Sleep and the Brain

• Lower metabolic and neural activity rate in the brain during sleep: SWS < NREM stage 1 & 2 < awake

• Exception is REM sleep, where some areas actually more active (e.g., pons)

The brain and wakefulness: The reticular formation and the ascending reticular activating system (ARAS).

Reticular formation:

• One of the oldest parts of the brain.
• A poorly differentiated part of the brain stem (brain stem = pons, medulla oblongata, midbrain, reticular formation), centered roughly round the pons.
• Involved in routine action: waking/sleep, walking, lying down.
• Speculation that it may be involved in about 25 behaviors (e.g., eating, urination, sex, introversion/extroversion).
Reticular Formation close-up

**Ascending Reticular Activating System (ARAS)**

- Part of the Reticular Formation.
- Critical for maintaining the waking state.
  - Projects to the thalamus, hypothalamus, and basal forebrain.
  - Excites widespread areas of cortex to produce arousal/alertness/wakefulness.
  - Deactivated during NREM sleep, but reactivated during REM sleep.

The brain and NREM sleep

- The basal forebrain and adjacent hypothalamus.
  - Both structures can dampen general forebrain activity, both directly and by dampening ARAS activity
  - Lesions in this area cause long-lasting insomnia
  - Alzheimer’s patients who suffer from insomnia present with damage to this area.
  - Neurons in basal forebrain are most active during NREM sleep.
  - Electrical and chemical stimulation of basal forebrain induces NREM sleep.
  - Adenosine acts in this area to inhibit release of acetylcholine
The brain and NREM sleep

- Recent work shows that TMS in sensory-motor cortex can induce slow (Delta) waves:

The brain and REM sleep

Discovery driven largely by transection studies on cat brain stem

- Transection at B separates the brain stem from the forebrain.
  - Brain stem & body show signs of REM stage sleep (theta waves & atonia)
  - Forebrain EEG shows NREM stage cycling but no REM signatures (no REMs; no miosis).
  - Thus, REM stage is controlled by structures below the forebrain.
The brain and REM sleep

- Work driven largely by transection studies on cat brain stem.

After transection at C, between medulla and pons, REM stage sleep signs are observed only in rostral structures (pons, forebrain, rems, miosis).

If pons is destroyed, no REM signs at all occur.

Different regions of the pons contain REM-off and REM-on cells.

- REM-off neurons are always active except during REM stage, during which they are almost completely inhibited.

- REM-on neurons become active only during REMS. They inhibit REM-off cells and excite neurons in the thalamus, which in turn excite neurons in the cortex.

Chemistry of Wake / Sleep Overview:

- In waking state, high levels of:
  - Dopamine
  - Acetylcholine
  - Histamine
  - Glutamate
  - Serotonin
  - Adenosine (promotes NREM onset)
During NREM sleep, high levels of:

- Serotonin: facilitates sleep onset by dampening the brain’s response to sensory input
- GABA: dampens overall neural activity and decreases arousal
- Glutamate: promotes slow waves and spindles

(Acetylcholine, histamine, norepinephrine, and dopamine levels low during NREM)

REM sleep: high level of acetylcholine (back to awake levels)
Histamine, norepinephrine, dopamine levels dramatically reduced