横浜市立大学大学院

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知覚情報科学

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(5-7)

後期２０１０年

THE VISION, What is light ?

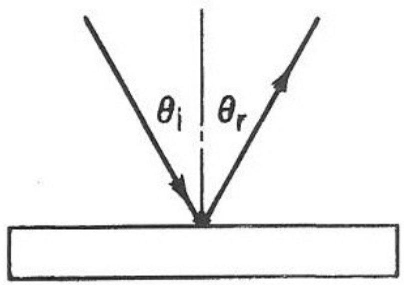


Fig. 26–1. The angle of incidence is equal to the angle of reflection.

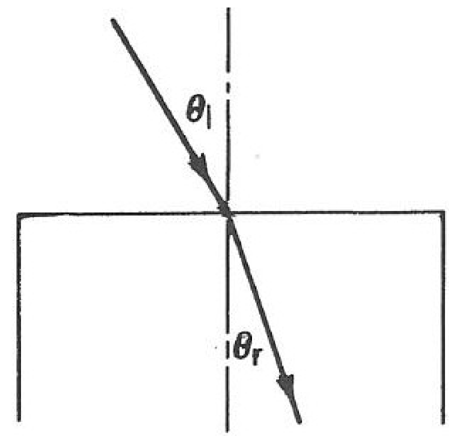


Fig. 26–2. A light ray is refracted when it passes from one medium into another.

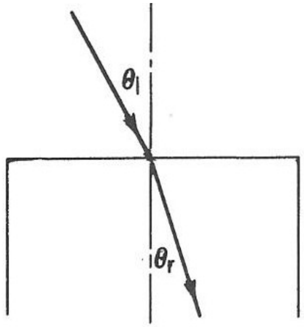


Table 26–1

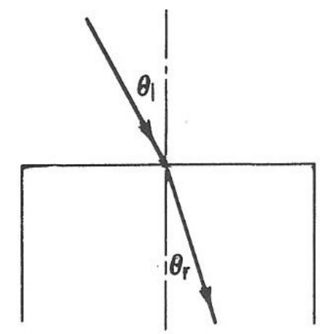
Angle in air	Angle in water
10°	8°
20°	15-1/2°
30°	22-1/2°
40°	29°
50°	35°
60°	40-1/2°
70°	45-1/2°
80°	50°

140 A.D., Claudius Ptolemy

Table 26–2

Angle in air	Angle in water
10°	7-1/2°
20°	15°
30°	22°
40°	29°
50°	35°
60°	40-1/2°
70°	45°
80°	48°

$$\sin\theta_i = n\sin\theta_r.$$



Snell law (1621)

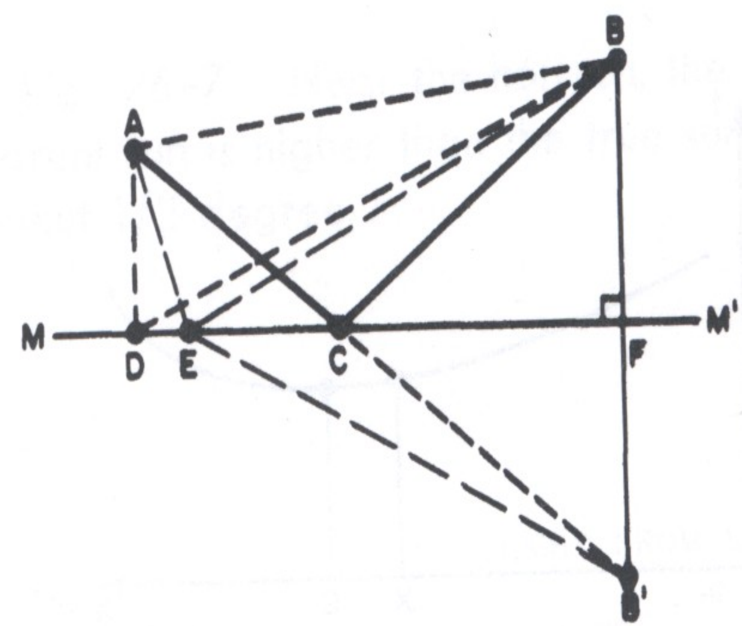
Principle of Fermat (1650, Snell+29 years!)

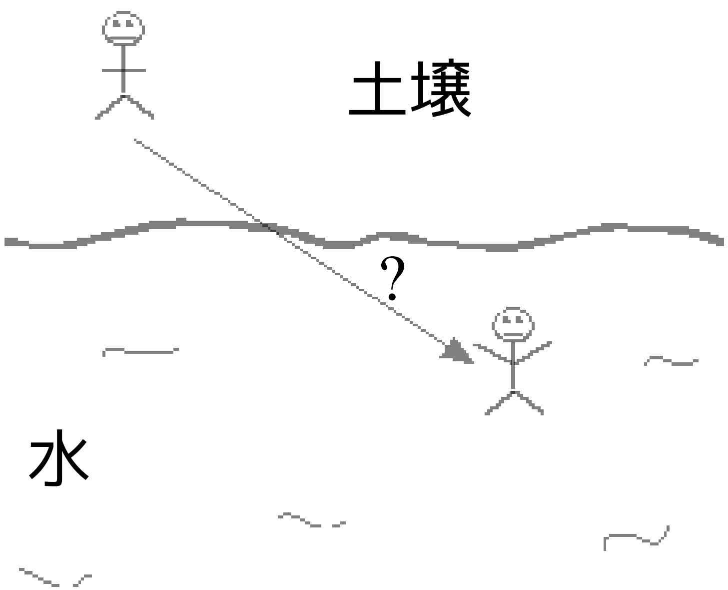
フェルマット原則

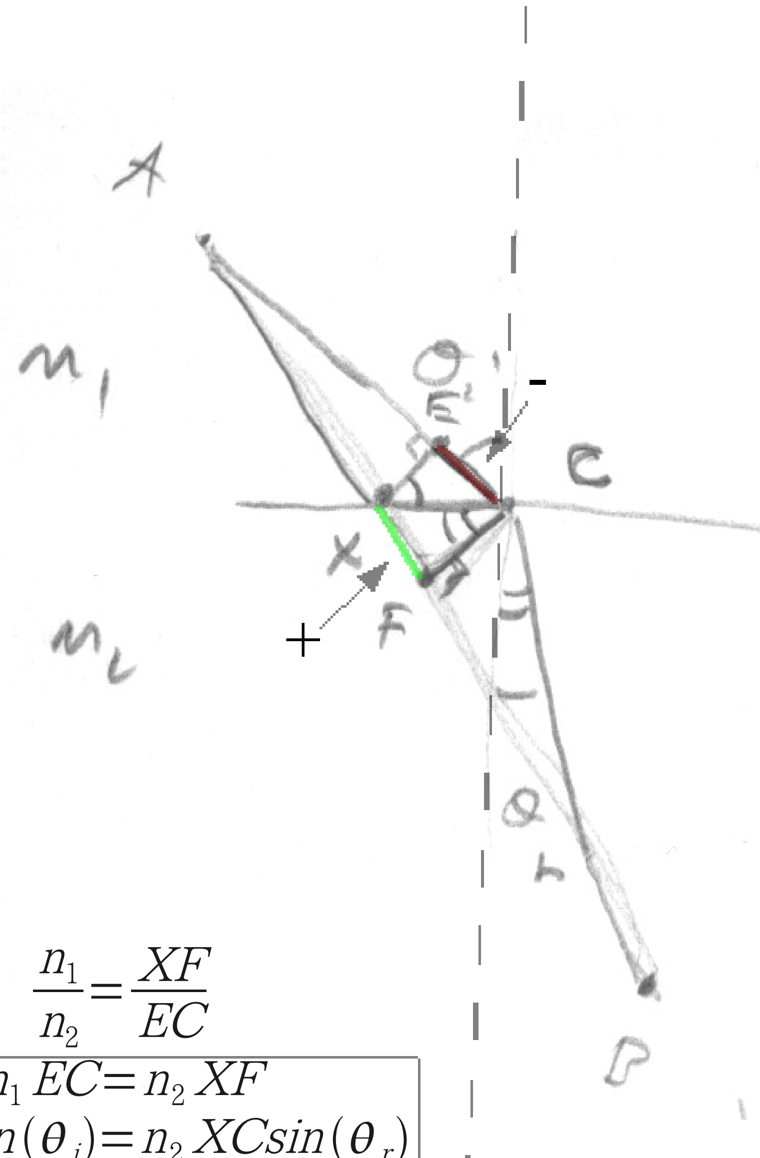
Out of all possible paths, light takes the path which requires the *less time*

$$n = \frac{c}{V_{\text{光のスピード}}}$$

$$c = 300.000\text{Km}/sec$$







$$\frac{n_1}{n_2} = \frac{XF}{EC}$$

Snell Law
(1650)

$$\boxed{\begin{array}{c} n_1\, EC = n_2\, XF \\ n_1\, XC\sin(\theta_i) = n_2\, XC\sin(\theta_r) \end{array}}$$

$$n_1 \sin(\theta_i) = n_2 \sin(\theta_r)$$

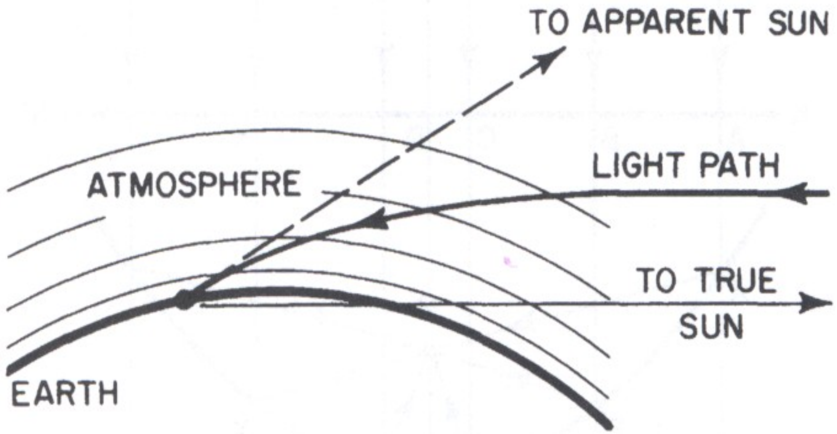


Fig. 26–7. Near the horizon, the apparent sun is higher than the true sun by about 1/2 degree.

