Circadian rhythm and Sleep

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Homeostasis

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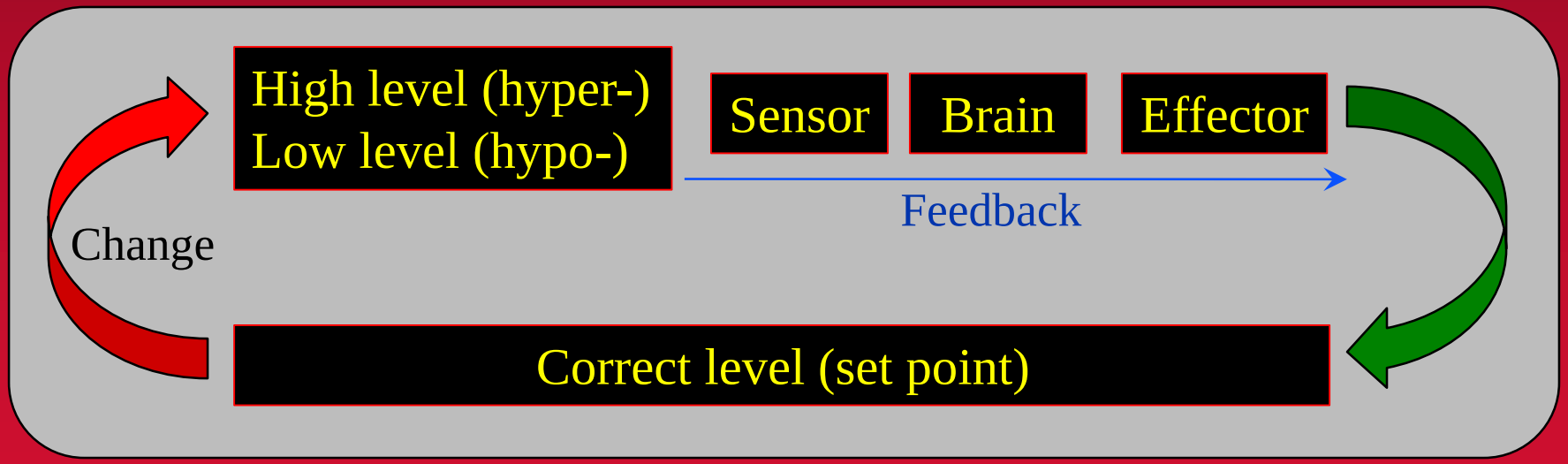
Maintenance of equilibrium by active regulation of internal states:

- Cardiovascular function (blood pressure, heart rate)
- Body temperature
- Food and energy regulation
- Fluid regulation



Summary of homeostatic control

Multiple mechanisms control homeostasis

- Emphasises the importance to survival

Set points are not fixed

- Many homeostatic functions show daily rhythms
- Maintain levels appropriate for the level of activity
- Therefore efficient in energy use.

Example

- During sleep body temperature decreases
- Heart rate decreases
- Respiration rate decreases
  - ➢ **Energy conservation**

Biorhythms

Many functions show natural biological rhythms

- Circadian rhythms (daily cycle)
  - Body temperature, heart rate, respiration, sleep

- Circannual rhythms (yearly cycle)
  - Hibernation, mating behaviour, migration

Linked to:

- Light/dark cycle
- Season (day length probably critical)

Circadian rhythms

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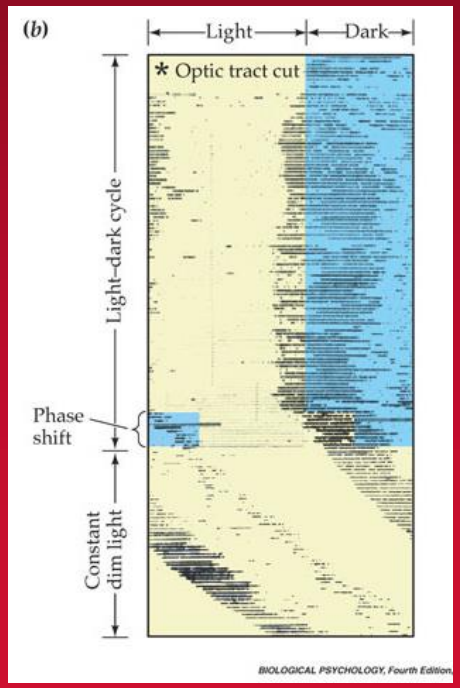
Bodily functions linked to day length

