

What is Going on with Sleep in Adolescent Development...and Why it is a Problem

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Overview

- Adolescence & Puberty Defined
- Sleep phenomenology
- Sleep regulation
 - Process S (sleep homeostasis)
 - Process C (circadian rhythms)
- Lifestyles of the 21st century
- Public policy
 - School start time example

What is adolescence?

- Ages vary by culture
- WHO: 10-19 years; 10 -14 = early adolescence; 15-19 = late adolescence

What about puberty?

- Time when the reproductive organs become functional and the secondary sexual characteristics appear
- Tanner staging can be used to scale puberty
- Tanner stage and age are highly correlated
- In early adolescence, if girls show finding at a younger age than boys, pubertal maturation may be relevant

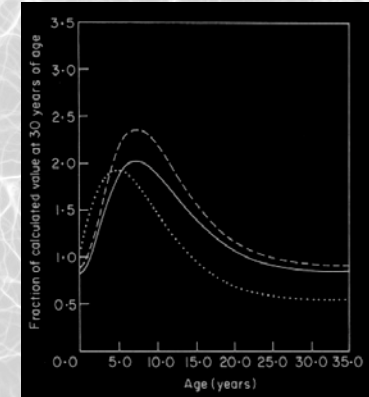
The central question

Why do adolescents (once such champion sleepers, so eager to start the day) struggle to wake up in the morning and struggle against going to sleep in the evening?



Adolescent Brain Changes

- Density of neuronal connections, blood glucose metabolism, and brain wave amplitude are stable in adulthood
- All decline during adolescence...a lot!

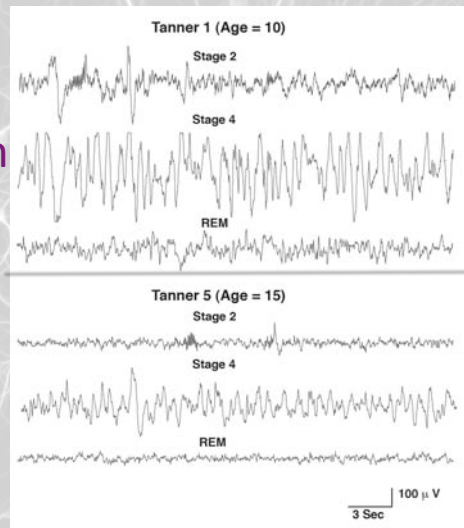


Feinberg et al., *J Theor Biol.*, 1990

The "look" of sleep changes

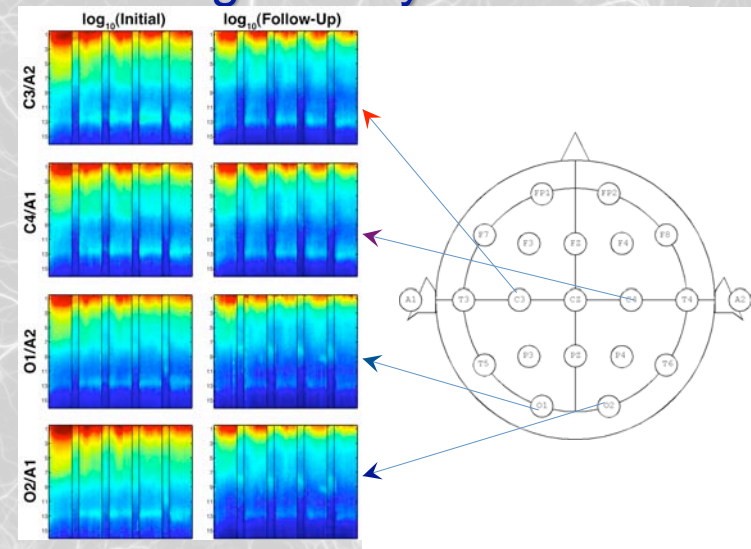
Pre teen

Teen



Tarokh & Carskadon, *Encyclopedia of Neuroscience*, 2009

Change is Asymmetrical



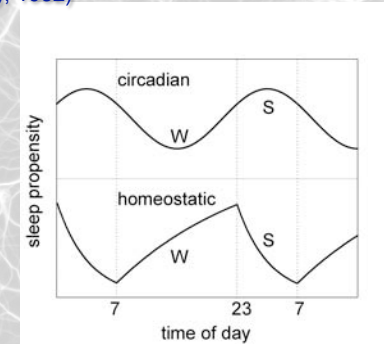
Tarokh & Carskadon, *Sleep* in press.

Sleep phenomenology changes across adolescence, but how does sleep regulation change developmentally and how does this play out behaviorally?

