Effects of Light Spectrum on Circadian, Neuroendocrine and Neurobehavioral Regulation in Humans

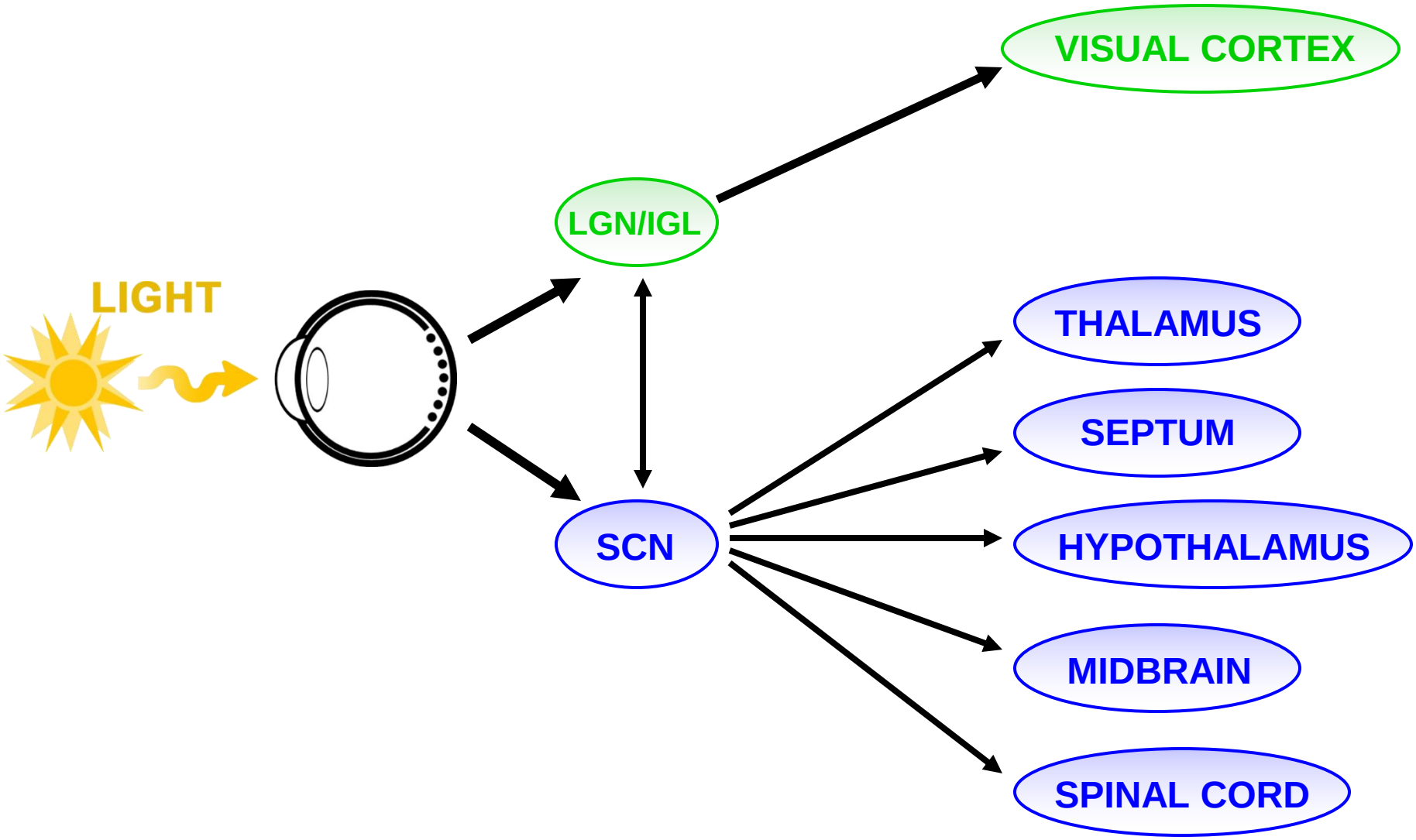
John P. Hanifin, Ph.D. & George C. Brainard, Ph.D.
The Light Research Program
Thomas Jefferson University, Philadelphia, PA