Light/dark cycle important determinant.

How does light/dark information affect body systems?



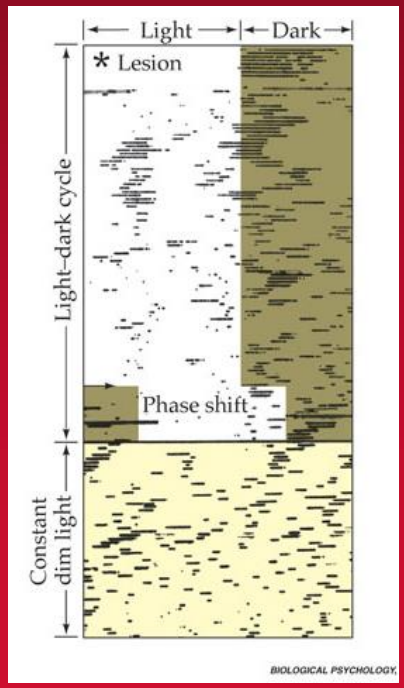
Optic tract lesion

- Circadian rhythm maintained, even in constant light
- Periodicity changed

Suprachiasmatic nucleus lesion

- Circadian rhythm abolished
- No periodicity

Therefore suprachiasmatic nucleus important for circadian rhythm



Suprachiasmatic nucleus (SCN)

Located in hypothalamus, just above optic chiasm

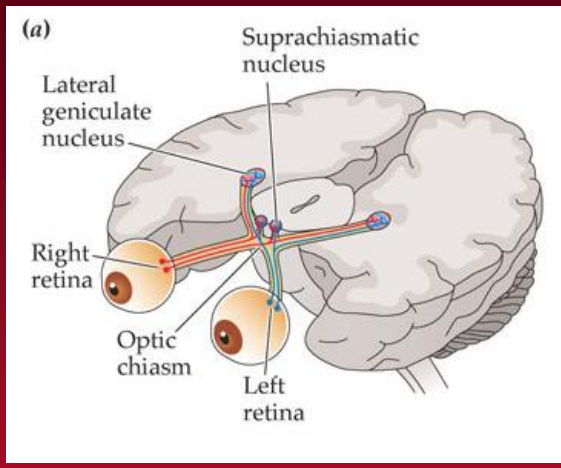
Cells in SCN show oscillations of activity

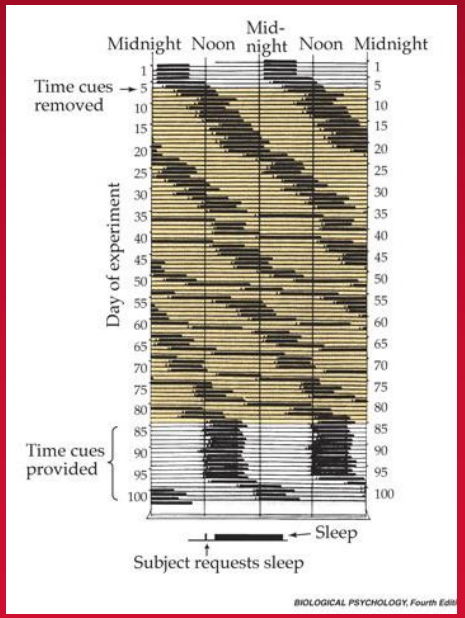
- Related to circadian rhythm
- Believed to form the 'biological clock'

