Greenlighting : a Route toward Circadian Lighting

Joint Workshop on *Large – area Solid State Lighting*
Thursday, October 30th 2014
Pantheon Basel, Muttenz BL (Switzerland)

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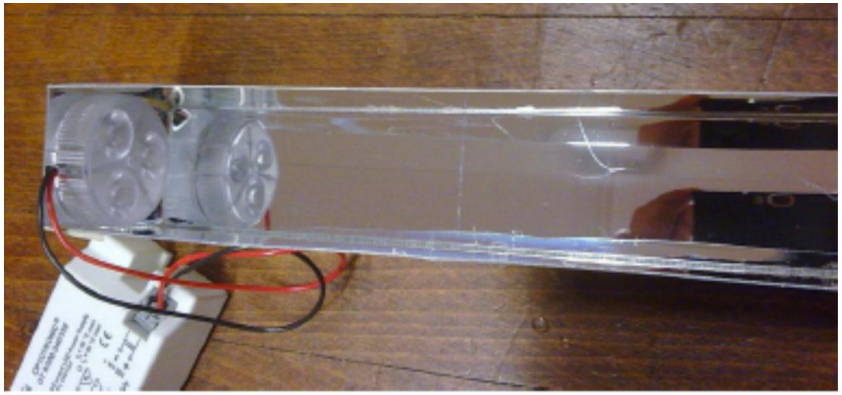
Solar Energy and Building Physics Laboratory
Ecole Polytechnique Fédérale de Lausanne

Greenlighting : Non-Image Forming Effects of Daylighting and Solid State Lighting



Linhart et al., Proc. of SPIE, Vol. 7423, San Diego (CA), 2009.

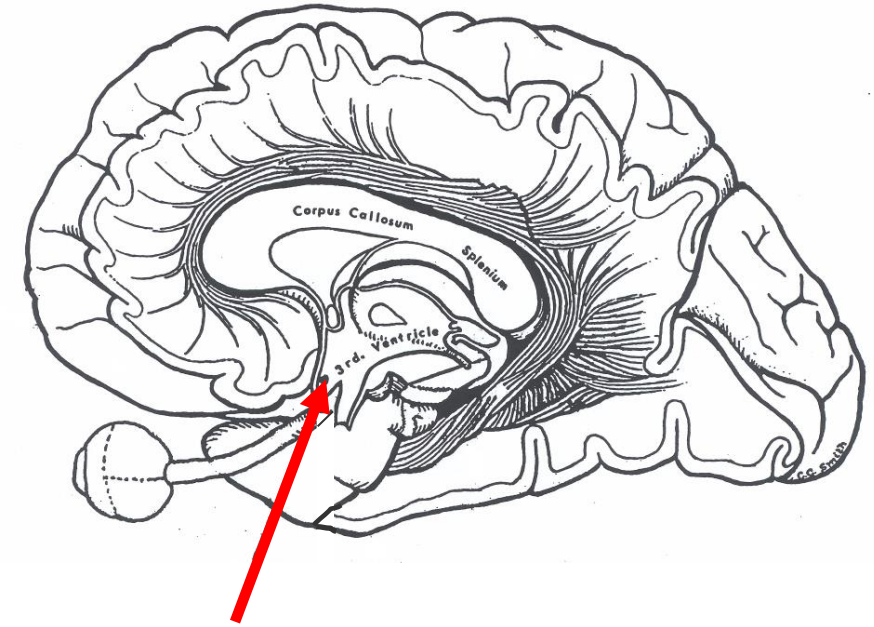
Non-Image Forming Lighting Systems (Anidolic Daylighting Systems)

Scartezzini and Courret, Solar Energy, 73(2), 2002.

External 24 hours Solar Light-Dark Cycle

Most stable Time Cue
(> 4 Billion Years)

Internal Biological Clock in Humans



Suprachiasmatic Nucleus

Approximately
but not exactly 24 hours

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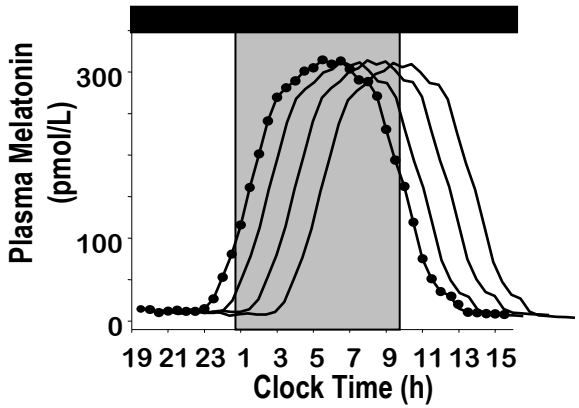
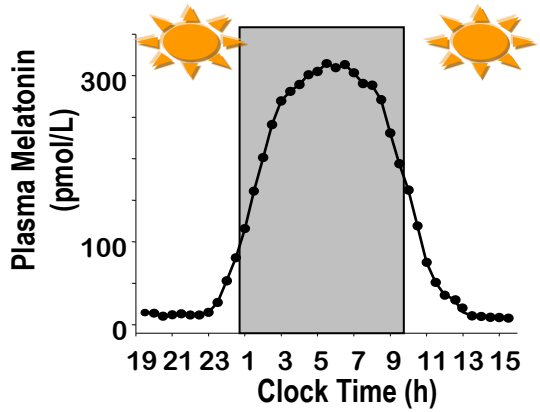
Daily Synchronization of Rhythms by Light

