

# Sensing and the Imaging Process (I)

**Introduction to Computational and Biological Vision**

CS 202-1-5261

Computer Science Department, BGU

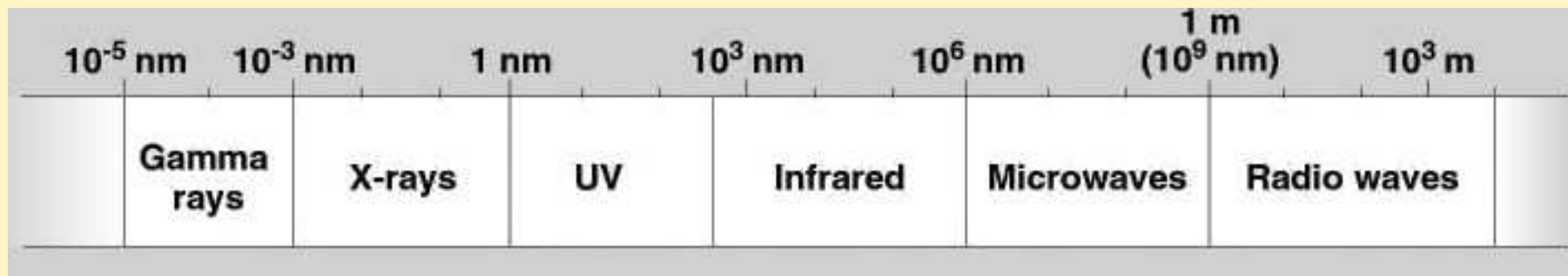
Ohad Ben-Shahar

# *What is light*

## The electromagnetic spectrum

Shorter Wavelength

Longer Wavelength



Higher frequency  
Higher energy

$$f = \frac{c}{\lambda}$$

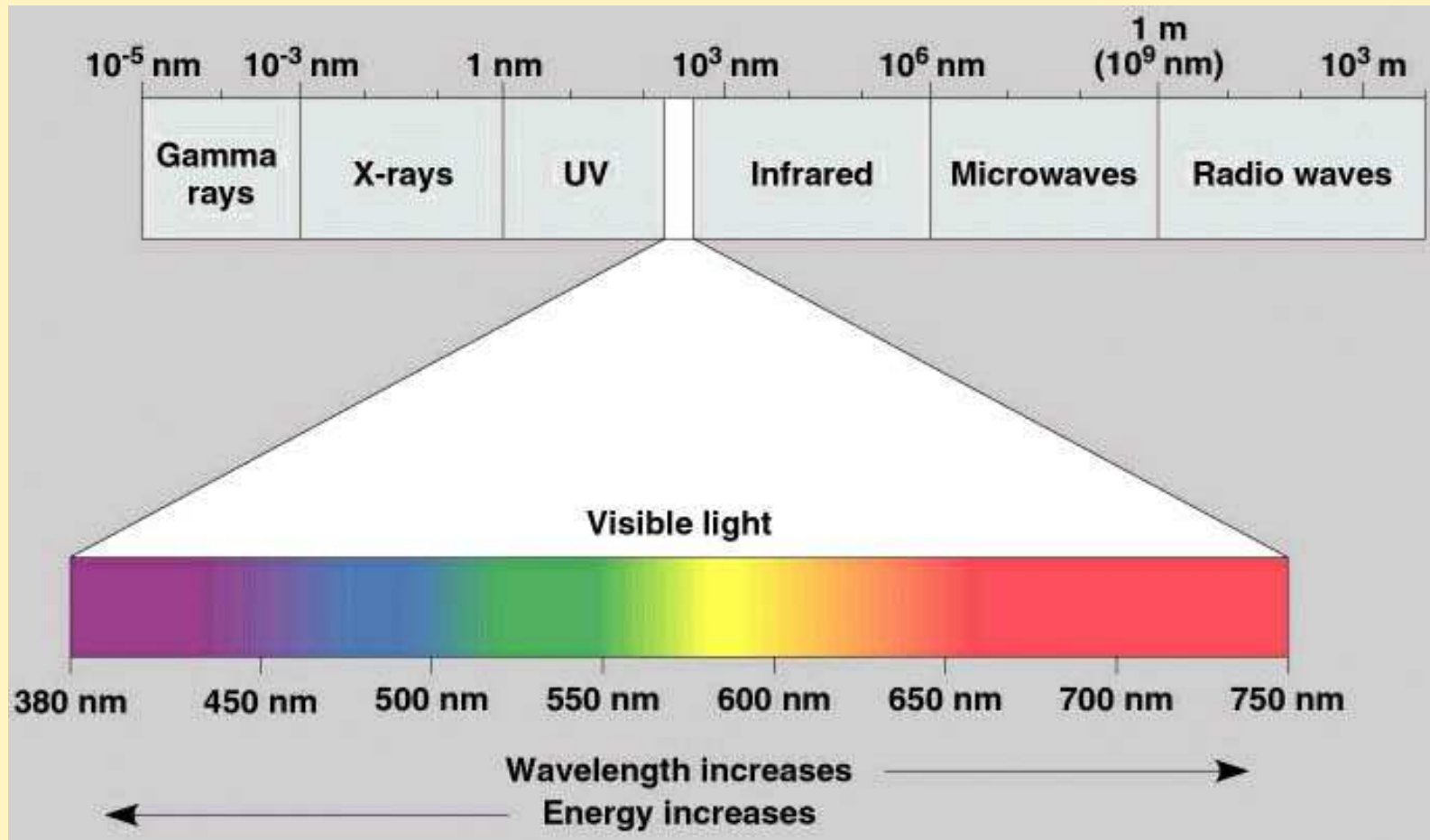
$$E = h \cdot f$$

$$c = 2.998 \cdot 10^8 \text{ m/s}$$

$$h = 6.623 \cdot 10^{-34} \text{ Js}$$

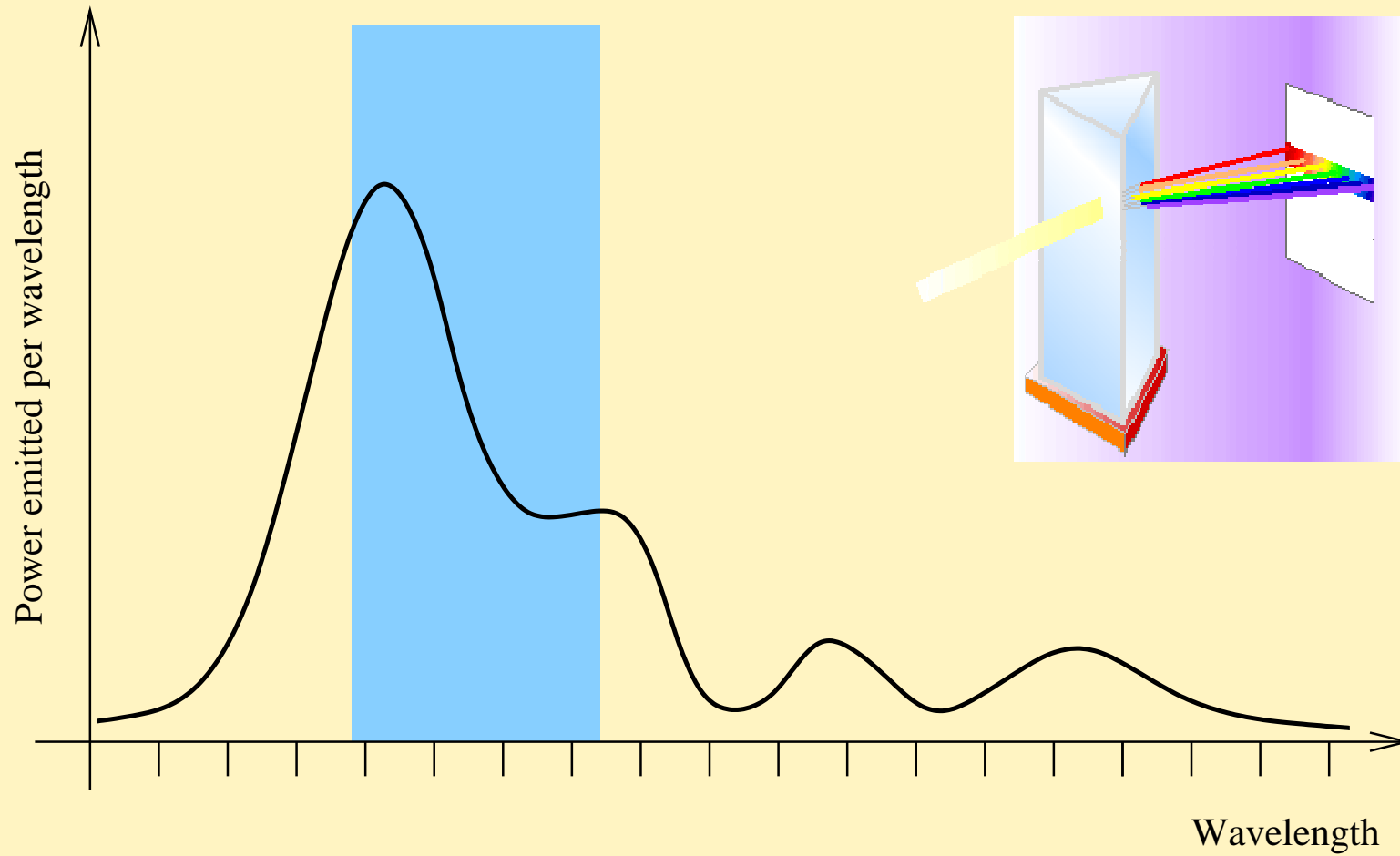
Smaller frequency  
Smaller energy

# *What is light*



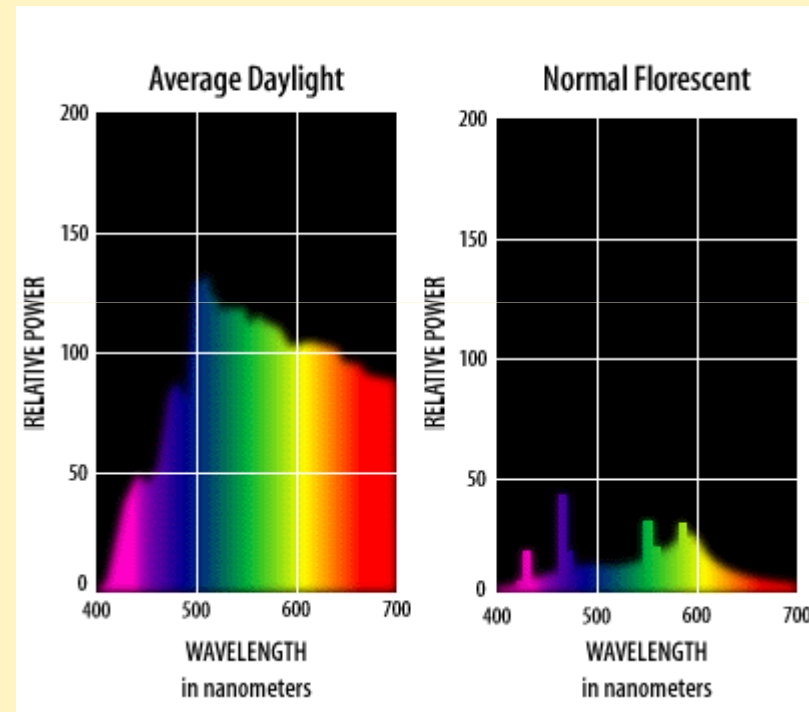
