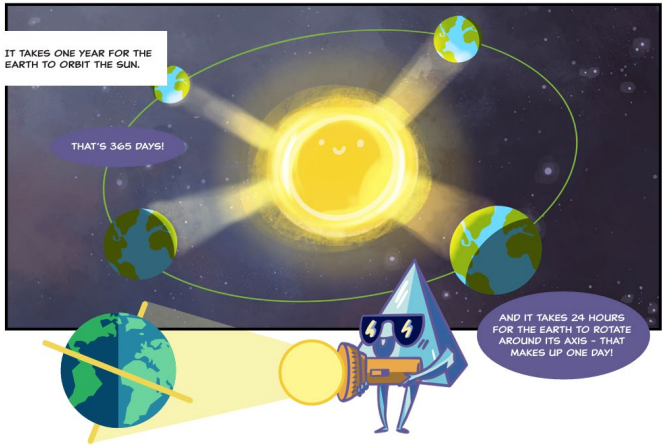
Case Studies in Spectral Lighting for Healthcare Design

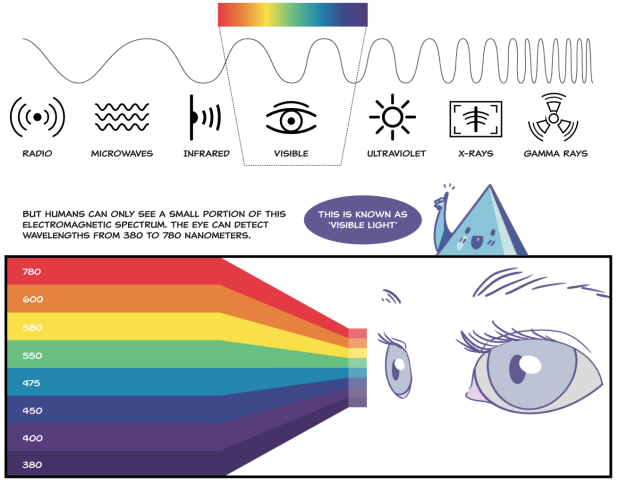
The 24th International Radiance Workshop
September 1, 2026

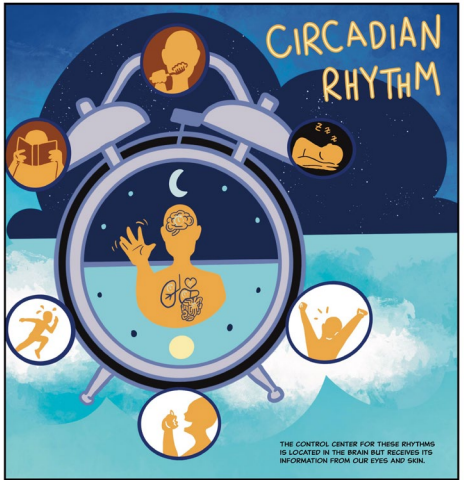
Marty Brennan, AIA Well AP

ZGF

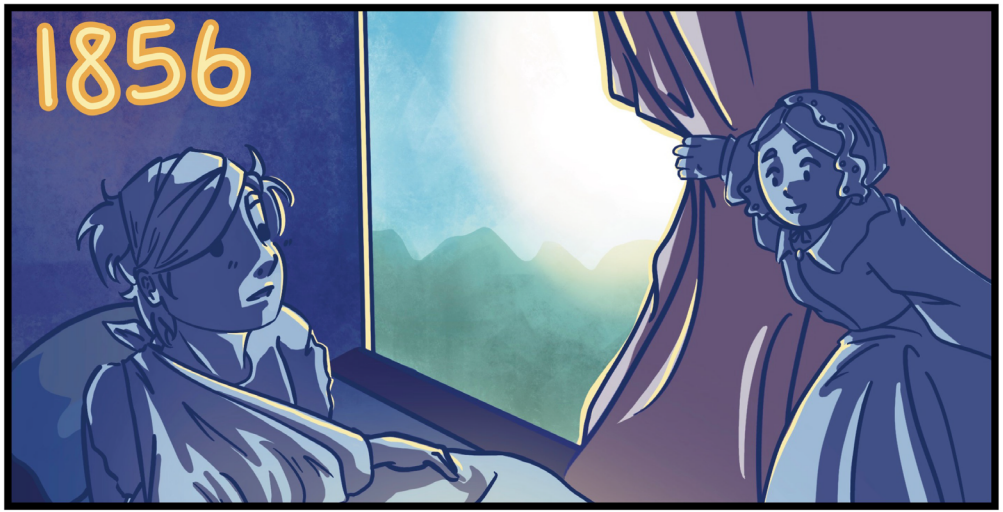
Circadian Lighting Basis of Design



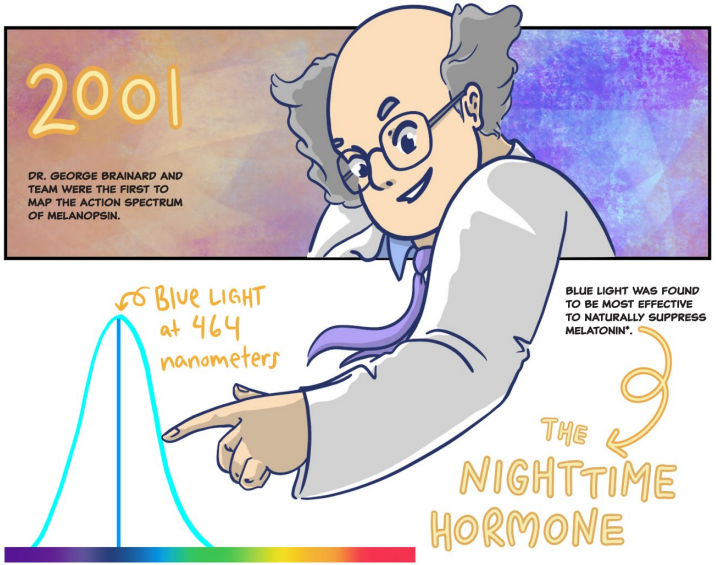




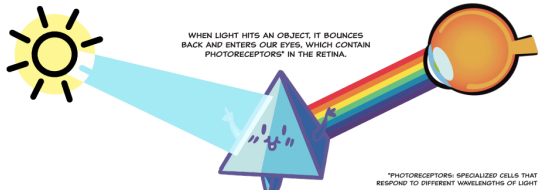


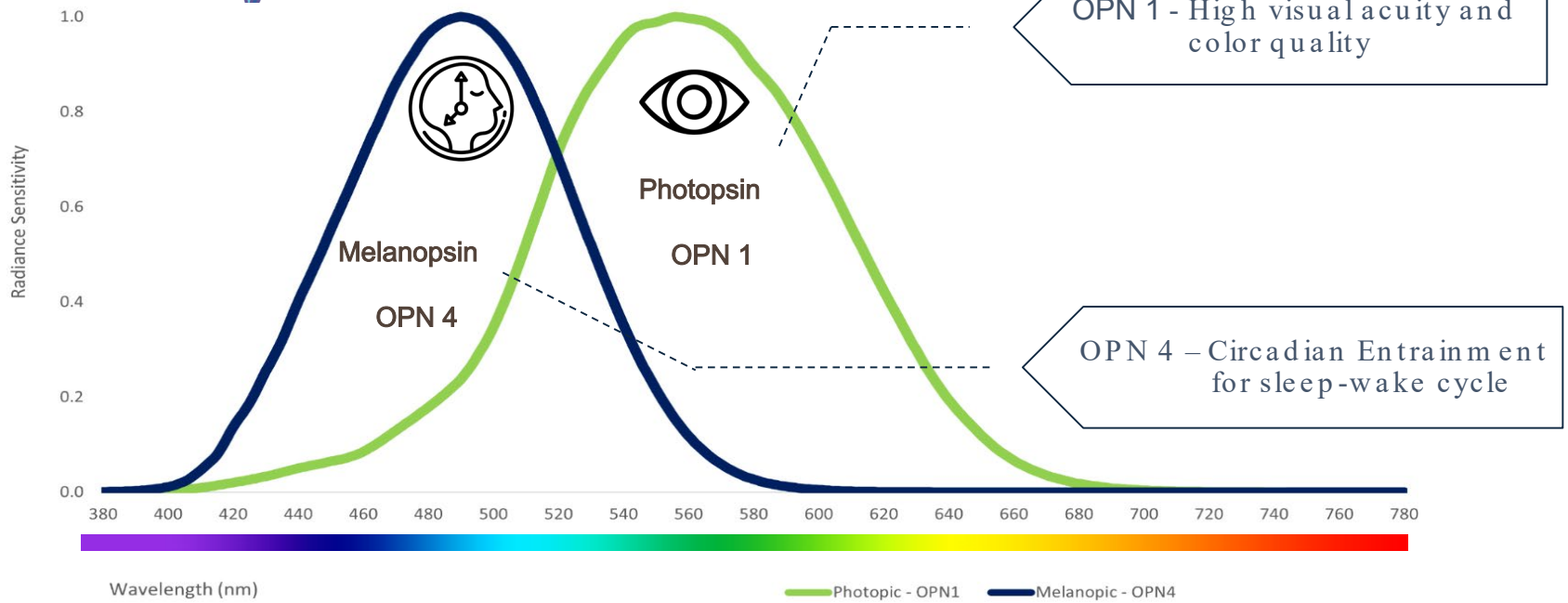


FLORENCE NIGHTINGALE, WHO PIONEERED MODERN NURSING PRACTICES, OBSERVED AND DOCUMENTED THE HEALTH BENEFITS OF SUNLIGHT.