Melatonin Secretion (Sleep Hormon) by the Pineal Gland during Night





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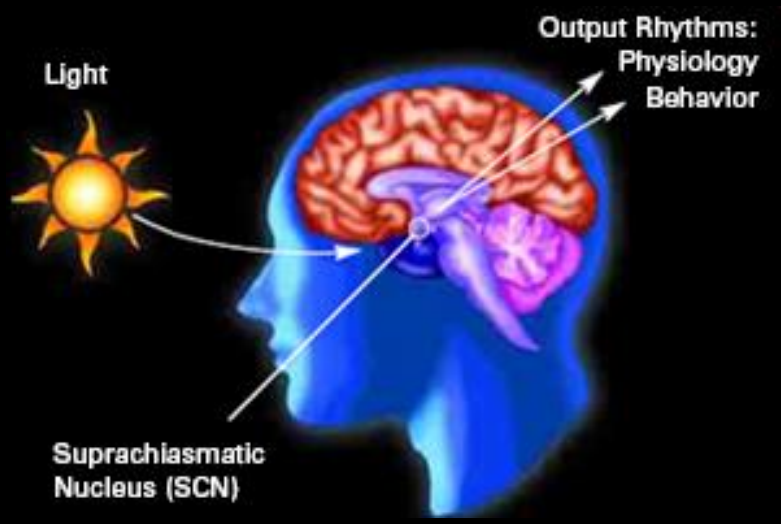
Circadian Regulation of Physiology/Behavior in Humans



Circa (latin) = approximately
-dian (latin, dies) = Day

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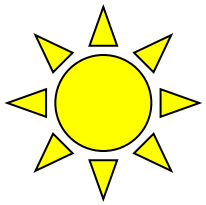
What is wrong in our Modern 24/7 Society ?

Day Time



→ **Lack of Daylight Exposure**
→ **Poor Indoor Lighting**

- **Visual System**
  Visual Comfort & Performance, Productivity, Safety

- **Non-Visual System**
  Alertness, Entrainment of Circadian Rythms, Sleep-Wake Disturbances

Night Time

→ **Light at the wrong Time**

- **Circadian 'Misalignment'**
  Behavorial Rhythms (Melatonine Suppression)

Long-Term Effects on Health and Wellbeing

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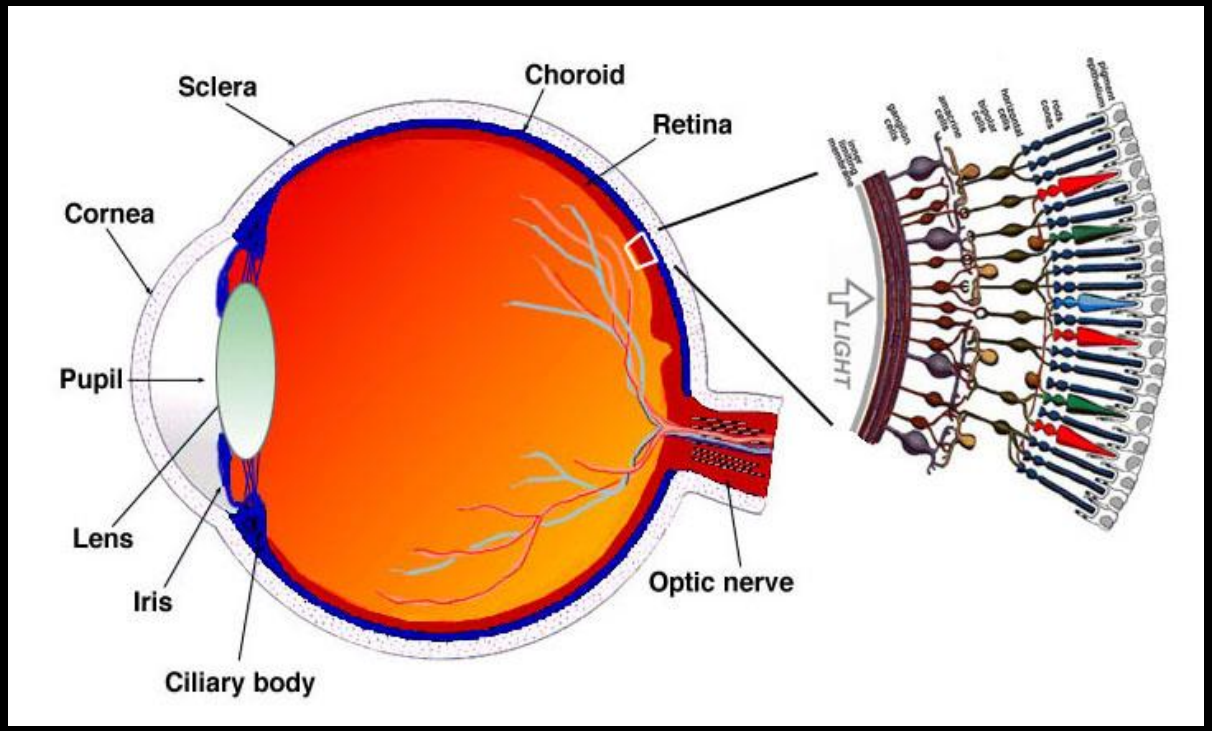
Non-Image Forming Visual System