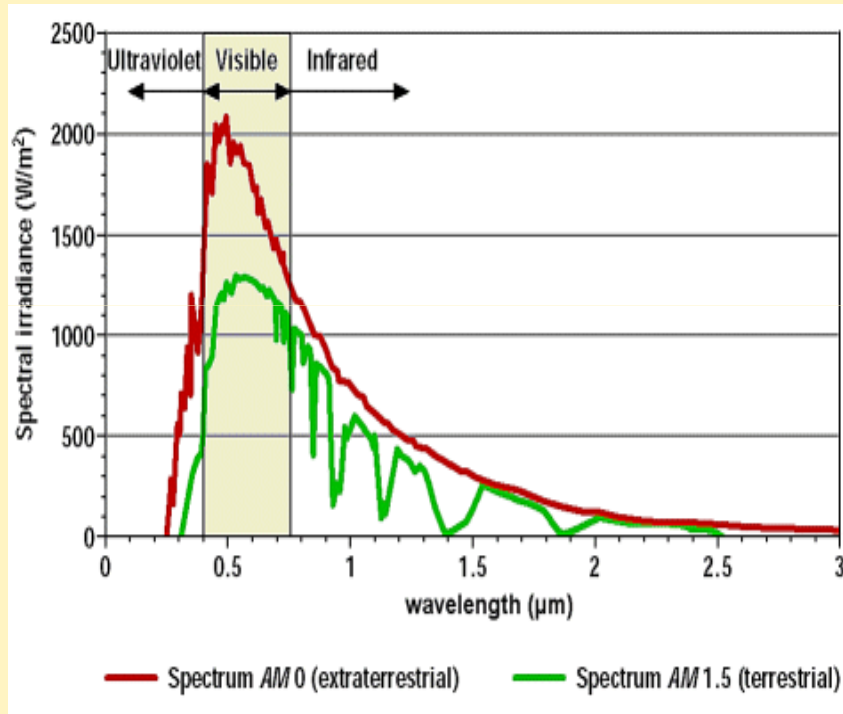
# *What is light*

## Power spectrum (spectral power)



# *What is light*

**A light source can be described by its spectral power**



## *The evolution of biological light-capturing devices*

“The sun ...offered the chance of remote guidance technology. It pummeled every square millimeter of Earth’s surface with a fusillade of photons: tiny particles traveling in straight lines at the greatest speed the universe allows, criss-crossing and ricocheting through holes and cracks so that no nook escaped, every cranny was sought out. **Because photons