Circadian and sleep strategies to optimize health, performance and safety: Brighter days & darker nights

Charles A. Czeisler, Ph.D., M.D.*
Professor of Medicine,
Frank Baldino, Jr., PhD Professor of Sleep Medicine
Director, Division of Sleep Medicine, Harvard Medical School
Senior Physician and Chief, Division of Sleep
and Circadian Medicine;
Director, Sleep Matters Initiative, Department of
Medicine, Brigham and Women's Hospital
Boston, Massachusetts

18th Annual Sleep Medicine CME Course

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Claude Monet

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HARVARD MEDICAL SCHOOL

Brigham and Women's Hospital
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UCLA 18th Annual SLeep Medicine CME Course

April 25, 2026

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*Dr. Czeisler is the incumbent of an endowed professorship provided to Harvard Medical School by Cephalon, Inc. and reports institutional support for a Quality Improvement Initiatives from Delta Airlines and Puget Sound Pilots; education support to Harvard Medical School (HMS)/Brigham and Women's Hospital (BWH) from: Jazz Pharmaceuticals PLC, Inc, Philips Respironics, Inc., Optum, and ResMed, Inc.; research support to BWH from Axsome Therapeutics, Inc., Dayzz Ltd., Jazz Pharmaceuticals PLC, Inc, Peter Brown and Margaret Hamburg, Summus, Inc., Takeda Pharmaceutical Co., CDC Foundation, Teva Pharmaceuticals Industries, Ltd., and Vanda Pharmaceuticals; personal royalty payments on sales of the now-discontinued Actiwatch-2 and Actiwatch-Spectrum devices from Philips Respironics, Inc; personal consulting fees from Axsome Therapeutics, Bryte Foundation, and Vanda Pharmaceuticals; lecture fees from Merck Sharpe and Dohme, and the Institute of Digital Media and Child Development; personal fees for serving as an expert witness on a number of legal matters; equity interest in Vanda Pharmaceuticals and Signos, Inc; and institutional educational gifts to BWH from Johnson & Johnson, Mary Ann and Stanley Snider via Combined Jewish Philanthropies, Alexandra Drane, DR Capital, Harmony Biosciences, LLC, San Francisco Bar Pilots, Whoop, Inc., Eisai Co., LTD, Idorsia Pharmaceuticals LTD, Sleep Number Corp., Apnimed, Inc., Avadel Pharmaceuticals, Bryte Foundation, f.lux Software, LLC, Vanda Pharmaceuticals and Quan Charitable Fund. Dr Czeisler's interests were reviewed and are managed by BWH and Mass General Brigham in accordance with their conflict-of interest policies. ©2000-2025 Charles Czeisler and Brigham & Women's Hospital.

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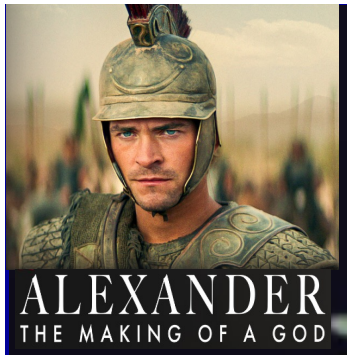

In 324 BC, Androsthenes reported **daily leaf movements of the tamarind tree**, *Tamarindus indicus*, on the island of Tylos (now Bahrein) in the Persian Gulf during the marches of Alexander the Great (Bretzl, 1903).

Sleep, 2(2):155–1
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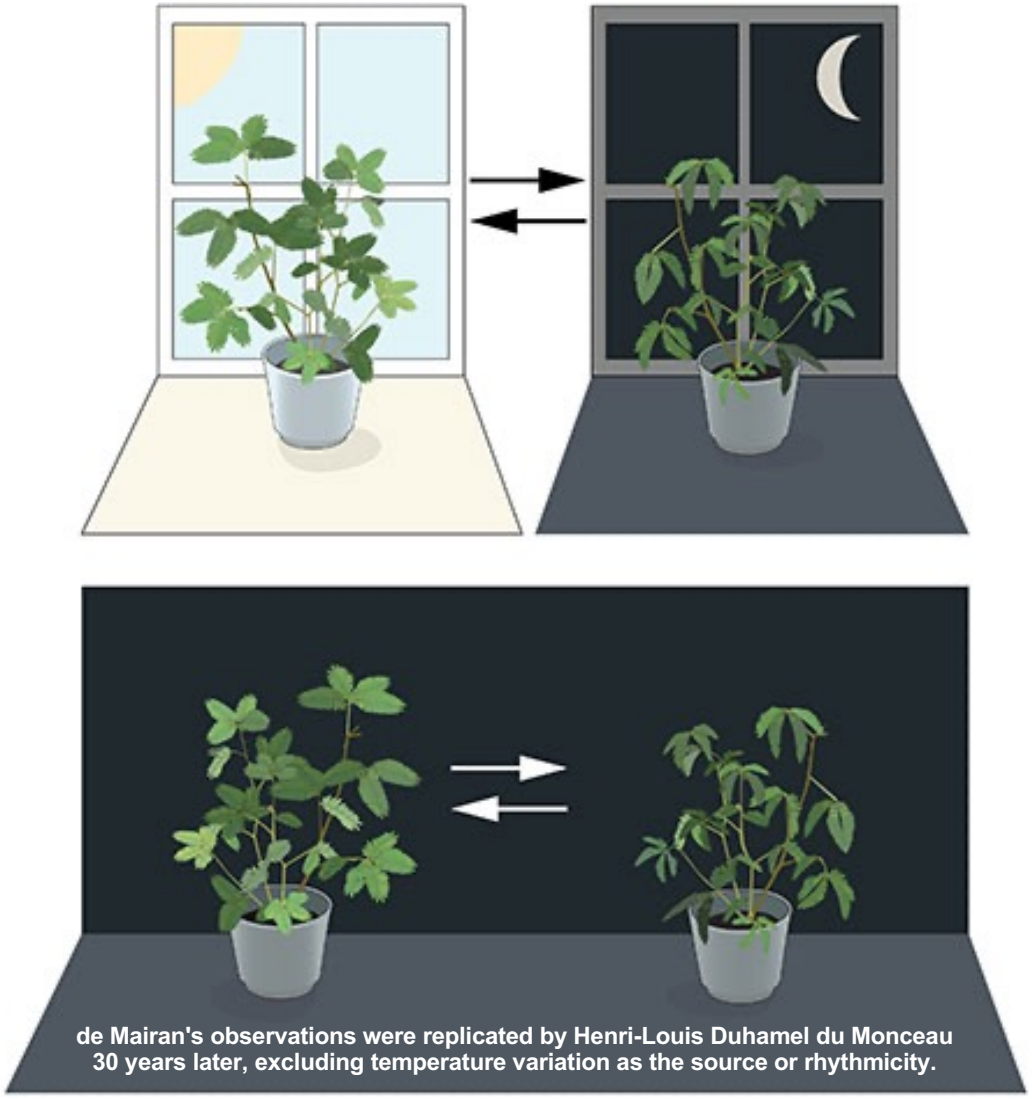

de Mairan's observations were replicated by Henri-Louis Duhamel du Monceau 30 years later, excluding temperature variation as the source or rhythmicity.

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It took nearly 2,000 years (1729 AD) for the endogenous nature of this daily rhythm to be discovered by the French astronomer s Jean-Jacques d'Ortous de Mairan, who reported that the daily leaf movements of the sensitive heliotrope plant (probably Mimosa pudica) persisted in constant darkness (de Mairan, 1729).

It is known that the "Sensitive" plant is a *heliotrope;* that is, its branches and leaves always turn toward the side where there is the greatest amount of light. In addition to this property which it has in common with other plants, it also exhibits another more unique property. It is sensitive to the sun or to daylight; its leaves and pedicles fold and contract at sundown, similar to what happens when the plant is touched or stirred. But Mr. de Mairan observed that it is not necessary that the plant be in sunlight or open air for this phenomenon to occur. It is only a bit less marked when the plant is kept in a dark place: it still opens during the day and folds or closes in the evening for the entire night. The experiment was done toward the end of summer and repeated. The "Sensitive" feels the sun without seeing it in any way. This seems to be related to the sensitivity of a great number of bed-ridden sick people, who, in their confinement, are aware of the differences of day and night.

It would be interesting to find out whether other plants, whose leaves or flowers open during the day and close at night, will still exhibit this property when kept in the dark, as the "Sensitive" plant does. If we could simulate day and night conditions by changes in the ambient temperature [by art (i.e., science) and an oven more or less warm], and if we could also in this way reverse the order of the true day and night phenomena, it would be interesting to note the plant's responses. But the everyday chores of Mr. de Mairan did not permit him to pursue his experiments that far; he extends an invitation to Botanists and Scientists, who may find other points to pursue. The progress of true Physics, which is Experimental, can only be very slow.

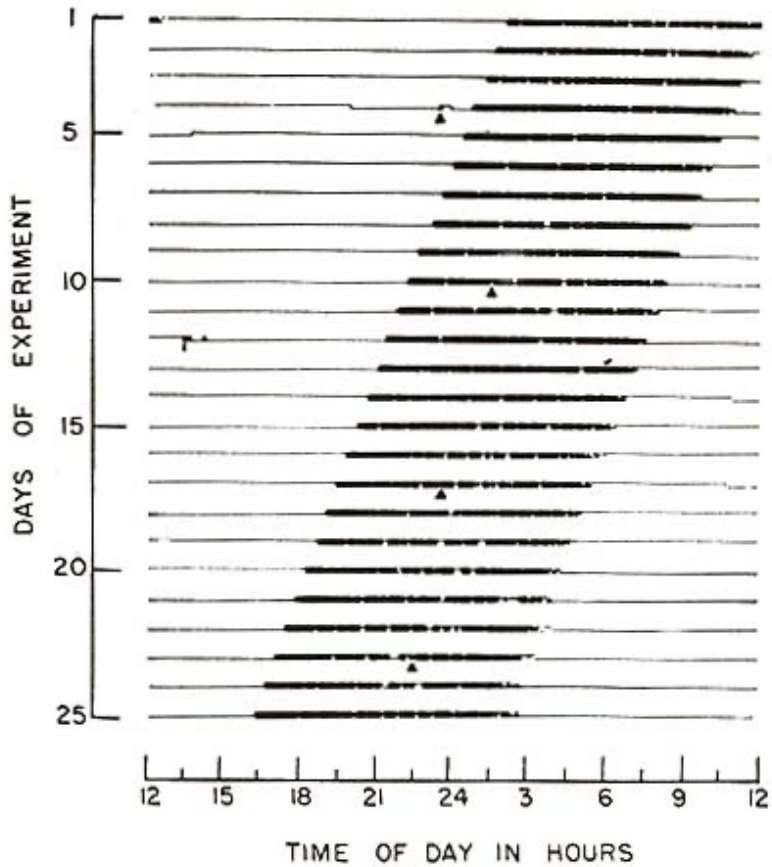
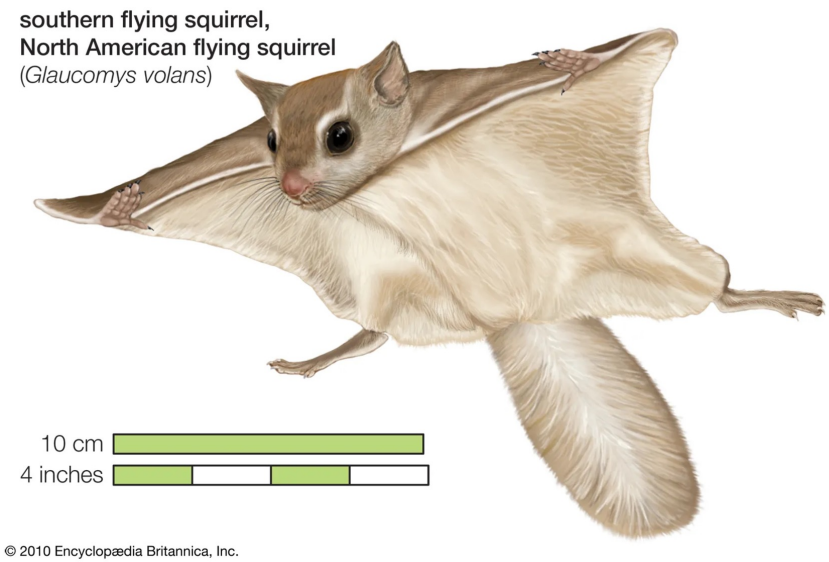


FIGURE 2. Activity graph of one flying squirrel in a recording wheel cage in continuous darkness at 20°C. from June 14–July 8, 1959. Solid triangles indicate the time of feeding in darkness; Σ the time of dim light during an equipment repair.



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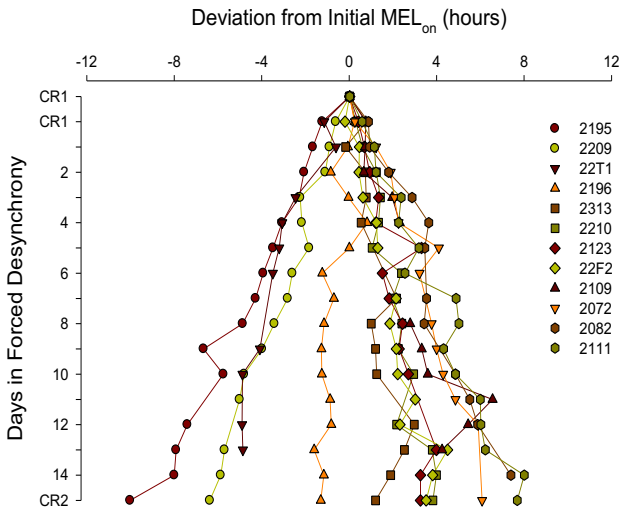

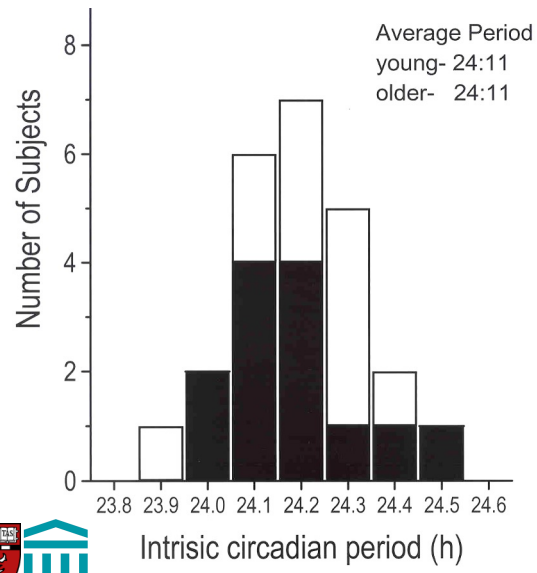

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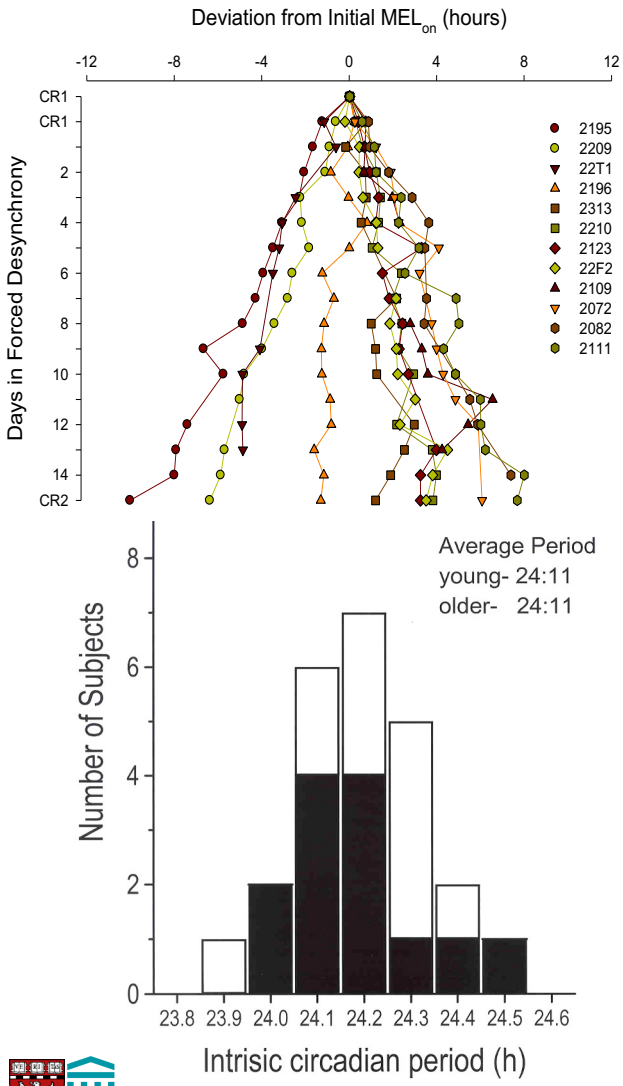

