MEBS6004 Built Environment

http://ibse.hk/MEBS6004/

Lighting and daylighting design

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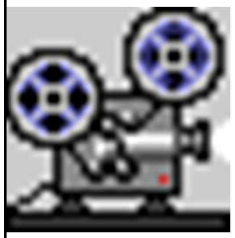
Basic principles

- Video: What is lighting design? (4:13)



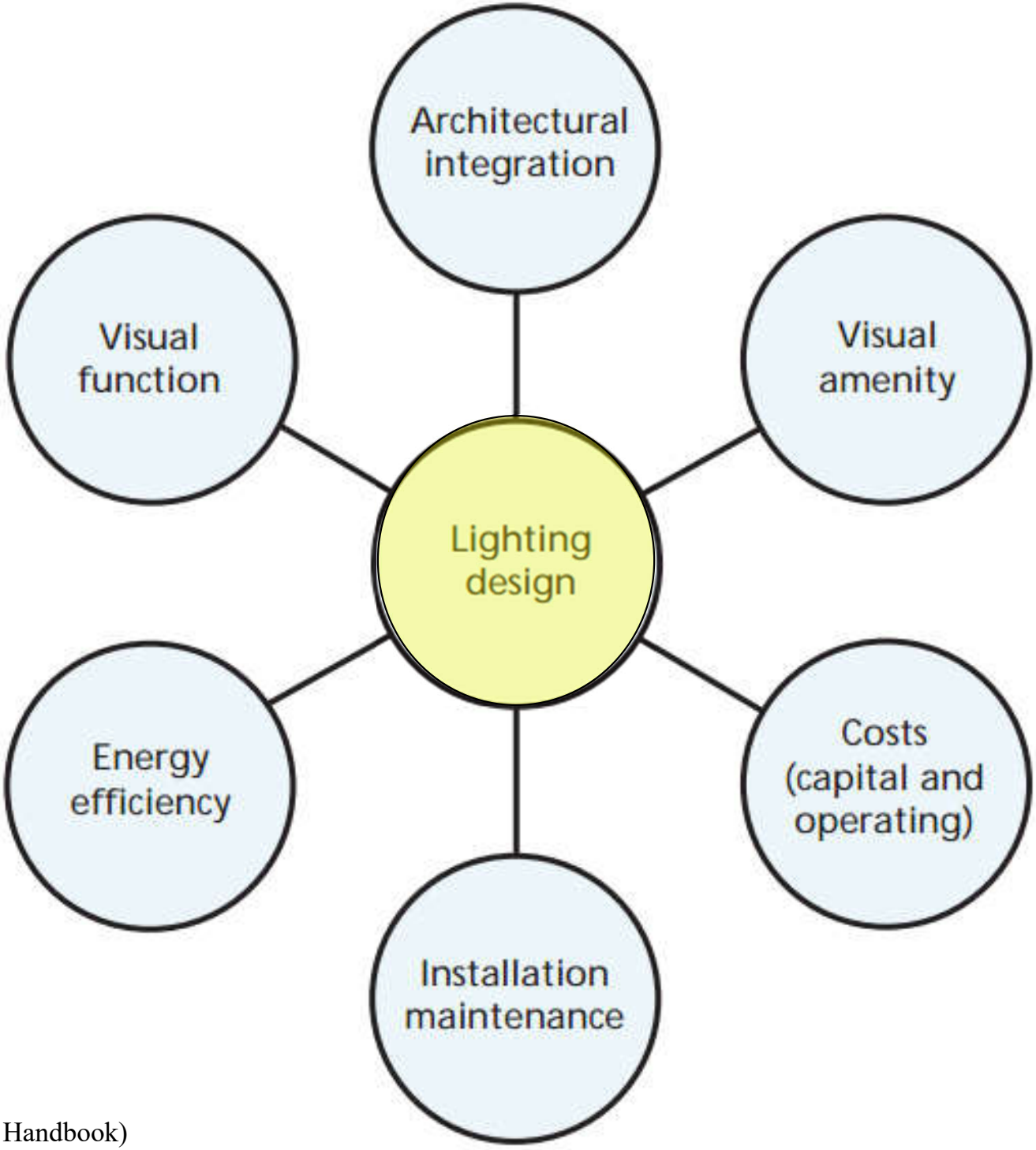
  - https://youtu.be/hqT4alUaHfQ
  - Award winning Architectural Lighting Designer, Annette Hladio, discusses her views on lighting design
  - She has an education in architectural engineering
  - Galleries of lighting design portfolio by Annette Hladio:
    - http://www.archltg.com/

Basic principles

- Lighting design can have many different objectives
  - Determined by the client & the designer
  - The most common objective is to allow the users of a space to carry out their work quickly & accurately, without discomfort

- Design constraints
  - Such as financial & environmental concerns
  - Architectural integration, installation & maintenance issues

Considerations for lighting design



(Source: The SLL Lighting Handbook)

Basic principles

- Examples of indoor lighting design:
  - Emergency lighting
  - Office lighting
  - Industrial lighting
  - Lighting for educational purposes
  - Lighting for museums & art galleries
  - Lighting for hospitals
  - Lighting for homes & hotels
  - Retail lighting

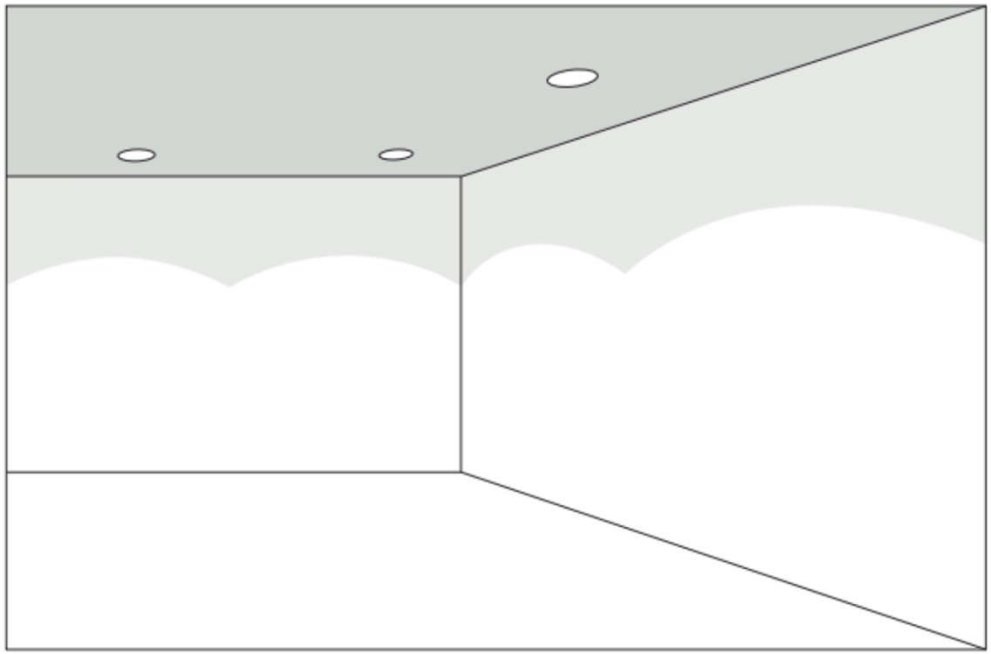
Basic principles

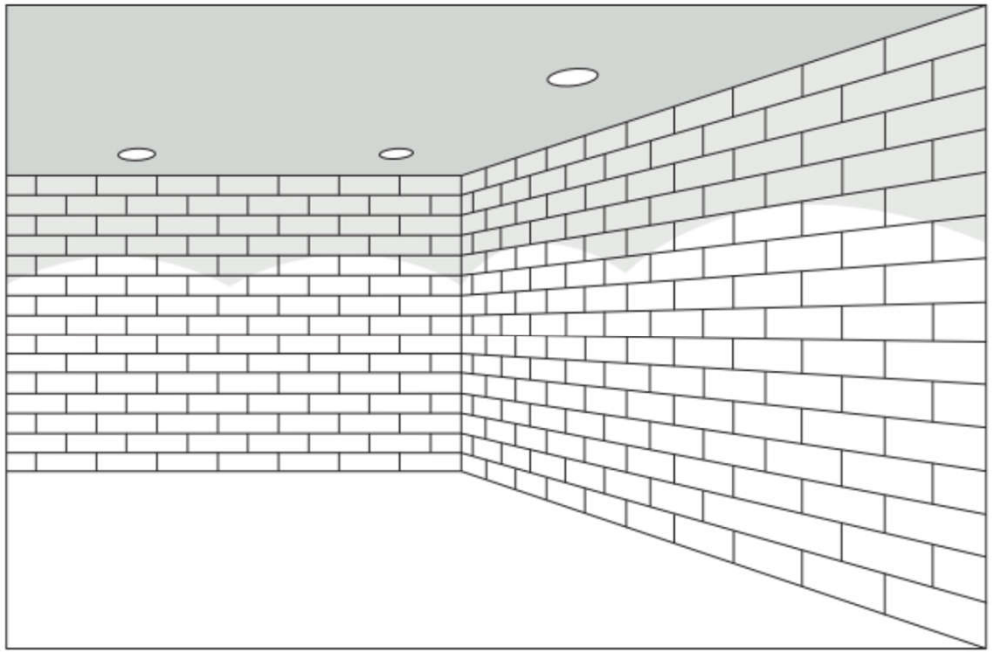
- Basic design decisions
  - Use of daylight (what role would daylight plays)
    - To provide a view out
    - To provide enough light to work by
    - To save energy
    - To provide lighting for particular tasks requiring very good colour rendering
    - To enhance the appearance of the space by providing meaningful variation in the lighting
  - Choice of electric lighting system
    - Such as general, localised & local lighting systems

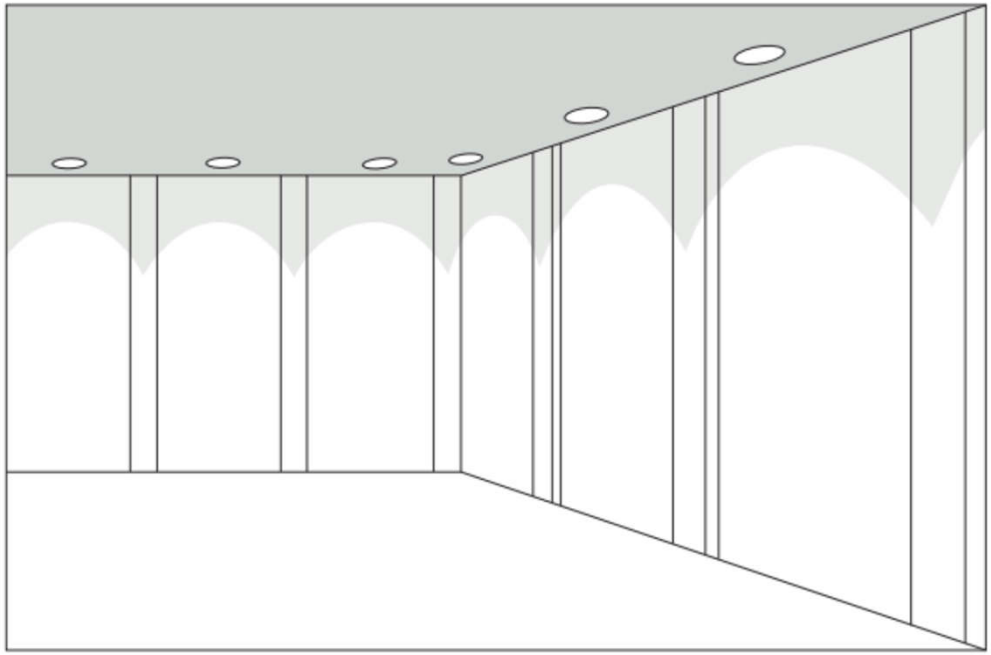
Basic principles

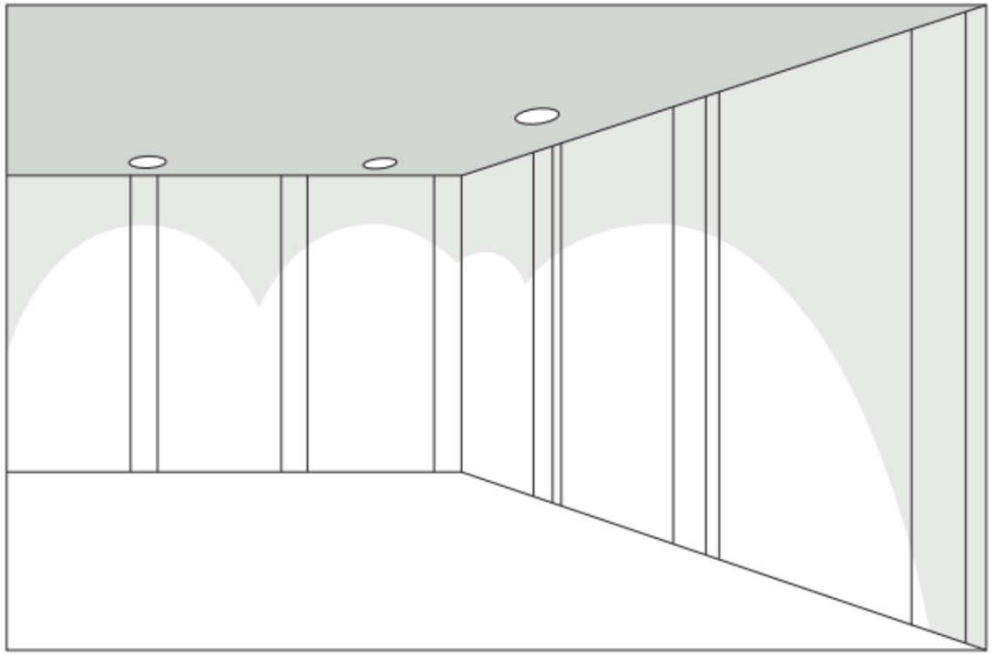
- Basic design decisions (cont'd)
  - Integration
    - Within the space, architecture, interior design
    - With other services (e.g. fire, HVAC)
    - With daylight
    - With the surroundings

Lighting distribution on the wall and the perception









(Source: Handbook of Lighting Design (ERCO Edition) https://download.erco.com/en/media/handbook)

Basic principles

- General lighting practice:
  - Two objectives – good visual performance without discomfort
  - Two systems of measurement – photometry & colorimetry
  - Five criteria – Illuminance, luminance, uniformity, correlated colour temperature (CCT), colour rendering index (CRI), unified glare rating (UGR)
  - One location – the horizontal working plane
- Lighting design is all about people
  - Activity, experience, well-being

Basic principles

- Three main functions of lighting:
  - Ensure the safety of people
  - Facilitate the performance of visual tasks
  - Aid the creation of an appropriate visual environment (appearance & character)

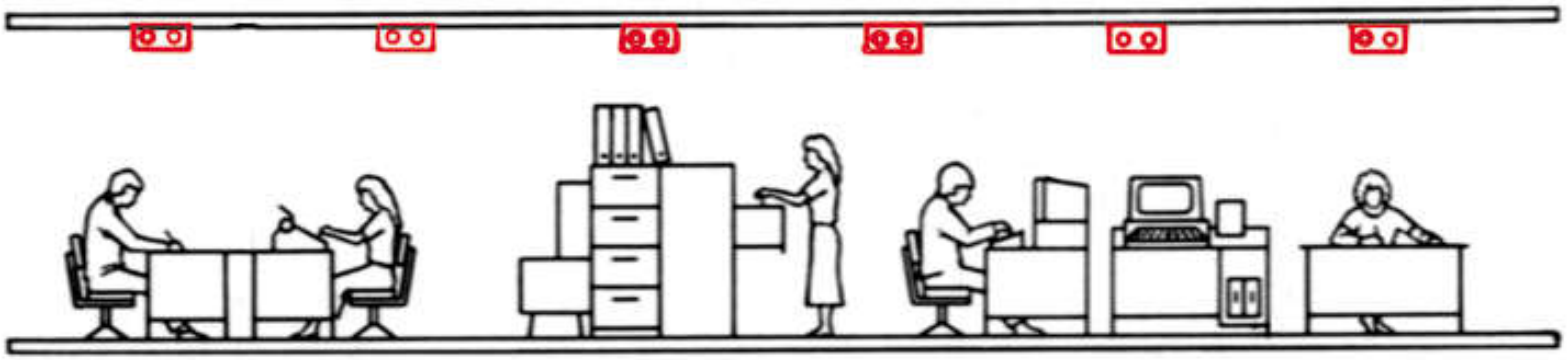
Basic principles

- Lighting design criteria
  - Luminous environment & luminance distribution
  - Illuminance & uniformity
  - Lighting directional effects
  - Colour aspects, variability of light
  - Glare, flicker & stroboscopic effects
  - Lighting of work stations with display screen equipment (DSE)
  - Maintenance factor
  - Energy efficiency requirements

Basic principles

- Effect of lighting
  - On architecture (defines space & shows form)
  - On interior design (reveals texture & colour)
- Psychological effects of an environment are as important as the physiological
  - Good quality light to "see by" & to "feel by"
- Three main aspects to consider:
  - General lighting
  - Localised lighting
  - Local (task) lighting

General lighting



[Source: CIBSE Lighting Code]

Localised lighting

[Source: CIBSE Lighting Code]

Local (task) lighting

[Source: CIBSE Lighting Code]

