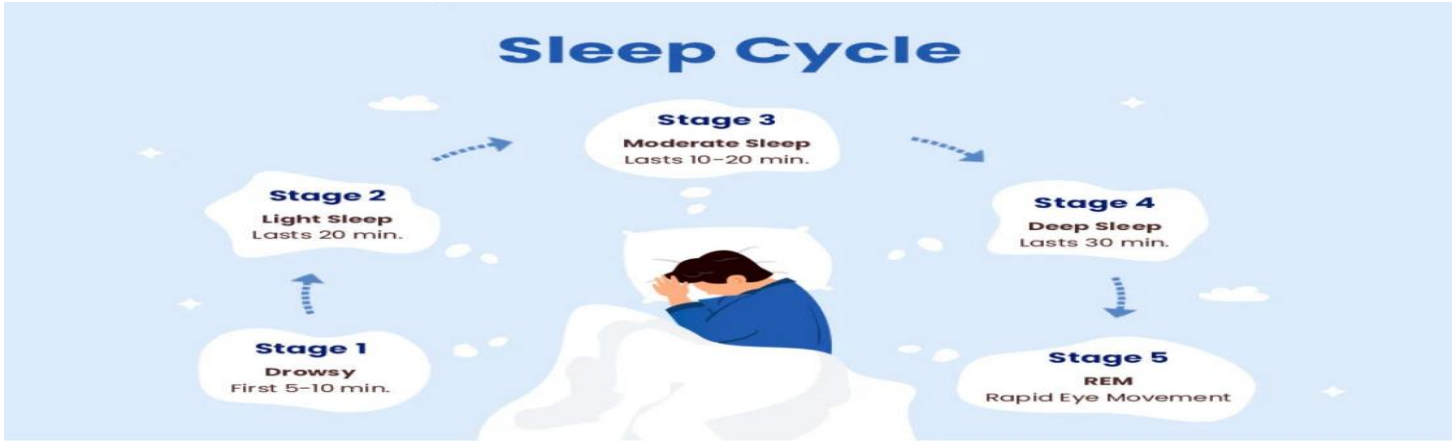
CNS MODULE
PHYSIOLOGY (LECTURE 8)
CONSCIOUSNESS & SLEEP



PRESENTED BY

DR. FATMA FARRAG ALI

ASSOCIATE PROFESSOR OF MEDICAL PHYSIOLOGY

FACULTY OF MEDICINE-MUTAH UNIVERSITY

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States of Consciousness

- It refers to levels of alertness.

- A person's state of consciousness is defined in two ways:

(1) By behavior.

(2) By the pattern of brain activity that can be recorded electrically (EEG). The EEG is such a useful tool in identifying the different states of consciousness.

SLEEP

- **Definition:**

Sleep is a physiological state of temporary unconsciousness (from which the person can be aroused by proper stimulation; sensory or other stimuli).

N.B. It is to be distinguished from coma in which a person exhibits a sustained loss of the capacity for arousal even in response to vigorous stimulation.

Periods of sleep and wakefulness alternate about once a day; that is, they manifest a circadian rhythm consisting on average of 8 h asleep and 16 h awake.

- **Types of sleep:**

✓ There are two types of sleep, the names of which depend on whether or not the eyes move behind the closed eyelids:

✓ NREM (non–rapid eye movement) sleep and REM (rapid eye movement) sleep.

(1) Non-rapid eye movement (NREM) sleep; Slow wave sleep (SWS)

- This type is the first to occur when the person falls a sleep.
- It is characterized by absence of rapid eye movements and slow EEG waves.
- NREM sleep is divided into four stages:

✓ **Stage 1 (very light sleep), the EEG begins to show theta rhythm (4–7 Hz)**.

✓ **Stage 2 (light sleep) is marked by the appearance of sleep spindles (12–14 Hz) and occasional high voltage biphasic waves called K complexes**.

✓ **In stage 3 (moderately deep sleep), a high-amplitude delta rhythm (1–3 Hz) dominates the EEG waves.**

✓ **In stage 4 (deep sleep), maximum slowing of delta rhythm is seen**.