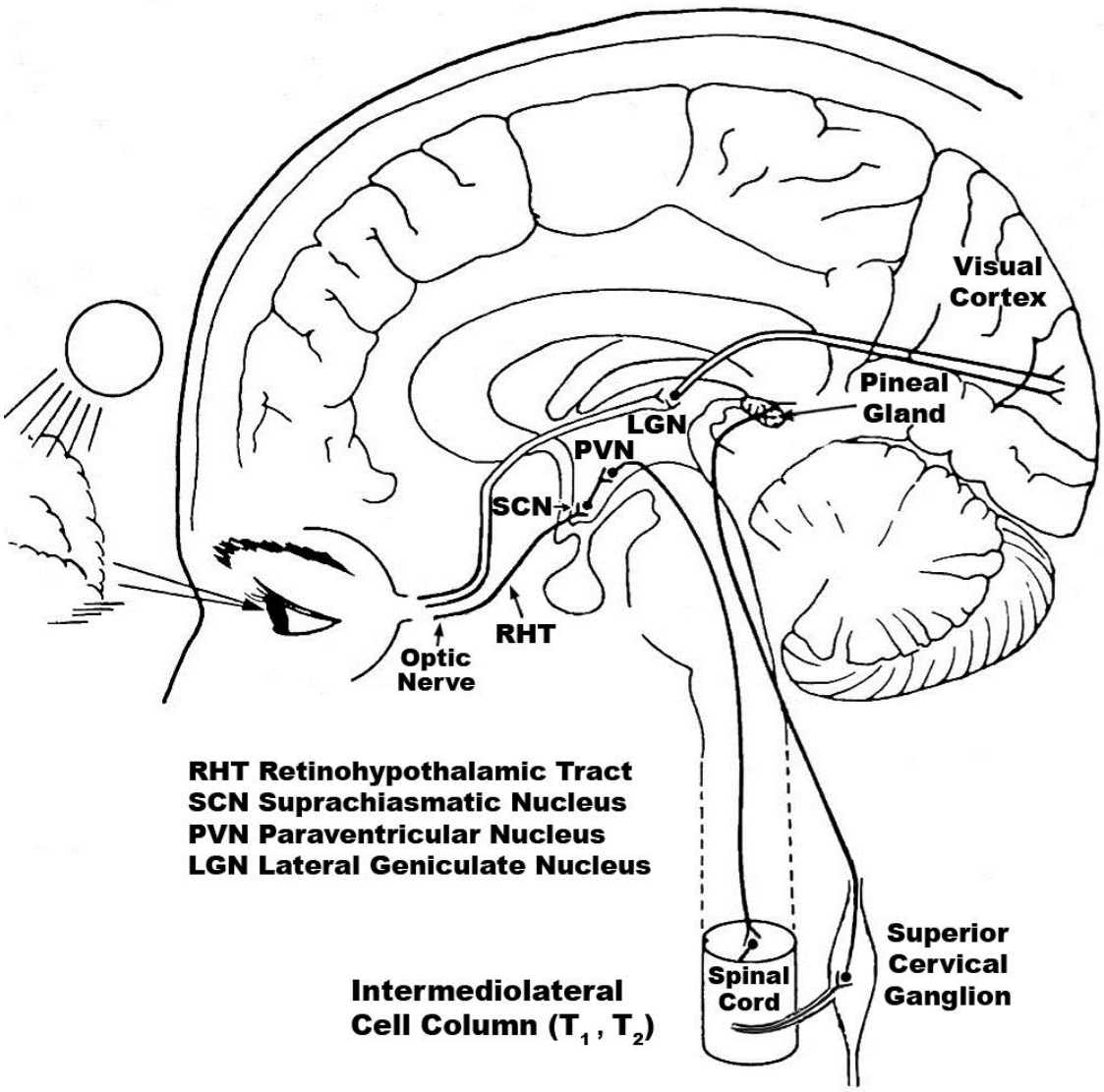
Effects of Light Spectrum on Circadian, Neuroendocrine and Neurobehavioral Regulation in Humans

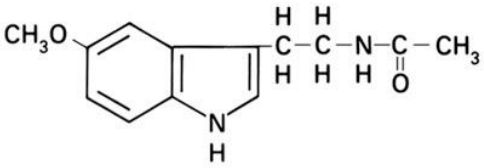
Federal Support: National Institutes of Health (NINDS, NIMH, NCI, NCCAM), National Science Foundation, NASA, National Space Biomedical Research Institute, DOD, FDA