Major aspects & issues of lighting design

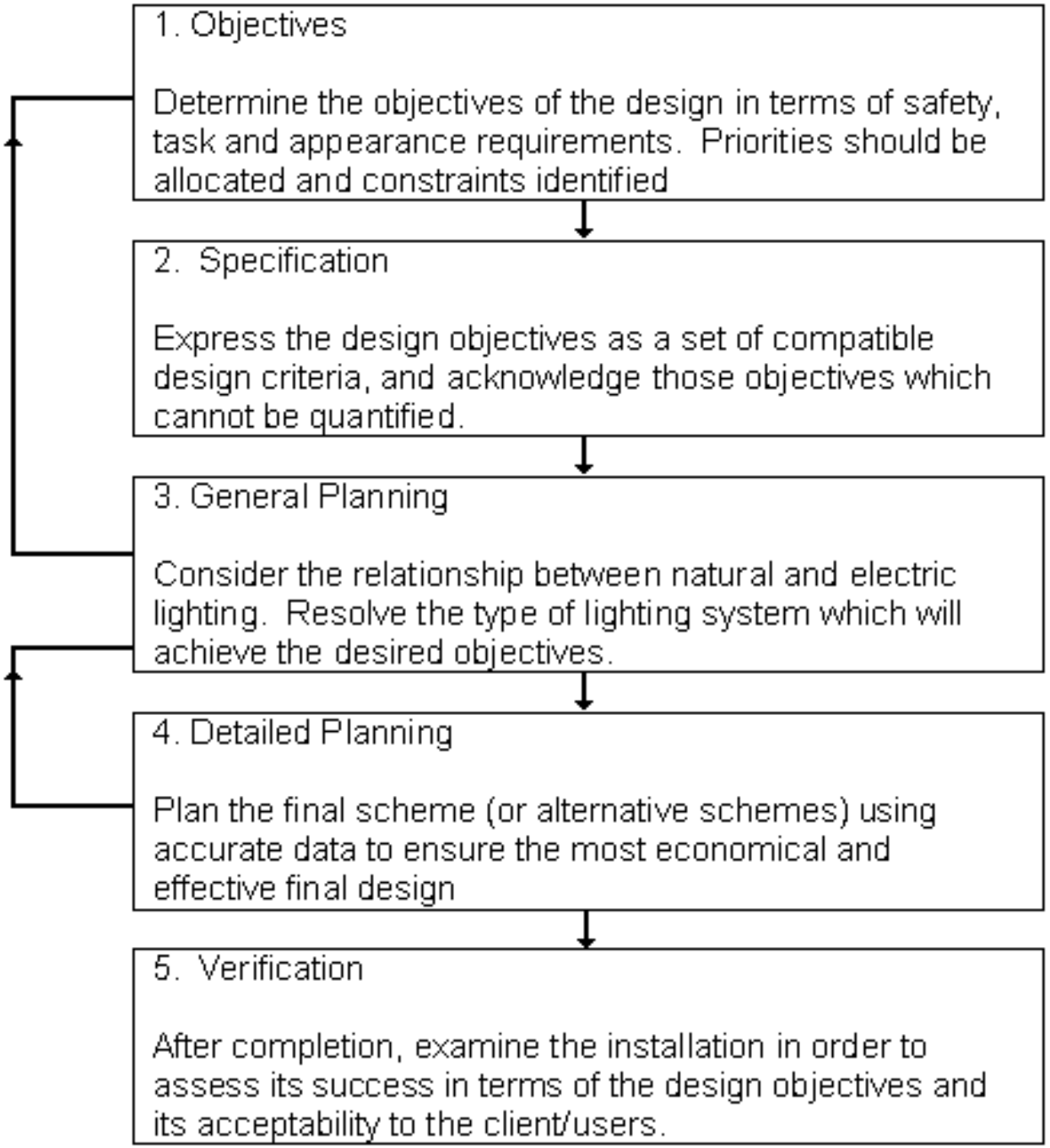
Light for Architecture	Light for Activity	Light for Atmosphere
• Illuminate vertical surfaces to improve spatial perception • Separate functional areas • Emphasise architectural elements with accent lighting • Observe materials, texture & modelling • Mounting location & method, luminaire shape & arrangement • Visual comfort & light pollution	• Adjust the brightness level to the visual task & adjacent areas • Avoid glare • Consider the time of day & natural light • Facilitate facial recognition & support person-to-person communication • Consider the room functions & zoning	• Provide spatial orientation by highlighting entrances, routes & vertical surfaces • Create temporal orientation to give a sense of time • Create perceptual hierarchies by emphasising important areas with focal points • Allow individual adjustment • Consider visual comfort (glare & colour)

* Animation to demonstrate how the different aspects can change our perception of space & the atmosphere: https://www.erco.com/en/service/human-centric-lighting-7320/)

Basic principles

- Planning process for lighting
  - Project analysis (quantitative & qualitative)
    - Utilisation of space, psychological requirements, architecture & ambience
  - Lighting concept (consult with other trades)
  - Design (design decisions, calculations)
  - Installation (luminaire types & mounting)
  - Maintenance (e.g. cleaning, replacement)

Lighting design & planning



Set the goals

Specify criteria

System type

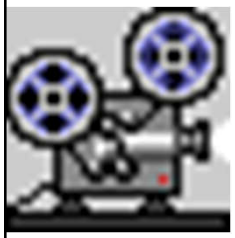
Calculations/ details

Verification

[Source: CIBSE Lighting Code]

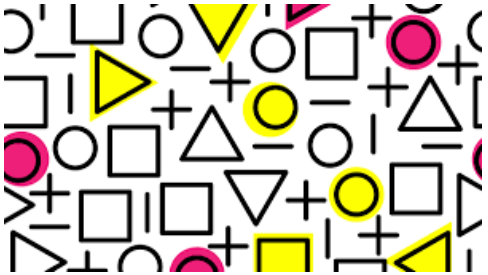
Lighting design

- Video: Lighting Design Process (4:12)



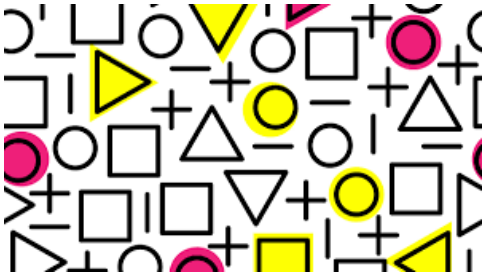
  - https://youtu.be/hpyq6uktBwM
  - Typical building design process (7 steps):
    - Programming
    - Schematic design
    - Design development
    - Construction documents
    - Bidding (tendering)
    - Construction & handover
    - Post-occupancy evaluation (POE)

Lighting design



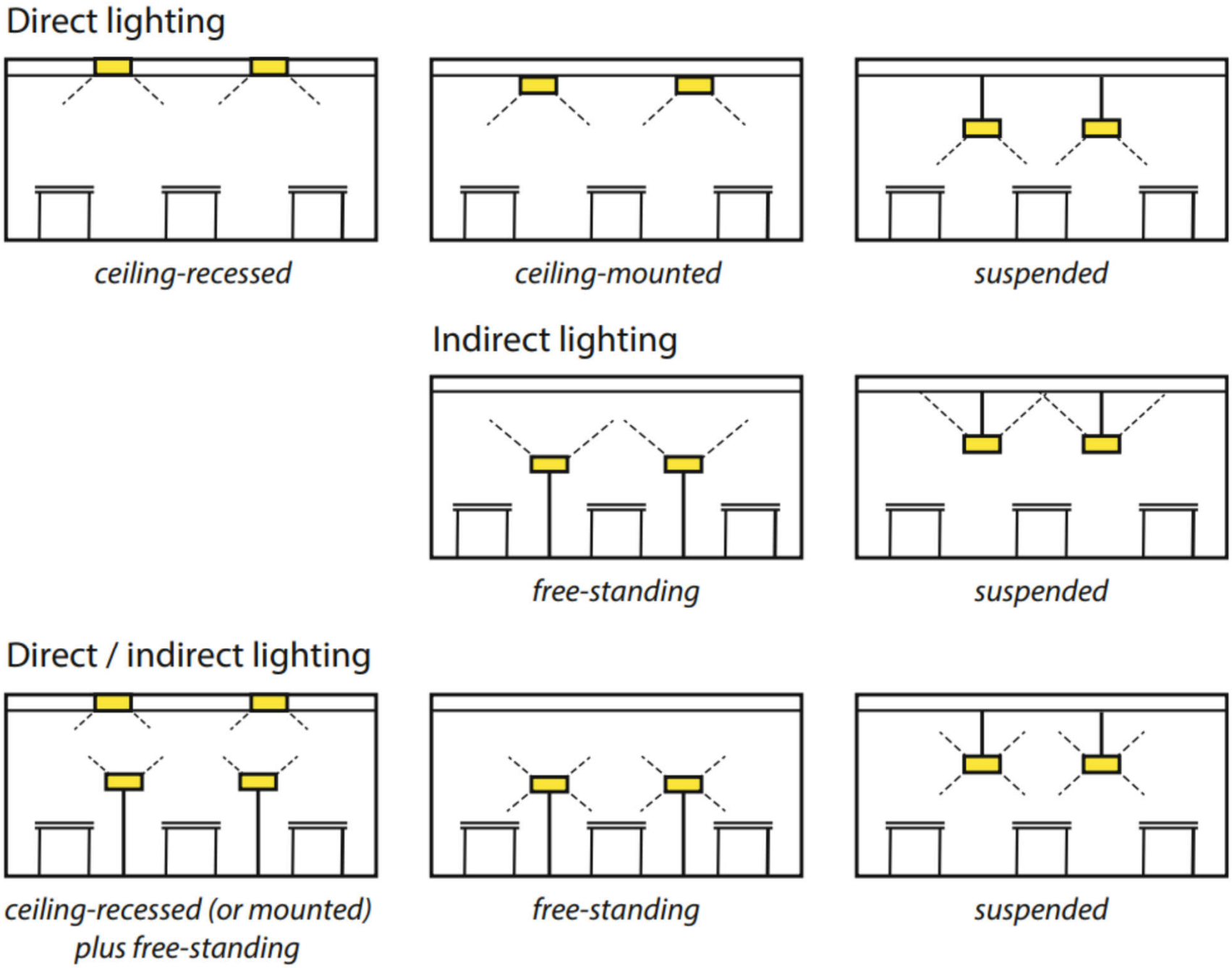
- Basic approach to lighting design
  - Determine lighting design criteria
    - Quantity of illumination (lighting level, lux)
    - Quality of illumination (e.g. overall appearance, colour)
    - Codes and regulations (e.g. building, electrical, energy)
  - Record architectural conditions & constraints, e.g.
    - Window location & size, ceiling height, finish materials
  - Determine visual functions & tasks to be served
  - Select lighting system to be used

Lighting design



- Basic approach to lighting design (cont'd)
  - Select luminaire & lamp types
    - To produce the desired light & fit the client's needs
  - Determine number & location of luminaires
    - Through calculations & assessment
  - Place switching & other control devices
    - User convenience & energy management
  - Aesthetic & other intangibles
    - Aesthetic, psychological, cultural & contextual factors

Different mounting methods for fully direct, fully indirect & a combination of direct-indirect general lighting systems



(Source: van Bommel W., 2019. *Interior Lighting: Fundamentals, Technology and Application*, Springer International Publishing, Cham.)

Lighting design

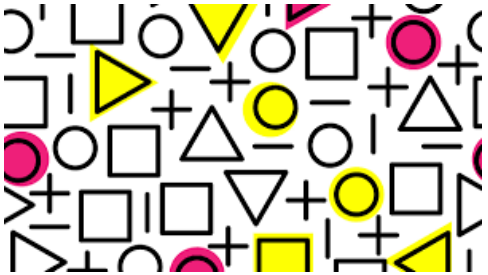
- Factors affecting visual performance:
  - Inadequate illuminance
  - Too great or too low a contrast
  - Disability & discomfort glare
  - Veiling reflection
  - Flicker from fluorescent lamps
  - Psychological factor (occupant's satisfaction with the environment)

Lighting quality aspects & parameters for indoor lighting installations

Visual aspects	Non-visual biological aspects
Lighting level • On the tasks • On the room surfaces	Lighting level • On the eye • Time dependent • Melanopic irradiance
Lighting uniformity & direction • Face recognition & modelling (e.g. cylindrical illuminance)	Spectrum • Time dependent • Chromaticity
Glare restriction • Unified glare rating (UGR)	Timing • Circadian stimulus
Colour appearance & rendering • Correlated colour temperature • Colour rendering index	Duration

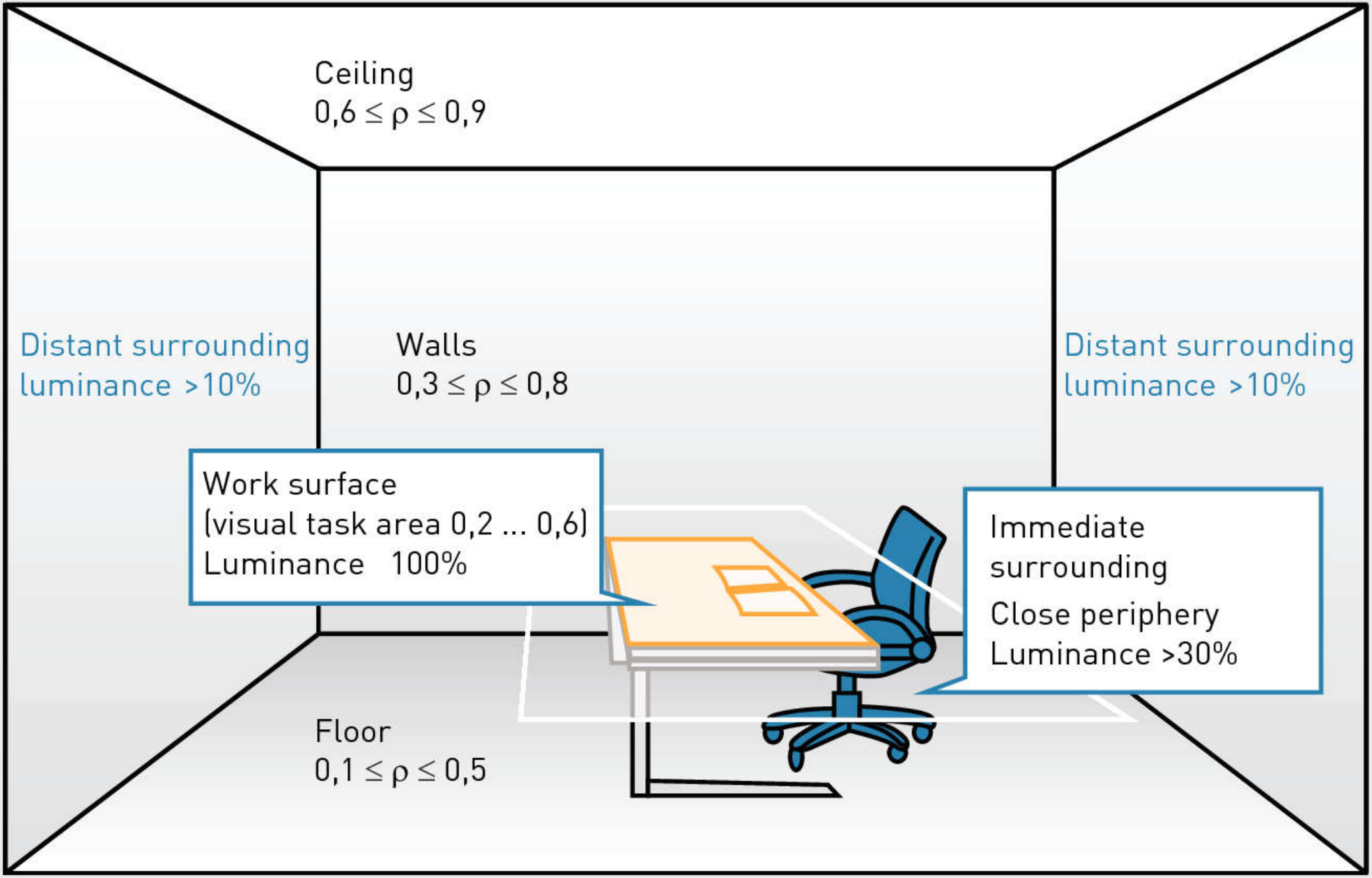
(Source: van Bommel W., 2019. *Interior Lighting: Fundamentals, Technology and Application*, Springer International Publishing, Cham.)

Lighting design



- Lighting quality & criteria
  - Lighting level (illuminance or luminance)
    - Horizontal, wall & ceiling
  - Luminance distribution
    - Better distribution of brightness within the field of view
  - Freedom from disturbing glare
  - Spatial distribution of light
    - General lighting, directional lighting, backlighting & uplighting, diffuse lighting
  - Light colour & colour rendering
    - Colour temperature & colour rendering index

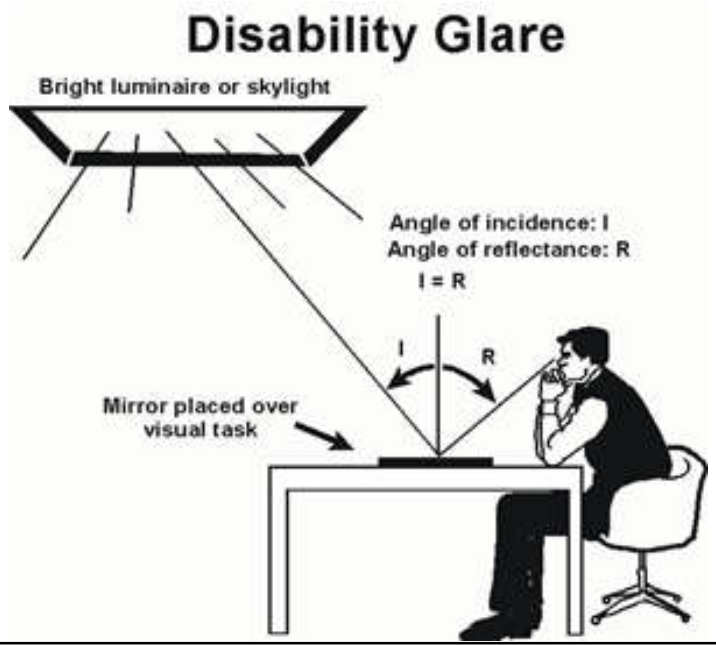
Recommended room reflectances (ρ) & luminance distribution