Visual & Non-Visual Photoreceptors (Human Eye)



webvision.med.utah.edu

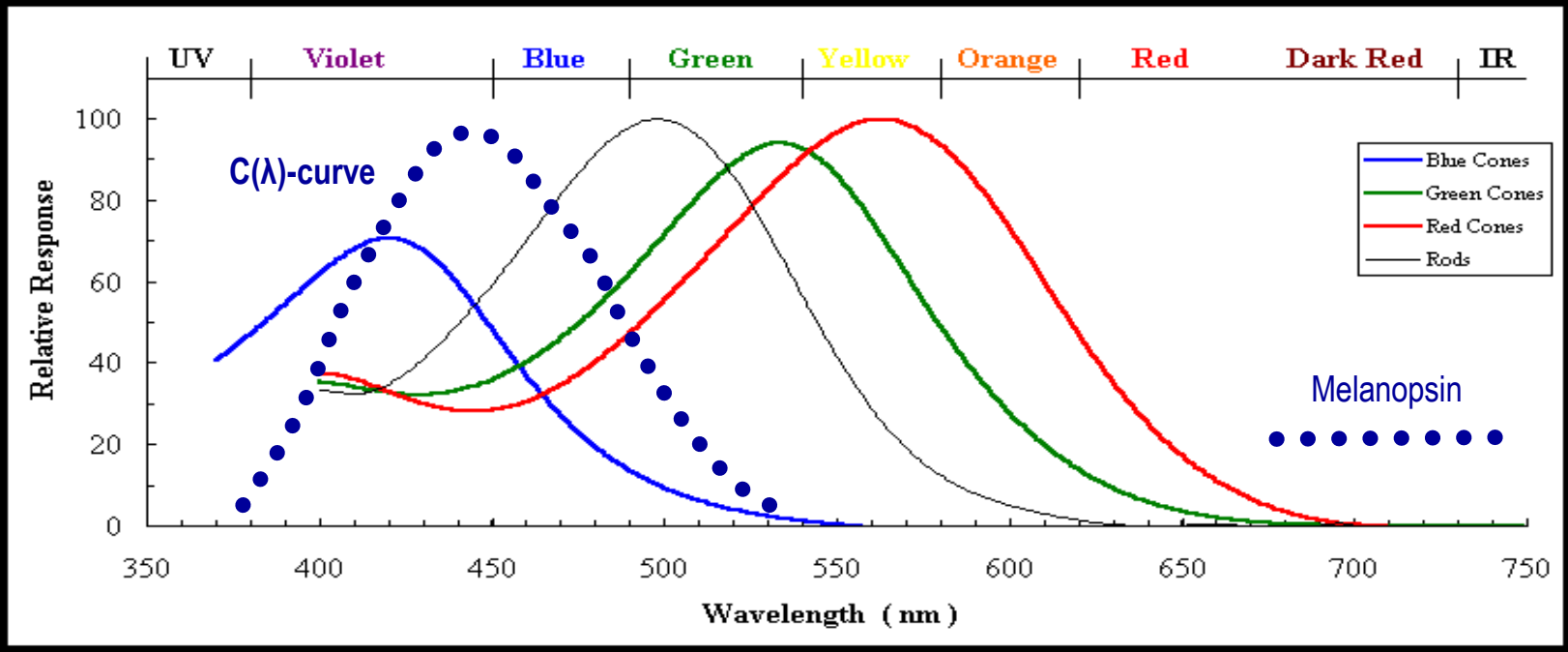
Visual System
Rods & Cones

Non-Visual System
Ganglion Cells

- Circadian Rhythms
- Sleep/Wake States
- Hormons Regulation
- Pupillary Reflex

Non-Image Forming Visual System

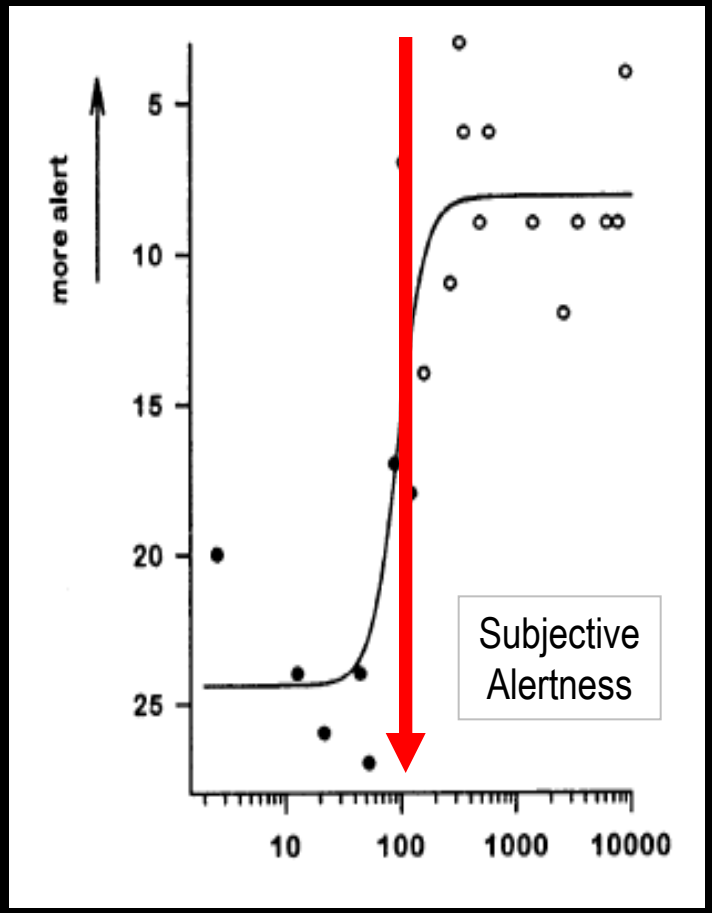
Visual & Non-Visual Photoreceptors (Spectral Sensitivity)



Brainard et al, 2001/Thapan et al, 2001.

- Nocturnal Melatonin Suppression is Wavelength dependent
- Peak Sensitivity at 460 – 465 nm (Blue Light)
- Pigment differing from those of Cones and Rods (Melanopsin)