Industry Support: Lutron, Philips Lighting, OSRAM, Panasonic, Apollo Lighting, Lighting Sciences Group, BioBrite Inc.

Philanthropic Support: IESNA Philadelphia Section, Keller Corporation, Philips Lighting, The Institute for Integrative Health







MELATONIN

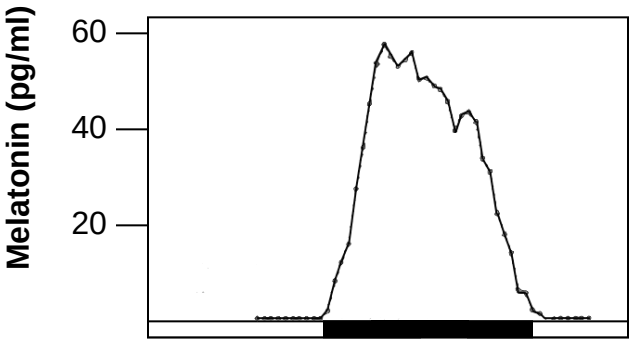
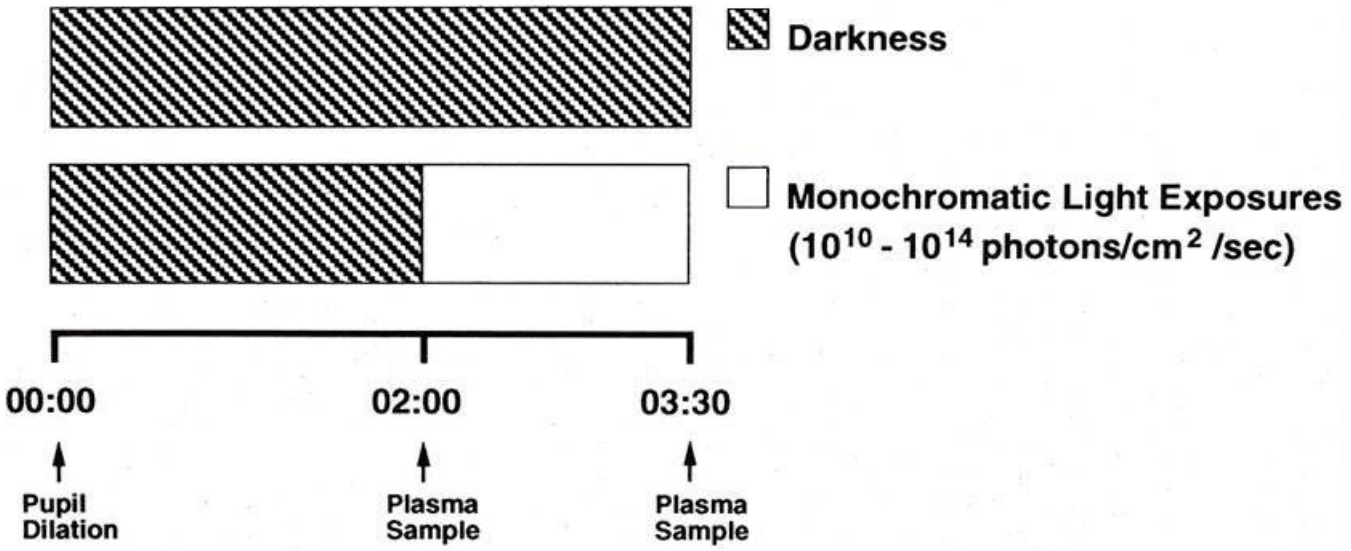
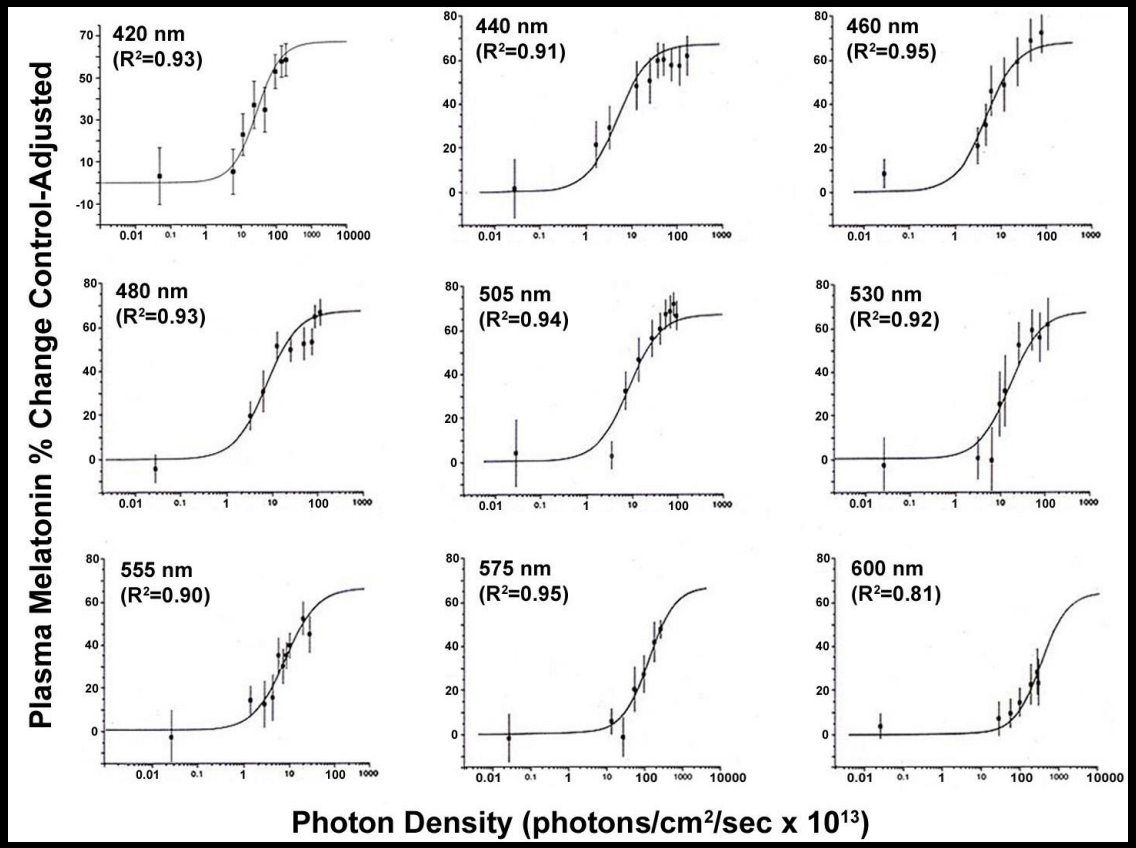


