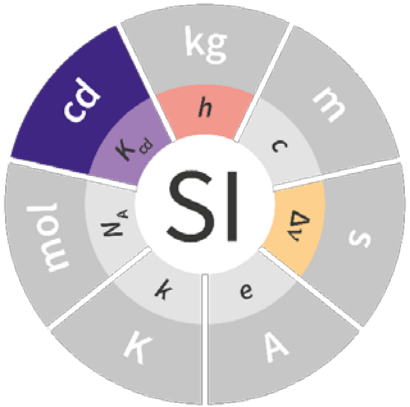
Key Scientific questions in the definition of the SI unit of luminous intensity, the candela

25th Meeting of the CCU

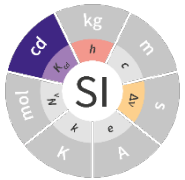
Bureau International des Poids et Mesures

- Introduction of **defining constant** for photometry, K_{cd}
  ***luminous* efficacy** of monochromatic radiation of frequency 540×10^{12} Hz
- **Reformulation** of definition of the candela
  - (not a redefinition), to bring it in **explicit constant** form:



THE CANDELA

The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, to be 683 when expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1}, or cd sr $kg^{-1} m^{-2} s^3$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$.



- K_{cd} makes a direct link between photometric and radiometric quantities for monochromatic radiation of frequency 540 THz

flux	illuminance	intensity	luminance
lm $\leftrightarrow$ W	lx $\leftrightarrow$ W·m^{-2}	cd $\leftrightarrow$ W·sr^{-1}	cd·m^{-2} $\leftrightarrow$ W·sr^{-1}·m^{-2}
K_{cd}	K_{cd}	K_{cd}	K_{cd}

- *Mise en pratique* for the definition of the candela in the SI (20 May 2019)
- BIPM report 05/2019: Principles governing photometry (20 May 2019)
- Appendix 3 Units for photochemical and photobiological quantities (20 May 2019)

The present definition serves very well all practical requirements for global trade, science and society.

However, still there is a key scientific challenge related to the fact the defining constant, linking the given photometric unit to the corresponding radiometric unit, has no fundamental character.

COMITÉ CONSULTATIF

DE PHOTOMÉTRIE ET RADIOMÉTRIE

9e SESSION — 1977

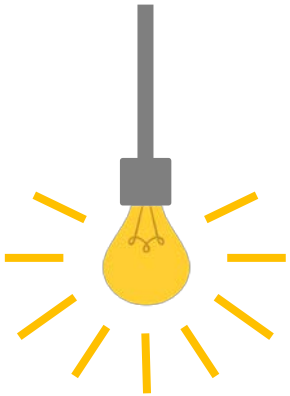
COMITÉ CONSULTATIF

DE PHOTOMÉTRIE ET RADIOMÉTRIE

8e SESSION — 1975

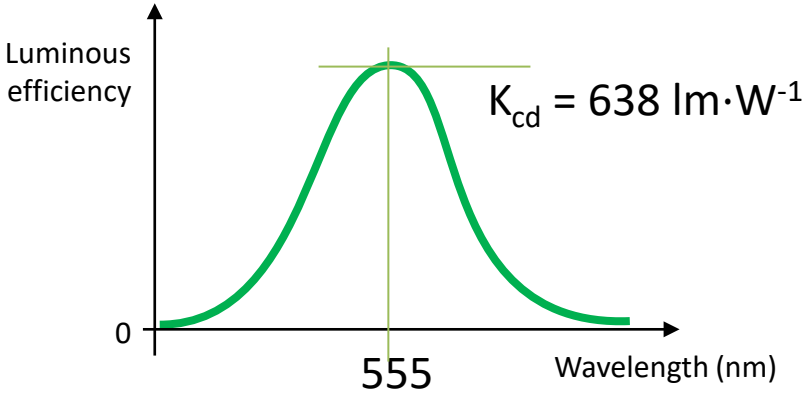
(3-5 septembre)

Success story : Photometry



Luminous intensity
(visual)

Standard Photopic observer
(CIE 1924)