Acute Non-Image Forming Effects

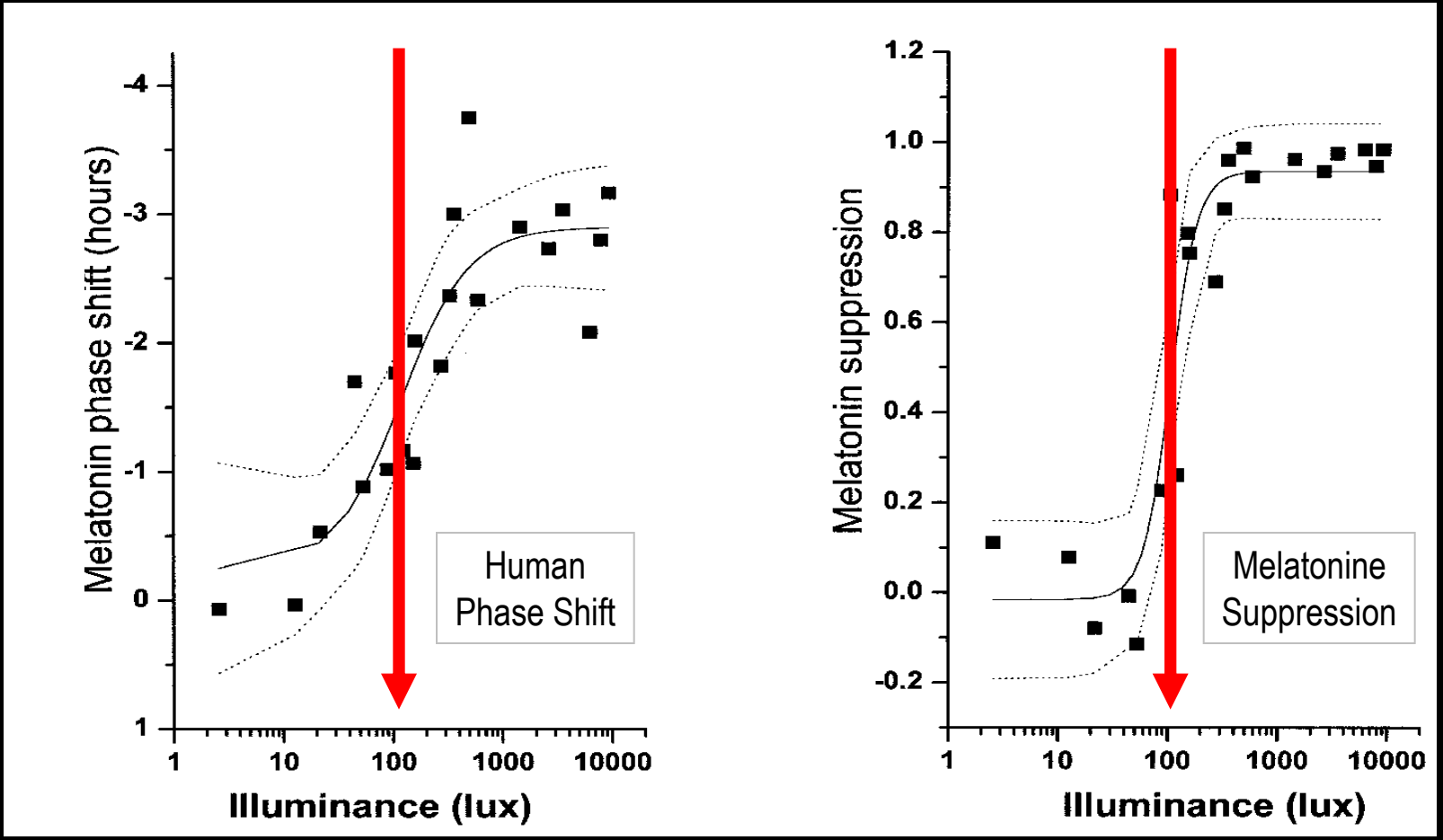


Dose-Response Curve (Subjective Alertness)

- Half Maximal Alerting Night Effect (young subjects) @ 90 - 180 lux
- Same Effects on EEG Activity (5-9Hz) during Wakefulness
- Slow Eye Movements
- Hormones & Performance

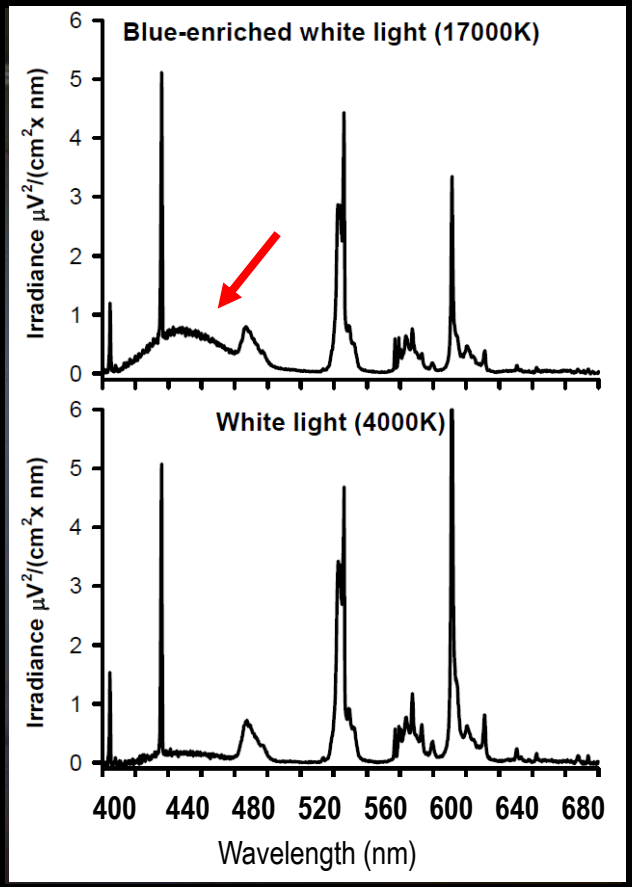
Cajochen et al., Behavioural Brain Res 115, 2000.

