Digital Image Processing (CSE/ECE 478)

Lecture # 04: Human Eye & Color Perception

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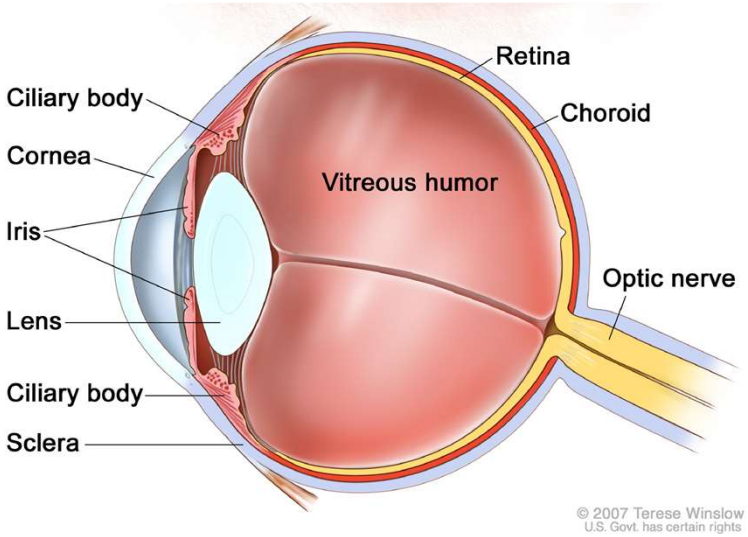
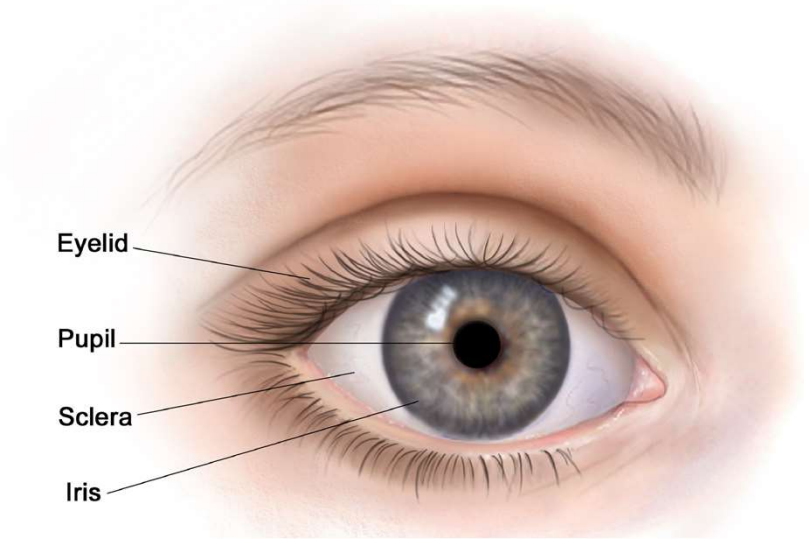
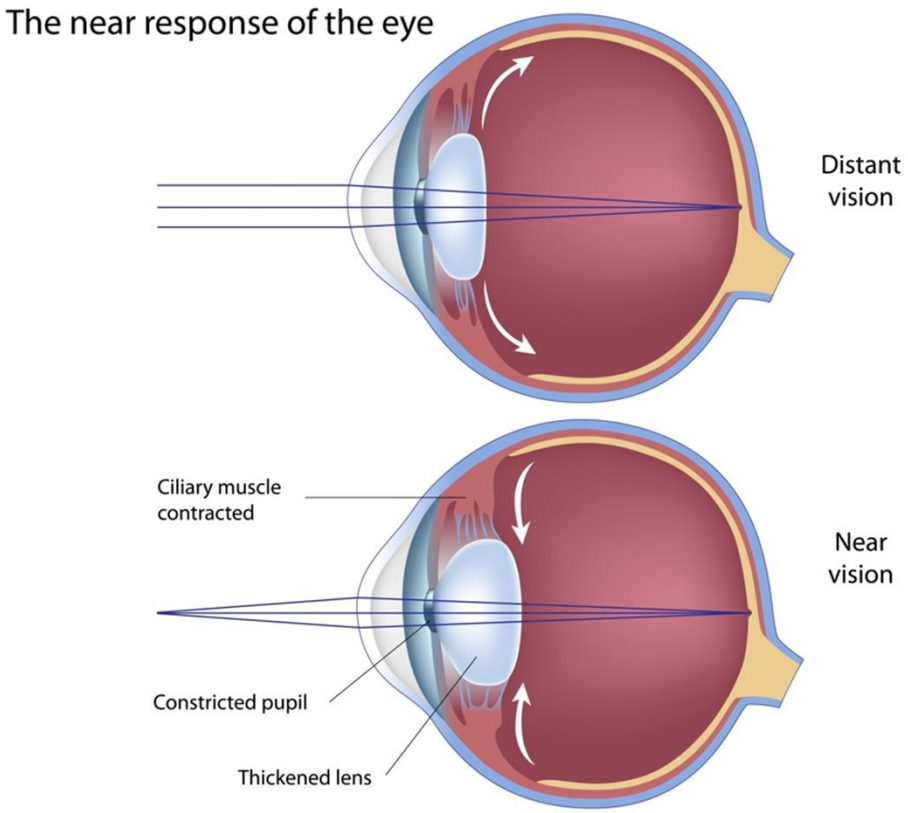
Mechanism of human eye





courtesy: 123diagrams

Accommodation of the eye

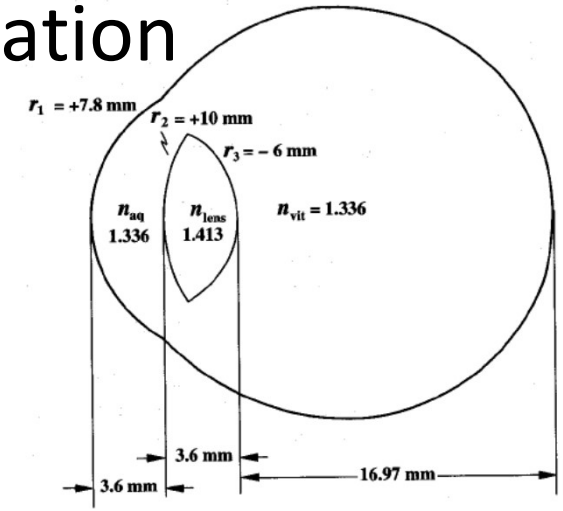


The lens changes its shape to add refractive power to the eye optics and helps focusing near objects