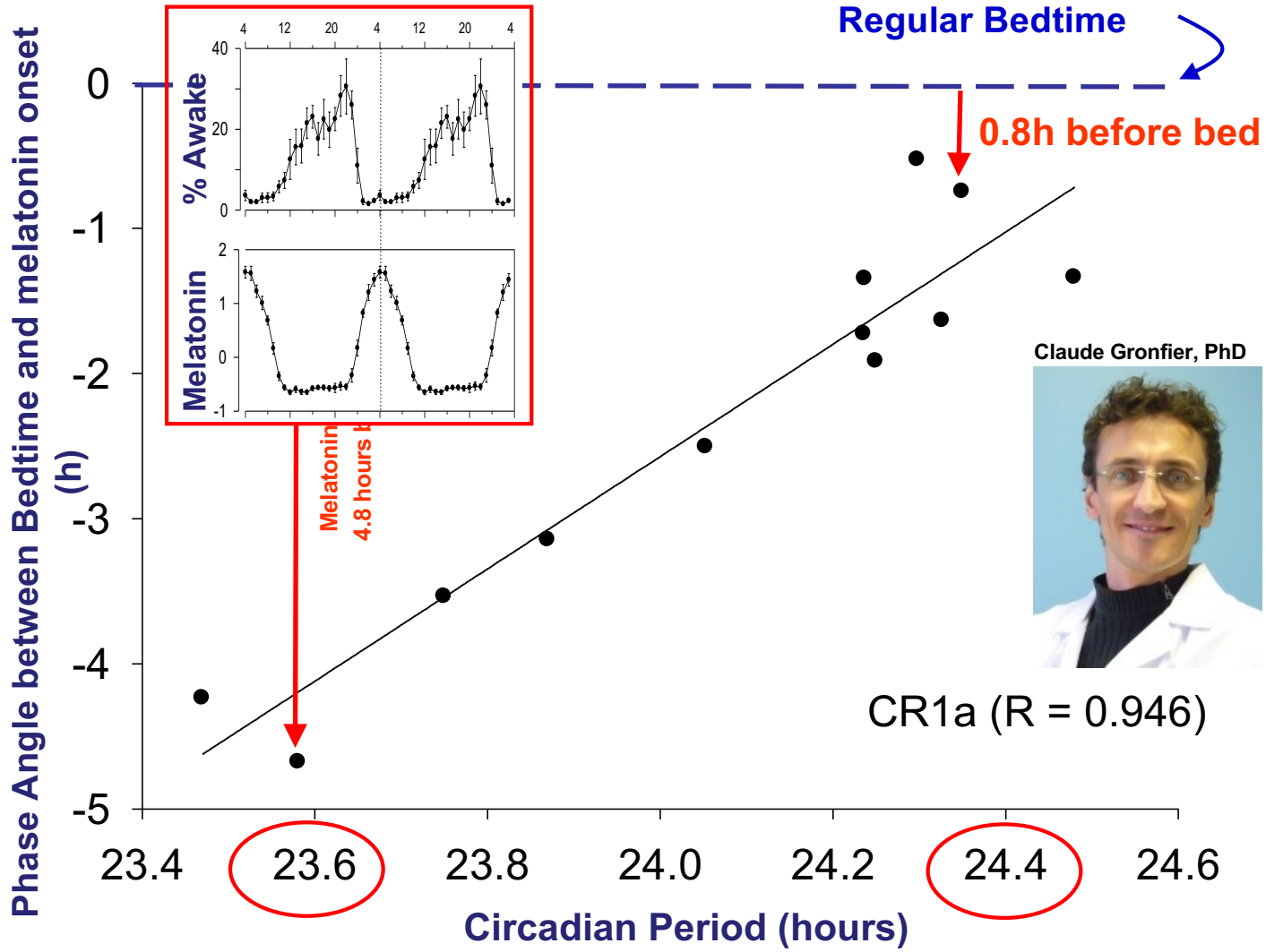

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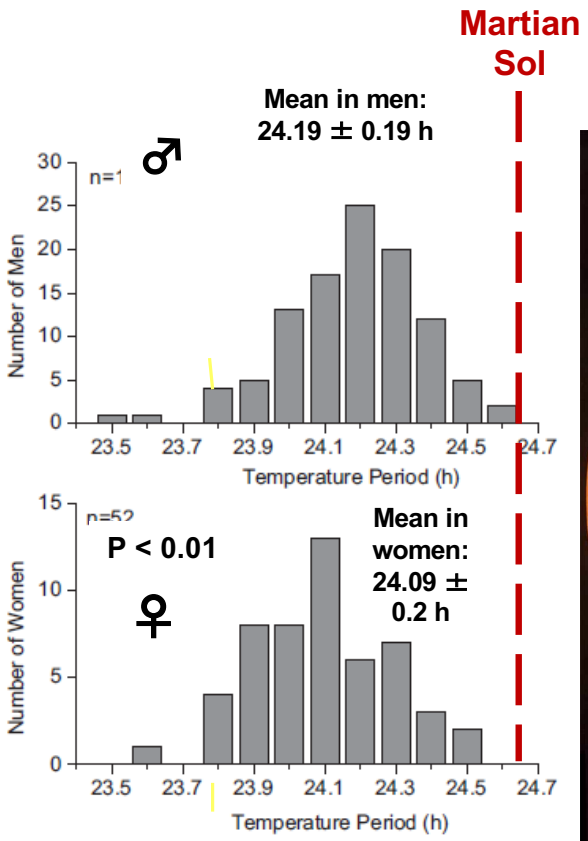

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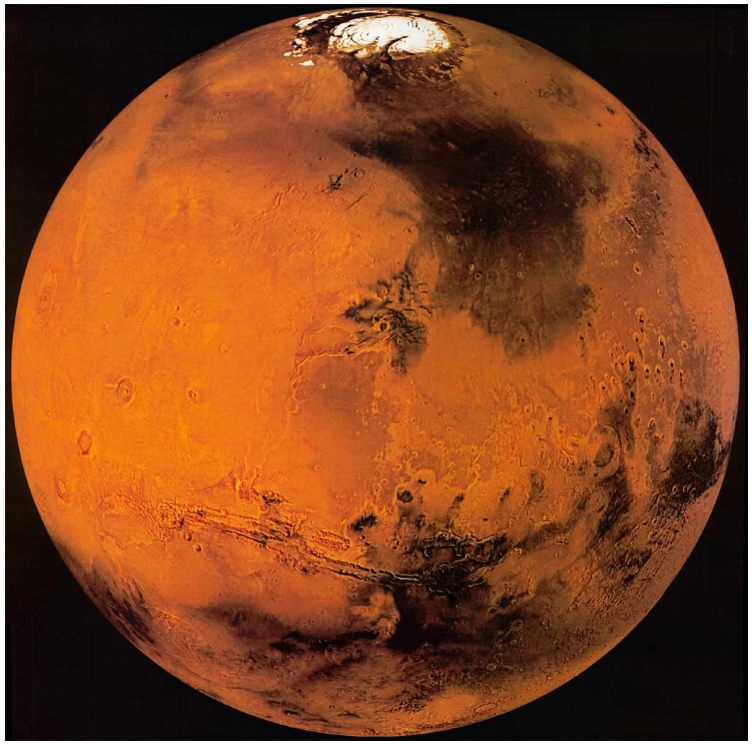
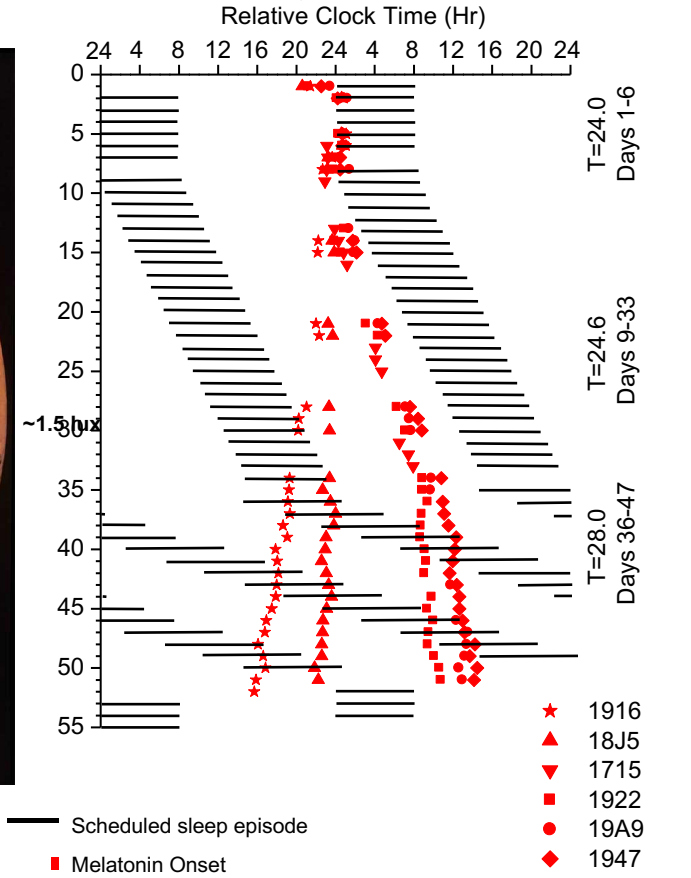


T = 24.6 hours in very dim light



~1.5 lux insufficient for entrainment in 100% of the subjects

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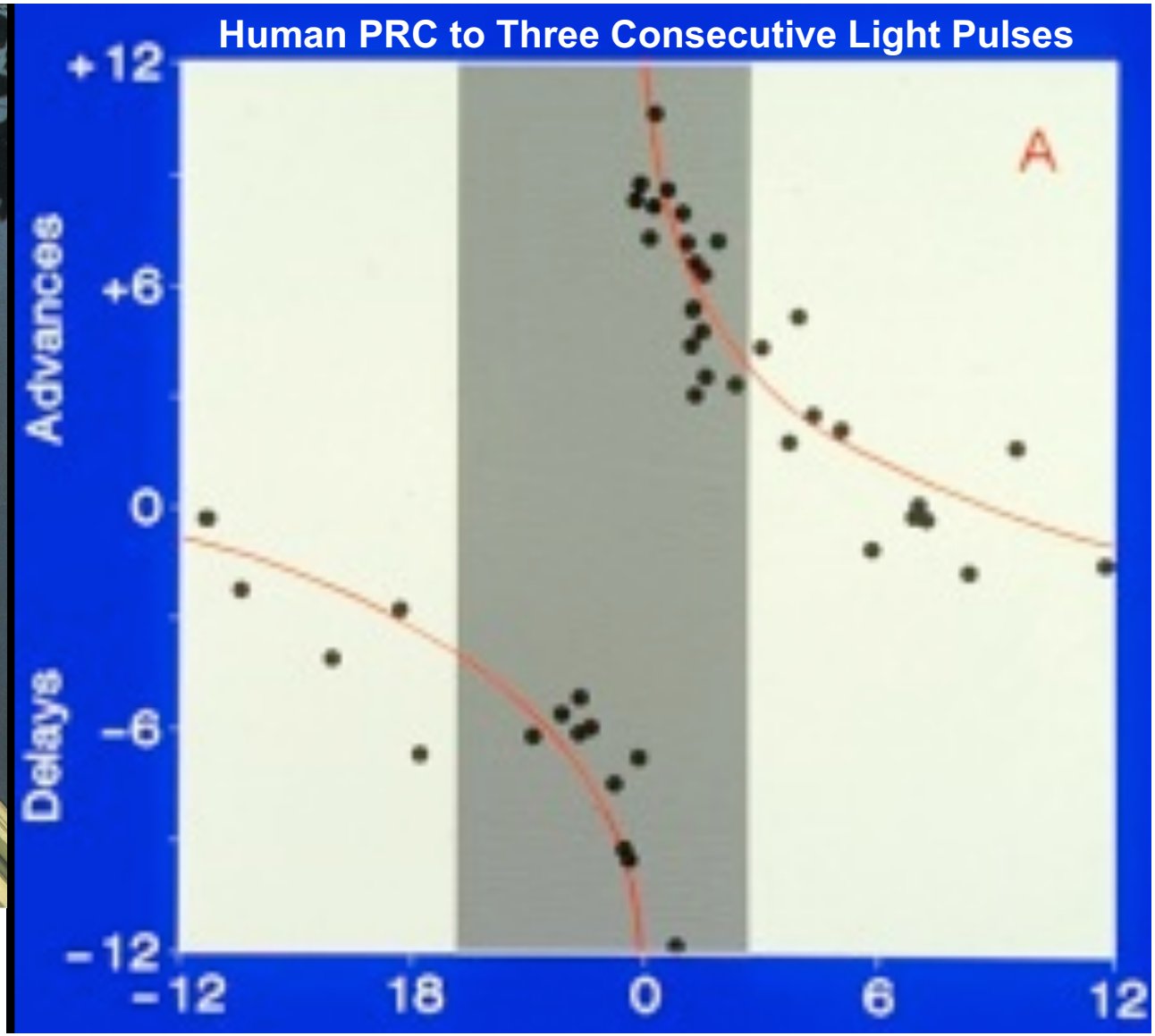

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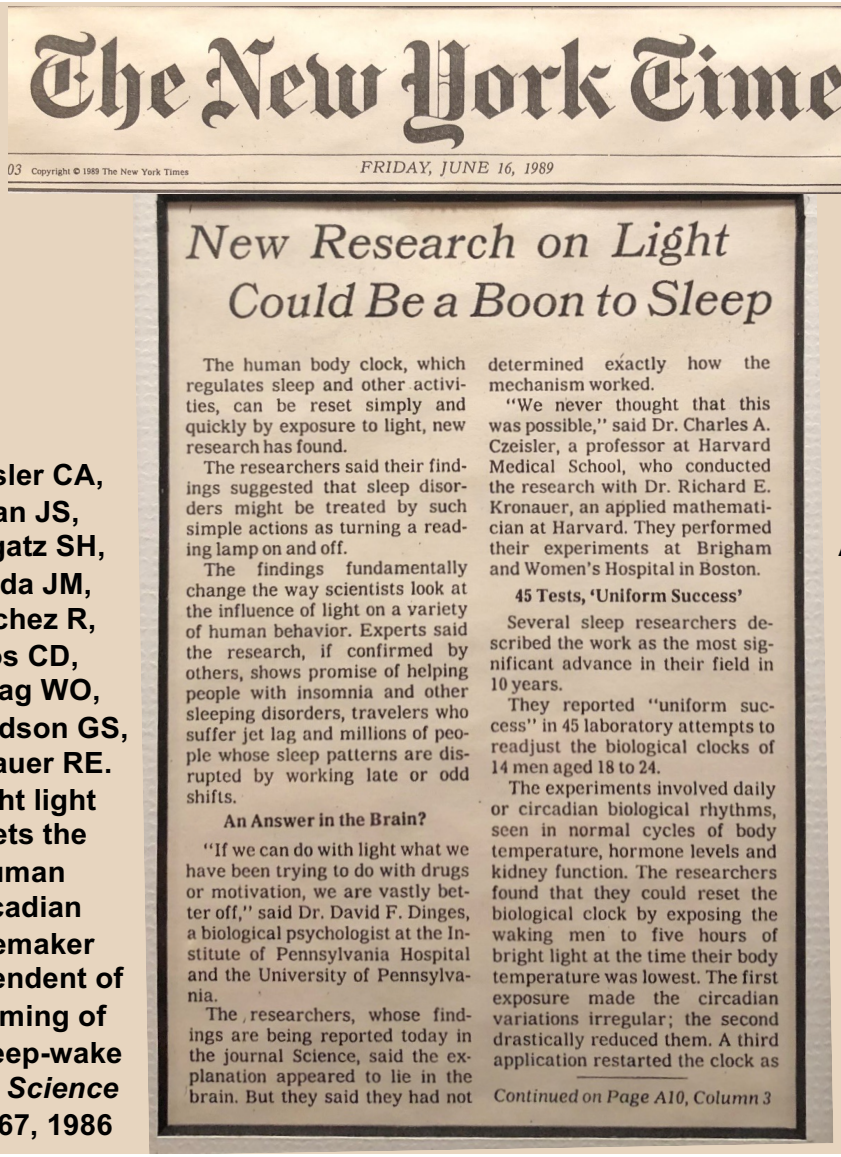


The New York Times

03 Copyright © 1989 The New York Times — FRIDAY, JUNE 16, 1989 — P

New Research on Light Could Be a Boon to Sleep

The human body clock, which regulates sleep and other activities, can be reset simply and quickly by exposure to light, new research has found.