- **Decreases in blood pressure, heart rate, and respiratory rate** also occur during **NREM** sleep.
- **Skeletal muscle tone is decreased**.
- During NREM sleep, there are pulsatile releases of hormones from the anterior pituitary gland such as growth hormone and the gonadotropic hormones, so adequate sleep is essential for normal growth in children and for regulation of reproductive function in adults.
- Although **slow-wave sleep is frequently called "dreamless sleep,"** dreams and sometimes even nightmares do occur but they are usually **not remembered**.
- The process then reverses itself; the EEG ultimately resumes a small-amplitude, high-frequency, asynchronous pattern that looks very similar to the alert, awake state. Instead of the person waking, however, the behavioral characteristics of sleep continue at this time, but this sleep also includes rapid eye movement (REM).

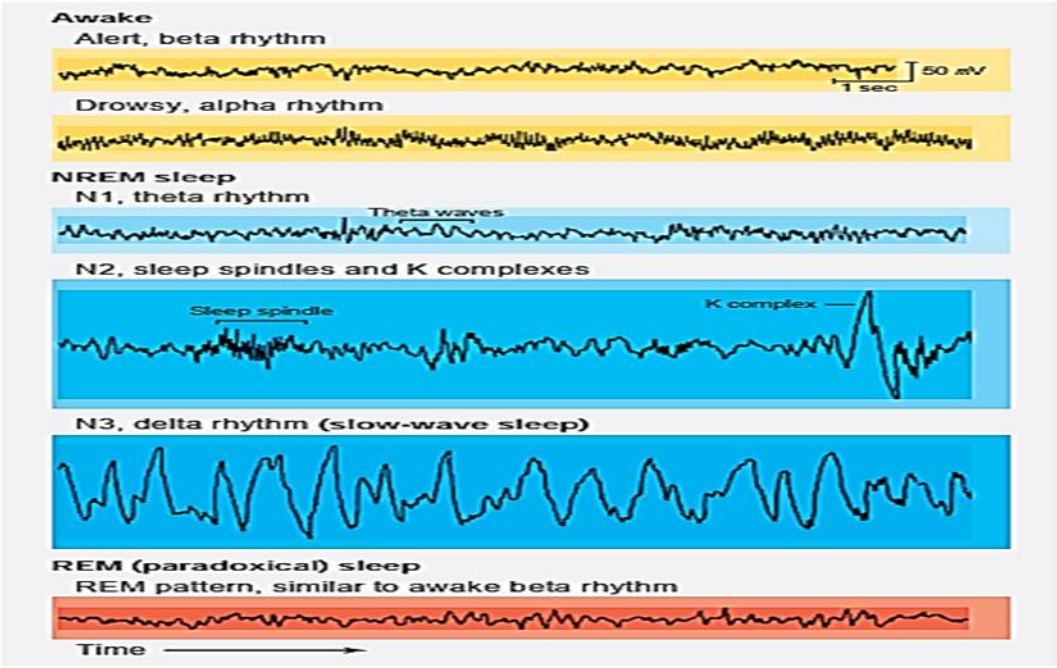
(2) Rapid eye movement (REM); paradoxical sleep