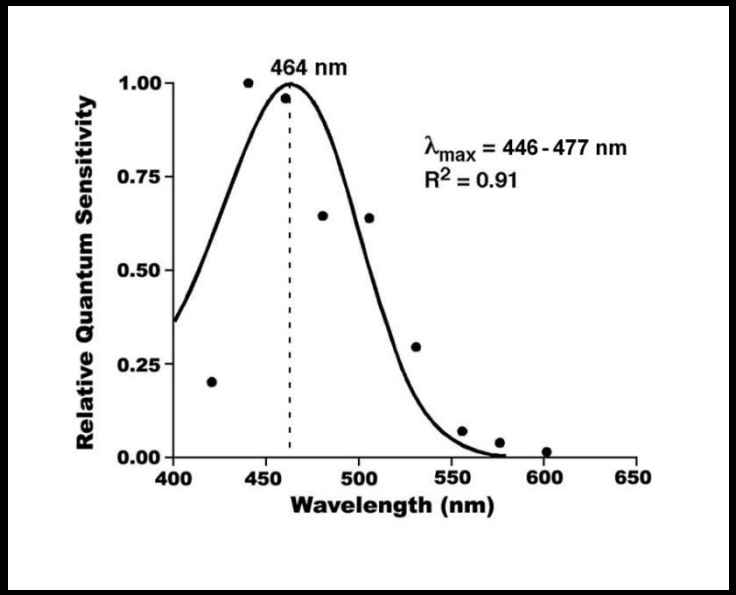
Figure adapted from NY Times, 1980

Action Spectrum Protocol



Exposures in Healthy Subjects (N=72) Fitted to Univariant Curves





Brainard et al., J. Neuroscience 2001; J. Biol. Rhythms 2008

SHORT WAVELENGTH ACTION SPECTRA

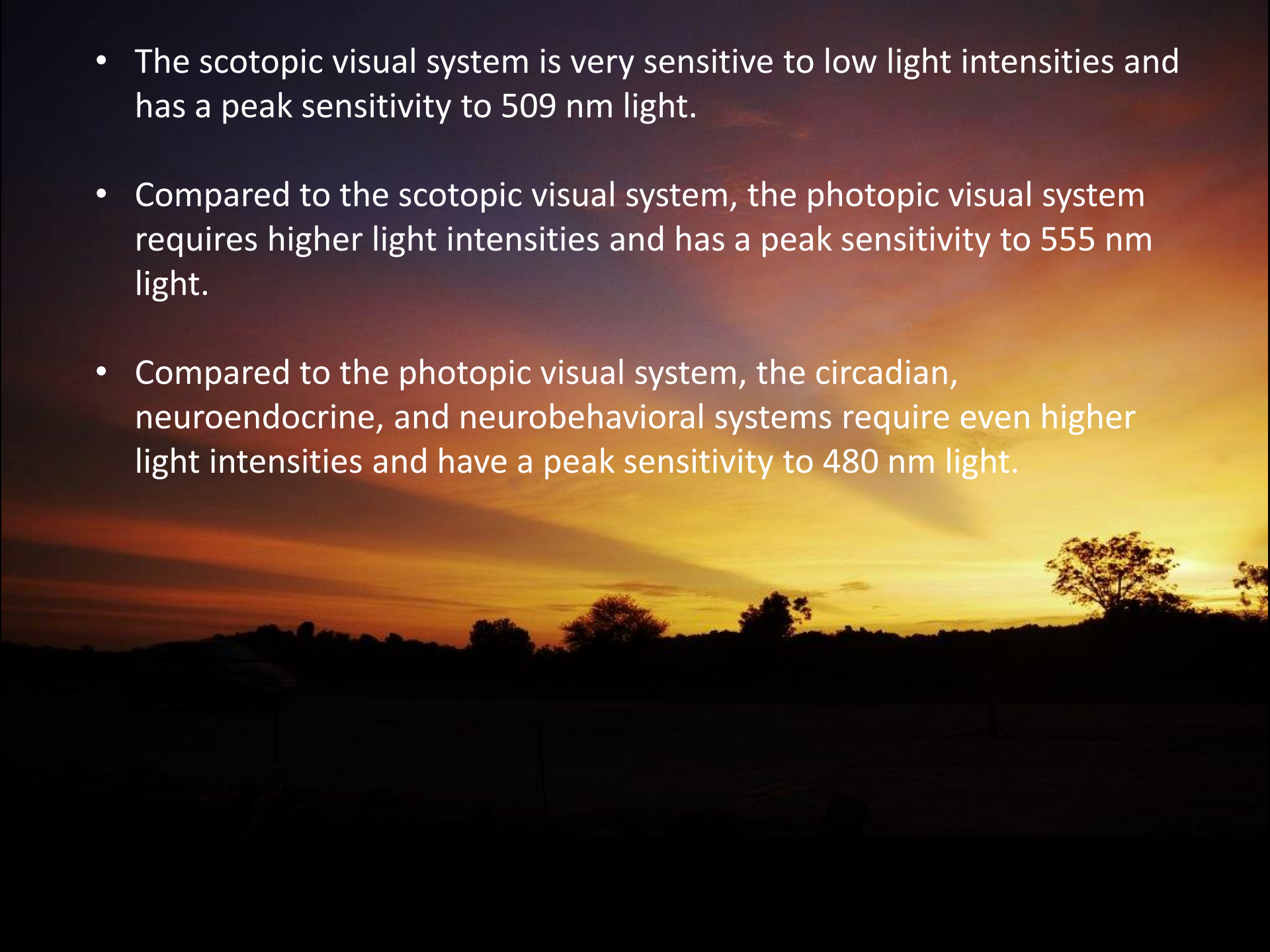
λ Max	Species	Response	Author, Year
480	Mouse *rd/rd*	Circadian Phase-Shifting	Yoshimura 1996
464	Human	Melatonin Suppression	Brainard 2001
459	Human	Melatonin Suppression	Thapan 2001
479	Mouse *rd/rd*	Pupillary Light Reflexes	Lucas 2001
483	Human	Cone Cell ERG–wave	Hankins 2002
484	Rat	Ganglion Cell Depolarization	Berson 2002
481	Mouse *rd/rd cl*	Circadian Phase-Shifting	Hattar 2003
482	Monkey	Ganglion Cell Depolarization	Dacey 2005
482	Monkey/Human	Pupillary Light Reflex	Gamlin 2007
480	Human	Pupillary Light Reflex	Zaidi 2007

For reviews see *Brainard GC and Hanifin JP (2005) Photons, clocks and consciousness. J Biol Rhythms 20:314-325* and *Lucas RJ, Peirson SN, Berson DM, Brown TM, Cooper HM, Czeisler CA, Figueiro MG, Gamlin PD, Lockley SW, O'Hagan JB, Price LLA, Provencio I, Skene DJ and Brainard GC (2014) Measuring and using light in the melanopsin age. Trends Neurosci 37:1-9.*

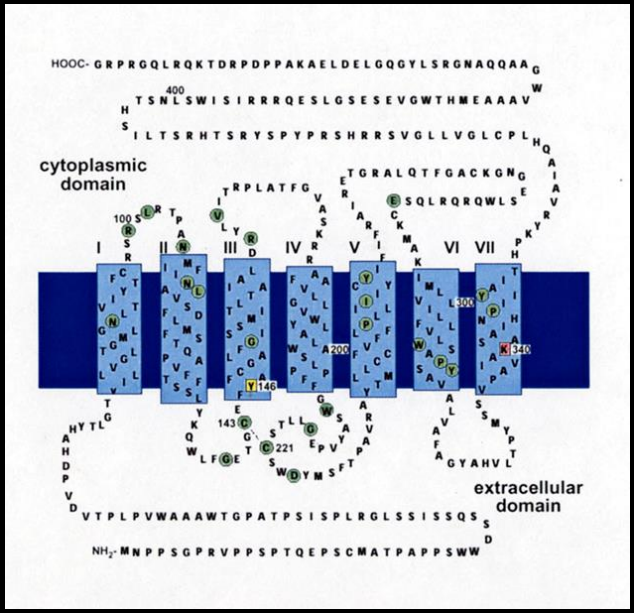
- The scotopic visual system is very sensitive to low light intensities and has a peak sensitivity to 509 nm light.

- Compared to the scotopic visual system, the photopic visual system requires higher light intensities and has a peak sensitivity to 555 nm light.

- Compared to the photopic visual system, the circadian, neuroendocrine, and neurobehavioral systems require even higher light intensities and have a peak sensitivity to 480 nm light.