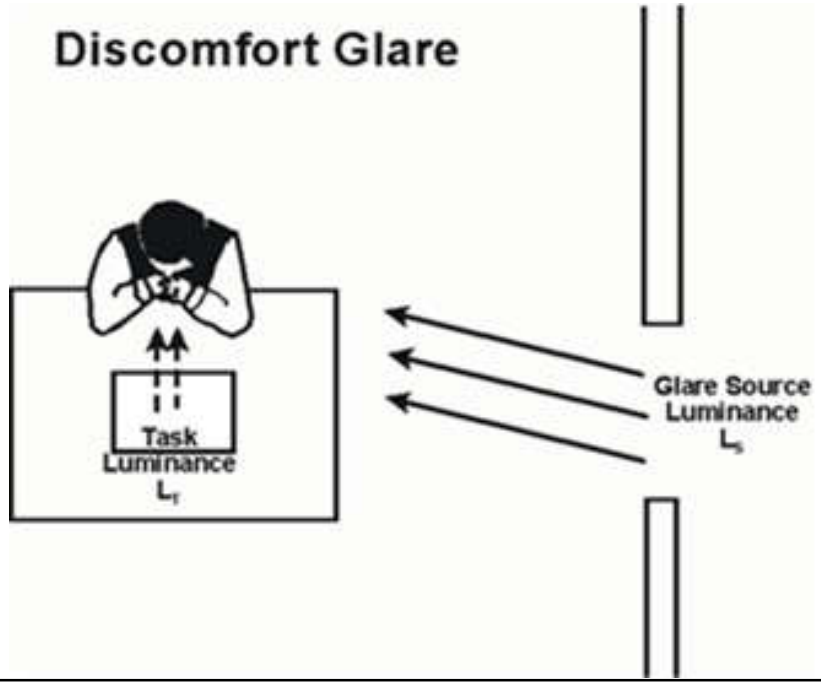


(Source: http://trilux.com)

Disability glare from bright sky in front of a VDT makes the screen difficult to read

Discomfort glare from bright luminaires

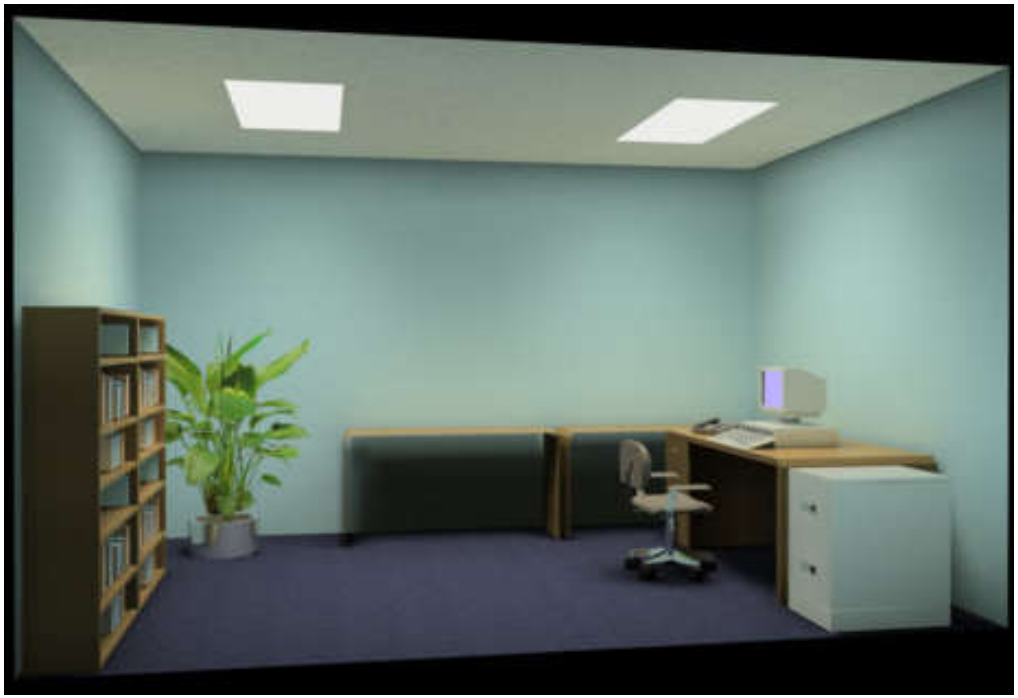




Lighting design

- Typical lighting design issues
  - Planes of brightness (high brightness creates cheerful atmosphere)
  - Glitter & sparkle (stimulating points)
  - Light & shadow (create focal points)
  - Modelling (reveal dimensionality)

Different lighting effects in a private office



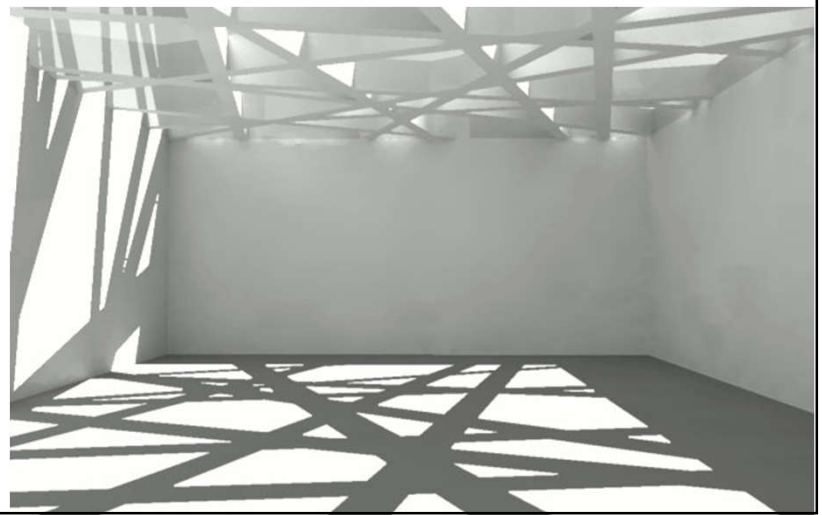
(Source: https://www.lightnowblog.com/2016/03/introduction-to-lighting-design/)

Daylight benefits

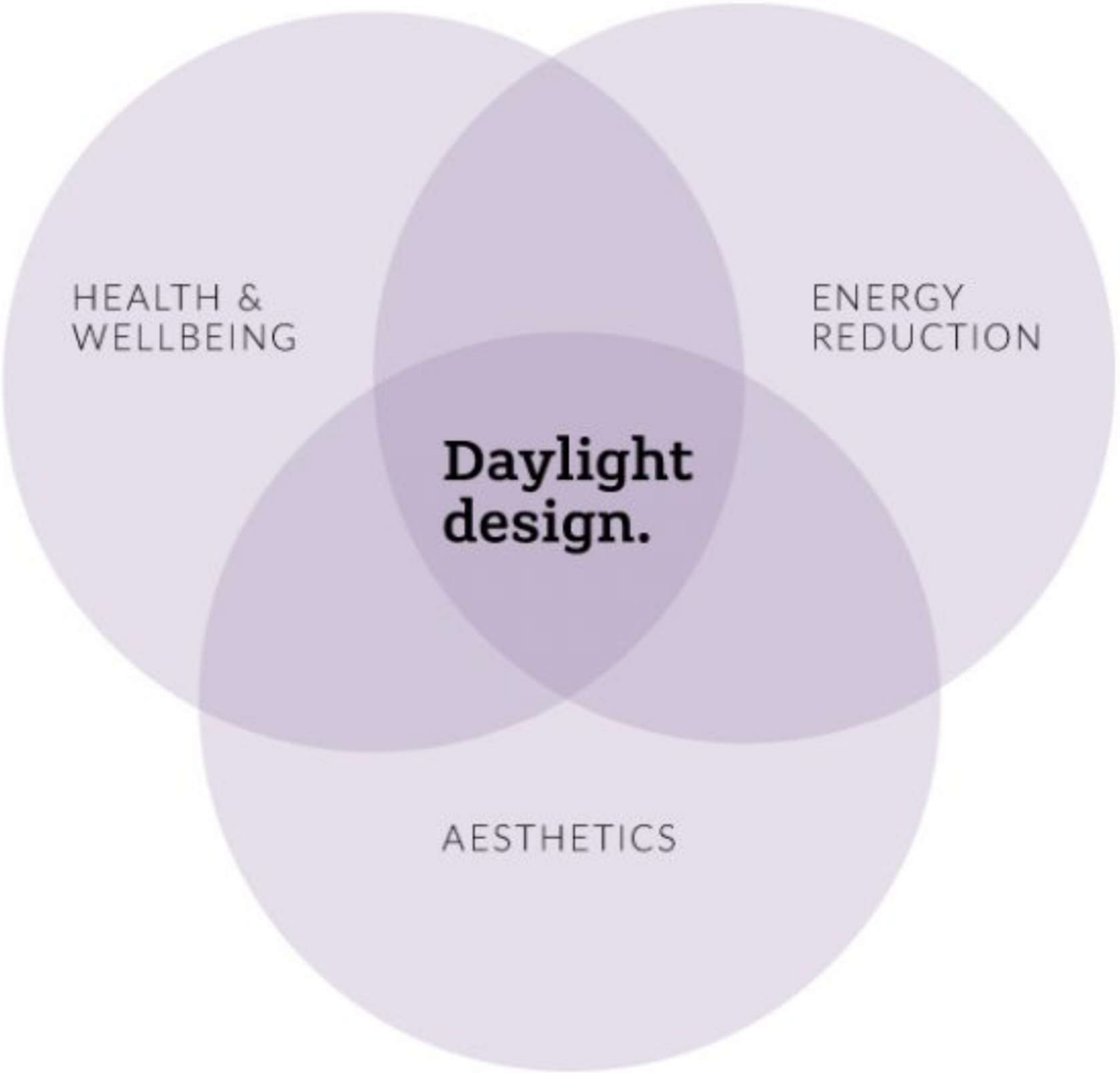
- Well-planned, imaginative use of daylight will strengthen the character of a building & enhance the architectural design
  - It also has a positive effect on the physical & psychological well-being (e.g. light therapy)
- Existing daylight conditions depend on
  - Building's orientation, location & surroundings
- Also, daylight has a significant effect on landscape & urban spaces

Daylight benefits

- Daylight as a building material
  - It is celebrated in architecture
    - To create & dissolve space
    - To shape an uncontoured space in an almost material way to turn an instant into an intense experience
    - To create ambience & movement to articulate the space
  - Examples of techniques
    - Light reflex
    - Intersecting light
    - Sidelight

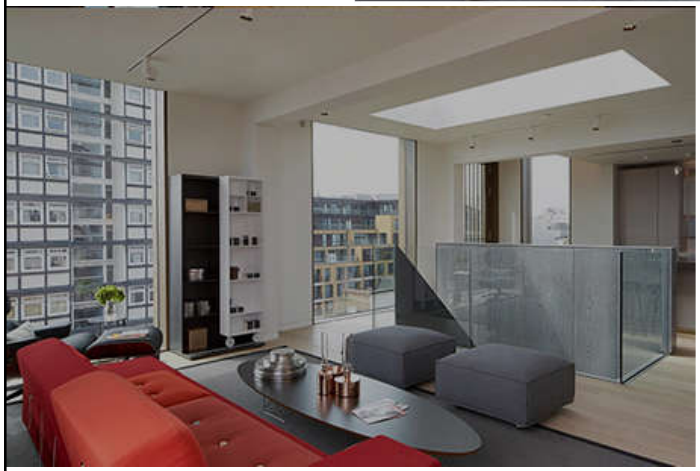


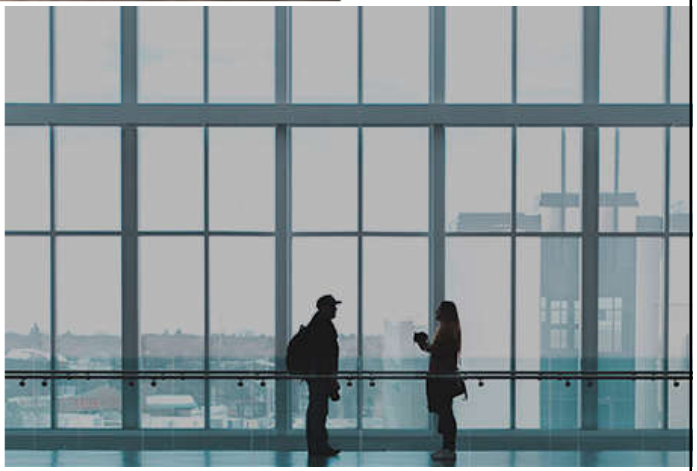
The power of daylight design



(Source: https://hoarelea.com/2018/09/07/the-power-of-daylight-design/)

Examples of daylight design in buildings





(Source: https://hoarelea.com/2018/09/07/the-power-of-daylight-design/)

Benefits of daylighting design

Workplaces & Offices
Improve efficiency & concentration, and thus increase productivity

Educational Organizations
Improve motivation & engagement with teachers & students at school

(Source: https://www.lightengine-tech.com/circadian-light-solution)

Benefits of daylighting design

Hospitals & Nursing Homes
Unwind & calm patients with light, which also helps them to sleep better & heal faster

Fitness & Wellness Centres
Energize for active work-outs

(Source: https://www.lightengine-tech.com/circadian-light-solution)

Daylight benefits

- Daylight & well-being
  - Psychological effects of daylight
    - Prevention of Seasonal Affective Disorder (SAD)
  - Photobiological processes of human eye & skin
  - The dynamics of daylight has a stimulating effect
  - Qualities of daylight
    - Brightness
    - Colour & the spectral composition
    - Light direction
    - Time duration

Daylight benefits

- The non-visual systems (ipRGC) are mostly sensitive to short-wavelength light (blue light) and have impacts on alertness, performance & circadian rhythms by the regulation of sleep-wake cycle & hormonal processes on our mood & emotions
- Viewing nature is one of the countermeasures that could minimize the negative effect of bright light

(ipRGCs = Intrinsically Photosensitive Retinal Ganglion Cells)

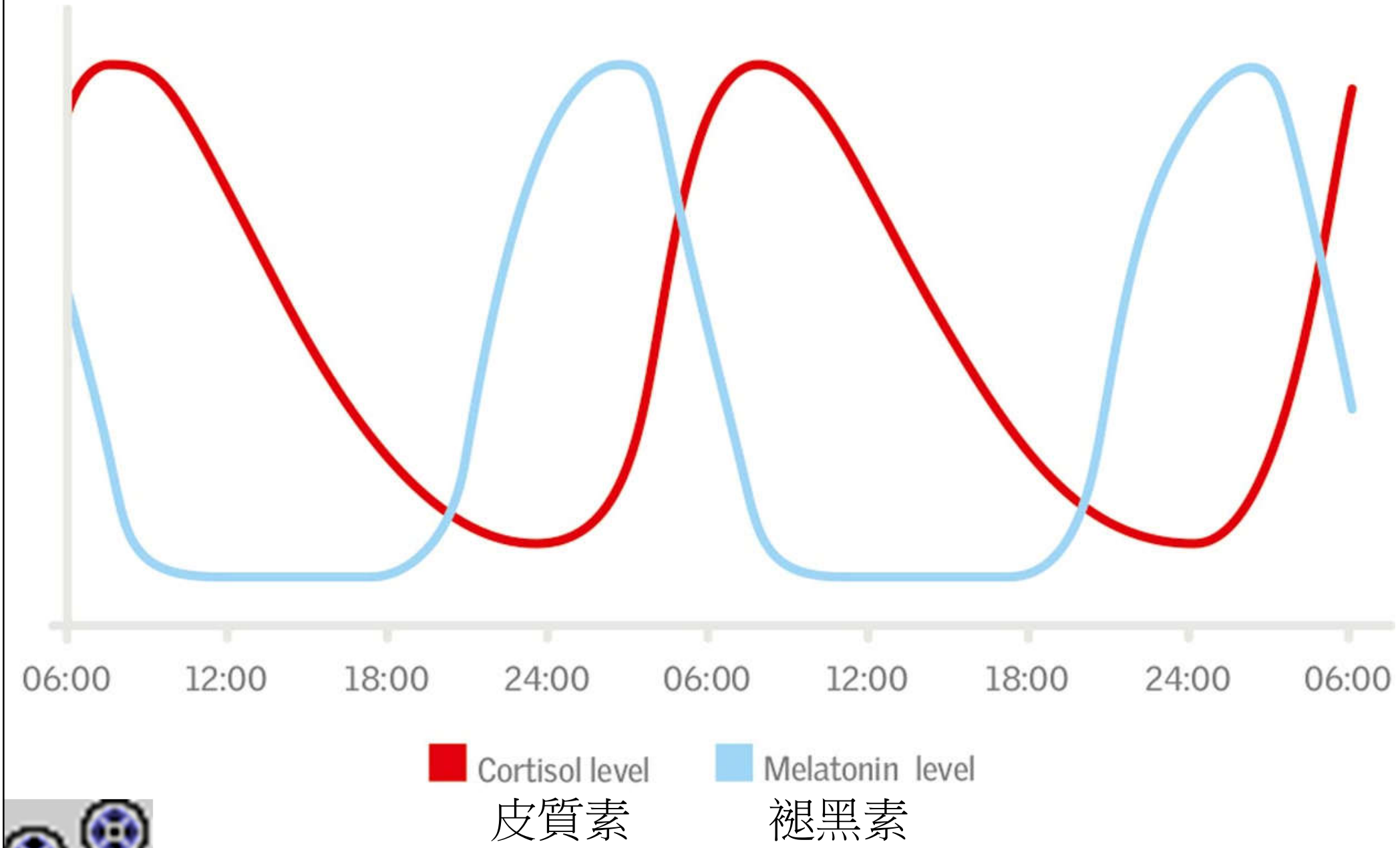
Daylight benefits

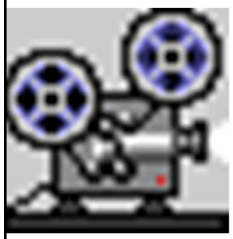
- Human beings have evolved over millions of years with the sun & our ipRGCs are more sensitive to light that hits the bottom of the back of our eyes
- In our built environment, most of our lighting is directly overhead for the entire day, and is not optimized to impact our circadian rhythm, even at high intensities
  - Optimal circadian stimulus is beneficial to health

Daylight benefits

- Circadian lighting 自然光韻律系統
  - Minimize negative effects of electric light on the human circadian rhythm (a 24-hour internal clock)
    - The hypothalamus (下丘腦) in the brain receives signals from the eyes and controls the amount of melatonin (褪黑素) released to correlate sleepiness with darkness & alertness with lightness
  - Affect people's health, alertness & productivity
  - Three approaches: intensity tuning, colour tuning, and stimulus tuning