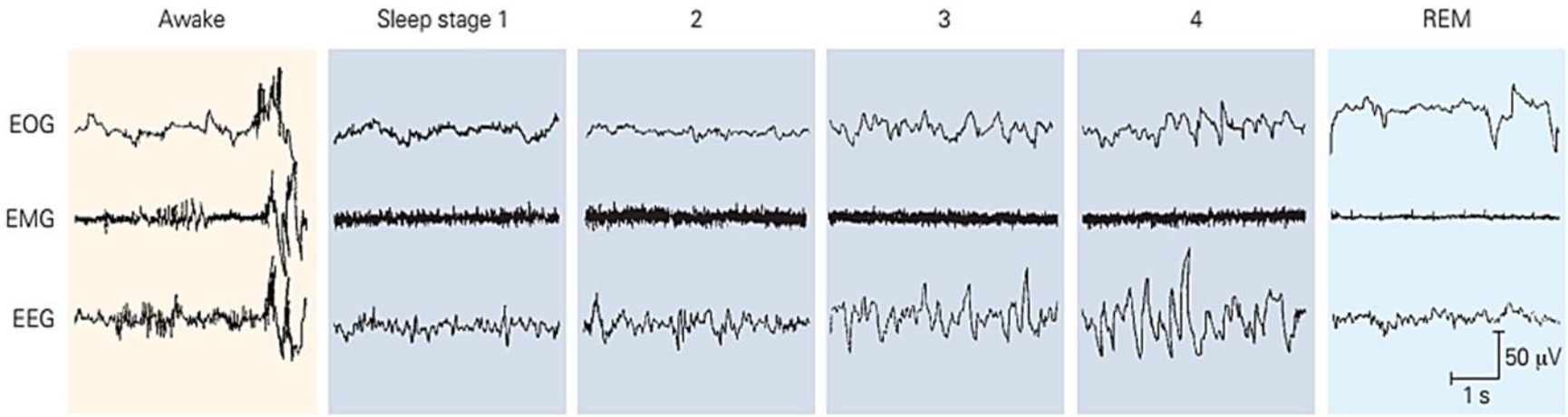
- ✓ The high-amplitude slow waves seen in the EEG during sleep are periodically replaced by rapid, low-voltage EEG activity, which resembles that seen in the awake, aroused state **(beta rhythm)**. For this reason, **REM sleep is also called paradoxical sleep.**
- ✓ **However, the threshold for arousal by sensory stimuli and by stimulation of the reticular formation is elevated**.
- ✓ **Rapid, roving movements of the eyes occur during paradoxical sleep**, and it is for this reason that it is also called **REM** sleep.
- ✓ **In fact, brain O_2 consumption is higher during REM sleep than NREM sleep.**
- ✓ Another characteristic of REM sleep is the occurrence of **large phasic potentials that originate in the cholinergic neurons in the pons and pass rapidly to the lateral geniculate body and from there to the occipital cortex. They are called pontogeniculo-occipital (PGO) spikes.**

- ✓ **The tone of the skeletal muscles is markedly reduced during REM sleep**.

- ✓ Humans aroused at a time when they show the EEG characteristics of REM sleep generally report that they were **dreaming**, whereas individuals awakened from slow-wave sleep do not. This observation and other evidence indicate that **REM sleep and dreaming are closely associated**.

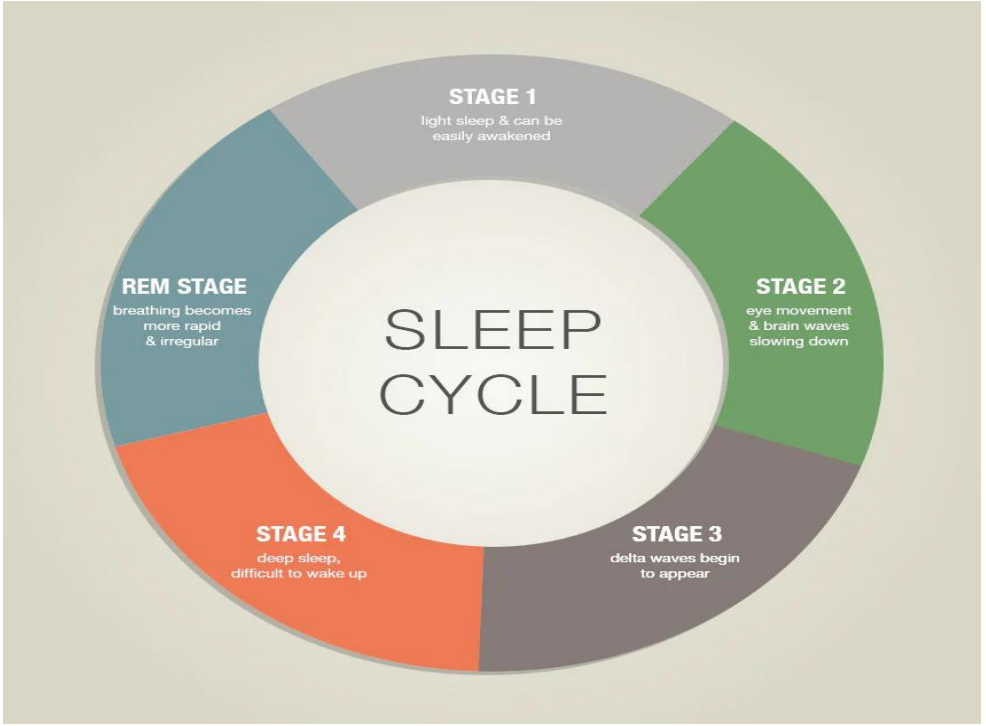
- ✓ REM sleep is associated with an **increase and irregularity in blood pressure, heart rate, and respiratory rate**.

