



Physiology of Sleep



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Objectives:

1. Explain the difference between **sleep** and **coma**.
2. Define **NREM** and **REM** sleep.
3. Describe how NREM and REM sleep **are distributed** during a normal night sleep in the average adult human.
4. Describe the **behavioral** and **autonomic** features associated with **NREM** and **REM** sleep.
5. Describe **EEG**, as a **physiological tool**, is being used to delineate in which stage of sleep (or wakefulness) a person is.
6. Appreciate how the **total sleep duration** and **different sleep stages** vary with different ages in normal humans.
7. Describe the **current theories** about the neural basis of sleep.

WHAT IS SLEEP?

Sleep: State of unconsciousness from which a subject can be aroused by appropriate sensory or other stimuli.

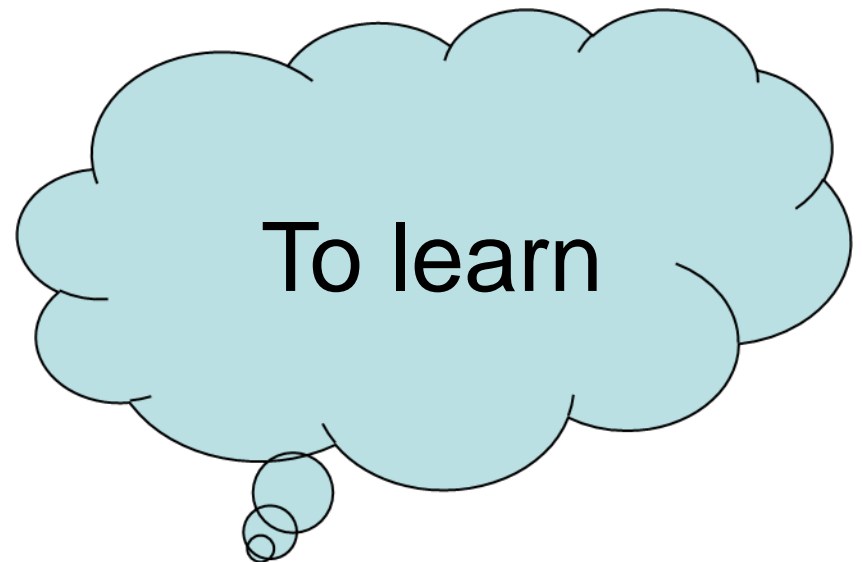
- Sleep may also be defined as a normal, periodic, inhibition of the reticular Activating system.

Awake: State of readiness/alertness & ability to react consciously to various stimuli.

Coma: State of unconsciousness from which a person cannot be aroused by any external stimuli.



Why Do We Sleep?



Why do we sleep?

- **Sleep Theory #1 - To Rest** : to gain relief from this hyperactive state.
- **Sleep Theory #2 - To Heal** : Sleep also allows us to heal our bodies. the immune system (our ability to fight disease) sleep deprivation affects our metabolism (our internal chemical reactions). It may also help us save energy for when we most need it.
- **Sleep Theory #3 - To Learn** : Sleep may help the human brain get better organized - by filing away important memories and discarding unwanted information.
- **Sleep Theory #4 - To Dream** : Dreaming appears to be a by-product of REM sleep. So is it possible that the main reason why we sleep is to dream? If so, why do we dream?

Theories of sleep

Restoration theory:

Body wears out during the day and sleep is necessary to put it back in shape.

* This is supported by findings that many of the major restorative functions in the body like muscle growth, tissue repair, protein synthesis, and growth hormone release occur mostly, or in some cases only, during sleep.

Preservation & protection theory:

Sleep preserve energy and it provides protection.

* For example, both body temperature and caloric demand decrease during sleep, as compared to wakefulness.

Why Do We Sleep?

- **Ultimate goal:**

Sustains our ability to reproduce successfully, by maintaining good health.