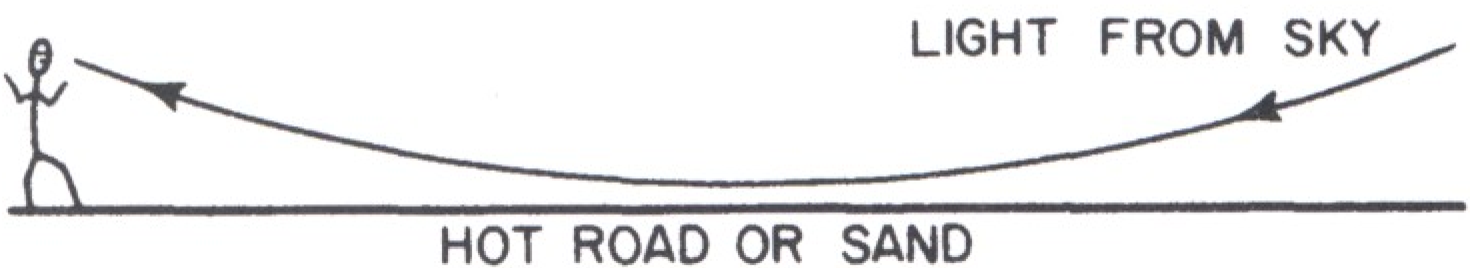
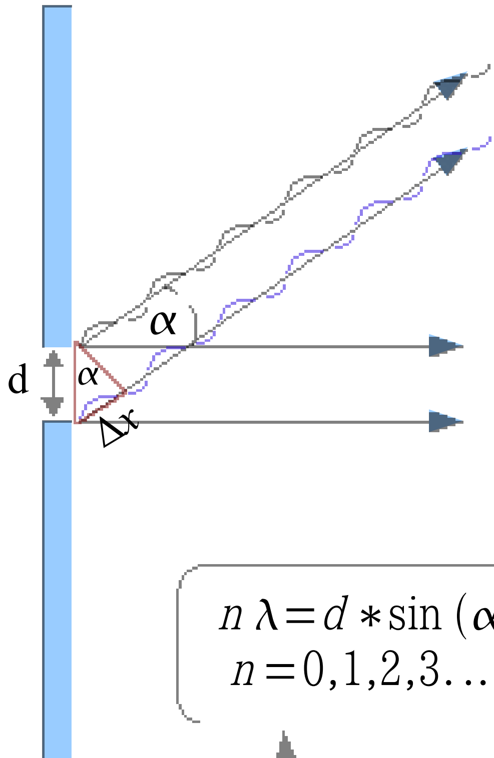
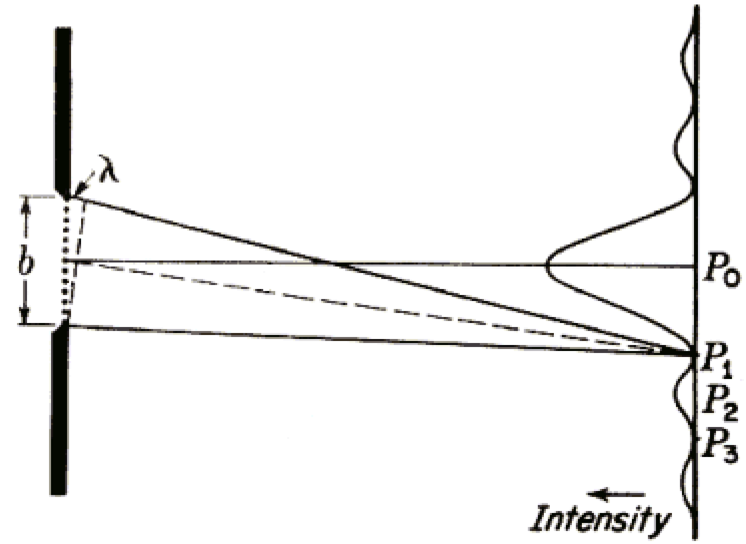


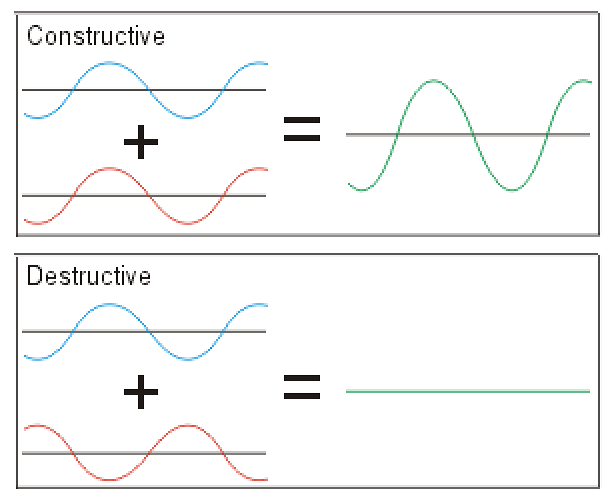
Fig. 26–8. A mirage.

干涉

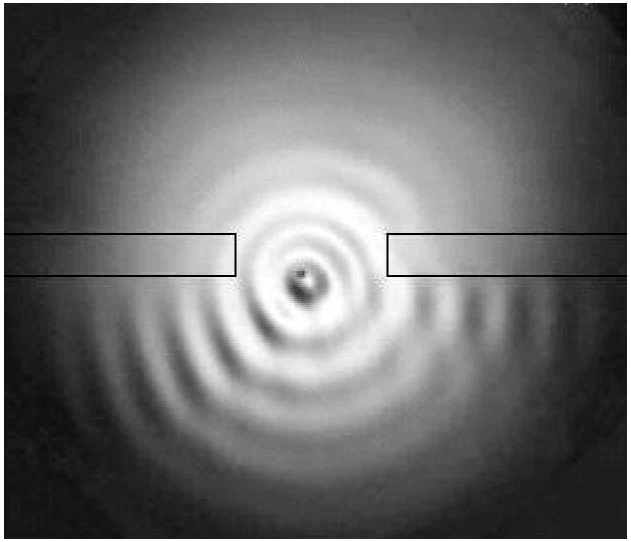


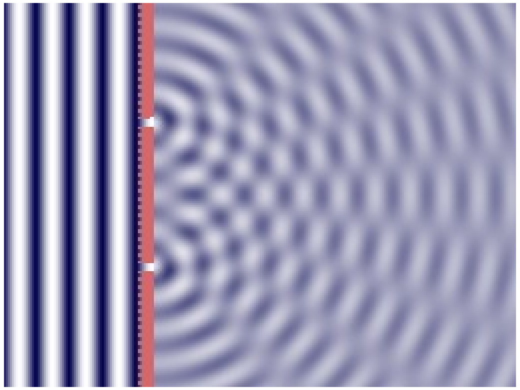


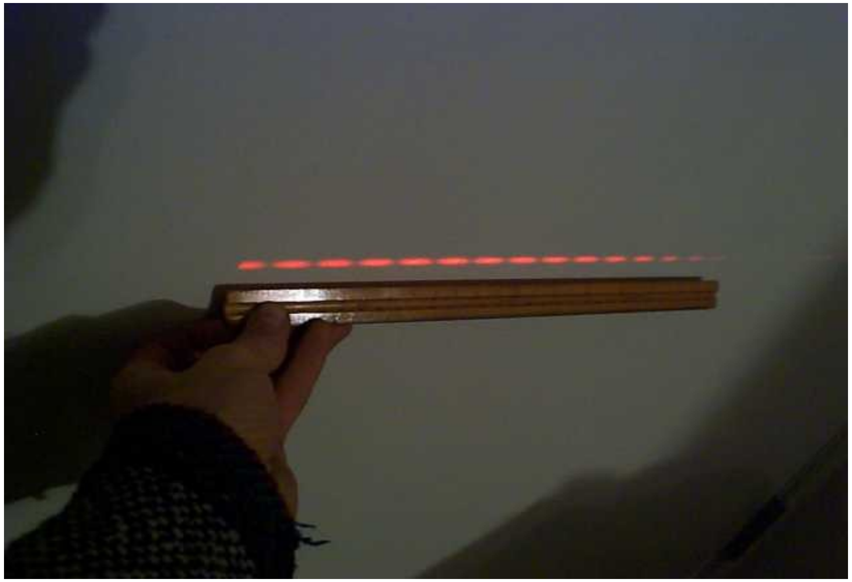
$$n\lambda = d * \sin(\alpha)$$
$$n = 0, 1, 2, 3....$$



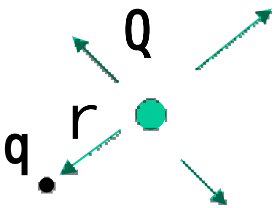
Interference: **Max** condition







チャージを存在



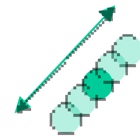
静電場

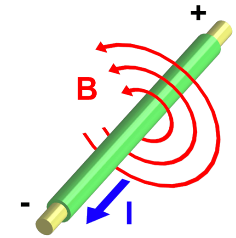
Coulomb法:

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{\mathbf{r}}$$

$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}\hat{\mathbf{r}} = q\mathbf{E}$$

チャージを動くと



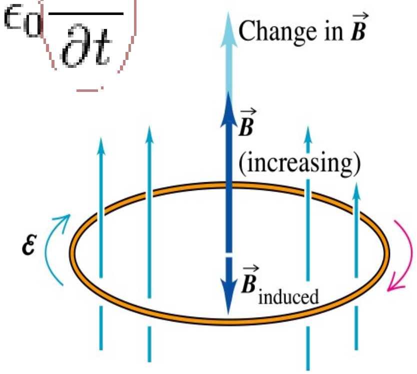


Ampere法

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

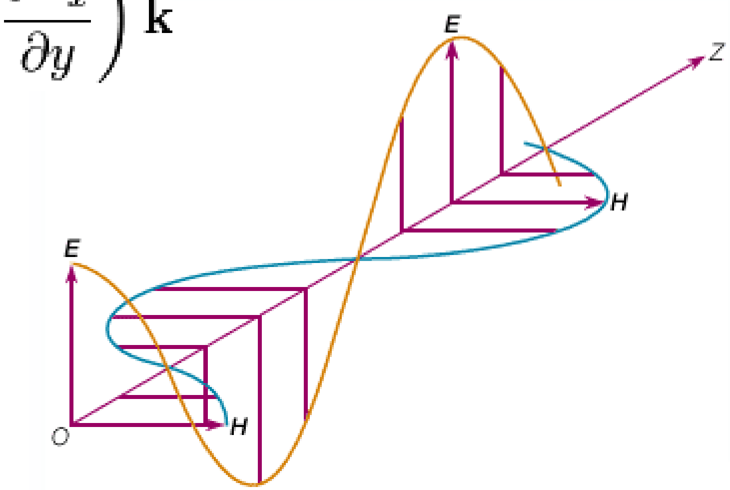
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