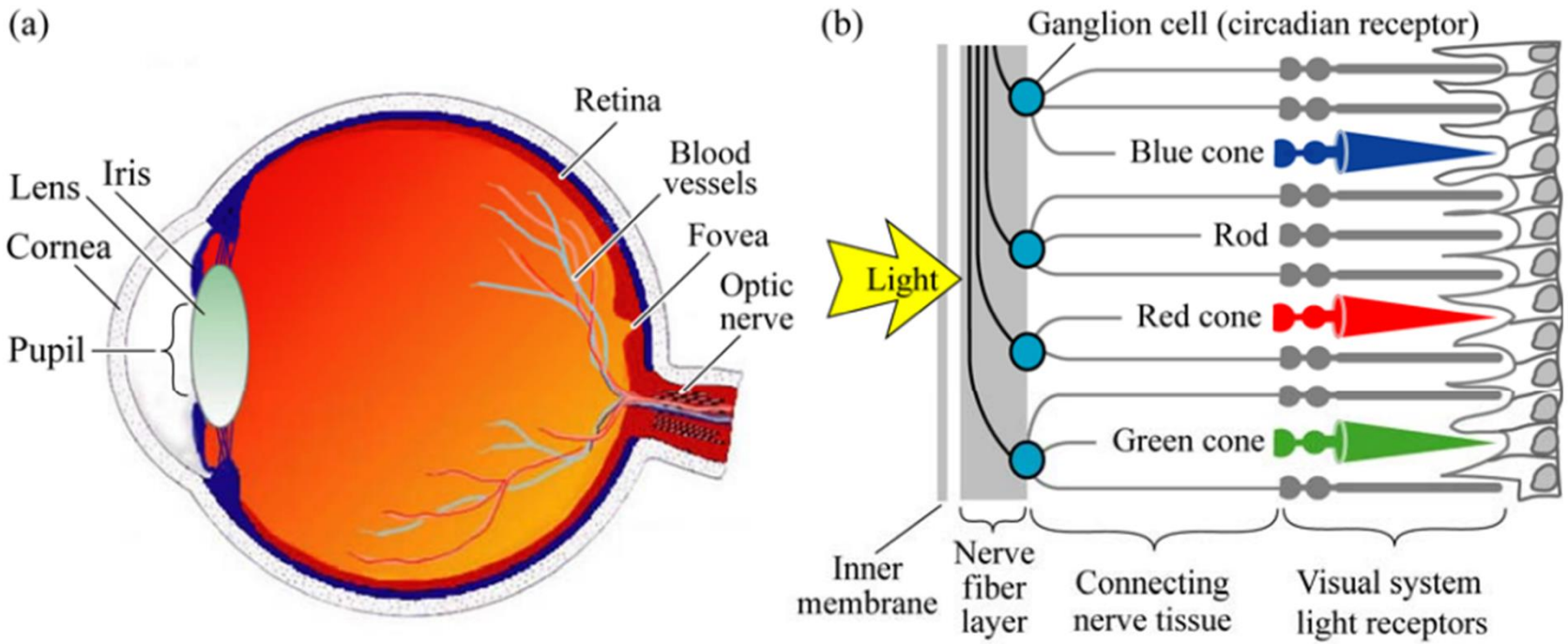
courtesy: charllaas.com

Power of accommodation

- The maximum variation in the power of the eye is called the Power of Accommodation
- Near point, far point
- From infinity to 7 cm in approximately 350 milliseconds
- Mechanism different in different organisms (example fishes)

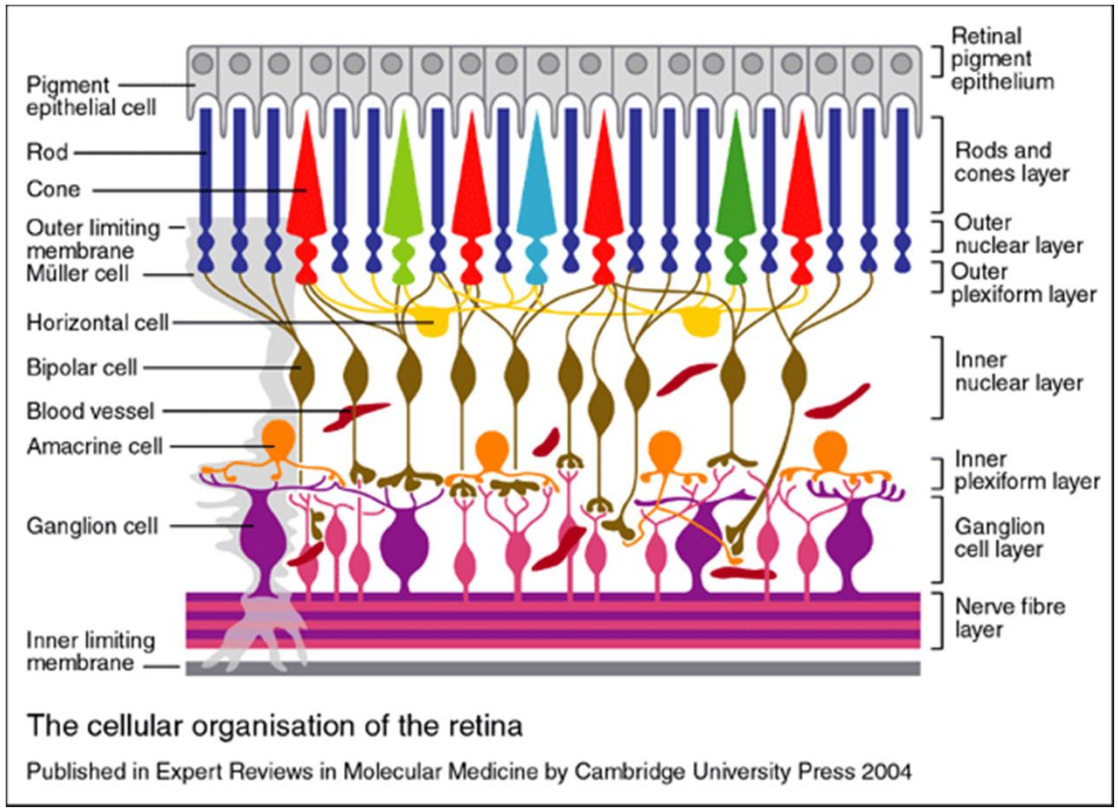


The Retina



courtesy: Britannica encyclopedia

The Retina (Rods and Cones)