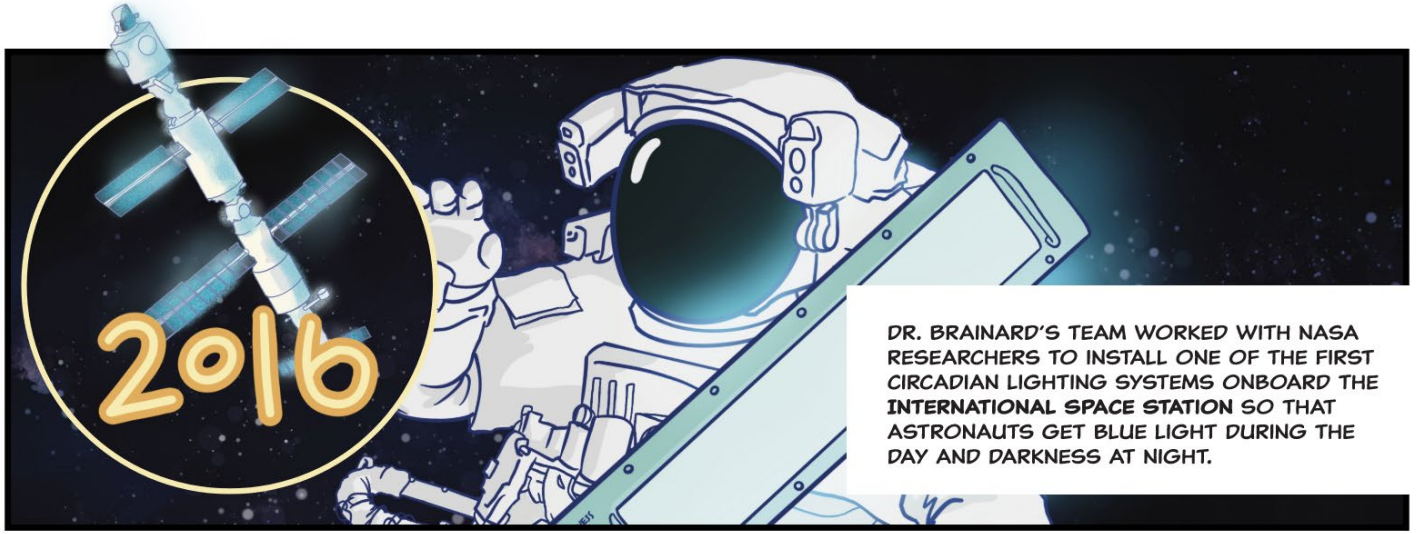
Visual & Non-Visual Response to Light





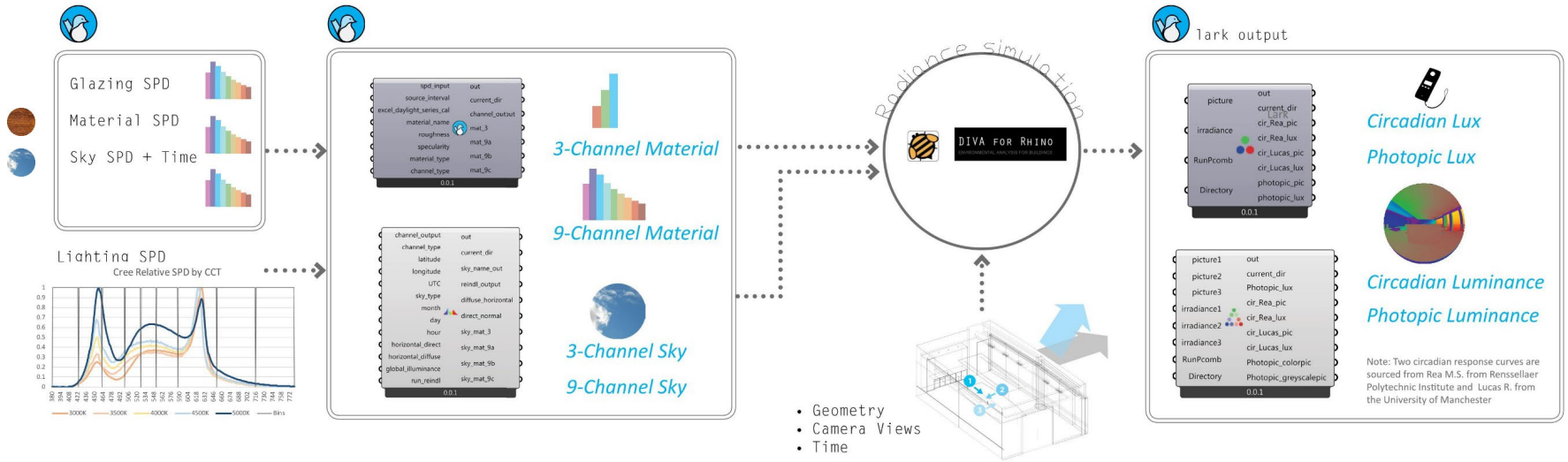
OPN 1 - High visual acuity and color quality

OPN 4 – Circadian Entrainment for sleep-wake cycle

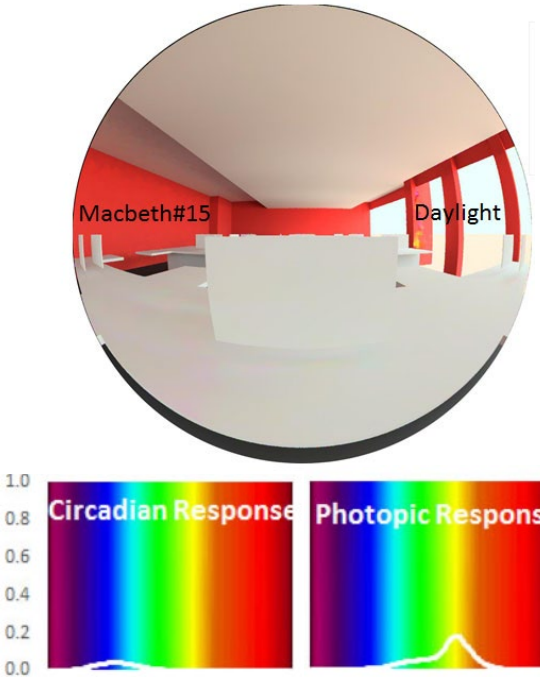

2016
DR. BRAINARD'S TEAM WORKED WITH NASA RESEARCHERS TO INSTALL ONE OF THE FIRST CIRCADIAN LIGHTING SYSTEMS ONBOARD THE **INTERNATIONAL SPACE STATION** SO THAT ASTRONAUTS GET BLUE LIGHT DURING THE DAY AND DARKNESS AT NIGHT.

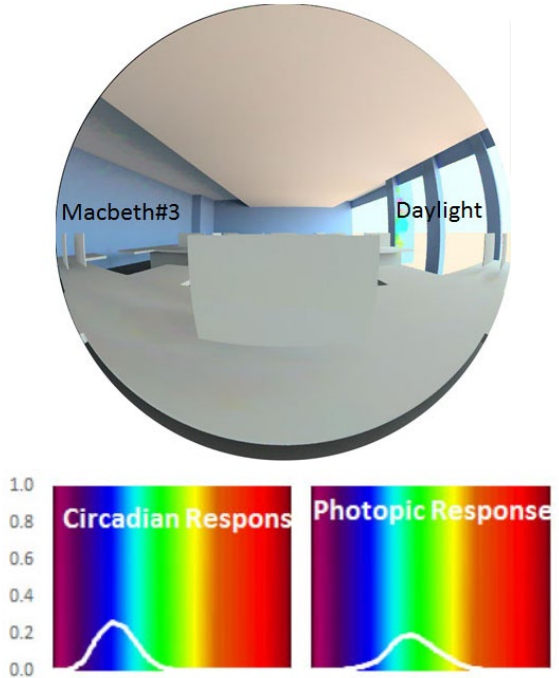

NOW ASTRONAUTS CAN SLEEP AND PERFORM BETTER!