travel in straight lines and so fast, because they are absorb by some material more than others and reflected by some materials more than others, and because they have always been so numerous and so all-pervading, photons provided opportunity for remote sensing technologies of enormous accuracy and power.** It was necessary only to detect photons and – more difficult – distinguish the directions from which they came. Would the opportunity be taken up?

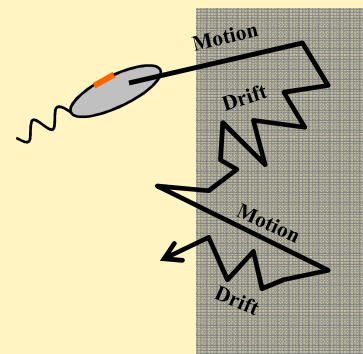
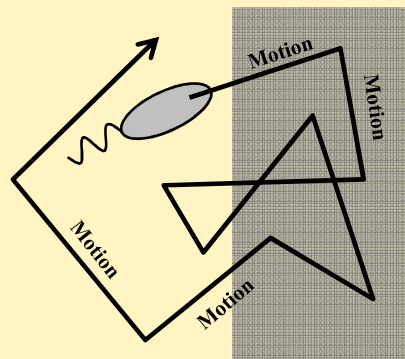
Three billion years later you know the answer, for you can see these words.”