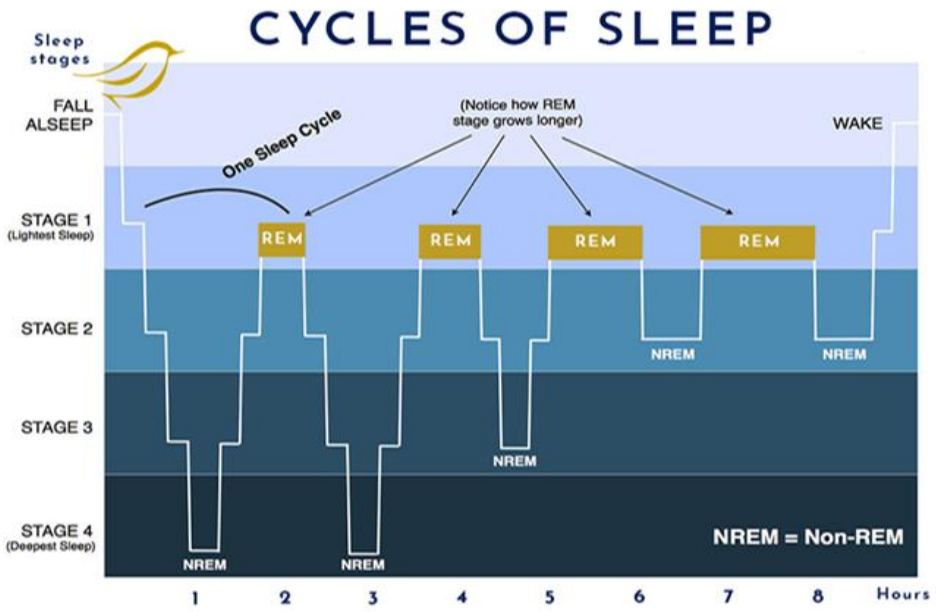

Awake
Alert, beta rhythm
50 μV
1 sec
Drowsy, alpha rhythm
NREM sleep
N1, theta rhythm
Theta waves
N2, sleep spindles and K complexes
Sleep spindle
K complex
N3, delta rhythm (slow-wave sleep)
REM (paradoxical) sleep
REM pattern, similar to awake beta rhythm
Time


Awake
Sleep stage 1
2
3
4
REM
EOG
EMG
EEG
50 μV
1 s

DISTRIBUTION OF SLEEP STAGES (Sleep Cycle)

- In a typical (uninterrupted) night of sleep, a young adult first enters NREM sleep, passes through stages 1, 2, 3 and 4. Sleep then lightens, and a REM period follows.
- This cycle is repeated at intervals of about 90 minutes throughout the night.
- Significantly more time is spent in NREM during the first few cycles, but time spent in REM sleep increases toward the end of an undisturbed night.
- Thus, four to six REM periods (sleep cycles) occur per night.
- **In young adults**, **REM sleep constitutes 20% to 25% of the total sleeping time**.
- Children have more total sleep time than adults.
- Initially, in stage 1 NREM sleep, there is a considerable tension in the postural muscles. Eventually, the muscles become progressively more relaxed as NREM sleep progresses.
- Most sleep during each night is of the slow-wave variety; this is the deep, restful sleep that the person experiences during the first hour of sleep after having been awake for many hours.
- On the other hand, REM sleep occurs in episodes and isn’t so restful as it is usually associated with vivid dreaming.


