

MEASUREMENT OF LIGHT FOR HUMAN HEALTH

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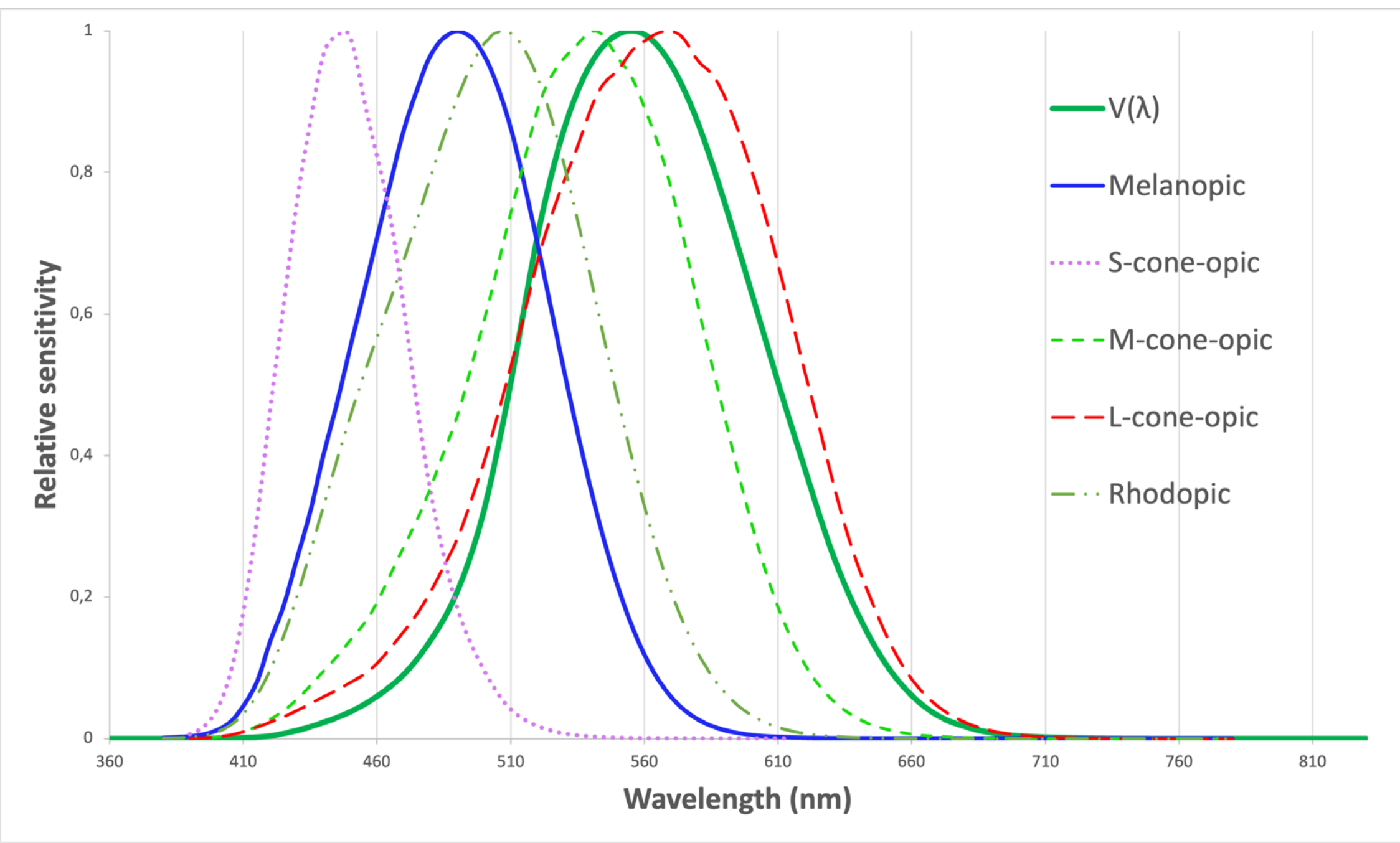
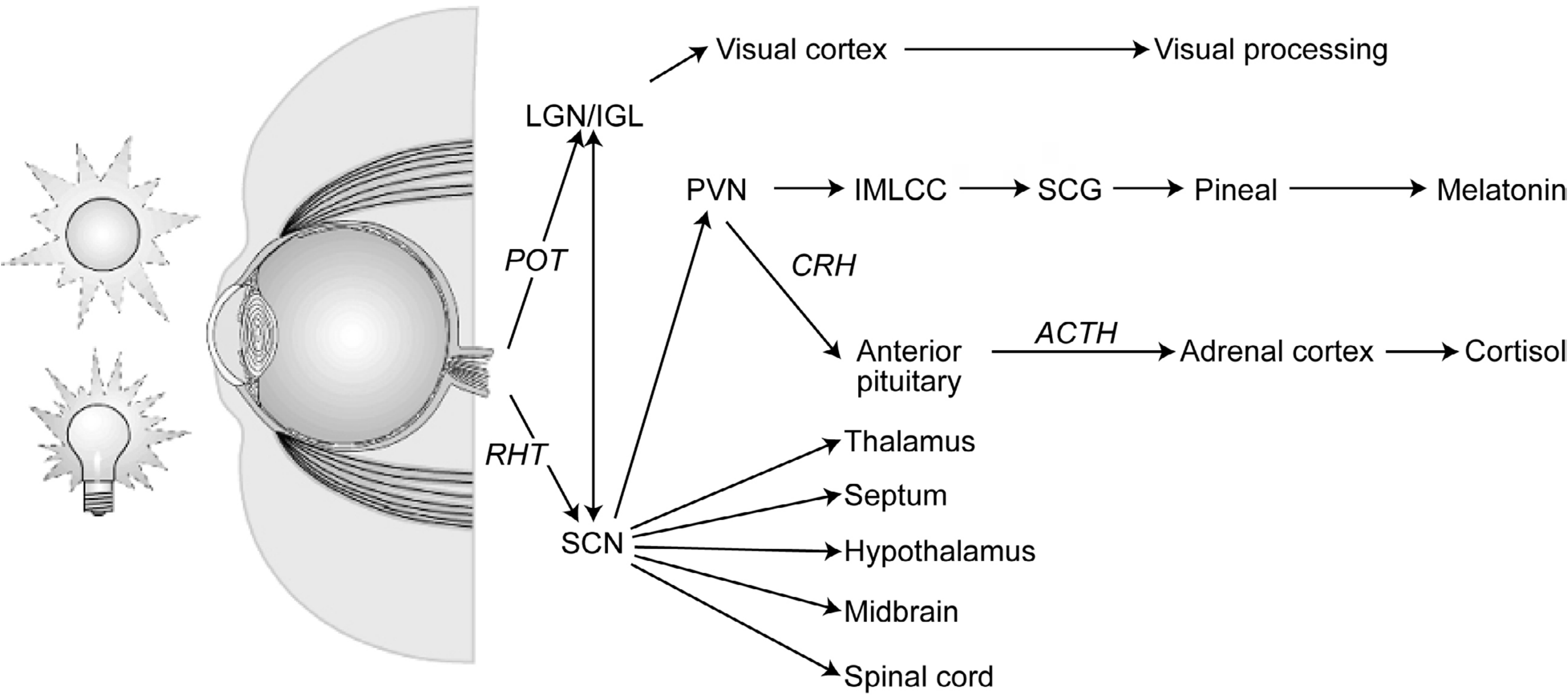
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A quarter-century ago it became clear that there are two primary pathways through which information about light reaches the brain. The primary optical tract (POT) carries image information to the visual cortex via the lateral geniculate nucleus (LGN) and intergeniculate leaflets (IGL). The retino-hypothalamic tract (RHT) carries signals about irradiance to the suprachiasmatic nucleus (SCN), from which many pathways carry this information to various brain structures.