Faraday法



$$\nabla \times \mathbf{F}$$

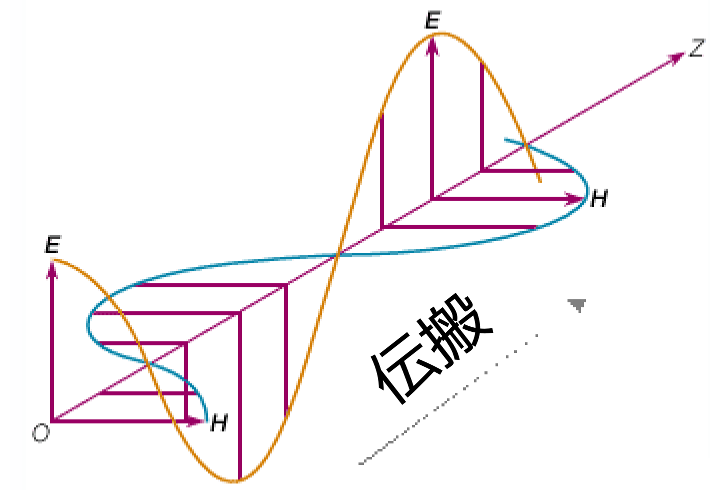
$$\left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right)\mathbf{i} + \left(\frac{\partial F_x}{\partial z} - \frac{\partial F_z}{\partial x}\right)\mathbf{j} + \left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)\mathbf{k}$$

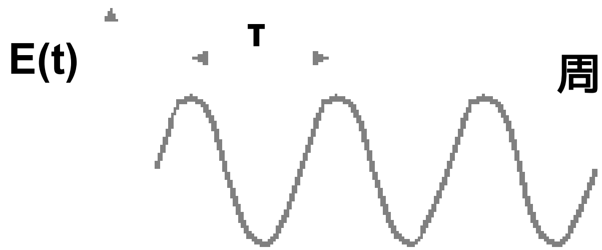


チャージを存在 ▸ 静電場
（Coulomb法）

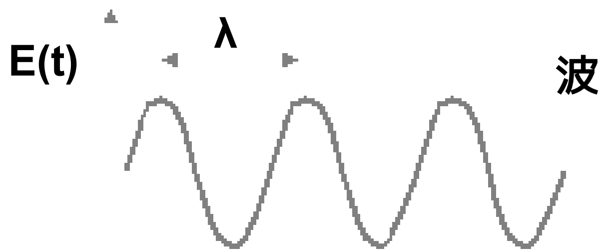
チャージを動く ▸ 変動磁場 ▸ 変動電場
(Ampere法) (Faraday法)

$$\begin{cases} \mathbf{E}(\mathbf{r},t) = \mathbf{E}_0 \cos(\omega t - \mathbf{k}\cdot\mathbf{r} + \phi_0) \\ \mathbf{B}(\mathbf{r},t) = \mathbf{B}_0 \cos(\omega t - \mathbf{k}\cdot\mathbf{r} + \phi_0) \end{cases}$$