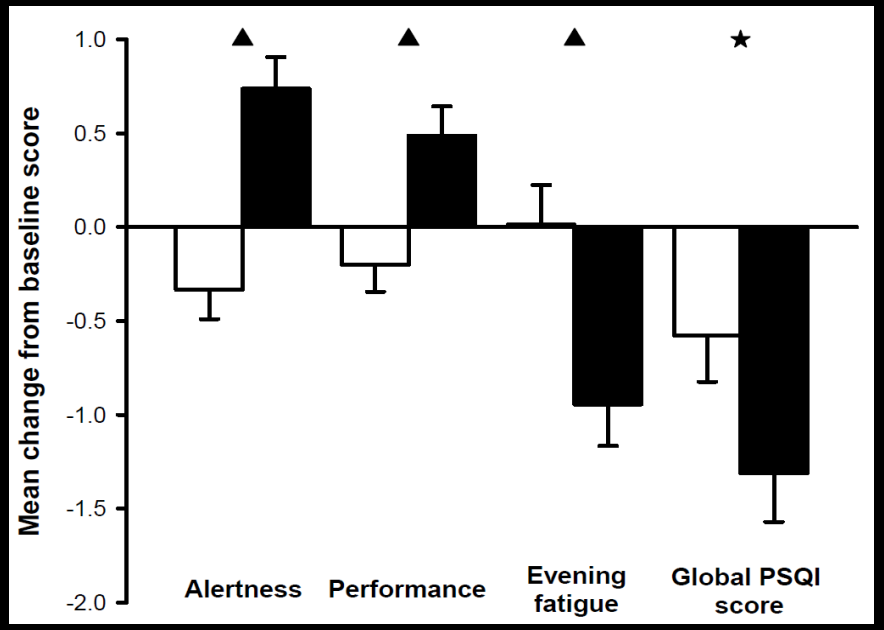
Acute Non-Image Forming Effects



Zeitzer et al., J Physiol 526.3, 2000.

Blue-Enriched White Light Source





Acute Light Effects (Office Rooms, 104 Subjects)

Positive Effects on Alertness, Mood, Eye Strains, Performance and Sleep Quality

Viola et al., Scand J Work Environ Health 34(4), 2008.

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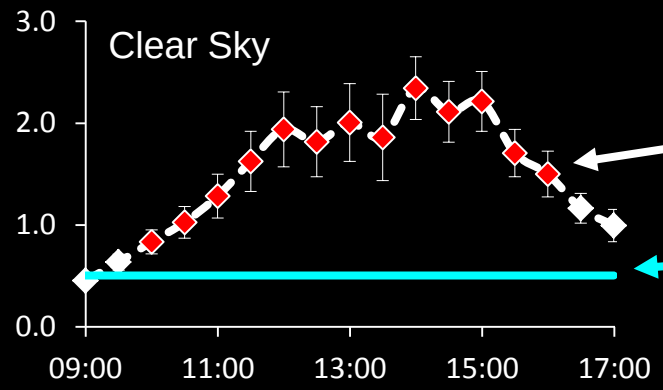
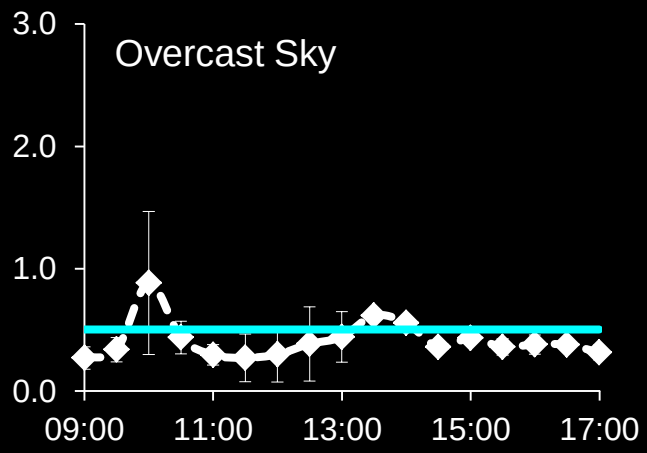
Acute Non-Image Forming Effects





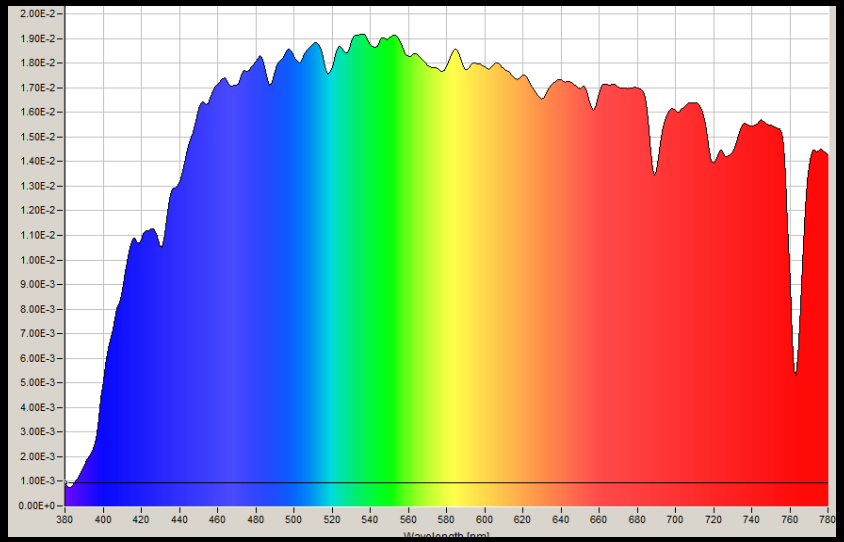
Daylight (5700 K)