Production of the hormones melatonin & cortisol during 24-hour daily

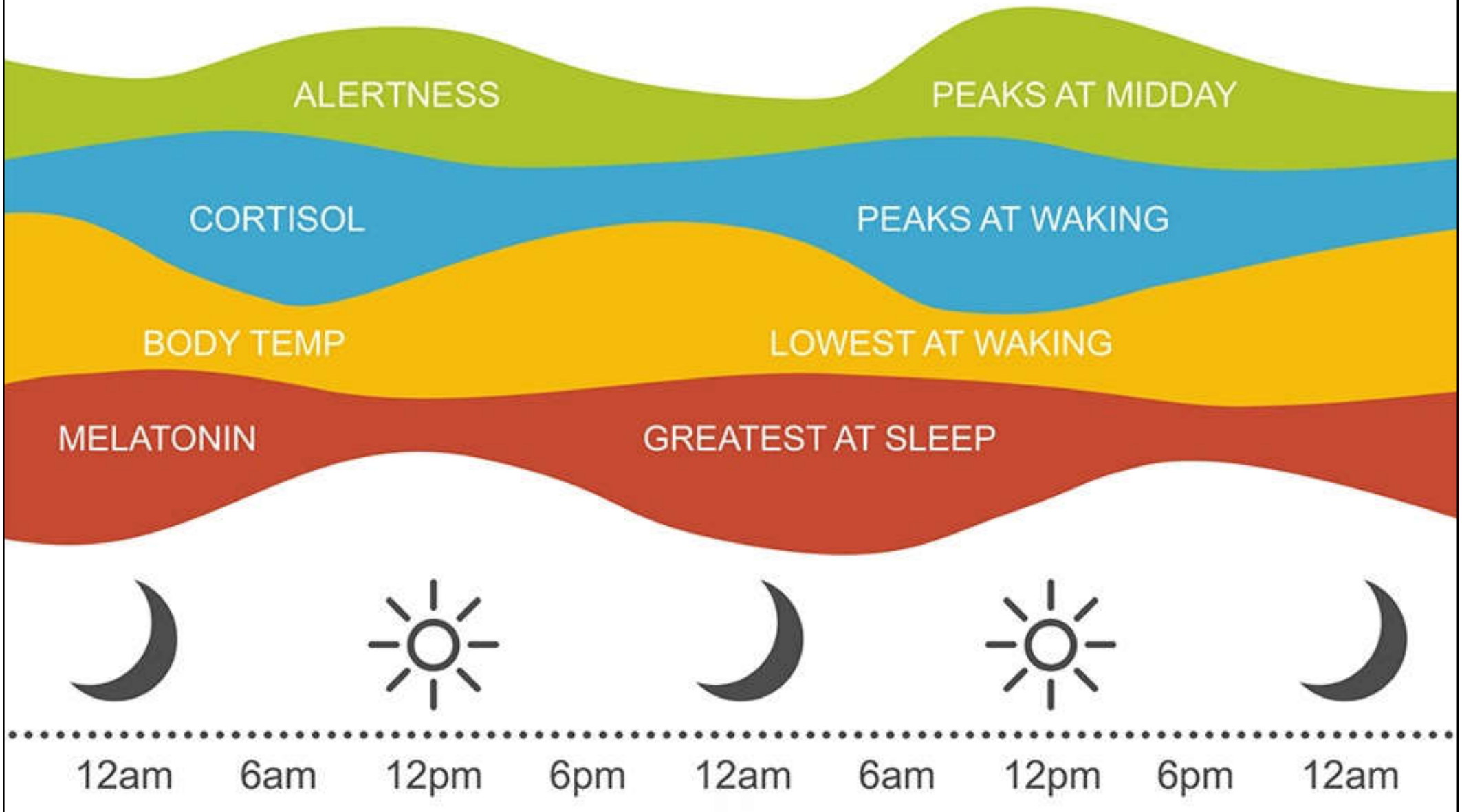




Video: SMUD: What is Circadian Lighting? (3:05) https://youtu.be/arm-QRAwNc4

(Source: https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/daylight/daylighting-quality)

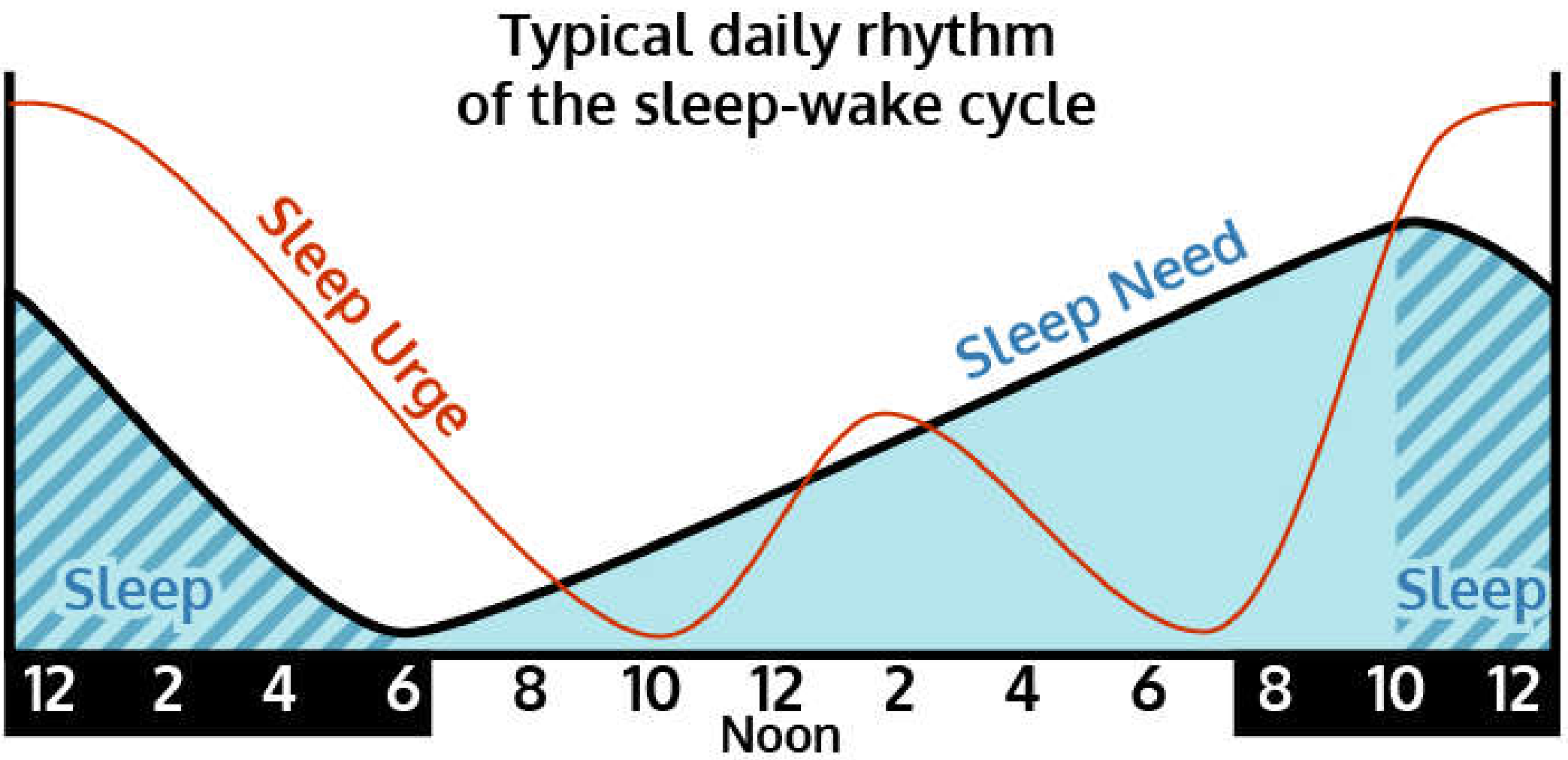
Lighting impacts on circadian rhythms



(Source: https://www.buildingenclosureonline.com/blogs/14-the-be-blog/post/86105-lighting-impacts-on-circadian-rhythms)

Normal circadian sleep rhythm

Sleep urge (circadian biological clock) is greatest at night with a small increase at mid-day. Sleep need (sleep homeostasis) increases throughout the waking hours and is replenished during sleep

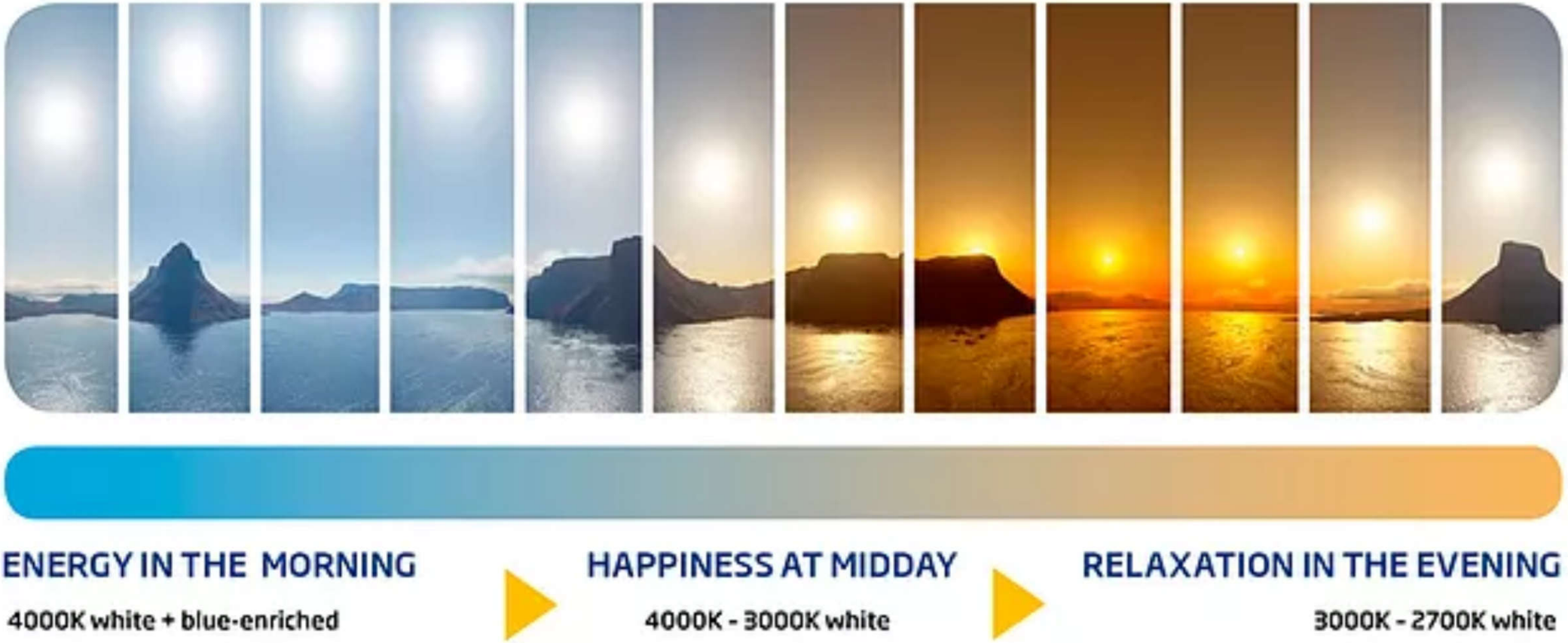


(Source: https://medium.com/lumossleep/circadian-rhythm-and-sleep-quality-5587c11792d5)

Daylight benefits

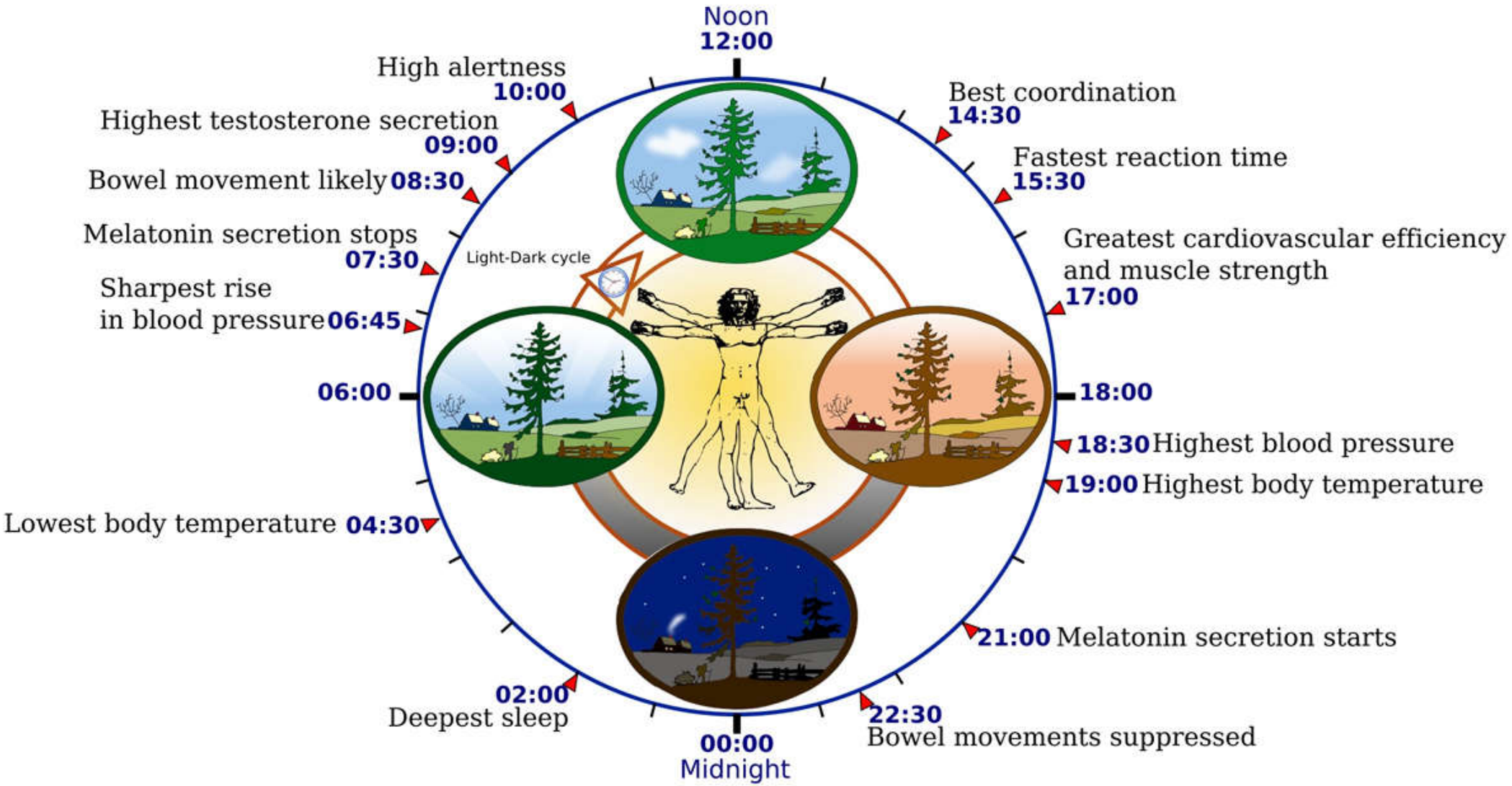
- Circadian lighting methods:
  - 1. Intensity tuning
    - Maintain a fixed correlated colour temperature (CCT) while the light intensity (brightness) is adjusted through a dimming system to correlate with time of day
  - 2. Colour tuning
    - Change the light intensity & CCT to mimic the daytime/night-time cycle
  - 3. Stimulus tuning
    - Replaces the “bad blue” with “good blue” light wavelengths

Circadian lighting & correlated colour temperature (CCT)



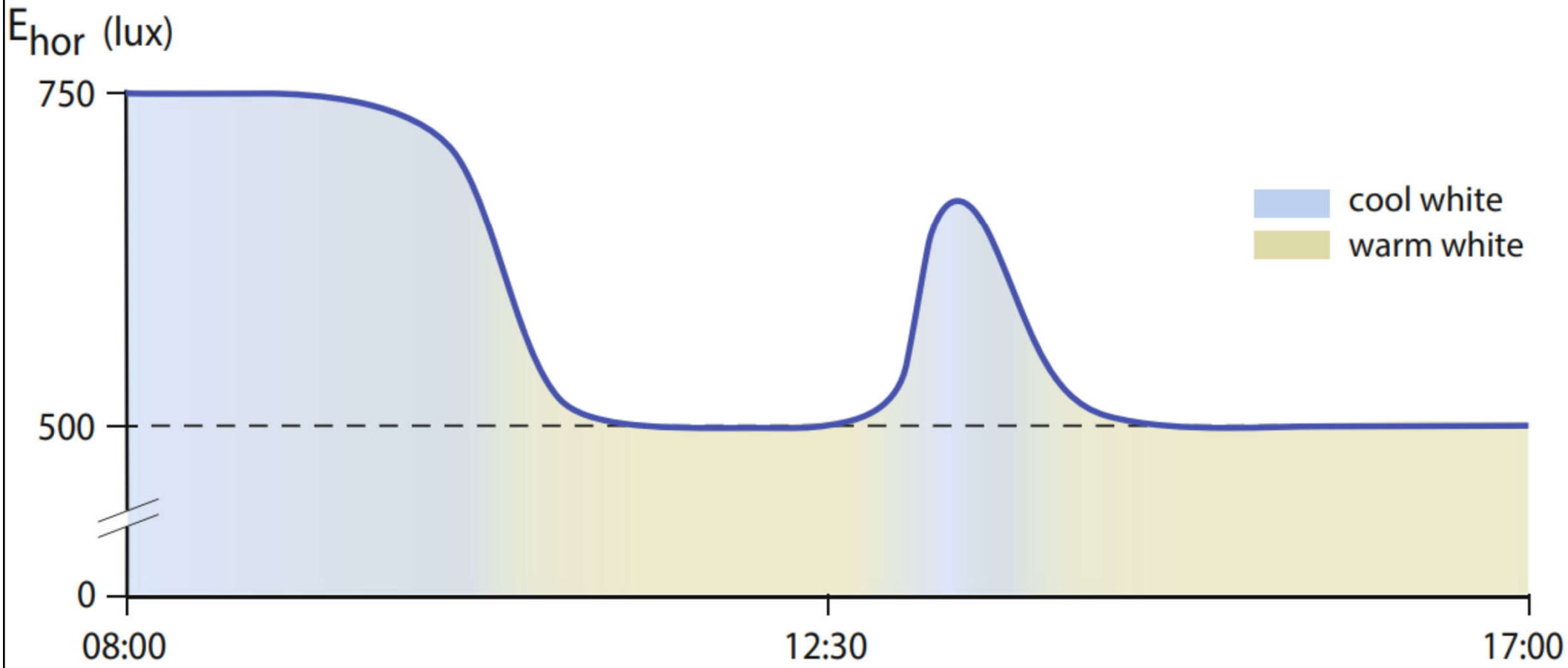
(Source: https://www.lightengine-tech.com/circadian-light-solution)

Rhythm of life & circadian disruption



(Source: https://www.manufacturer.lighting/info/245/)

Example of a dynamic lighting scenario for human-centric lighting in offices (daytime use)



Gradually changing lighting level from 750 to 500 lux (horizontally) and light colour from cool white (approx. 6500 K) to warm white (3000–4000 K) to facilitate both adequate visual & non-visual biological effects (i.e. entrainment of the biological clock, night-time sleep, daytime alertness and performance). The value of 750 lux horizontal illuminance for 6500 K corresponds to roughly 250 lux melanopic equivalent daylight (D65) illuminance. The value of 500 lux for 3000-4000 K corresponds to roughly 85 lux melanopic equivalent (D65) illuminance.