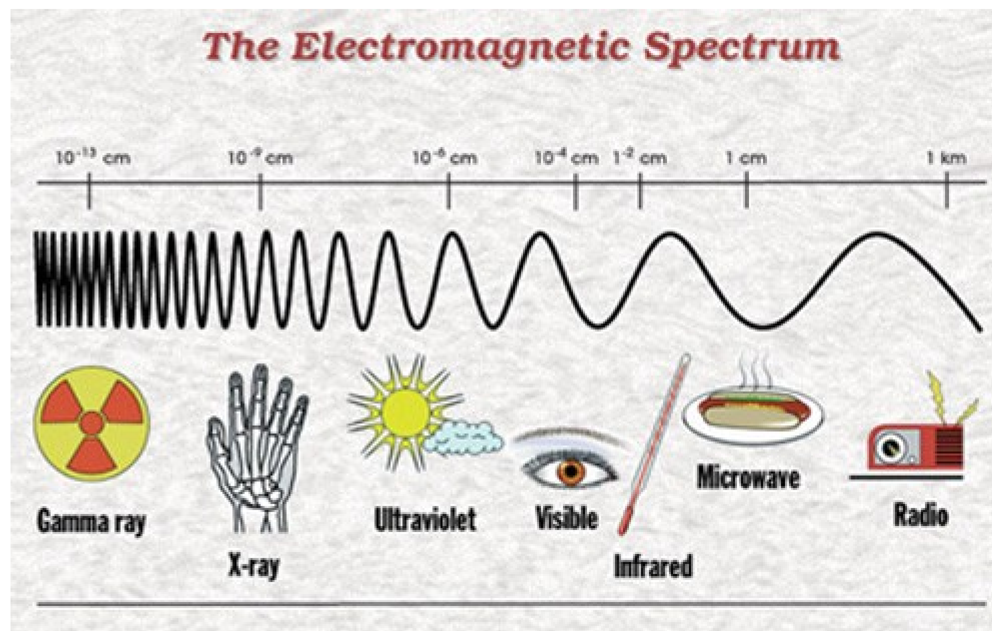


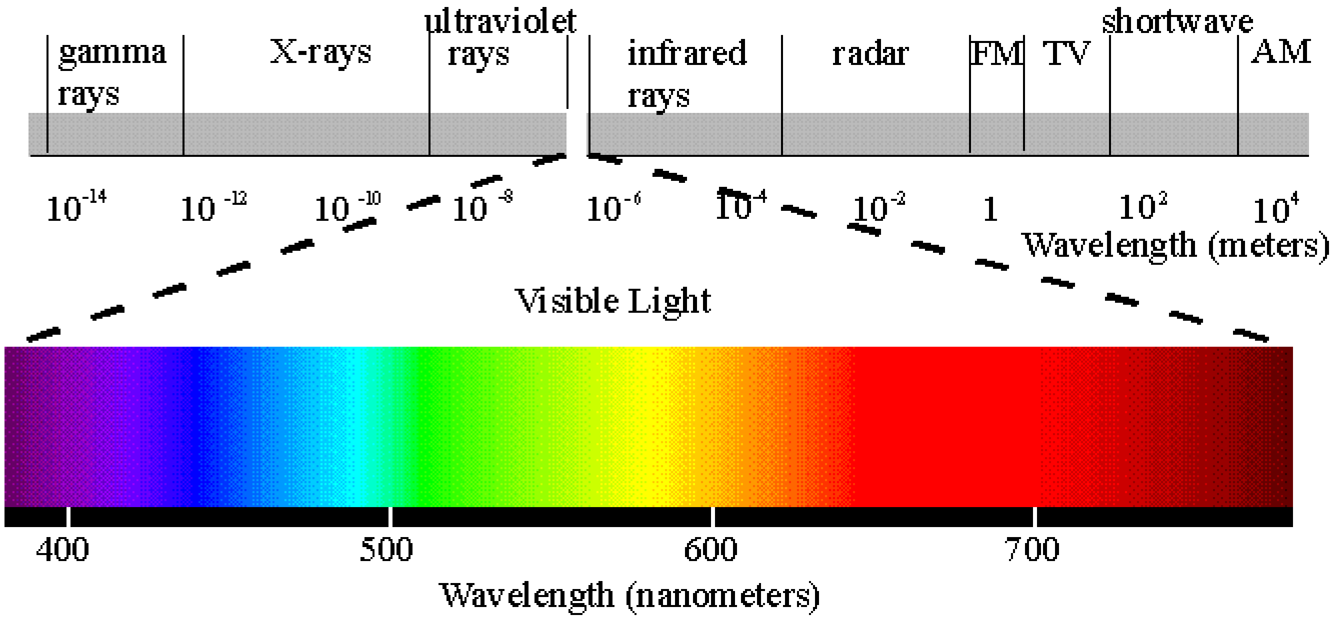


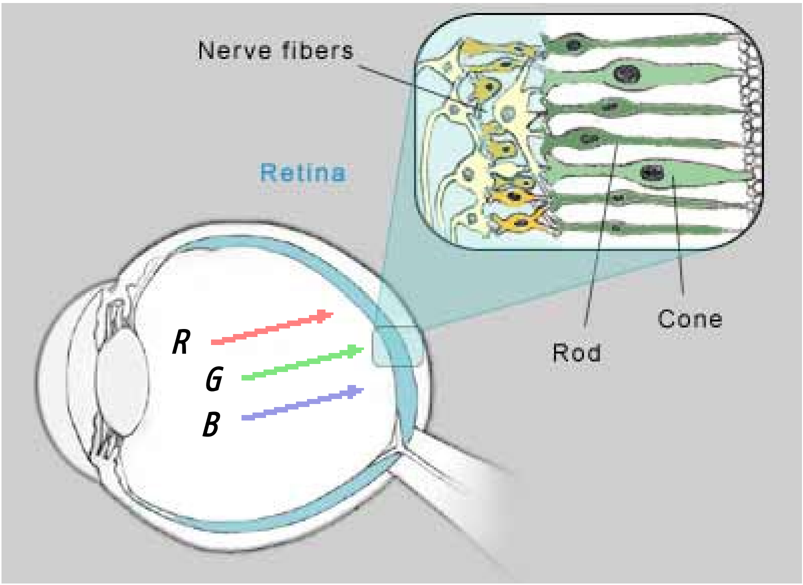
周波数： f = 1/τ

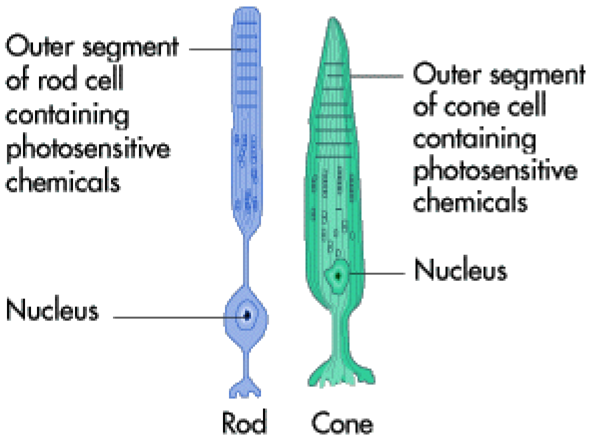


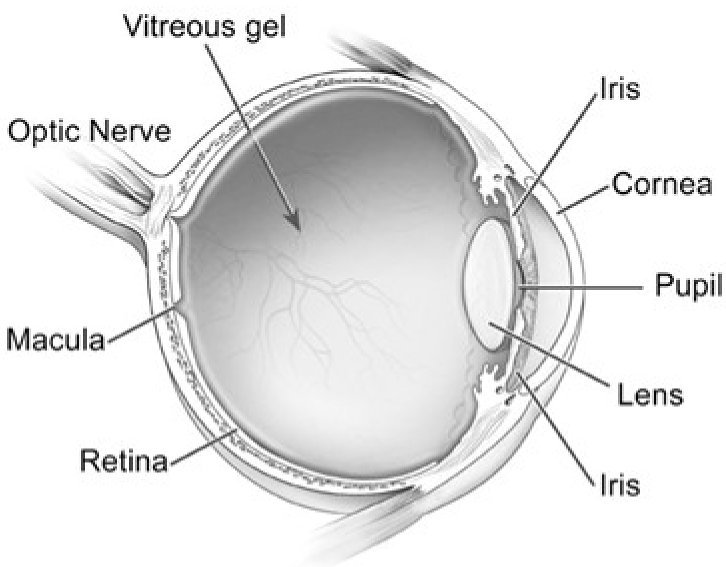
波長： f = λ

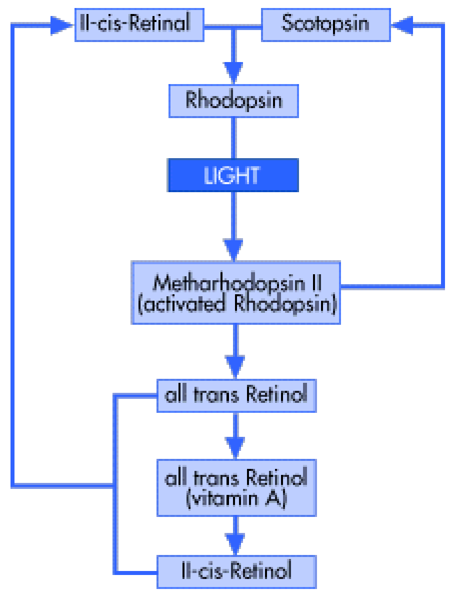


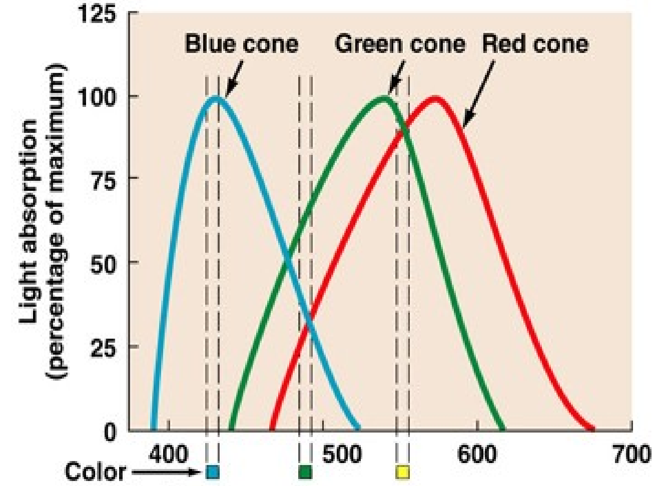

gamma rays
X-rays
ultraviolet rays
infrared rays
radar
FM
TV
shortwave
AM
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
Wavelength (meters)
Visible Light
400
500
600
700
Wavelength (nanometers)


Nerve fibers
Retina
R
G
B
Rod
Cone


Outer segment of rod cell containing photosensitive chemicals
Nucleus
Outer segment of cone cell containing photosensitive chemicals
Nucleus
Rod
Cone





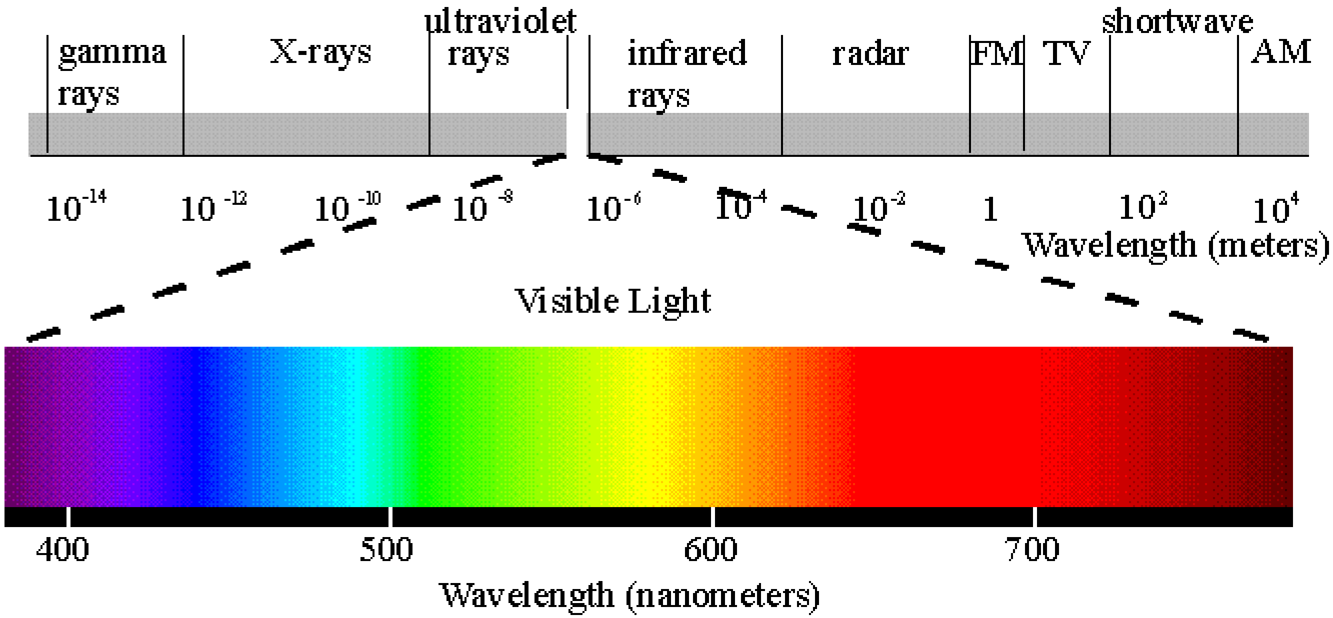


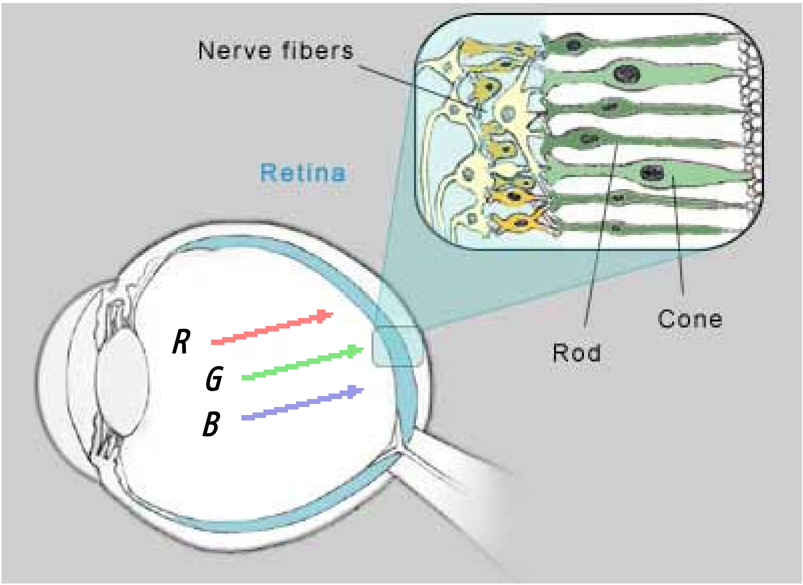
“RGB”の色で全部の色を作る。この事は光の特性ではない、人間の目の特性です（！）

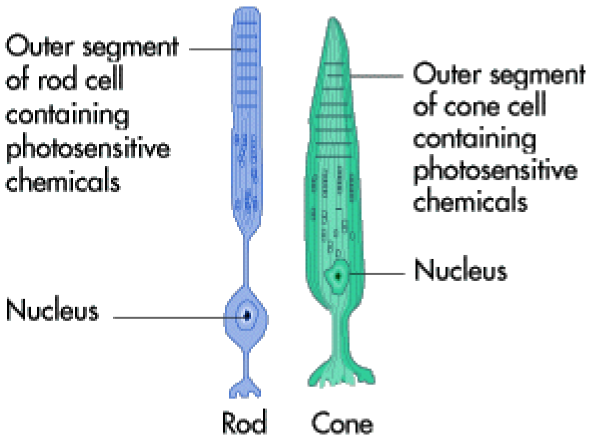
人間は　「Trichromatic Vision」

動物の世界の中に「Tetrachromacy」「Pentachromats」などがあります

THE VISION, How does it work ?


gamma rays
X-rays
ultraviolet rays
infrared rays
radar
FM
TV
shortwave
AM
10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 1 10^{2} 10^{4}
Wavelength (meters)
Visible Light
400
500
600
700
Wavelength (nanometers)


Nerve fibers
Retina
R
G
B
Rod
Cone


Outer segment of rod cell containing photosensitive chemicals
Nucleus
Outer segment of cone cell containing photosensitive chemicals
Nucleus
Rod
Cone

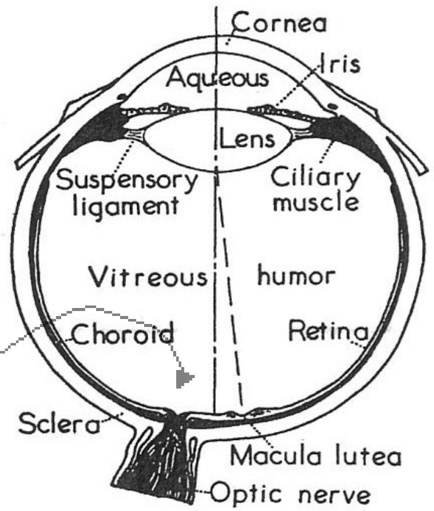


Fig. 35–1. The eye.