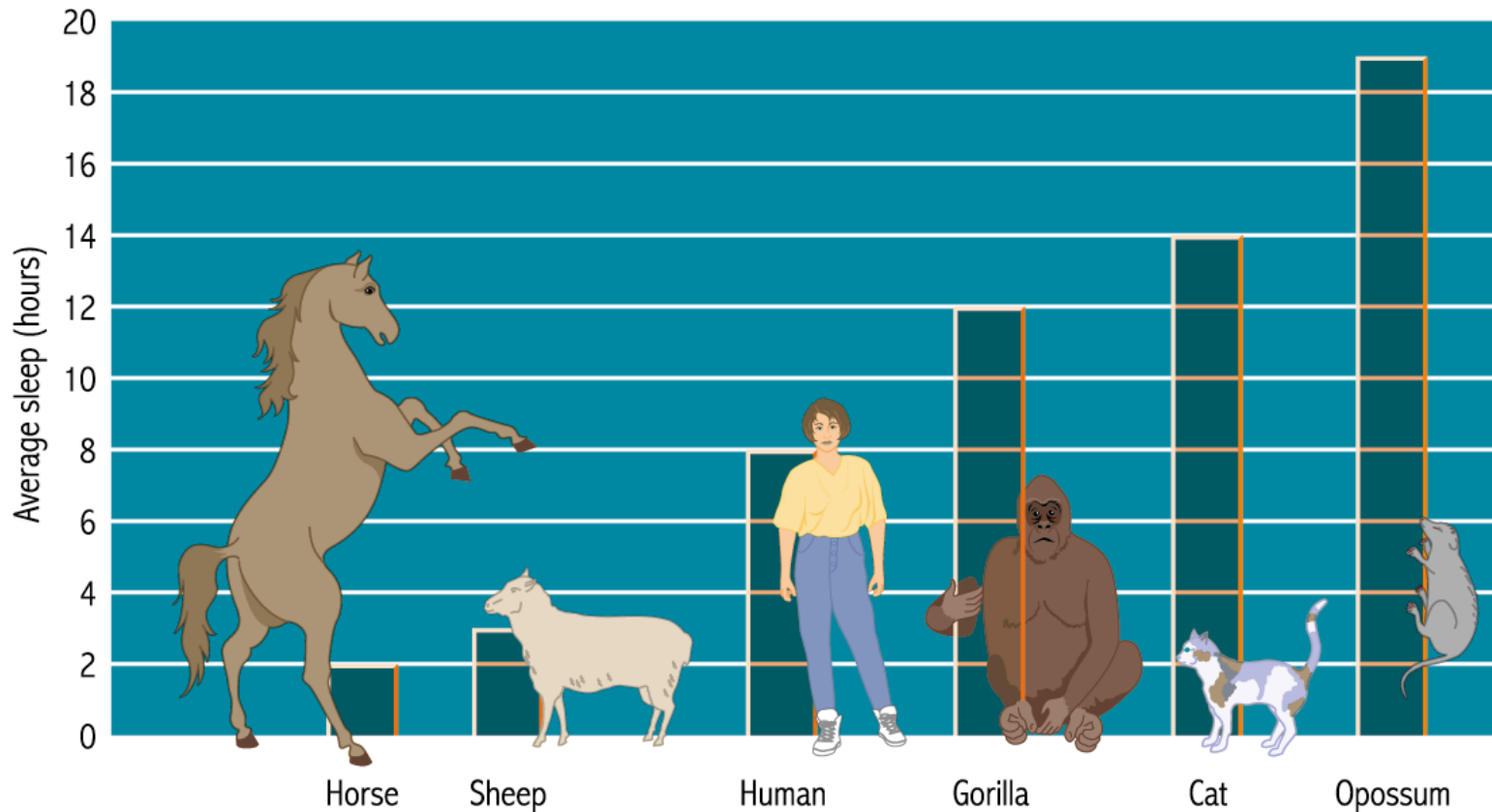
Humans (Sleep Duration)