(Source: van Bommel W., 2019. *Interior Lighting: Fundamentals, Technology and Application*, Springer International Publishing, Cham.)

A workplace circadian lighting design strategy

Design for Daylight

- Sequential spatial experience
- Access to sunlight
- Flexible shading
- Views out

Supplement with Electric Light

- Spatial distribution/ contrast and visual experience
- Variation
- Activity based

Control

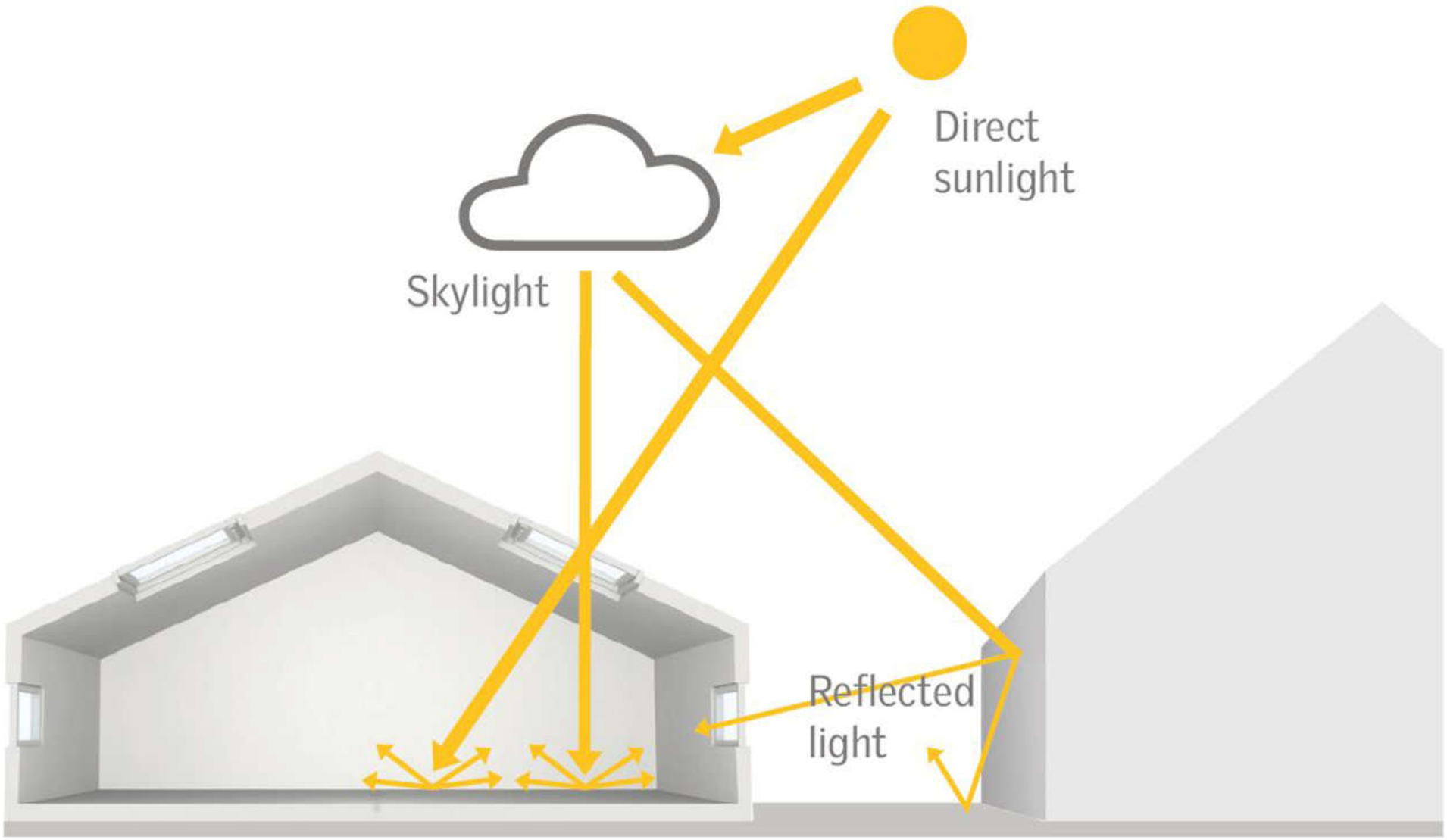
- Daylight responsive
- Personal control
- User interaction

(Source: https://www.arup.com/perspectives/publications/research/section/circadian-lighting-definition-and-strategy)

Daylighting design

- Daylighting: controlled use of natural light
  - Placing windows & reflective surfaces so that natural light provides effective internal illumination during the day
  - Successful daylighting requires design considerations at all stages of the building design process, from site planning to architectural, interior & lighting design
  - Components of daylight: (a) direct sunlight, (b) diffuse skylight & (c) reflected light

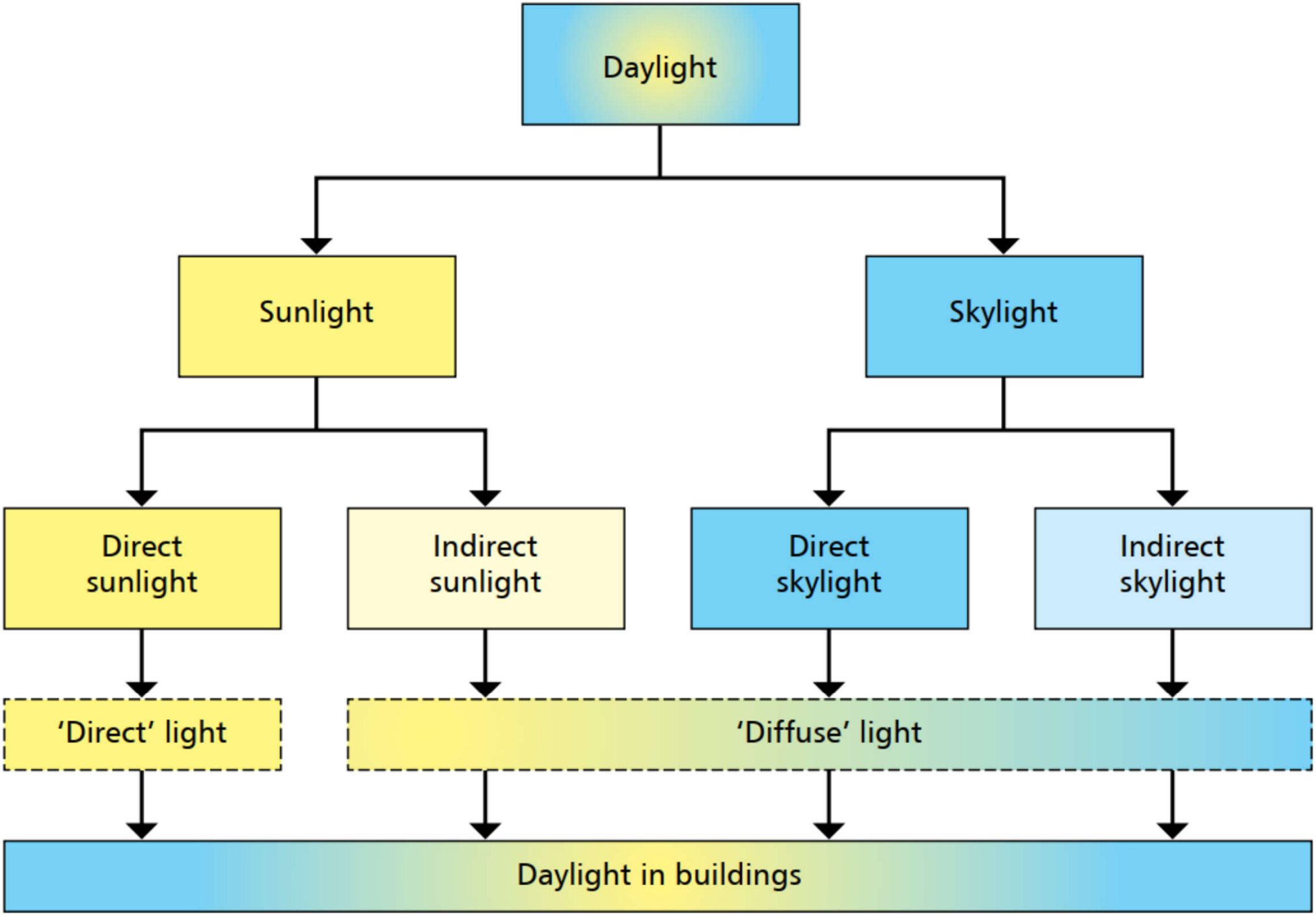
The components of daylight



(a) Direct sunlight (bright direct solar radiation)
(b) Diffuse skylight (diffuse light through clouds or partially cloudy skies; overcast sky)
(c) Reflected light (from natural & man made surfaces)

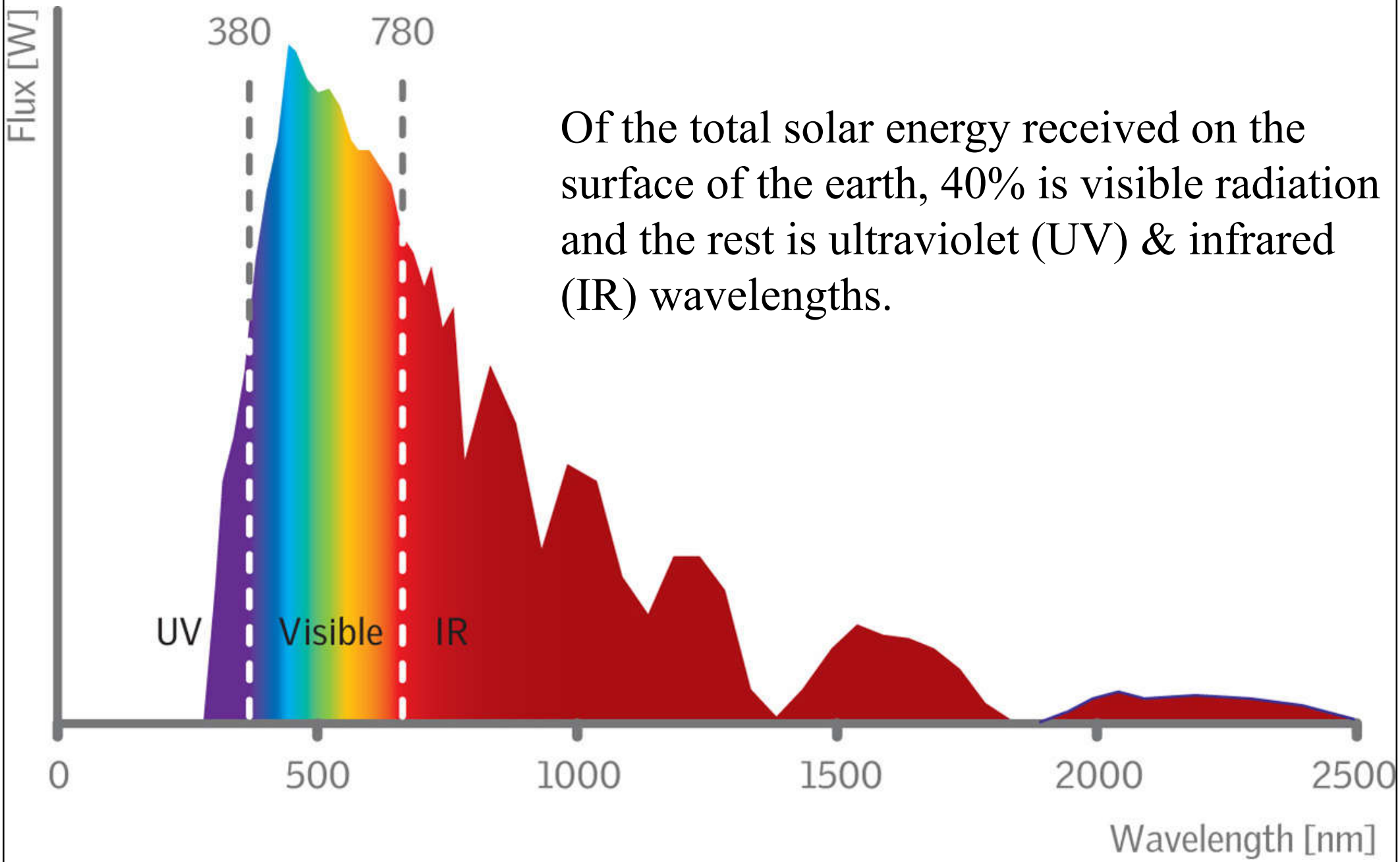
(Source: https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/daylight/daylighting)

Components of daylight illumination in buildings



(Source: SLL, 2014. *Daylighting: A Guide for Designers*, Lighting Guide 10, The Society of Light and Lighting (SLL), London.)

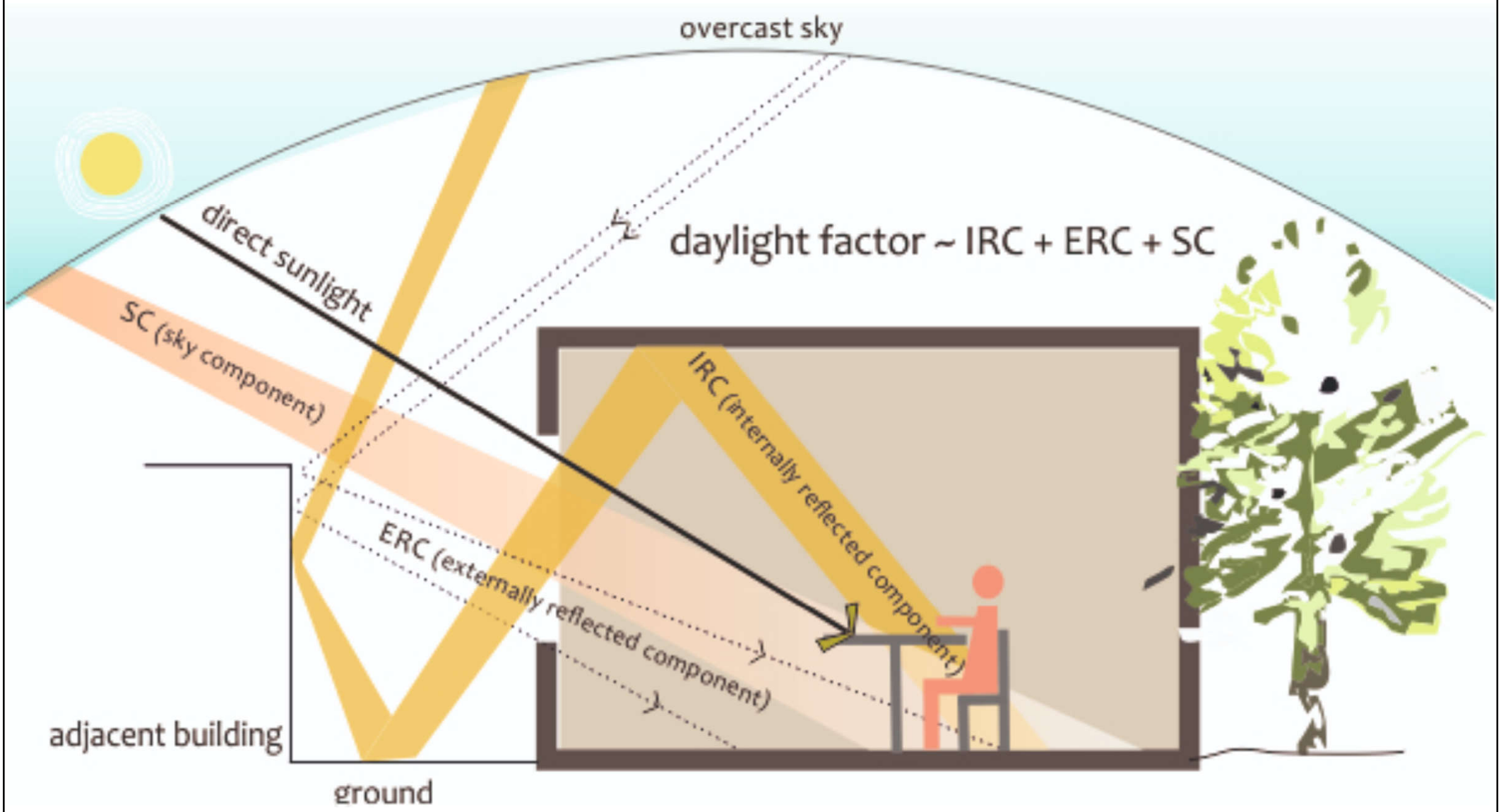
Electromagnetic spectrum of daylight



Of the total solar energy received on the surface of the earth, 40% is visible radiation and the rest is ultraviolet (UV) & infrared (IR) wavelengths.