Lark Spectral Lighting v1

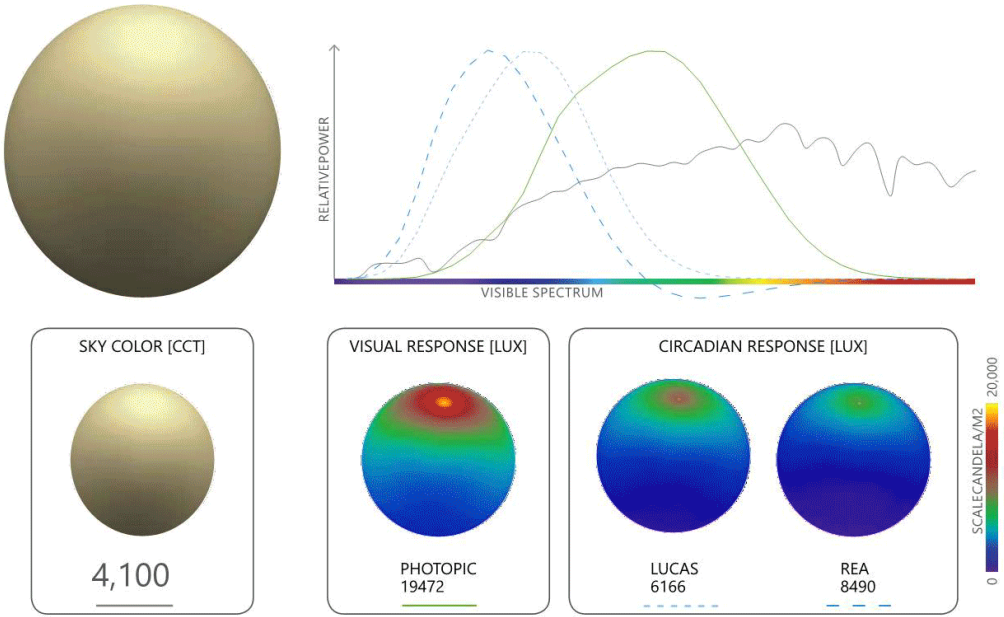


Spectral Interactions: Light & Materials





Visual and Non-Visual Response



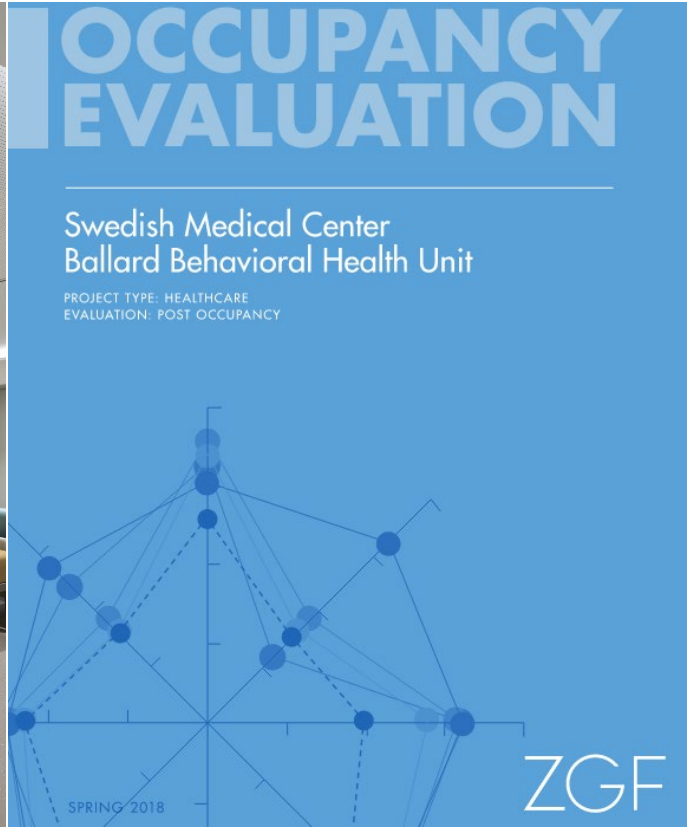
MARCH 21 - NOON - INTERMEDIATE SKY

SPDs from Rochester Institute Technology Daylight Series

Providence Health & Services, Swedish Medical Center-Ballard, Behavioral Health Unit

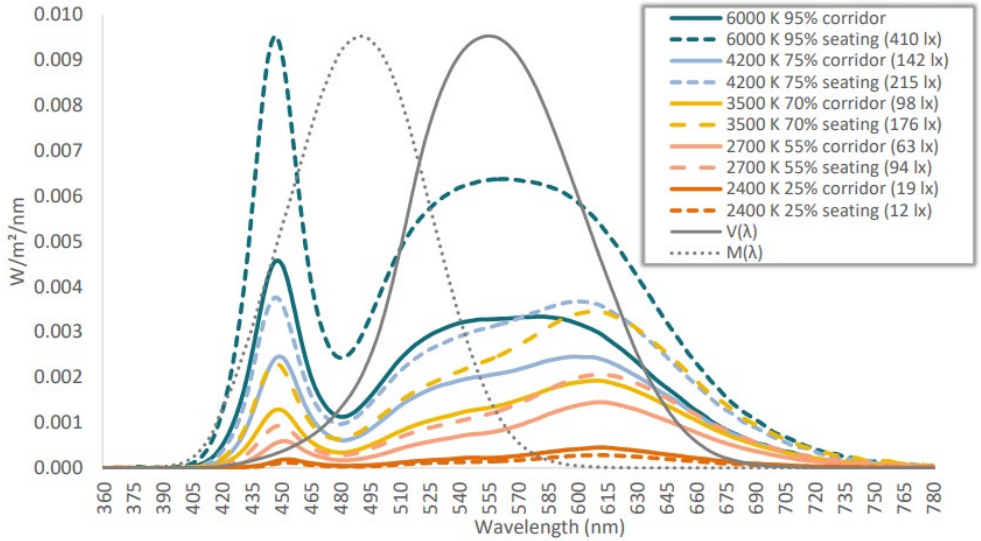


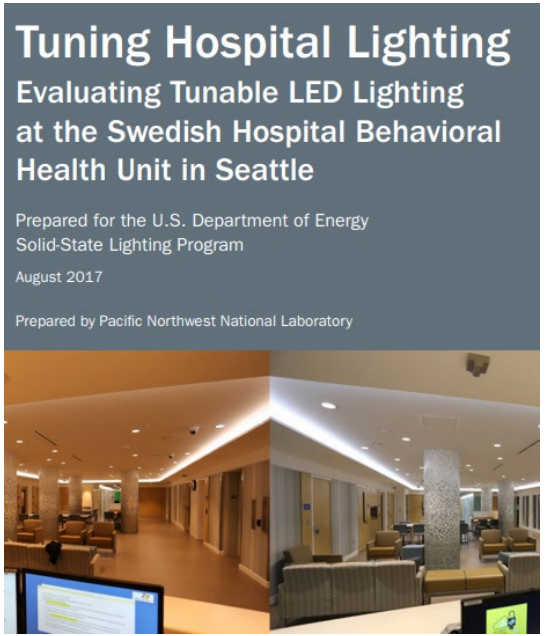




Interior design by Kari Thorsen, Circadian lighting design by Ed Clark at ZGF

Spectral Power Distribution

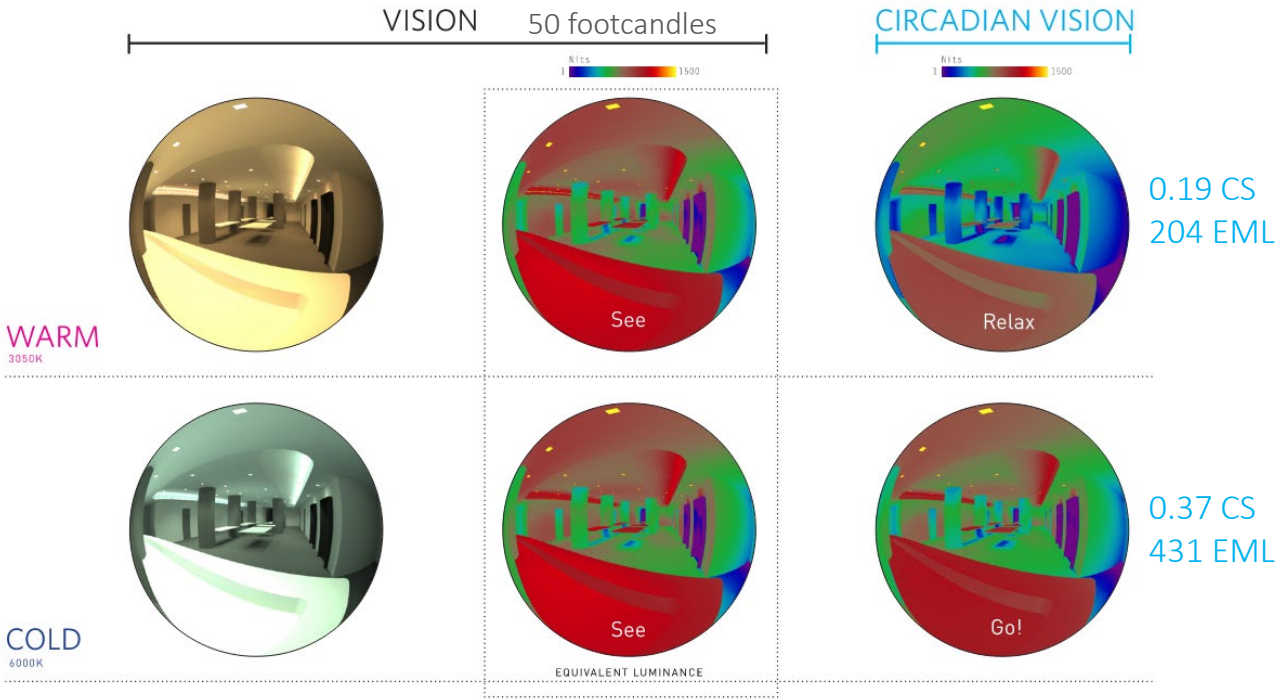




Interior design by Kari Thorsen, Circadian lighting design by Ed Clark at ZGF

ZGF

Circadian Light Simulation

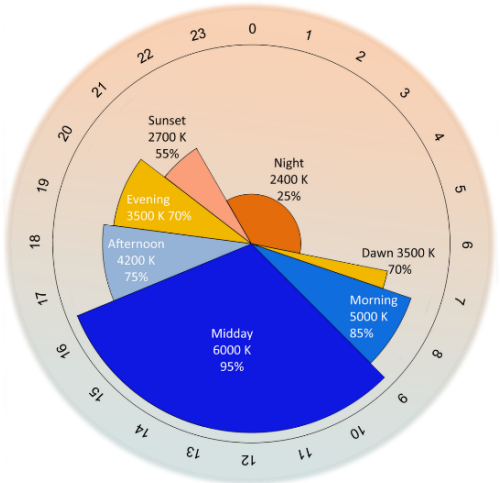


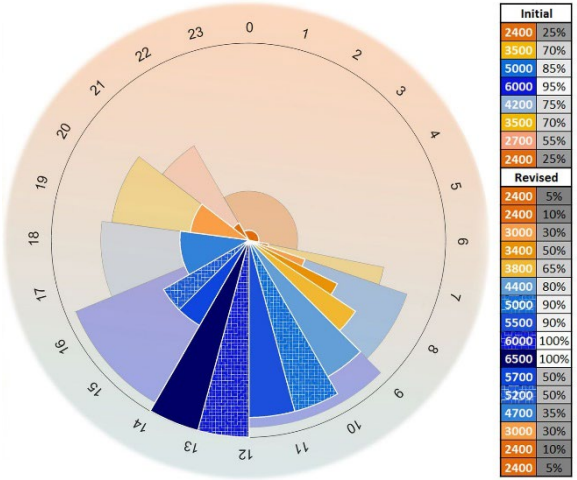
LARK

Circadian Stimulus (CS)
Equivalent Melanopic Lux (EML)