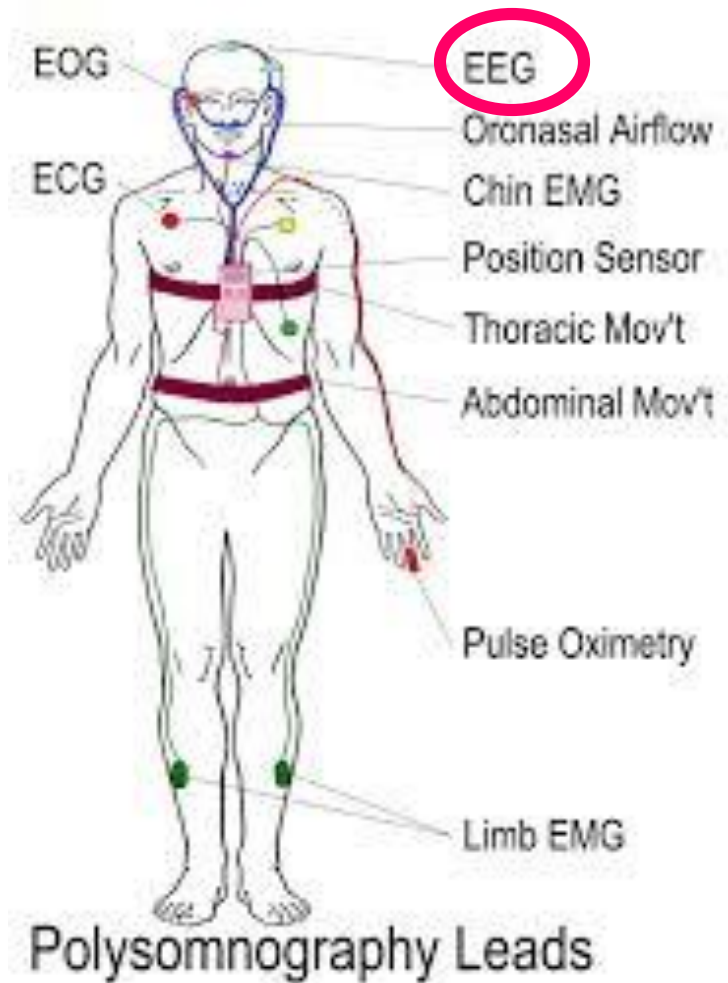
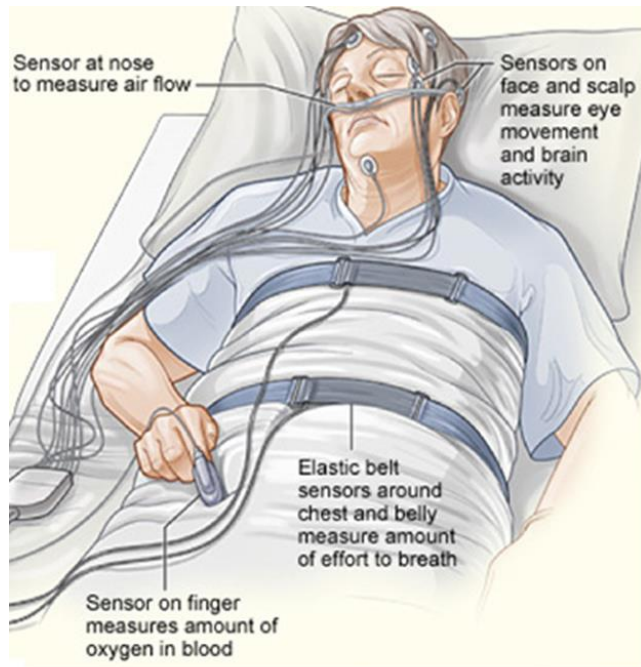
New born 15 - 20 hours.

Children 10 -15 hours.

Adults 6 - 9 hours.

Old age 5 - 6 hours.



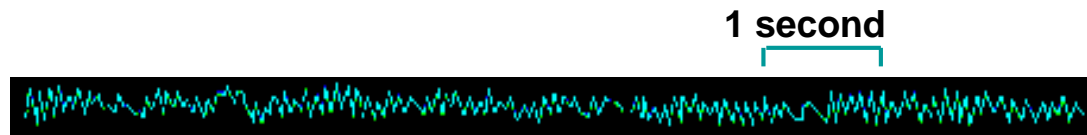


Stages of Sleep: recorded by EEG



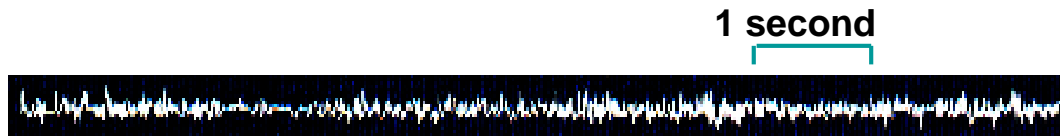
EEG WAVES IN WAKKFULNESS

Awake, but non-attentive, large, regular **alpha waves**



◀ **Alpha waves** ▶

Awake and attentive - low amplitude, fast, irregular beta waves



◀ **Beta waves** ▶

Sleep Classification



NREM (non-rapid eye movement) - (SWS) slow wave Sleep

REM (rapid eye movement) Sleep

Types of Sleep:

(1) SWS (Slow-Wave Sleep),

- EEG waves are generally of low frequency .
- Non-Rapid Eye Movement (NREM) sleep is not associated with rapid eye movements .

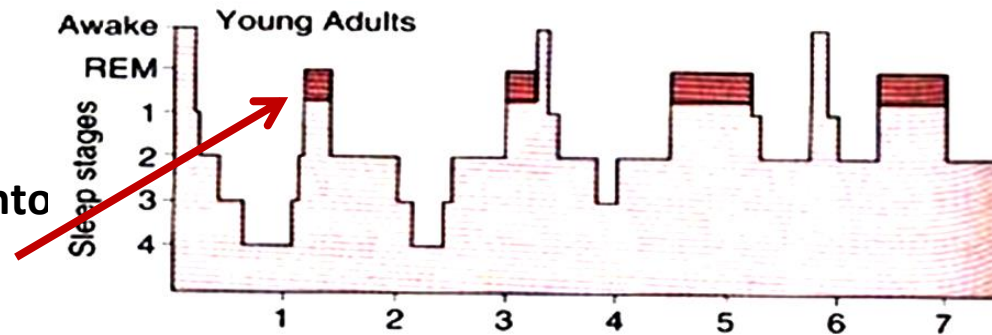
(2) REM sleep (Rapid Eye Movement)

- this type of sleep rapid eye movements occur (**Neurons of the pons**)

Distribution of Sleep Stages

In a typical night of sleep, a young Adult

- SWS occupies most of the total night sleep time ($\cong 75-80\%$), it is interrupted by intervening REM sleep periods, \cong every 90 minutes .
- first enters into NREM sleep, passes through stages 1 , 2 , 3 & 4 SWS, then, 60-100 min from sleep onset, goes into the first REM sleep episode.
- This cycle is repeated at intervals of about 90 min throughout the 8 hours of night sleep.
- There are 4-6 sleep cycles/night (& 4-6 REM periods per night)
- As the night goes on \rightarrow there is progressive reduction in stages 3 & 4 sleep and a progressive \uparrow in REM sleep .

