

Bases Físicas para a Visão

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Novembro de 2009

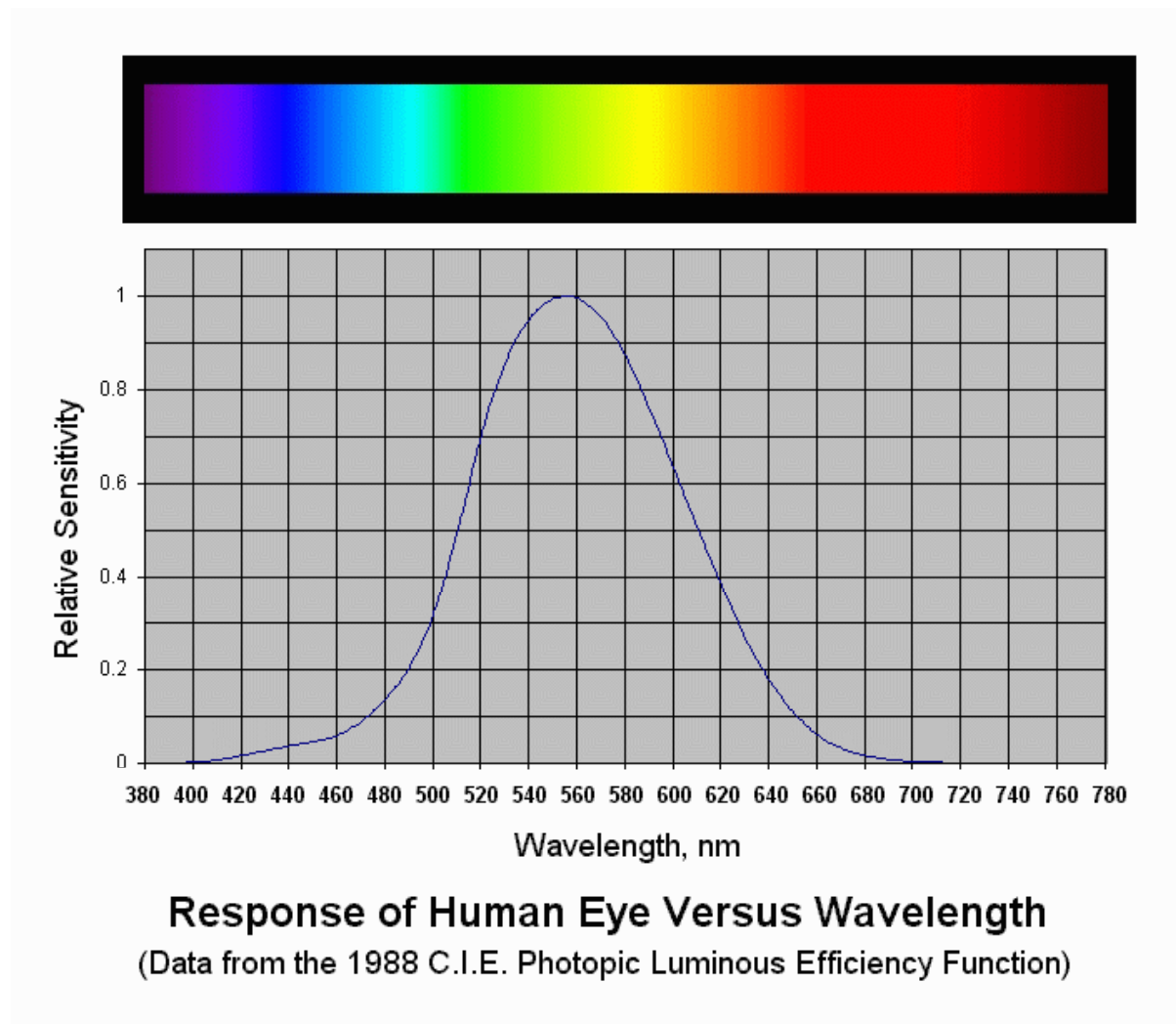


Mestrado Profissional em Ensino de Física



George Wald (1906-1997) dividiu com outros dois cientistas o Prêmio Nobel de Medicina em 1967 por suas descobertas sobre os processos fisiológicos e químicos da visão. Descobriu que a vitamina A é um ingrediente vital para os pigmentos na retina.

A **curva fototrópica** (curva de resposta à luz) para o olho humano, apresenta um pico em 550 nm, correspondente à região verde do espectro visível.



Some paradoxes, errors, and resolutions concerning the spectral optimization of human vision

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Am. J. Phys. 67 (11), November 1999

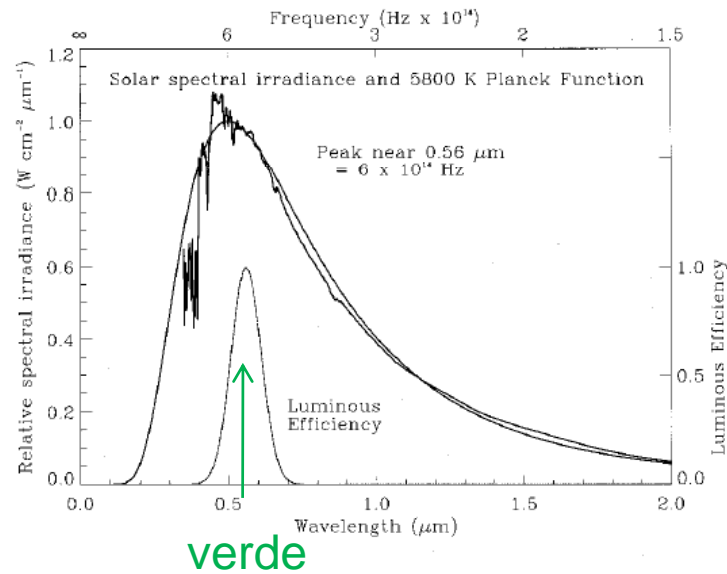


Fig. 1. The solar spectrum plotted in wavelength units peaks near 500 nm. Also shown is an approximate fit of a 5800 K Planck function that has been scaled to match the solar spectrum. This shows that the solar spectrum is roughly Planckian in the optical part of the spectrum. The luminous efficiency of the eye peaks at 560 nm. All three curves appear to peak near 500–560 nm, a wavelength region generally perceived as being green.

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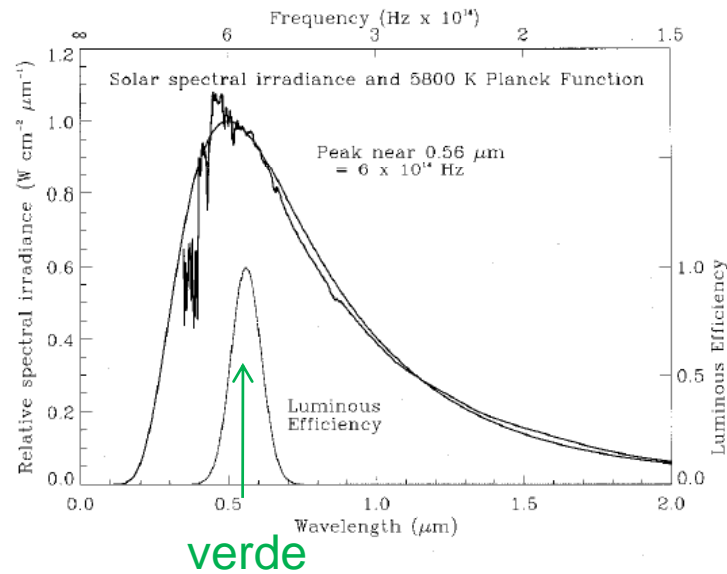


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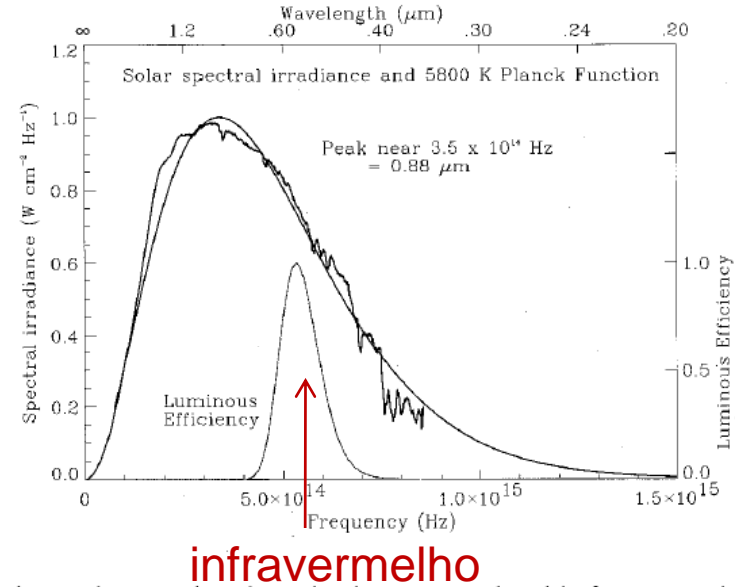
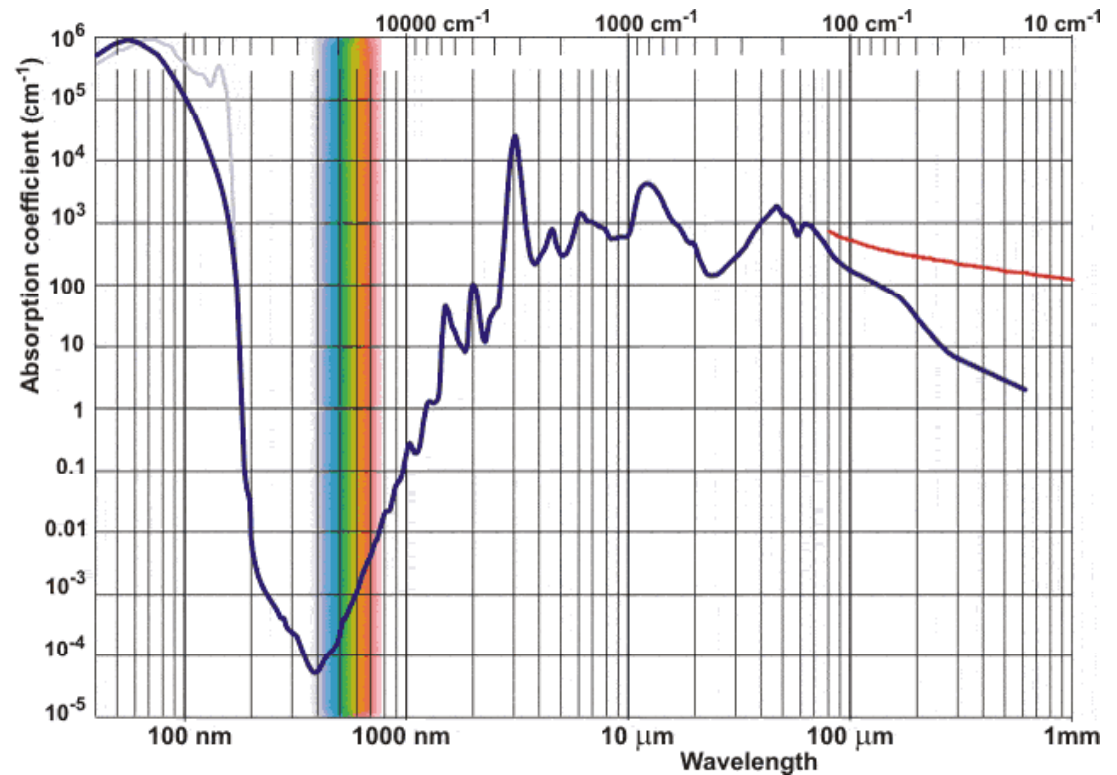
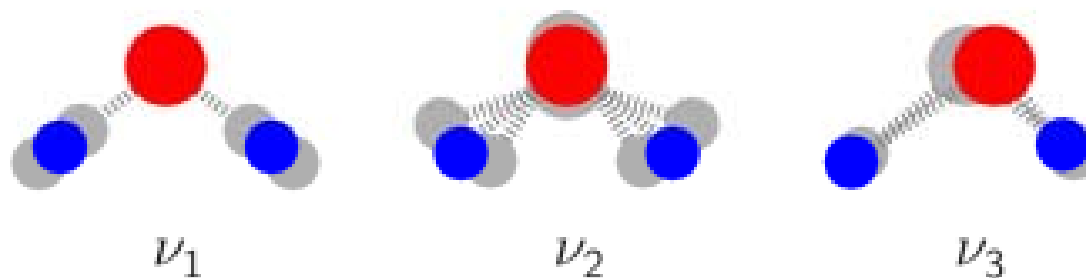