Richard Dawkins, *The Forty-Fold Path to Enlightenment*, 1996

# *The evolution of biological light-capturing devices*

## **I. In the beginning: Formation of photopigments (>3BYA)**

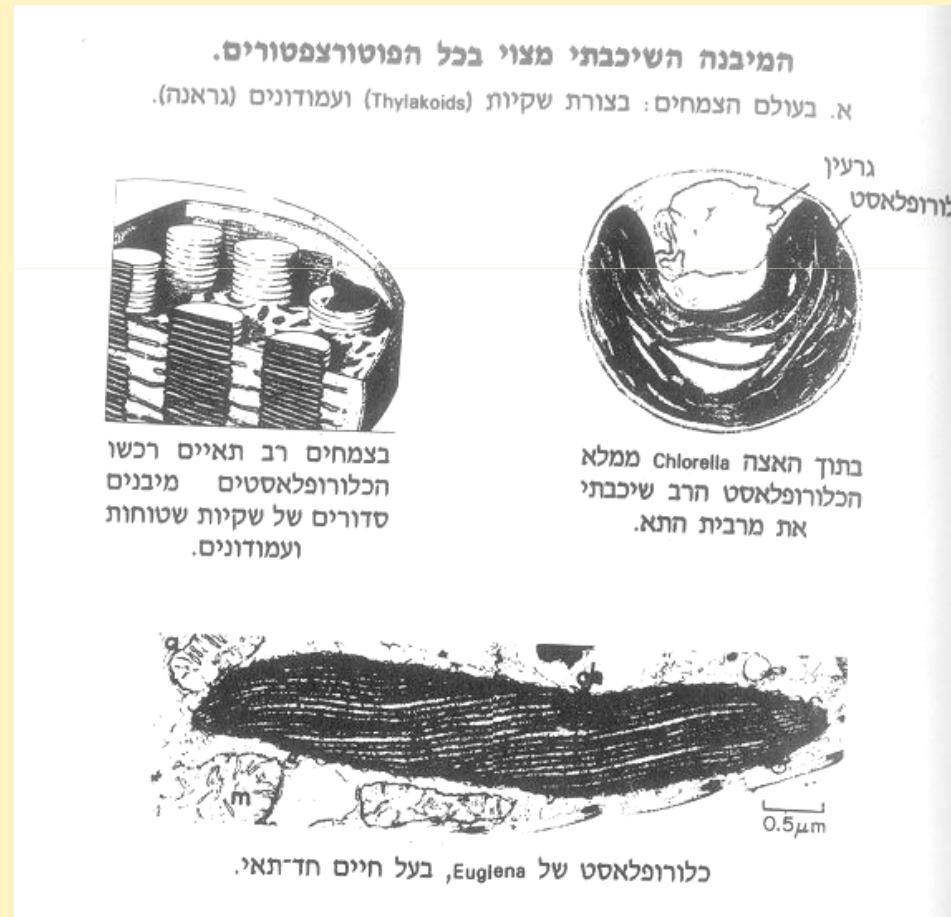
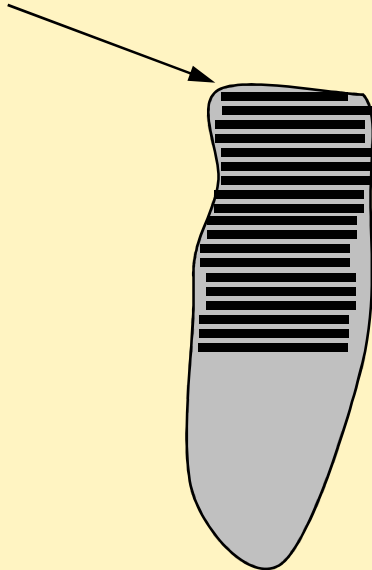
- **Molecules in which light triggers a physical or chemical change.**
- **Captured photons lead to release of energy (of different forms)**
- **Released energy is used for**
  - **Building food (photosynthesis)**
  - **Behavioral reaction (nerve reaction)**