Many functions (e.g. sleep wake cycle) are maintained in constant light or constant dark

- Periodicity may not be 24 hours

- In normal light/dark cycle SCN rhythm is 'phase locked' to light dark





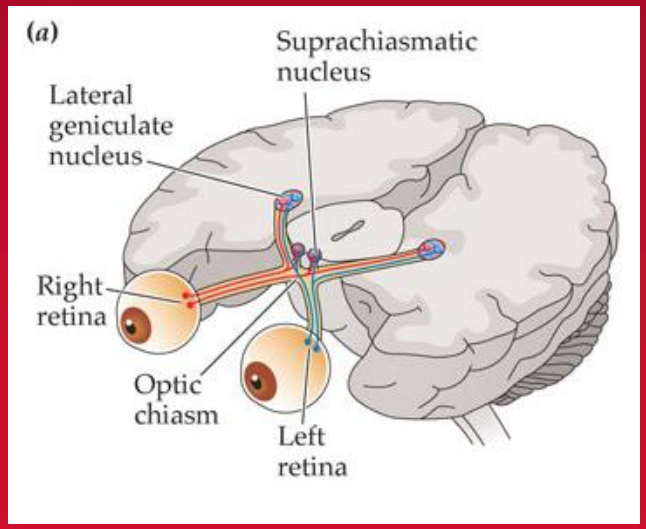
How does light information reach SCN

Many non-mammalian species have photoreceptors outside the eye

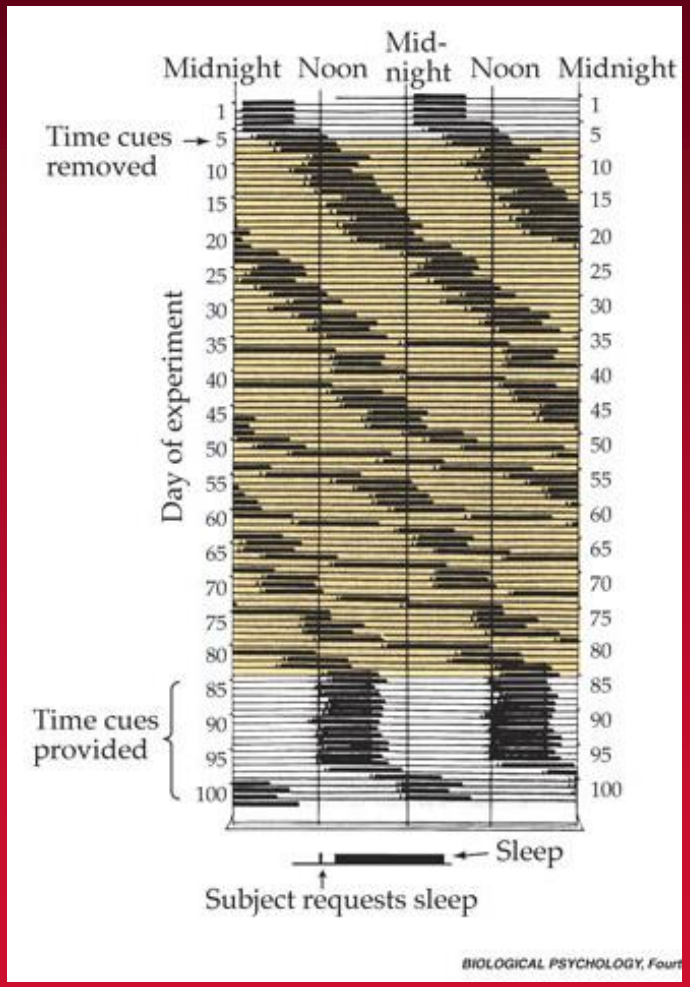
- e.g. amphibians and reptiles – pineal gland is light sensitive

In mammals a direct pathway from eyes to SCN has been identified

- Carries light information to SCN
- Rods and cones do influence SCN function
- Light sensitive information still reached SCN in the absence of rods and cones
  - Therefore other light receptors also present in eye.