Fig. 2. The same data shown in Fig. 1 except plotted in frequency units. Here the sun and Planck functions peak near the wavelength equivalent to 880 nm in the near-infrared while the luminous efficiency curve still peaks at 560 nm. The solar irradiance and Planck function transform differently than the luminous efficiency.

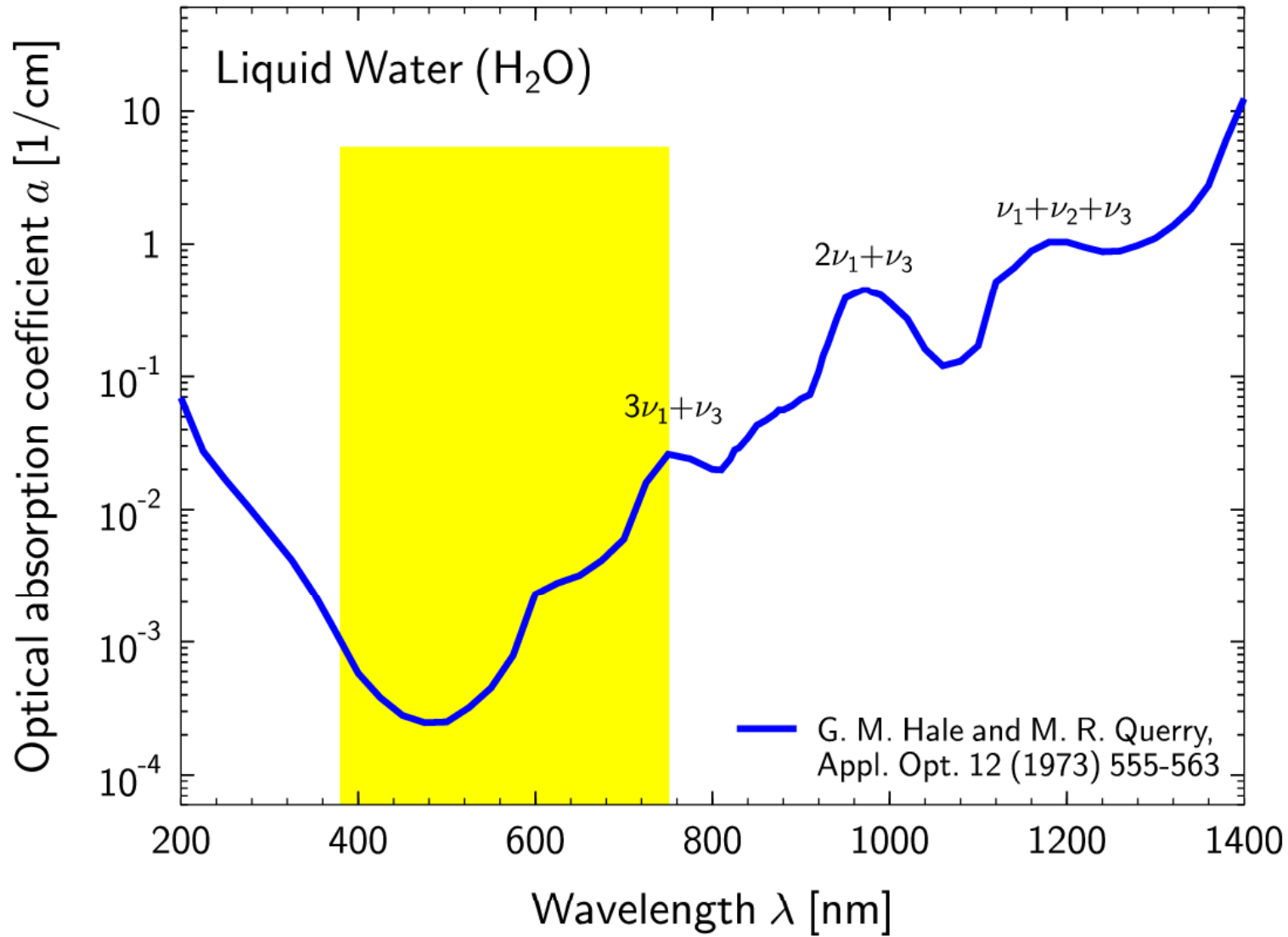
As cores características da maior parte das substâncias têm origem na **absorção seletiva**. A água, tem uma tonalidade ligeiramente azul-esverdeada devido à absorção de luz vermelha, isto é, as moléculas têm uma grande zona de absorção no infravermelho, que se estende um pouco ao visível.