STAGE 1
light sleep & can be easily awakened
STAGE 2
eye movement & brain waves slowing down
STAGE 3
delta waves begin to appear
STAGE 4
deep sleep, difficult to wake up
REM STAGE
breathing becomes more rapid & irregular
SLEEP CYCLE


CYCLES OF SLEEP
Sleep stages
FALL ALSEEP
One Sleep Cycle
(Notice how REM stage grows longer)
WAKE
STAGE 1 (Lightest Sleep)
STAGE 2
STAGE 3
STAGE 4 (Deepest Sleep)
REM
NREM
NREM = Non-REM
1
2
3
4
5
6
7
8
Hours

	NREM (Slow wave) sleep	REM (Paradoxical) sleep
1. Timing:	At the start of sleep	After the 4th stage of NREM sleep
2. Duration/night:	75-80 % / sleep time	20 -25 %/ sleep time
3. Depth of sleep & EEG findings:	4 stages: *Stage 1 (very light sleep): Theta waves *Stage 2 (light sleep): Sleep spindles superimpose on theta waves. *Stage 3 (moderately-deep sleep): Delta waves (3 Hz) *Stage 4 (deep sleep): Delta waves with maximal slowing (1 Hz).	Small rapid irregular beta waves (like an awake alert person)
4. Eyes movements:	No rapid eye movements	Rapid eye movements
5. Dreams:	Absent (if present → not remembered)	Present & can be remembered
6. HR, RR, BP:	Decreased	Increased (may be irregular)
7. Muscles tone:	Slight decrease	Marked decrease
8. Awakening:	Easy	Difficult (high threshold)
9. Brain O_2 consumption	Lower	Higher

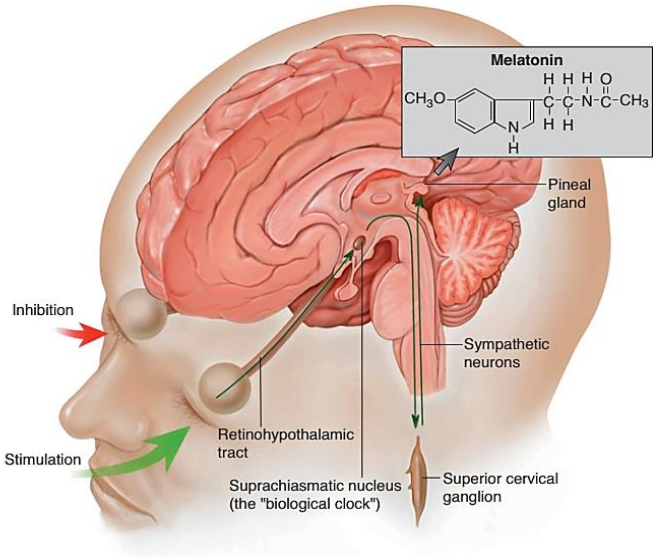
CIRCADIAN RHYTHMS & THE SLEEP–WAKE CYCLE

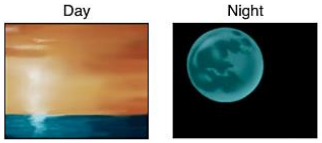
CIRCADIAN RHYTHMS

The suprachiasmatic nucleus (SCN) is the principle **circadian pacemaker of the body**.

These nuclei receive information about the **light–dark cycle via** a special neural pathway, the **retinohypothalamic fibers**.

Efferents from the **SCN** initiate signals that entrain a wide variety of well-known circadian rhythms including the **sleep–wake cycle and the secretion of the pineal hormone melatonin**.