ZGF

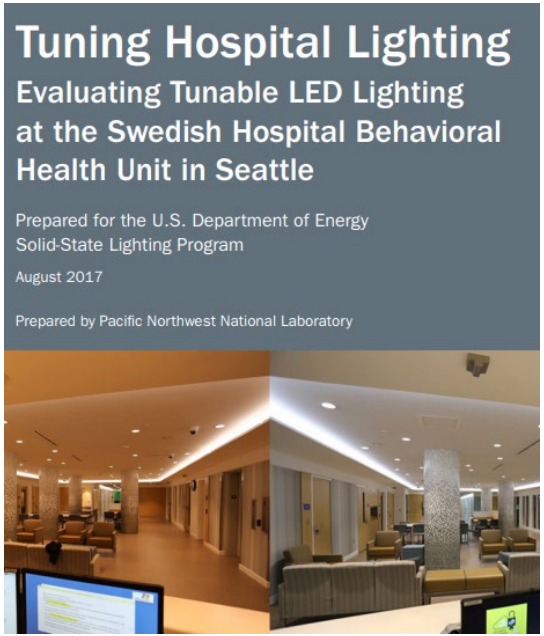
24 Hour Light Schedule





Initial	
2400	25%
3500	70%
5000	85%
6000	95%
4200	75%
3500	70%
2700	55%
2400	25%
Revised	
2400	5%
2400	10%
3000	30%
3400	50%
3800	65%
4400	80%
5000	90%
5500	90%
6000	100%
6500	100%
5700	50%
5200	50%
4700	35%
3000	30%
2400	10%
2400	5%

Commissioning led to more transitions



energy.gov/sites/prod/files/2017/08/f36/2017_gateway_swedish-tuning-led_0.pdf

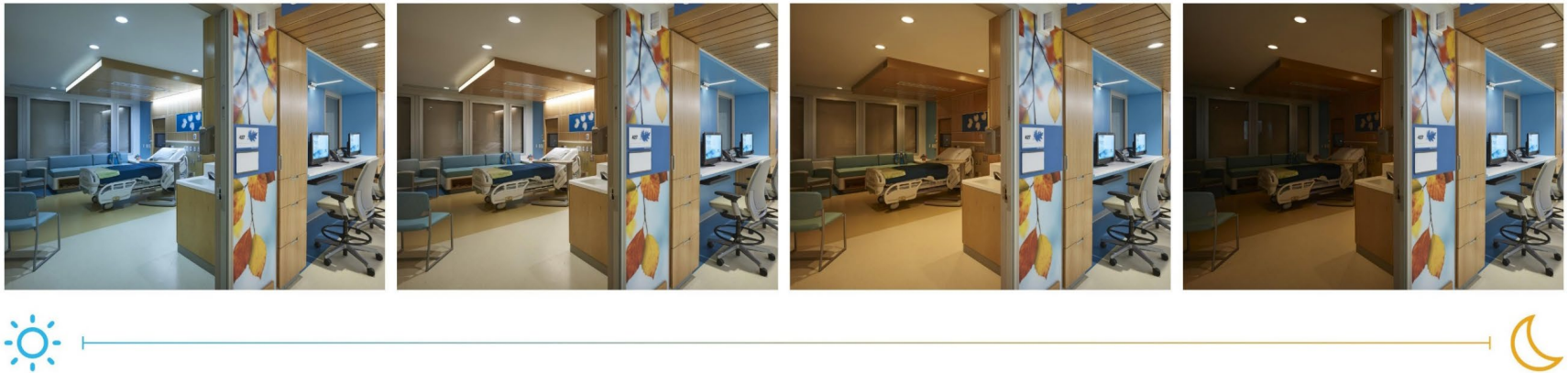
Interior design by Kari Thorsen, Circadian lighting design by Ed Clark at ZGF

ZGF

Circadian Lighting System

Children's Hospital of Philadelphia, Medical Behavioral Unit

Daily circadian lighting cycle in a typical PA patient room



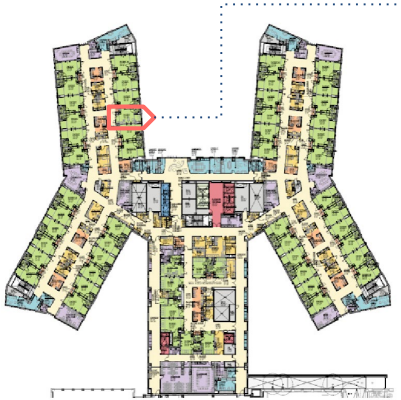
The era of circadian lighting in health care is dawning (inquirer.com)

Learning from Cincinnati Children's Spectral Lighting System

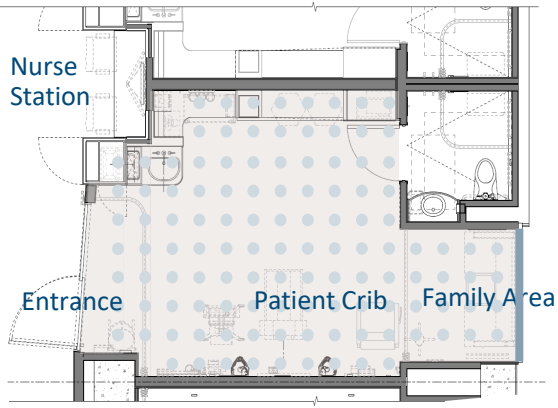
NICU PATIENT ROOM



Critical Care Building

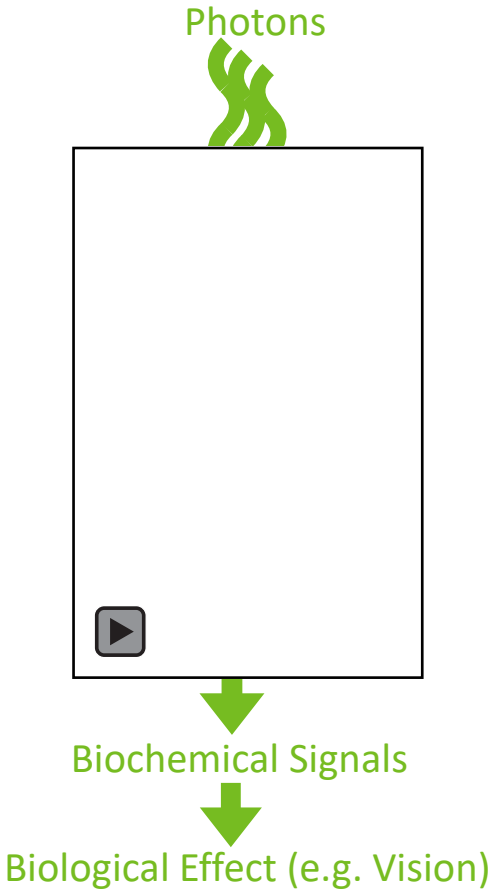


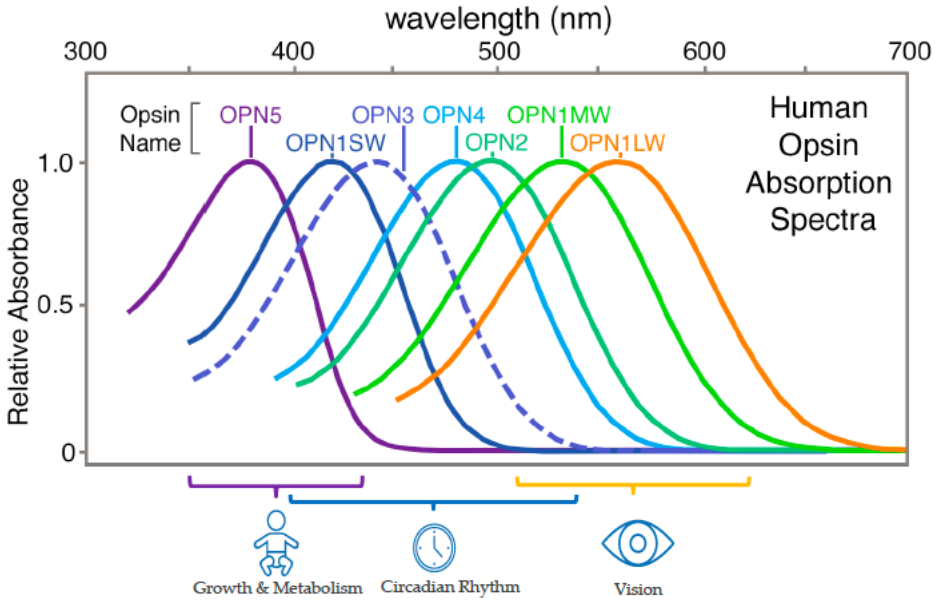
Typical Floor Plan



East-facing Room Plan

BIOLOGY OF NON-VISUAL OPSINS





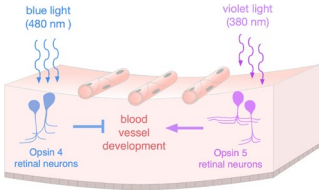
SUN-COUPLED PHYSIOLOGY

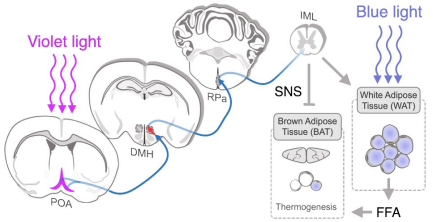
Mammalian physiology is tightly coupled to photon opsin ligands from the Sun

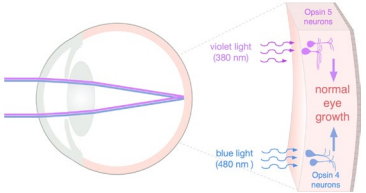
Short wavelength photons are crucial for **OPN3**, **OPN4**, and especially **OPN5**

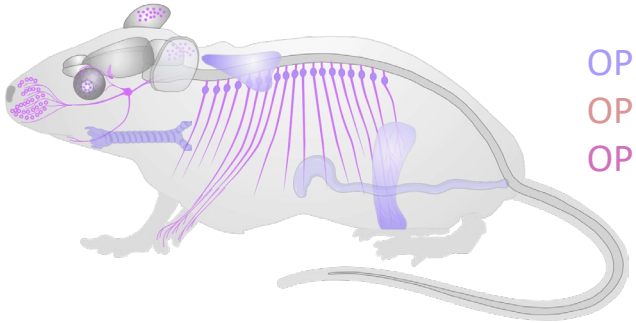
Absence of these photons in our built spaces is creating **disease susceptibility**











OPN3
OPN4
OPN5

CAN WE...