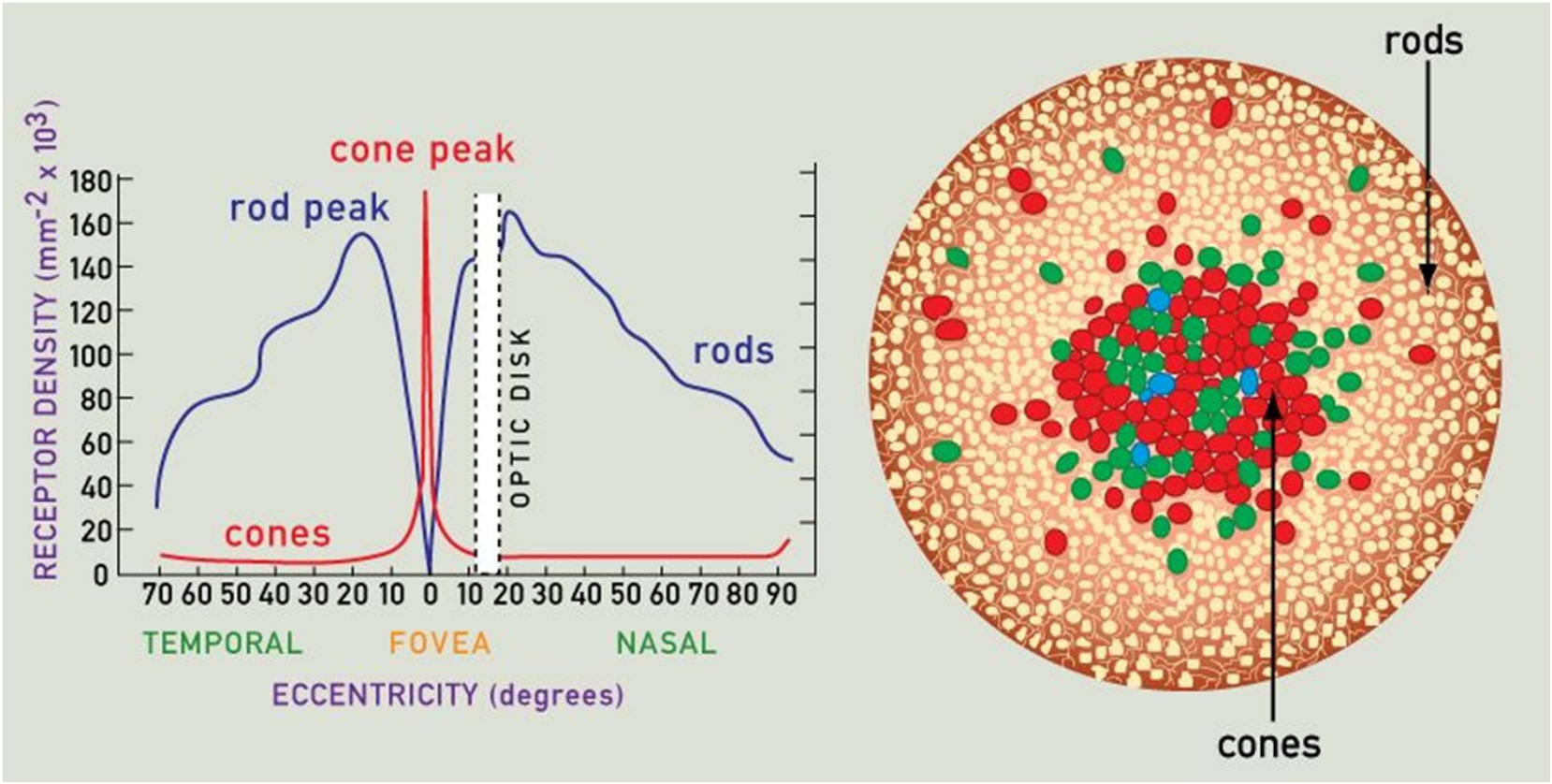


The cellular organisation of the retina

Published in Expert Reviews in Molecular Medicine by Cambridge University Press 2004

1) rods (one type, 100 millions)
2) cones (three types, 6-7 millions). A million of fibers in the optic nerve

The Retina (Rods and Cones)



courtesy: webexhibits.org

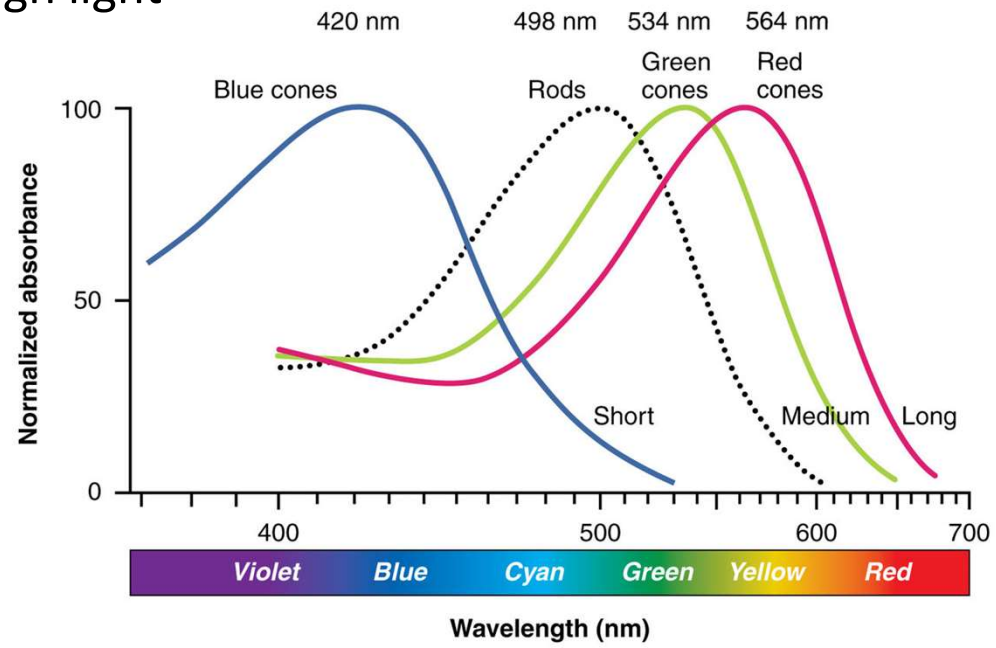
Blind Spot

Fixate on the cross and close your right eye. Start from around 1.5 feet distance (approximately equal to 3× the distance between the **two objects**) from the screen and slowly move towards the screen. When the filled circle disappears, its image is on your blind spot. Do the same thing with the line and cross.

LMS cones and rods

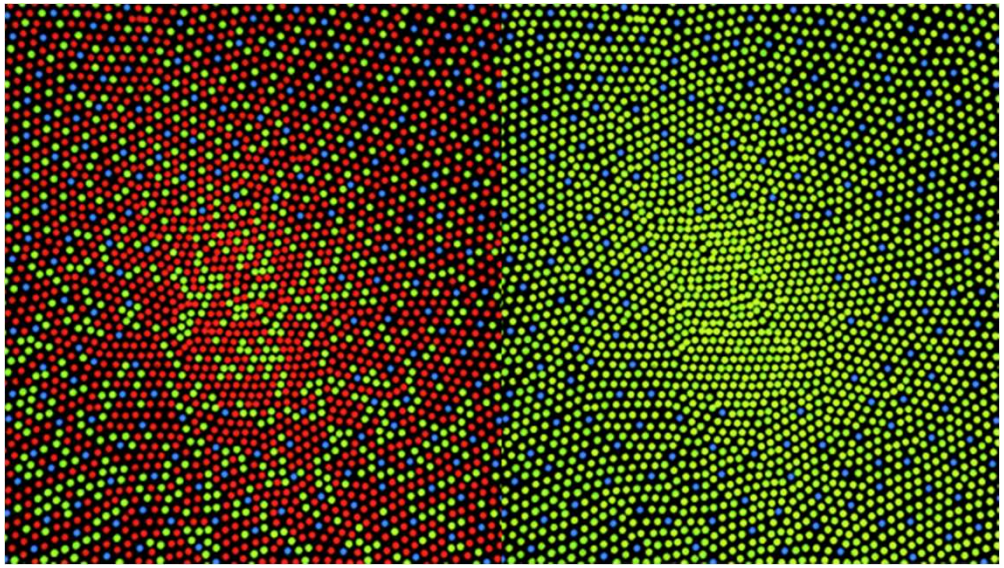
- L, M, S cones responsible for color vision
- Cones are active if there is enough light
- Rods active for low light only

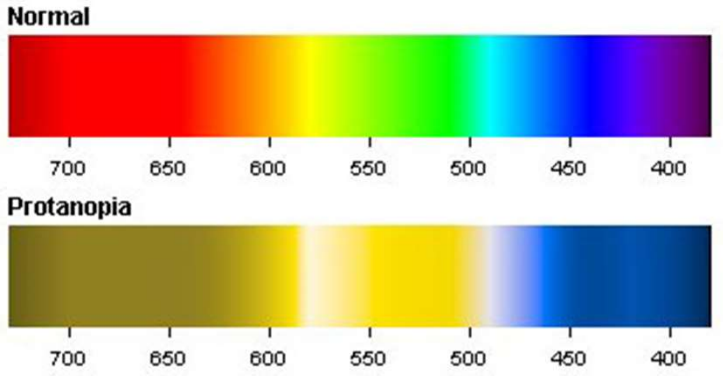
LMS cones do not perceive color,
Brain does! They are just receptors providing signals.



courtesy: Wikipedia

The Fovea (Rods and Cones)





Normal

Protanopia (Color Blind)

courtesy: wikipedia and colorblindness.com

Scotopic vision

- **Scotopic vision**: when the observer sees stimulus of luminance between $\mathbf{10^{-6}cd/m2}$(absolute threshold) and $\mathbf{10^{-3}cd/m2}$

- Rods are the only active photoreceptors, no color vision and low spatial resolution (like in outdoors night vision)

Mesopic vision

- **Mesopic vision**: when the observer sees stimulus of luminance between $\mathbf{10^{-3}}$**cd/m2** and **3-10 cd/m2**

- Rods and cones are active, there is faint color vision and low spatial resolution (like in outdoors sunset or sunrise).