The researchers said their findings suggested that sleep disorders might be treated by such simple actions as turning a reading lamp on and off.

The findings fundamentally change the way scientists look at the influence of light on a variety of human behavior. Experts said the research, if confirmed by others, shows promise of helping people with insomnia and other sleeping disorders, travelers who suffer jet lag and millions of people whose sleep patterns are disrupted by working late or odd shifts.

An Answer in the Brain?

"If we can do with light what we have been trying to do with drugs or motivation, we are vastly better off," said Dr. David F. Dinges, a biological psychologist at the Institute of Pennsylvania Hospital and the University of Pennsylvania.

The researchers, whose findings are being reported today in the journal Science, said the explanation appeared to lie in the brain. But they said they had not determined exactly how the mechanism worked.

"We never thought that this was possible," said Dr. Charles A. Czeisler, a professor at Harvard Medical School, who conducted the research with Dr. Richard E. Kronauer, an applied mathematician at Harvard. They performed their experiments at Brigham and Women's Hospital in Boston.

45 Tests, 'Uniform Success'

Several sleep researchers described the work as the most significant advance in their field in 10 years.

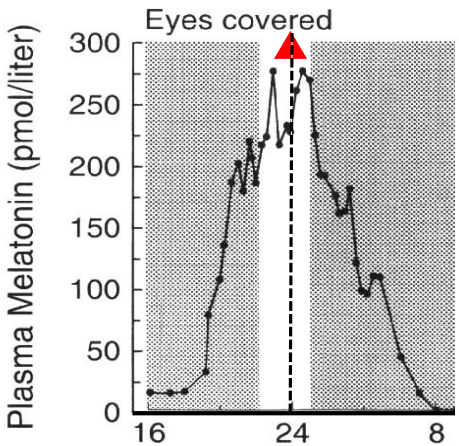
They reported "uniform success" in 45 laboratory attempts to readjust the biological clocks of 14 men aged 18 to 24.

The experiments involved daily or circadian biological rhythms, seen in normal cycles of body temperature, hormone levels and kidney function. The researchers found that they could reset the biological clock by exposing the waking men to five hours of bright light at the time their body temperature was lowest. The first exposure made the circadian variations irregular; the second drastically reduced them. A third application restarted the clock as

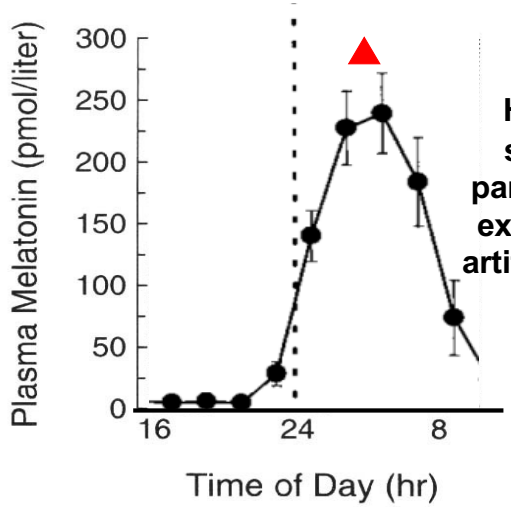
Continued on Page A10, Column 3

Czeisler CA, Kronauer RE, Allan JS, Duffy JF, Jewett ME, Brown EN, Ronda JM. *Science* *244*:1328, 1989

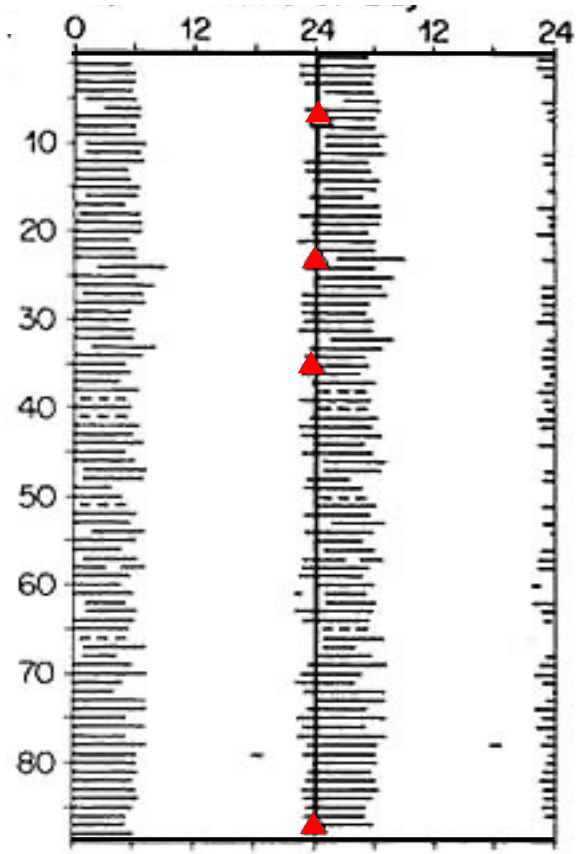
Phase Angle of Entrainment in Blind Person With Circadian Photoreception



Healthy blind participant living in a single dorm room without artificial light



Healthy sighted participants exposed to artificial light



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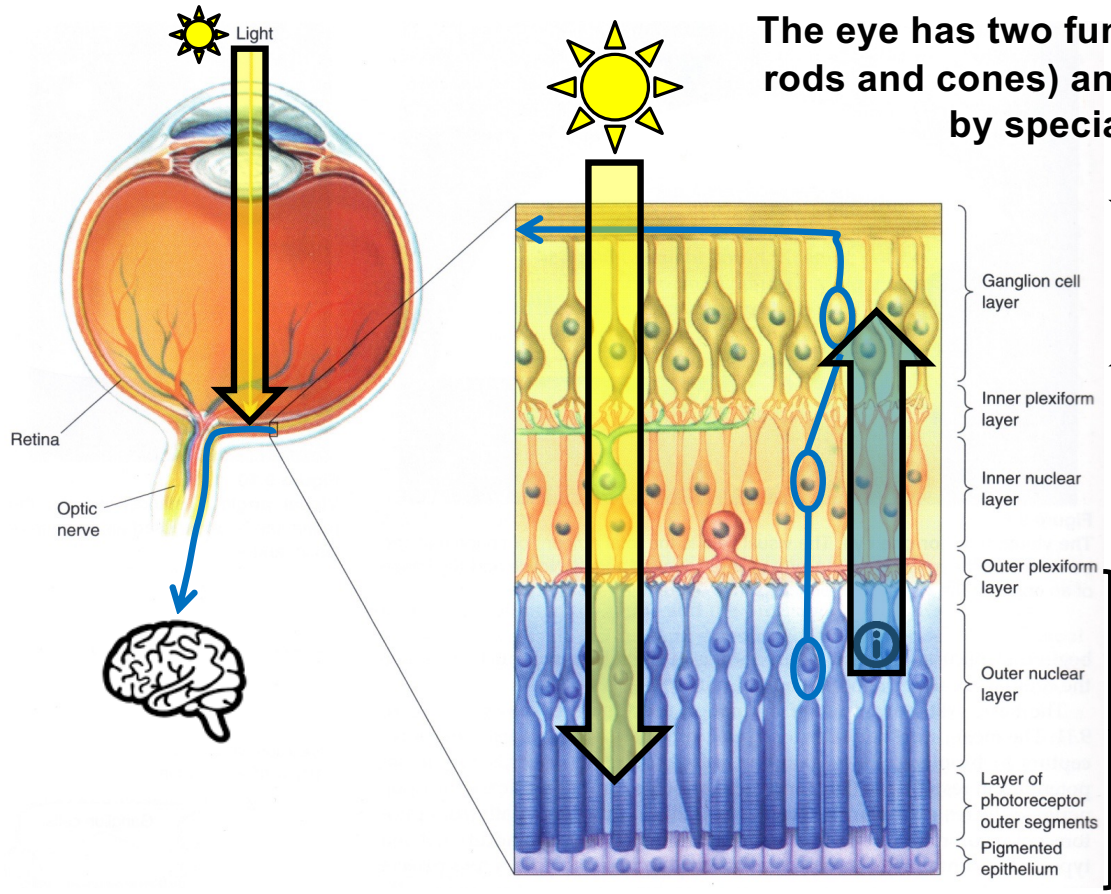
Organization of the Retina

Classic understanding, unchanged for last ~2 centuries

The eye has two functions: image formation (mediated by rods and cones) and circadian photoreception (mediated by specialized retinal ganglion cells)



Light

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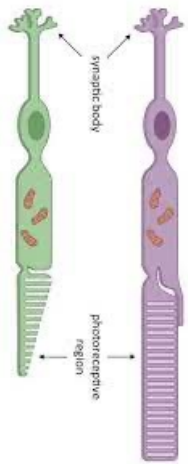
Rod cells (dark vision)

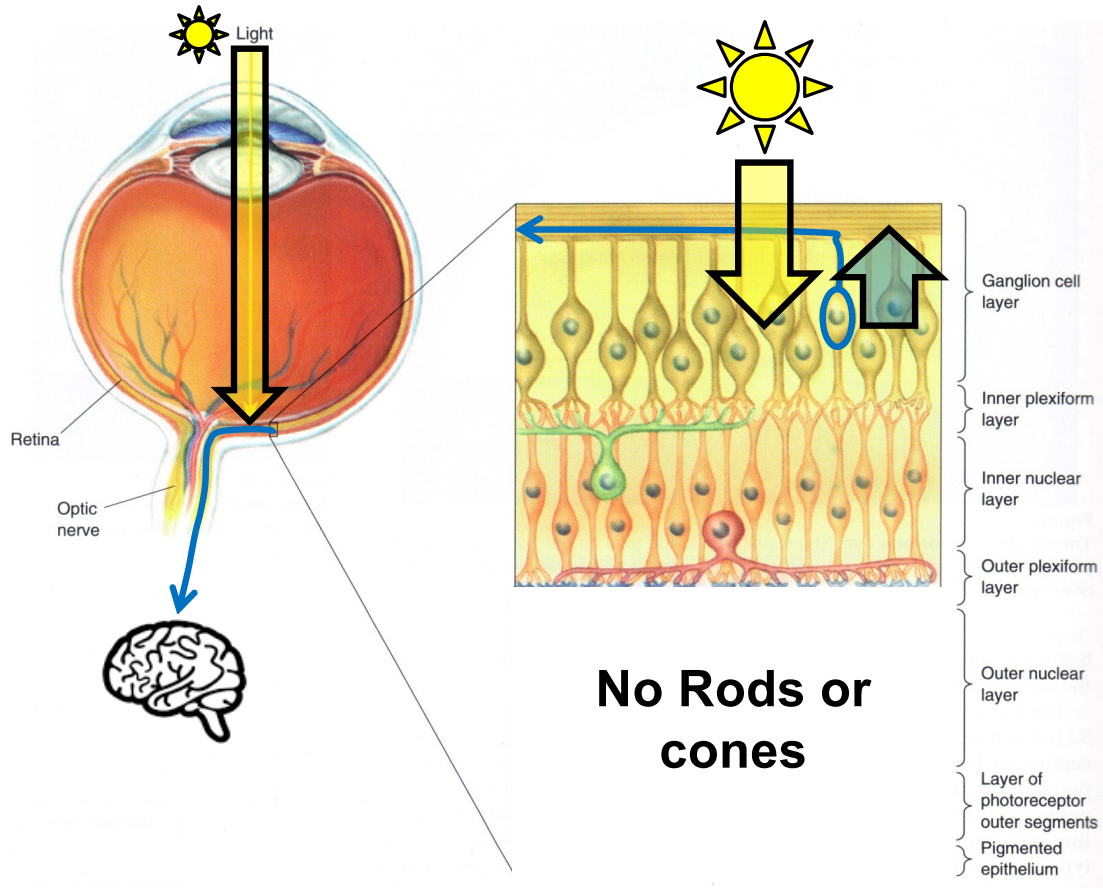
Cone cells (color vision)



Modified from slide courtesy of Dr. Joshua Gooley

Organization of the Retina

Newly recognized input mediating circadian photoreception in some otherwise totally blind people



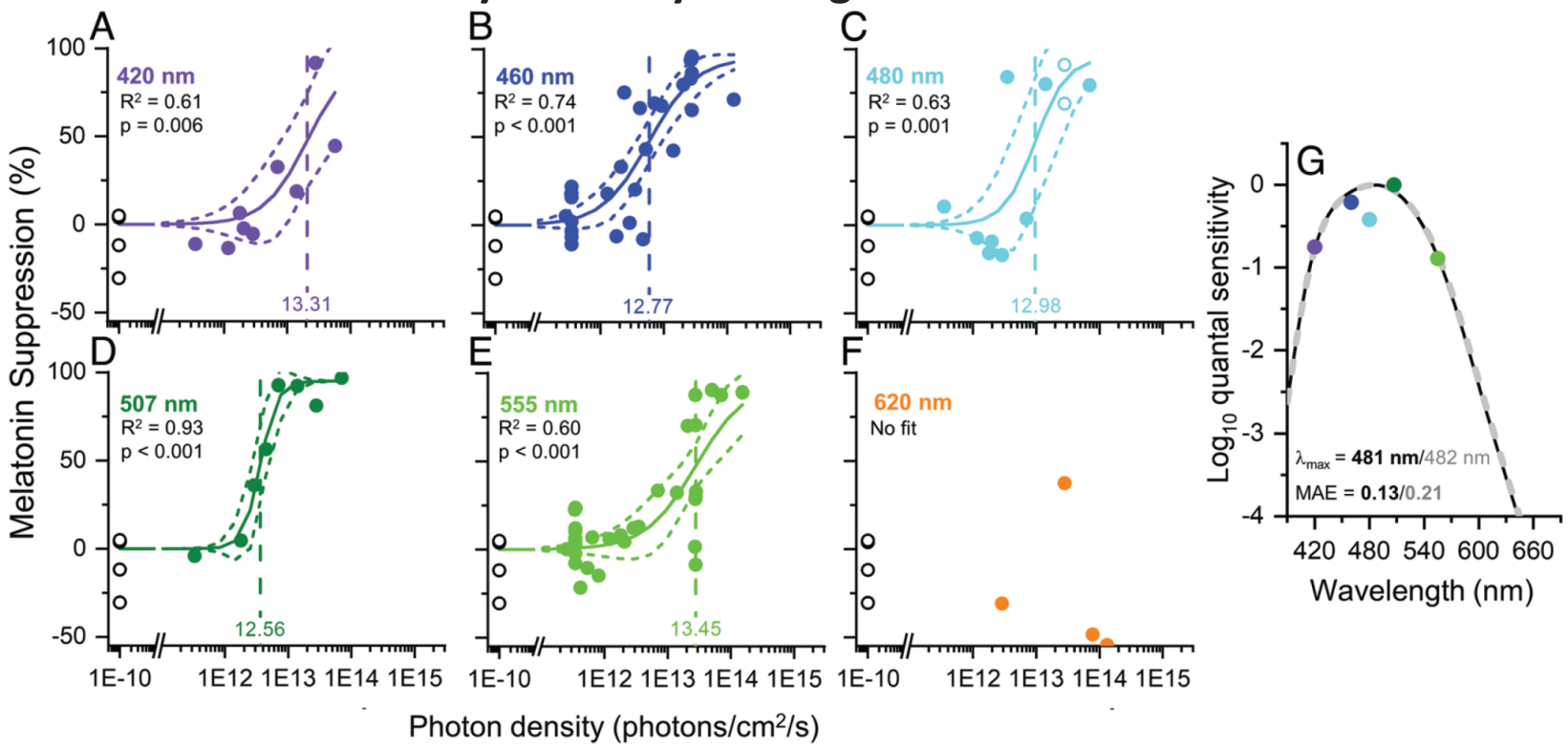
Light

Information

Special retinal ganglion cells (RGCs) <u>projecting to brain's central circadian clock,</u> contain a novel photopigment: <u>melanopsin</u>—most sensitive to short-wavelength (blue) light

Modified from slide courtesy of Dr. Joshua Gooley

Spectral sensitivity of human melatonin suppression to light changes dynamically with light duration



Dr. Melissa St Hilaire

Fig. 1. Best-fit dose response curves for melatonin suppression across 6.5 h of light exposure. (*A–F*) The best-fit dose response curves for melatonin suppression in response to 6.5 h of light exposure as a function of photon density for monochromatic wavelengths of 420 (n = 9), 460 (n = 30), 480 (n = 11), 507 (n = 8), 555 (n = 33), and 620 nm (n = 4). The minimal and maximal responses were fixed at 0% and 95%, respectively; the ED_{50} and slope were allowed to vary. The $log_{10}ED_{50}$ values (vertical dashed line) ranged from 12.56 to 13.45 photons/cm^2/sec and the slopes ranged from 1.10 to 3.29. The adjusted R^2 values for the fits ranged from 0.60 to 0.93. The n = 4 darkness controls plotted at 1e^{-10} photons/cm^2/sec were included in the fits for all wavelengths. The data for 620 nm (panel *F*) were not fit due to the small sample size in this group. (*G*) Action spectra for long-duration melatonin suppression responses. The full dataset best matches a Govardovskii opsin template with $lambda_{max}$ = 481 nm (MAE = 0.13; solid black line), assuming a correction for lens transmission of a 22-y-old individual; the best-fit opsin without lens transmission correction is shown in the dashed gray line for comparison ($lambda_{max}$ = 482 nm; MAE = 0.21).