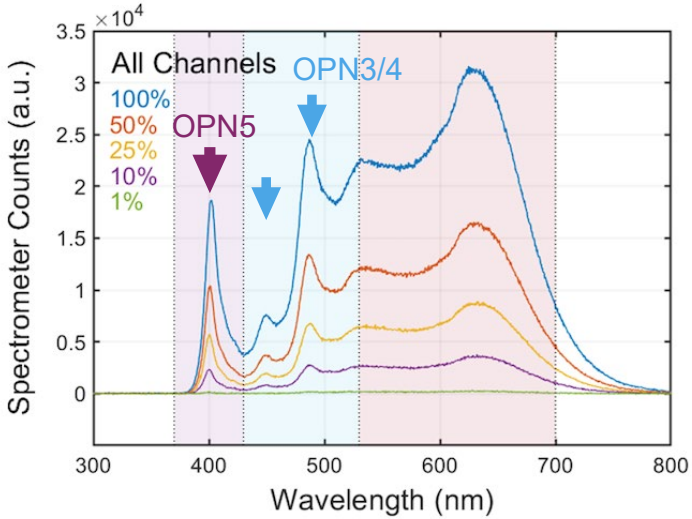
- Design, manufacture, and install a lighting system that can activate all human opsins
- Reproduce daytime spectral variation from dawn through dusk
- Reproduce seasonality
- Support patient care and research
- Aesthetically pleasing and easy to use





Improving Patient Health with Biologically Aware Lighting

- Spectrally tunable
- Research grade
- In the new NICU rooms







LIGHT FIXTURE

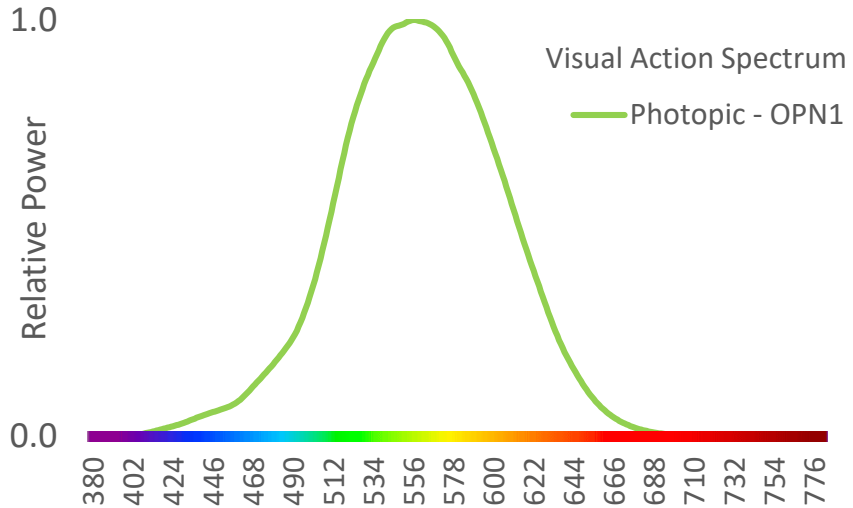
Design Parameters

- Indirect illumination
- Supplemental to room lighting
- Consistent with pediatric patient room design
- Easily maintainable, infection control
- Asymmetric optics



LIGHT SOURCE

Visual Requirements



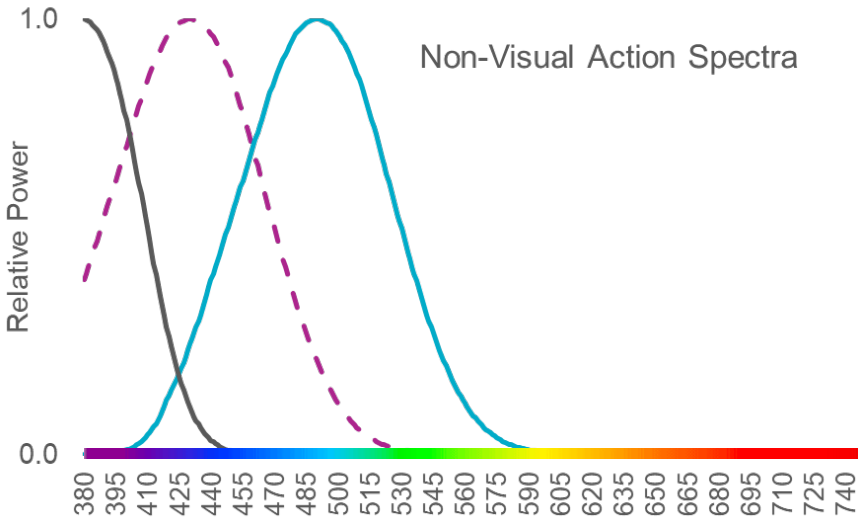
Illuminance Level

Color Quality:

- TM-30 Fidelity Index (**R_f**)
- TM-30 Gamut Index (**R_g**)
- Cyanosis Observation Index (**COI**)
- Chromatic Distance from Blackbody Locus (**D_{uv}**)
- Correlated Color Temperature (**CCT**)

LIGHT SOURCE

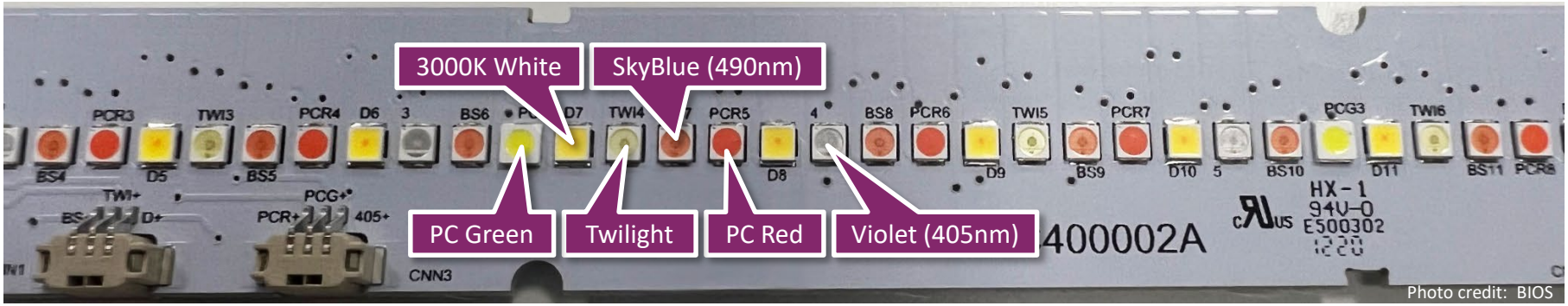
Non-visual Requirements

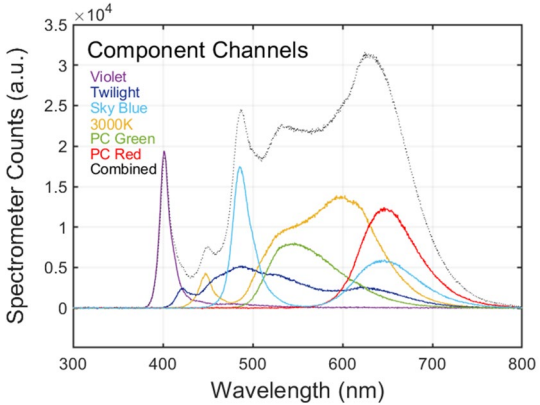


Stimulation of light sensing opsins:

- **OPN3** – 430nm
- **OPN4** – 480nm
  - Healthy growth
  - Circadian regulation
- **OPN5** – 380nm
  - Healthy eye growth
  - Metabolism

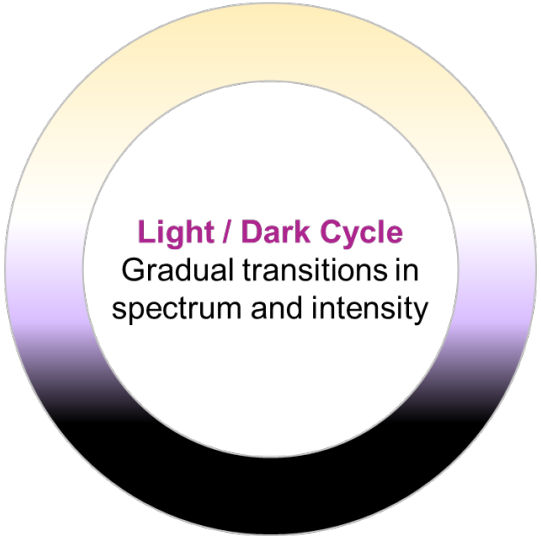
LIGHT SOURCE





	photons cm^{-2} s^{-1}				lumen m^{-2}
Range	370-400 nm	430-530 nm	530-700 nm	370-700 nm	400-700 nm
	Violet	**Blue**	**Red**	**Total**	**Total Lux**
Violet	3.36 x 10^{14}	3.52 x 10^{13}	6.40 x 10^{11}	3.72 x 10^{14}	28
Twil	3.80 x 10^{13}	2.40 x 10^{14}	2.54 x 10^{14}	5.32 x 10^{14}	337
SB	1.16 x 10^{10}	2.60 x 10^{14}	4.39 x 10^{14}	6.99 x 10^{14}	267
3000K	4.92 x 10^{12}	1.87 x 10^{14}	9.83 x 10^{14}	1.17 x 10^{15}	1051
PC G	1.06 x 10^{10}	5.87 x 10^{13}	3.53 x 10^{14}	4.12 x 10^{14}	558
PC R	9.33 x 10^{9}	1.32 x 10^{10}	8.52 x 10^{14}	8.52 x 10^{14}	196