# The evolution of biological light-capturing devices

## II. Efficient photo traps: the evolution of “photocells”

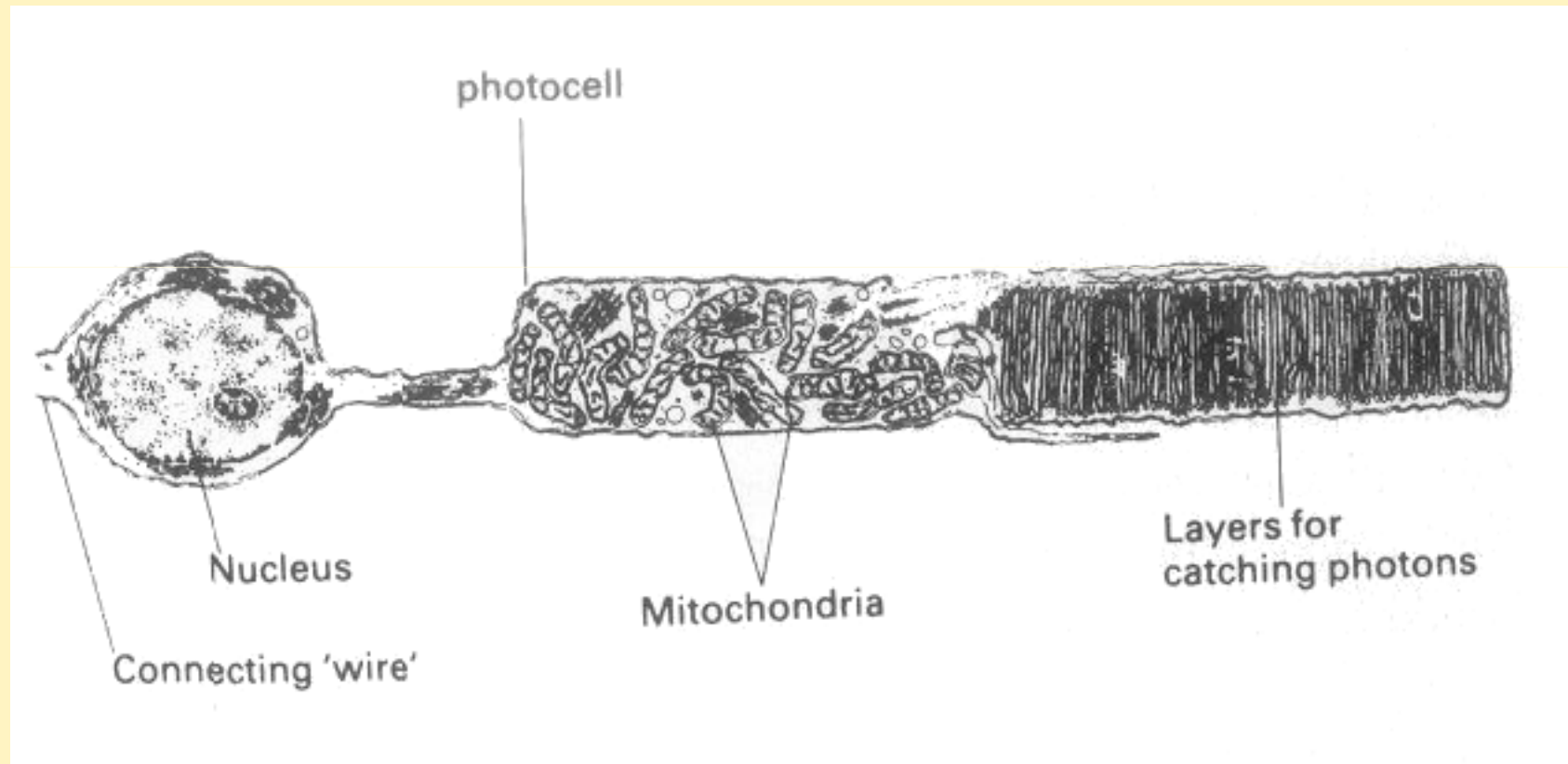
Light sensitive patch



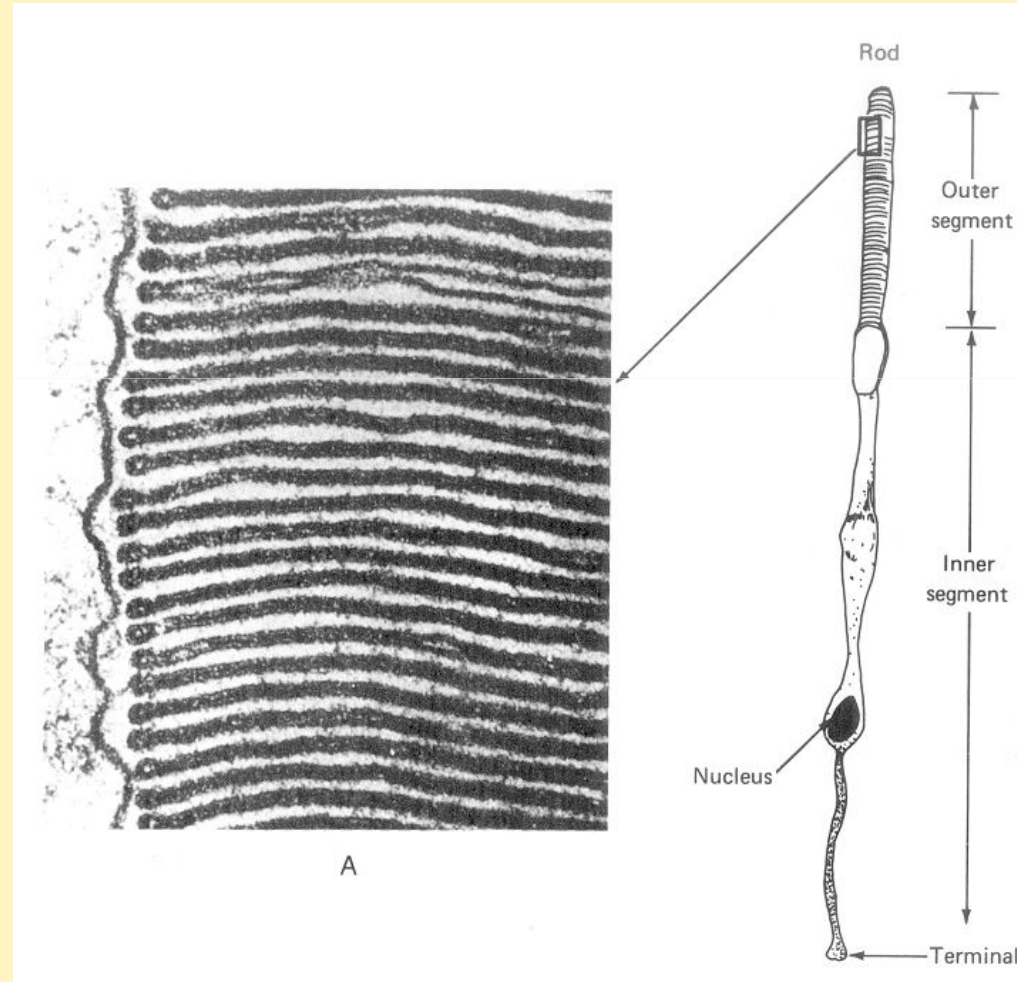