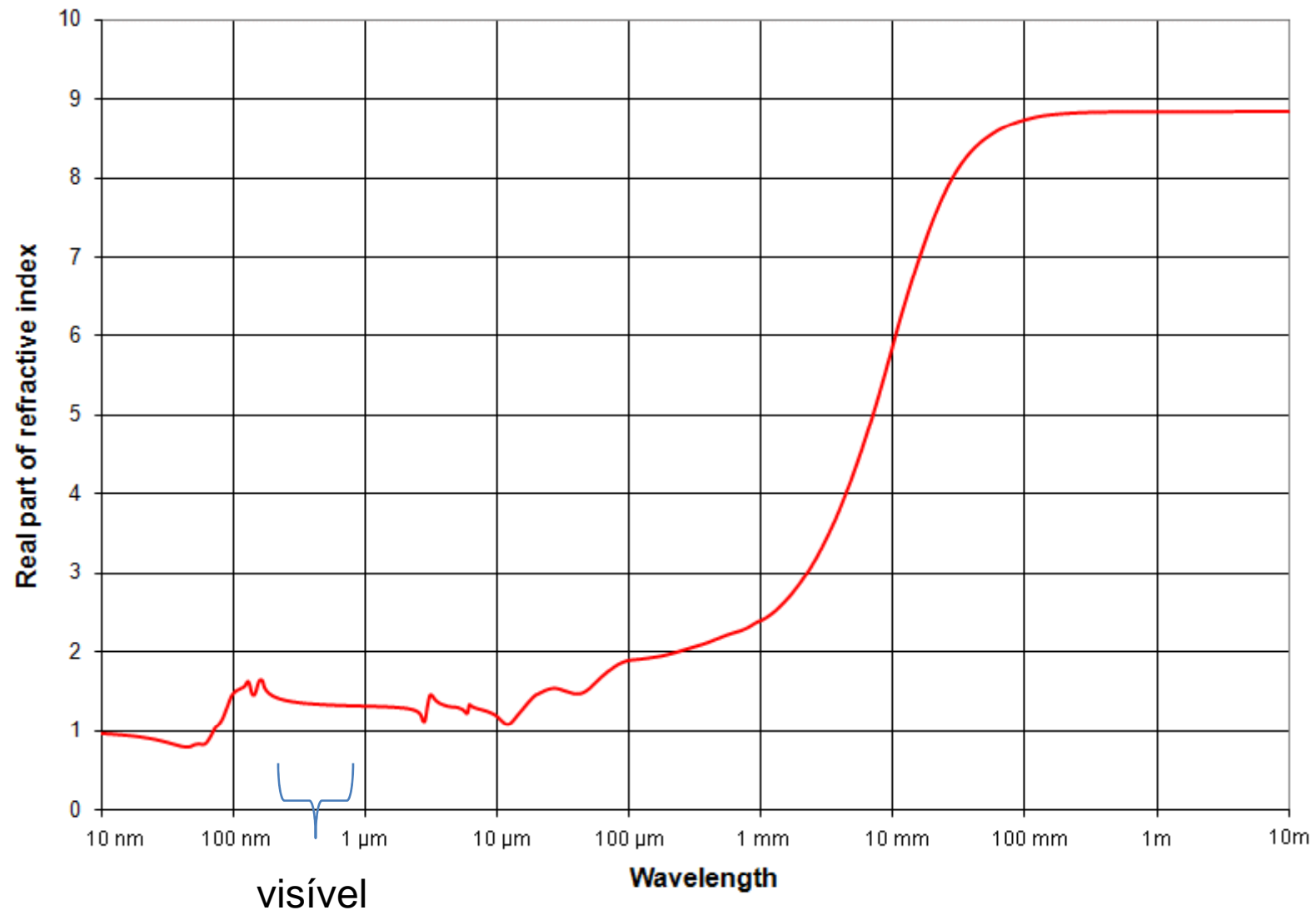


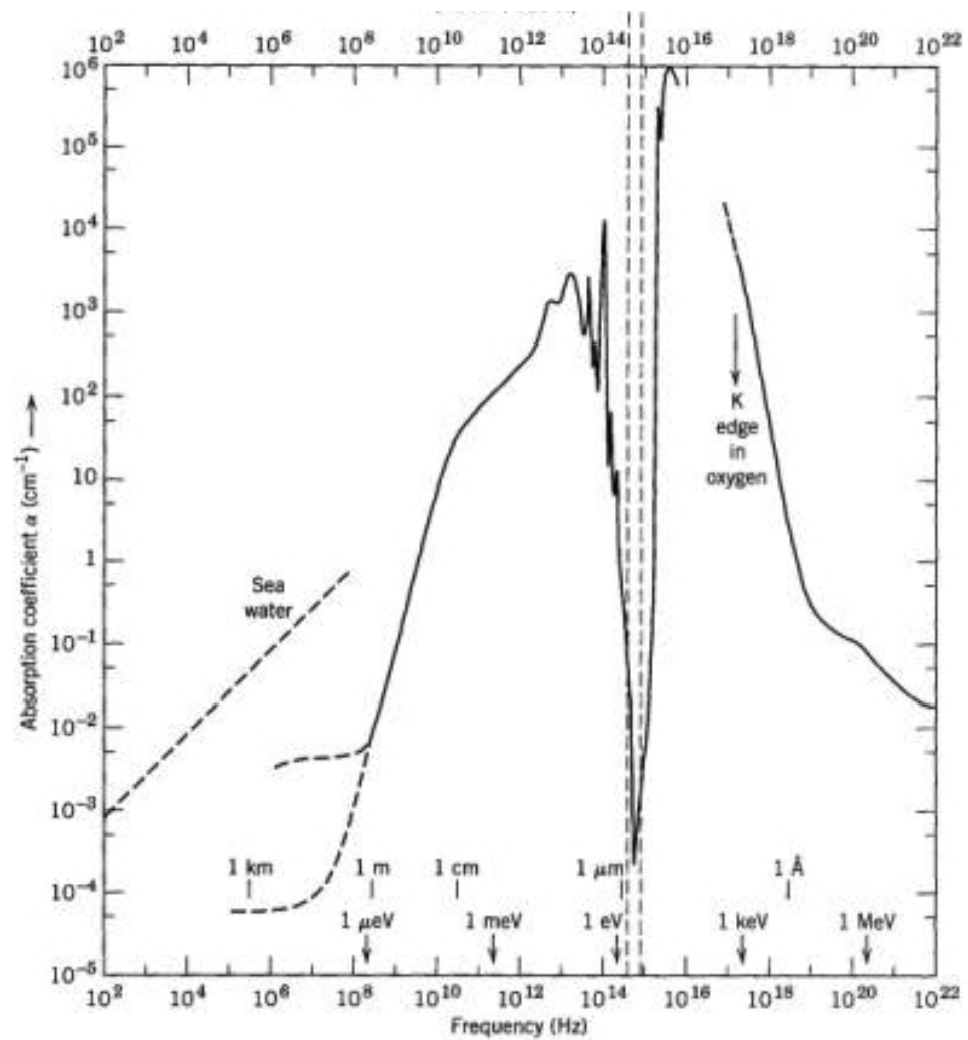
A água vibra



Optical absorption coefficient of water (<http://omlc.ogi.edu/spectra/water/data/hale73.dat>)

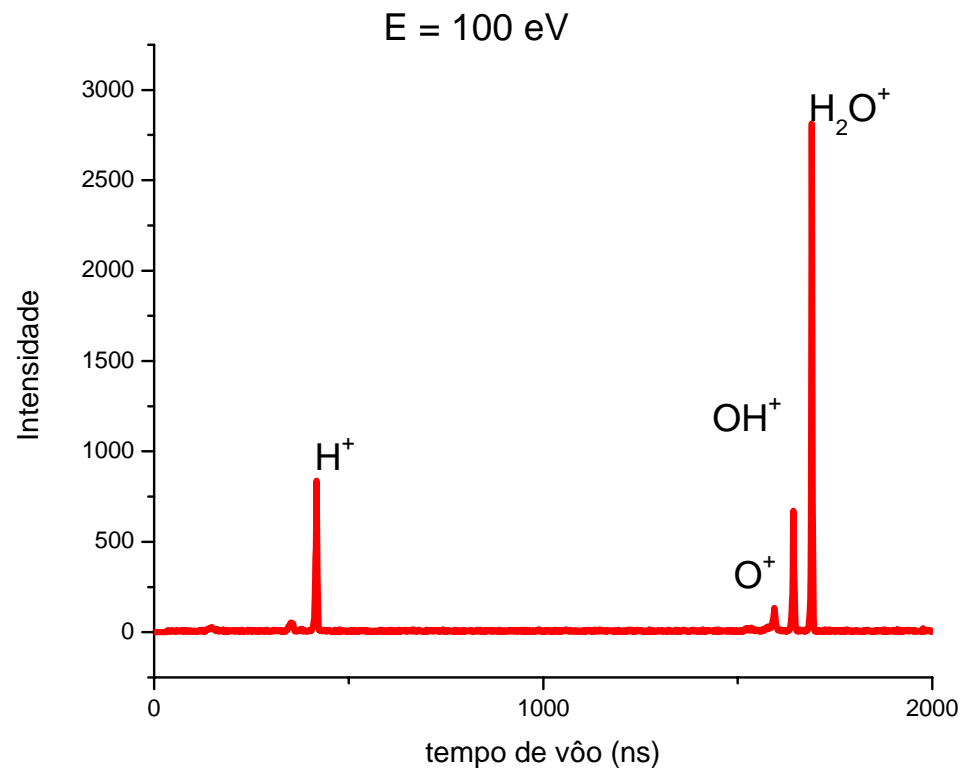


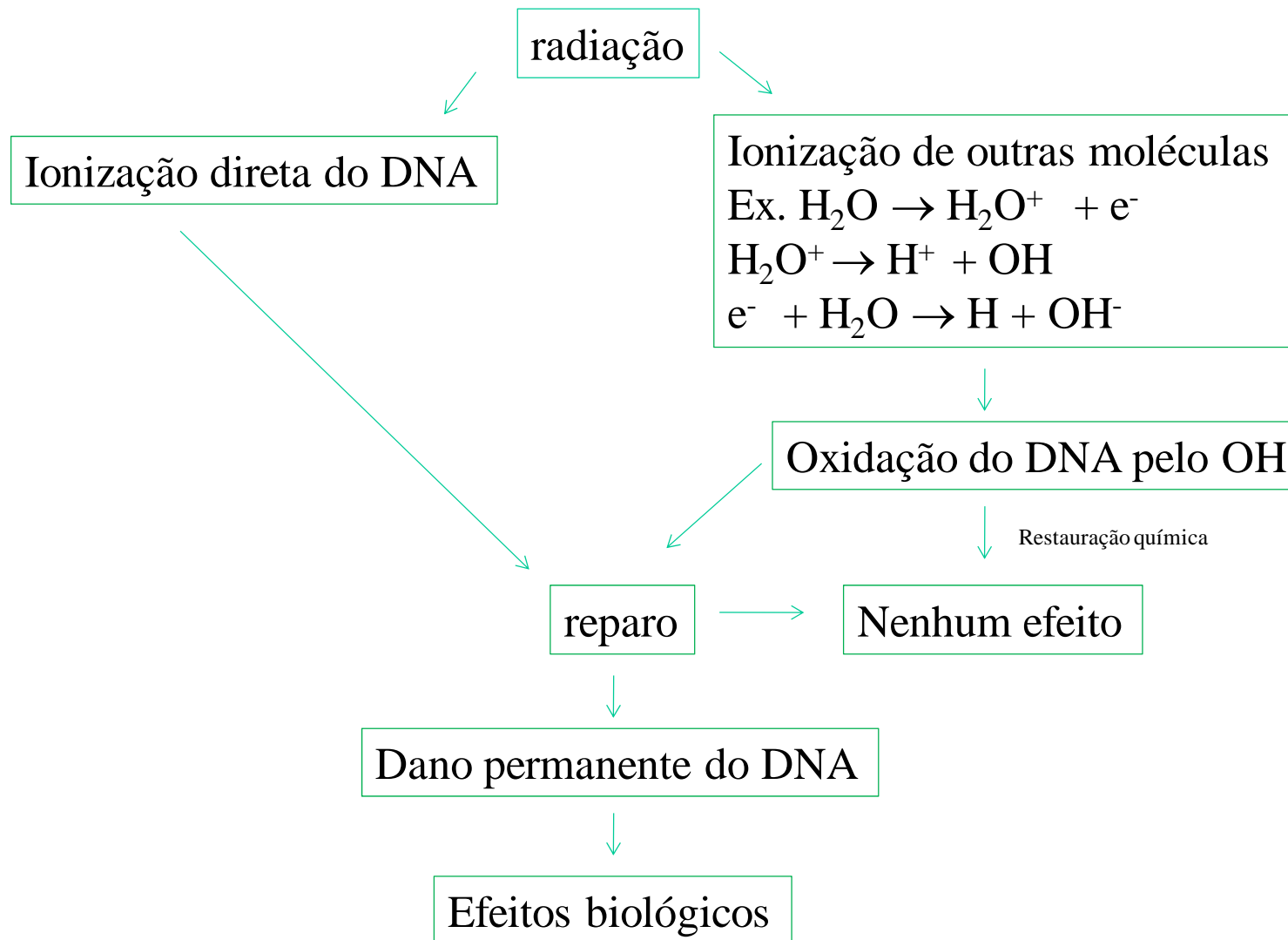






LNLS – Campinas (SP)





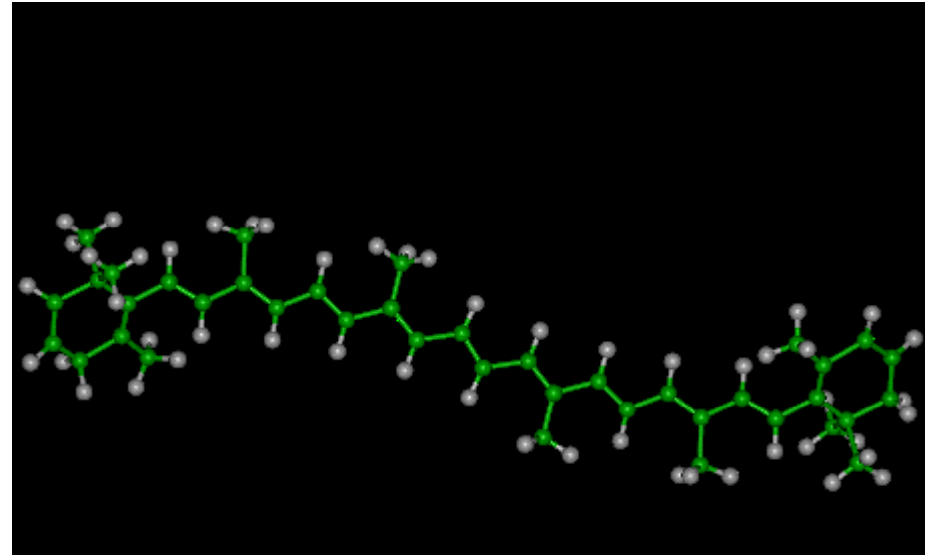
Exemplos de absorção seletiva:



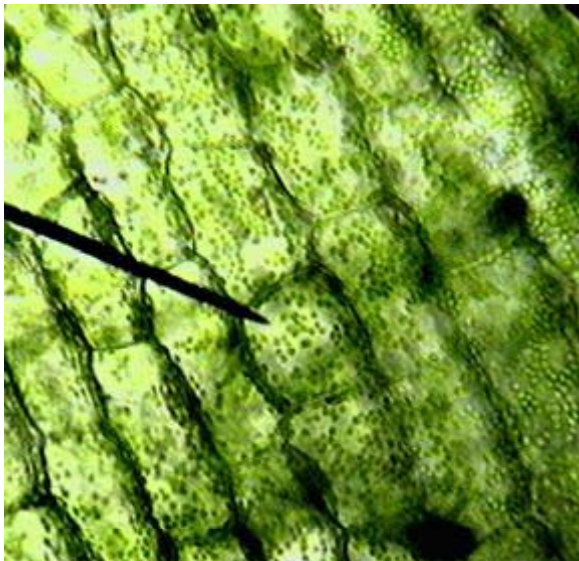
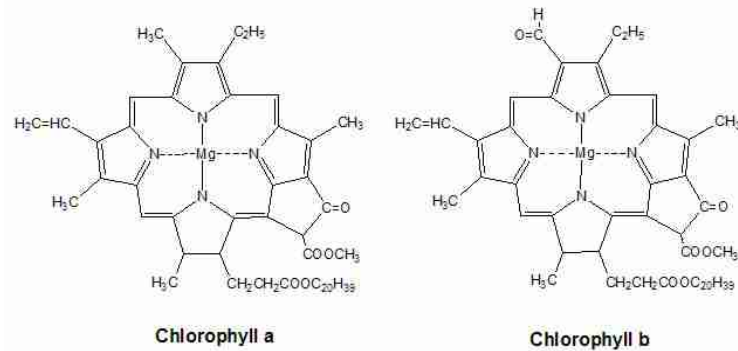
As moléculas dos pigmentos cromáticos têm ressonâncias no visível (de 1,6 a 3,2 eV)

Algumas substâncias, quer naturais, quer sintéticas, possuem longas cadeias de moléculas constituídas por ligações alternadamente simples e duplas como a molécula do caroteno ($C_{40}H_{56}$)

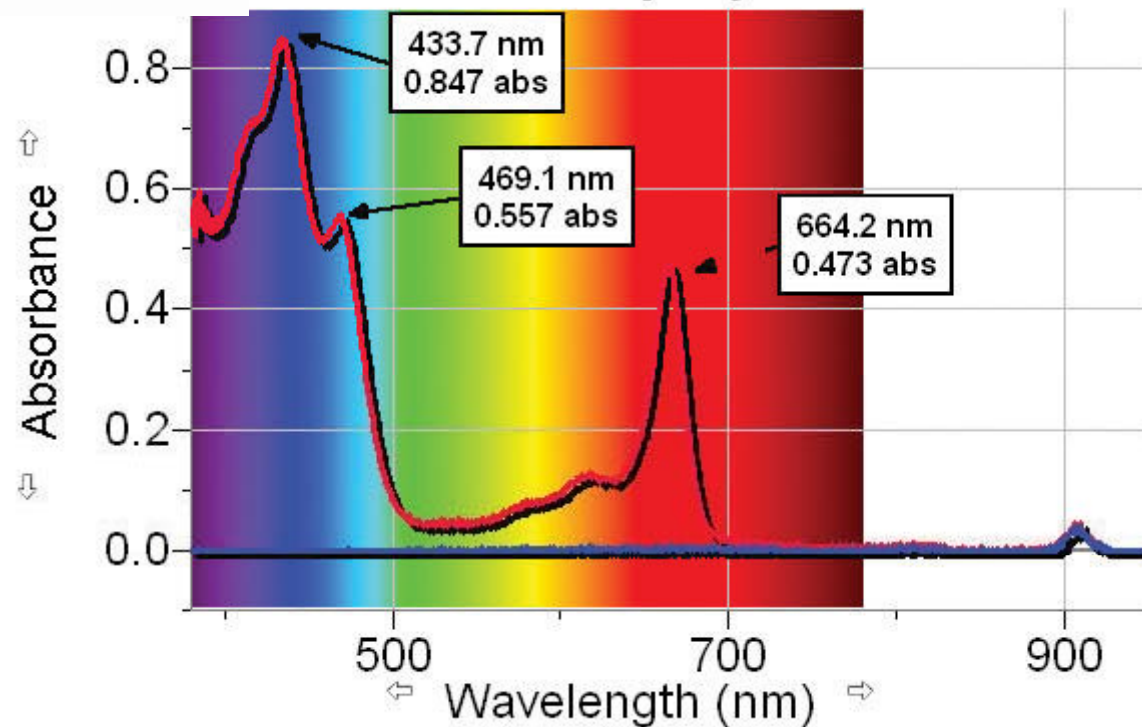
Os carotenóides têm cores que variam desde o amarelo ao vermelho .



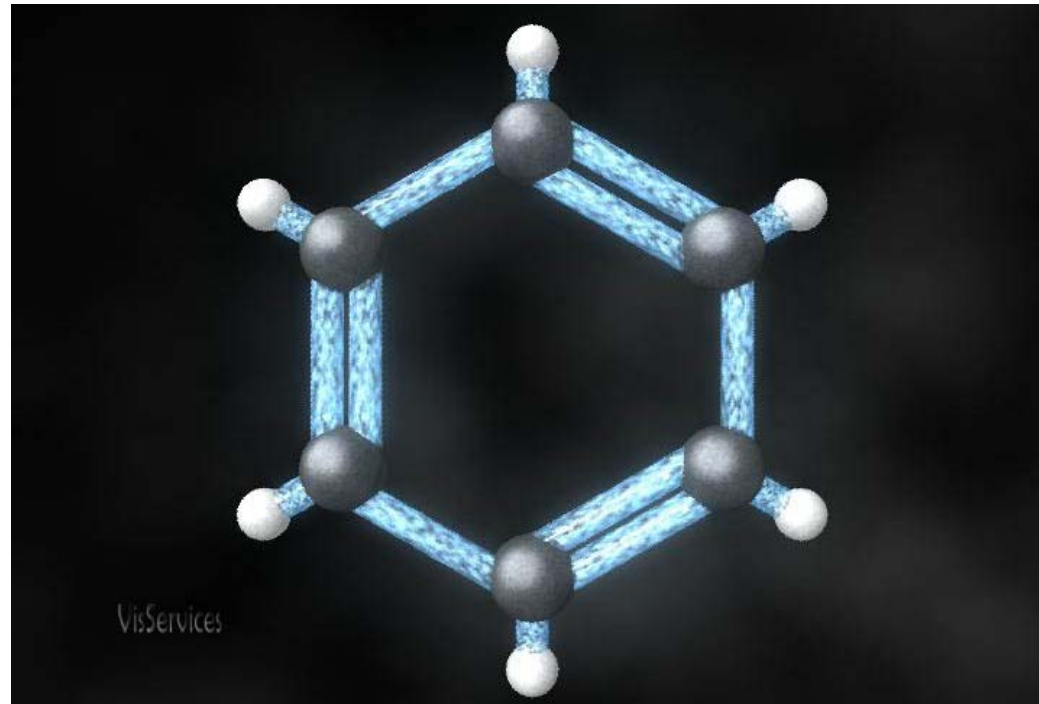
As clorofilas constituem outro grupo de pigmentos naturais familiares, mas nestes uma parte da longa cadeia fecha-se em anel.



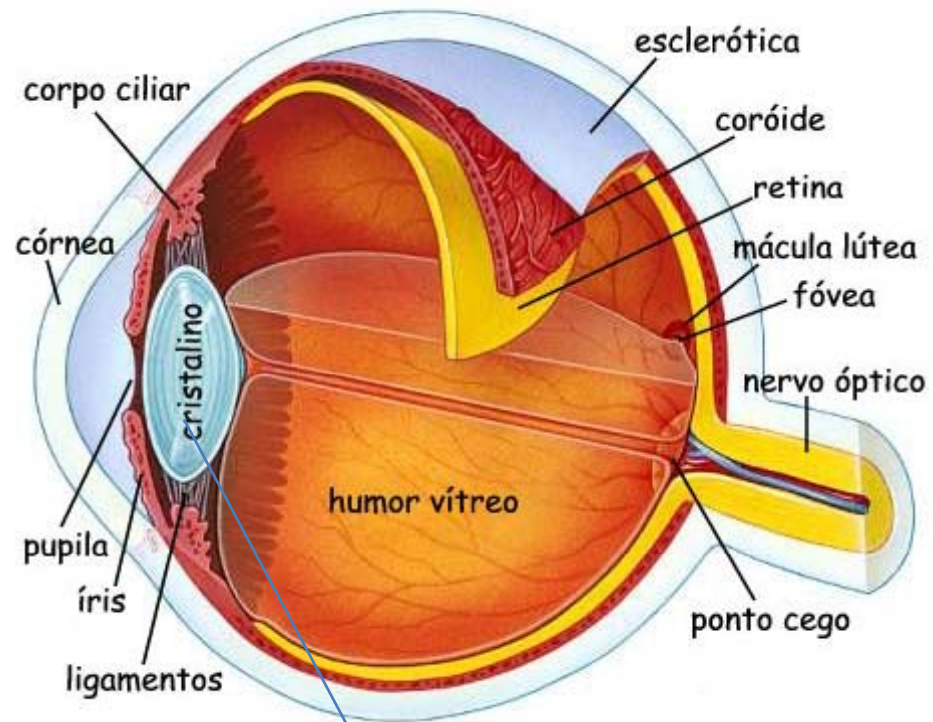
Chlorophyll



Os carotenóides, como as clorofilas, contêm um número de elétrons particularmente móveis conhecidos como **elétrons pi**: não estão ligados a nenhum átomo em particular e podem circular ao longo da cadeia ou anel molecular. Na terminologia da mecânica quântica, fala-se de estados de grande comprimento de onda, baixa frequência e, portanto, de baixa energia (1,6 -3,2 eV- no visível)