Photopic vision

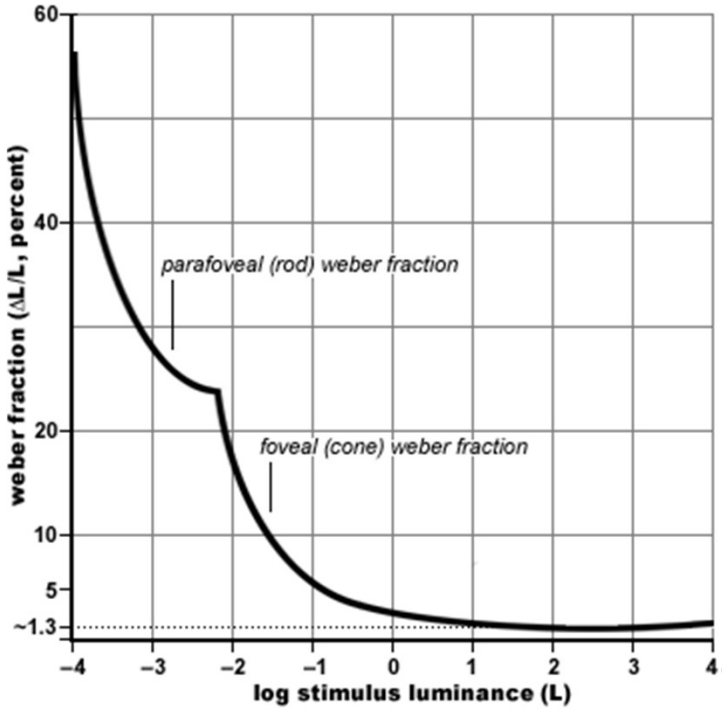
- **Photopic vision**: when the observer sees stimulus of luminance between **1-10 cd/m2**and $\mathbf{10^5 - 10^6}$**cd/m2**

- Cones are mainly active, there is color vision and high spatial resolution (like in outdoors diurnal vision).

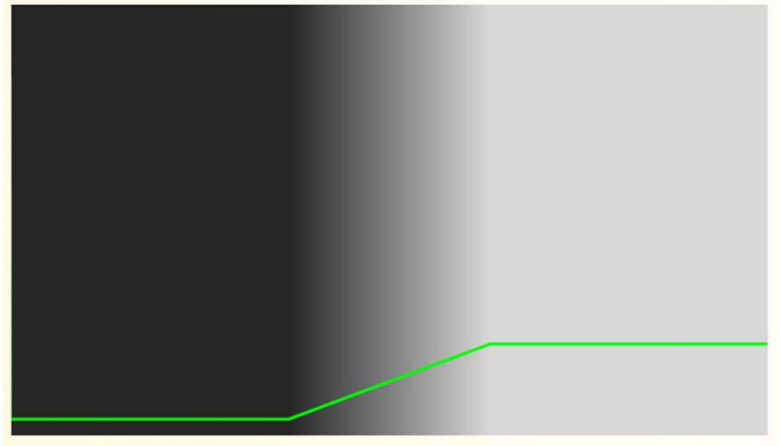
Scotopic, Mesopic and Photopic vision

- During the day the rods are saturated (overstimulated) so the brain ignores them It uses the components of the cone responses to invent the sensation "color
- At night the cones are usually only weakly stimulated, so the brain sees only with the more sensitive rods, and little or no color.

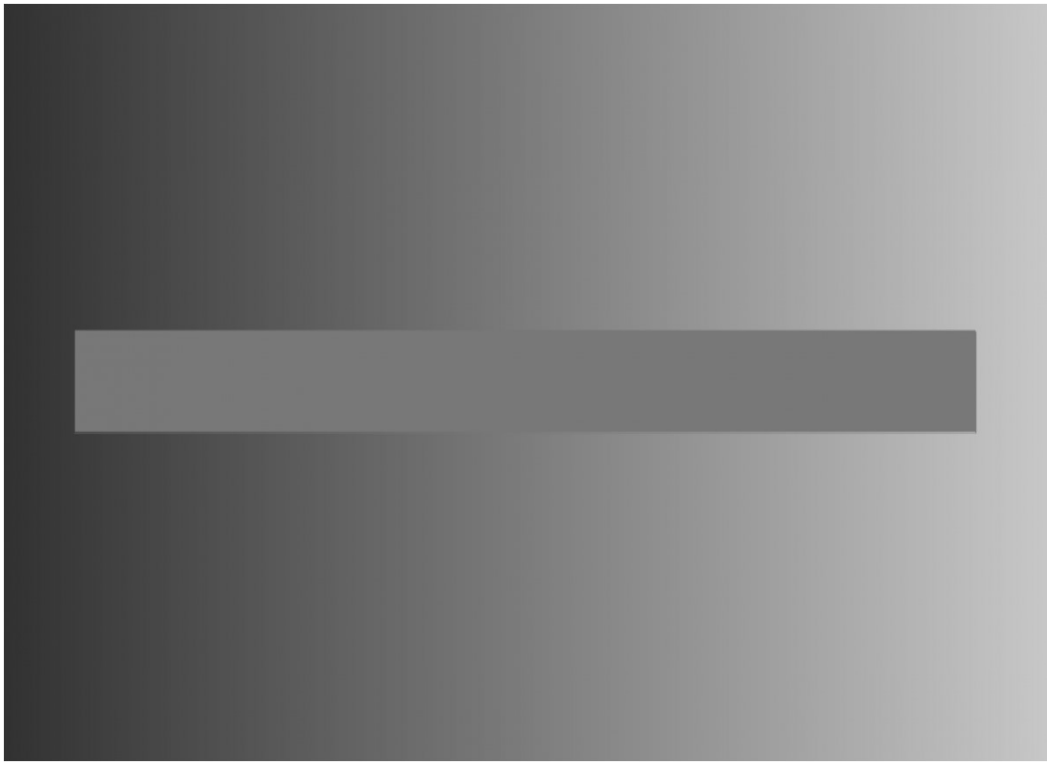
Weber Law


60
40
20
10
5
~1.3
weber fraction (ΔL/L, percent)
parafoveal (rod) weber fraction
foveal (cone) weber fraction
−4
−3
−2
−1
0
1
2
3
4
log stimulus luminance (L)