# *The evolution of biological light-capturing devices*

## **Typical advanced photocell**

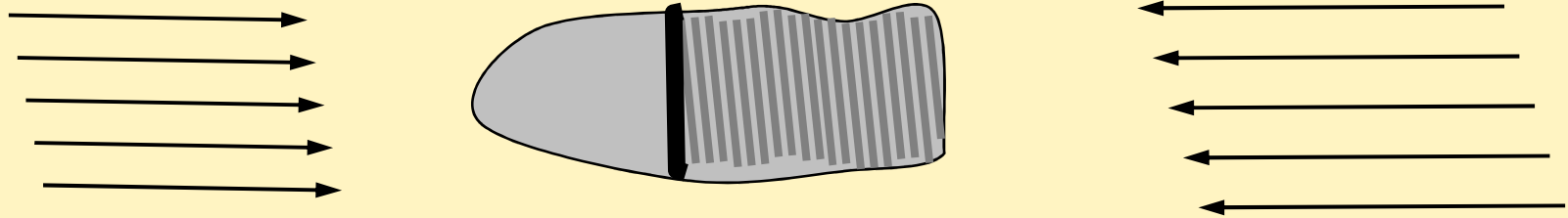


# *The evolution of eyes*



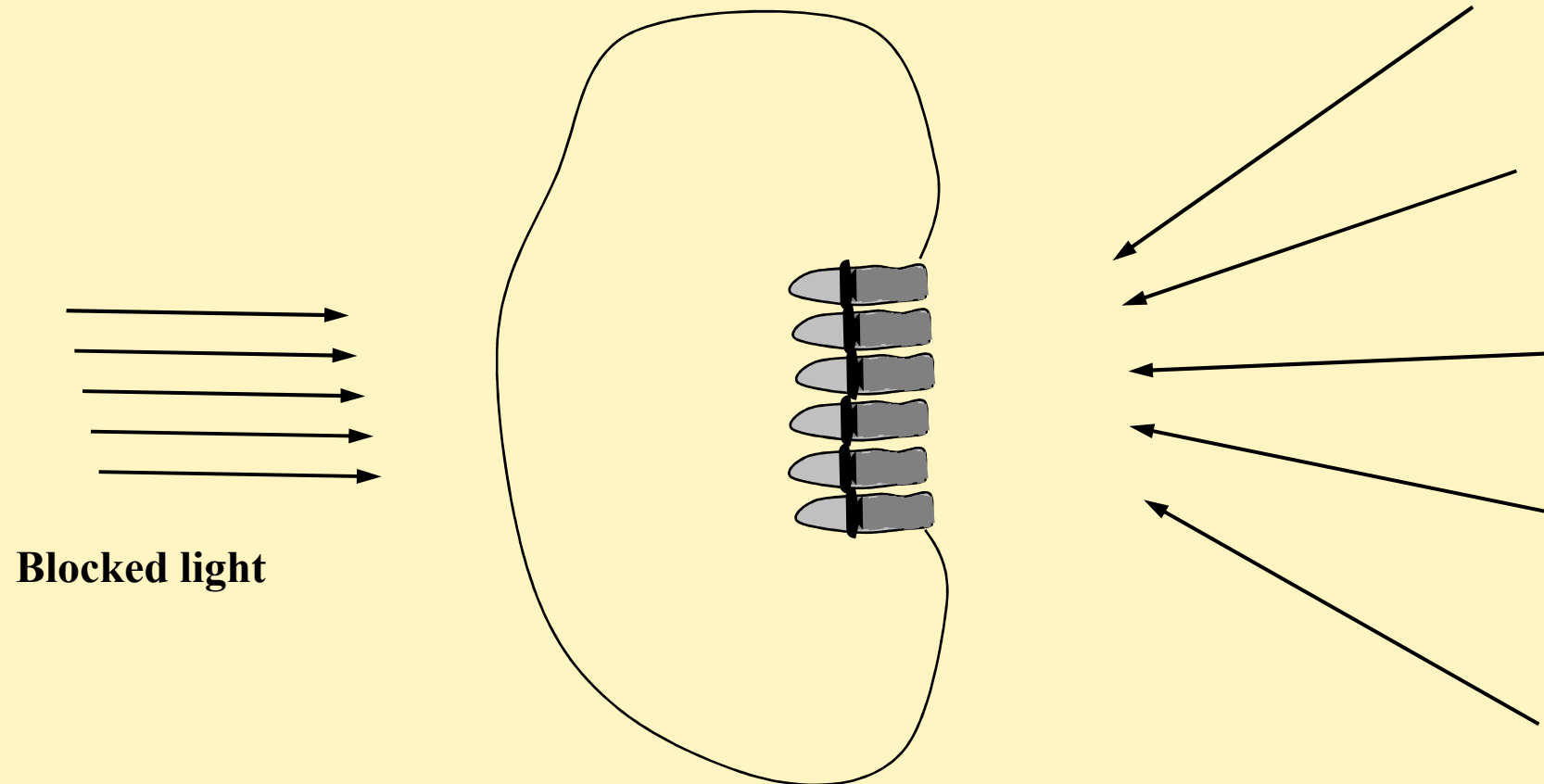