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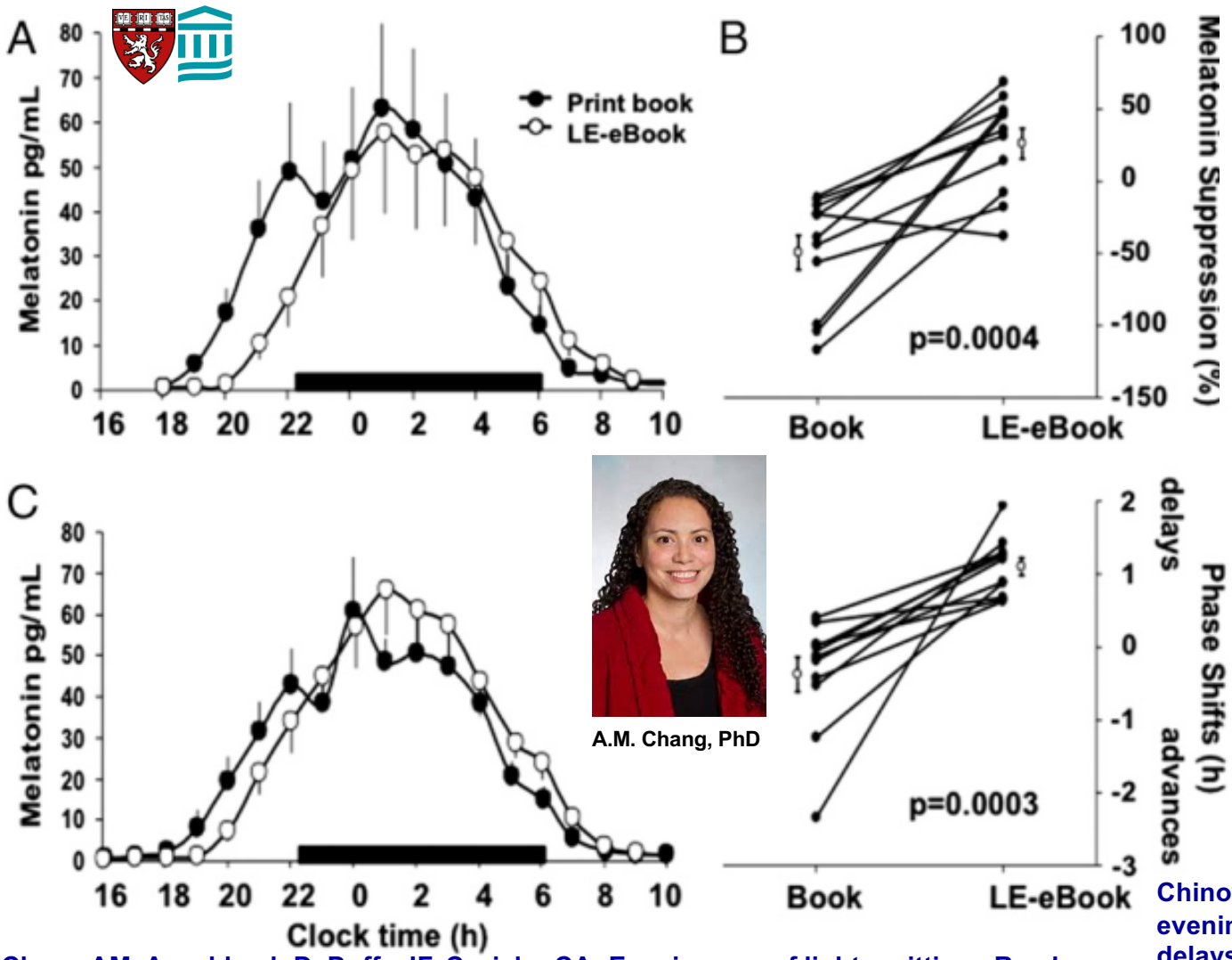

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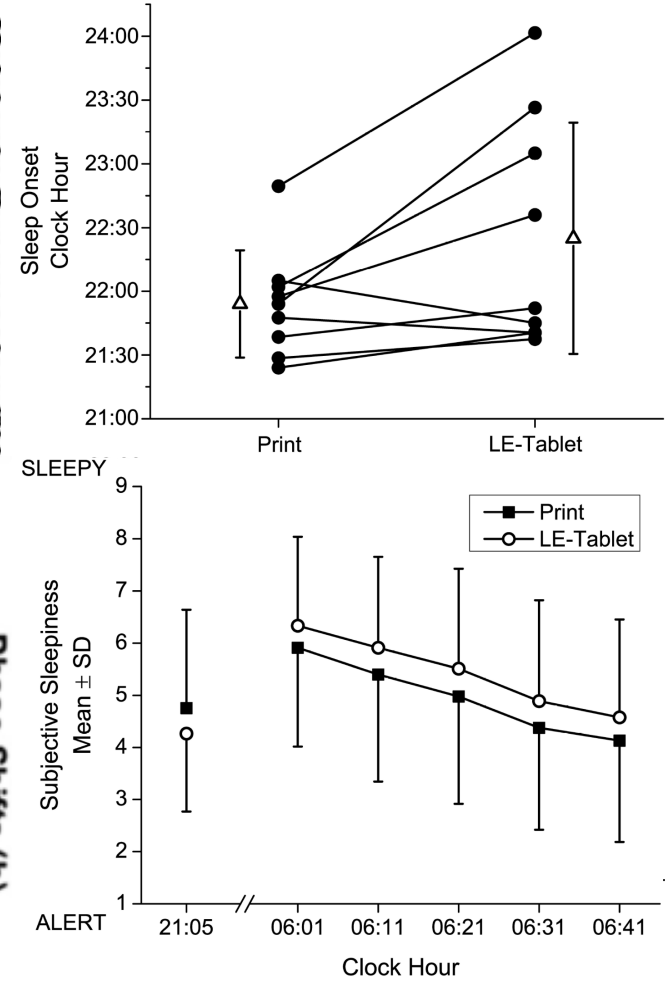

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An Exploration of the Temporal Dynamics of Circadian Resetting Responses to Short- and Long-Duration Light Exposures: Cross-Species Consistencies and Differences

Richard E. Kronauer,[*,†,1] Melissa A. St. Hilaire,[†,‡,1,2] Shadab A. Rahman,[†,‡] Charles A. Czeisler[†,‡] and Elizabeth B. Klerman[†,‡]

[*]*School of Engineering and Applied Sciences, Harvard University, Cambridge, Massachusetts,* [†]*Division of Sleep Medicine, Harvard Medical School, Boston, Massachusetts, and* [‡]*Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital, Boston, Massachusetts*

Richard E. Kronauer, PhD

J Biol Rhythms. 2019 Aug 1:748730419862702.

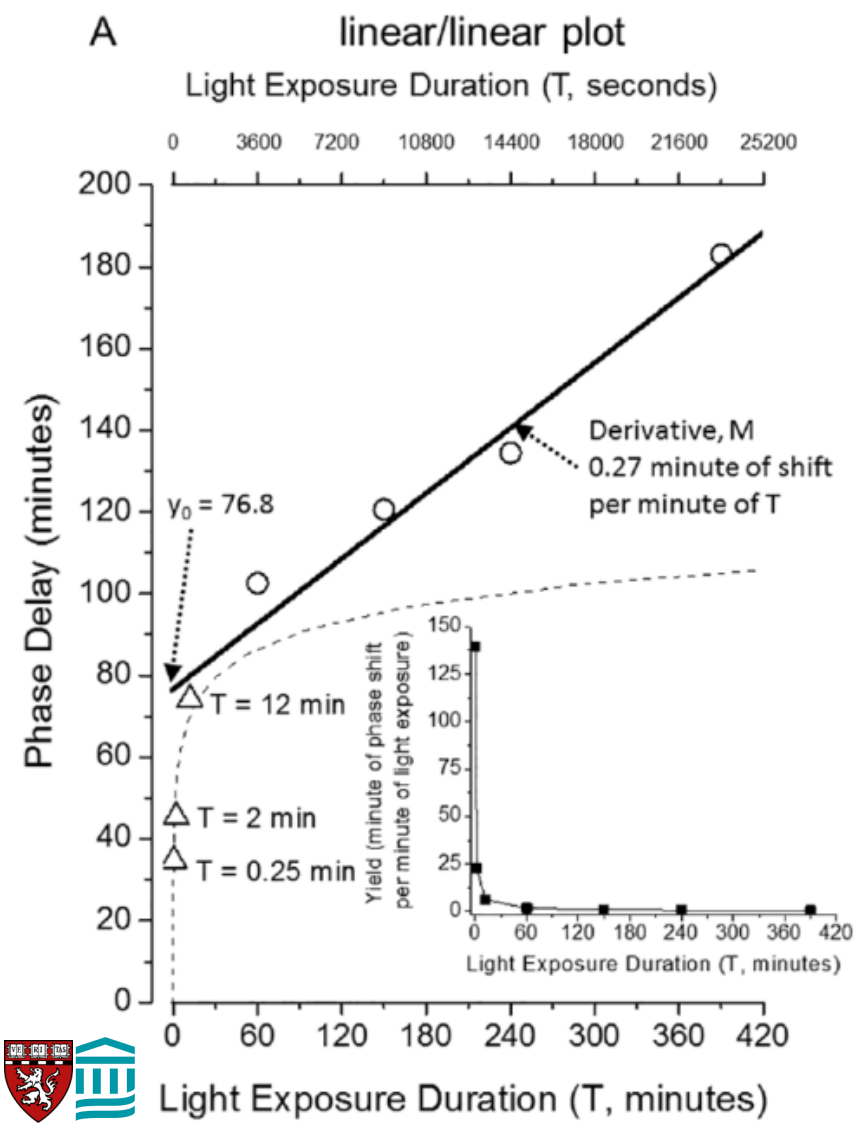
An Exploration of the Temporal Dynamics of Circadian Resetting Responses to Short- and Long-Duration Light Exposures: Cross-Species

Table 1. Phase-delay shifts and shift rate of the human duration response curve.

T: Duration of Light Exposure (min)	Y: Delay Shift (Median ± SD, min)	$\frac{y}{T}$: Resetting Rate (i.e., Minute of Phase Shift per Minute of Light Exposure)
0.25	34.8 ± 47.2	139.2
2.00	45.4 ± 28.4	22.7
12.00	74.2 ± 35.2	6.2
60.00	102.6 ± 35.6	1.7
150.00	120.6 ± 37.2	0.8
240.00	134.5 ± 46.8	0.6
390.00	183.0 ± 27.0	0.5

Richard E. Kronauer, PhD

J Biol Rhythms. 2019 Aug 1:748730419862702.



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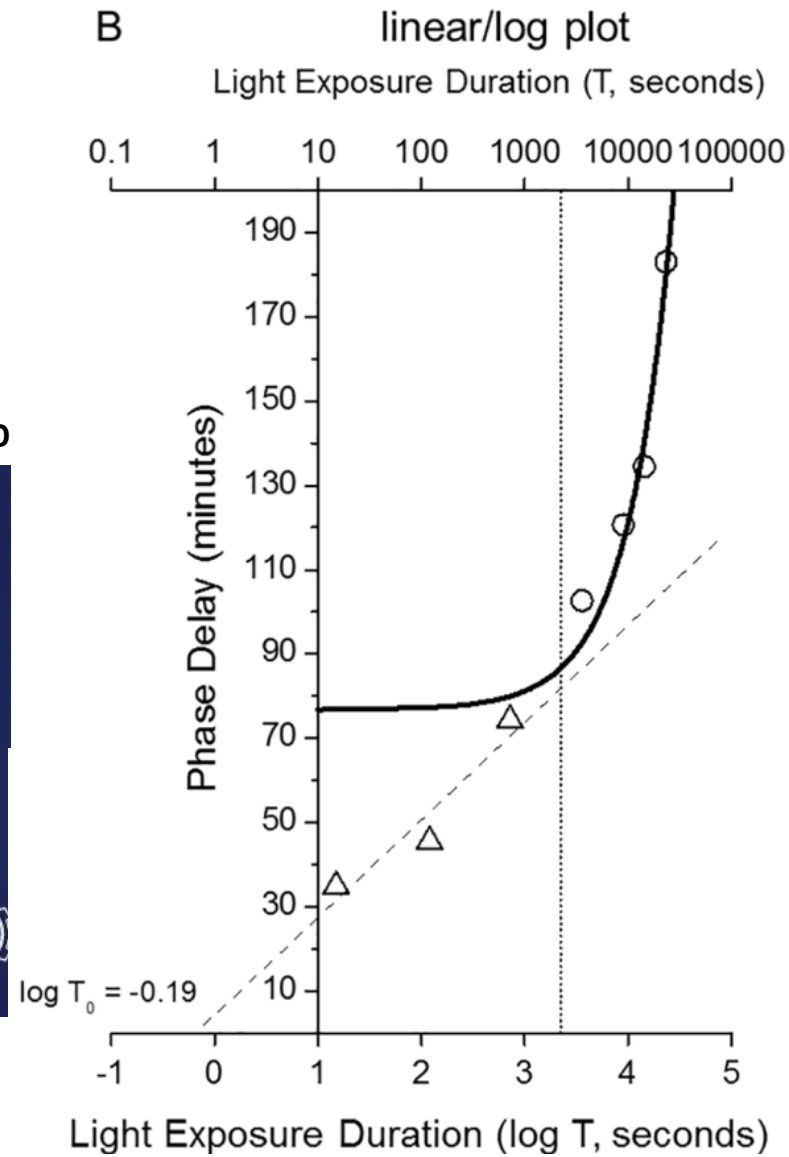
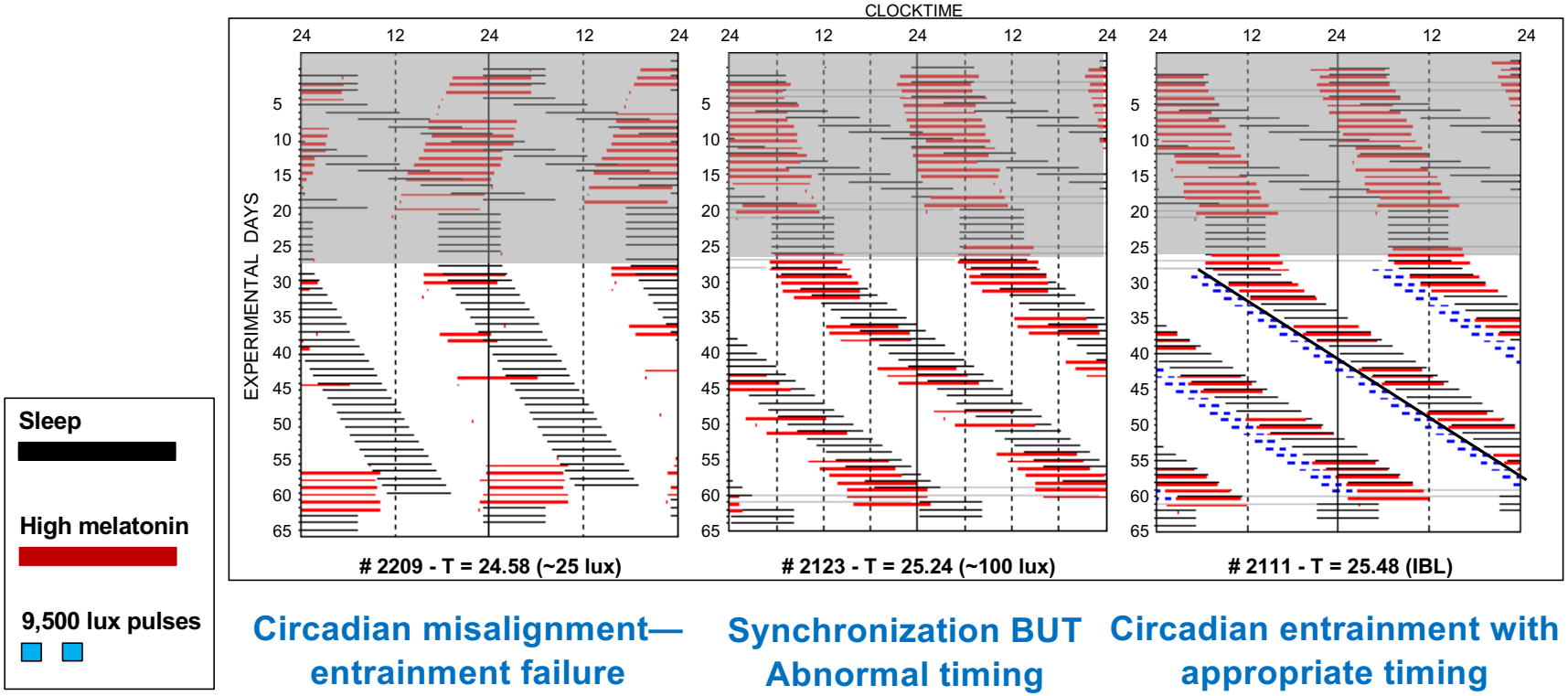
J Biol Rhythms.
2019 Aug 1.