Circadian rhythms in action: sleep



‘Free running’ sleep rhythm about 25 hrs

Entrainment to light dark cycle maintains a 24 hr periodicity

Mediated through SCN activity

Jet-lag

- Rapid shifts in light dark cycle
- Takes a few days for endogenous rhythm to re-entrain

Passive onset of sleep

Bremer (1930)

- Surgically separated midbrain from forebrain in cats
  - Animals remained permanently asleep
- Proposed that in the absence of sensory input the cortex became quiescent (i.e. sleep)

Moruzzi & Magoun

- Electrical stimulation of the midbrain woke sleeping animals
- Lesions to this area caused persistent sleep

- Activating system in the midbrain, which activates the cortex
- Lack of tonic activating influence of midbrain causes cortical neurones to cease firing, and sleep to ensue

Normal Sleep

- Normal sleep consists of 1-4 series of phases of increasing depth(Non REM) and REM phases.
- Each phase has a characteristic EEG.
- There is a decrease with age in sleep length.

Characteristics of sleep

Slow-wave sleep(NON REM)

- Progressive decrease in spinal reflexes
- Progressive reduction in heart rate and breathing rate
- Reduced brain temperature and cerebral blood flow
- Increased hormone secretion (e.g. growth hormone)
- Synchronised cortical activity

Characteristics of sleep

REM sleep

- Spinal reflexes absent
- Rapid eye movements behind closed eyelids
- Increased body temperature and cerebral blood flow
- Desynchronised cortical activity
- Dreams

Dreams

- REM sleep dreams : sexual, clear, sleep paralysis, connected to external stimuli easy to be recalled.
- Nightmares
- Non REM sleep dreams : No story and no recall(Night terrors).

Normal night Sleep

In the first cycle:

* 15-20 minutes to fall a sleep.
  * Over the next 45 min. one descends to stage 3 & 4(Non REM)
  * After 45 min. after stage 4 reaches the first REM stage. (REM latency = 45 + 45 = 90 min.)

Normal sleep

<u>As the night progresses</u>:

*** Each REM period gets longer.**

*** And stage 3+4 gets shorter until they disappear.**

*** Further into the night sleep becomes lighter and dreams become more.**

Brain activity during sleep

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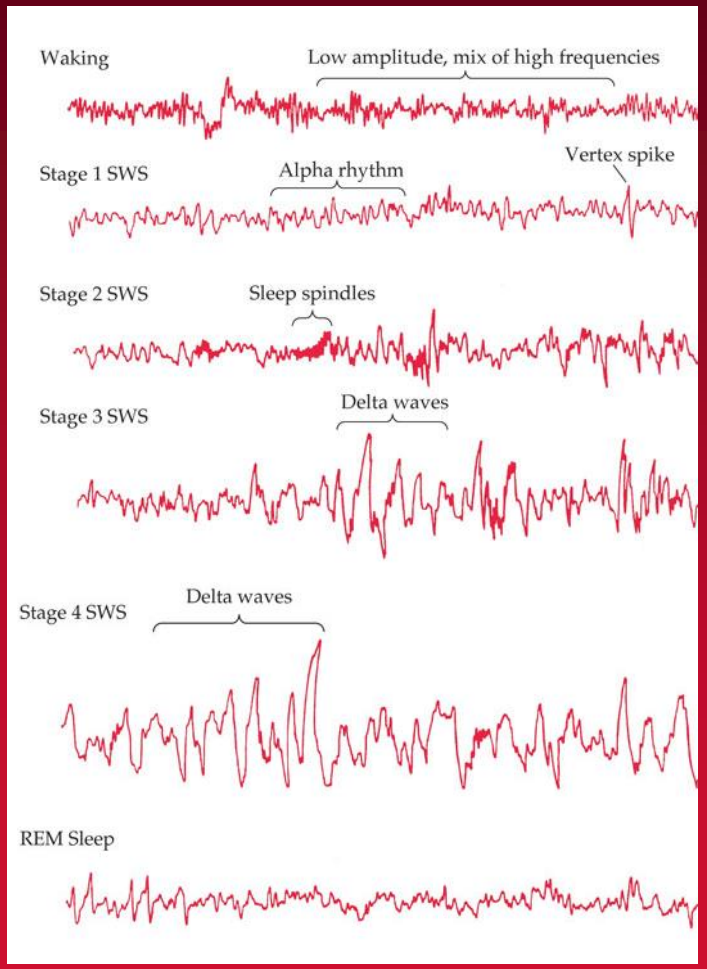