Human Melanopsin
Provencio et al. *J. Neurosci.* 2000



Gooley et al. *Nature Neurosci.* 2001

Berson et al. *Science* 2002

Hattar et al. *Science* 2002

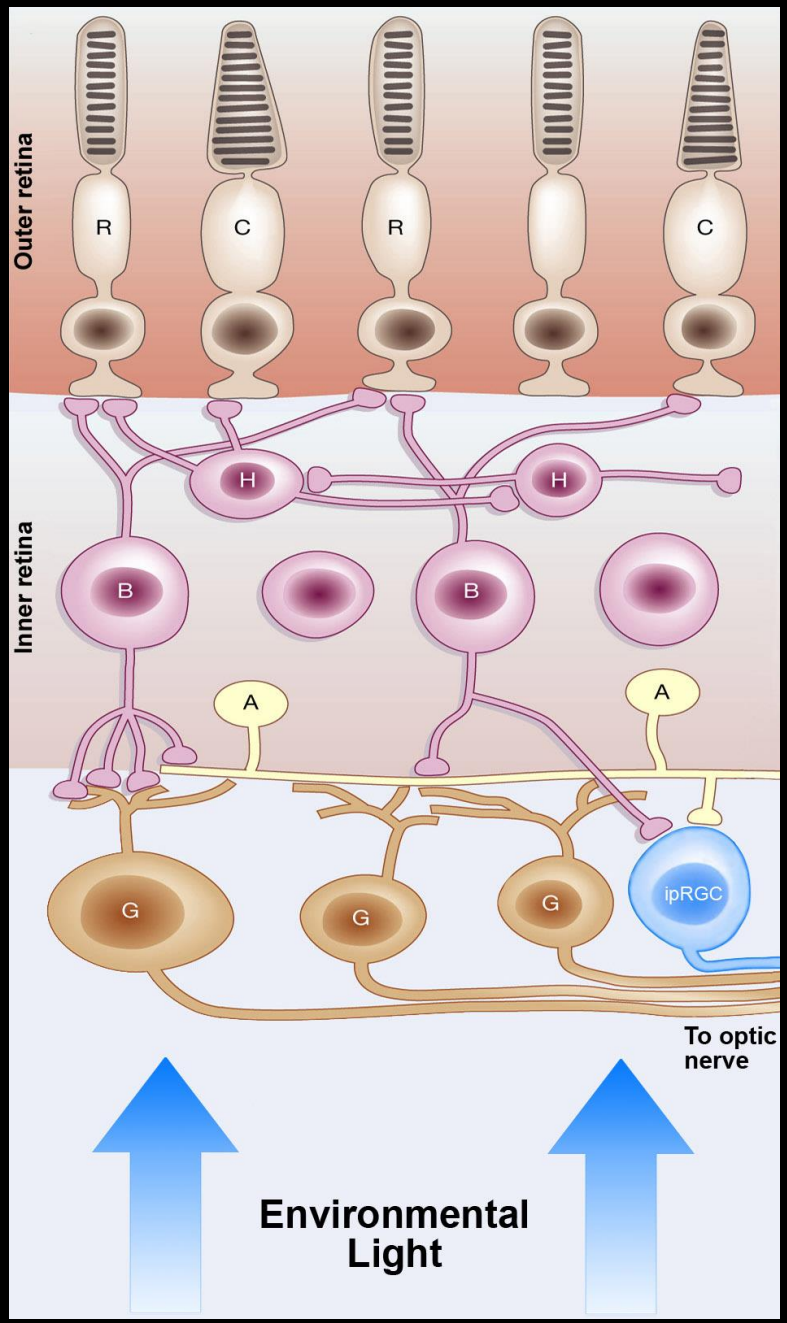
Provencio et al. *Nature* 2002

Hattar et al. *Science* 2003

Qiu et al. *Nature* 2005

Altimus et al. *Nature Neurosci.* 2010

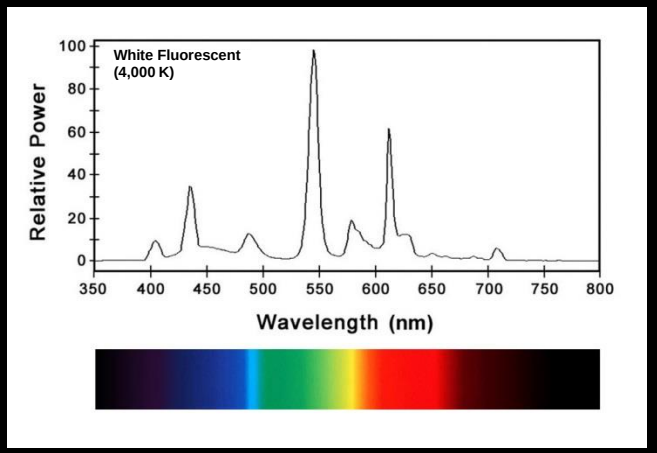
Lall et al. *Neuron* 2010



Adapted from Foster *Nature* 2005

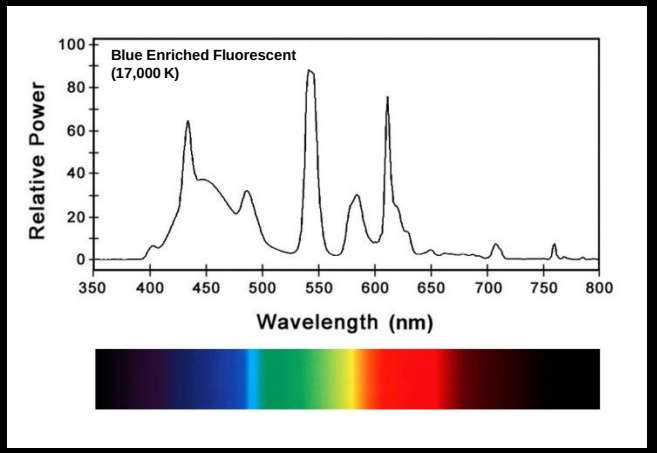
4,000 K

Exposure System



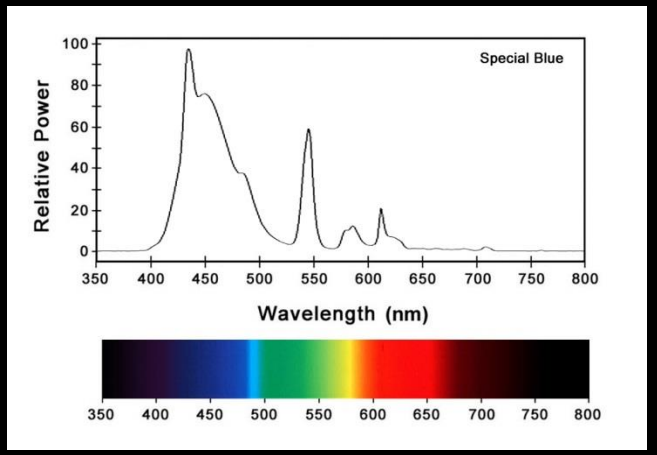
17,000 K

Exposure System

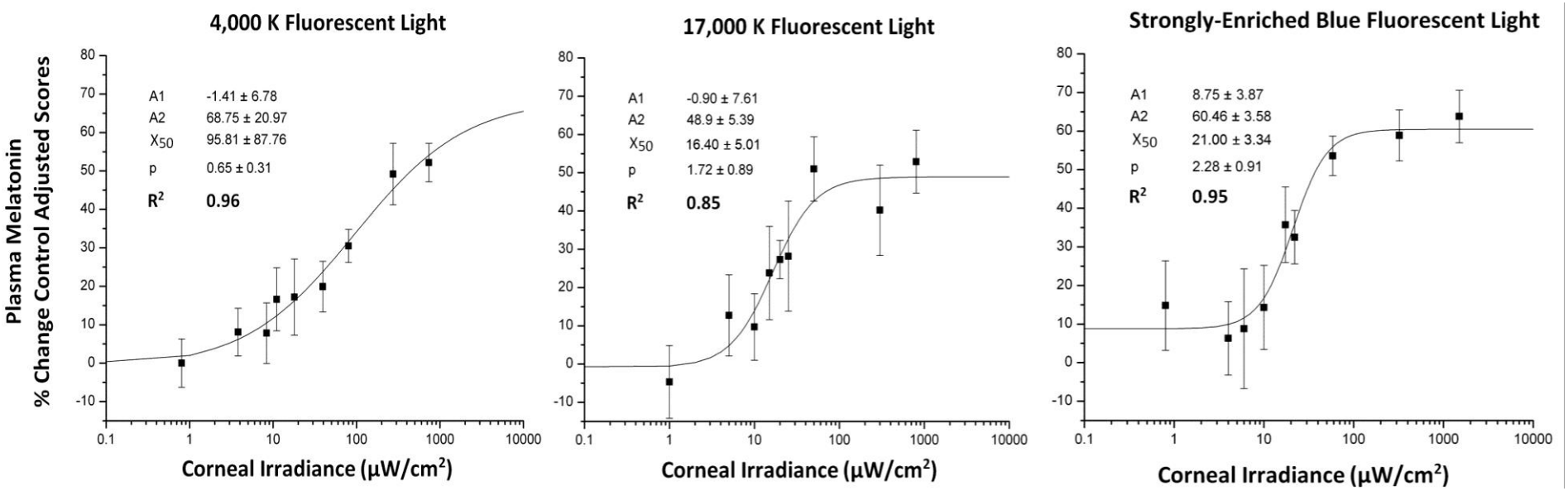


Strongly-Enriched Blue

Exposure System



Polychromatic Fluence Response Curves (N=24)