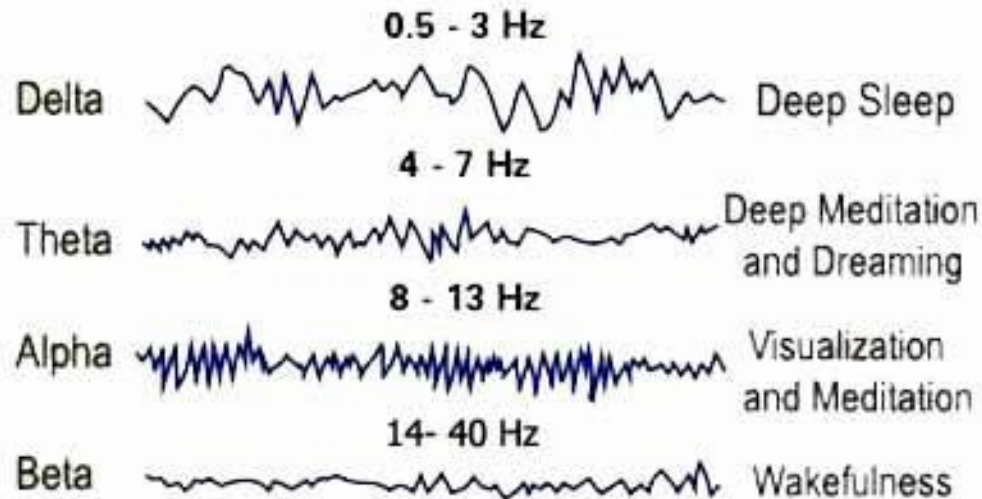


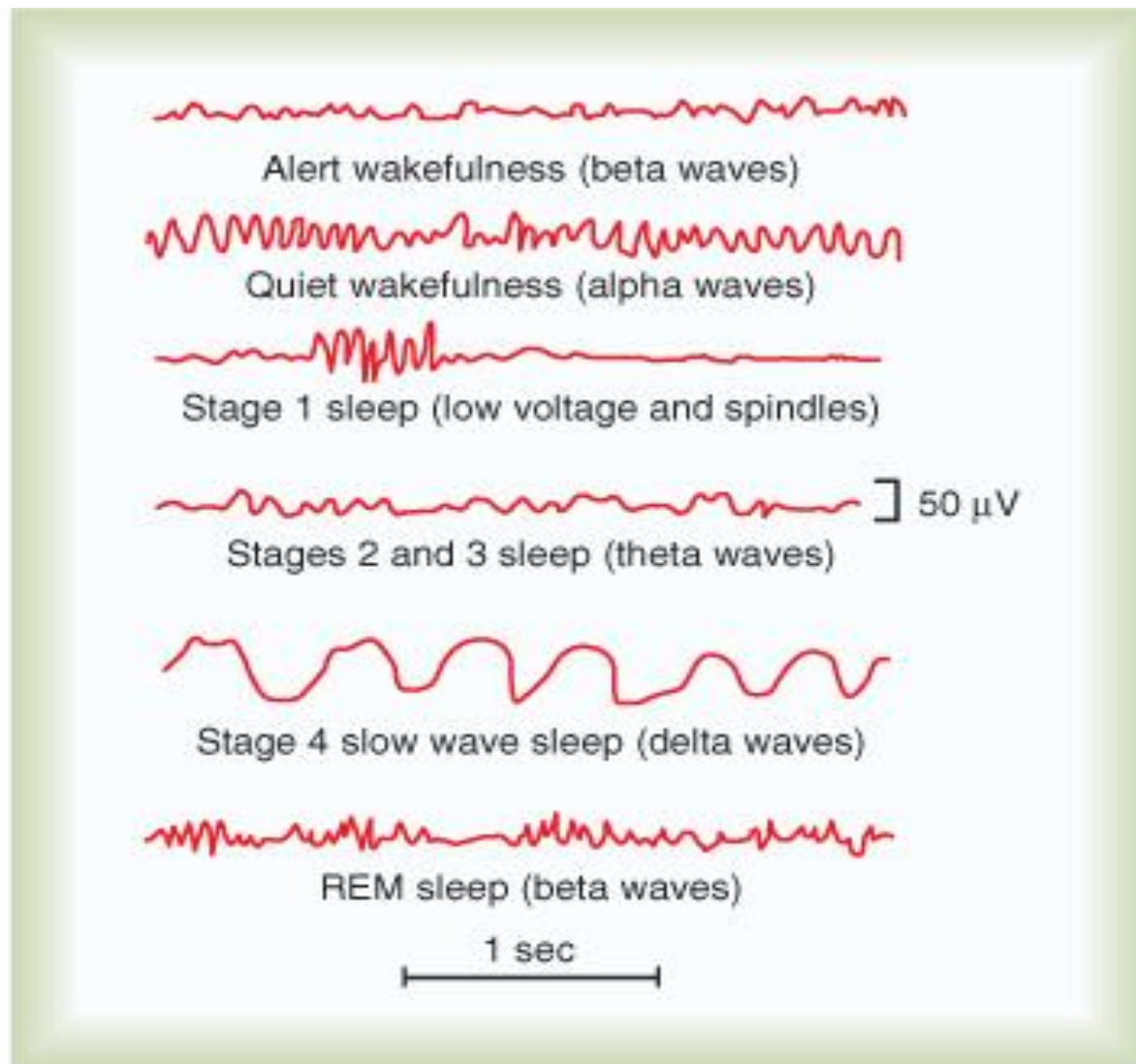
REM sleep periods are shown in red

In young adults SWS (NREM sleep) occupies 75-80% of night sleep time & REM sleep occupies 20-25% of sleep time.