(Source: https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/daylight/daylight)

Daylighting design at the building envelope and fenestration



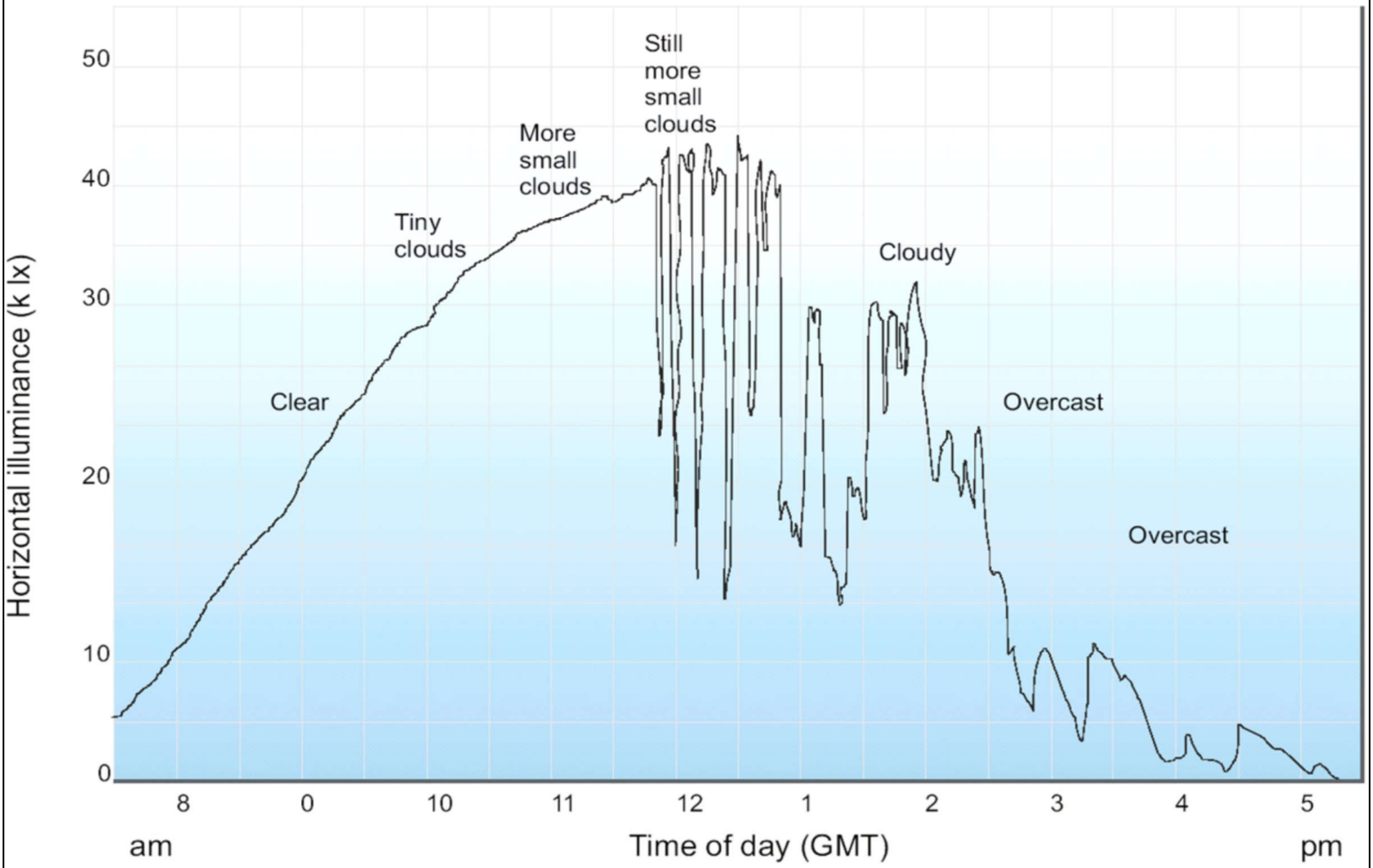
Video: Energy 101: Daylighting (2:43) https://youtu.be/-7EG4d-W4W8

(Source: https://nzeb.in/knowledge-centre/passive-design/daylighting/)

Daylighting design

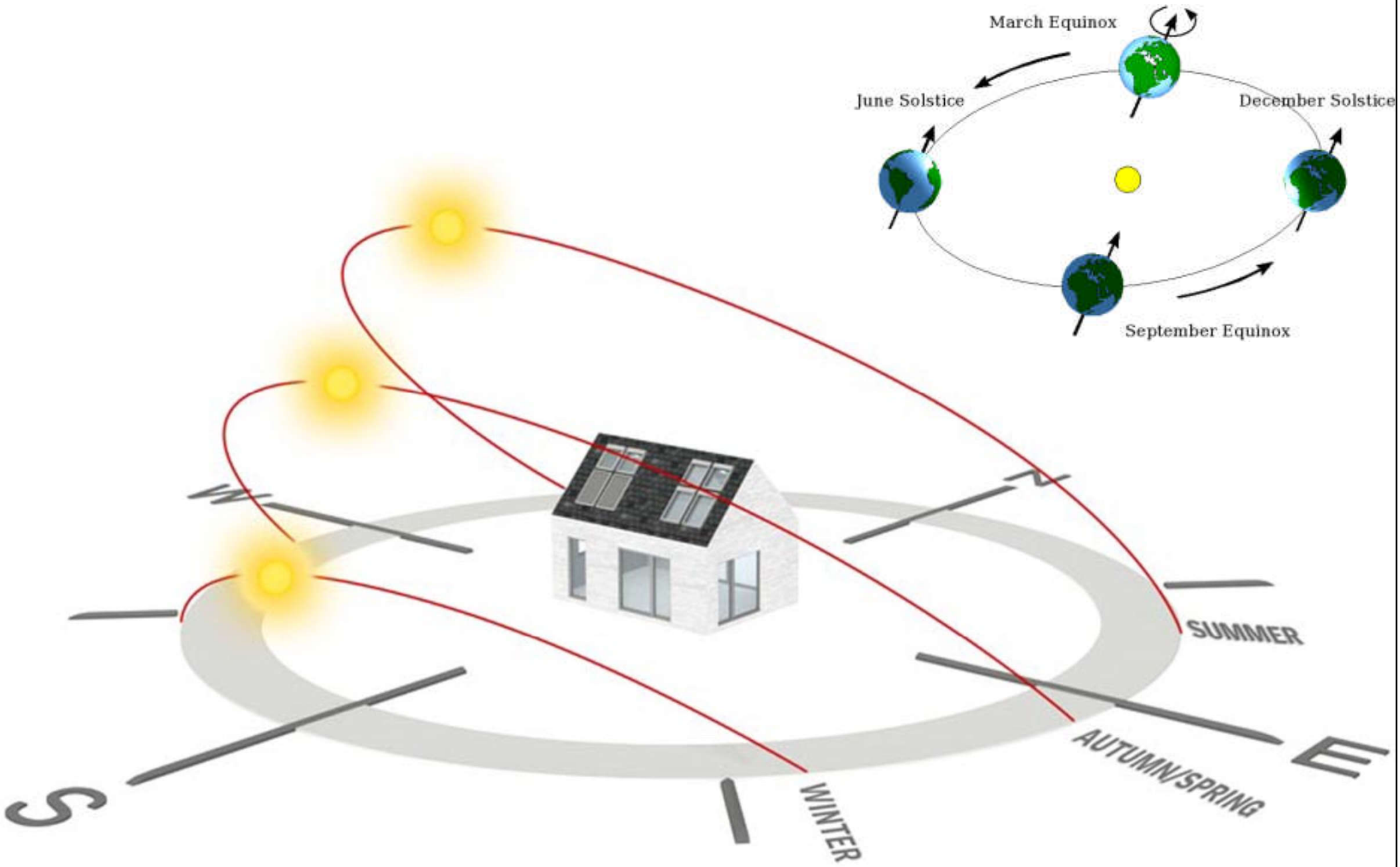
- Daylight is closely dependent on:
  - Weather conditions (blue sky or cloud)
  - Time of the day (morning & afternoon)
  - Geographic location (altitude & latitude)
  - The environment (rural or urban)
  - Building orientation (north, east, south & west)
  - Season (winter, spring, summer & autumn)
- Natural & artificial light are distinct
  - Also, view quality in & out from a window

Example of daylight variability



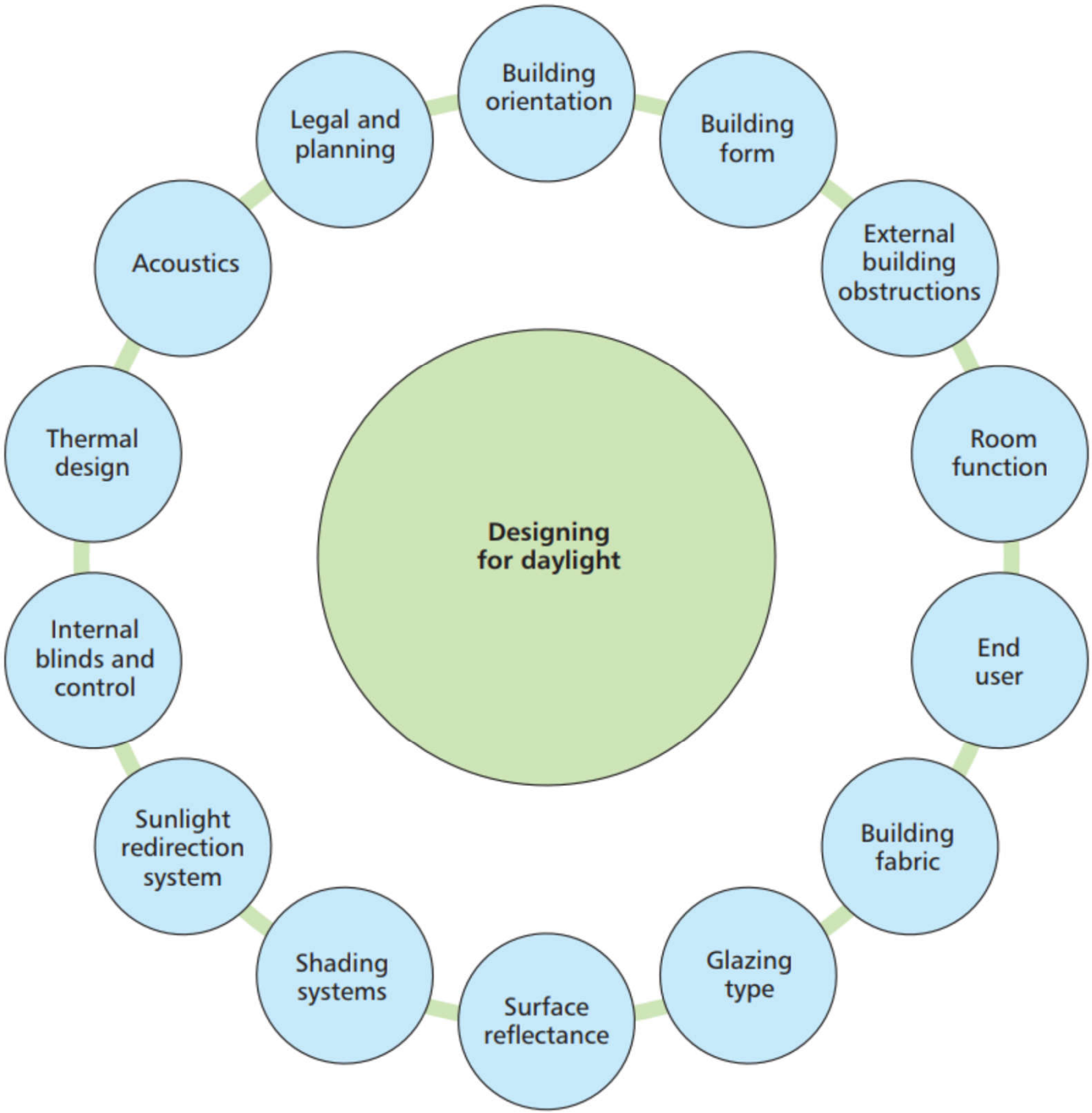
(Source: Integrated Design Lab, University of Washington)

Sun's paths on the winter solstice (shortest day), the equinox (day & night almost equal) and the summer solstice (longest day)



(Source: https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/daylight/parameters-influencing-daylighting-performance)

Common factors to consider in daylight design



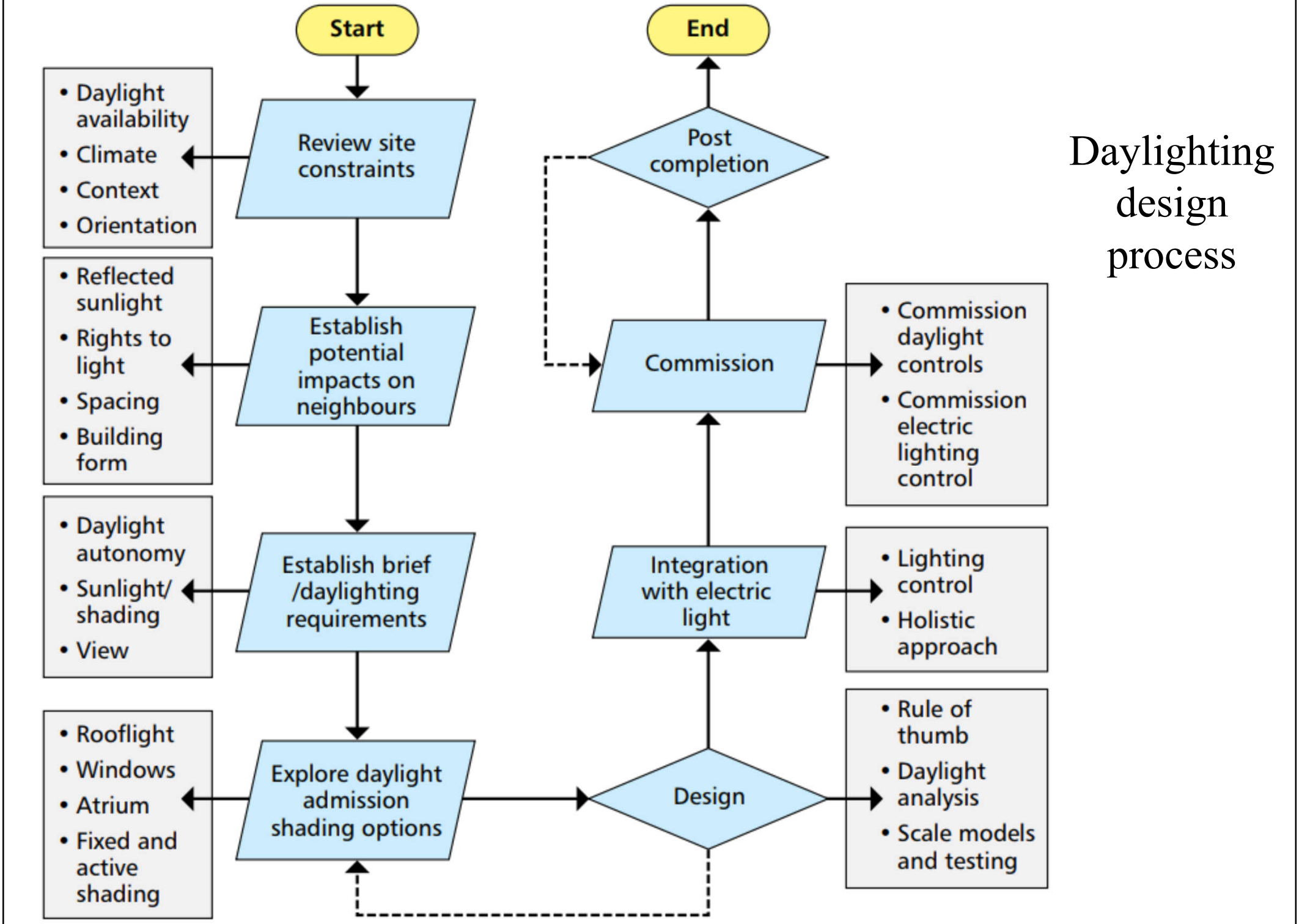
(Source: SLL, 2011. *Lighting for Education*, Lighting Guide 5, Society of Light and Lighting (SLL), London.)

Properties of daylight & electric light to achieve harmony

Diffuse daylight	Electric light
Cannot be switched on or off, but can be modulated using shading	Can be fully controlled - switched or dimmed
Quantity varies throughout the day & year	Quantity is controllable & predictable
Diffused from large area sources	Can be very focussed/directional, often emitting from small area sources
Direction is usually from the walls (vertical) or roof (horizontal)	Direction can be from any position in the space
Correlated colour temperature (CCT) varies throughout the day & year	CCT is fixed & can be a controlled variable
Colour rendering is 'perfect'	Colour rendering can approach 100 R_a if desired

(Source: SLL, 2014. *Daylighting: A Guide for Designers*, Lighting Guide 10, The Society of Light and Lighting (SLL), London.)

Daylighting design process



(Source: SLL, 2014. *Daylighting: A Guide for Designers*, Lighting Guide 10, The Society of Light and Lighting (SLL), London.)