Blind Spot !

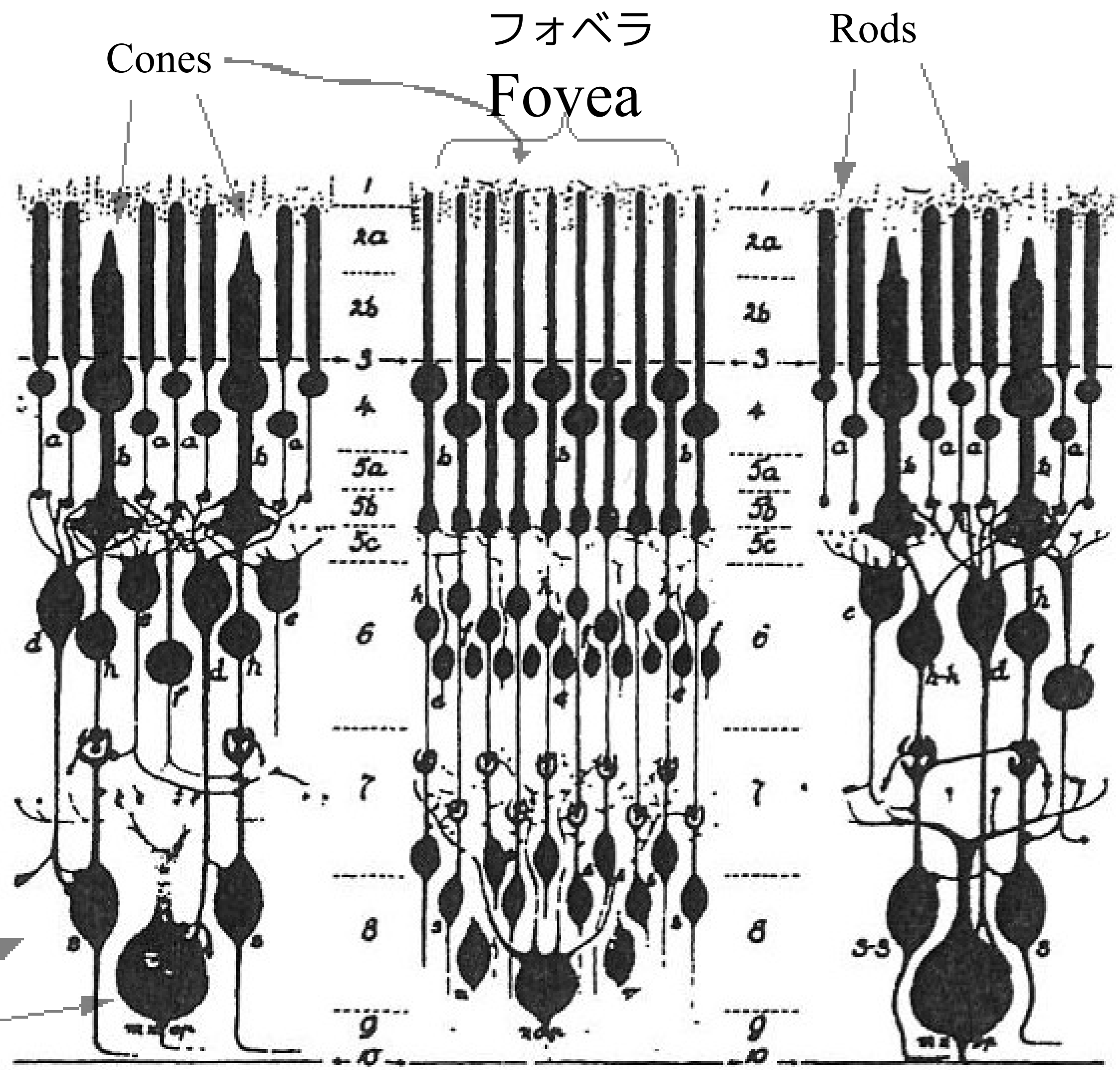
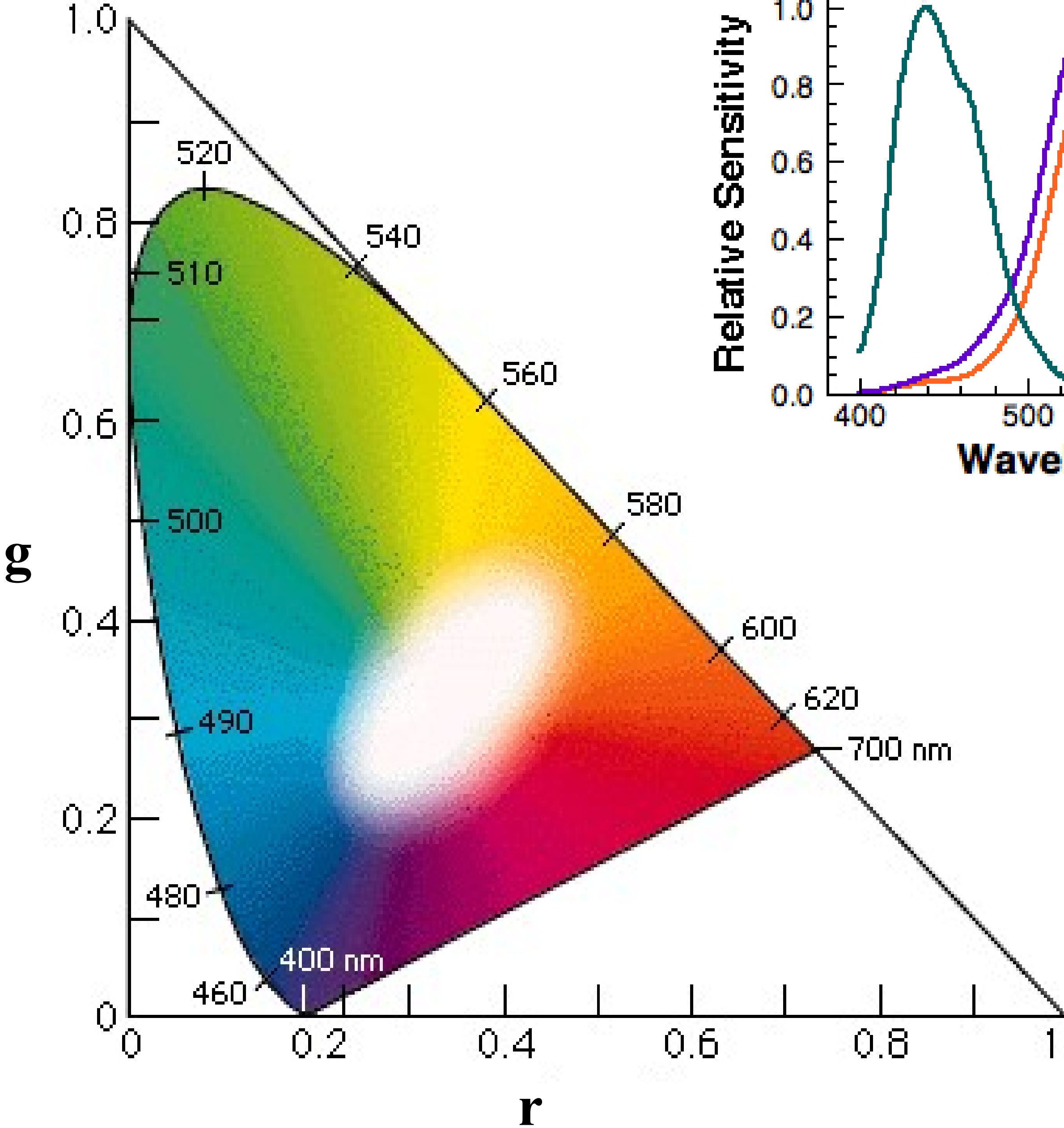
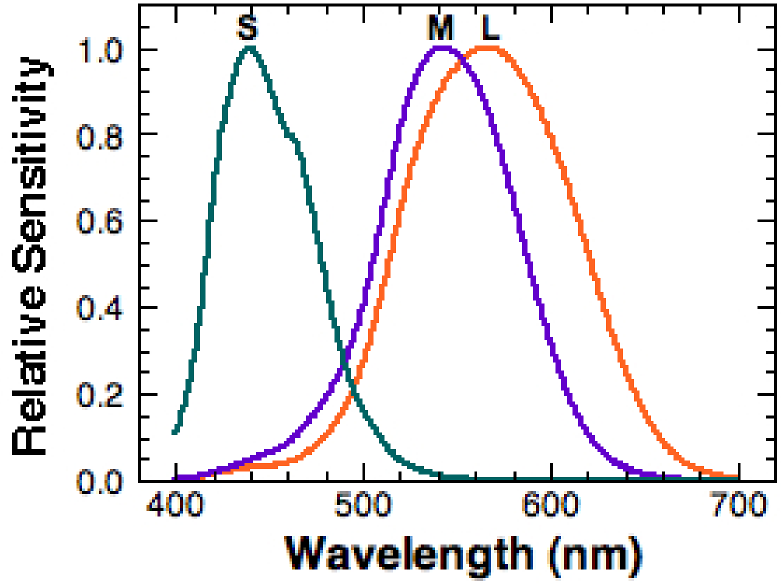


Fig. 35–2. The structure of the retina. (Light enters from below.)





This diagram is based on the values of r, g, and b (where **r** = R/(R+G+B), **g** = G/(R+G+B), and **b** = B/(R+G+B)). Furthermore, because **r** + **g** + **b** = 1, if two values are known, the third can always be calculated and the **b** value is usually omitted. The **r** and **g** values together constitute the **chromaticity** of a sample.

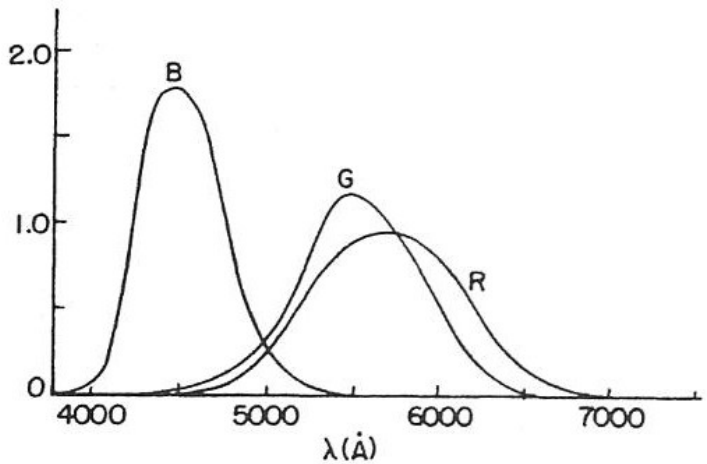


Fig. 35–8. The spectral sensitivity curves of a normal trichromat's receptors.