EEG waves

Waves	Frequency	Type of activity
Alpha	8 – 13 hz	Smooth electrical activity
Beta	14– 40 hz	Irregular electrical activity
Theta	4– 7 hz	
Delta	Less than 4 hz	Regular , synchronous electrical activity





EEG waves

Waves	Associated with / occurs
Alpha	Associated with a state of relaxation.
Beta	Associated with a state of arousal.
Theta	Occurs intermittently during early stages of slow wave sleep and REM sleep.
Delta	Occurs during the deepest stages of slow-wave sleep.

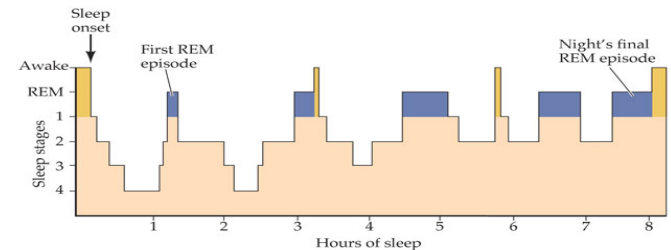
REM Sleep (Paradoxical Sleep)

- In a normal night of sleep, episodes of REM sleep lasting 5 to 30 minutes usually appear on the average every 90 minutes.
- REM sleep is not as restful as SWS .
- When the person is extremely sleepy, each episode of REM sleep is short, and it may even be absent.
- Conversely, as the person becomes more rested through the night, the durations of the REM episodes increase.

- *Characteristics of REM sleep:*

(1) There are rapid eye movements .

(2) Muscle tone throughout the body (except eye muscles) is exceedingly depressed .



- REM sleep is a type of sleep in which the brain is quite active, but this brain →

(1) is not aware cut-off the external world.

(2) its activity is not channeled into purposeful external motor activity.

- REM sleep occupies 80% of total sleep time in premature infants & 50% in full-term neonates.
- Thereafter, the proportion of REM sleep falls rapidly and plateaus at about 25% until it falls further in old age .
- Children have more total sleep time & stage 4 sleep than adults.

PHYSIOLOGICAL CHANGES IN SLEEP

CVS: Pulse Rate, cardiac output, blood pressure & vasomotor tone are decreased but the *blood volume* is increased.

Respiration: Tidal volume & respiratory rate are decreased. BMR is decreased 10-15%.

Urine volume: decreased.

Secretions: Salivary/lacrimal secretions are reduced, gastric/sweat secretions are increased.

TABLE 14.1 *Properties of Slow-Wave and REM Sleep*

Property	Slow-wave sleep	REM sleep
AUTONOMIC ACTIVITIES		
Heart rate	Slow decline	Variable with high bursts
Respiration	Slow decline	Variable with high bursts
Thermoregulation	Maintained	Impaired
Brain temperature	Decreased	Increased ←
Cerebral blood flow	Reduced	High ←
SKELETAL MUSCULAR SYSTEM		
Postural tension	Progressively reduced	Eliminated
Knee jerk reflex	Normal	Suppressed
Phasic twitches	Reduced	Increased ←
Eye movements	Infrequent, slow, uncoordinated	Rapid, coordinated ←
COGNITIVE STATE		
	Vague thoughts	Vivid dreams, well organized
HORMONE SECRETION		
Growth hormone secretion	High ←	Low
NEURAL FIRING RATES		
Cerebral cortex (sustained) activity	Many cells reduced and more phasic	Increased firing rates; tonic
EVENT-RELATED POTENTIALS		
Sensory-evoked	Large ←	Reduced

Mechanisms of Sleep

- Although several theories of sleep have been proposed, most current evidence is in favor of the following:

(1) **Serotonin**, produced by the **Raphe Nuclei**, induces **SWS** sleep.

(2) The mechanism that triggers **REM** sleep is located in the **Pontine Reticular Formation** & the **Ponto-Geniculo-Occipital circuit** is instrumental in generation of **REM sleep**.

(3) **Melatonin** (released from **Pineal Gland**) plays a role in day-night alternation of sleep.