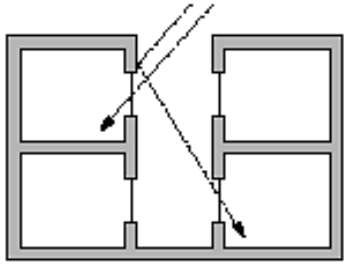
Daylighting design

- Methods to harvest & enhance daylight
  - Top lighting – skylights, light pipes
  - Side lighting – windows, curtain wall glazing, light shelves
- Design issues:
  - Depth, shape & orientation of the rooms
  - Colours of the walls, ceiling & floor
  - Colour & finish of the furniture
  - Problems related to heat gain & glare

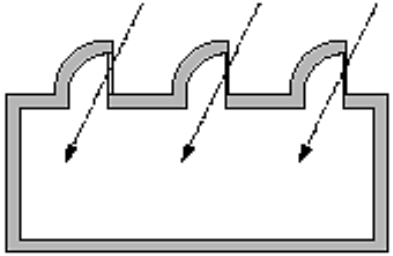
Shading and controls

- Purpose of daylighting design
  - Indirect & diffuse radiation to provide useful illumination
  - Minimise direct sunlight & glare in the spaces
  - Controlling electric lighting in accordance with daylight
  - Reduce contrast in daylight between perimeter & interior areas
- Shading devices & window glazing

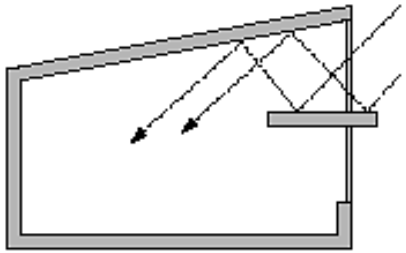
Daylighting design & control



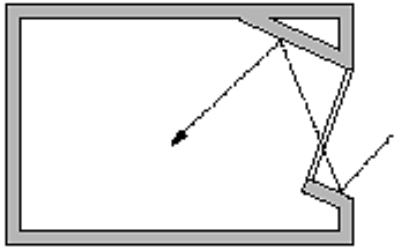
Light well



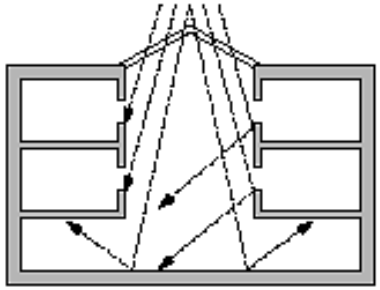
Roof monitor



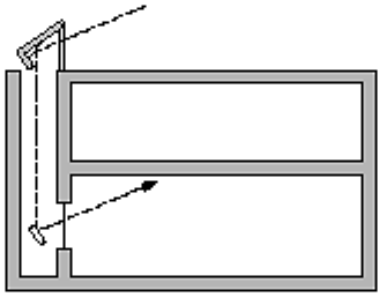
Light shelf



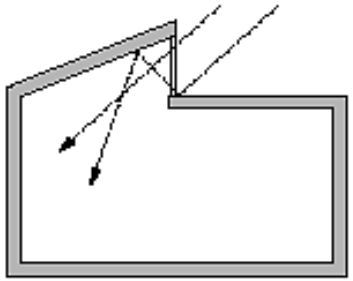
External reflectors



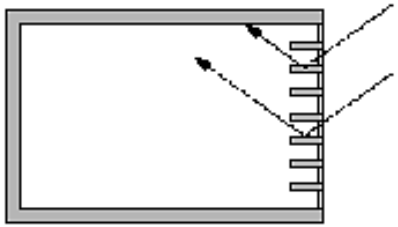
Atrium



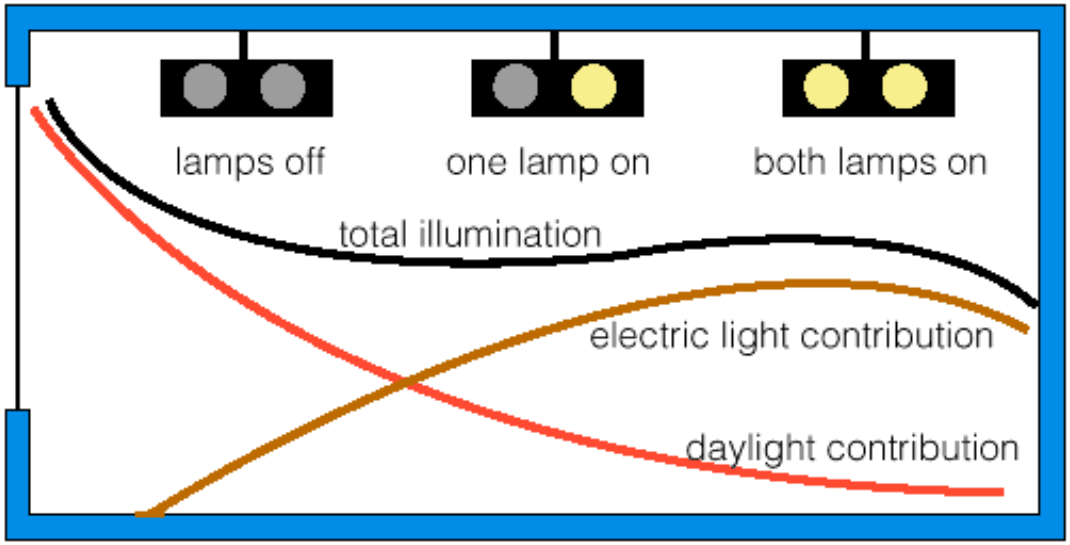
Light duct



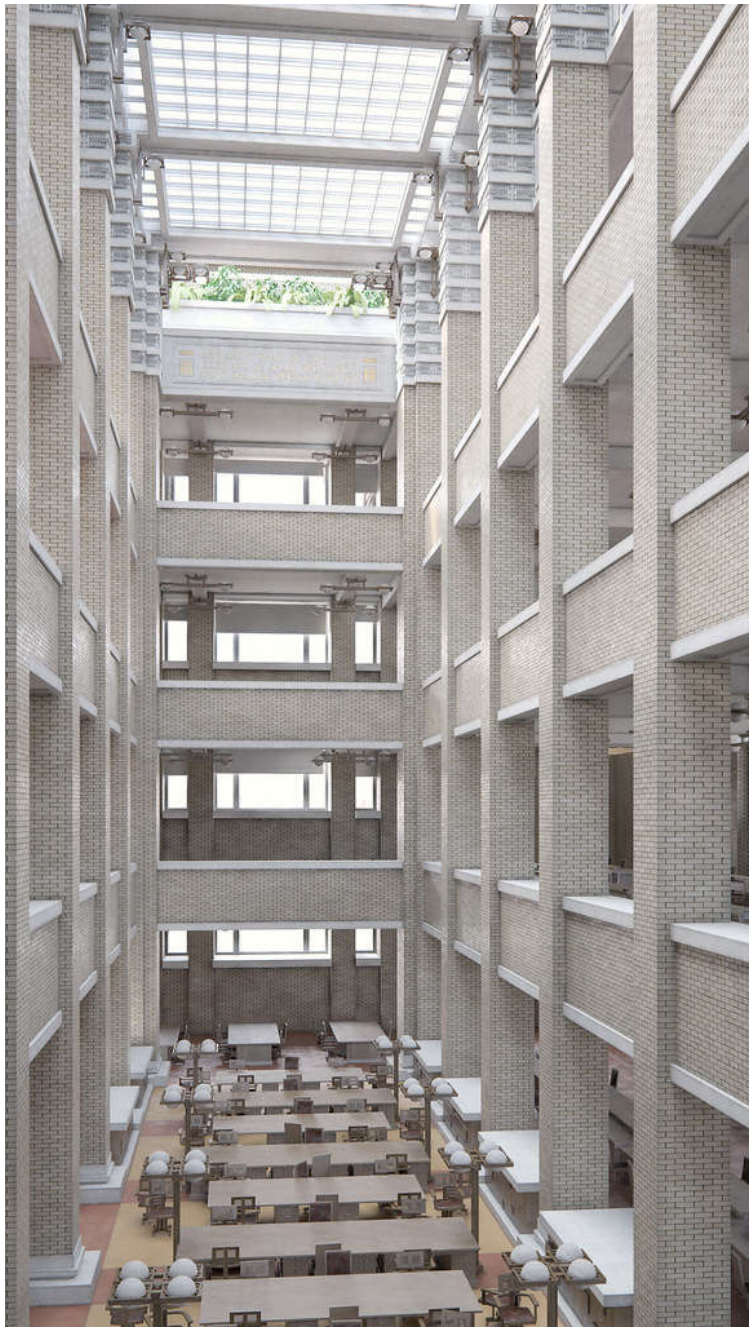
Clerestory



Reflective blinds

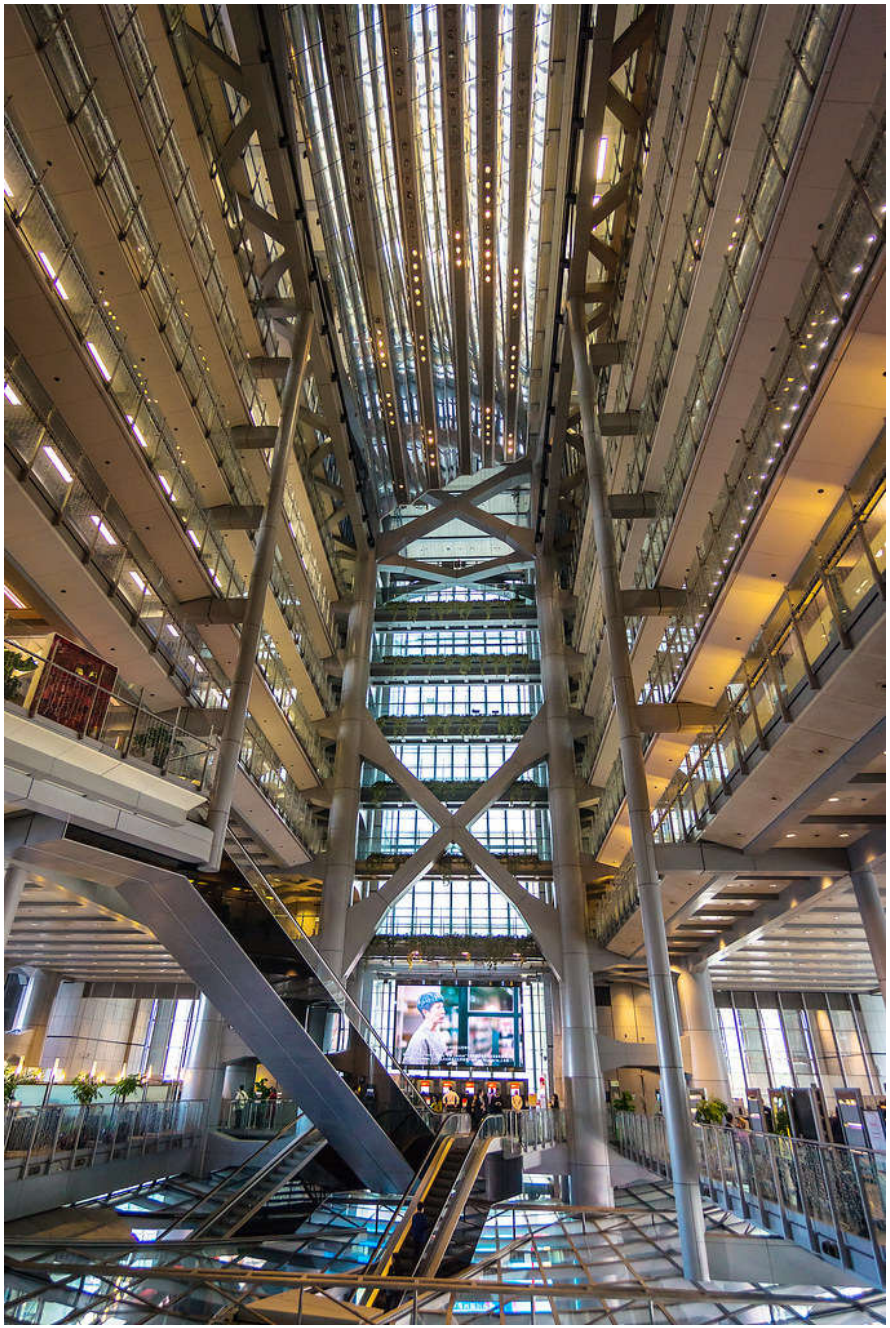


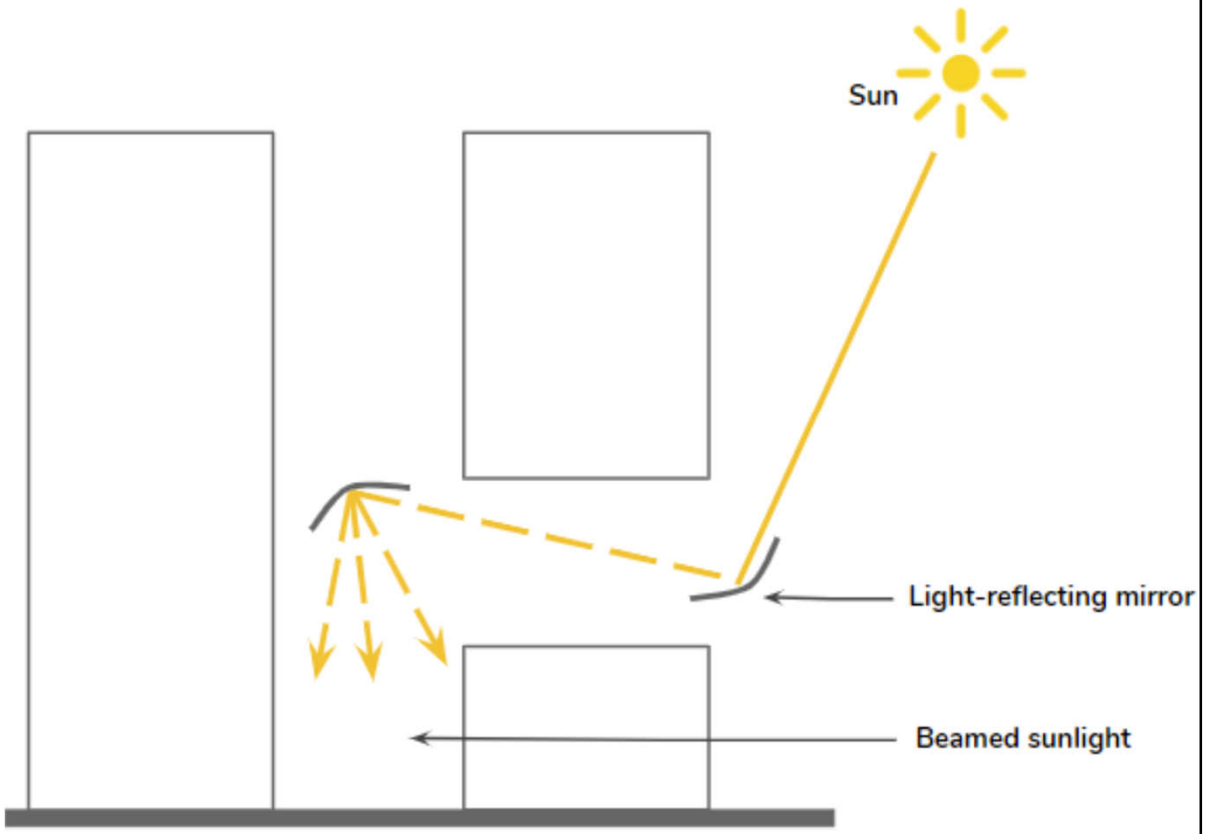
Atrium daylighting design
(Frank Lloyd Wright's Guggenheim Museum & Larkin Building)



(Source: https://planlux.net/sun-catchers-atria/)

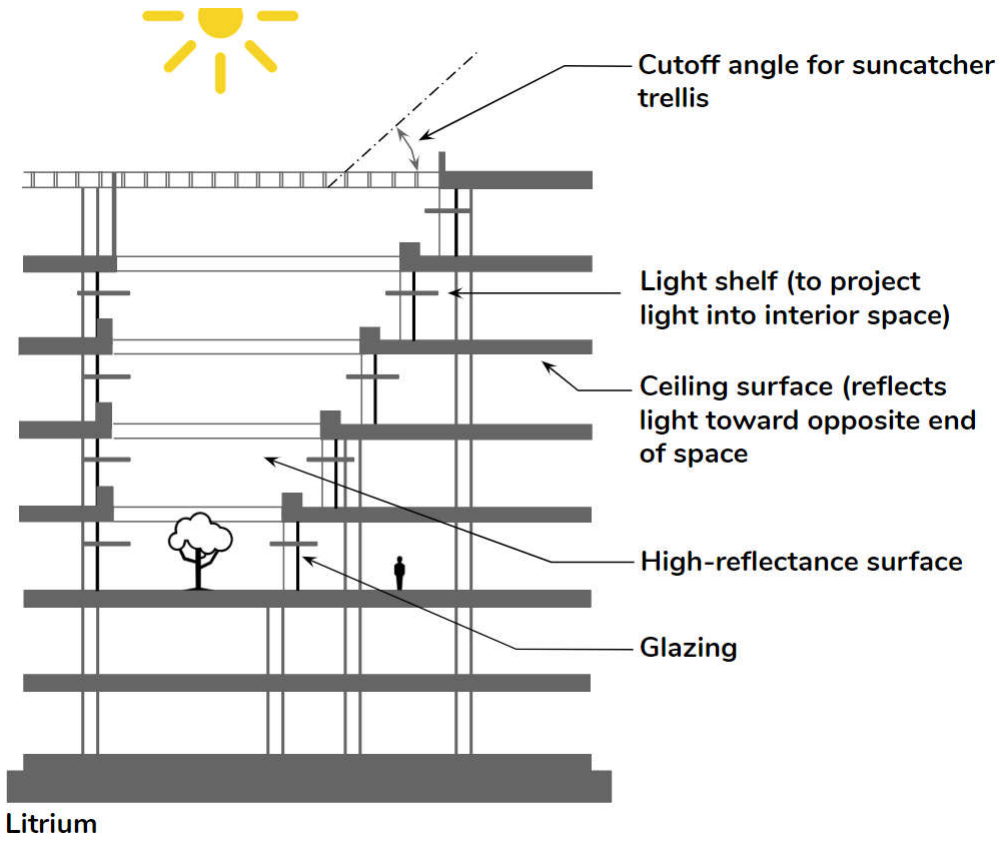
Atrium daylighting design with reflecting devices (HSBC Headquarters Building, Hong Kong)





