before the light of a new day.
- When the SCN detects light in the morning, it inhibits the release of melatonin.
- When light is detected, the SCN also performs functions such as initiating an increase in body temperature and the release of stimulating hormones like cortisol to promote alertness and support other arousal activities .

Ultradian rhythms: involves changes in bodily functions or activities that occur as part of a cycle shorter than 24 hours.

- e.g. sleep, heartbeat, respiration, activity of neurotransmitters, secretion of hormones
- Influenced by many variables such as age, health and environmental cues

REM and NREM:

- During sleep the amount of time spent in NREM sleep decreases and the amount of time in REM sleep increases.

NREM sleep:

- 4 stages
- Represents 80% of total sleep time in adults
- Brain activity – less than NWC but not as much as REM sleep
- NREM sleep believed to be when the restoration of the body occurs.

Sleep onset - hypnagogic state:

- Sleep onset is often called a *hypnagogic state* because of the unusual hallucinatory type perceptual experiences that may occur.

- It is primarily characterised by the slowing, reduction and eventual disappearance of alpha brain activity. This is also a key characteristic of NREM stage 1, so some sleep researchers describe sleep onset as occurring *through* NREM stage 1 rather than into stage 1.

Stage 1 NREM:

- Lasts for around 5-10mins (4-5% of total sleep time) in adults
- Light sleep → can be easily awakened (low arousal threshold)

Physiological changes include:

- Decrease in heart rate
- Decrease in respiration rate
- Decrease in body temperature
- Decrease in muscle tension - muscles relax (hypnic jerk).
- Slow eye rolls
- There is an overall slowdown in the brain wave pattern

Stage 2 NREM:

- Lasts for about 10 to 25 minutes and lengthens with each successive cycle, eventually constituting about 45-55% of the total sleep episode.
- Initially, can be awaken by external stimuli and when this occurs, most believe that haven't yet been asleep.

Physical changes:

- No eye rolling
- Muscles relaxed
- Breathing and heart rate decreases
- Body temperature continues to fall
- Brain waves slow further

Stage 3 NREM:

- Marks the start of deep sleep (slow wave sleep)
- Stage 3 typically lasts only a few minutes, sometimes up to 10 minutes, and constitutes about 3 to 8% of total sleep time. In sleep cycles in the latter half or so of a sleep episode there may be no stage 3 sleep at all
- Less responsive to external stimuli
- When woken disorientation

Physical changes:

- Eyes do not move
- Muscles relaxed
- Blood pressure continues to drop
- Heart and breathing rate continues to decrease
- Brain waves slow further still (lower frequency/higher amplitude)

Stage 4 NREM:

- Deepest sleep
- In the first sleep cycle, a person may spend between 20 to 40 minutes in stage 4.
- As the night progresses, less and less time is spent in stage 4 and stage 4 sleep may disappear altogether, as may occur with stage 3 sleep. Overall, stage 4 makes up about 10 to 15% of total sleep time.

Physical indicators (very similar to stage 3):

- Muscles completely relaxed → little movement
- There are no eye movements. Heart rate, blood pressure and body temperature are at their lowest and most regular.
- Brain waves are at their slowest (highest amplitude, lowest frequency)
- *Sleep inertia* – pronounced disorientation when woken during this stage.
- During stages 3 and 4 sleep walking (*somnambulism*) and night terrors occur.

After Stage 4:

We quickly cycle back through stage 3, then stage 2 and then skip stage 1 and onto REM sleep.

REM sleep: Rapid Eye Movement

- Approximately 20–25% of our total sleep time is spent in REM sleep
- REM sleep periods lengthen and occur closer together as a sleep episode progresses
- Difficult to wake

Physical changes:

- Spontaneous bursts of rapid eye movement
- Heart and breathing rate increase and fluctuate
- Blood pressure rises
- High frequency/low amplitude waves (similar to those experienced when awake and alert.)

- '**paradoxical sleep**':
    - physically little movement (muscle atonia or cataplexy – muscle paralysis) but
    - greatest brain activity
- Most dreaming occurs and dreams are more likely to be remembered compared with NREM sleep
- Sleep talking can occur (but also occurs during NREM sleep). Sleep talking which makes sense often occurs during REM sleep.

Purpose/Importance of Sleep:

Two groups of theories:

- Restoration

- Evolutionary(circadian)
- Sleep is a result of circadian rhythms (physiological functions operating on a 24hr cycle)

1. Restoration theory:

- Also called recover theory and repair theory
- Evidence for restoration theories comes largely from sleep studies.
- Sleep provides an opportunity for the body to replenish the stores of physical and mental energy that have been depleted during the day.
- It allows damaged cells to be repaired and various muscles to be detoxified (removing waste products)
- Sleep provides an opportunity to replenish resources that have been used during the day including neurotransmitters.