Entrainment of circadian pacemaker to sleep/wake cycle period 1 hour longer than individual's circadian period—enabling adaptation to the Martian sol)

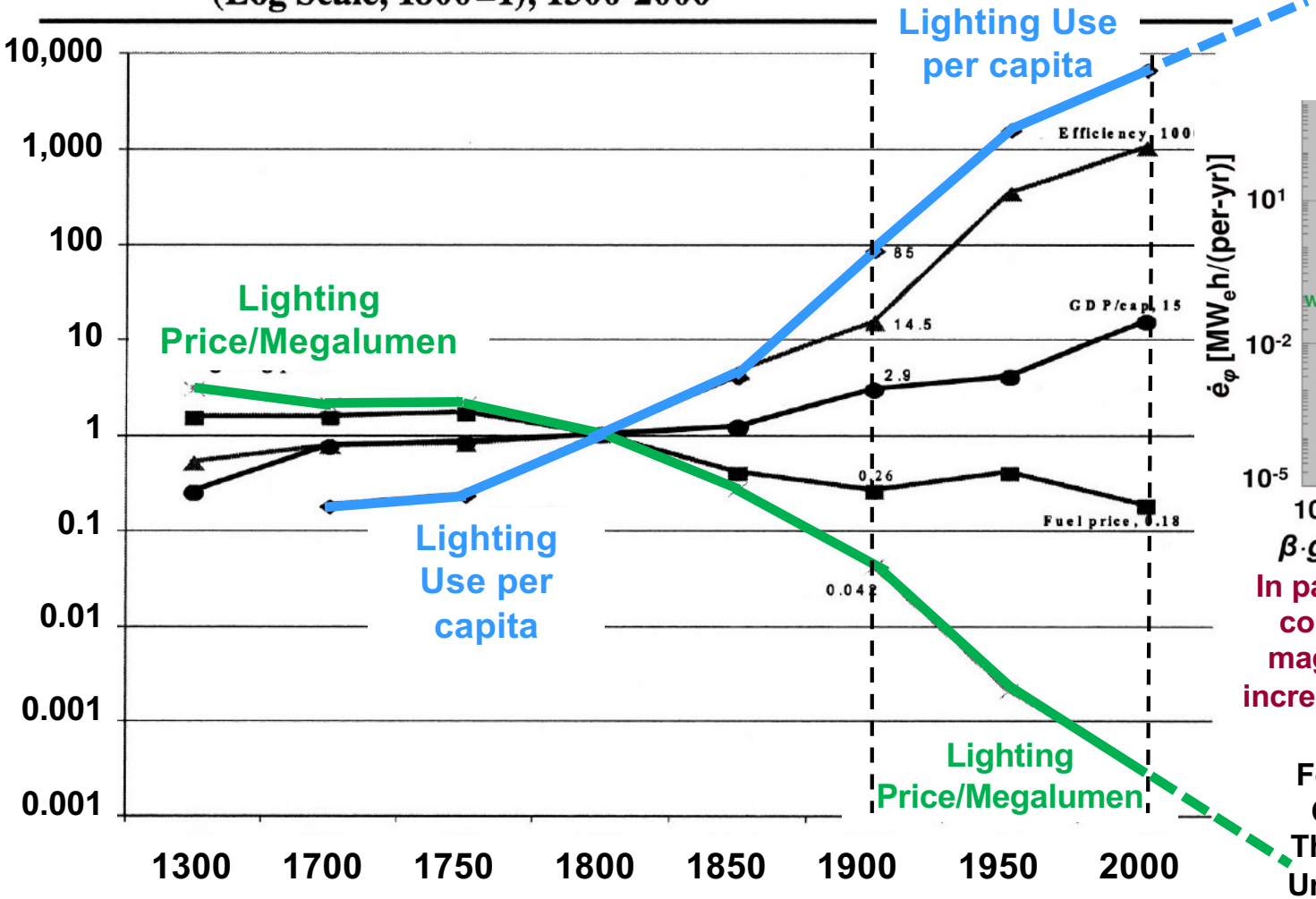
Dim light (~25 lux) **Room light (~100 lux)** **Intermittent Light**



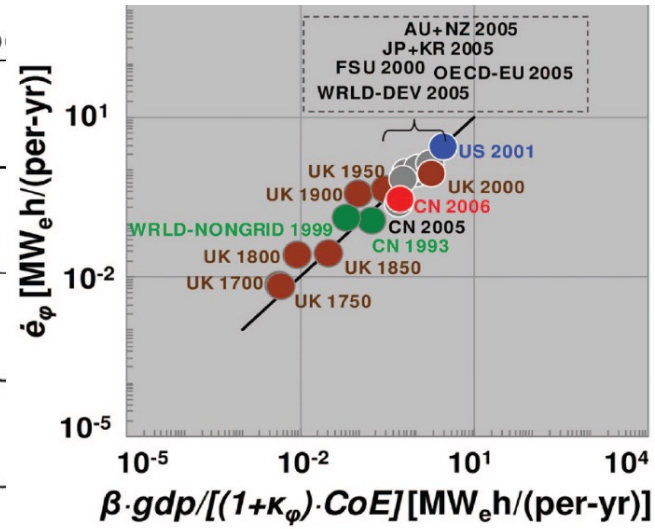
Circadian misalignment—entrainment failure **Synchronization BUT Abnormal timing** **Circadian entrainment with appropriate timing**

Gronfier C, Wright KP Jr, Kronauer RE, Czeisler CA. Entrainment of the human circadian pacemaker to longer-than-24-h days. *Proc Natl Acad Sci USA.* 2007;104:9081-6. doi: 10.1073/pnas.0702835104.

Figure 14. Indices of Key Lighting Variables in the United Kingdom (Log Scale, 1800=1), 1300-2000

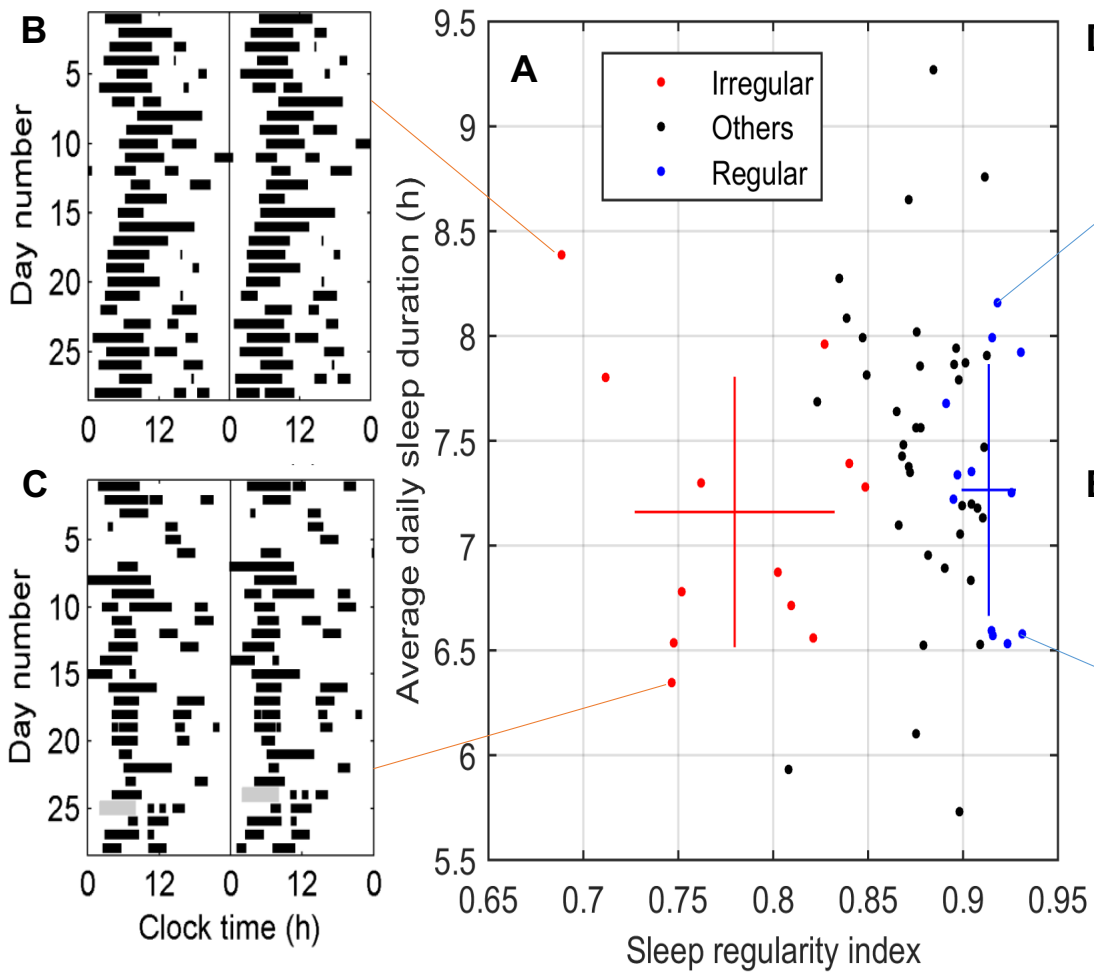


Tsao JY, Waide P. The World's Appetite for Light: Empirical Data and Trends Spanning 3 Centuries and 6 Continents. *Leukos* 6: 259-281, 2010



In past 3 centuries, per capita light consumption rose 5.4 orders of magnitude, double the per capita increase in energy consumption (2.6 orders of magnitude)

Fouquet R, Pearson PJG. Seven Centuries of Energy Services: The Price and Use of Light in the United Kingdom (1300-2000). *The Energy Journal;* 2006; 27.