The best known of these pathways is the connection to melatonin secretion by the pineal gland. Melatonin suppression by light exposure at night revealed the existence of **intrinsically photoreceptive retinal ganglion cells (ipRGCs)**, which contain the photopigment melanopsin. The signal from the ipRGCs in response to incident irradiance is carried on the RHT and triggers various neuro-bio-behavioural effects including sleep, alertness, mood, and immune function.

There are now five known photoreceptors: rods (providing vision in low light conditions), the short-, medium-, and long-wavelength cones (providing high-resolution, colour vision in higher light conditions), and the ipRGCs. Each receptor type has a characteristic spectral efficiency function, which is now codified in the **CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light (CIE S026:2018)**. This system incorporates five action spectra (middle panel) collectively known as the “ α -opic action spectra” to enable calculations of SI-compliant quantities (right panel) that describe the effect of optical radiation on the five known photoreceptors (ipRGCs = melanopic; rods = rhodopic; short-, medium-, and long-wavelength cones = s-cone-opic, m-cone-opic, and l-cone opic). The familiar $V(\lambda)$ function that underlies photometry is also shown in the middle panel.



Quantity	Formula	Meaning	Unit
α -opic radiant flux	$\Phi_{\alpha} = \int \Phi_{e,\lambda}(\lambda) s_{\alpha}(\lambda) d\lambda$	weighted spectral power distribution (SPD) integrated over wavelength	W
α -opic irradiance	$E_{\alpha} = \int E_{e,\lambda}(\lambda) s_{\alpha}(\lambda) d\lambda$	weighted SPD integrated over wavelength per area	W/m ²
α -opic radiance	$L_{\alpha} = \int L_{e,\lambda}(\lambda) s_{\alpha}(\lambda) d\lambda$	weighted spectral radiance integrated over wavelength	W/(m ² ·sr)
α -opic efficacy of luminous radiation	$K_{\alpha,v} = \Phi_{\alpha} / \Phi_v$	quotient of α -opic radiant flux, Φ_{α} , and luminous flux, Φ_v	W/lm
α -opic equivalent daylight (D65) illuminance	$E_{v,\alpha}^{D65} = \frac{E_{\alpha}}{K_{\alpha,v}^{D65}}$	Illuminance level of daylight D65, producing an equal α -opic irradiance as the test source	lx

The first expert consensus on the necessary daily pattern of light exposure for good health recommends the following melanopic equivalent daylight (D65) illuminance (melanopic EDI) levels, based on data from healthy young adults:

During the day:
min. 250 lx melanopic EDI at the eye



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For 3 hours before bed:
max 10 lx melanopic EDI at the eye



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Overnight, while sleeping:
< 1 lx melanopic EDI at the eye



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The CIE Position Statement on Integrative Lighting - Recommending Proper Light at the Proper Time (3rd Edition) outlines the urgent research needs related to making these recommendations achievable. These in turn bring new measurement needs:

- Spectral measurements rather than the usual analogue integration using filters, to enable calculation of any α -opic quantity
- Small personal light dosimeters to measure the light received at the eye by people as they go about their lives.
- Sensors and control systems to monitor and modify lighting system performance to meet exposure targets while minimizing energy use.



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