Mach Bands

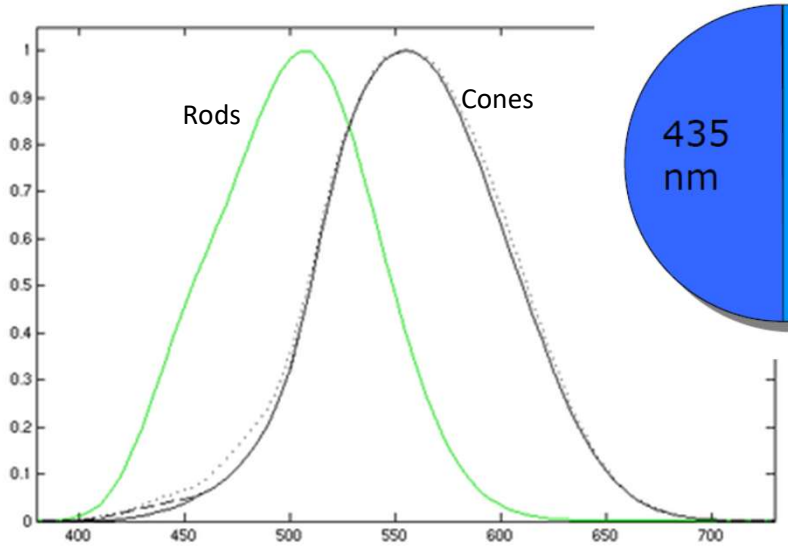


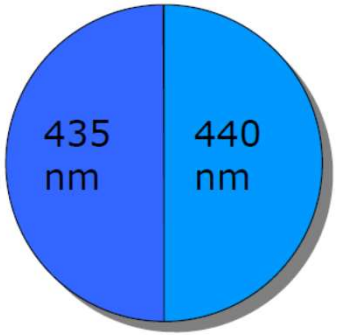
Human Perception



Luminous efficiency

- Describes the average spectral sensitivity of human visual perception of brightness
- It is based on subjective judgements of which of a pair of different-colored lights is brighter, to describe relative sensitivity to light of different wavelengths



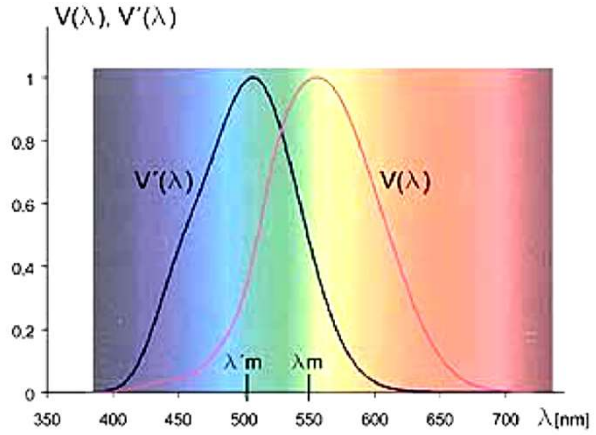


Luminous efficiency

Purkinje shift: the displacement of the spectral human responsivity (sensitivity) to shorter wavelength for low levels of light.

Luminous efficiency

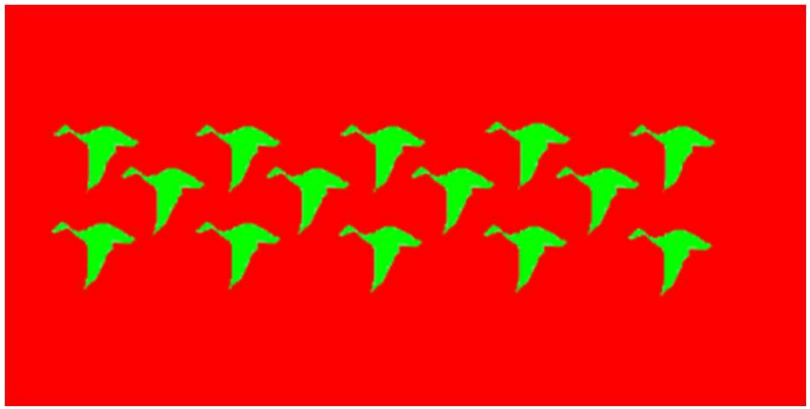
Wavelength (nm)	Photopic vision $V(\lambda)$	Scotopic vision $V'(\lambda)$
380	0.0000	0.0006
390	0.0001	0.0022
400	0.0004	0.0093
410	0.0012	0.0348
420	0.0040	0.0966
430	0.0116	0.1988
440	0.0230	0.3281
450	0.0380	0.4550
460	0.0600	0.5670
470	0.0910	0.6760
480	0.1390	0.7930
490	0.2080	0.9040
500	0.3230	0.9820
510	0.5030	0.9970
520	0.7100	0.9350
530	0.8620	0.8110
540	0.9540	0.6500
550	0.9950	0.4810
560	0.9950	0.3288
570	0.9520	0.2076
580	0.8700	0.1212
590	0.7570	0.0655
600	0.6310	0.0332
610	0.5030	0.0159
620	0.3810	0.0074
630	0.2650	0.0033
640	0.1750	0.0015
650	0.1070	0.0007
660	0.0610	0.0003
670	0.0320	0.0001
680	0.0170	0.0001
690	0.0082	0.0000
700	0.0041	0.0000
710	0.0021	0.0000
720	0.0010	0.0000
730	0.0005	0.0000
740	0.0003	0.0000
750	0.0001	0.0000
760	0.0001	0.0000
770	0.0000	0.0000
780	0.0000	0.0000



How do humans perceive color!

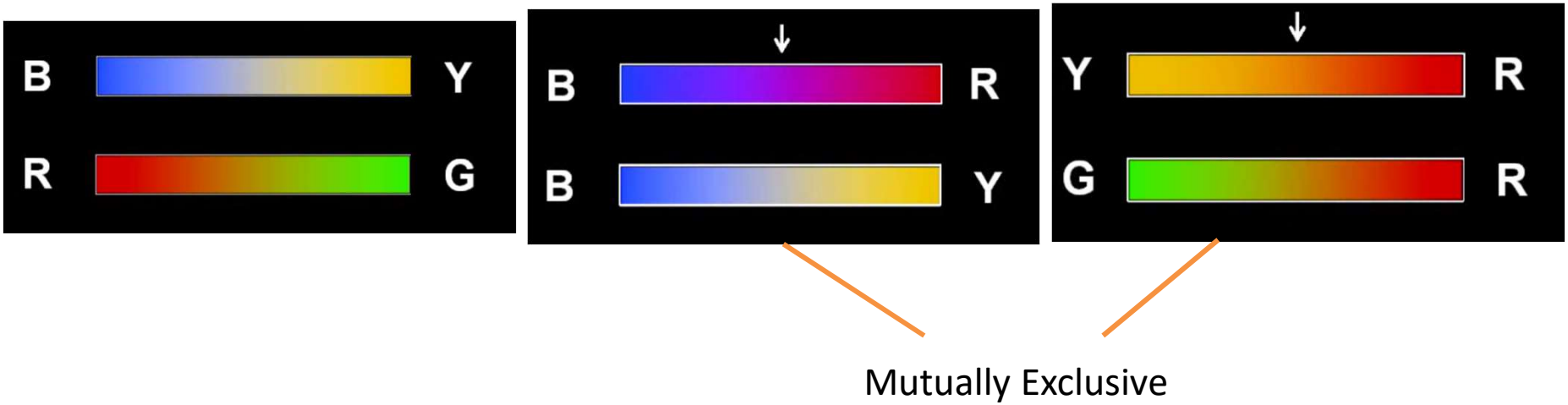
- Trichromatic theory
  - Red, green, blue (LMS)
  - Mixing of these by brain gives color

Not so easy!



How do humans perceive color!

- Opponent theory
  - Three pairs Red-Green, Blue-Yellow, Black-White
  - There is no such color as reddish-green or greenish-red.