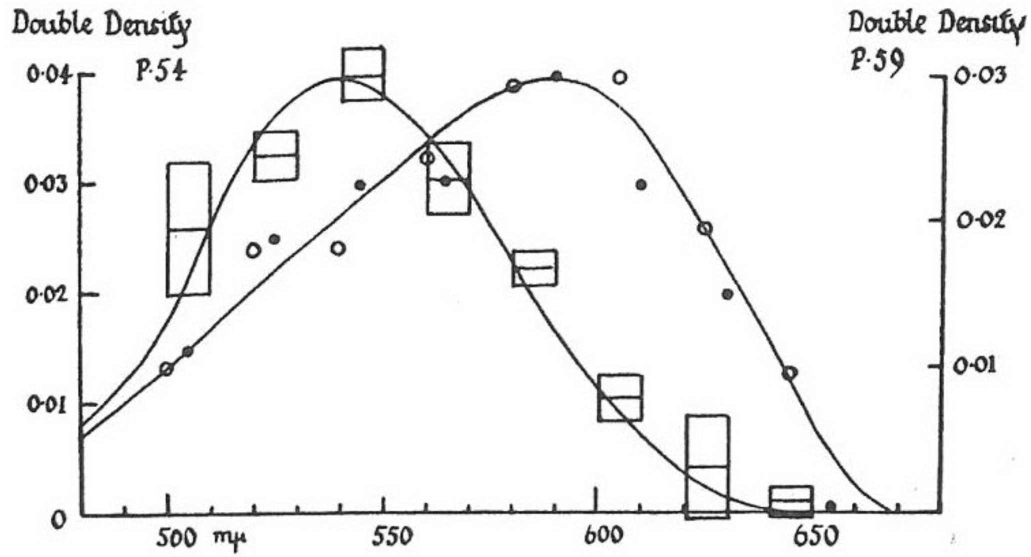
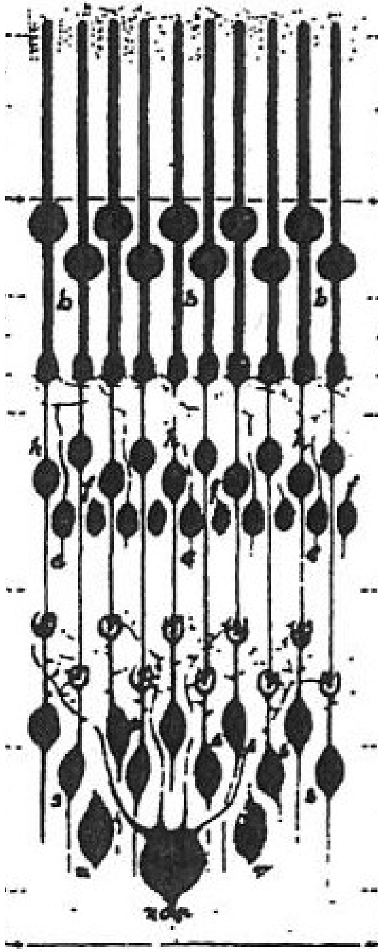
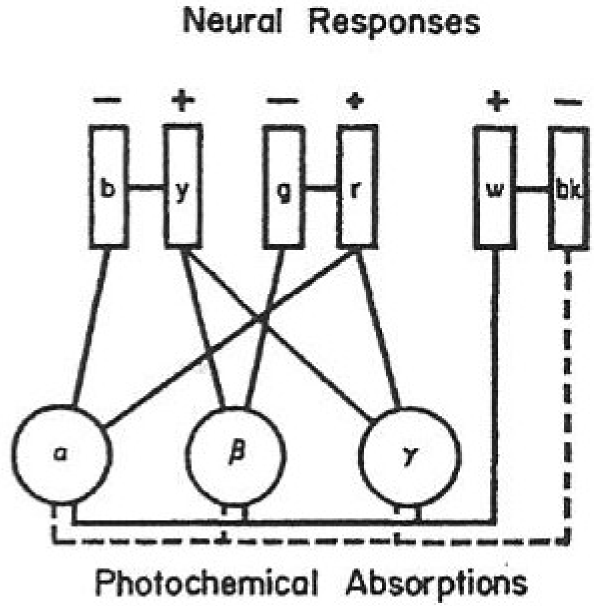


Fig. 35–10. Absorption spectrum of the color pigment of a protanope color-blind eye (squares) and a normal eye (dots).





$$y-b = k_1(\beta+\gamma-2\alpha)$$
$$r-g = k_2(\alpha+\gamma-2\beta)$$
$$w-bk = k_3(\alpha+\gamma+\beta)-k_4(\alpha+\beta+\gamma)$$

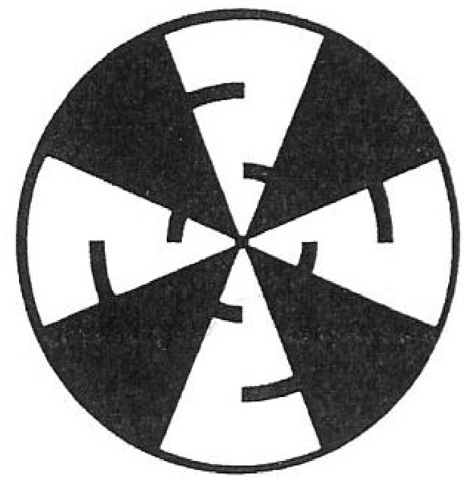


Fig. 36–1. When a disc like the above is spun, colors appear in only one of the two darker "rings." If the spin direction is reversed, the colors appear in the other ring.

Fig. 36–2. Neural connections according to an "opponent" theory of color vision.

Are we **pre-wired**, or we **learn** ?!?

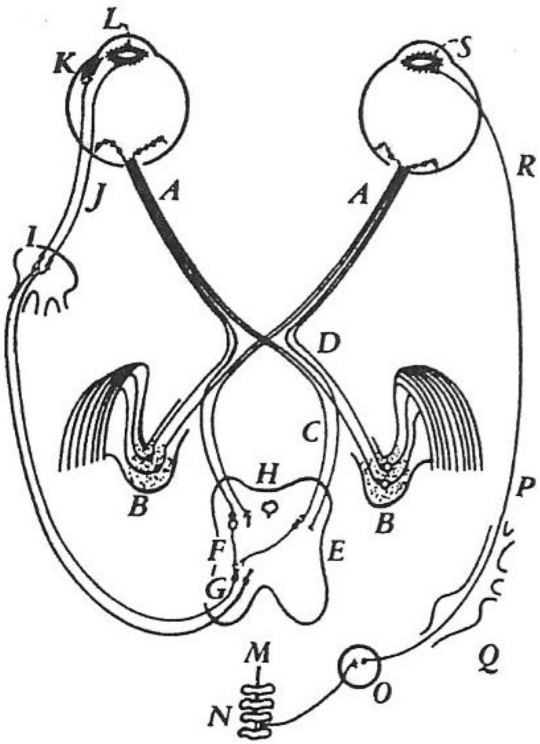


Fig. 36–3. The neural interconnections for the mechanical operation of the eyes.