4,000 K ED_{50} = 95.81

17,000 K ED_{50} = 16.40

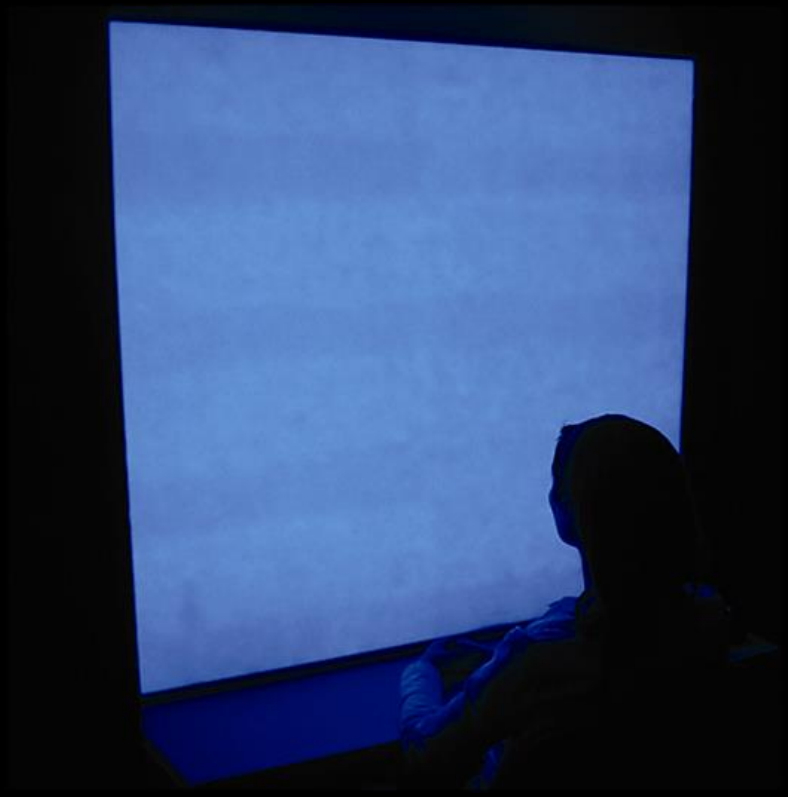
SEB ED_{50} = 21.00

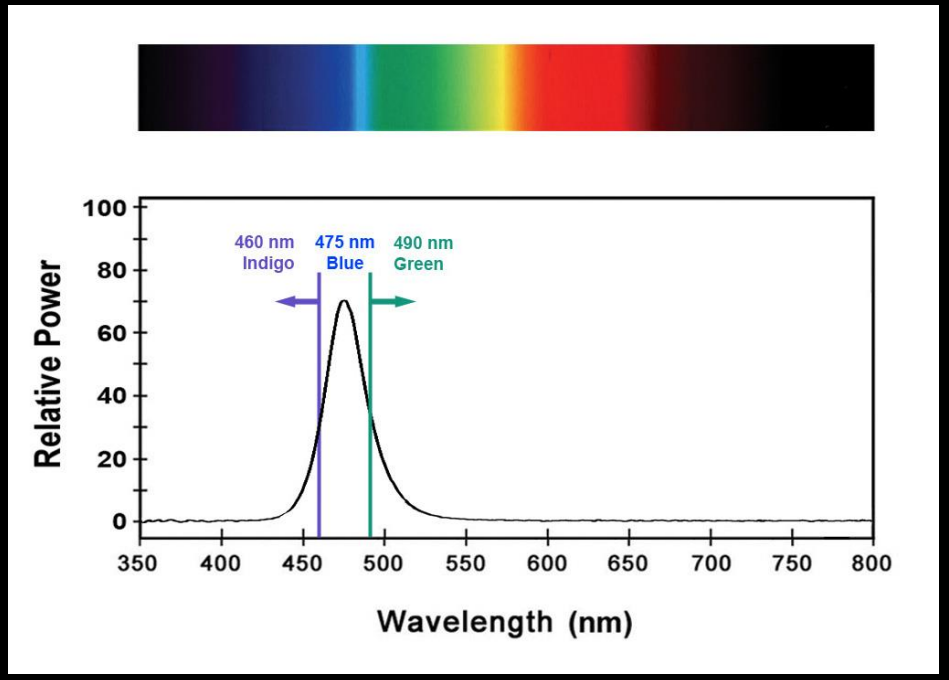
CONCLUSION I: Short wavelength enrichment increase potency 5-6 X

CONCLUSION II: The results show that monochromatic data do not completely predict the performance of polychromatic light