LIGHTING CONTROL

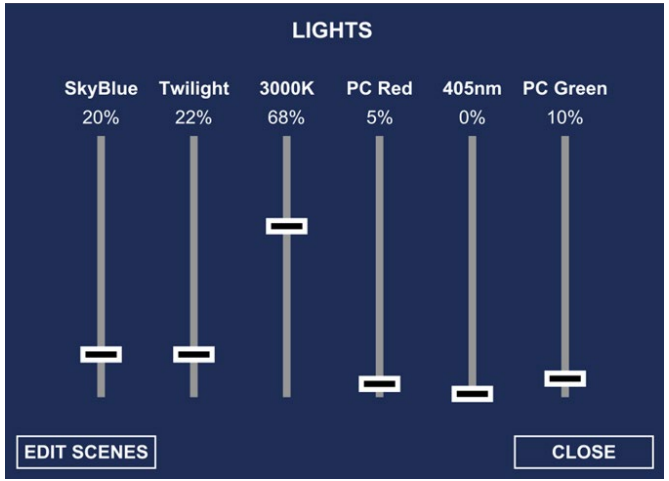


Tailored interfaces for:

- Staff
- Research
- Family

Channel Control





DUSK LIGHTING SPECTRUM

Spectral Day Name: CCHMC Default Day - September 13

Description: Based on 9-13-21 measurements

Export Current Spectrum | Import Spectrum Reference

Dusk recipe includes 405nm violet light “bump” to activate Opsin 5, which plays a role in eye growth and development



Spectral Frame

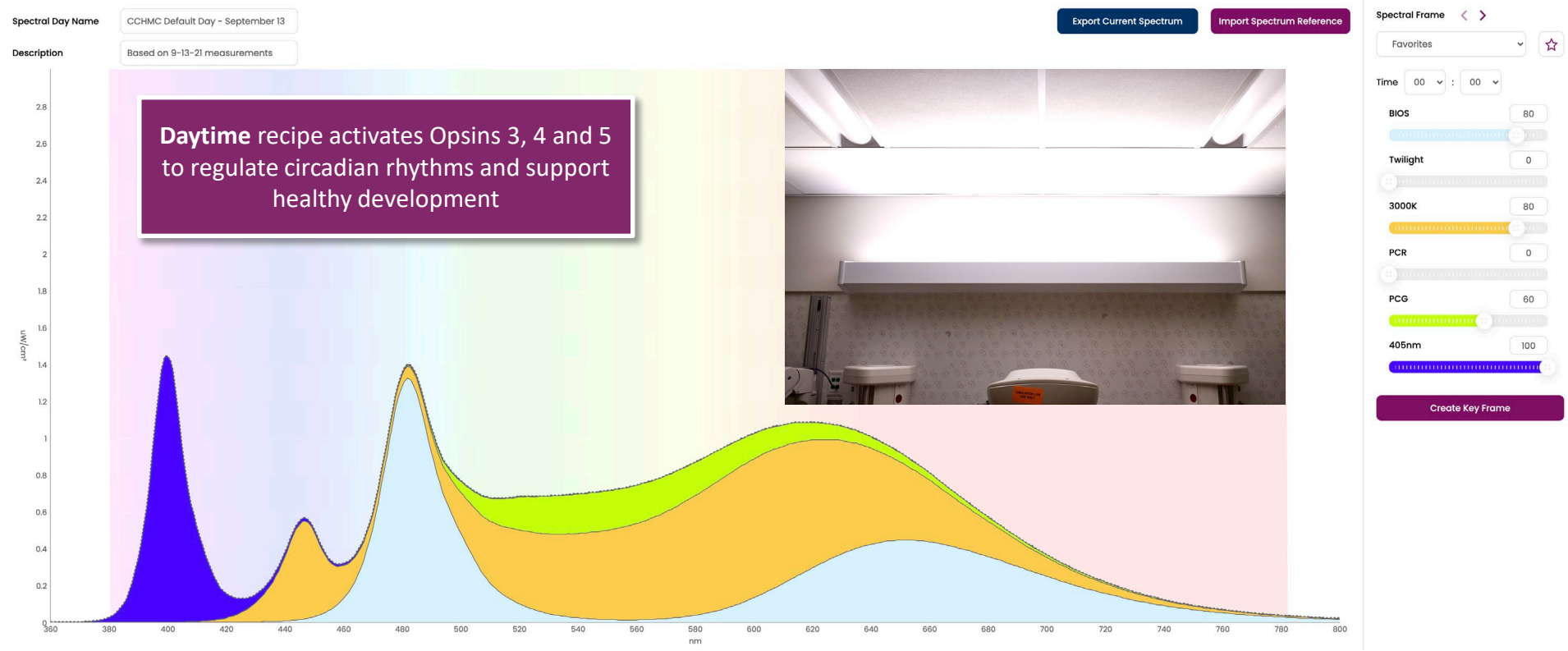
Favorites

Time 00 : 00

BIOS	0
Twilight	20
3000K	5
PCR	5
PCG	5
405nm	35

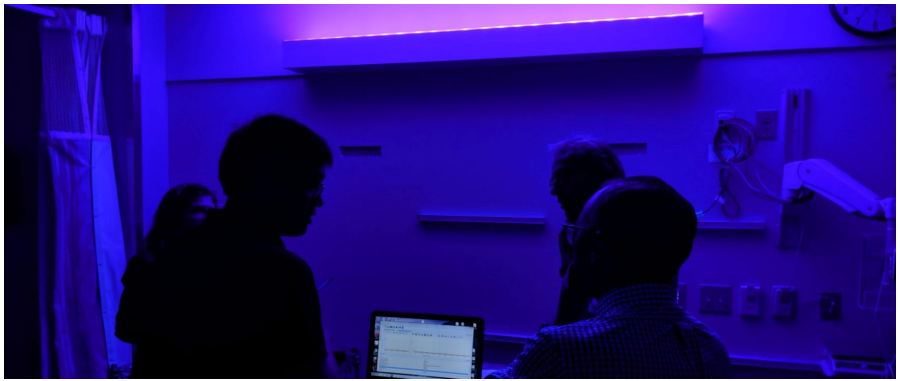
Create Key Frame

DAYTIME LIGHTING SPECTRUM



TESTING

- Full-scale mockups
- Intensity, aesthetics
- Participation of multidisciplinary lighting team
- Bi-weekly software design sessions





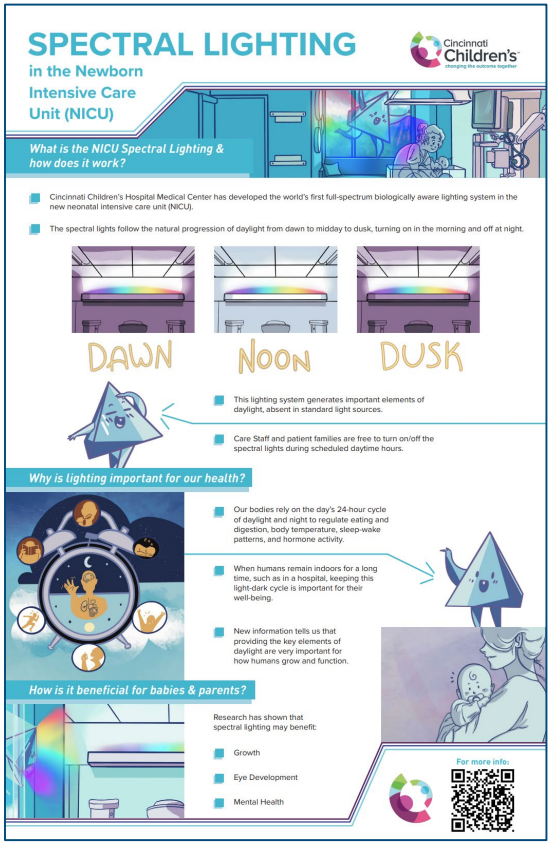


In-Service Education & Training – Post-Occupancy

- Monthly presentations at NICU RN Manager meetings
- Virtual forum for spectral lighting Q&A
- Educational resources
- Ad hoc rounds and presentations for bedside staff
- 3 post-occupancy surveys