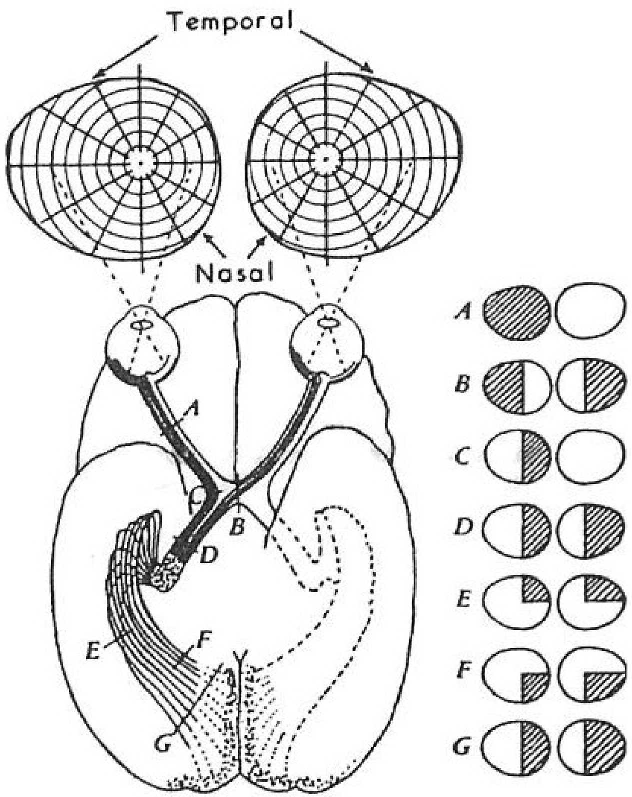
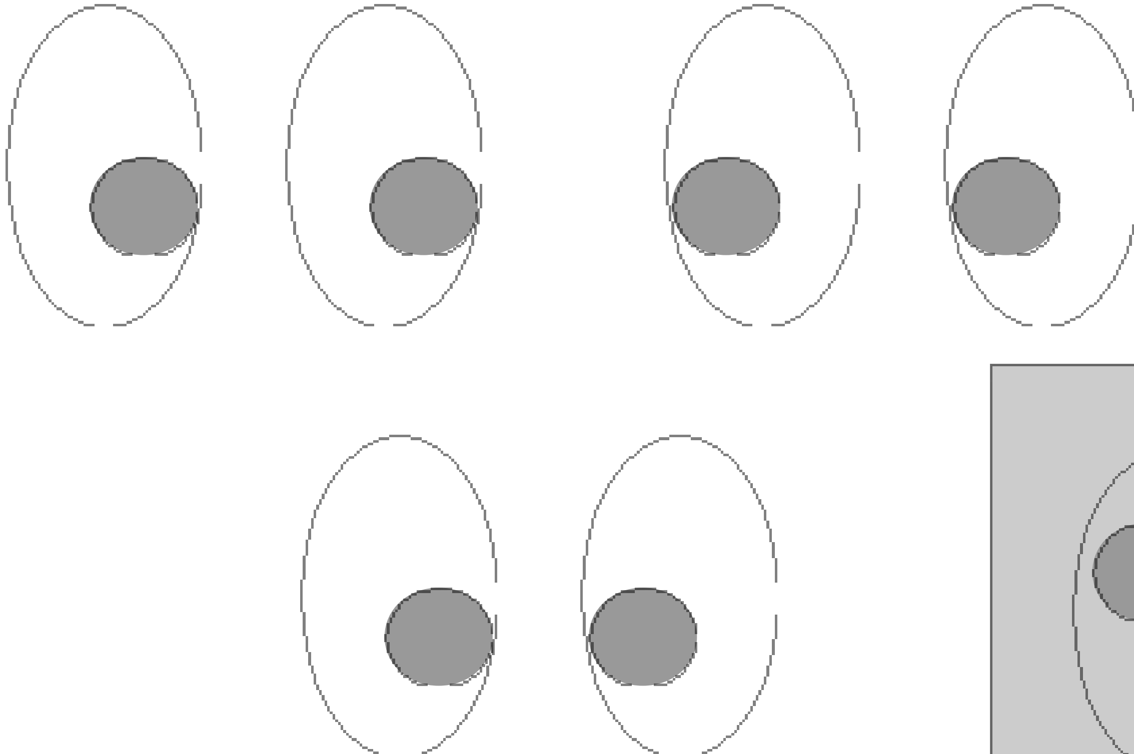
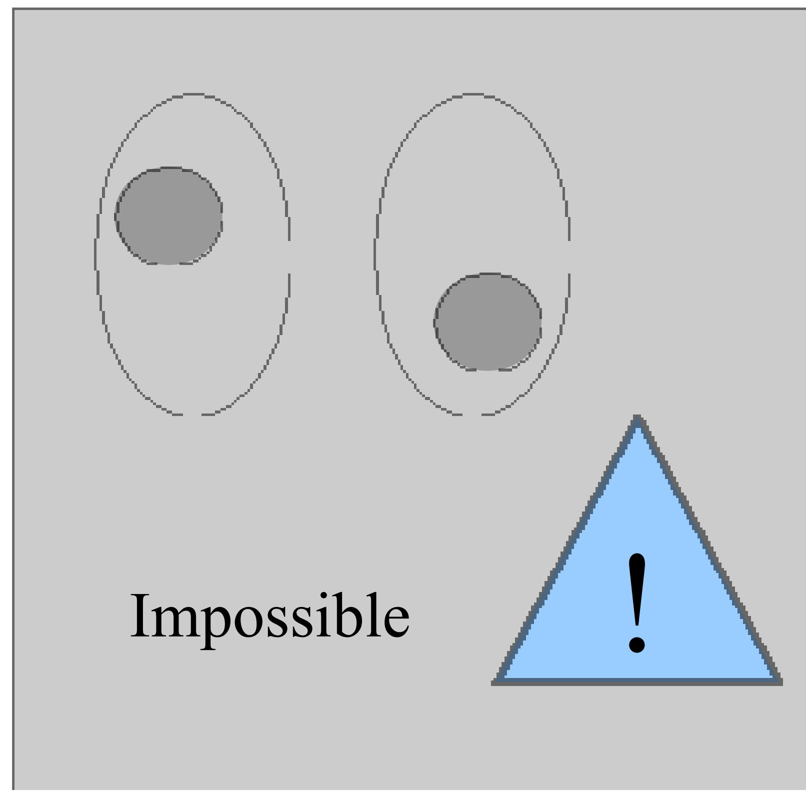


Fig. 36–4. The neural connections from the eyes to the visual cortex.

Possible





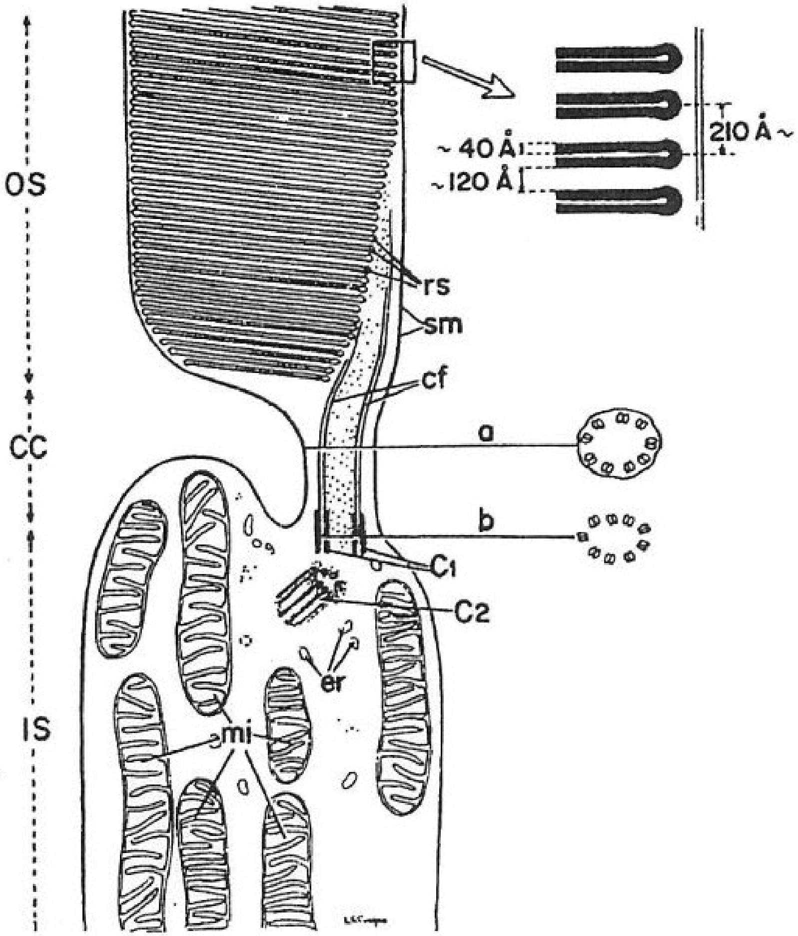


Fig. 36–5. Electron micrograph of a rod cell.

We have to eat this!
(vitamin A)

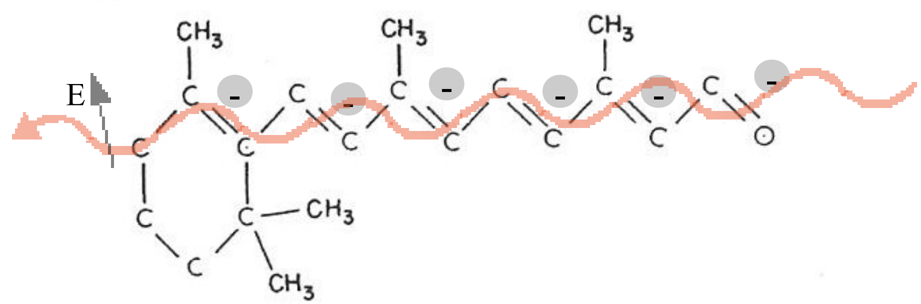
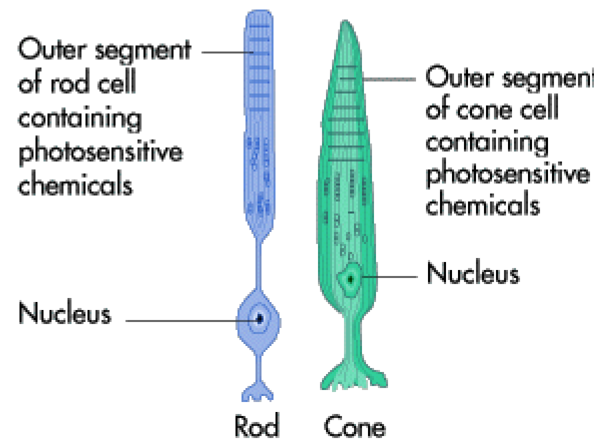


Fig. 36–6. The structure of retinene.



r=3mm
λ=400nm

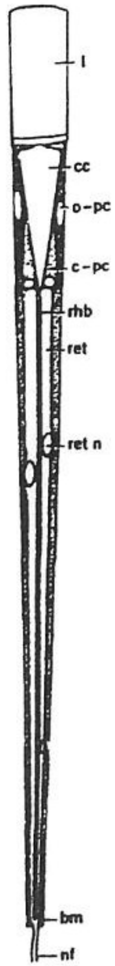


Fig. 36–7. The structure of an ommatidium (a single cell of a compound eye).

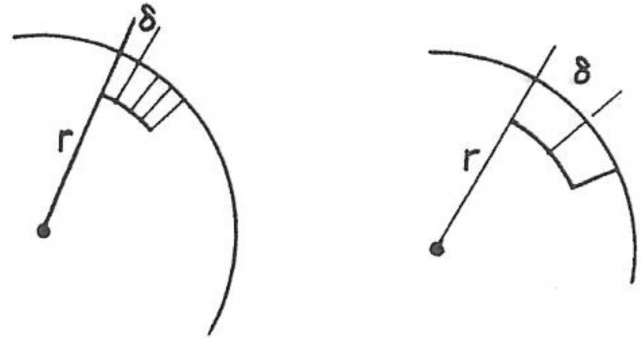


Fig. 36–8. Schematic view of packing of ommatidia in the eye of a bee.