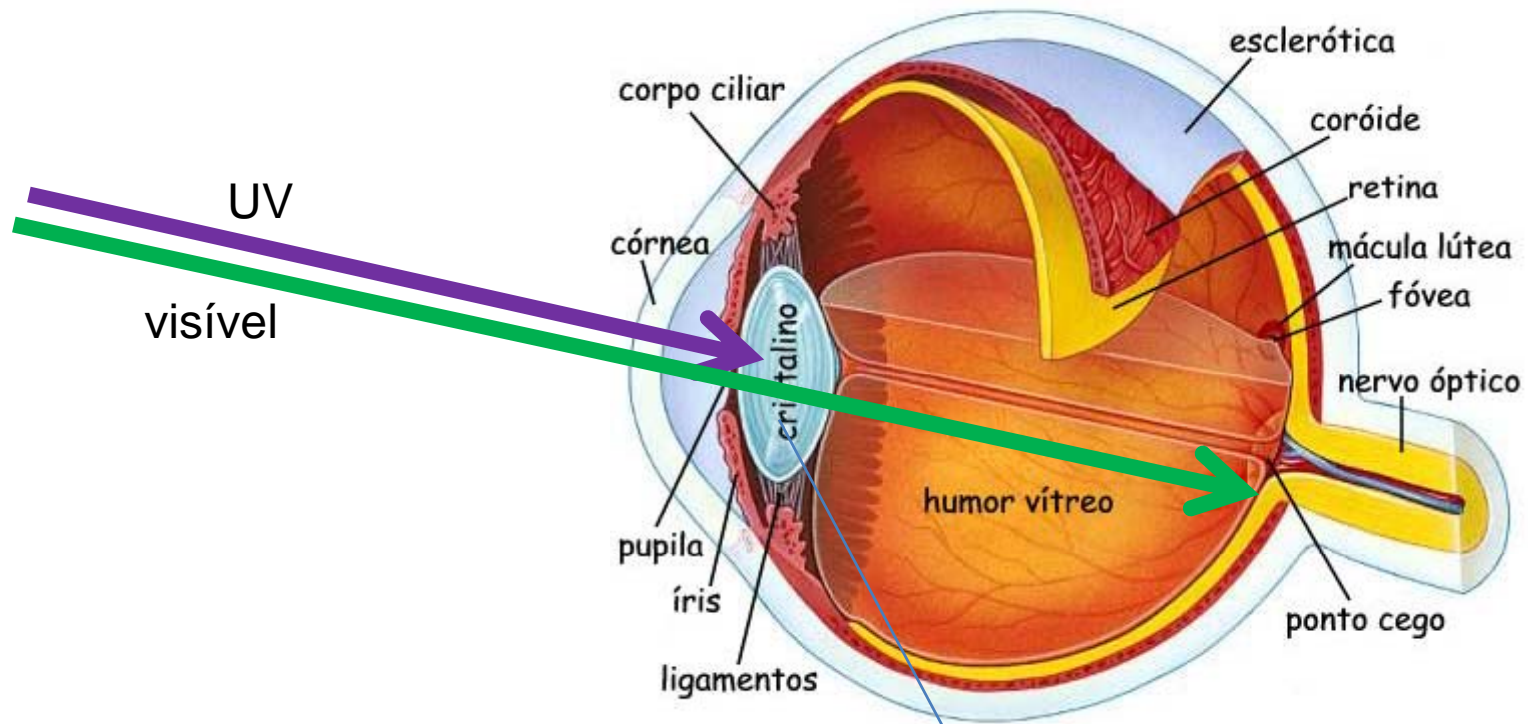


O olho humano



Absorve UV diferentemente,
dependendo da idade

O olho humano

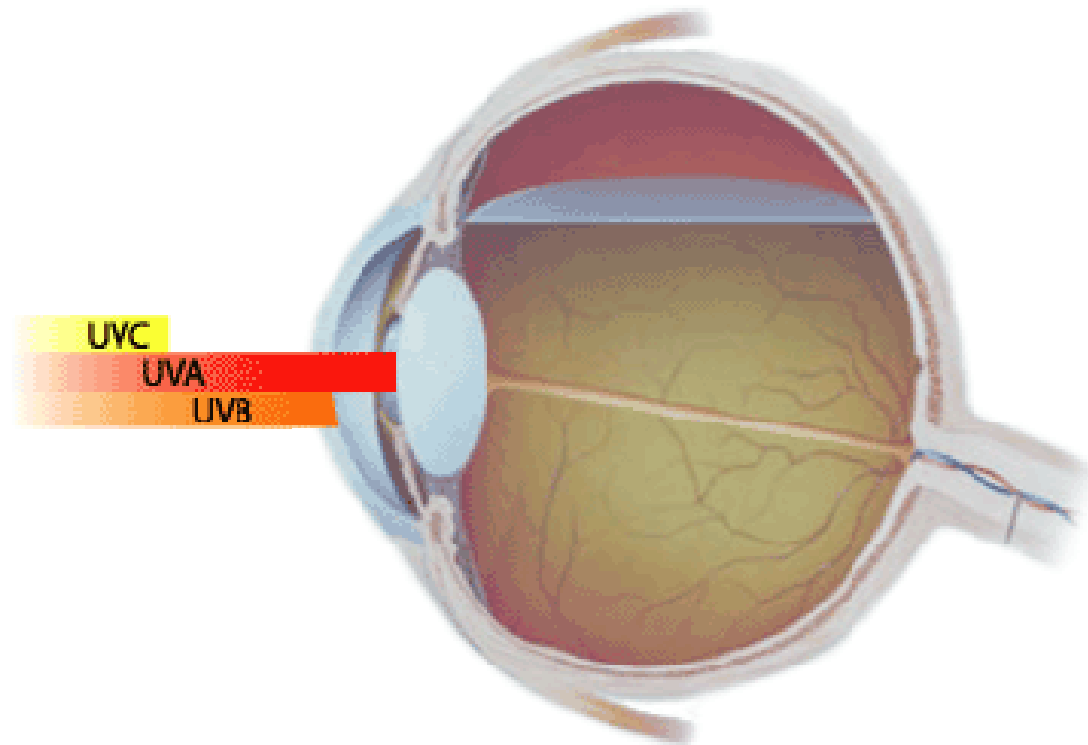


Absorve UV diferentemente,
dependendo da idade

UVC $\rightarrow \lambda < 280 \text{ nm}$ (grande absorção no cristalino)

UVB $\rightarrow 280 \text{ nm} < \lambda < 315 \text{ nm}$ (responsável pela queimadura solar)

UVA $\rightarrow 315 \text{ nm} < \lambda < 380 \text{ nm}$



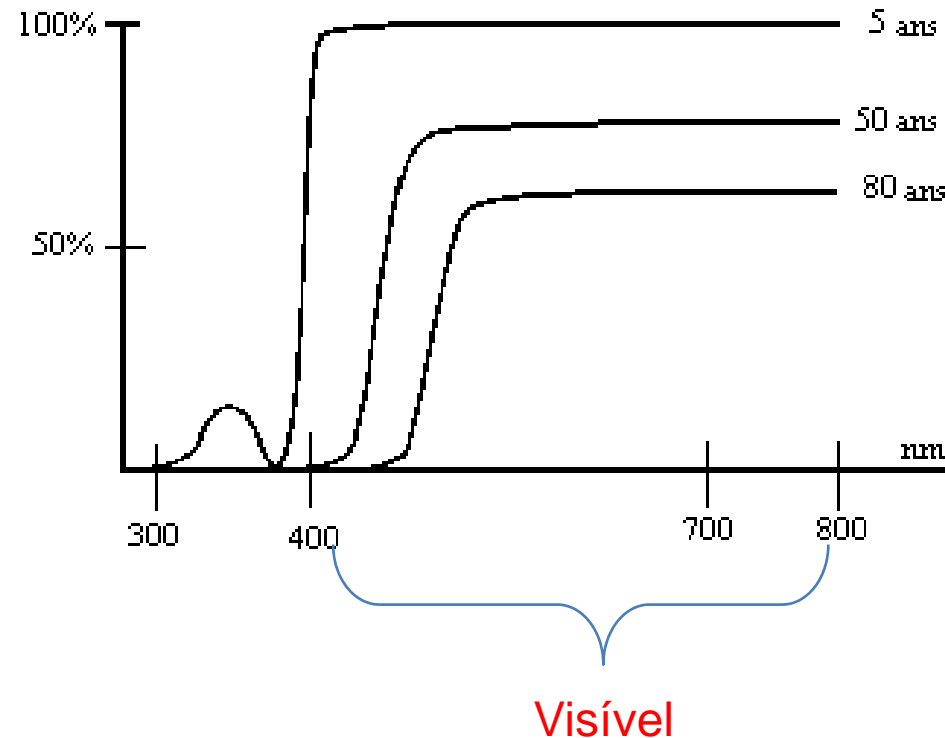
Transmissão de UV através do cristalino

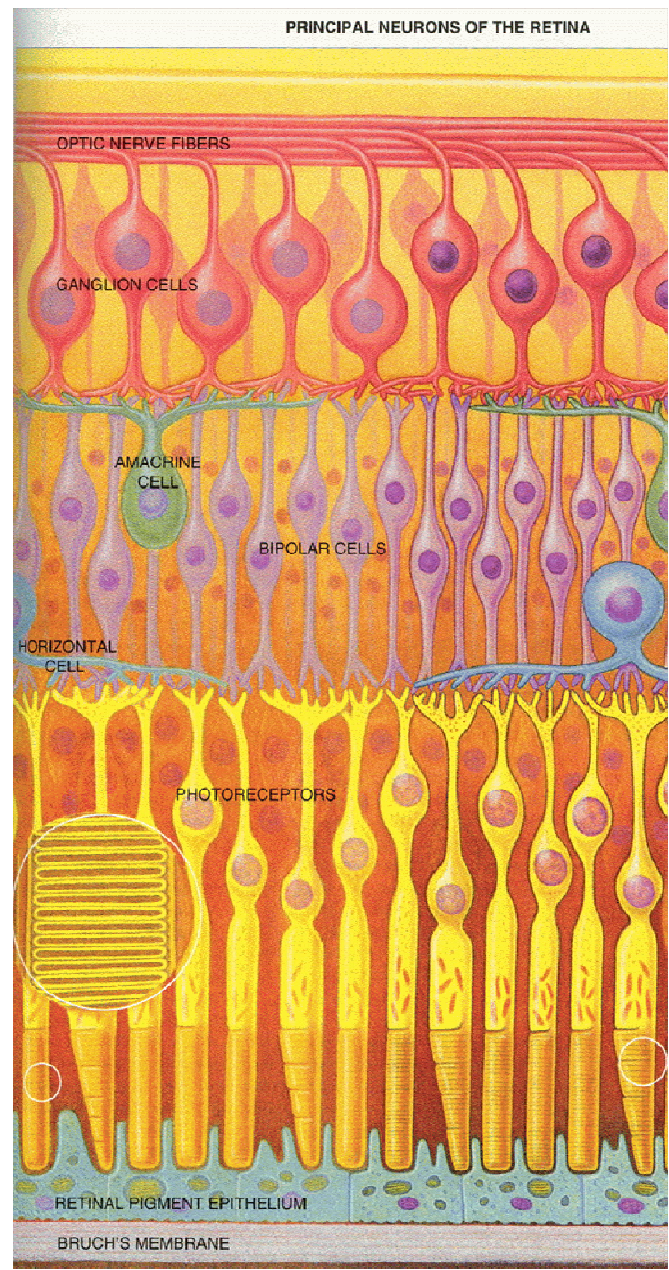
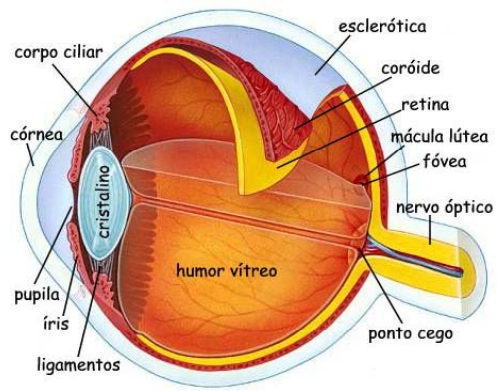
Em crianças e adultos jovens, temos a janela de UV, onde quase todo o UV abaixo de 295 nm é absorvido na retina. O cristalino absorve mais com a idade.