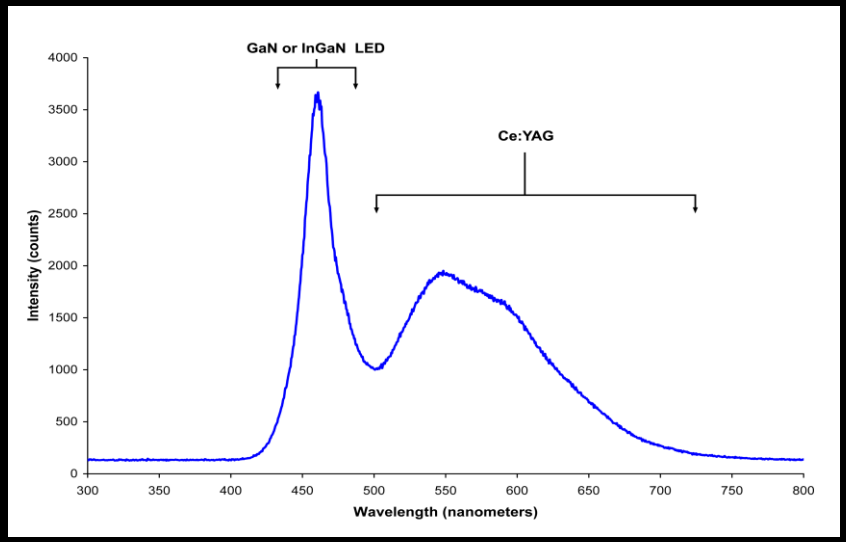
Blue-Enriched Fluorescent Light Source (17'000 K)

- Higher Circadian-Weighted Irradiance for Daylight during Office Hours (10 AM - 4 PM)
- Larger for Clear/Intermediate skies
- Comparable for Overcast sky

Linhart, Scartezzini and Münch, CISBAT 2009.

Office Lighting Scenarios
Daylighting vs. Solid State Lighting





- Daylight provided with Anidolic Daylighting Systems (CCT 5200 K)
- Pupilar Illuminance (1300 lux)

- Electric Light provided with SSL Source (CCT 4000 K)
- Pupilar Illuminance (200 lux)