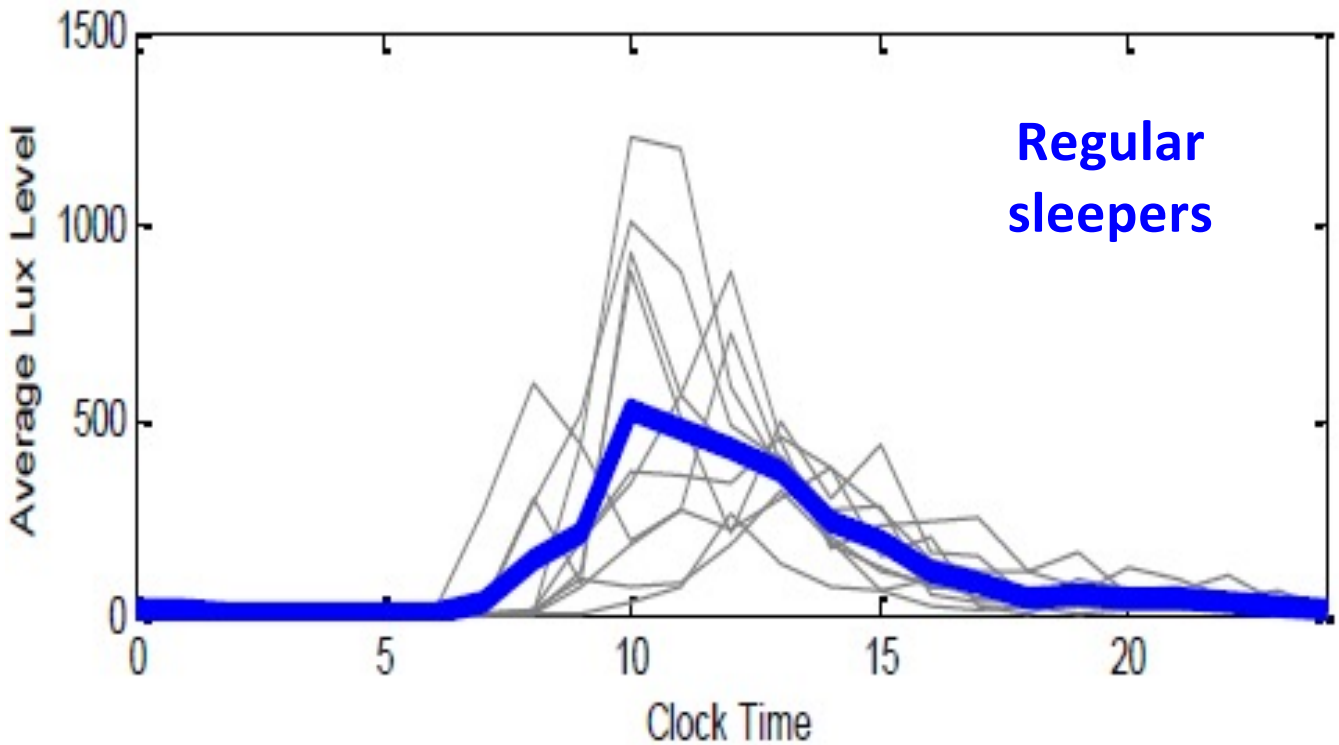


W.M. Clerx

A.J.K. Phillips, PhD

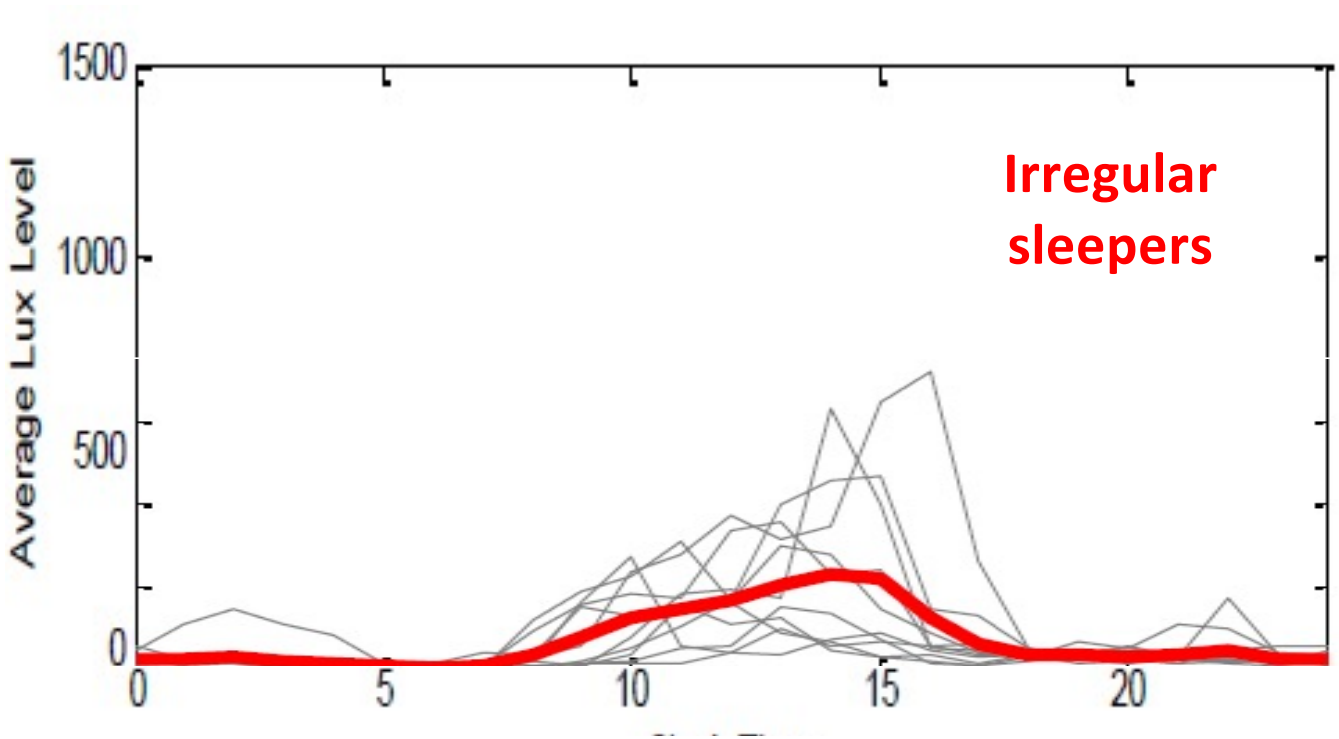
Phillips AJK, Clerx WM, O'Brien CS, Sano A, Barger LK, Picard RW, Lockley SW, Klerman EB, Czeisler CA. Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Sci Rep* 2017; 7:3216.

Light exposure



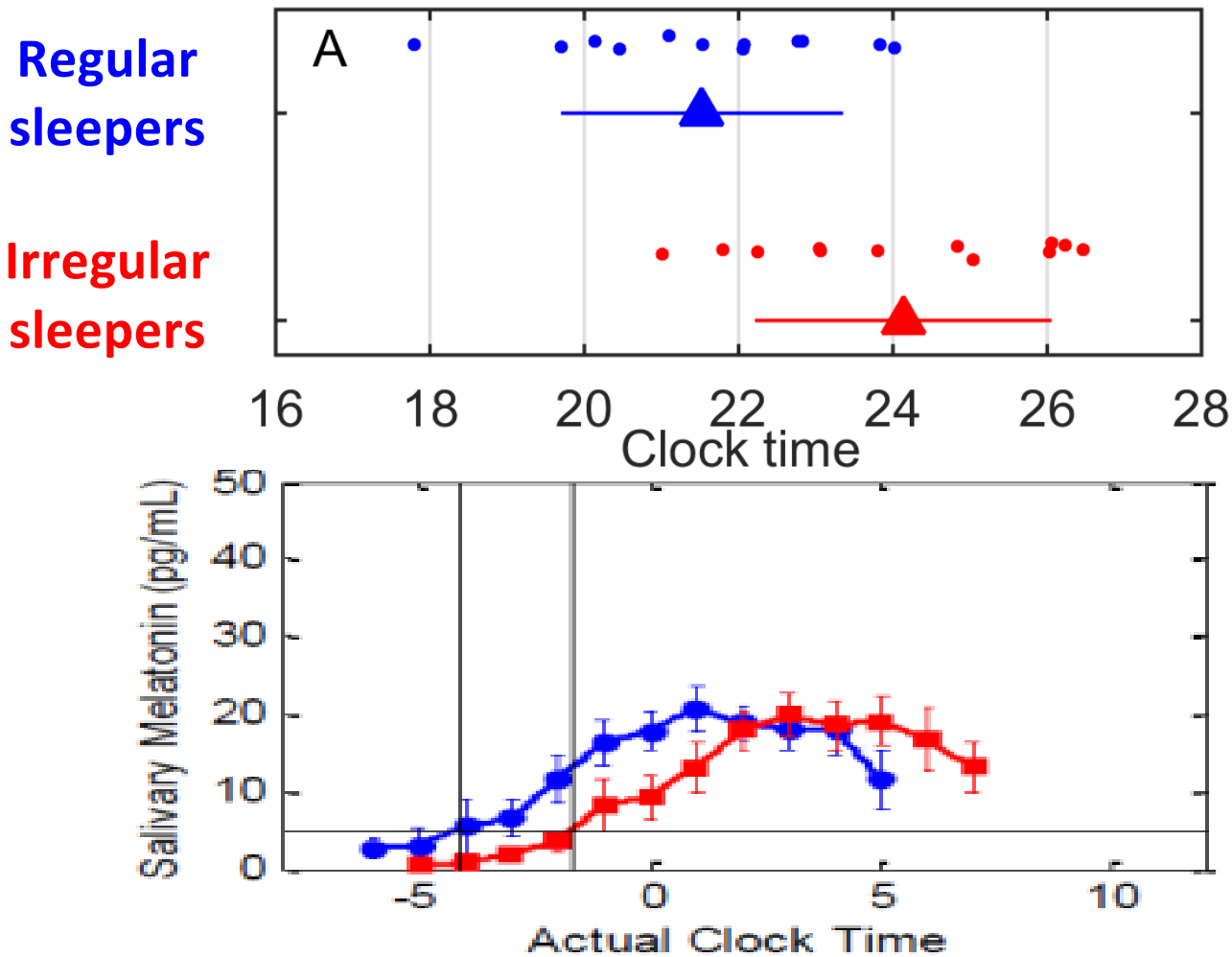
Phillips AJK, Clerx WM, O'Brien CS, Sano A, Barger LK, Picard RW, Lockley SW, Klerman EB, Czeisler CA. Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Sci Rep* 2017; 7:3216.

Light exposure



Total daily light exposure was 80% greater for regular sleepers; normalized nighttime (22:00h-10:00h) illuminance was 65% higher for irregular sleepers.

Phillips AJK, Clerx WM, O'Brien CS, Sano A, Barger LK, Picard RW, Lockley SW, Klerman EB, Czeisler CA. Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Sci Rep* 2017; 7:3216.



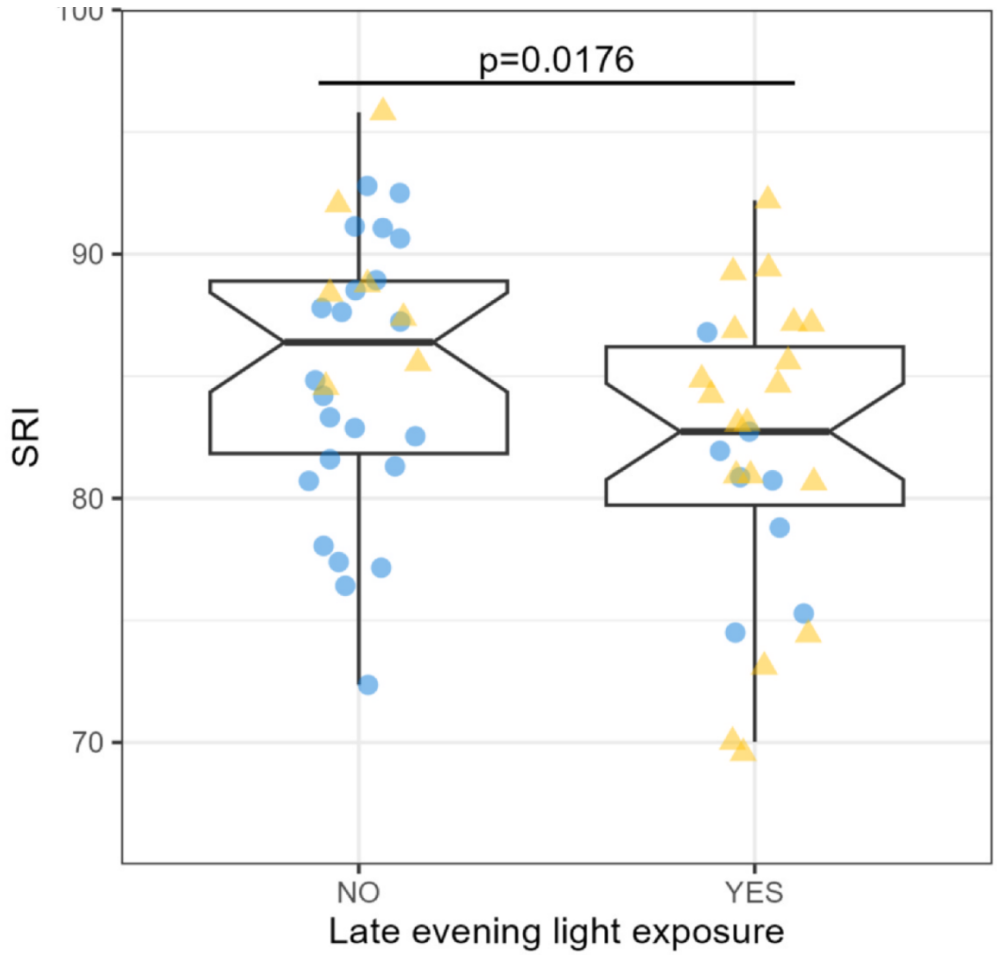
W.M. Clerx

A.J.K. Phillips, PhD

Phillips AJK, Clerx WM, O'Brien CS, Sano A, Barger LK, Picard RW, Lockley SW, Klerman EB, Czeisler CA. Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Sci Rep* 2017; 7:3216.

Visit to home in remote area near Adrianopolis, Brazil, with Fernando Louzada, PhD of the Universidade Federal do Paraná, Curitiba, Brazil

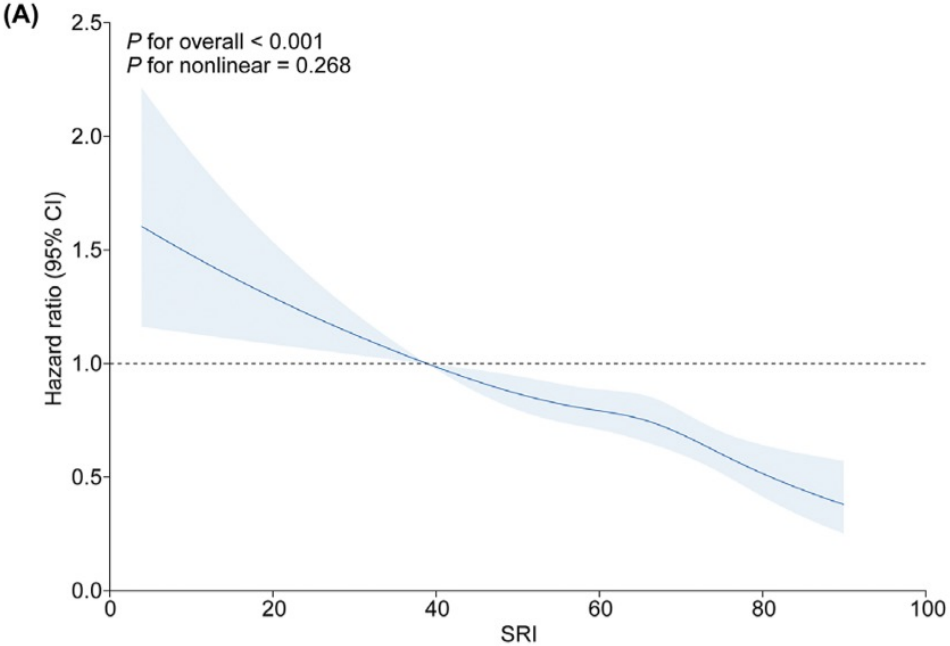
Late evening electric light exposure associated with low sleep regularity in adolescents living in rural areas



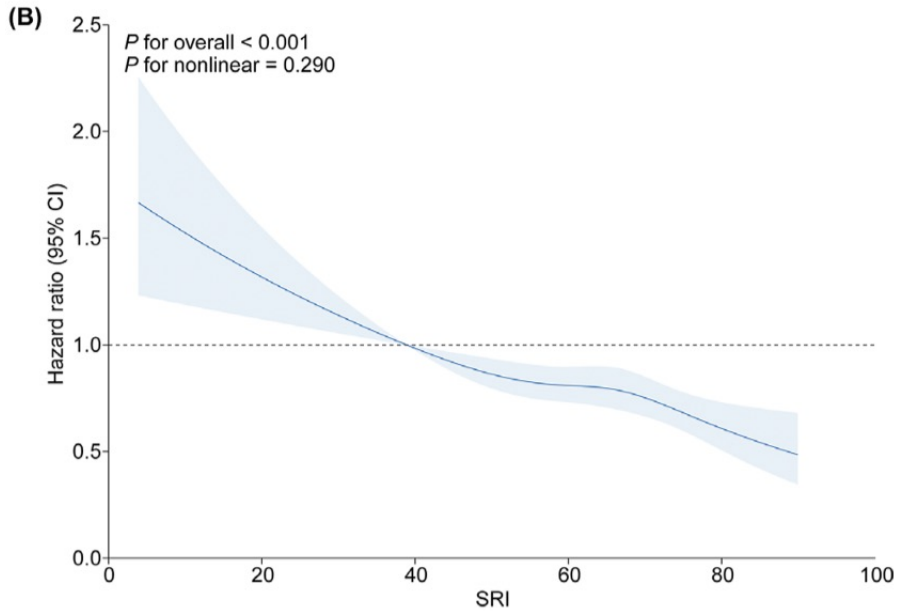
AR – Argentinian adolescents
BR – Brazilian adolescents

Louzada FM, Cesar-Silva AHA, Moreno CRC, Azevedo CVM, Casiraghi LP, de la Iglesia HO. *Sleep Health*. 2024;10(1S):S180-S183.