SI brochure
Principle governing photometry

$$L = K_m \int L_{e,\lambda} \, V(\lambda) \, d\lambda$$

CIE Photometric standard observer

6th session of CIE, Geneva, 1924

K. S. Gibson :
Visibility function

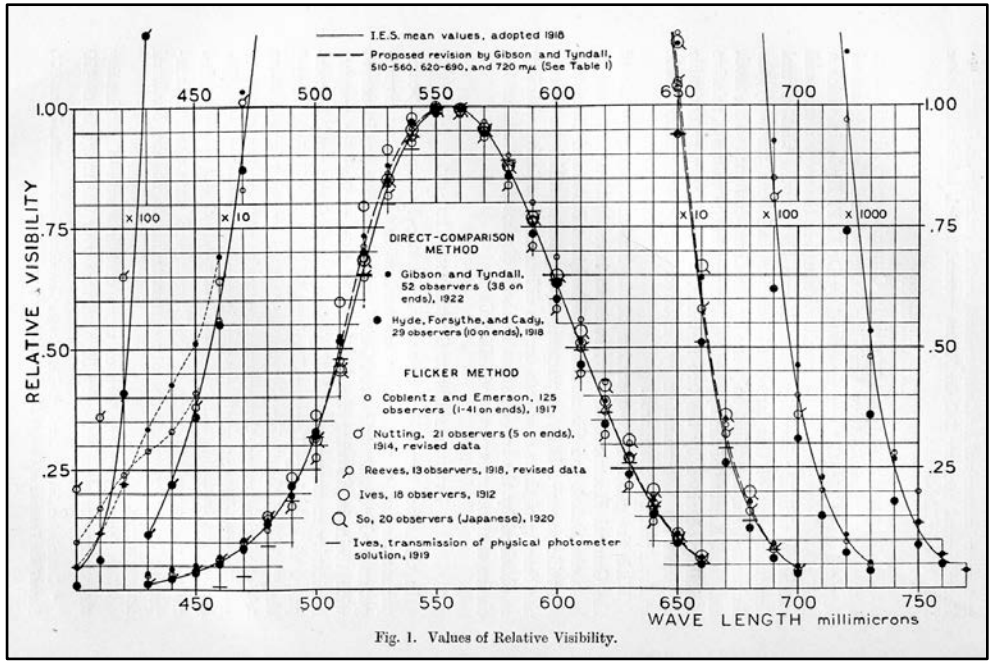
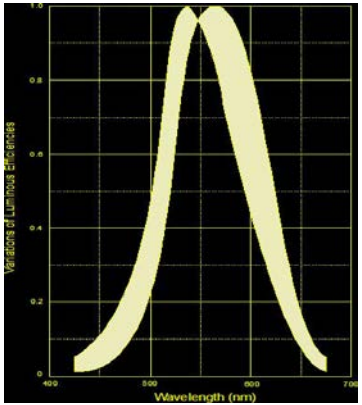


Fig. 1. Values of Relative Visibility.



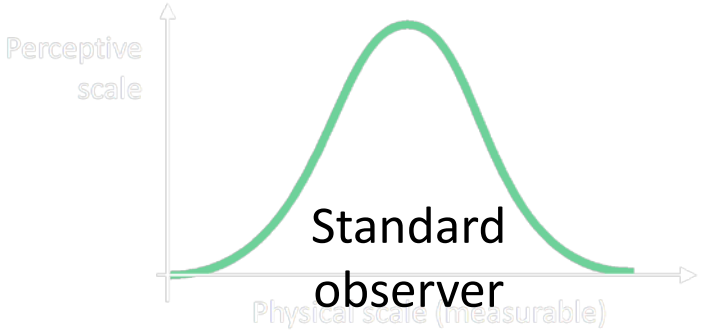
272 observers (UK, Japan, US)

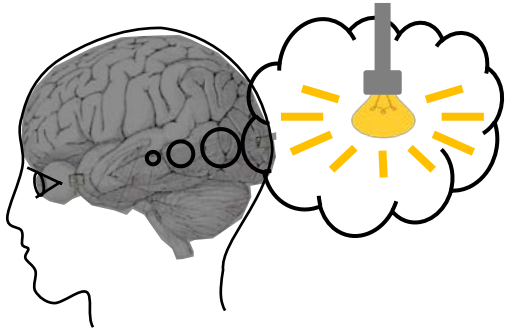
Photometry – a success story

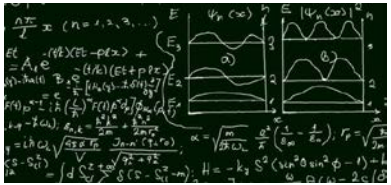
Radiometry & spectrophotometry

Current method

Psychophysic experiments







Perception model $\int_{380}^{780} P_\lambda \cdot V(\lambda)\, d\lambda$

Normalization activity

Photometry

Photometry is the science of the measurement of light, in terms of its perceived brightness to the human eye.