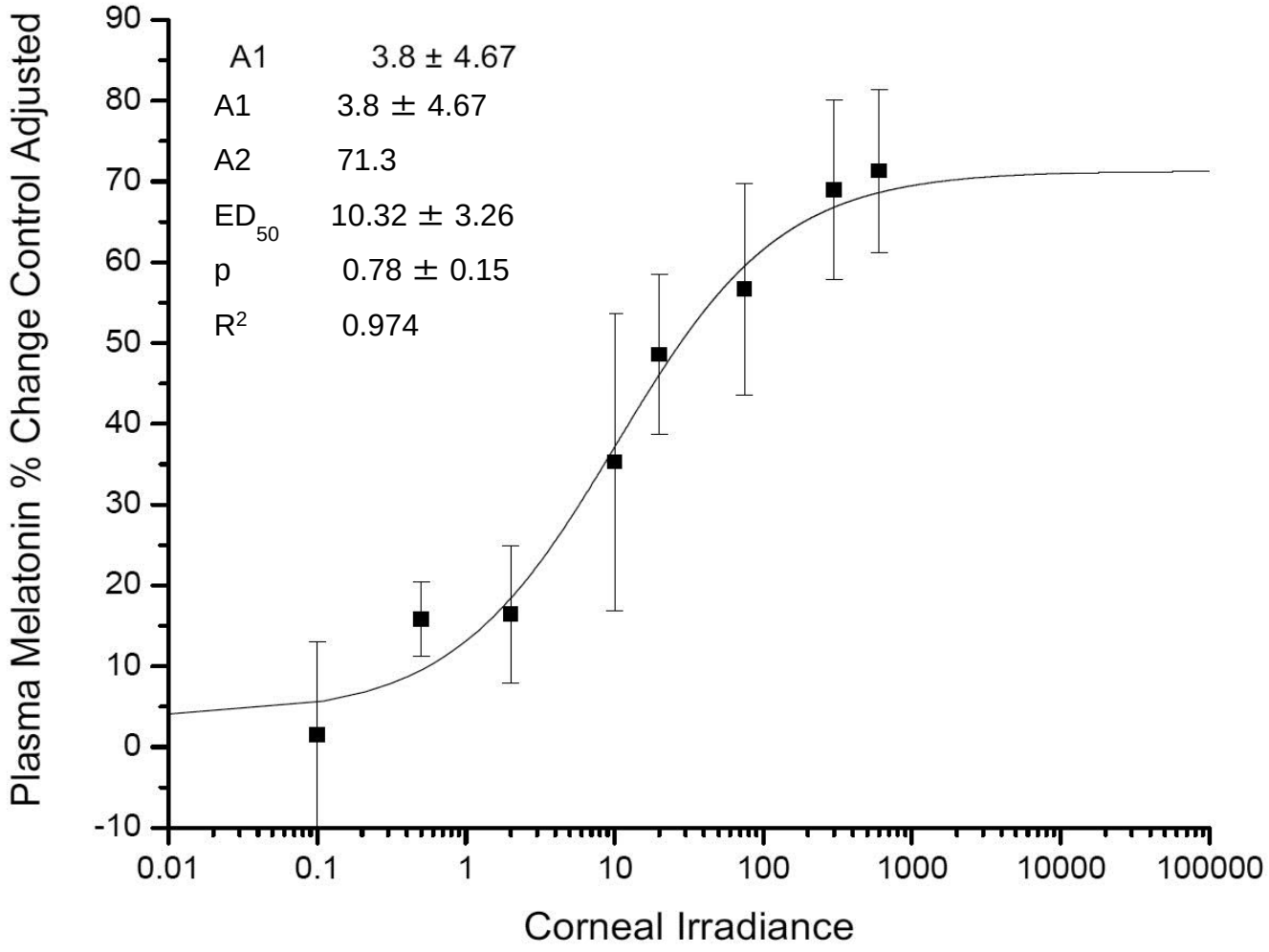
Brainard et al., J. Pineal Res. 2015

Blue LED Exposure System

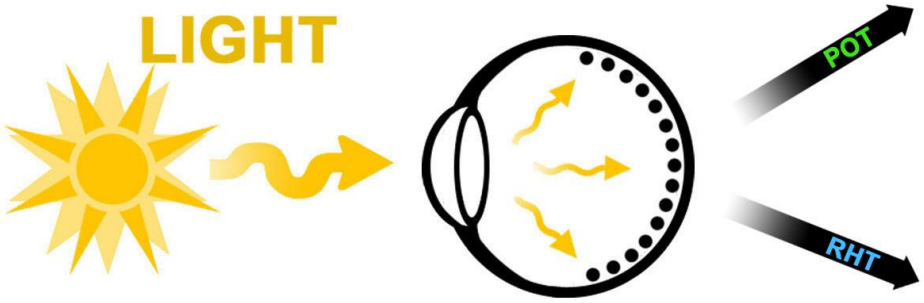




Blue LED Fluence Response Curve



Adapted from: J. Applied Physiology: West et al. 2011



VISUAL EFFECTS
VISUAL REFLEXES

BIOLOGICAL/BEHAVIORAL

Acute Effects
- Melatonin Secretion
- Body Temperature
- Cortisol Secretion
- Heartrate
- Alertness
- Brain Bloodflow
- EEG Responses
- Clock Gene Expression
- Cognitive Performance
- Psychomotor Performance

Longer Term Effects
- Circadian Phase-Shift
- Circadian Entrainment
- Sleep Physiology
- Light Therapy (eg SAD)

International Agency for Research on Cancer

World Health Organization

December 5, 2007

Shift Work: Class 2A Carcinogen

"Shiftwork that involves circadian disruption is probably carcinogenic to humans"

The majority of night shiftwork involves light exposure during the nighttime

AMA AMERICAN MEDICAL ASSOCIATION

AMA Adopts New Policies, June 19, 2012

The American Medical Association (AMA), the nation's largest physician organization, voted today during its annual policy-making meeting to adopt the following new policy:

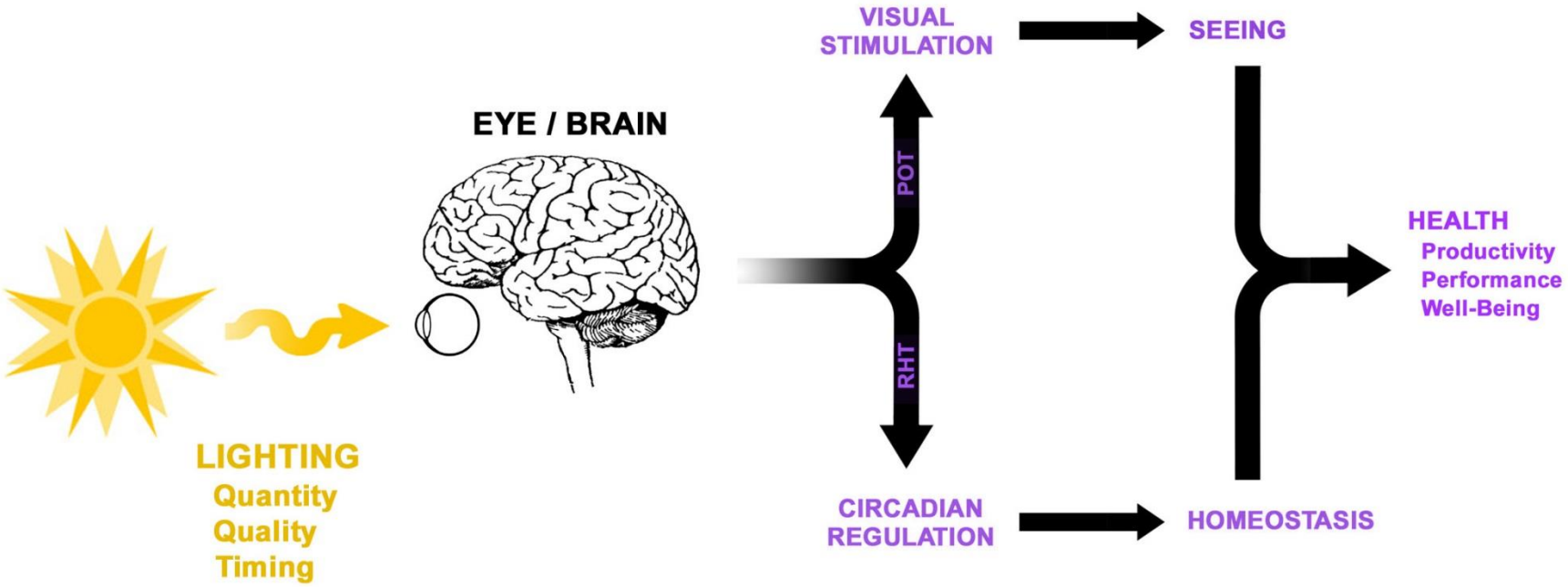
Adverse Health Effects of Nighttime Lighting