## *The evolution of eyes*

### **III. Where does the light come from?**



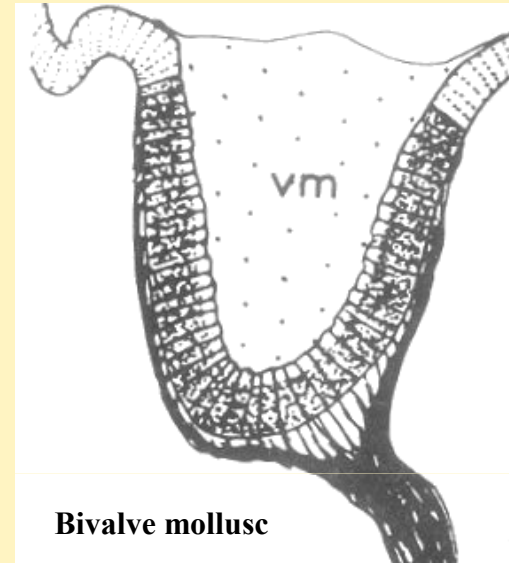
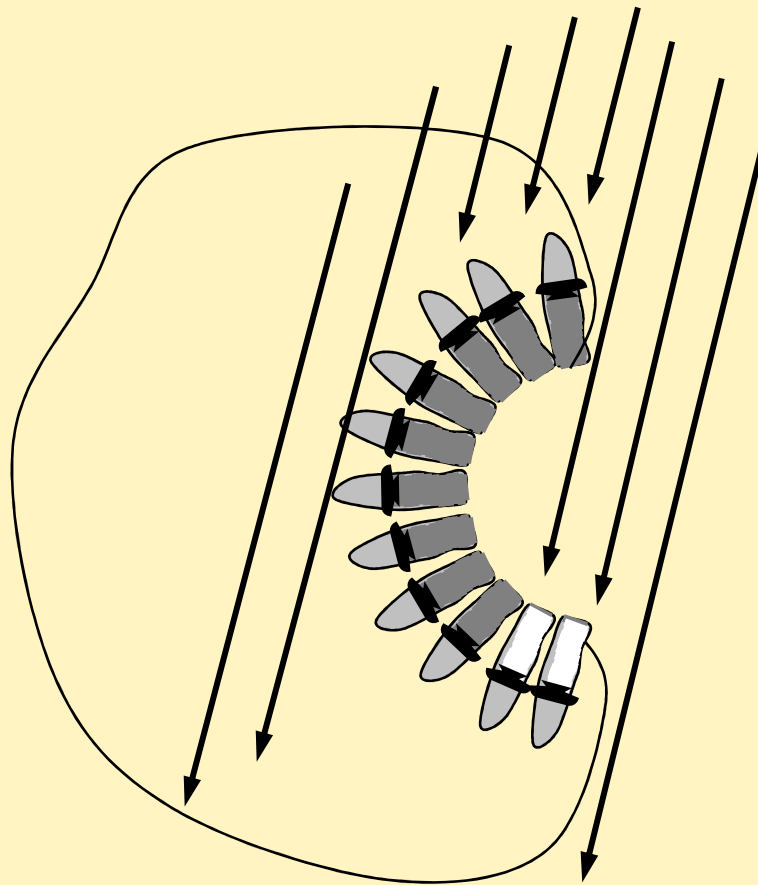
# *The evolution of eyes*