light stimulus

eyes

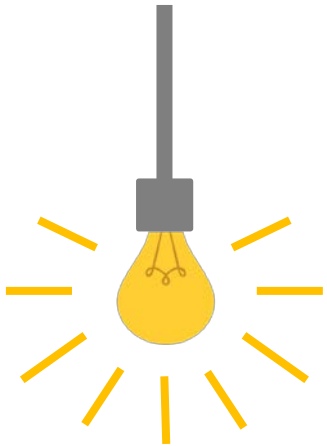
brain

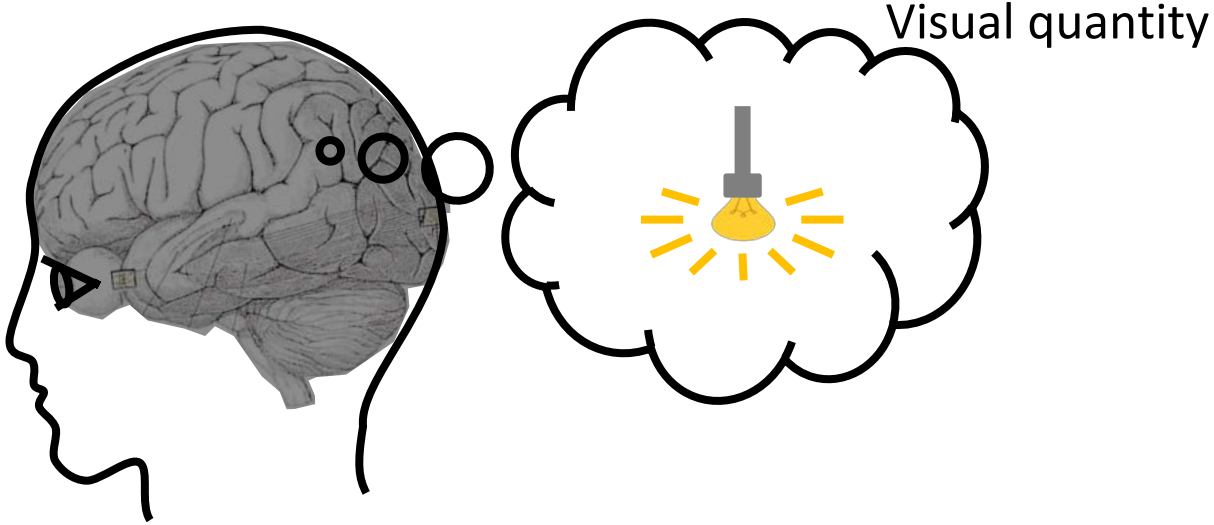
Measurement of visual quantities

Photometry deals with visual quantities.

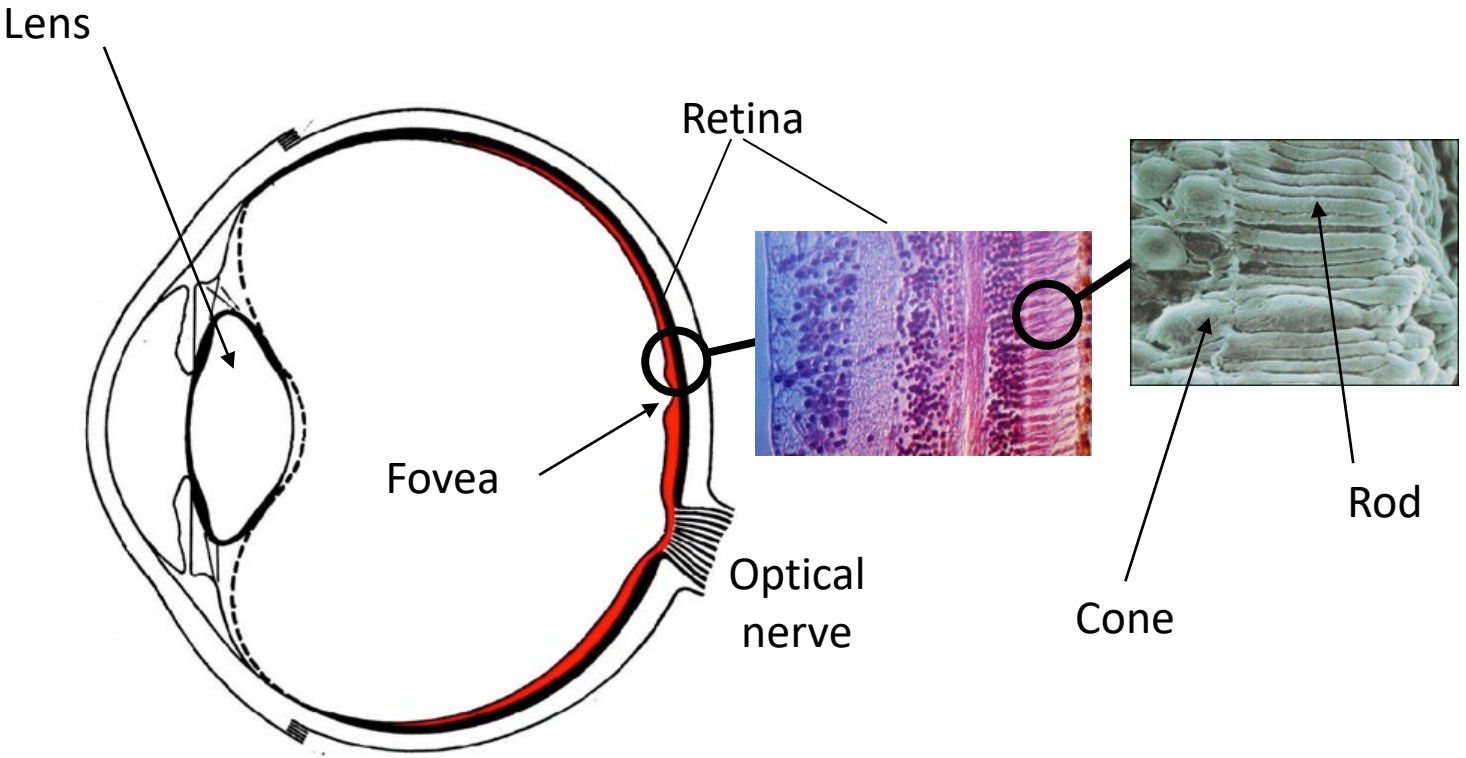
The measurand is not accessible by the measuring instrument