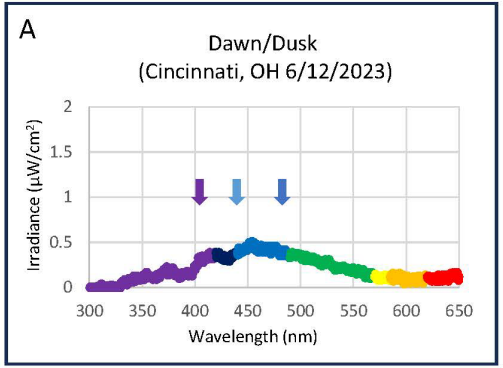


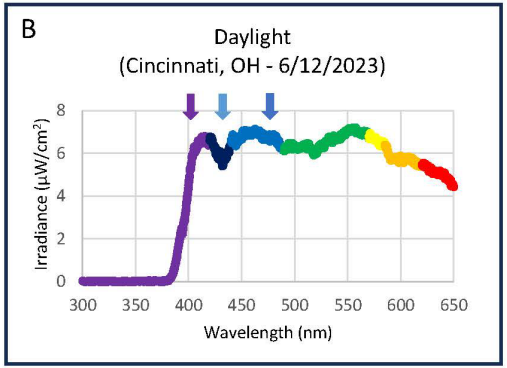
FAMILY & STAFF ONBOARDING

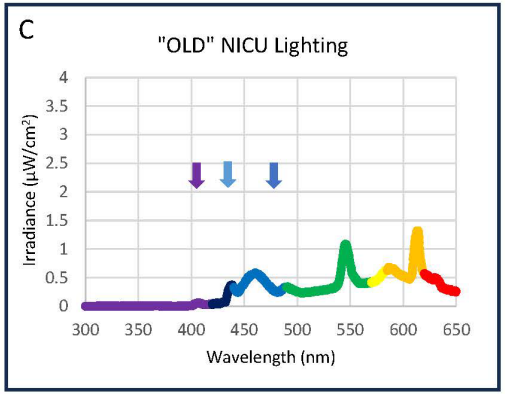


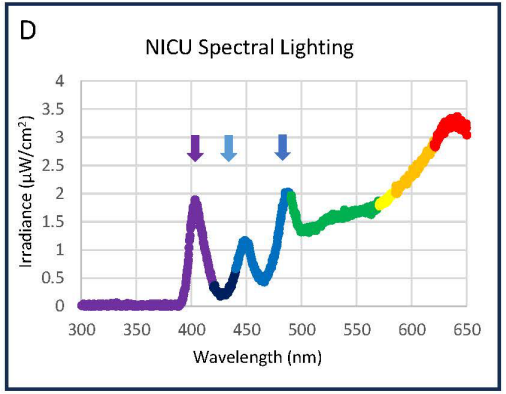


LESSONS LEARNED SO FAR



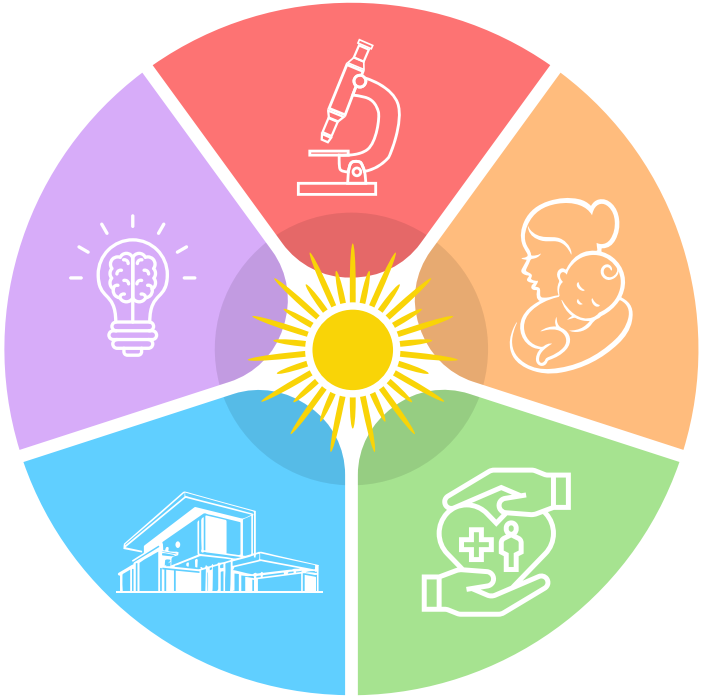






Science of Light Center

Exploring the vital connections between light and health.



Basic and Pre-Clinical Research

Led by Dr. Richard Lang, our basic science research team is focused on the discovery of new mechanisms in sun-coupled physiology.

Clinical Research

Led by Dr. James Greenberg, our translational research team is considering new ways to address human health and wellness issues using our knowledge of sun-coupled physiology.

Public Health

A long-term goal of the SOL Center is to partner with the public health sector for the propagation of new information on the relationship between light and health.

Architecture

Seeking the design of the built environments to be biologically aware and promote health and well-being through partnerships with architects and designers.

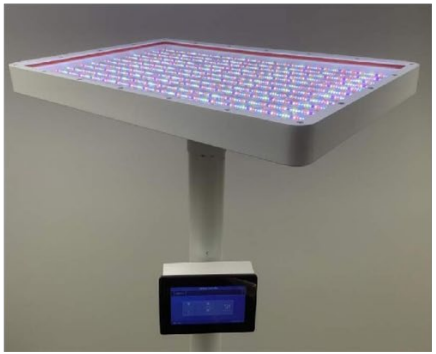
Commercialization

The SOL Center will seek technology partners for the distribution of biological lighting technology to provide a path for the dissemination of basic science and clinical research findings.

CLINICAL TRIALS

- Metabolism
- Performance
- Behavioral health
- Myopia



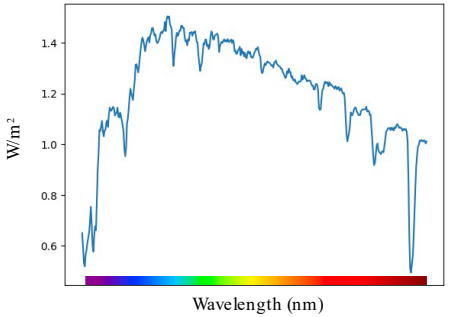





LARK
SPECTRAL LIGHTING
v3.0

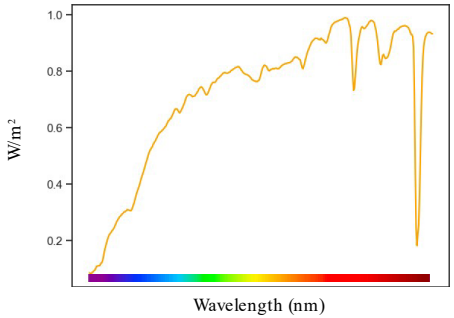
SUN + SKY SPECTRUM OUTDOORS

1 Sky (Diffuse horizontal)



5600K

2 Sun (Direct Solar)



4250 K

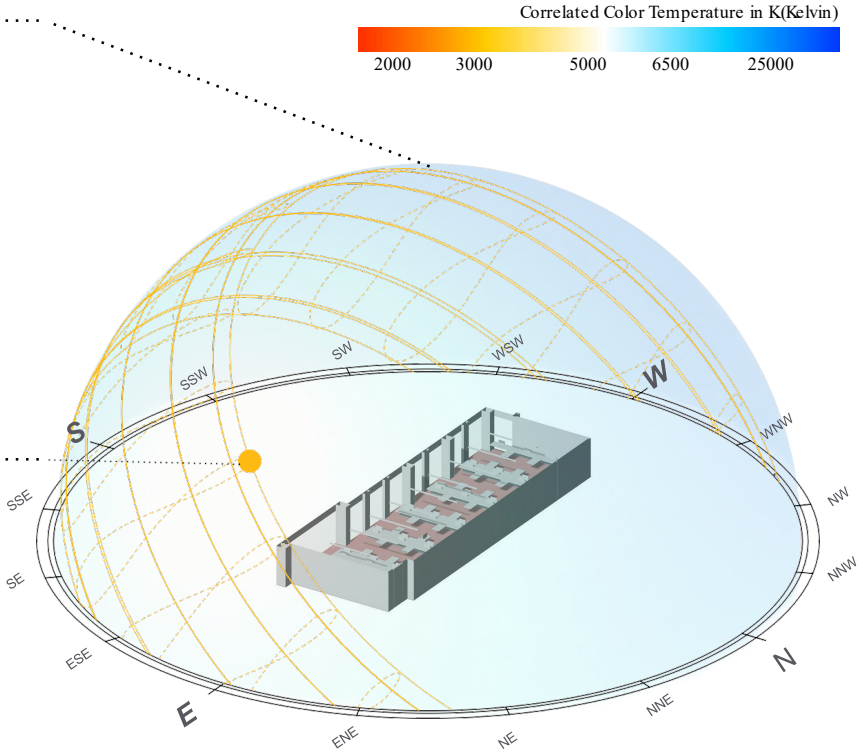
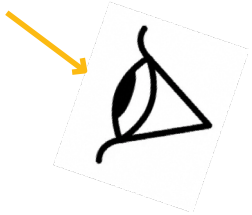
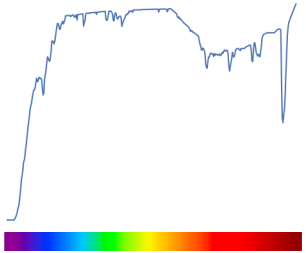


Image by Bo Jung

INTERACTION WITH DAYLIGHT

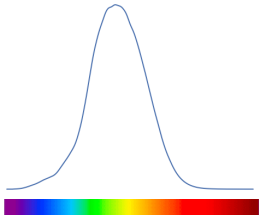




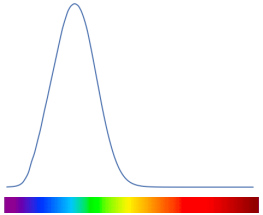
Reflected Light Entering eyes

Energy level of reflected light entering our eyes

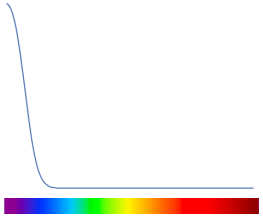
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Opsin 1 (Photopic)

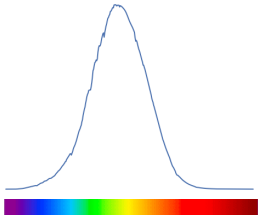


Opsin 4 (Melanopic)

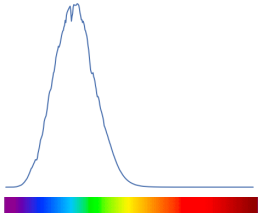


Opsin 5 (Neuropic)

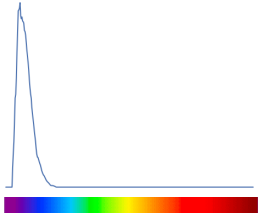
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400lux



300 lux



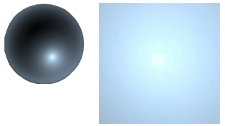
100 lux

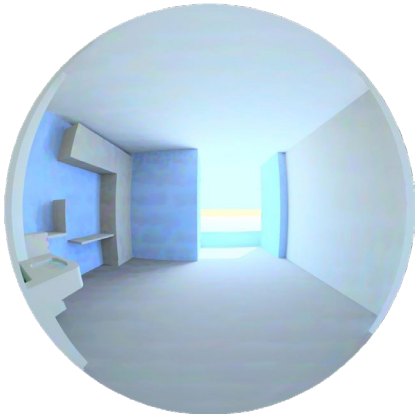
Image by Bo Jung

SPECTRAL SKY + SUN – WHY IS IT IMPORTANT?