THE SLEEP–WAKE CYCLE

Factors involved in regulating the transition between waking and sleeping states:

- **Transition to the wakeful state is favored by three main inputs to orexin-secreting neurons:**

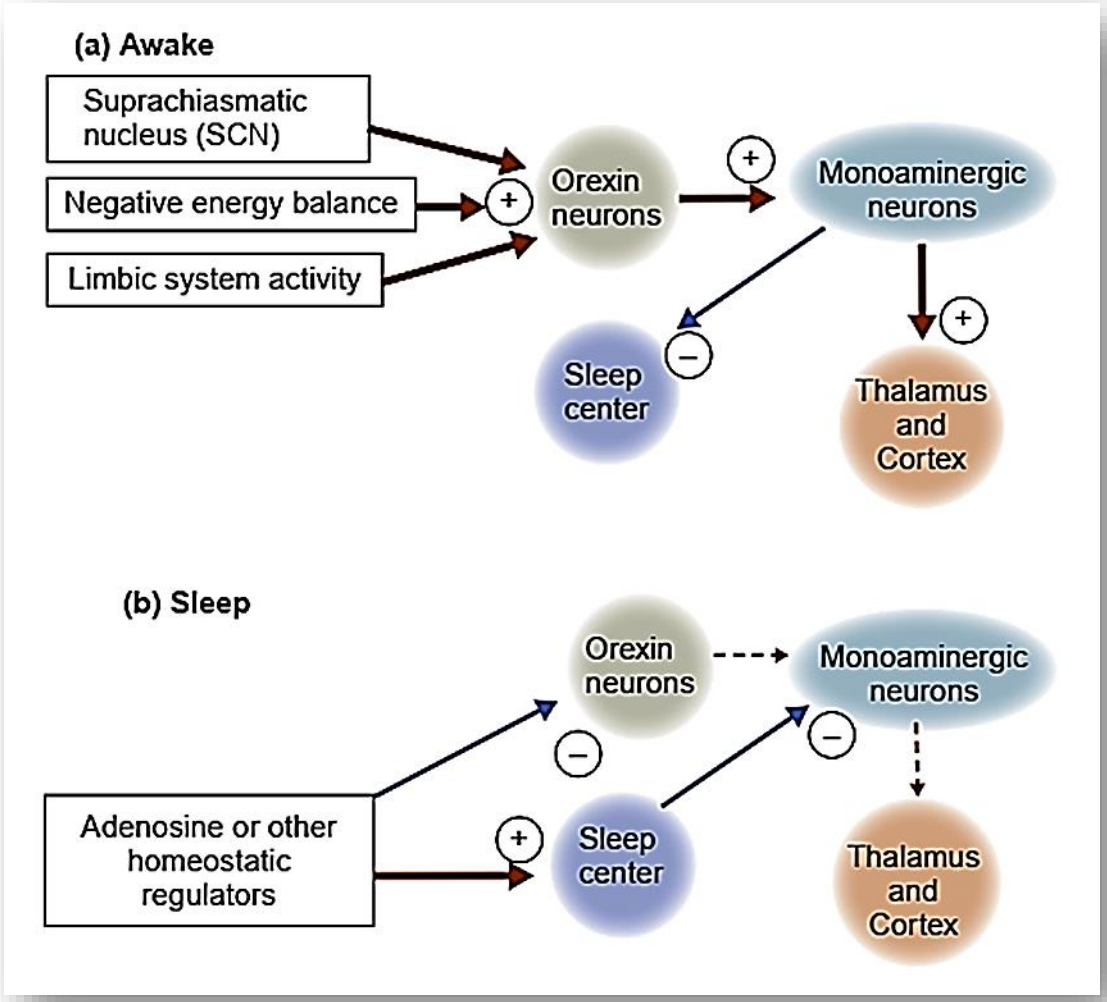
(1) Action potential firing from the **suprachiasmatic nucleus (SCN)**,
(2) Indicators of negative energy balance, and
(3) Arousing emotional states signaled by **the limbic system**.

- ✓ The **SCN activates orexin-secreting neurons in the morning. It also triggers the secretion of melatonin at night**.
- ✓ **Metabolic indicators of negative energy balance stimulate orexin release**, which may be adaptive because the resulting arousal would allow you to seek out food at times when you would otherwise be asleep.
- ✓ **Limbic system inputs coding strong emotions such as fear or anger also stimulate orexin neurons**. This may be adaptive by interrupting sleep at times when we need to respond to situations affecting our well-being and survival.