Role of Serotonin & Melatonin in SWS:

- Raphe nucleus:

- **Stimulation of** Raphe Nuclei (in the lower pons & medulla) **induces SW.**

[Destruction of the Raphe Nuclei renders the animal **sleepless** for several days until it dies]. [Administration of drugs that **block serotonin** formation make the animal sleepless for several days].

- **Transecting the brainstem at the level of the mid pons**, leaves the animal in a state of intense wakefulness for a period of days. [The transection cuts the nerves going from the inhibitory serotonin-secreting Raphe Nuclei to the Bulboreticular Facilitory area of the RAS].

Indication that the serotonin-secreting Raphe fibers normally **inhibit** the Bulboreticular Facilitory area to produce sleep.

Injections of melatonin induce sleep.

- **Stimulation of the Supra-chiasmatic Nucleus** (SCN) of hypothalamus **by light** falling on the retina

—————→ inhibits Melatonin release from Pineal gland & produces wakefulness.

□ Physiological Mechanisms of Sleep & Waking:

- **Acetylcholine:**

One of the most important neurotransmitters involved in arousal.

- Two groups of acetylcholinergic neurons are located in **pons** & **basal forebrain**.

- **Muramyl peptide:** induces sleep

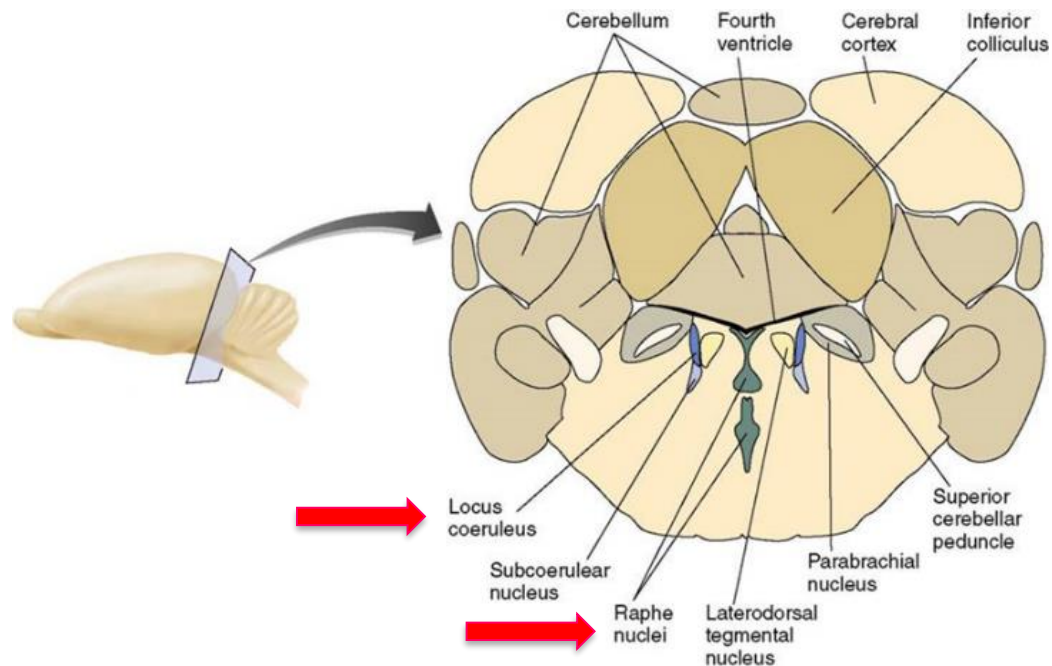
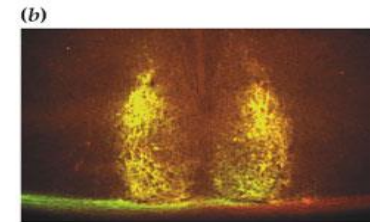
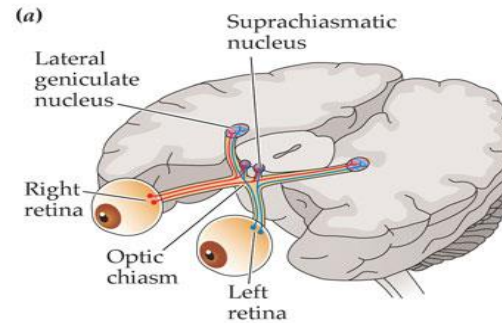
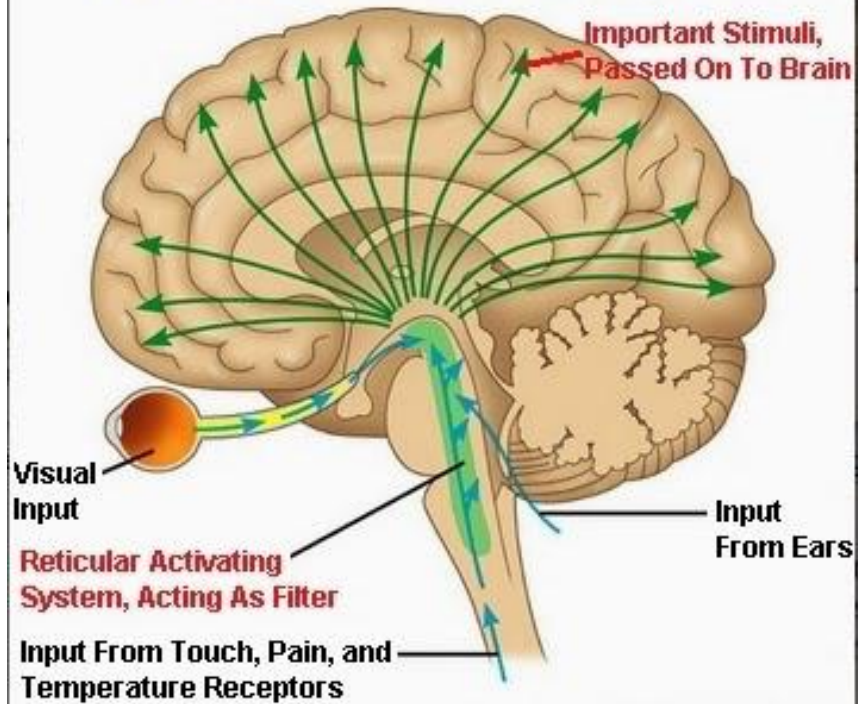