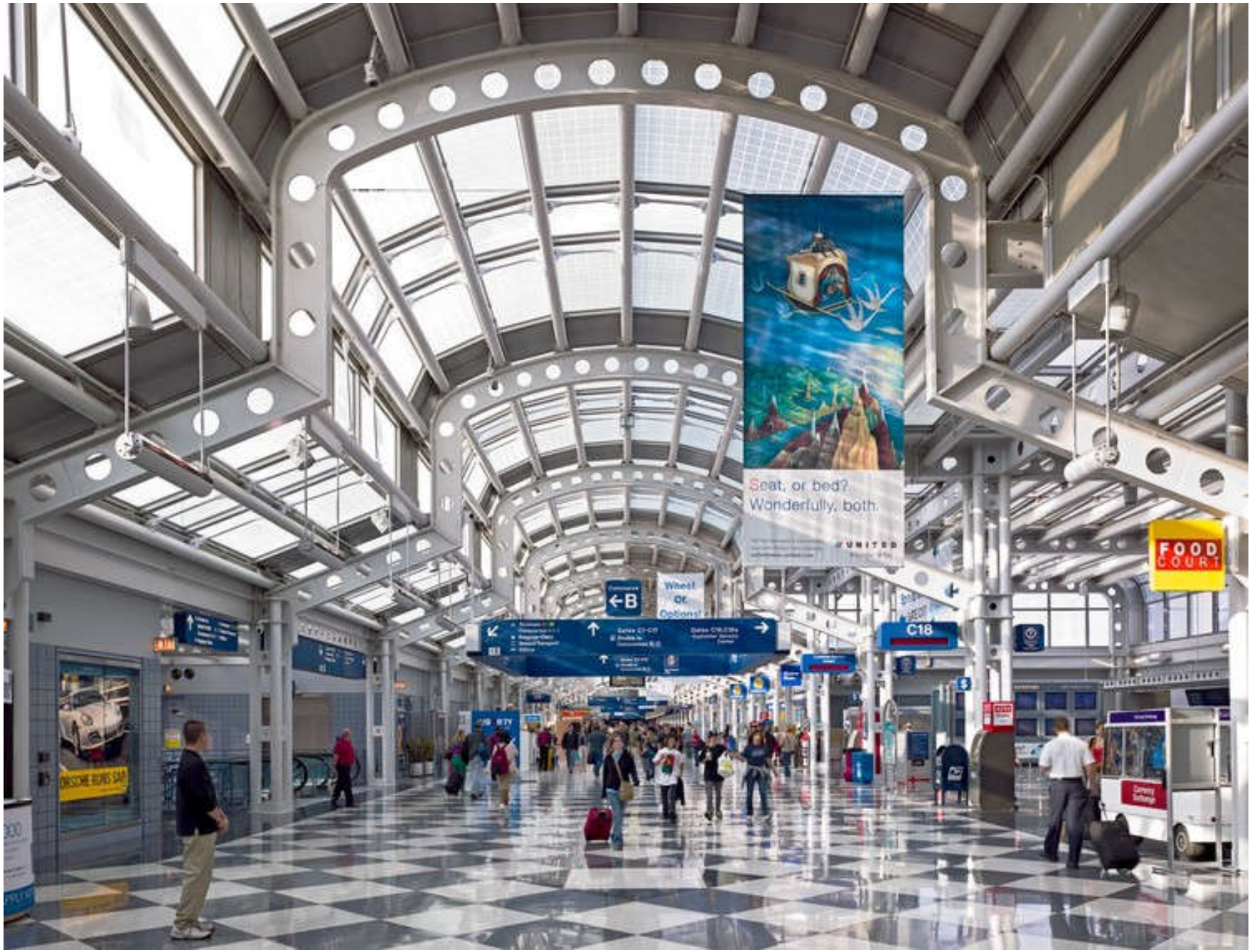
(Source: https://planlux.net/sun-catchers-atria/)

Atrium light enters through vertical clerestory openings



(Source: https://planlux.net/sun-catchers-atria/)

Skylights in O'hare International Airport, Chicago create a bright cheerful combination of natural light, electric light & architectural space

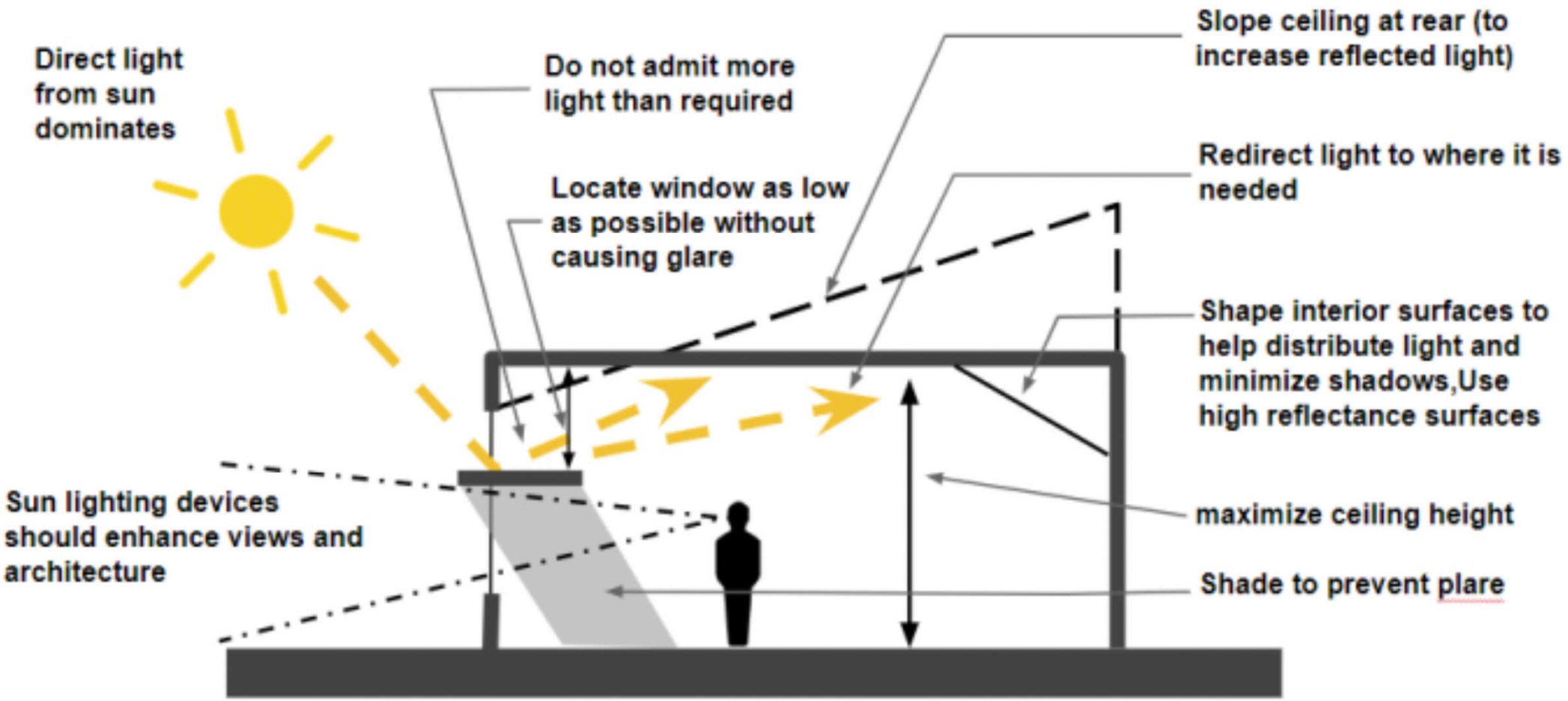


(Source: https://planlux.net/checklist-for-designing-with-natural-light/)

Shading and controls

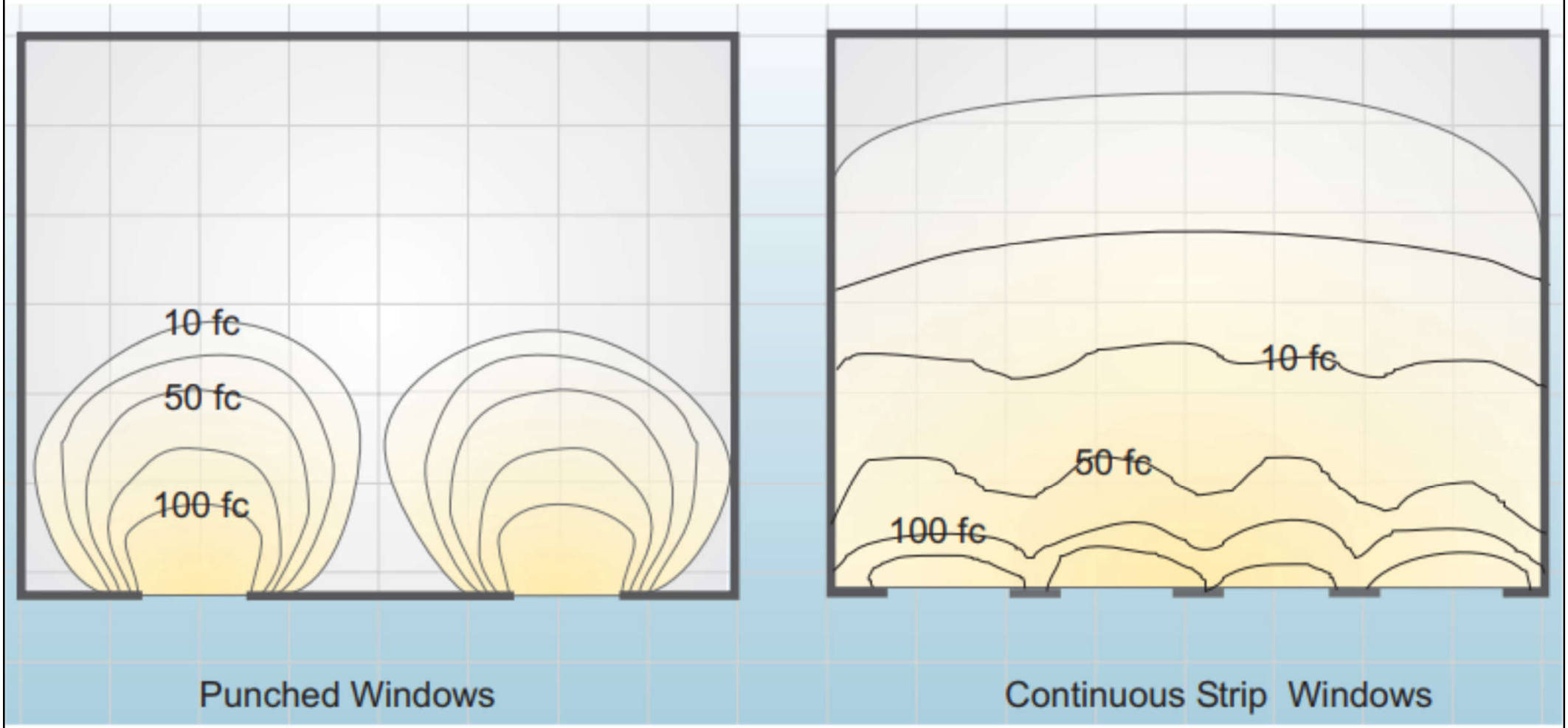
- Glare/Thermal control strategies:
  - Automated exterior shading
  - Fixed exterior architectural shading
  - Exterior fabric awnings
  - High performance glazing
  - Operable windows
  - Automated interior shading / double skin systems
  - Manual interior shading

Sunlighting strategies (should be integrated with architecture to use the sunlight indirectly)



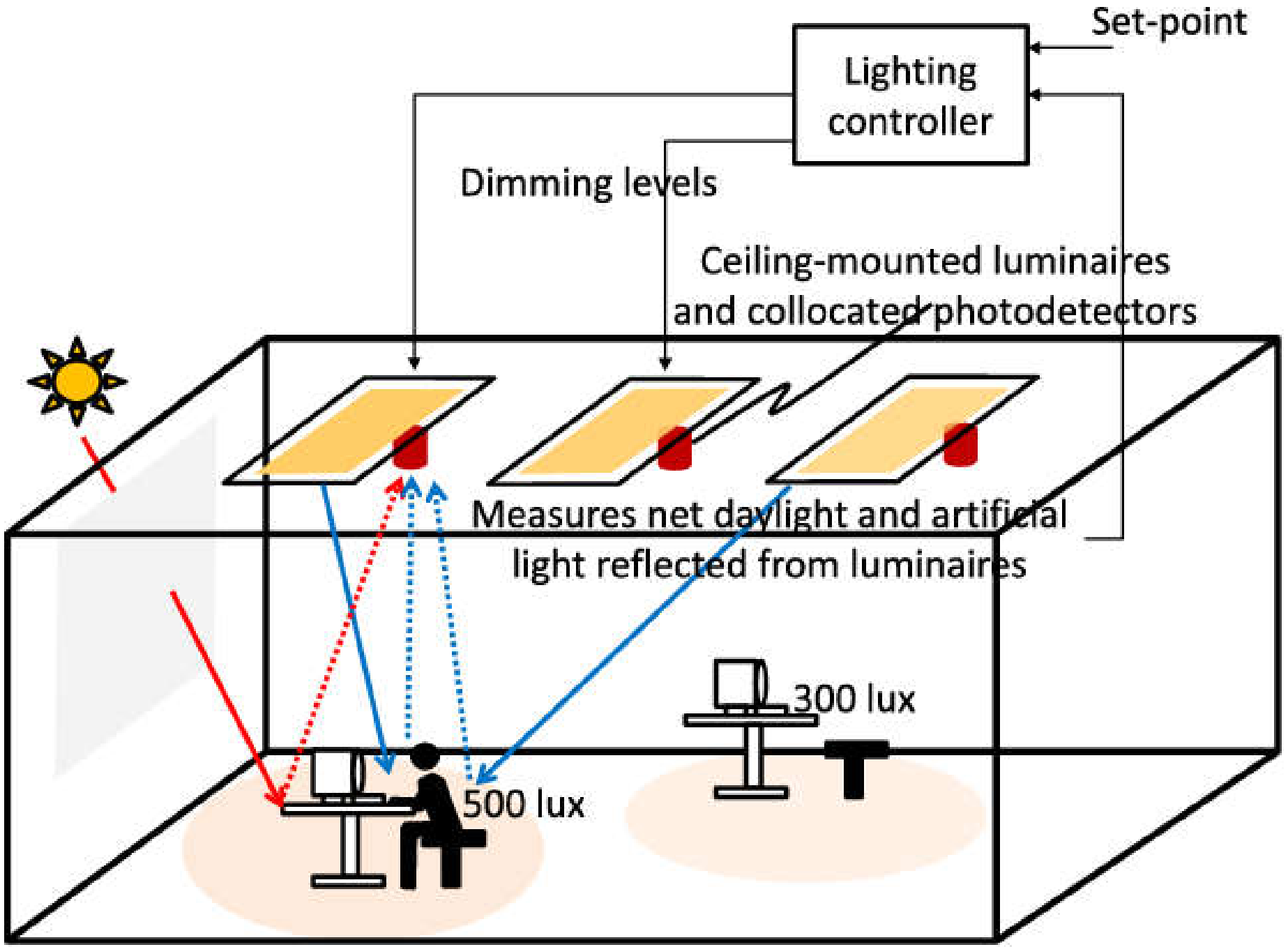
(Source: https://planlux.net/sources-of-natural-light-sunlight-strategies/)

Lighting level contours for punched windows & continuous strip windows



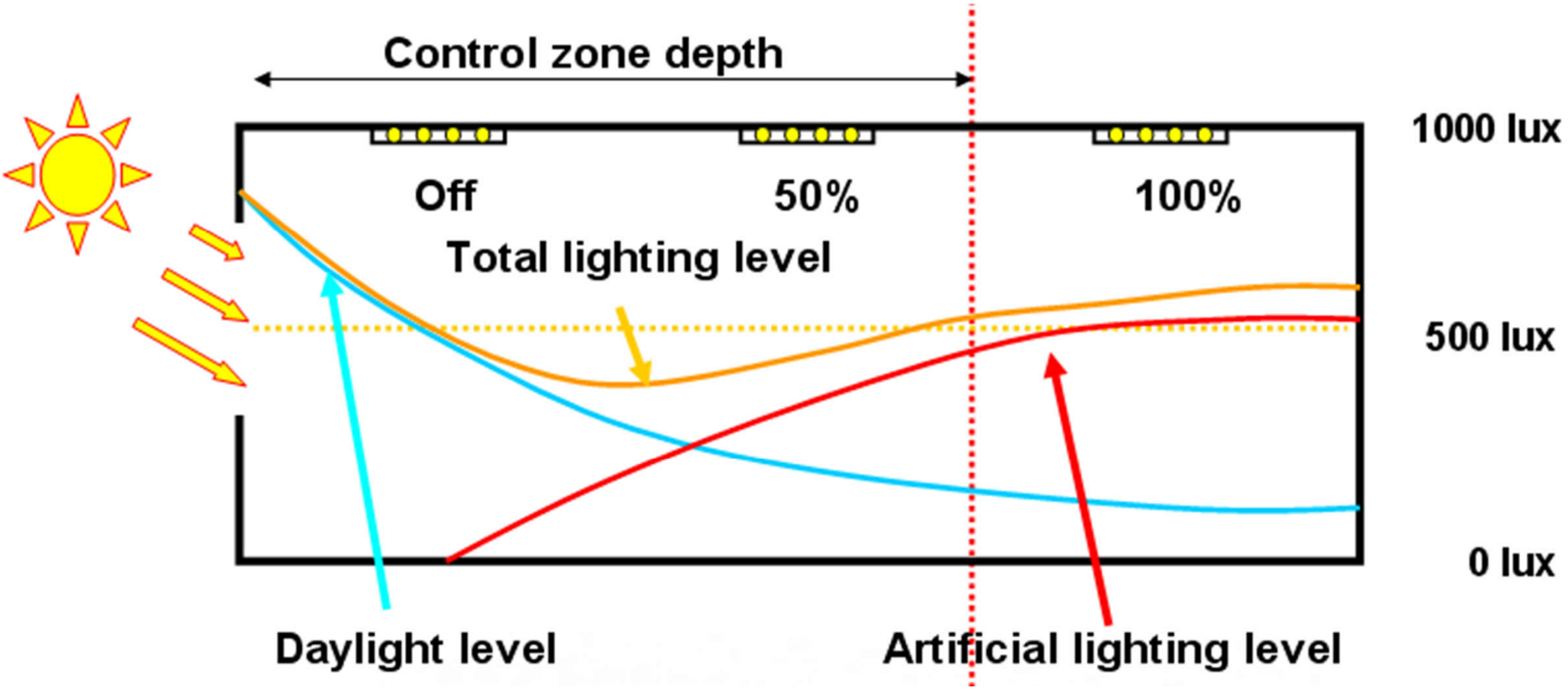
(Source: Advanced Lighting Guidelines 2003)

Photodetector based lighting control system



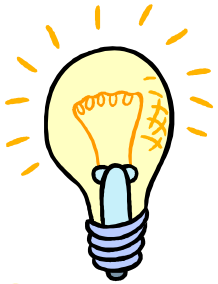
(Source: https://www.semanticscholar.org/paper/Daylight-Sensing-LED-Lighting-System-Li-Pandharipande/)

A room with the profiles of daylight, artificial and total lighting



(Source: https://www.researchgate.net/publication/228372427_Reviewing_the_role_of_photosensors_in_lighting_control_systems/)

Further Reading



- Introduction to Lighting Design | LightNOW https://www.lightnowblog.com/2016/03/introduction-to-lighting-design/
- Daylight (DEIC Basic Book) https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/daylight