Sleep, Memory & Cognitive Function
Proportion of people sleeping less than 7 hours per night (adults > 18)
What is MEMORY?

- The INPUT, STORAGE and RECALL of sensory information.
Sensory input → Sensory memory → Attention → Short-term memory → Encoding → Maintenance rehearsal → Long-term memory → Retrieval

- Unattended information is lost.
- Unrehearsed information is lost.
- Some information may be lost over time.
Memory Systems

SENSORY REGISTER
- Quick Scan for Importance
- Precoding

WORKING OR SHORT-TERM MEMORY
- Coding
- Rehearsal
- Recoding

LONG-TERM MEMORY
- Process
- Store
- Recall
We forget 50% of what we learn within one hour of learning it unless we put it into practice or are continuously supported and provided with access to “knowledge.”

Forgetting Curve

Herman Ebbinghaus 1885
The Issue of ATTENTION

"It [attention] is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought...."

- WILLIAM JAMES
The Issue of ATTENTION

- Fragile nature of the wake state
- Microsleeps: intrusions into wakefulness
- The “grey area” between sleep and wake
The **LOCUS COERULEUS** is the principal site for brain synthesis of norepinephrine (noradrenaline). Norepinephrine from the locus coeruleus has an excitatory effect on most of the brain, mediating *arousal* and *attention*...and priming the brain’s neurons to be activated by stimuli.
The stereotypic condition of locus coeruleus activation is the orienting response: After a salient stimulus (e.g., a loud sound), we interrupt whatever we were doing before, orient to the stimulus, and then analyze the situation to initiate a new course of action.
Lack Of Sleep Kills Brain Cells, New Study Shows

If you’re burning the midnight oil, you may be burning out brain cells, too, new research shows. A study published this week in the Journal of Neuroscience found that staying awake too long destroys brain cells in mice, and may do the same in humans.
Extended Wakefulness: Compromised Metabolics in and Degeneration of Locus Ceruleus Neurons

Jing Zhang, Yan Zhu, Guanxia Zhan, Polina Fenik, Lori Panossian, Maxime M. Wang, Shayla Reid, David Lai, James G. Davis, Joseph A. Baur, & Sigrid Veasey

Journal of Neuroscience.

March 2014

Sleep deprived mice lost 25% of neurons in the locus coeruleus
Conclusions

- Is there lasting injury to the brain after sleep loss?
- Can we recover from nights of short sleep by “catching up” on weekends?
- Do we ever fully recover from chronic insufficient sleep?

*Is this why everybody has ADD these days???
Consolidation is the process of creating a memory trace after the initial acquisition, so that it available for later recall.
**Potentiation:**

- a synapse increases in strength as increasing numbers of signals are transmitted between two neurons.

- synchronous firing of multiple neurons makes those neurons more likely to fire together in the future.
Waking vs. Sleeping Rehearsal

- Waking Rehearsal is simply practice and repetition
- In a sense, purposeful repetition of the initial stimuli or piece of information

- What exactly then is Sleeping Rehearsal?
The role of the HIPPOCAMPUS in memory

Dr. Brenda Milner & Patient H. M.
Early Brain Research

- Dr. William Scoville surgically removed entire hippocampus
  - Cured seizures
  - No new memories after surgery
- Dr. Brenda Milner devoted career to studying Patient H. M.
  - Two types of memory: procedural/explicit
Rehearsal during Sleep

- During sleep, there is continual activation between the hippocampus and the cerebral cortex (with a number of relay stations along the way).
Rehearsal during Slow Wave Sleep

• Activation patterns in the sleeping brain mimic those recorded during the learning of the task during the previous day
Causal evidence for the role of REM sleep theta rhythm in contextual memory consolidation

Richard Boyce
Stephen D. Glasgow
Sylvain Williams
Antoine Adamantidis

Science 13 May 2016:
Vol. 352, Issue 6287, pp. 812-816

• OPTOGENICS: technology that allows scientists to control the activity of specific neurons by LIGHT
• Mice were trained to spot a new object placed in a field with two other objects of similar size and shape
• The exact neurons within the hippocampus were identified (i.e., those activated during the learning process
• Using optogenics, the researchers then turned off these same neurons while the mice were in REM sleep
• Compared to a control group, the experimental mice failed the next day at the same task, suggesting their memory of the task had been erased or impaired.
Silencing the same neurons for similar durations OUTSIDE OF REM SLEEP had no effect on memory consolidation.