Two-Process Model of Sleep Regulation

(Borbély, 1982)

- **Process C:** Circadian Rhythm
- **Process S:** Sleep/Wake Homeostasis (sleep pressure)



Borbély & Achermann, 2000

Measures of Process S

- Slow wave (NREM stages 3+4) sleep [qualitative: deep sleep]
- Slow-wave activity (SWA) in sleep [quantitative: slow EEG waves]
- Sleep propensity (speed of falling asleep)

Process S: Sleep Homeostasis

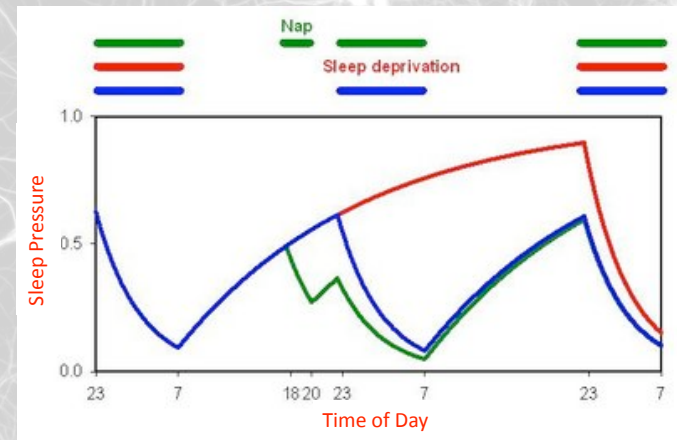
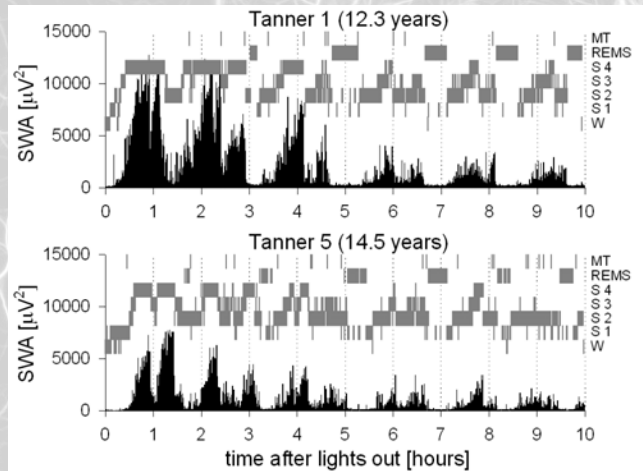


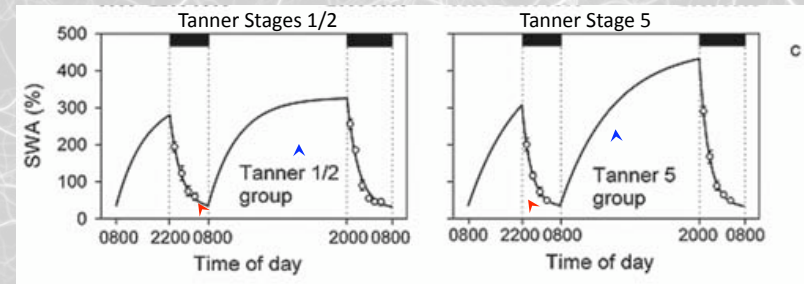
Image downloaded from *Scholarpedia* after Borbély

Changes of Slow Wave Sleep and Slow Brain Waves of Sleep



Jenni & Carskadon, *Sleep*, 2004

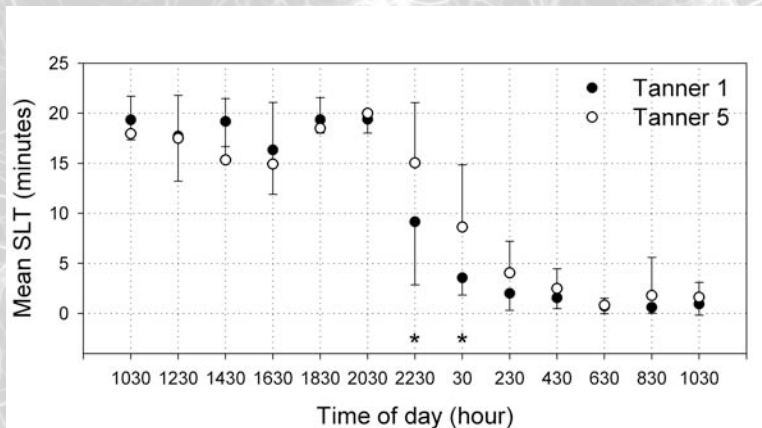
Dynamics of Sleep Pressure: Building Up and Letting Go