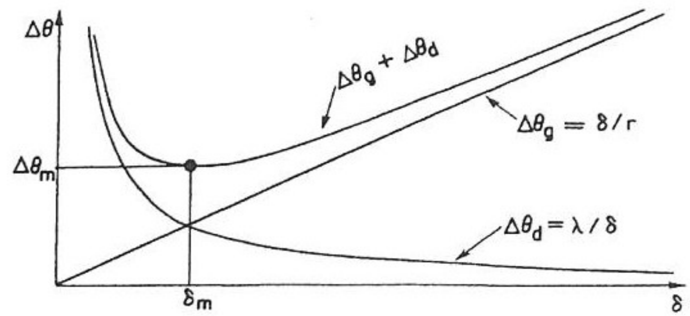


Fig. 36–9. The optimum size for an ommatidium is δ_m.

$$\Delta\theta_g = \delta/r.$$

$$\Delta\theta_d = \lambda/\delta.$$

$$\delta = \sqrt{\lambda r}.$$

$$\frac{d(\Delta\theta_g + \Delta\theta_d)}{d\delta} = 0 = \frac{1}{r} - \frac{\lambda}{\delta^2},$$

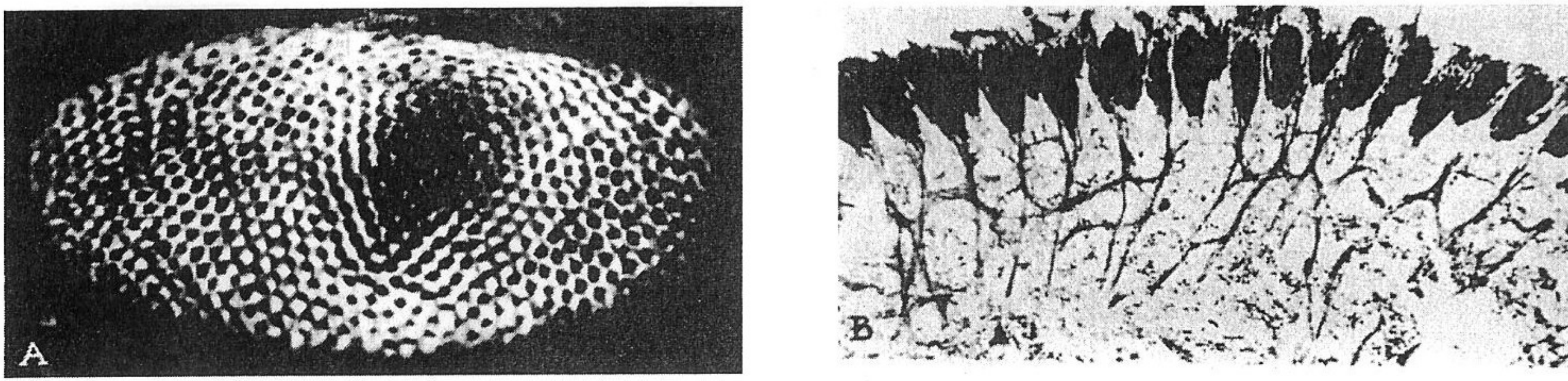
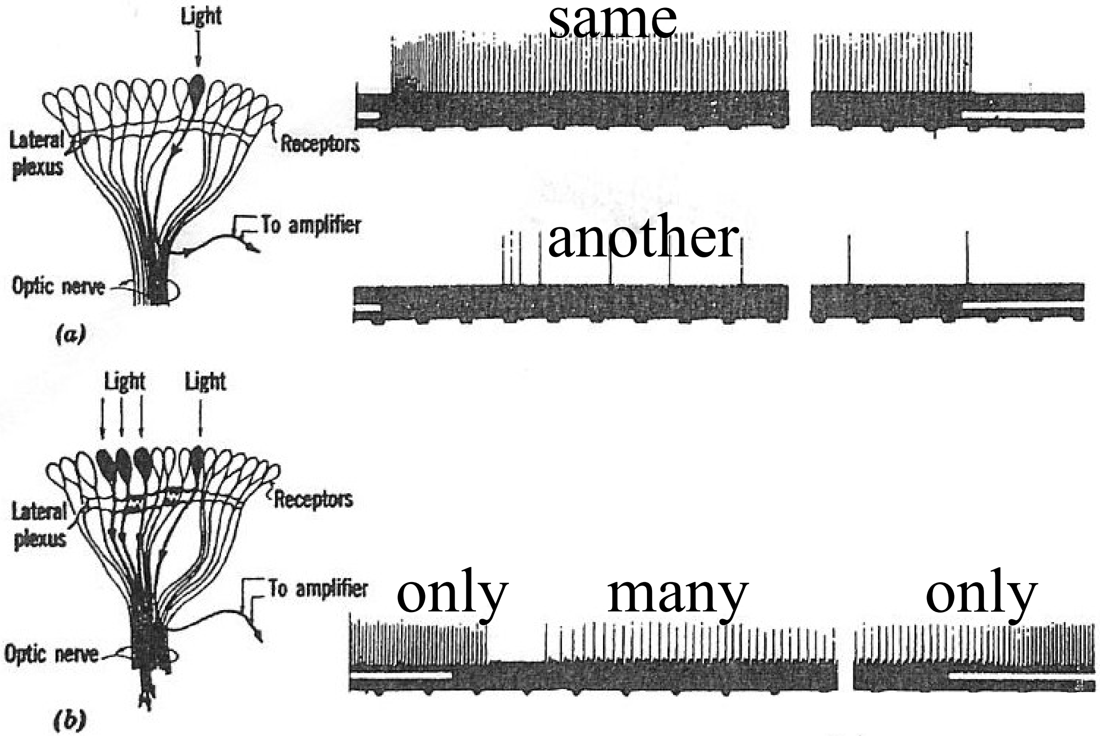


Fig. 36–11. The compound eye of the horseshoe crab. (a) Normal view. (b) Cross section.



Edge enhancement!

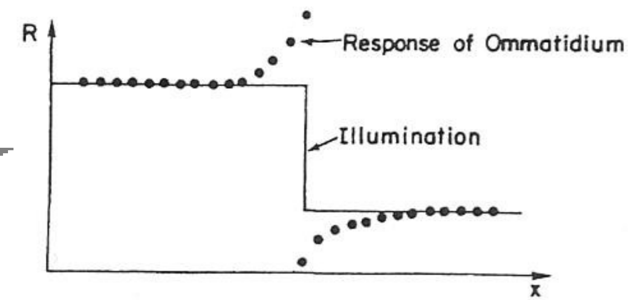


Fig. 36–13. The net response of horseshoe crab ommatidia near a sharp change in illumination.

Types of response in optic nerve fibers of a frog

Type	Speed	Angular field
1. Sustained edge detection (nonerasable)	0.2–0.5 m/sec	1°
2. Convex edge detection (erasable)	0.5 m/sec	2°–3°
3. Changing contrast detection	1–2 m/sec	7°–10°
4. Dimming detection	Up to $\frac{1}{2}$ m/sec	Up to 15°
5. Darkness detection	?	Very large

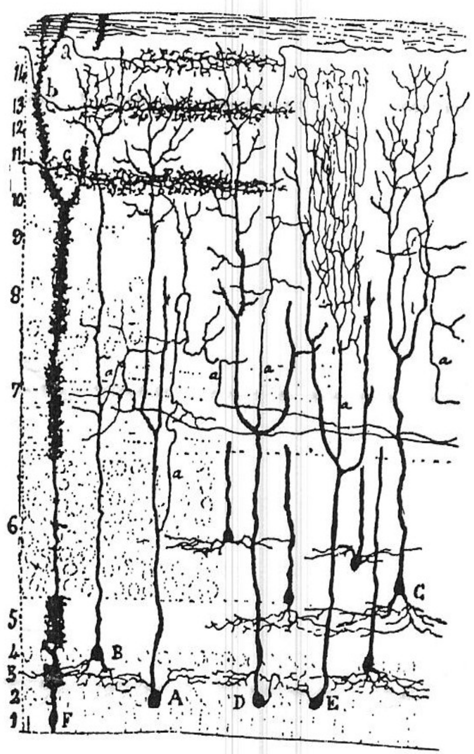
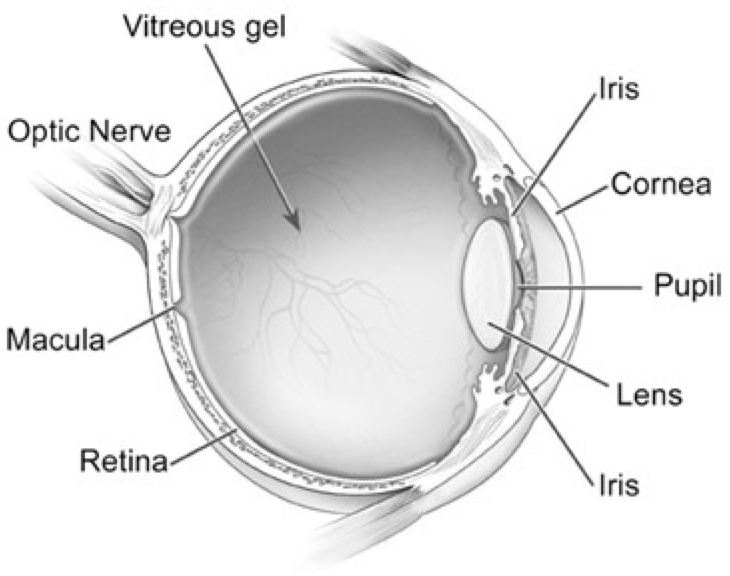
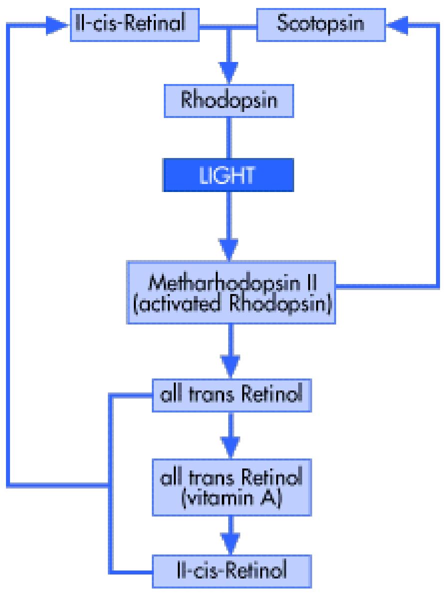
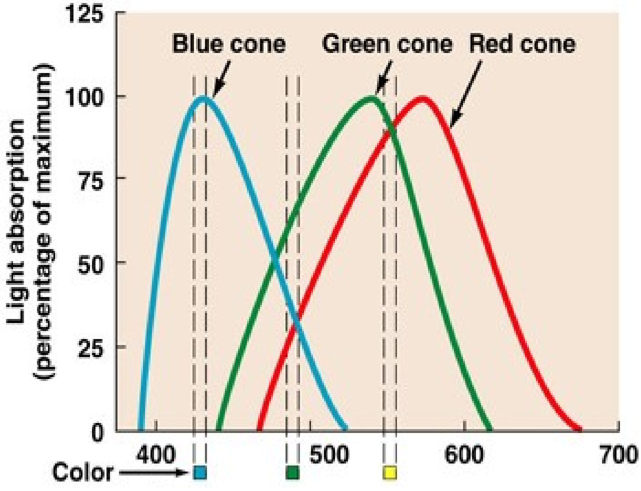


Fig. 36–14. The tectum of a frog.







“RGB”の色で全部の色を作る。この事は光の特性ではない、人間の目の特性です（！）

人間は 「Trichromatic Vision」

動物の世界の中に「Tetrachromacy」「Pentachromats」などがあります