The factors that activate the sleep center

Adenosine:

- ✓ A metabolite of ATP is one likely candidate.
- ✓ Its concentration is increased in the brain after a prolonged waking period, and it has been shown to reduce firing by orexin-secreting neurons.
- ✓ This in part explains the stimulatory effect of caffeine, which blocks adenosine receptors.

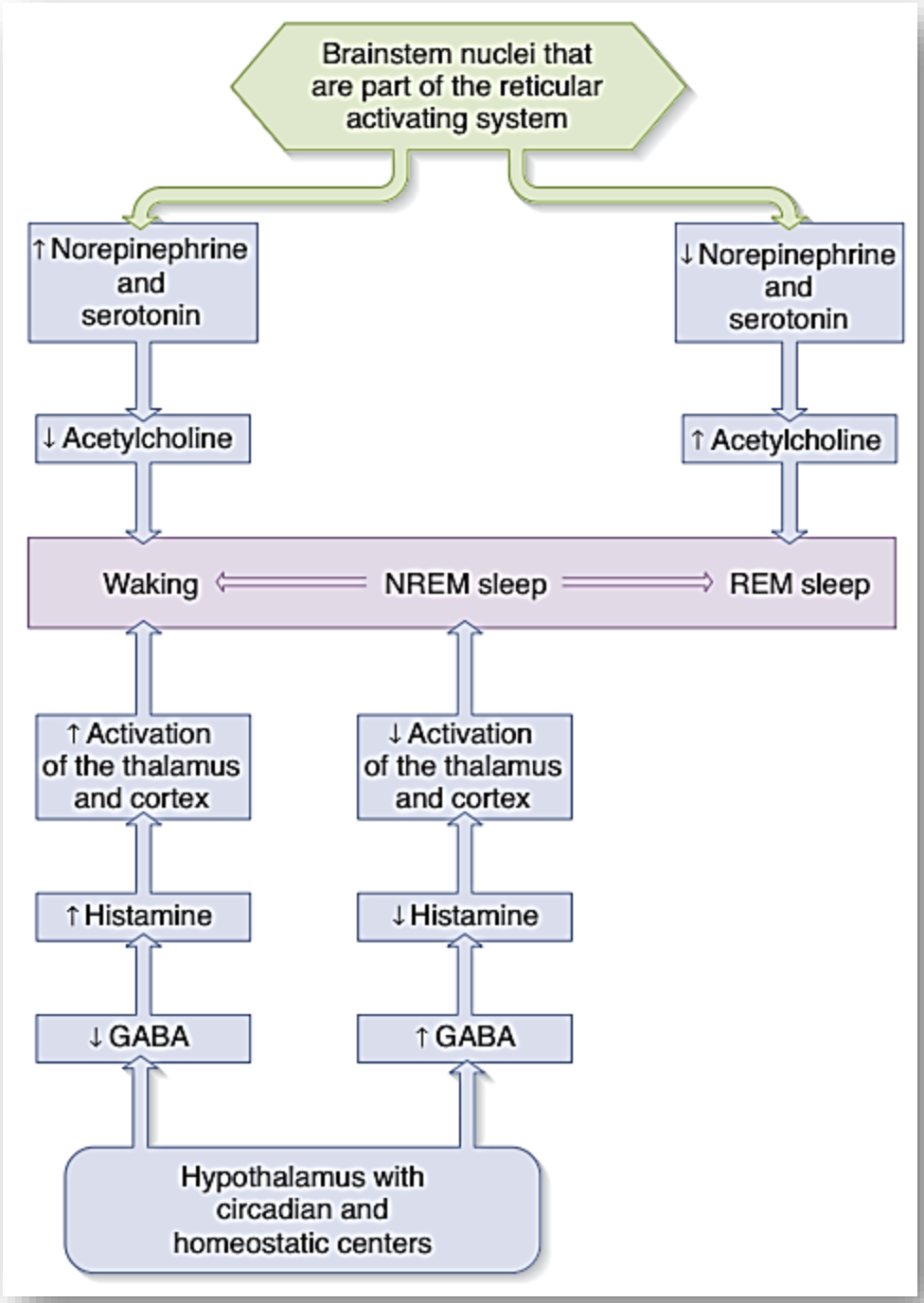

(a) Awake
Suprachiasmatic nucleus (SCN)
Negative energy balance
Limbic system activity
+
Orexin neurons
+
Monoaminergic neurons
−
Sleep center
+
Thalamus and Cortex
(b) Sleep
Orexin neurons
Monoaminergic neurons
−
−
Adenosine or other homeostatic regulators
+
Sleep center
Thalamus and Cortex

