A. Functions of Sleep

Why do we sleep? Short answer: **we do not know (but we are beginning to figure out some answers)**

- Note, too, that any theory of sleep in humans needs to consider why other animals sleep!

Some potential answers (see excellent Mignot [2008] & Krueger et al [2015] articles referenced below). Here are three suggestions which have received significant attention:

1. Sleep and Energy Conservation

   - Note that even single-cell organisms like bacteria have a circadian rhythm with periods of higher activity and relative rest.
   - Since all living organisms with a neural & glial system sleep (Krueger et al, 2015), what might evolution have been doing to promote sleep? Saving energy particularly at times of inefficiency (e.g., human vision is much better in day whereas other predators' vision is better at night)
     - Body temperature goes down (~1-2º C) & thus lower use of calories
     - Body is still and not moving much & thus more energy savings

   - **Analogous to Sleep: Hibernation.**
Why Sleep? Why REM? Why Dreams?

- Body temp to just above freezing, brain activity almost nothing
- Small mammals (bats, squirrels, hamsters) actually hibernate while bears mostly sleep (they do not lower body temperature as much as smaller animals)
- Most hibernating animals come out of hibernation every few days for a few hours. They mostly sleep at these points.
- Helps retard aging process & protects against infection & trauma. (A study in March 2012 found that wounds on bears during the winter tend to heal without scars!)

- Alternative sleep strategies in animals
  - Little sleep in cows, horses, sheep, goats
  - Much sleep in cats, bats
  - Moderate sleep in humans, rabbits, foxes
  - Dolphins & some other animals have one hemisphere asleep and the other awake
  - Migratory birds \textit{during migration period} appear to have a suppressed need for sleep

2. Sleep and Memory

- Studies regularly find that sleep is a time when \textit{long-term memories are strengthened (consolidation)}.

- "...much of the legwork of memory is done during other phases of sleep [i.e., \textit{during NREM sleep}] — helping the brain shuffle memories around, reactivating them in the hippocampus, editing them in areas such as the prefrontal cortex, and returning them to areas of the cortex nearer the hippocampus for longer-term storage and retrieval" (Smith, 2013, p. S4, boldface added)

- Various studies of multiple species of animals find that patterns of activation of the hippocampus during the day seem to be "replayed" during sleep. This suggests that one role of sleep may be to go through the experiences of the past day and "weed out" or otherwise discard unneeded connections.
  - Sleeping after learning something usually results in memory gain upon awakening

- Recent research (Payne, 2012) suggests that memory consolidation takes place during different points of sleep (see diagram above right):
  - Hippocampus-dependent episodic & spatial memory consolidation associated with SWS (slow-wave or non-REM sleep) in the first half of
Research in 2014 found evidence in mice that non-REM sleep is associated with the growth of new dendritic spines, that is, new synapses form, after the animal learns a new skill (Costandi, 2014; Yang et al, 2014; see diagrams above.)

Stage N2 sleep spindles (12-14 Hz) are associated with communication between thalamus & cerebral cortex and with new learning.
  - Amount of spindle activity correlates 0.7 with nonverbal IQ (i.e., explains 49% of variation!)


**Glymphatic System:** Researchers at the University of Rochester School of Medicine led by Dr. Maiken Nedergaard discovered a kind of "plumbing system" for the brain which they labeled as the "glymphatic" system (Illiff et al., 2012).
The brain does not have the usual lymphatic system of the rest of the body. The brain does have a system by which cerebrospinal fluid (CSF) is channeled along the very tiny penetrating arteries of the brain and, then, flows through the brain tissue to be collected by the veins.

**Toxic Waste Removal During Sleep**: In 2013, the same research team reported that, during sleep, the astrocytes in the brain of mice shrunk in size and created about 60% more space between themselves (i.e., in the interstitial space; Xie et al., 2013). This allowed much easier flow of various metabolic waste products (particularly Amyloid-β) to be cleared from the brain. The flow was about 10 times higher than during the awake period. When the mice were awake, the astrocytes resumed their usual size.

- These findings suggest that one of the functions of sleep in the mammalian brain is to permit the flushing or clearance from the central nervous system of toxic waste products which accumulate during waking hours.

### B. Functions of REM Sleep

- There is a higher percentage of REM sleep in organisms that sleep longer, e.g.,
  - the human baby (REM: at birth, 50% of 22 hrs/day of sleep);
  - at age 1 (30% of 17 hours/day of sleep)
  - human adult (15-20% of 7-8 hours/day of sleep)

- As noted above, REM may help in **memory storage**
  - However MAO inhibitors (a type of antidepressant medication) which decrease REM sleep do not lead to memory problems (perhaps because of the type of memory storage taking place during REM has not been really tested; see above)

- REM may help in **stimulating the nervous system** of the developing infant & child

- REM may help by **increasing the oxygen supply to the cornea** (patients taking MAO inhibitors don't suffer corneal damage, either)
- REM sleep deprivation leads to increased attempts at REM sleep subsequently

### C. Biological Perspectives on Dreaming

- Complex dreaming develops as we get older (Domhoff, 2001)
  - dreams of children < 5 yo are bland and static & children < 10 yo report dreams only in about 20-30% of REM sleep
  - adolescent/adult dreams are more dynamic & complex & dreams are reported in > 80% of REM sleep of adults

- REM dreaming is different than NREM dreaming (not in book; Kandel et al., 2013)
  - REM dreams: long, highly visual, often emotional, not often related to recent life experience
  - NREM dreams: short, non-visual, "conceptual" or thought-like, often related to recent life experiences
  - NOTE: we normally do no remember any NREM dreams. We know about these from lab research when participants in NREM sleep are awakened and asked to report if/what they might have been dreaming.

- There is no theory of dreaming which is now currently accepted by most psychologists
There is no theory of dreaming which is now currently accepted by most psychologists. Two biologically-based theories are the (1) **Activation-Synthesis** and (2) **Clinico-Anatomical** hypotheses.

### 1. Activation-Synthesis Hypothesis (J. Allan Hobson's initial thesis)

- **Activation**: During REM sleep, different brain areas, particularly the limbic system, become active under stimulation from the brain stem. These areas involve circuits related to emotion, memories, and sensations. Occasionally, sounds in the environment of the sleeper also activate the brain.
- **Synthesis**: The brain creates a story to make sense of the activity.

### 2. Clinico-Anatomical Hypothesis

- Grounded in studies of individuals with brain damage.
- This theory considers that dreaming is a kind of quasi-hallucinatory form or unusual form of thinking, that is, thinking under conditions without strong or direct sensory input or motor activity. How does this come about? Under the following conditions:
  - Stimulation (either internal or external) activates parietal, occipital, & temporal cortex.
  - No visual information contradicts the stimulation
  - Lowered prefrontal cortex activity leads to lowered levels of logical censorship about the stimulation (thus allowing contradictory or illogical ideas in the dream)

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**References**


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