A operação de catarata, (extração do cristalino), gera uma invasão brutal de UV na retina.

Os efeitos são acumulativos !

O aumento de 1 % da intensidade de UV leva a um aumento de 0,6 % de gerar catarata .





luz

Células fotorreceptoras da retina

Figure 2

Rod Cell

Luz incidente

Cone Cell

Disks Containing Rhodopsin

Bastonetes e cones utilizam pigmentos sensíveis na captação da luz. Cada pigmento é formado por uma proteína (opsina) e um cromóforo (retineno ou retinal, opsina), variantes da vitamina A.

Fotopigmentos:

Bastonetes → rodopsina

Cones → iodopsina

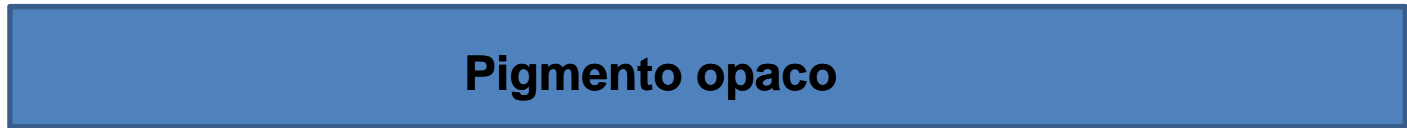
Nucleus

$n = 1,34$

$n = 1,36$

Synaptic Ending

Pigmento opaco



Science, vol. 211, 942-944 (1981)

A visão é iniciada quando um fóton é absorvido pela proteína rodopsina. Após a excitação ótica, a rodopsina sofre uma isomerização.

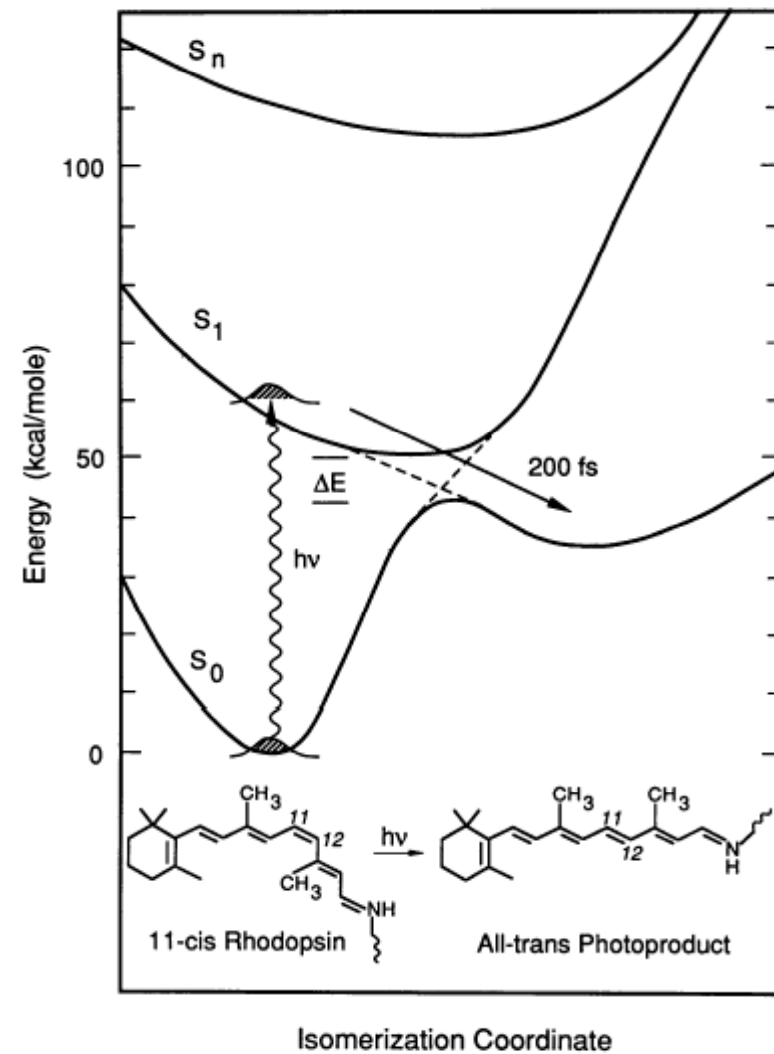
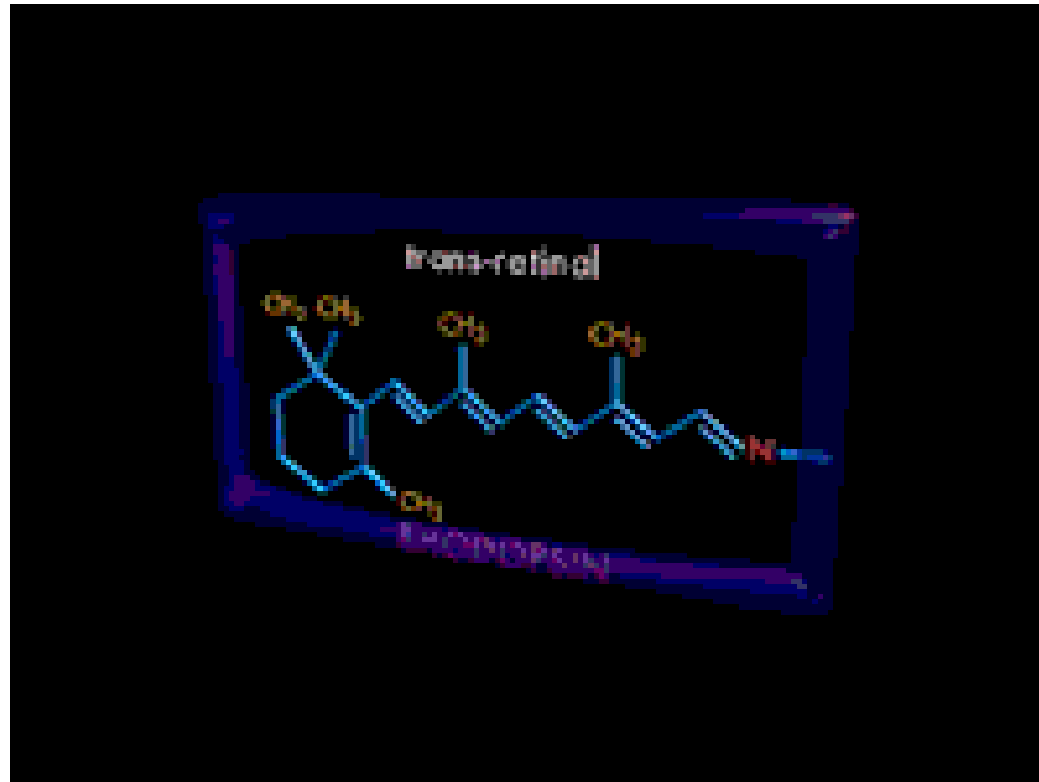
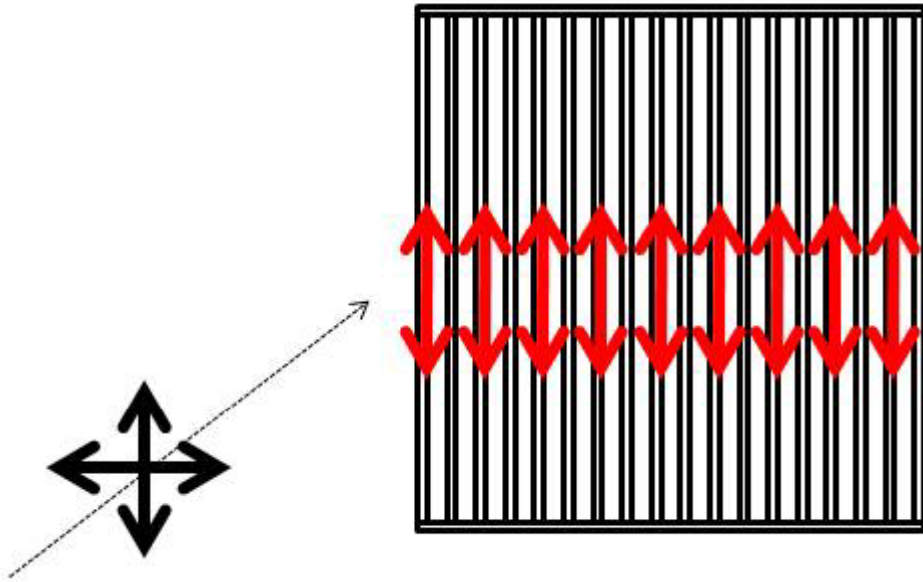


FIG. 1. Schematic ground-state and excited-state potential energy surfaces for the 11-*cis* → 11-*trans* isomerization in rhodopsin. Dashed lines connecting the S_1 and S_0 potentials represent the nonadiabatic surface upon which isomerization occurs.