Major Depressive Disorder



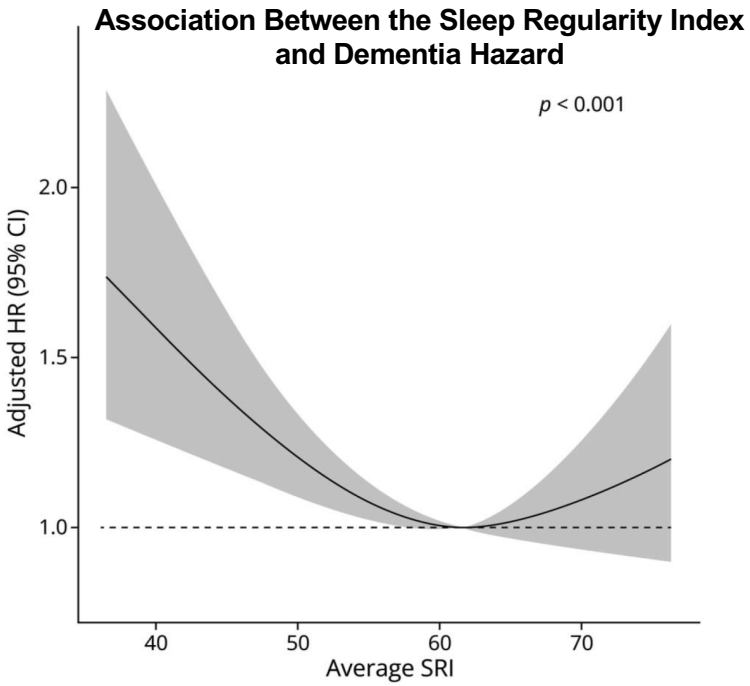
Generalized Anxiety Disorder



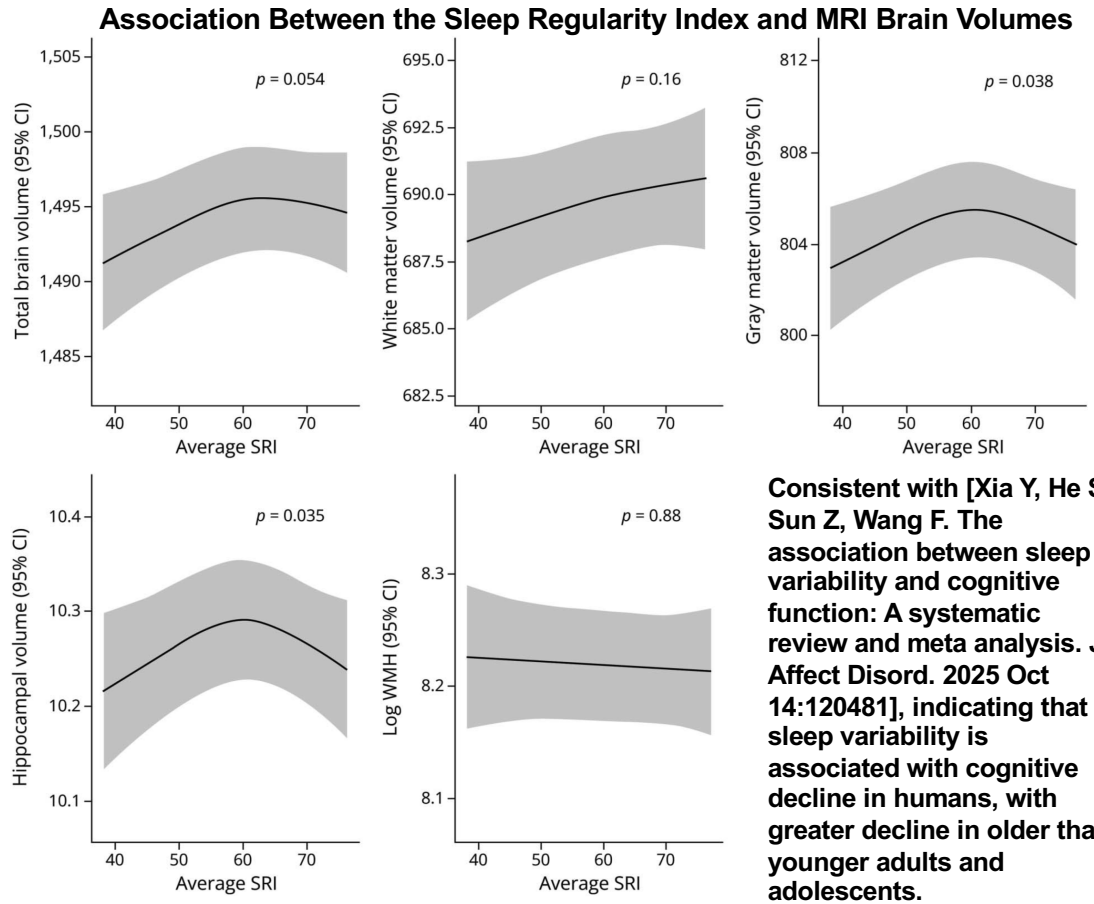
Results. During a median follow-up of 7.5 years, 1,646 participants developed depression, and 2,097 developed anxiety. Compared to irregular sleepers, regular sleepers had a 38% lower depression risk (hazard ratio [HR], 0.62; 95% confidence interval [CI], 0.52–0.73) and a 33% lower anxiety risk (HR, 0.67; 95%CI, 0.58–0.77). Participants with both irregular sleep and nonrecommended duration exhibited the highest risks (depression HR, 1.91; 95%CI, 1.55–2.35; anxiety HR, 1.61; 95%CI, 1.35–1.93). Notably, irregular sleepers who met duration guidelines still faced elevated risks (depression HR, 1.48; 95%CI, 1.18–1.86; anxiety HR, 1.35; 95%CI, 1.11–1.64).

Li, Dong-Run, et al. Regular sleep patterns, not just duration, critical for mental health: association of accelerometer-derived sleep regularity with incident depression and anxiety. *Psychological Medicine* 55 (2025): e239.

Association of the Sleep Regularity Index (as prospectively and objectively assessed from actigraphy) With Incident Dementia and Brain Volume in 88,094 UK Biobank participants followed for a median of 7.2 years



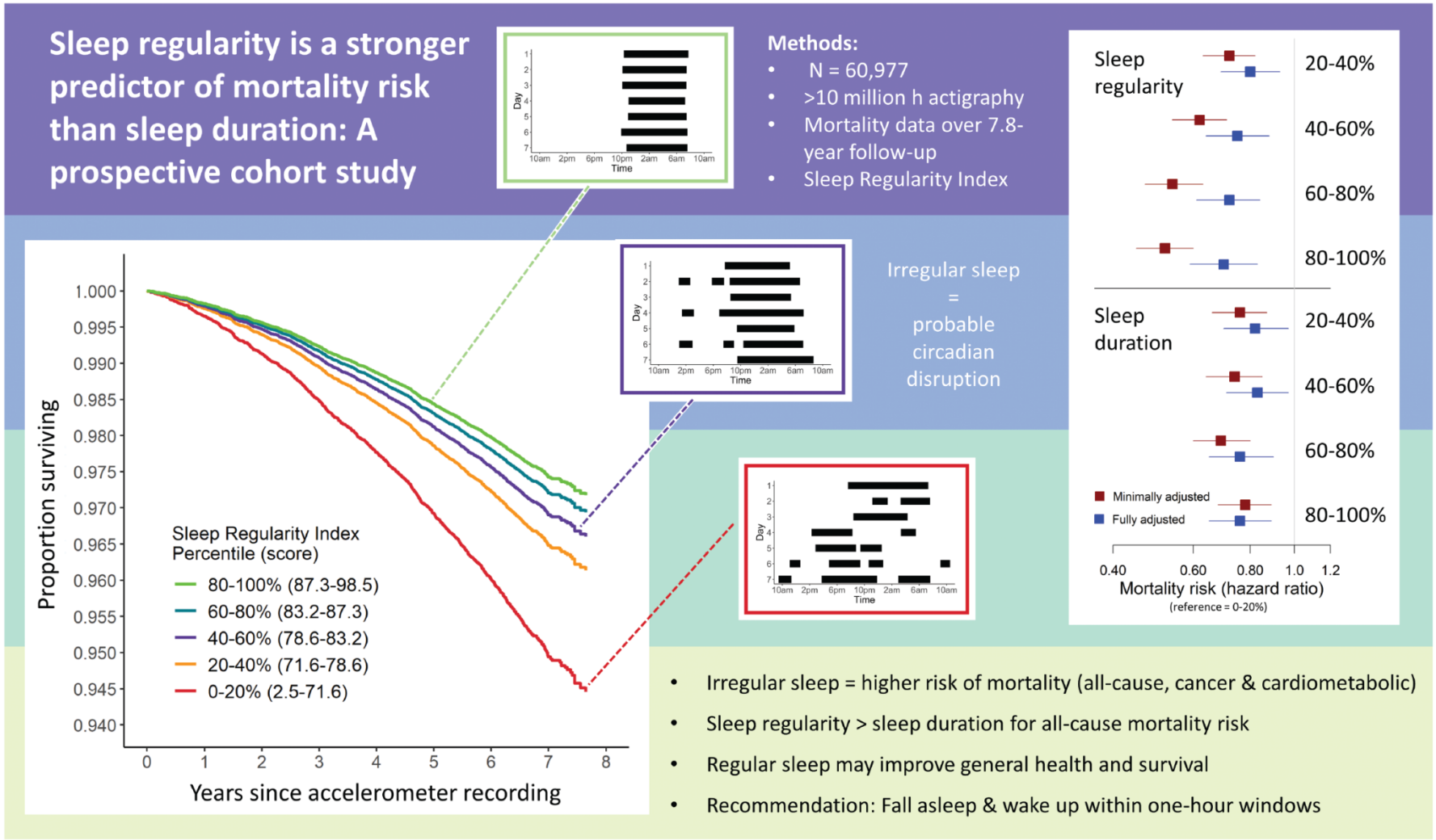
HRs for all-cause dementia diagnosis were estimated using Cox proportional hazards models, adjusting for age, sex, ethnicity, Townsend deprivation index, household income, highest level of education, smoking status, sedative use, antidepressant or antipsychotic medication, *APOE* ε4 carrier status (carrier vs noncarrier), retirement status, and shift work status. The SRI and all continuous confounders were modeled with restricted cubic splines with knots at the 10th, 50th, and 90th percentiles to allow for departures from linearity. HRs are relative to the median SRI (SRI = 60). HR = hazard ratio; SRI = sleep regularity index.



Consistent with [Xia Y, He S, Sun Z, Wang F. The association between sleep variability and cognitive function: A systematic review and meta analysis. J Affect Disord. 2025 Oct 14:120481], indicating that sleep variability is associated with cognitive decline in humans, with greater decline in older than younger adults and adolescents.

MRI outcome models were fitted using linear regression adjusting for age, sex, ethnicity, Townsend deprivation index, household income, highest level of education, smoking status, sedative use, antidepressant or antipsychotic medication, and *APOE* ε4 carrier status (carrier vs noncarrier), retirement status, shift work status, assessment site, mean tfMRI head motion, and location of head in scanner. The SRI and all continuous confounders were modeled with restricted cubic splines with knots at the 10th, 50th, and 90th percentiles to allow for departures from linearity. SRI = sleep regularity index; tfMRI = task-based fMRI.

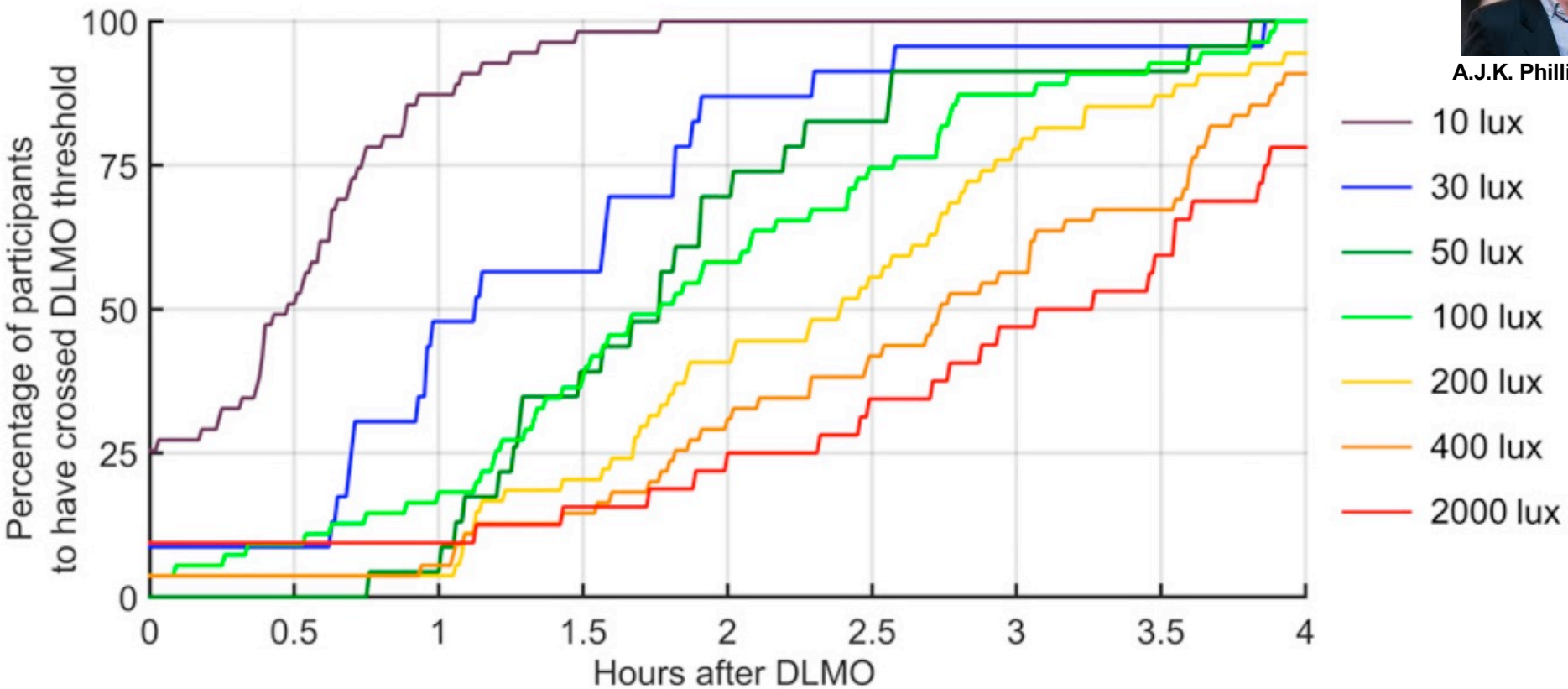
Yiallourou SR, Cribb L, Cavuoto MG, Rowsthorn E, Nicolazzo J, Gibson M, Baril AA, Pase MP. Neurology. 2024;102:e208029.



Windred DP, Burns AC, Lane JM, Saxena R, Rutter MK, Cain SW, Phillips AJK. Sleep regularity is a stronger predictor of mortality risk than sleep duration: A prospective cohort study. *Sleep*. 2024 Jan 11;47(1):zsad253.

High sensitivity and interindividual variability in melatonin suppression induced by evening light

A.J.K. Phillips, PhD



The time at which an individual crosses the DLMO threshold has a dose–response relationship with light intensity. The percentage of participants who had crossed the 4-pg/mL (DLMO) threshold at a given time after baseline DLMO. Colored curves correspond to different light intensities. From: Phillips AJK, Vidafar P, Burns AC, McGlashan EM, Anderson C, Rajaratnam SMW, Lockley SW, Cain SW. *Proc Natl Acad Sci* 2019;116:12019-12024.

Association of Exposure to Artificial Light at Night While Sleeping With Risk of Obesity in Women

RESULTS Among the population of 43 722 women (mean [SD] age, 55.4 [8.9] years), having any ALAN exposure while sleeping was positively associated with a higher prevalence of obesity at baseline, as measured using BMI (PR, 1.03; 95% CI, 1.02-1.03), WC (PR, 1.12; 95% CI, 1.09-1.16), WHR (PR, 1.04; 95% CI, 1.00-1.08), and WHtR (PR, 1.07; 95% CI, 1.04-1.09), after adjusting for confounding factors, with $P < .001$ for trend for each measure. Having any ALAN exposure while sleeping was also associated with incident obesity (RR, 1.19; 95% CI, 1.06-1.34). Compared with no ALAN, sleeping with a television or a light on in the room was associated with gaining 5 kg or more (RR, 1.17; 95% CI, 1.08-1.27; $P < .001$ for trend), a BMI increase of 10% or more (RR, 1.13; 95% CI, 1.02-1.26; $P = .04$ for trend), incident overweight (RR, 1.22; 95% CI,1.06-1.40; $P = .03$ for trend), and incident obesity (RR, 1.33; 95% CI, 1.13-1.57; $P < .001$ for trend). Results were supported by sensitivity analyses and additional multivariable analyses including potential mediators such as sleep duration and quality, diet, and physical activity.