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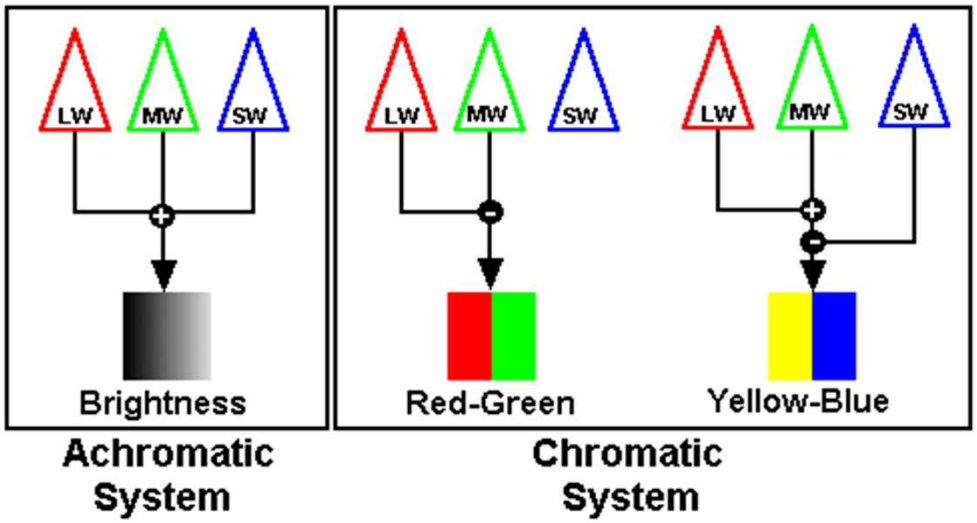

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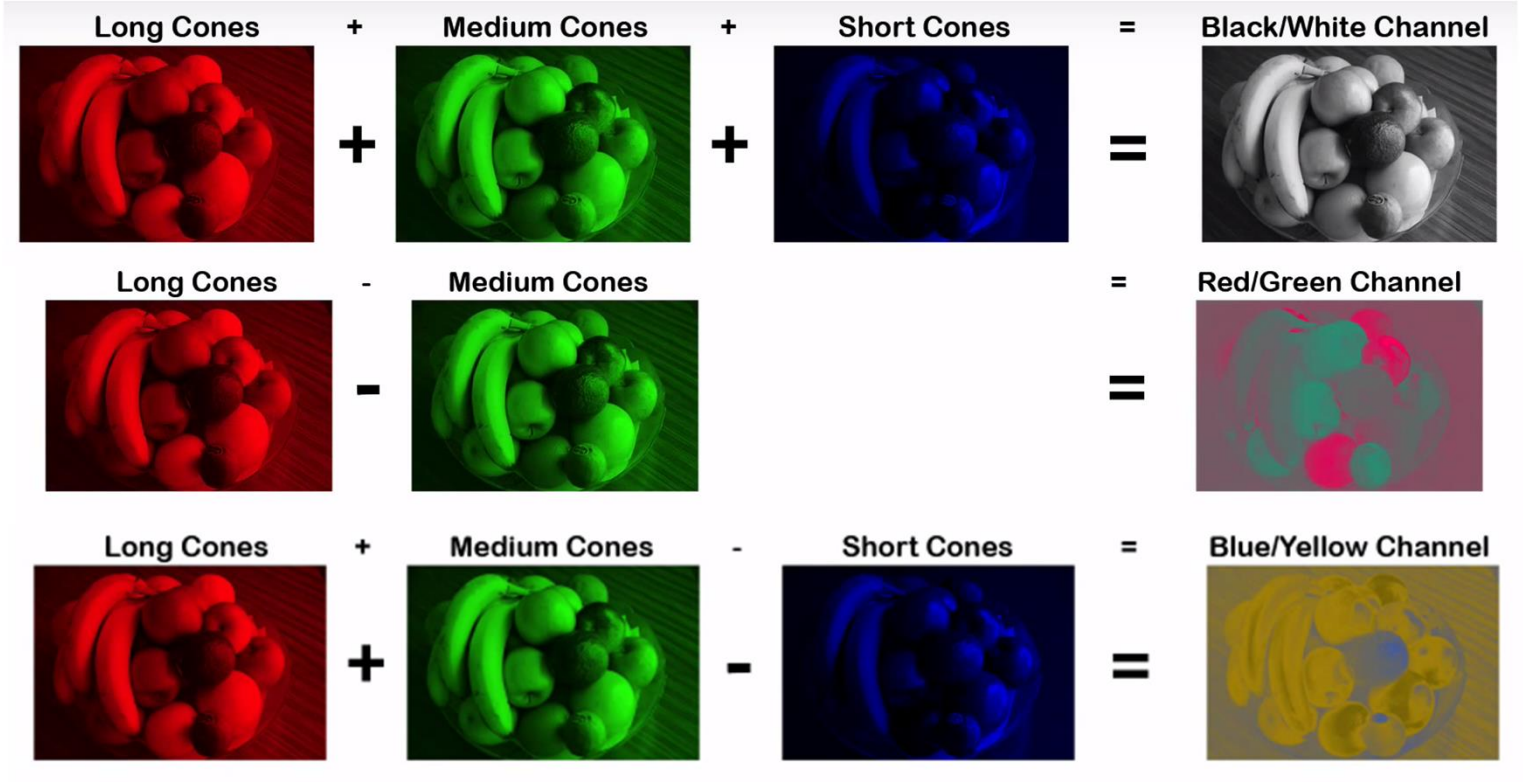

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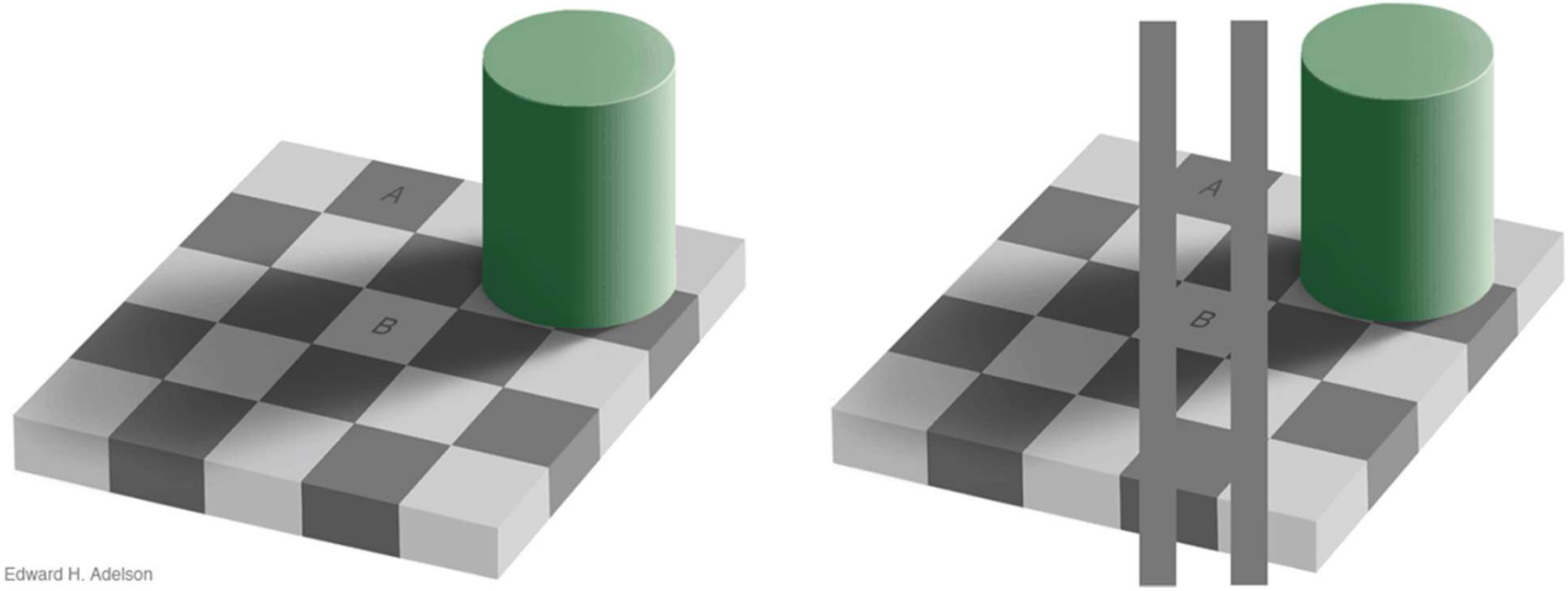