$t_d = 2.8$ h Decay Time Constant
 $t_r = 8.9$ h Rise Time Constant
 $t_d = 2.7$ h
 $t_r = 12.1$ h

Jenni, Achermann & Carskadon *Sleep*, 2005

Speed of Falling Asleep



Taylor et al., *J Sleep Res*, 2005

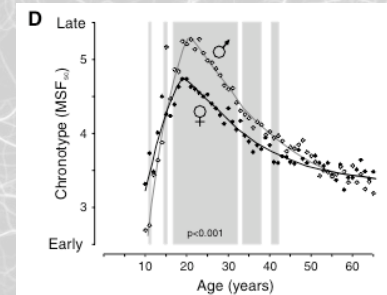
Summary of Process S Change

- Recovery sleep process does not change across adolescence
 - Need for sleep is stable
- Accumulation of sleep pressure slows
 - Staying awake longer is easier
- Result: late nights

Circadian Regulation Changes: Measures to Assess Process C

- **Phase preference**—when do you prefer to be active, sleeping, etc?
- **Phase** of circadian rhythms—what time is it in your brain?
- **Period** of the circadian timing system—what is the internal day length?
- **Phase response to light**—does light work the same in adolescents?

Phase Preference and Adolescence



- Time of midsleep on “free” days
- European sample
- Developmental changes occurred at a younger age in girls than boys

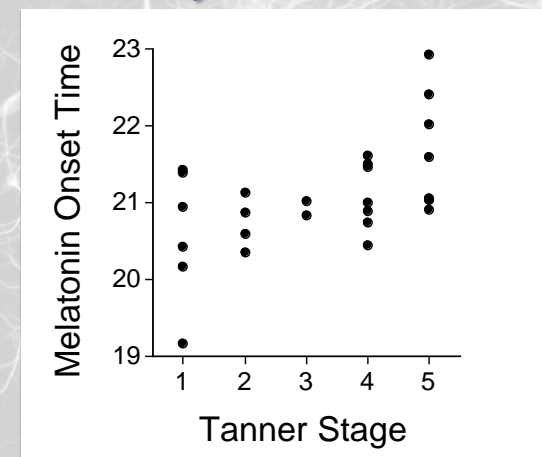
Roenneberg, *Current Biol.*, 2004

Animals with Adolescent Phase Delay

- *Homo sapiens* (humans)
- *Macca mulatta* (Rhesus monkeys)
- *Octodon degus* (degu)
- *Rattus norvegicus* (laboratory rat)
- *Mus musculus* (laboratory mouse)
- *Psammomys obesus* (fat sand rat)

Hagenauer et al., *Devel Neurosci*, 2009

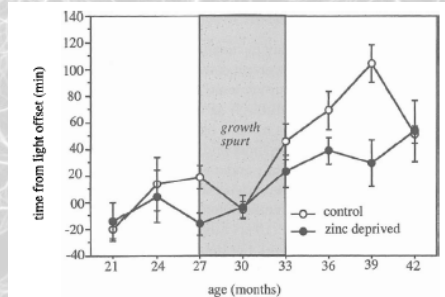
Melatonin Phase and Puberty in Humans



Carskadon & Acebo *NYAS*, 2004

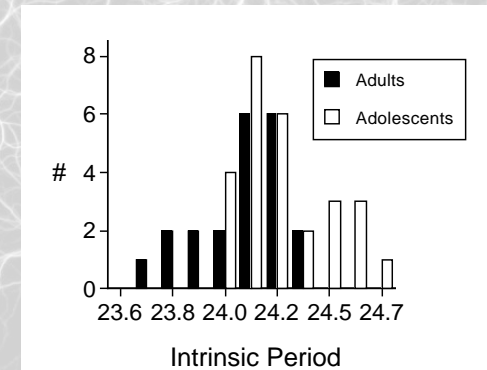
Activity offset delays in pubertal Macaques

- Puberty: phase delay in the daily offset of activity
- If puberty is inhibited by zinc deprivation, the phase delay does not occur.



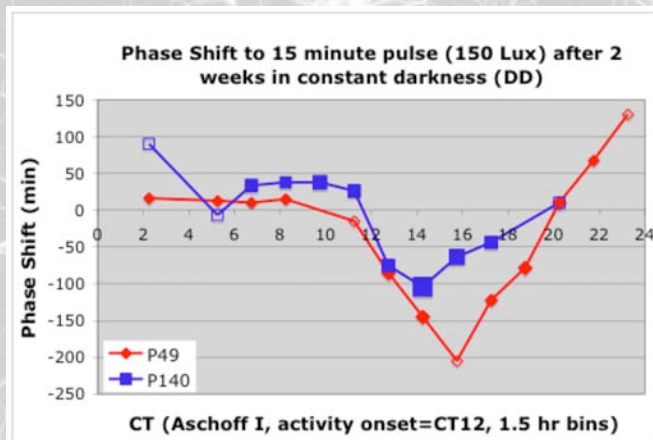
Golub et al., In: *Adolescent development...*, 2002