NEUROCHEMICAL MECHANISMS PROMOTING SLEEP & AROUSAL

- Nuclei in both the **brain stem and hypothalamus** are critical for the **transitions between these states of consciousness**.
- The brainstem reticular formation is composed of several groups of neurons which release norepinephrine and serotonin **(monoaminergic neurons); RAS, or acetylcholine (cholinergic neurons)**.
- In the case of the forebrain neurons involved in control of the sleep–wake cycles, **preoptic neurons in the anterior hypothalamus release GABA** and **posterior hypothalamic neurons release histamine**.

One theory regarding the basis for transitions from sleep to wakefulness involves:

- ✓ When the activity of **norepinephrine- and serotonin-containing neurons is dominant**, there is **a reduced level of activity in acetylcholine-containing neurons** in the **pontine reticular formation**. This pattern of activity contributes to the appearance of the **awake state**.
- ✓ **The reverse of this pattern leads to REM sleep**.
- ✓ **When there is a more even balance in the activity of the monoaminergic and cholinergic neurons, NREM sleep occurs**.
- ✓ In addition, **an increased release of GABA and reduced release of histamine increase** the likelihood of **NREM sleep** via deactivation of the thalamus and cortex.
- ✓ **Wakefulness occurs when GABA release is reduced and histamine release is increased**.
- ✓ The drowsiness that occurs in people using antihistamines may be a result of blocking the histaminergic inputs of this system.


Brainstem nuclei that are part of the reticular activating system
↑ Norepinephrine and serotonin
↓ Norepinephrine and serotonin
↓ Acetylcholine
↑ Acetylcholine
Waking
NREM sleep
REM sleep
↑ Activation of the thalamus and cortex
↓ Activation of the thalamus and cortex
↑ Histamine
↓ Histamine
↓ GABA
↑ GABA
Hypothalamus with circadian and homeostatic centers

MELATONIN AND THE SLEEP–WAKE STATE

- **Melatonin** release from the **pineal gland** plays a role in sleep mechanisms.
- The diurnal change in melatonin secretion may function as a timing signal to coordinate events with the light–dark cycle in the environment.
- **Melatonin synthesis and secretion** are increased during **the dark period of the day** and **maintained at a low level during daylight hours**.
- **This diurnal variation** in secretion is brought about by **norepinephrine secreted by the postganglionic sympathetic nerves that innervate the pineal gland**.
- **The discharge of the sympathetic nerves to the pineal** is entrained to **the light–dark cycle** in the environment via the **retinohypothalamic nerve fibers to the SCN**.
- From the **hypothalamus, descending pathways converge onto preganglionic sympathetic neurons that in turn innervate the superior cervical ganglion, the site of origin of the postganglionic neurons to the pineal gland**.

Physiologic Effects of Sleep

- ✓ Sleep is a homeostatic requirement, similar to the need for food and water.
- ✓ Deprivation of sleep impairs the immune system, causes cognitive and memory deficits, and ultimately leads to psychosis and even death.
- ✓ Much of the sleep research on humans has focused on the importance of sleep for learning and memory formation.
- ✓ EEG studies show that during sleep, the brain experiences reactivation of neural pathways stimulated during the prior awake state, and that subjects deprived of sleep show less effective memory retention.
- ✓ Based on these and other findings, many scientists believe that part of the restorative value of sleep lies in facilitating chemical and structural changes responsible for dampening the overall activity in the brain's neural networks while conserving and strengthening synapses in pathways associated with information that is important to learn and remember.


Thank
you!