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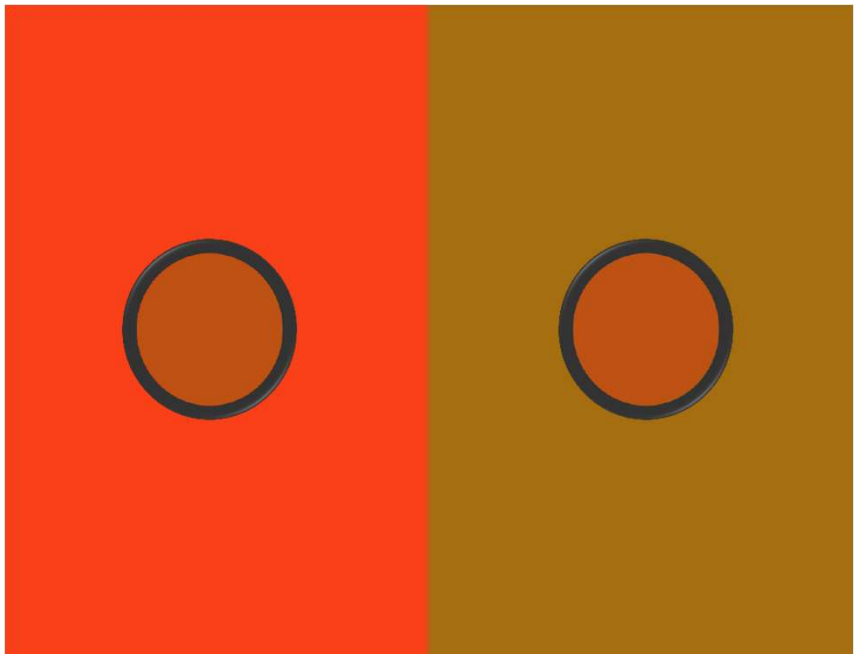

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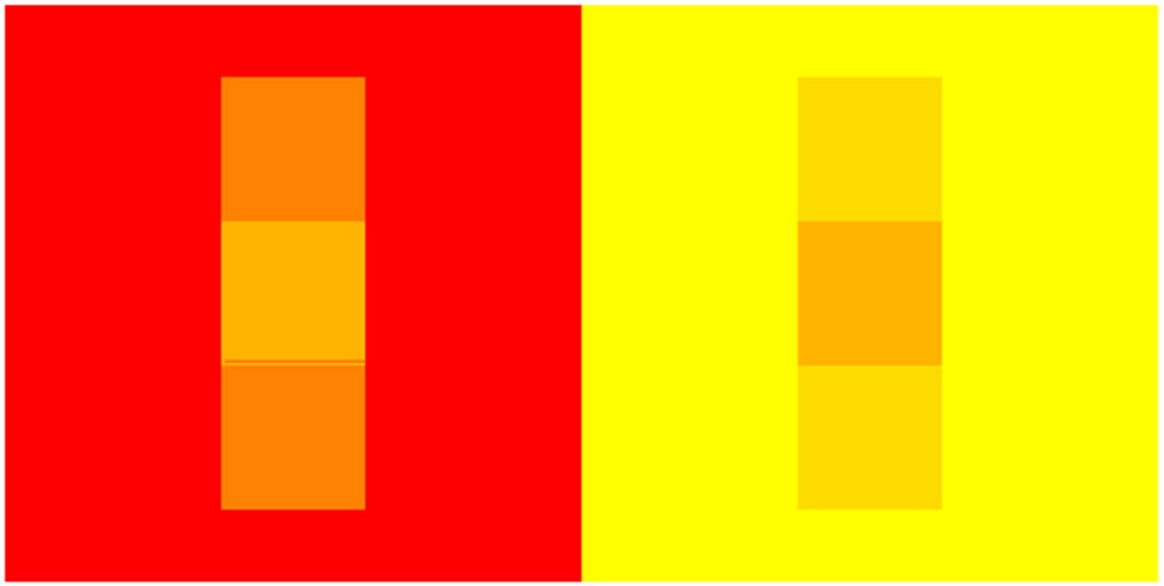

Courtesy: http://hookerlab.martinos.org

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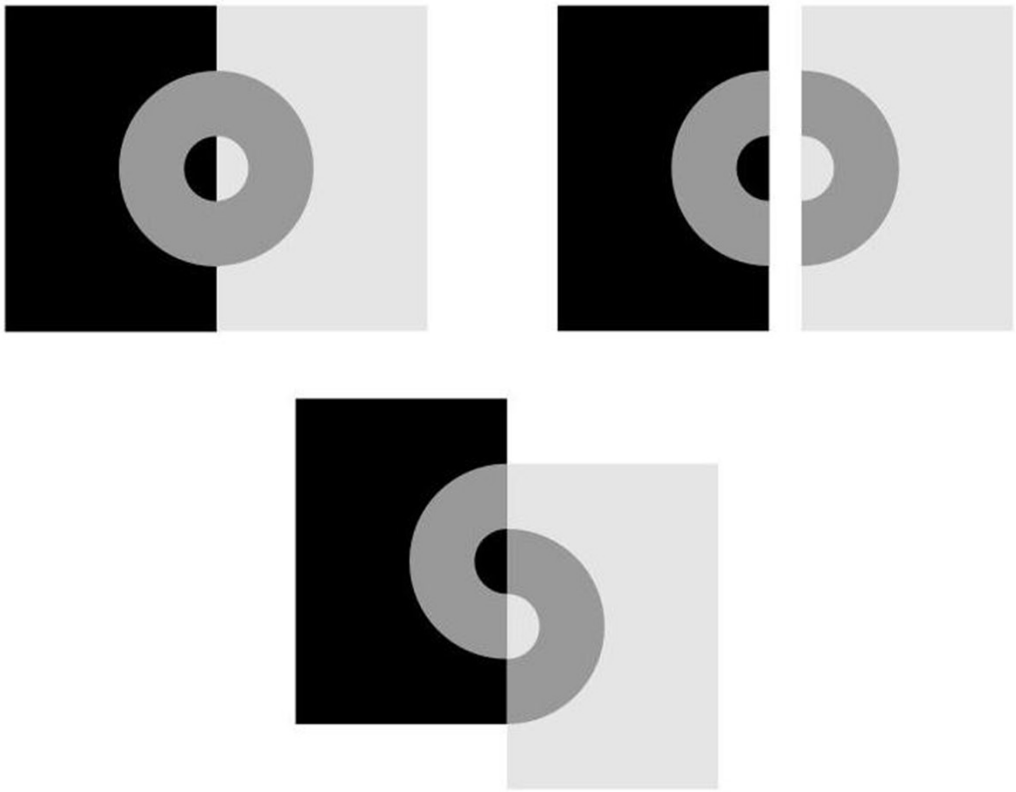