Prospective study: mean 5.7 year observation

women aged 35 to 74 years enrolled in the Sister Study

No history of cancer or CVD
Not shift workers, daytime sleepers, or pregnant at baseline

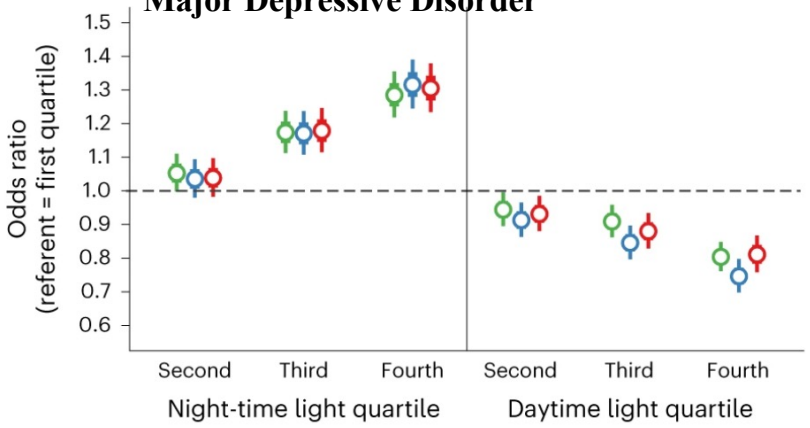
Park YM, White AJ, Jackson CL, Weinberg CR, Sandler DP. JAMA Intern Med. 2019 Jun 10. doi: 10.1001/jamainternmed.2019.0571.

nature mental health

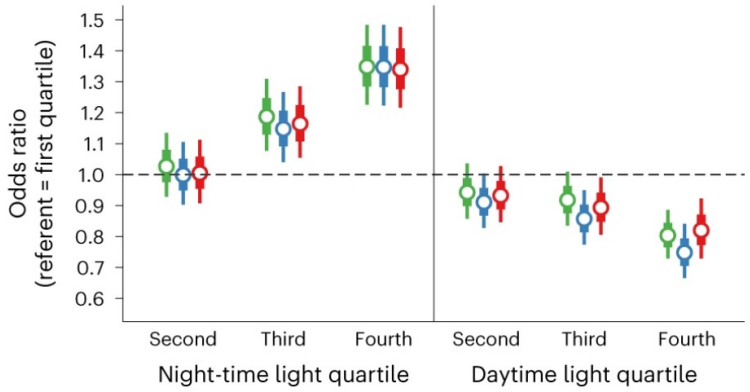
Day and night light exposure are associated with psychiatric disorders: an objective light study in >85,000 people

Angus C. Burns, Daniel P. Windred, Martin K. Rutter, Patrick Olivier, Céline Vetter, Richa Saxena, Jacqueline M. Lane, Andrew J. K. Phillips & Sean W. Cain

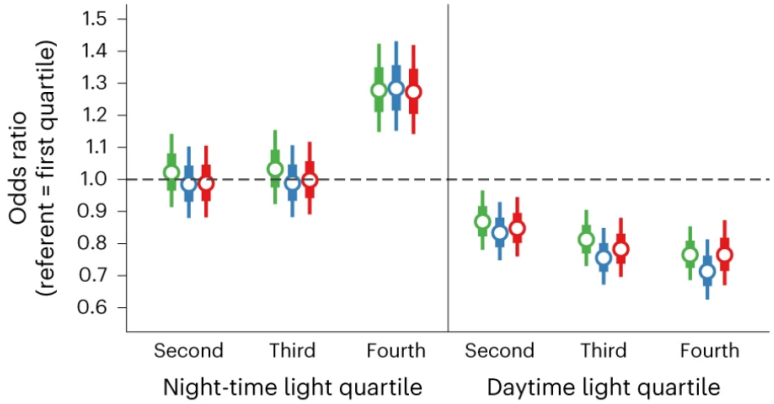
Major Depressive Disorder



PTSD



Self-harm



Psychosis

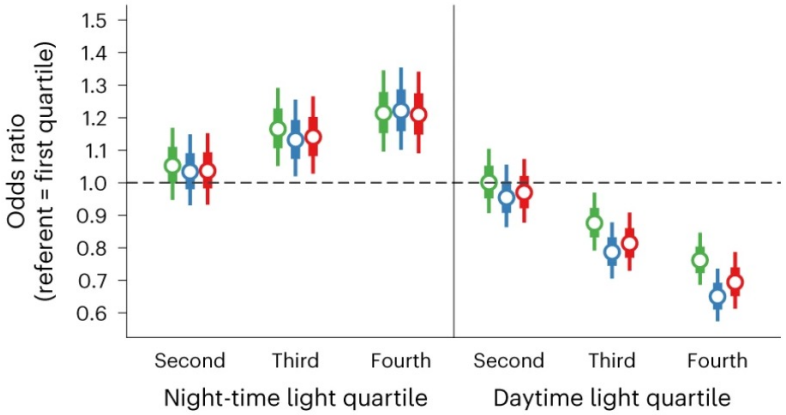
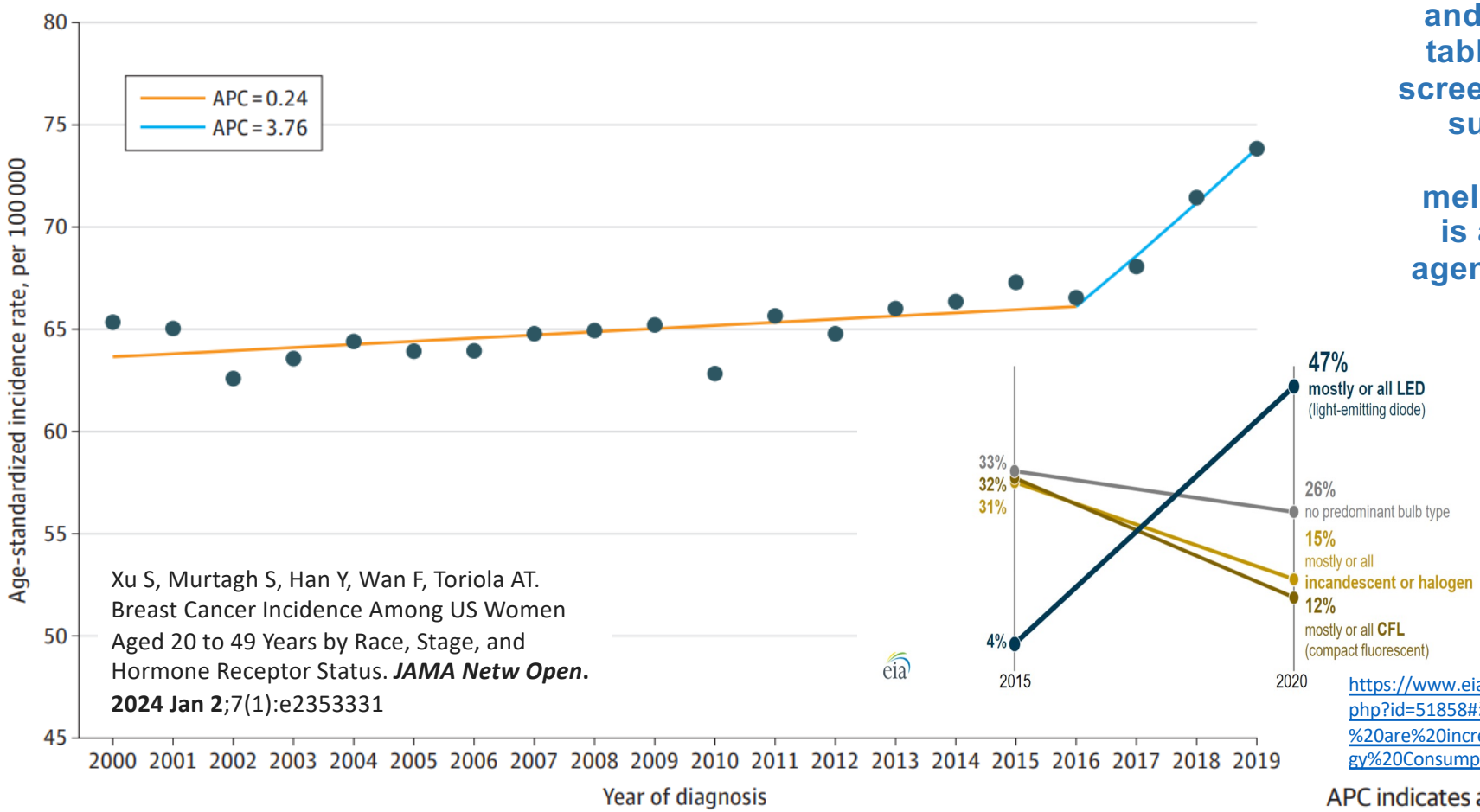


Figure 1. Joinpoint Analysis of Overall Incidence of Primary Invasive Breast Cancer Among US Women Aged 20 to 49 Years, 2000-2019



Xu S, Murtagh S, Han Y, Wan F, Toriola AT. Breast Cancer Incidence Among US Women Aged 20 to 49 Years by Race, Stage, and Hormone Receptor Status. ***JAMA Netw Open*. 2024 Jan 2**;7(1):e2353331

APC indicates annual percent changes.

Exposure to blue enriched light from LED lamps and smartphone, tablet and laptop screens after dusk suppresses the release of melatonin, which is an oncostatic agent that retards the growth of cancer cells

Source: U.S. Energy Information Administration, *Residential Energy Consumption Survey* (RECS)

https://www.eia.gov/todayinenergy/detail.php?id=51858#:~:text=U.S.%20households%20are%20increasingly%20switching,Energy%20Consumption%20Survey%20(RECS).

Table 2. Risk of Cardiovascular Outcomes According to Light Exposure Percentile Groups Across Models 1 to 3[a]

Light exposure by percentile	Coronary artery disease, HR (95% CI)	*P* value	Myocardial infarction, HR (95% CI)	*P* value	Heart failure, HR (95% CI)	*P* value	Atrial fibrillation, HR (95% CI)	*P* value	Stroke, HR (95% CI)	*P* value
Model 1										
Night										
0-50	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA
51-70	1.12 (1.03-1.23)[b]	.008	1.20 (1.05-1.36)[b]	.006	1.15 (1.01-1.30)[b]	.04	1.10 (1.01-1.20)[b]	.02	1.08 (0.93-1.26)	.32
71-90	1.20 (1.10-1.31)[b]	<.001	1.27 (1.12-1.44)[b]	<.001	1.21 (1.06-1.37)[b]	.003	1.13 (1.03-1.23)[b]	.007	1.10 (0.95-1.28)	.21
91-100	1.32 (1.18-1.46)[b]	<.001	1.47 (1.26-1.71)[b]	<.001	1.56 (1.34-1.81)[b]	<.001	1.32 (1.18-1.46)[b]	<.001	1.28 (1.06-1.55)[b]	.009
Day										
0-50	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA	1 [Reference]	NA-
51-70	0.99 (0.91-1.09)	.88	0.93 (0.81-1.06)	.25	0.92 (0.81-1.04)	.18	1.00 (0.92-1.10)	.96	0.89 (0.76-1.04)	.15
71-90	0.95 (0.86-1.05)	.32	0.89 (0.77-1.03)	.11	0.75 (0.65-0.86)[b]	<.001	0.93 (0.84-1.02)	.14	0.92 (0.78-1.09)	.34
91-100	0.87 (0.77-0.98)[b]	.03	0.91 (0.77-1.09)	.33	0.72 (0.60-0.86)[b]	<.001	0.93 (0.82-1.05)	.23	0.73 (0.58-0.93)[b]	.009

Abbreviations: HR, hazard ratio; NA, not applicable.

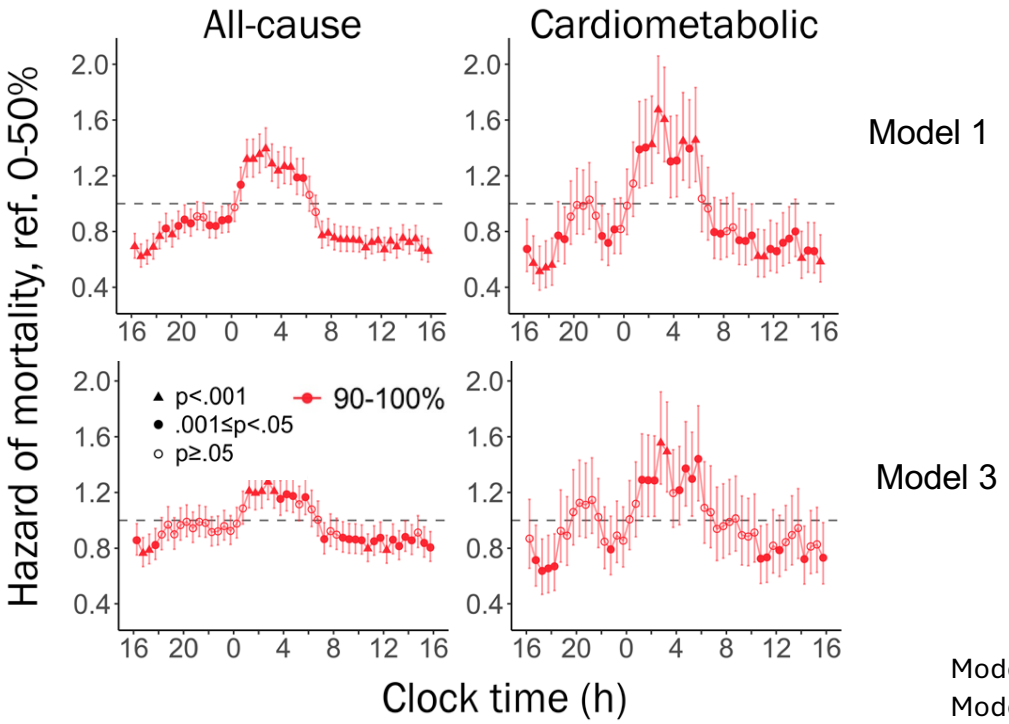
[a] HRs (95% CIs) adjusted for age, sex, ethnicity, and photoperiod (model 1); additionally adjusted for education, employment, income, and deprivation (model 2); and further adjusted for physical activity, smoking status, alcohol consumption, diet, and urbanicity (model 3). Case numbers by light exposure percentile groups for each model are reported in eTable 5 in Supplement 1.

[b] $P < .05$.

In this cohort study of 88 905 adults aged older than 40 years, exposure to brighter light at night was associated with higher risks of coronary artery disease, myocardial infarction, heart failure, atrial fibrillation, and stroke, independent of established cardiovascular risk factors. These findings suggest that **avoiding exposure to night light may lower risk of cardiovascular diseases**.

Windred DP, Burns AC, Rutter MK, Lane JM, Saxena R, Scheer FAJL, Cain SW, Phillips AJK. Light Exposure at Night and Cardiovascular Disease Incidence. *JAMA Netw Open*. 2025 Oct 1;8(10):e2539031. doi: 10.1001/jamanetworkopen.2025.39031.

Increased light at night and decreased light during the day associated with increased mortality



90 to 100% light percentile referenced against 0 to 50%

Windred DP, Burns AC, Lane JM, Olivier P, Rutter MK, Saxena R, Phillips AJK, Cain SW. Brighter nights and darker days predict higher mortality risk: A prospective analysis of personal light exposure in >88,000 individuals. Proc Natl Acad Sci U S A. 2024;121:e2405924121.

Model 1 adjusted for age, sex, ethnicity, and photoperiod
Model 3 adjusted additionally adjusted for employment status, education, income, deprivation, physical activity, smoking status, alcohol consumption, urbanicity, and social activity

This Room Is Equipped With

Edison Electric Light.

Do not attempt to light with match. Simply turn key on wall by the door.

The use of Electricity for lighting is in no way harmful to health, nor does it affect the soundness of sleep.

DIVISION OF
SLEEP MEDICINE
HARVARD MEDICAL SCHOOL

Brigham and Women's Hospital
Founding Member, Mass General Brigham

National Heart, Lung and Blood Institute (NHLBI)
National Institute of Mental Health
National Institute for Neurological Disease & Stroke (NINDS)
National Institute on Aging (NIA)
National Institute of General Medical Sciences (NIGMS)
National Institute of Diabetes and Digestive and Kidney Diseases
National Aeronautics and Space Administration (NASA)
National Space Biomedical Research Institute (NSBRI)
Naval Medical Research and Development Command
Air Force Office of Scientific Research (AFOSR)
Defense Advanced Research Projects Agency (DARPA)
Department of Defense
Agency for Healthcare Research and Quality (AHRQ)
National Institute of Occupational Health and Safety
Harvard Catalyst
National Center for Advancing Translational Sciences (NCATS)
Philips Lighting
Harvard Medical School
National Geographic Society
Brigham and Women's Hospital