Internal Day Length in Humans



Carskadon & Acebo, *Sleep (APSS)* 2005

Exaggerated phase delay to light in pubertal female mice



Hagenauer et al., *Devel Neurosci*, 2009; after Weinert & Kompaeurova, *Zoology*, 1998

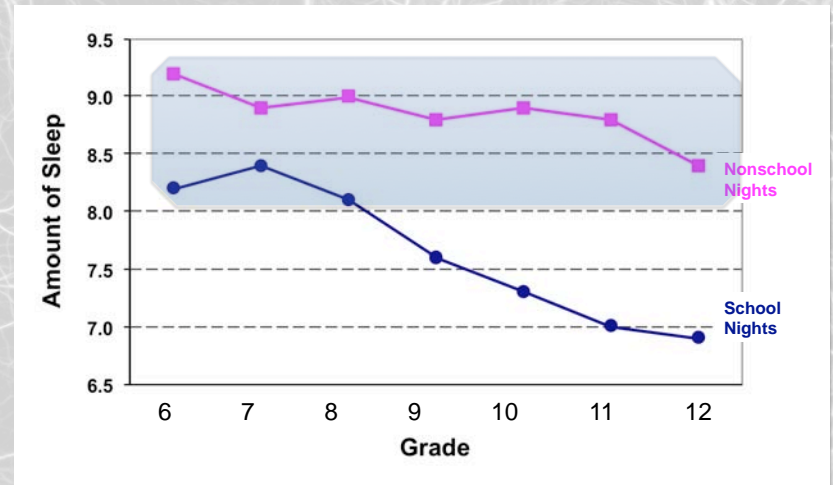
Circadian Rhythms Summary

- Phase delays during adolescence
 - Phase preference is later
 - Melatonin phase is later
- Intrinsic period may lengthen
- Phase-dependent light sensitivity may change
- Result: late nights

Other factors co-opt the biology...

- Academic obligations
- Social opportunities
- Substance use, including caffeine
- Psychological stressors
- Societal messages
- Stimulating activities (“screens”) in the evening
- Parental control vs. autonomy (Gangwisch et al., Sleep, 2010)
- School start time

Bottom Line for Sleep



NSF Sleep in America Poll, 2006

School Start Time



School Transition Project—A “real-life” example

9th Grade



8:25 am

10th Grade

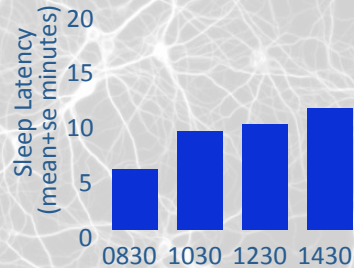


7:20 am

Carskadon et al., 1998

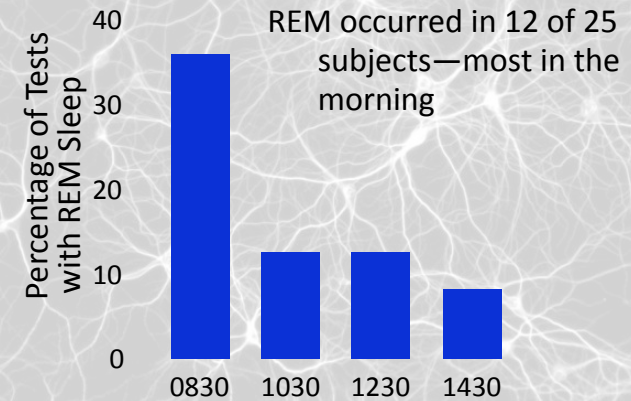
Measured sleepiness in high school students

- 10th grade
- Start time = 0720
- No schedule manipulation
- Sleeping about 7 hours a night



(Carskadon et al. *Sleep*, 1998)

REM tendency also affected



Carskadon et al. *Sleep*, 1998

Summary

- Long days
- Slower build-up of sleep pressure
- Later circadian phase
- Early school start time
- Same “need” for sleep/sleep recovery

- Too little sleep, waking up at the wrong time, resulting in excessive sleepiness and other waking consequences.

Consequences of Insufficient & Ill-timed Sleep

- Excessive sleepiness
- Impaired learning
- Impaired behavior regulation
- Increased risk taking
- Poor mood, depression
- Appetite and metabolic changes; possible association with weight gain, obesity, diabetes risk
- Stimulant use