Evidence for the restoration theory:

- We feel rested after sleep
- We tend to sleep longer during an illness suggesting it has a role to play in the recovery process
    - Immune system cells that fight infection and disease are produced during sleep (Motivala and Irwin, 2007)
- Death will occur when animals are deprived of sleep over an extended period time (Everson, 1997).
- The following biochemical, physiological and cognitive changes occur during sleep:
    - The neurotransmitter adenosine (produced from cells using energy) decreases when asleep.
    - Sleep increases alertness and humans are more sensitive to neurotransmitters (e.g. norepinephrine) which keeps us alert, when we are tired.
    - Sleep enhances mood

- Animals with higher metabolic rates require more sleep.
- Sleep increases immunity to disease

Restorative functions of NREM sleep:

- NREM – restoring and repairing the body:
  - Physical growth, tissue repair and recovery from the effects of fatigue may occur during slow wave, stages 3 and 4 of NREM sleep when the brain is least active.
  - Growth hormone, which also promotes body repair, is secreted at a much higher rate when asleep than when awake.
    - Its secretion typically takes place during the first few hours after falling asleep, especially during NREM deep sleep (Colten & Altevogt, 2006).

Evidence for the restorative functions of NREM sleep:

- Very strenuous activity (e.g. ultramarathon) increases NREM sleep and sleep time.

Restorative functions of REM sleep:

- About the cognitive part

Infancy:

- REM sleep is much more abundant in the developing fetus and infant than in childhood and subsequent lifespan stages.
- This indicates that REM sleep may play an important part in the peak period of brain development that occurs in the early stages of the lifespan.

Throughout the lifespan:

- REM sleep has a restorative role by providing regular 'exercise' to groups of neurons in the brain that form neural pathways, thereby promoting the maintenance of brain circuits.

- Synapses can undergo LTD if they go too long without being active, so the increased brain activity observed during REM sleep may help preserve important neural pathways (Hobson, 1988).

Other evidence for restorative functions of REM sleep:

- Sleep assists in forming memories and new skills
    - laboratory-bred rats performed better on a learning task (such as running a maze) several hours after learning if they were permitted REM sleep soon after learning, compared with rats deprived of REM sleep during that time (Kavanau, 2000; Smith, 1985).
    - similar experiment with people found improved performance when REM sleep occurred after learning a particular motor task (Karni, et al., 1994).
- REM rebound - After being deprived of REM sleep, humans then spend more time in the REM stage of sleep (Dement & Vaughan, 1999).

Arguments against restorative theory/limitations:

1. It is unclear exactly what is restored during sleep (that is not also restored during periods of wakefulness).
2. It is not necessarily the case that more sleep is required for recovery after regular physical activity (Horne and Minard, 1985).
3. Physically disabled people, confined to bed do NOT sleep less than physically active people.

2. Evolutionary (circadian theory):

- Also referred to more simply as evolutionary theory, circadian theory, adaptive theory or survival theory.
- Evolutionary (circadian) theory emphasises the relationship of sleep to circadian rhythms (biological processes that occur over 24 hours e.g. temperature) and how sleep has adaptive value and has evolved to enhance our survival.

    - There is an evolutionary advantage to sleeping. Sleep evolved to enhance survival by protecting an organism through making it inactive during the part of the day when it is most risky or dangerous to move about.
    - The organism's circadian sleep–wake cycle helps ensure its lifestyle and specific activities are synchronised with the day–night cycle of its environment and at the safest times.
- Evidence: While sleeping, an organism is not physically interacting with the environment and is less likely to attract the attention of potential predators. Thus, sleep serves the function of protecting the sleeper from harm or death, and therefore enhances survival of the species.
- Research evidence for survival theories comes from studies on behaviour patterns and sleep-waking cycles of different species.

Sleep-wake cycles of different animal species:

- An animal's typical amount of sleep depends to a significant extent on how much time it needs obtain food, how easily it can hide, and how vulnerable it is to attack.

Evidence:

Predators:

- Animals with few natural predators, such as lions, tigers and gorillas, may sleep as much as 15 hours a day.

Prey:

- Grazing animals such as cows, deer, horses, zebra and buffalo have many predators and struggle to escape from them, especially when isolated from their herd.
- They cannot hide easily, climb trees or burrow quickly to escape danger.

- Thus, they are safer awake, rely on vigilance and tend to sleep for short periods totalling about 4 hours per day.

Evidence:

Smaller animals:

- Smaller animals such as possums and bats eat less food and need less time to find and digest it.
- They are also able to sleep in safe places away from their natural predators.
- Consequently, they do not need to be awake for so long each day, nor to spend so much time safeguarding against attack from predators.

Arguments against evolutionary theory/limitations:

- It does not actually explain our need for sleep — why we (and other mammals) must and will eventually sleep, regardless of the environmental circumstances and possibly the danger to which we may be exposed if we fall asleep.
- The theory does not account for the loss of awareness and alertness during sleep, since their loss may place the organism at greater risk.

Factors affecting timing and duration of sleep:

- For example:
    - Sleep times depends on the need to find food
    - Sleep depends on vulnerability to predators
        - More sleep in hiding
        - Less sleep if exposed (e.g. grazers)
    - Sleep conserves energy → reduces metabolic rate