REM sleep is crucial for memory consolidation.
SLOW WAVE SLEEP seems to play more of a role in DECLARATIVE MEMORY:

Remembering Basic Factual Information

REM SLEEP plays a stronger role in the consolidation of PROCEDURAL MEMORY:

Remembering HOW to do something
Conclusions

- Without adequate sleep, rehearsal and encoding suffer.
- Again, a single night of insufficient sleep may impair the retention of information learned or acquired the previous day.
- Better to get some sleep before a big test than to pull an all-nighter.
The Issue of RETRIEVAL

- Recall or retrieval of a memory refers to accessing information from the past which has previously been encoded and stored in the brain.

- Commonly known as “remembering”

- Retrieval involves re-visiting (or reactivation of) the nerve pathways the brain formed when the information was first encoded.
Retrieval returns a memory from long-term storage to short-term, or working memory, where it can be more easily accessed.
Energy & Waste

Cardiovascular system

Lymphatic system
How are nutrients supplied to the brain?

The brain uses about 25% of the body’s energy supply, even though it occupies only 2% of body’s mass
LYMPHATIC SYSTEM

A parallel collection of vessels that extends throughout the body...collects proteins and waste products...sends to circulatory system for removal.
Given the supply of nutrients the brain needs to function, it creates a tremendous amount of waste. 

...but the brain has very little lymphatic involvement.
Cerebrospinal Fluid (CSF)

- CSF fills spaces that surround the brain.
- CSF doesn’t stay on the outer surface of the brain, but rather is pumped into the inner regions of brain.
- It flows along the outsides of the blood vessels, and cleans away the waste from spaces between brain cells.
- Access to entire brain volume.
• The extracellular space between brain neurons increased by approximately 60% in the sleeping brain compared to the waking baseline.

• Accomplished by brain cells actually shrinking in size during sleep

• The authors hypothesized that the restorative properties of sleep may be linked to increased clearance of metabolic waste products produced by neural activity in the awake brain.

Sleep Drives Metabolite Clearance from the Adult Brain

Lulu Xie,1,∗ Hongyi Kang,1,∗ Qiwu Xu,1 Michael J. Chen,1 Yonghong Liao,1 Meenakshisundaram Thiyagarajan,1 John O’Donnell,1 Daniel J. Christensen,1 Charles Nicholson,2 Jeffrey J. Iliff,1 Takahiro Takano,1 Rashid Deane,1 and Maiken Nedergaard1,†

Imaging the waking brain

Blood Vessels

CSF

... and after it falls asleep
What impact does this cleaning have on cognitive function, or retrieval?

- When the researchers injected beta-amyloid into the brains of mice, the CSF cleared away this “debris” twice as quickly during sleep as during wake.

- When beta-amyloid collects and forms plaque inside brain cells, Alzheimer's may develop.

- Impaired quality & quantity of sleep is associated with a buildup of beta-amyloid.
- Inadequate sleep results in inadequate cleansing of the brain.

- The buildup of debris and waste products blocks cell-to-cell signaling between synapses.

- Recovery of information previously stored is impaired.
In his 2004 book *Think Like a Billionaire*, Mr. Trump wrote the following:

“Don’t sleep any more than you have to, I usually sleep about four hours per night.”

In a similar vein, at a campaign event in Springfield, Illinois in November 2015, he said:

“You know, I’m not a big sleeper. I like three hours, four hours, I toss, I turn, I beep-de-beep, I want to find out what’s going on.”