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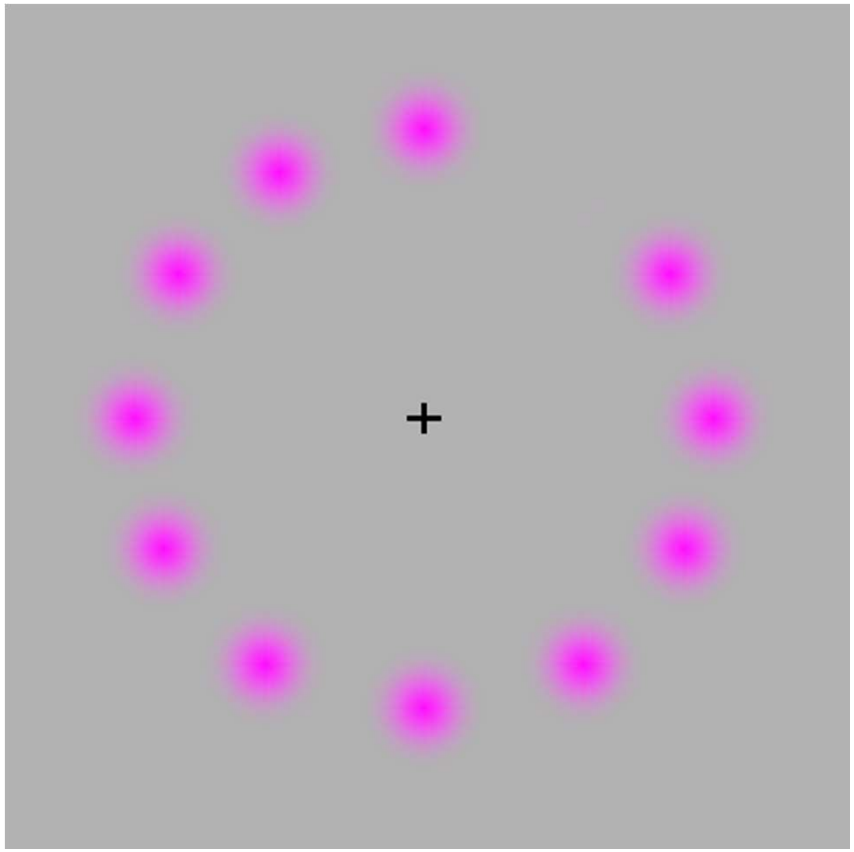


Courtesy: Hinton

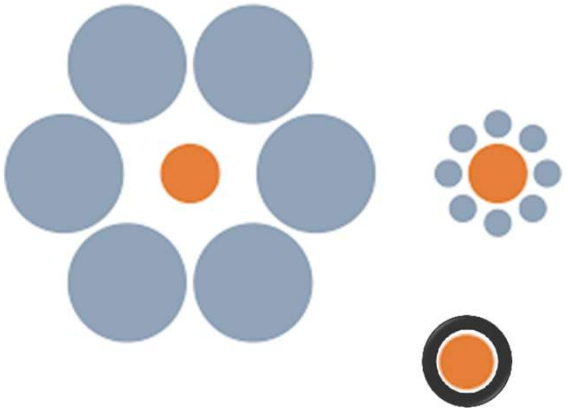
How do humans perceive color!

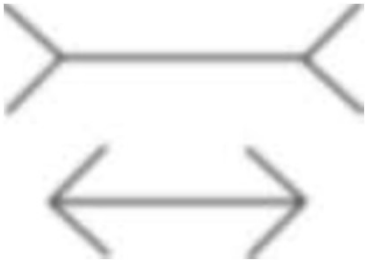
- The dress debate!

- A neuroscientist has claimed that the differences in perception are all down to whether you're a morning lark or a night owl.
- Those who thought that the dress was photographed in a shadow most likely saw the garment as gold and white.
- But those who thought it was illuminated by artificial light were more likely to see it as black and blue.

Read more: http://metro.co.uk/2017/04/07/has-the-blue-or-white-dress-debate-finally-been-solved-6560599/#ixzz4pKxzePJj

How do humans perceive world!





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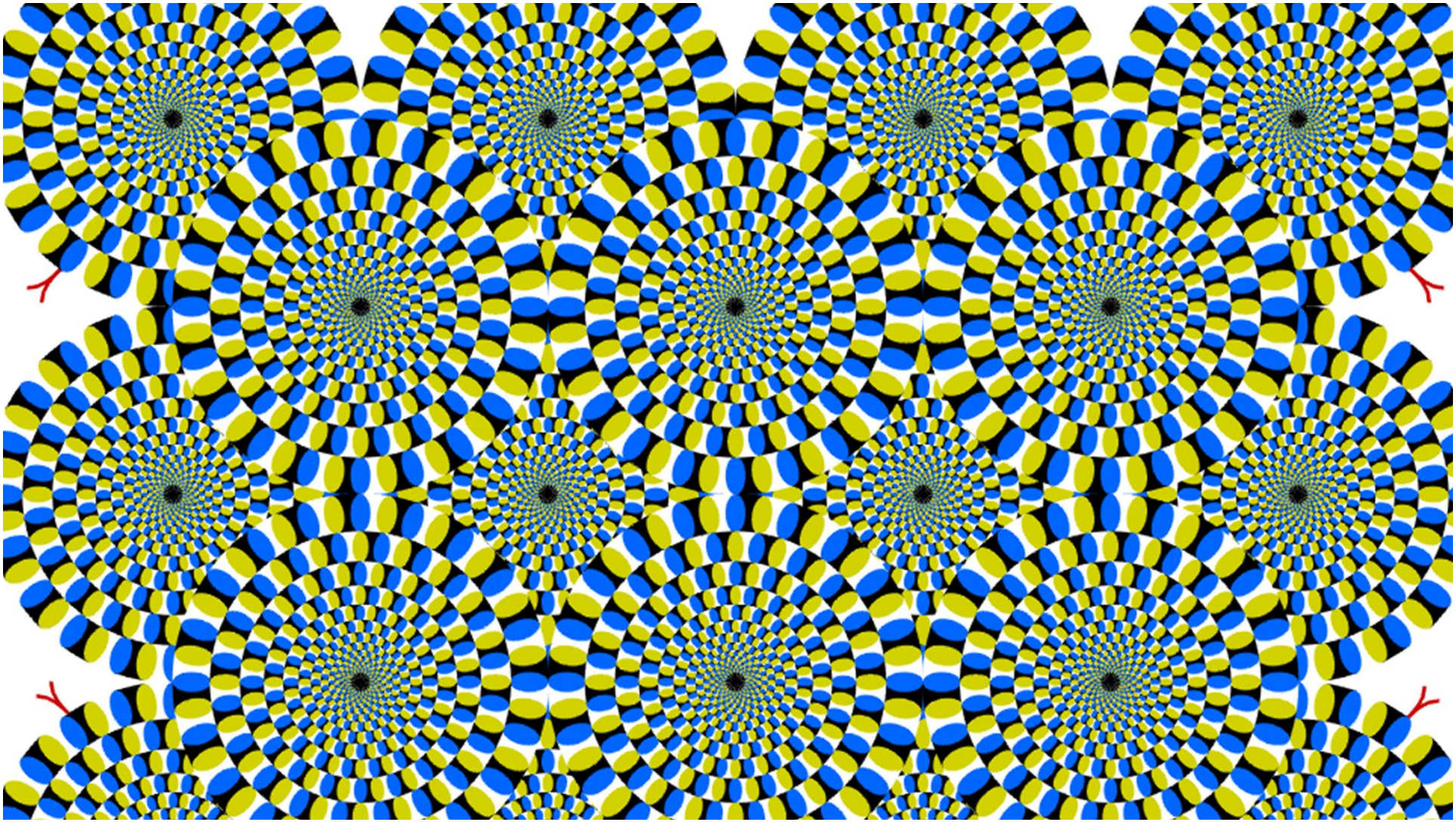

Interesting Link

- http://www.michaelbach.de/ot/
- http://www.ritsumei.ac.jp/~akitaoka/index-e.html