Awake

Low amplitude high frequency EEG

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Light sleep

Increasing amplitude decreasing freq. EEG

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Deep sleep

High amplitude low frequency EEG

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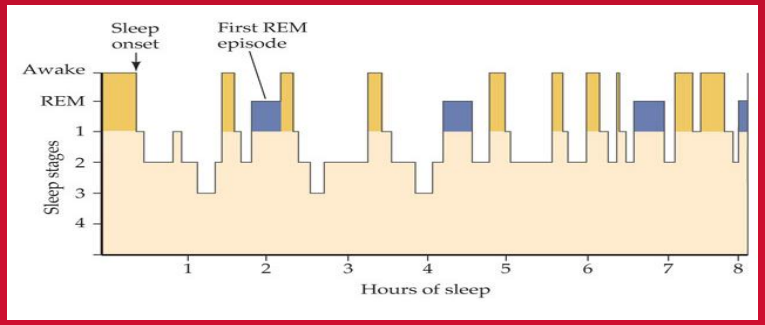
Rapid eye movement (REM) sleep

Low amplitude high frequency EEG



Sleep as an active process

Electroencephalographic (EEG) recordings showed abundant neuronal activity in cortex during sleep

- Therefore not passive neuronal quiescence

Pattern of the EEG was very different in sleep than in waking

- Waves of activity, indicating synchronous firing of cortical neurones
- Synchronising stimulus coming from sub-cortical areas

- Reticular formation still seen as important

Several different levels of sleep

- Sleep is a complex combination of different aspects

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Neuronal circuitry controlling sleep

Cortex “kept awake” by ascending activation from midbrain

5HT inputs inhibit midbrain ‘activating system’ areas

- therefore promotes sleep

Stimulation of area surrounding SCN induces slow wave sleep

- mechanism unclear: Probably involves SCN

No one stimulation site can promote REM sleep

- but lesions to specific brainstem areas abolish REM sleep

Neurochemistry of sleep

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Neurotransmitters

- 5HT - promotes slow wave sleep – inhibition of 'activating system'
- Noradrenaline - ? inhibition of muscle tone during REM sleep
- Dopamine - general arousal
- Acetylcholine - induces REM sleep

Also 'sleep-promoting substances'

- Factor S, DSIP (delta-sleep inducing peptide), melatonin
- Not much known about their action

- May modulate circadian rhythmicity rather than sleep *per se*

Disorders of sleep

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Insomnia - reduction or absence of sleep - transient or persistent

Hypersomnia (narcolepsy) - excessive drowsiness and falling asleep

Sleep-wake schedule disturbance - transient or persistent

Partial arousal - e.g. sleep-walking, nightmares

- Often associated with anxiety, psychological disturbance or drug taking
- Little known about causes
- Limited capacity for pharmacological treatment of sleep disorders

Summary

Homeostasis

- Maintenance of constant conditions
- e.g. hunger / satiety system

Circadian rhythms

- Biological rhythms with 24 hour periodicity
- Role of SCN as circadian clock: entrainment to light/dark cycle

Sleep

- Sleep as an active process – EEGs in different stages of sleep
- Characteristics of slow wave sleep and REM sleep
- Disorders of sleep