TABLE 14.2 *Neural Activity of Neurotransmitter Systems during Sleep and Arousal*

Neurotransmitter	Site of cell bodies	Activity during		
		Wakefulness	SWS	REM
Serotonin	Raphe nuclei	High	Low	Very low
Norepinephrine	Locus coeruleus	High	Low	Very low
Acetylcholine	Brainstem	High	Low	High

The Reticular Activating System



BIOLOGICAL PSYCHOLOGY, Fourth Edition, Figure 14.5 © 2004 Sinauer Associates, Inc.

RAS : is a diffuse network of nerve pathways in the brainstem connecting the spinal cord, cerebrum, and cerebellum, and mediating the overall level of consciousness.

SLEEP DISORDERS/BURDEN

70 million people in the US **suffer from sleep problems** [50% have chronic sleep disorder]

Insomnia = 30 million

sleep apnea = 18 million

Narcolepsy = 250,000 Americans have

Motor Car Accidents = 100,000

traffic fatalities = 1500 drowsy driving/annum

Approximately \$16 billion annually the cost of healthcare in USA & result in **\$50 billion** annually in lost productivity.

- **Disorders of Sleep:**

- Insomnia (inability to sleep).

- Somnolence: Extreme sleepiness.

- Drug dependency insomnia:

- An insomnia caused by the side effects of ever increasing doses of sleeping medications.

- Sleep apnea:

- Cessation of breathing while sleeping.

- **Narcolepsy:**
 - A sleep disorder characterized by periods of irresistible sleep, attacks of cataplexy, sleep paralysis, and hypnagogic hallucinations.
- **Sleep attack:**
 - A symptom of narcolepsy; an irresistible urge to sleep during the day, after which the person awakes feeling refreshed.
- **Cataplexy:**
 - A symptom of narcolepsy; complete paralysis that occurs during waking.
- **Sleep paralysis:**
 - A symptom of narcolepsy; paralysis occurring just before a person falls asleep.



Good night ...

Sleep tight ...