The AMA adopted the policy recognizing that exposure to excessive light at night can disrupt sleep, exacerbate sleep disorders and cause unsafe driving conditions. The policy also supports the need for developing lighting technologies that minimize circadian disruption and encourages further research on the risks and benefits of occupational and environmental exposure to light at night.

VT

Tufts UNIVERSITY

Evidence Based Lighting



Collaborators and Contributors

Thomas Jefferson University
Melissa Ayers
John Balaicuis, M.D.
George Brainard, Ph.D.
Brenda Byrne, Ph.D.
Kate Cecil
Bill Coyle
Michael Downes, M.D.
Robert Fucci
Gena Glickman, Ph.D., OT
Jeffrey Greeson, Ph.D.
John Hanifin, Ph.D.
Mike Jablonski, Ph.D.
Mary James, M.D.
Samar Jasser, M.D.
John Kemp
Alan Kubey, M.D.
Carrisa Pineda, M.D.
Tyisha Vincent
Benjamin Warfield
Kat West

Wills Eye Hospital
Edward Gerner, M.D.

University of Virginia
Mark Rollag, Ph.D.
Ignacio Provencio, Ph.D.

Aberdeen Proving Ground
David Sliney, Ph.D. (ret.)

NASA Johnson Space Center
James Maida
Charles Bowen, Ph.D.

Grant Support
NSF EEC-0812056
NINDS RO1NS36590
NSBRI, NASA NCC 9-58
NASA NNX09AM68G
Philips Lighting
Apollo Lighting
Philadelphia Chapter of the IES