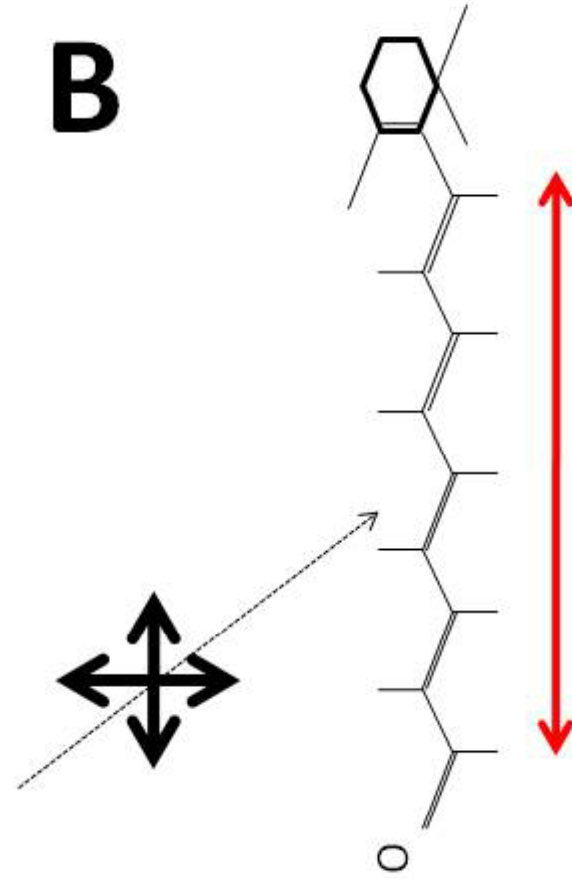


**Um modelo simples
para o mecanismo que
dá início ao processo de
visão**

A



B



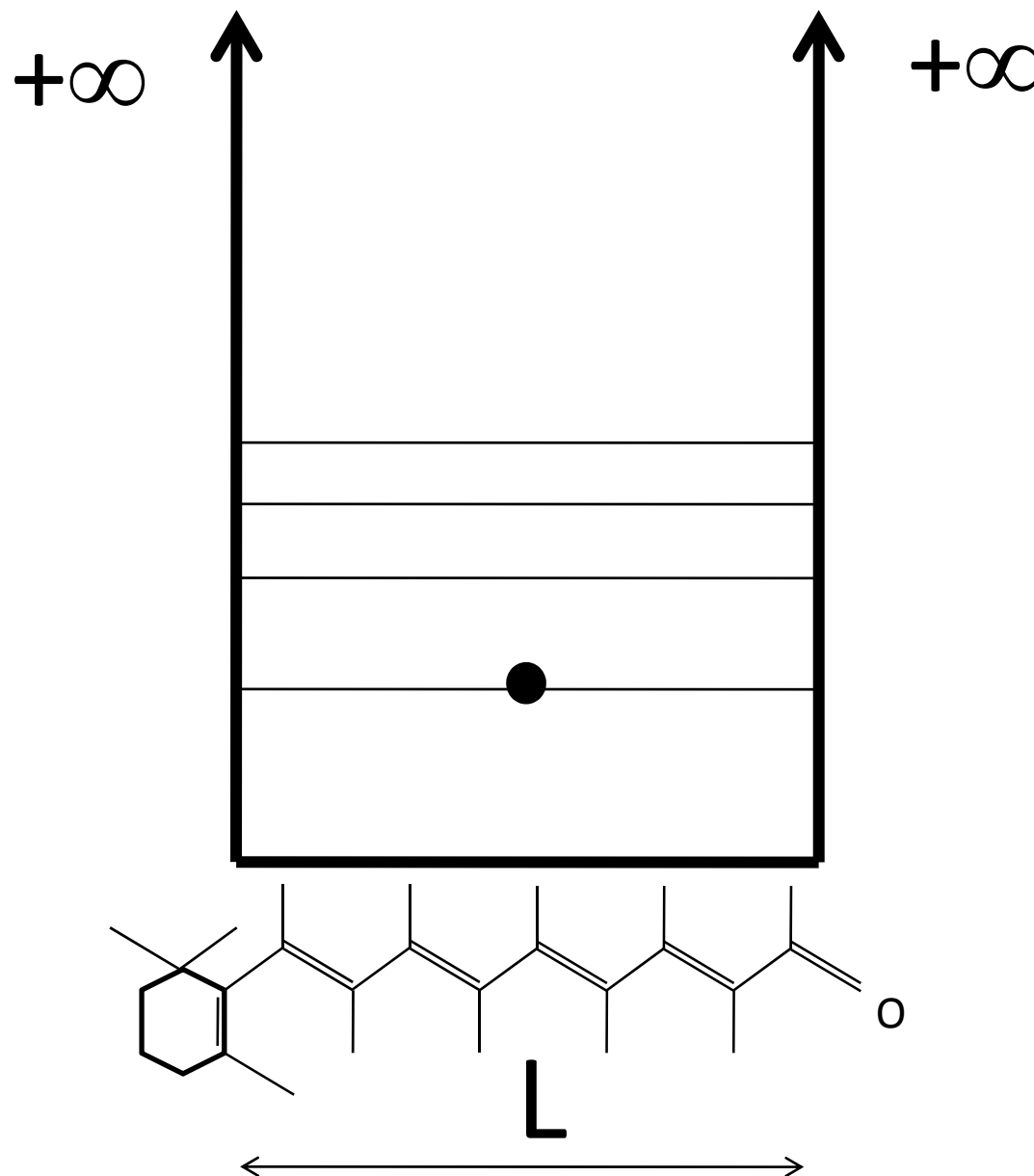
Um modelo simples para os elétrons pi

$$E_n = \frac{h^2 n^2}{8mL^2}$$

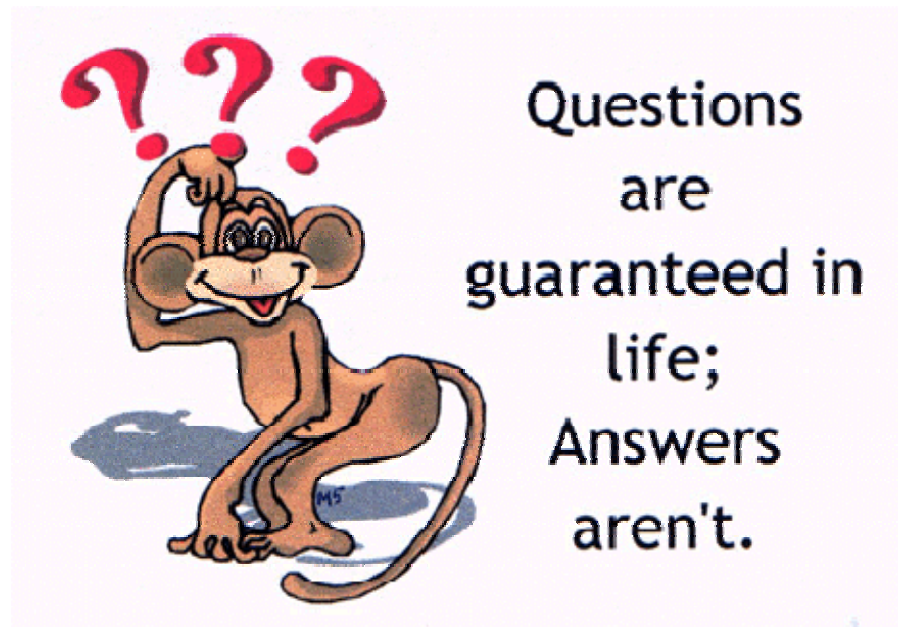
$$L = Nd$$

$d \sim 1,4 \text{ \AA}$

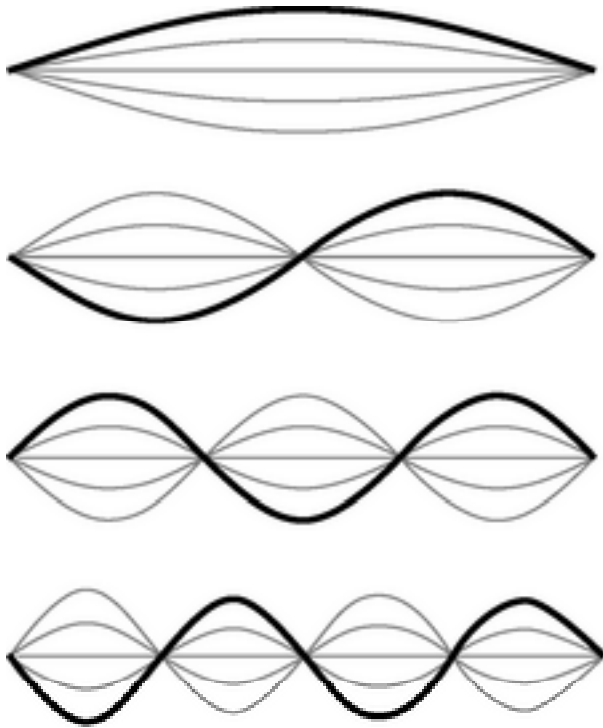
$N \rightarrow$ número de átomos de C



É possível discutir este assunto no nível médio ?