7000K sun + 9000K sky

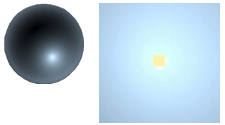
June 21 10am





3000K sun + 9000K sky

June 21 10am

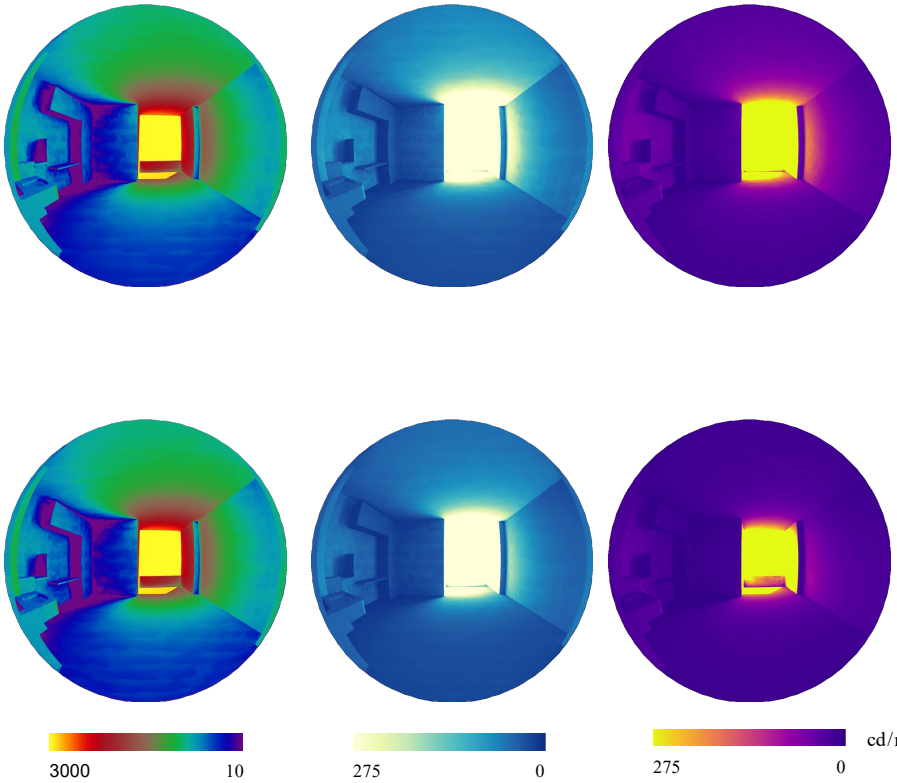




Photopic
Vision

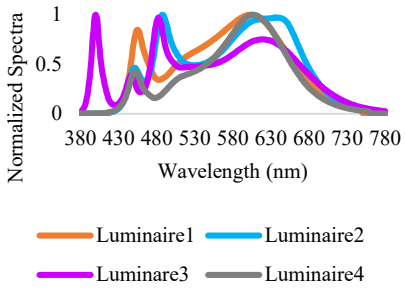
Melanopic
Circadian

Neuropic
Growth - Metabolism



Simulation by Bo Jung

ELECTRIC LIGHTING SIMULATION

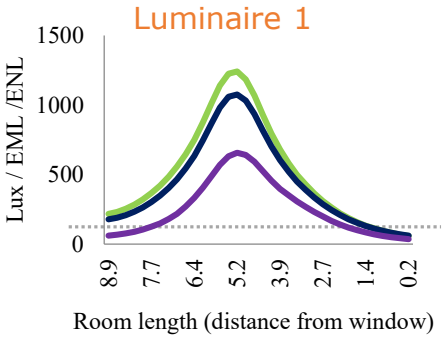


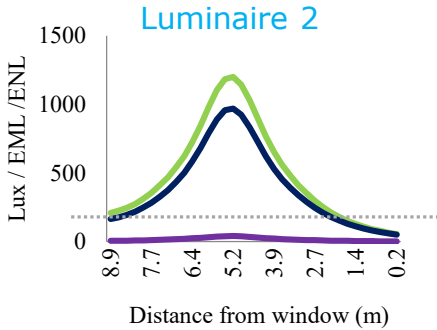
Luminaire 1: Fixed spectrum LED with 3500K

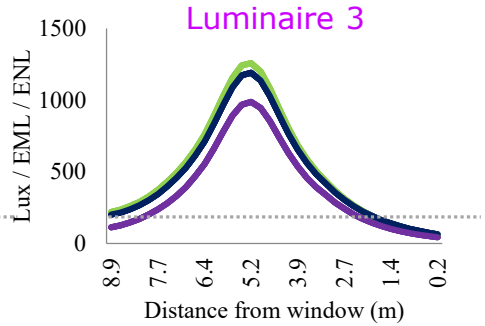
Luminaire 2: Programmable LED with 3500K, spikes at 490 nm to support melanopic stimulus

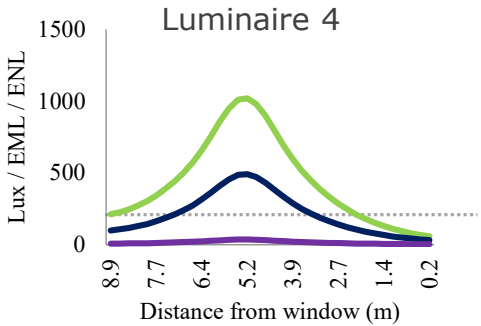
Luminaire 3: Custom programmable LED with 3500K, spikes at 405 and 482 nm to support neuropic and melanopic stimulus

Luminaire 4: Programmable LED with 2700K, for nighttime







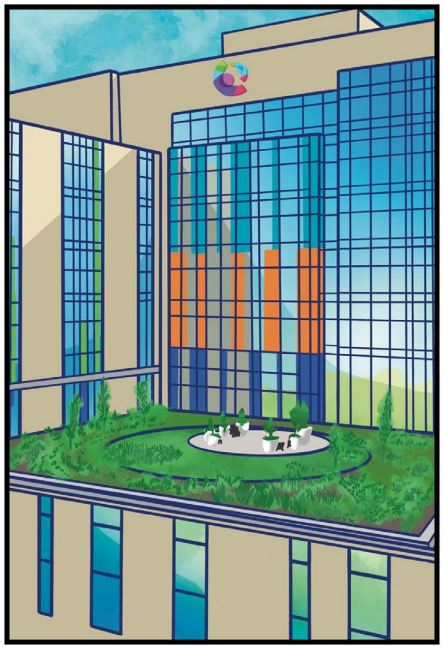


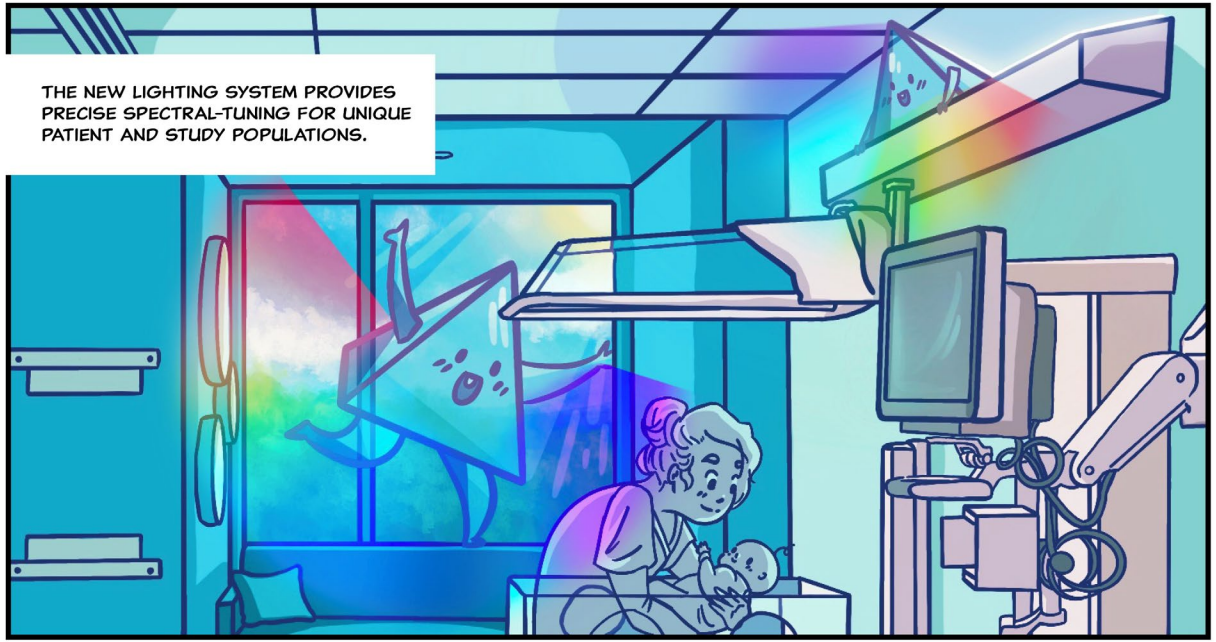
Photopic Lux
E. Melanopic Lux
E. Neuropic Lux

Simulation by Bo Jung

TODAY

THE NEW CRITICAL CARE BUILDING (CCB) INCLUDES A NOVEL LIGHTING TECHNOLOGY INSPIRED BY OUR BIOLOGICAL DISCOVERIES.





QUESTIONS?