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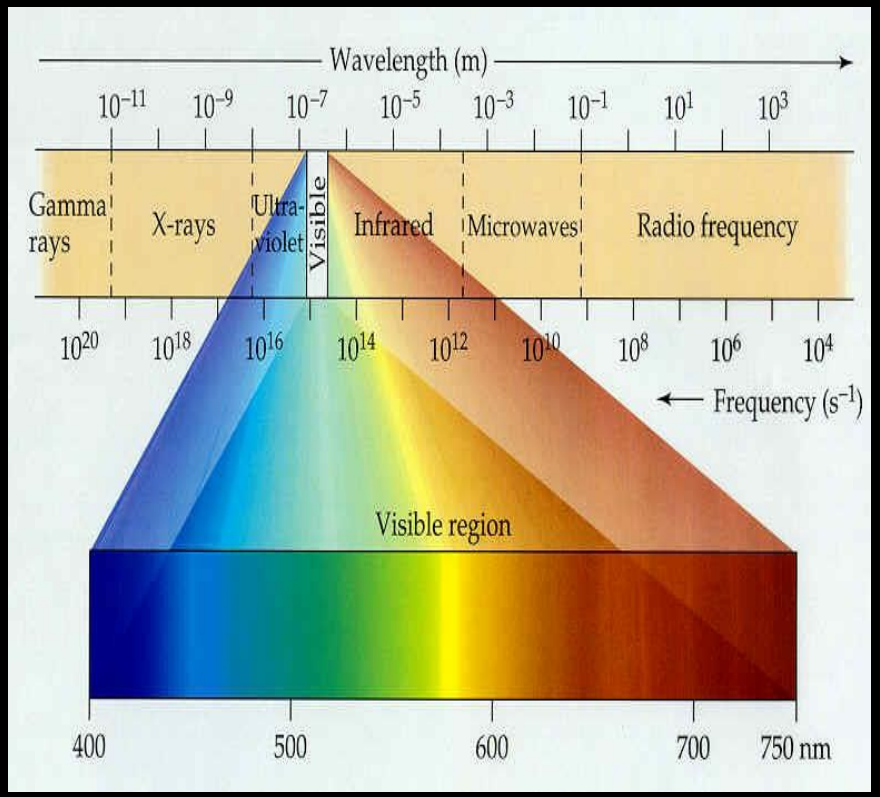
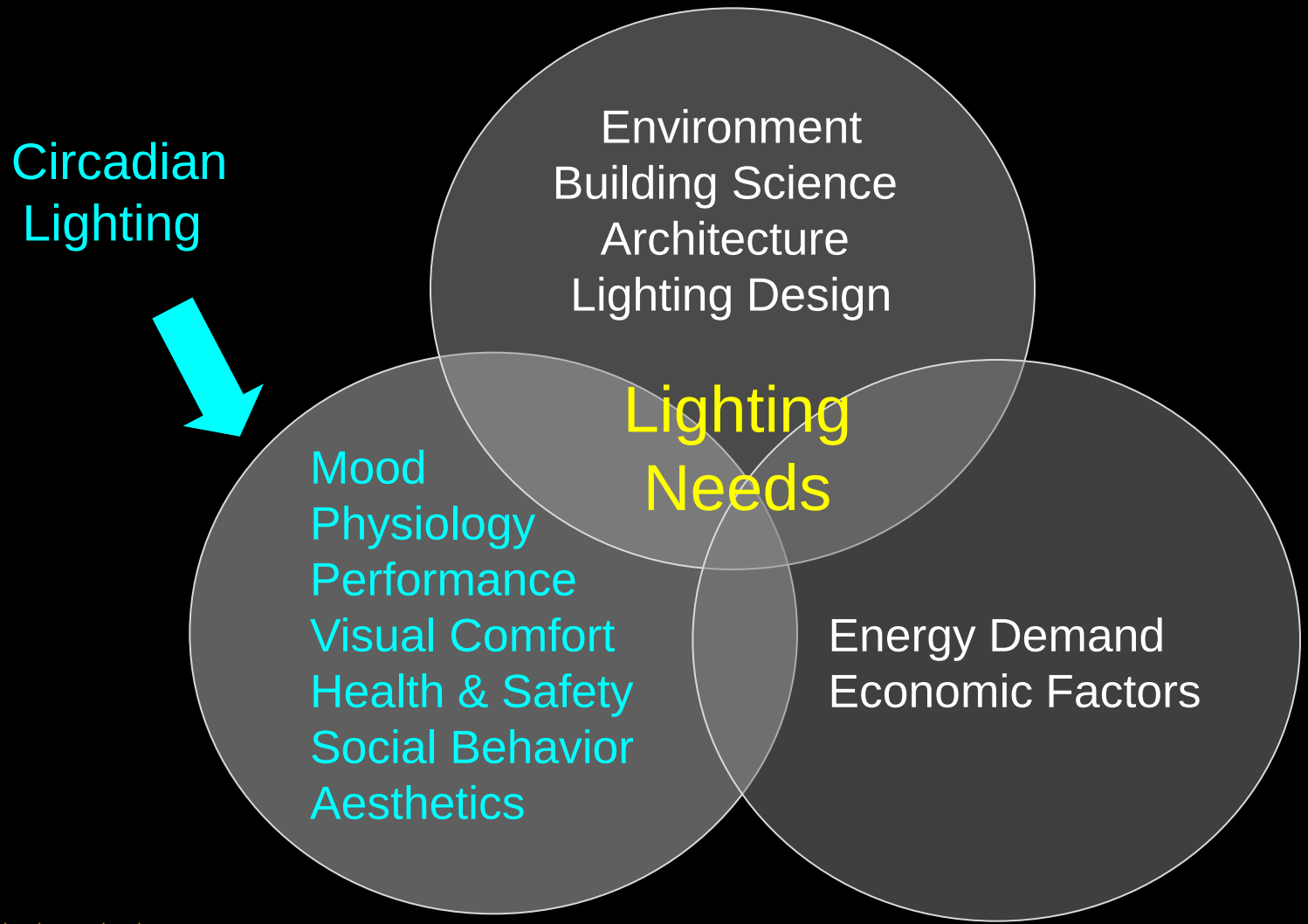
Conclusion

Key Circadian Lighting Factors

- Time of Day
- Luminous Intensity
- Exposure Duration
- Prior Light History
- Light Filtering
- Spectral Sensitivity
- Spectral Composition



Sustainable Lighting Strategy



Veitch CIE 2004.

Any Questions ?

More to discover
@ http//leso.epfl.ch

Thank you
for
your Attention

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