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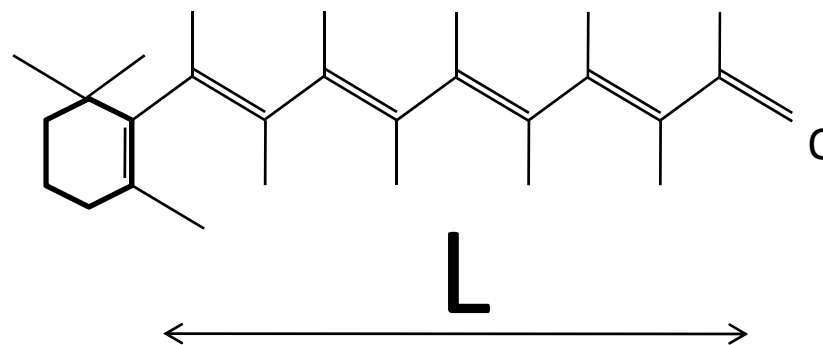
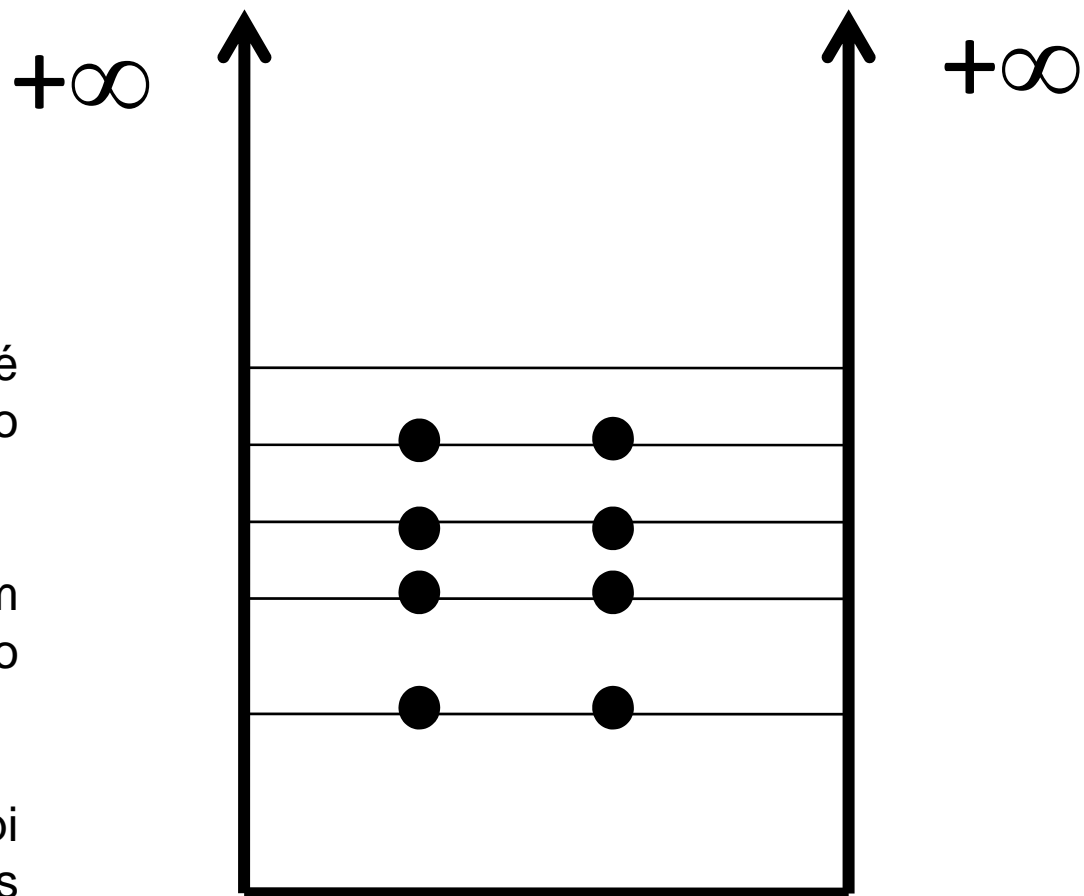


$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

O princípio de Pauli é considerado de um modo ad hoc:

Cada elétron é posto em um orbital-spin no estado fundamental.

Os N elétrons pi preenchem os primeiros $N/2$ níveis de energia



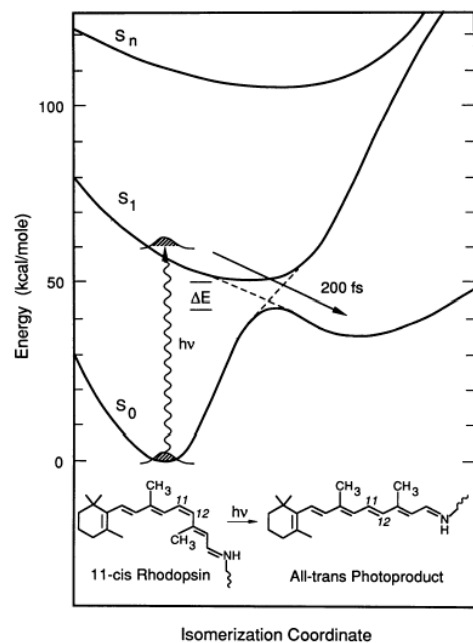
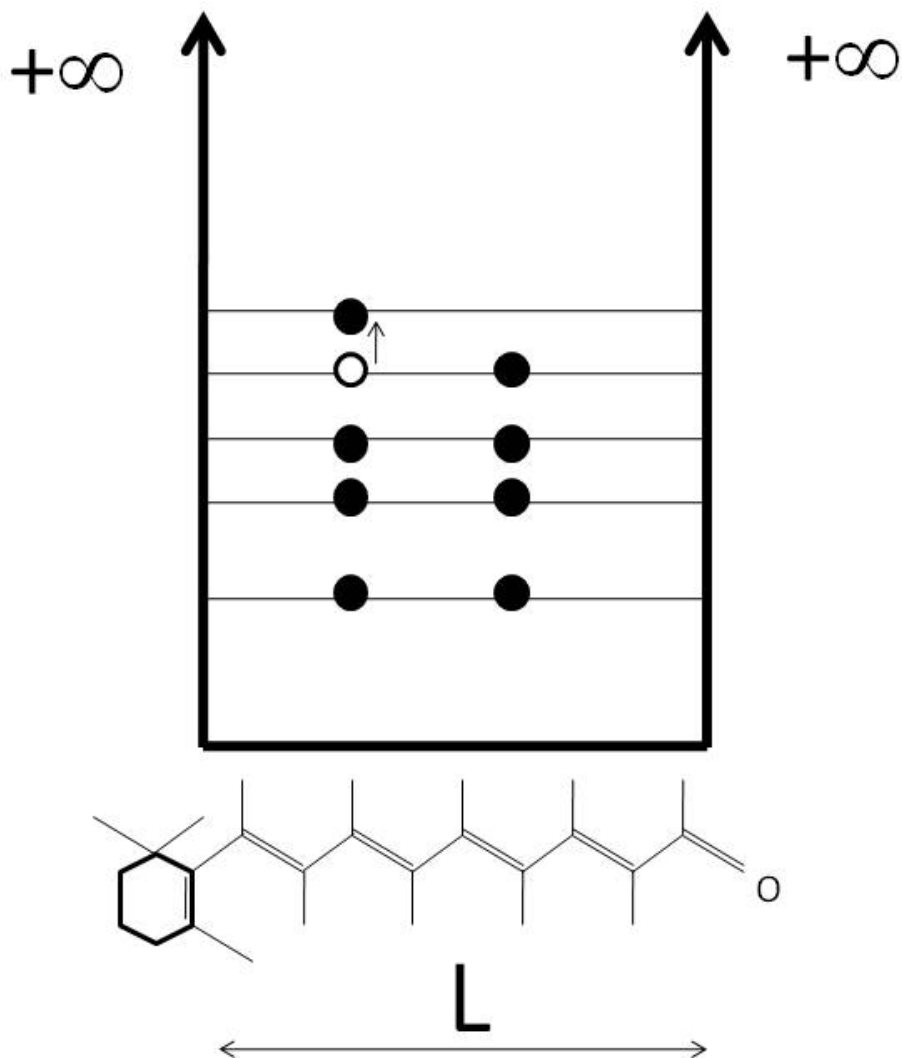


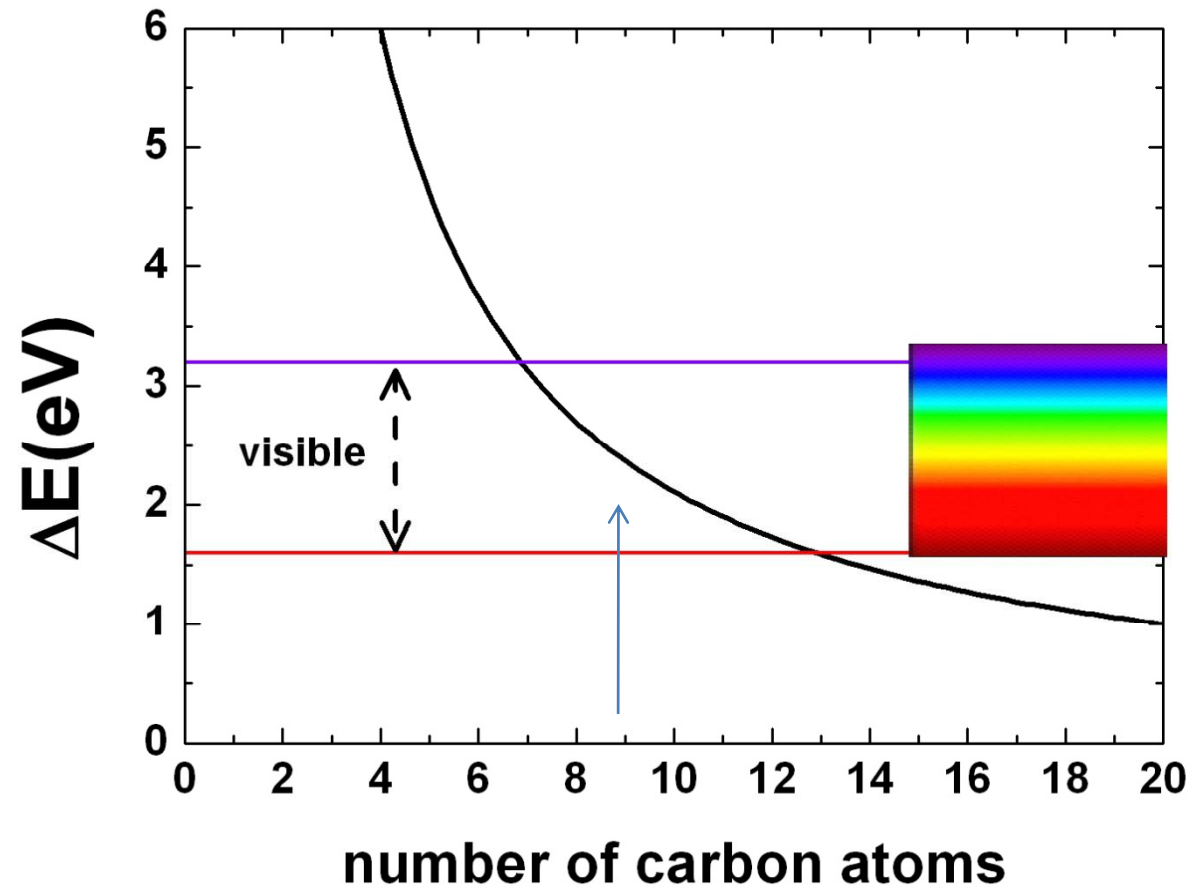
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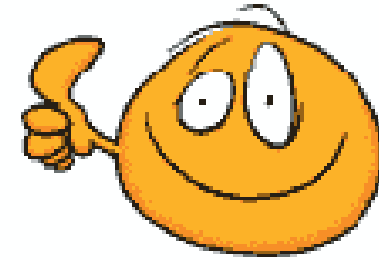
$$\Delta E = E_{n+1} - E_n = \frac{h^2(2n+1)}{8mL^2}$$

com $n = N/2$

$$\Delta E = 19,2 (N+1)/N^2 \text{ eV}$$



Obrigado!



referências

Ricardo Barthem, A Luz, Sociedade Brasileira de Física

The Feynmann Lectures on Physics