The measurand may vary from an observer to another



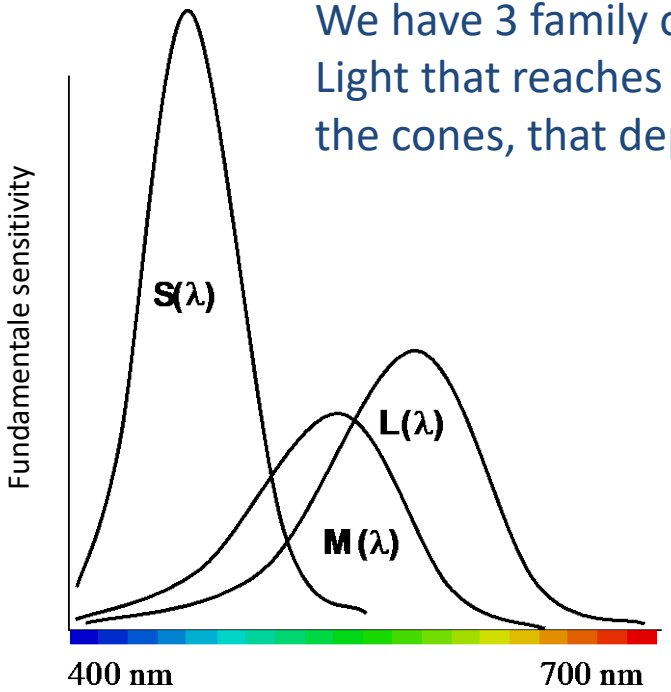


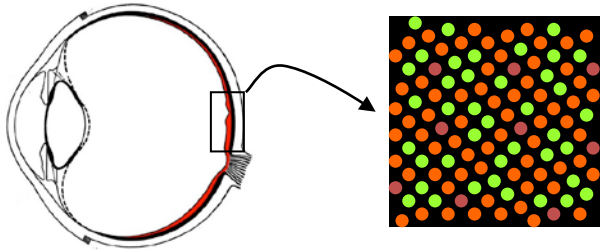
Human eye



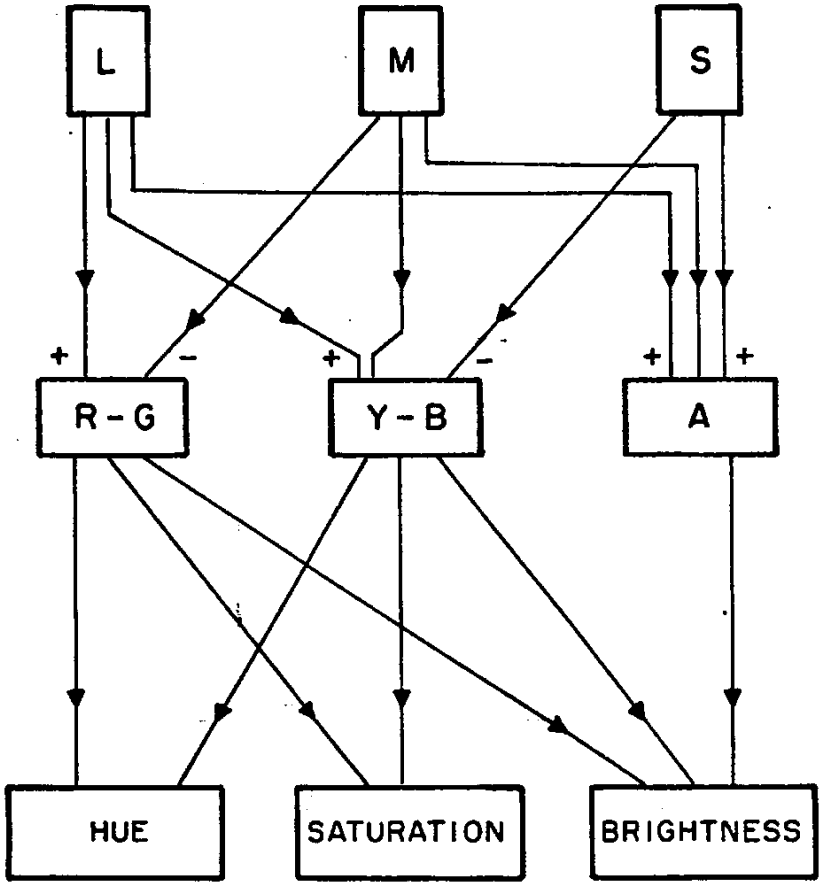
Cones (L M S)

We have 3 family of cones.
Light that reaches the retina generates 3 signals in the cones, that depend upon the wavelength





S(λ)	$\lambda_{max} \cong 440$ nm
M(λ)	$\lambda_{max} \cong 540$ nm
L(λ)	$\lambda_{max} \cong 570$ nm



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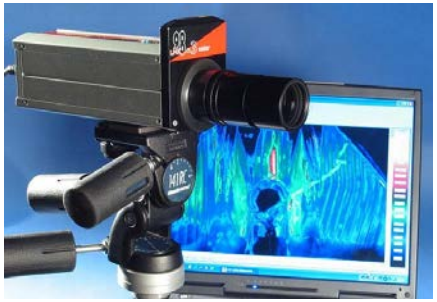
Measurement of perceptive quantities



Future method

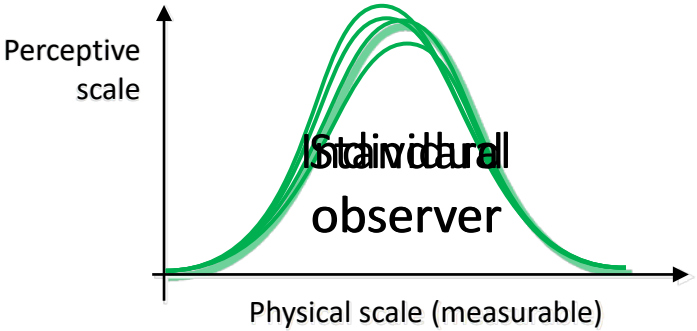
Radiometry

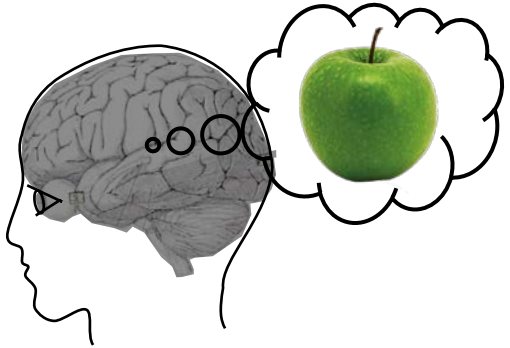
Image based photometry

Spectrophotometry

Psychophysic experiments

Machine Learning





Artificial intelligence

Perception models

Normalization activity

Taking into account the progress done so far and foreseeable in vision science and AI, there could be in few years some changes in the photometric quantities because of a much better understanding of the luminous perception using the cone-fundamentals system.

This cone-fundamental based photometric system would need a new link between photometry (lm, cd, lx,…) and radiometry (W, W/sr, W/m2…).

This link and its nature are the key scientific challenges in the definition of the candela for the next future.