## **IV. Better direction resolution**

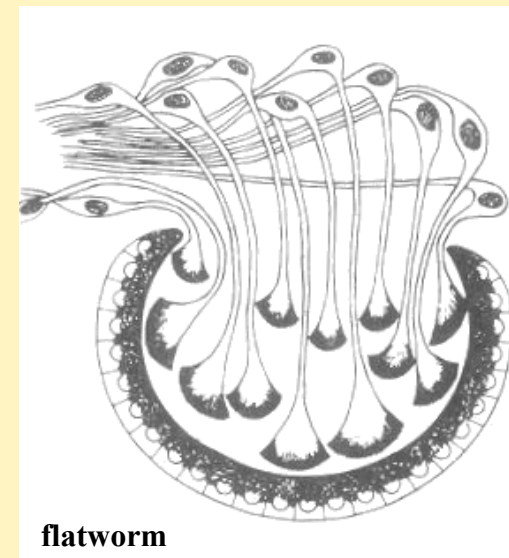


# *The evolution of eyes*

## **IV. Better direction resolution**



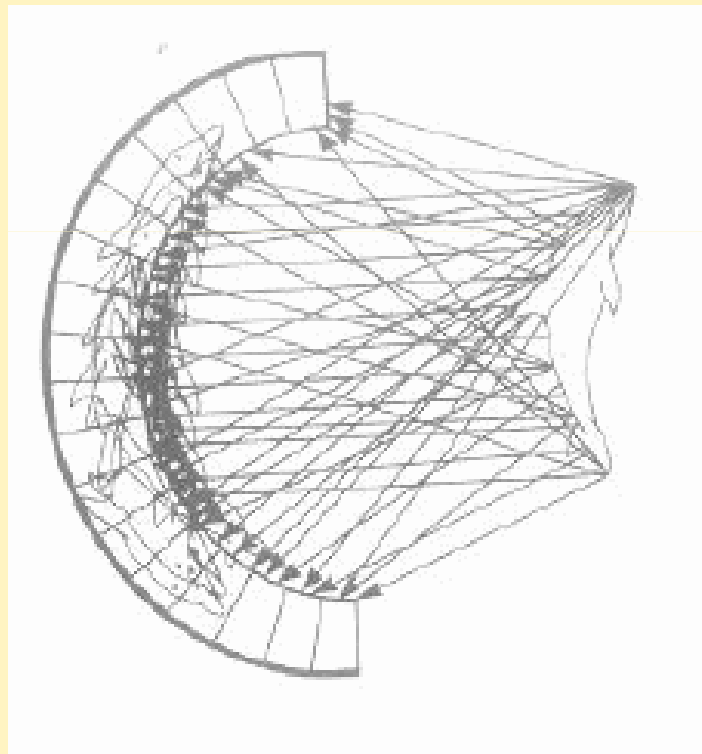
**Bivalve mollusc**



**flatworm**

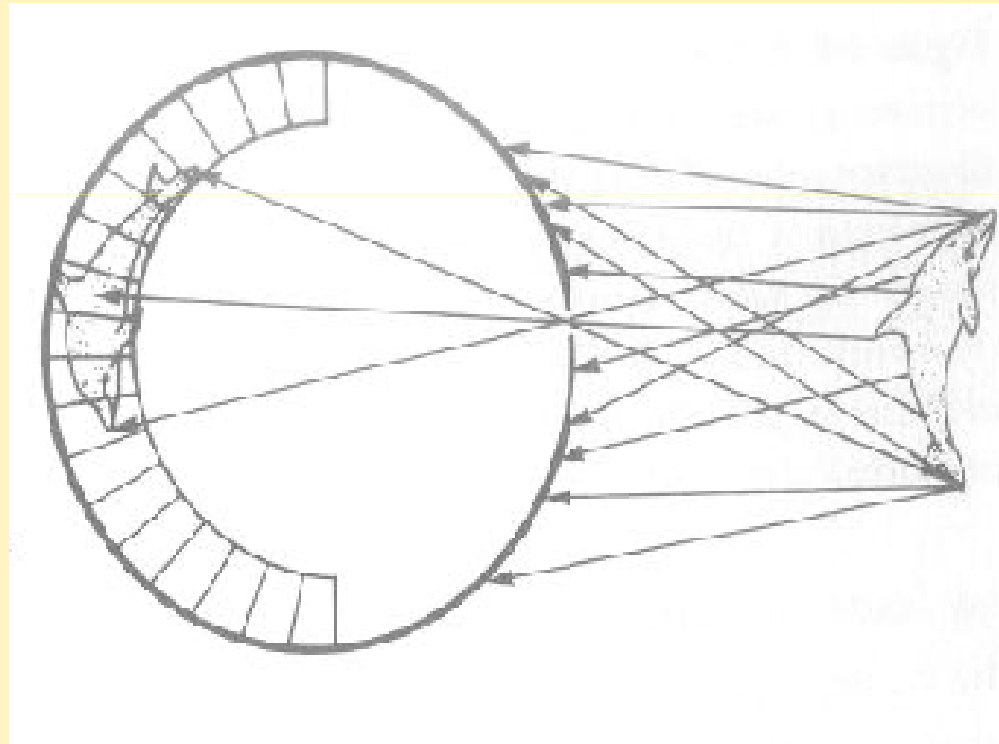
## *The evolution of eyes*

**V. But where is the image?**



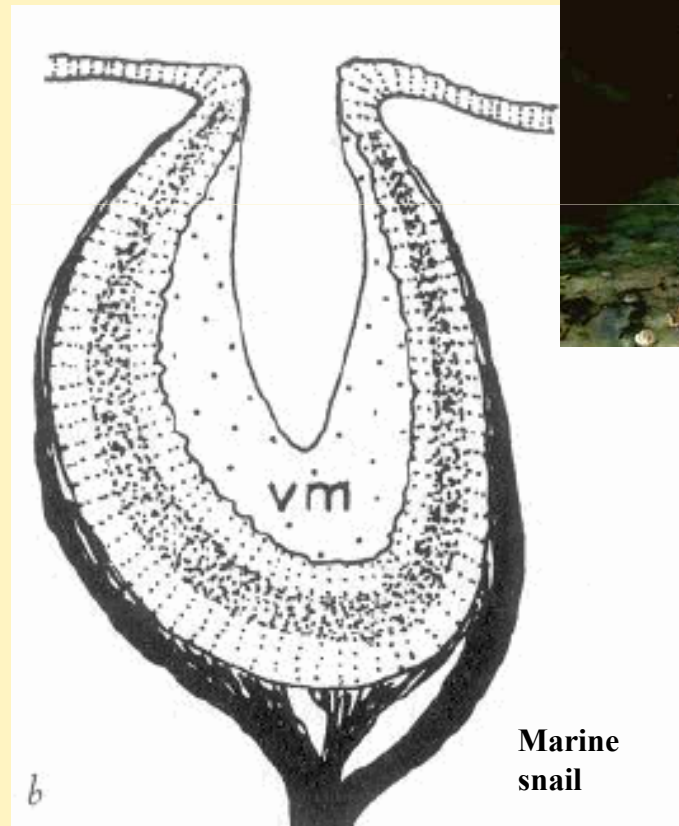
## *The evolution of eyes*

**V. But where is the image? Toward a pinhole camera eye**



## *The evolution of eyes*

**V. But where is the image? Toward a pinhole camera eye**

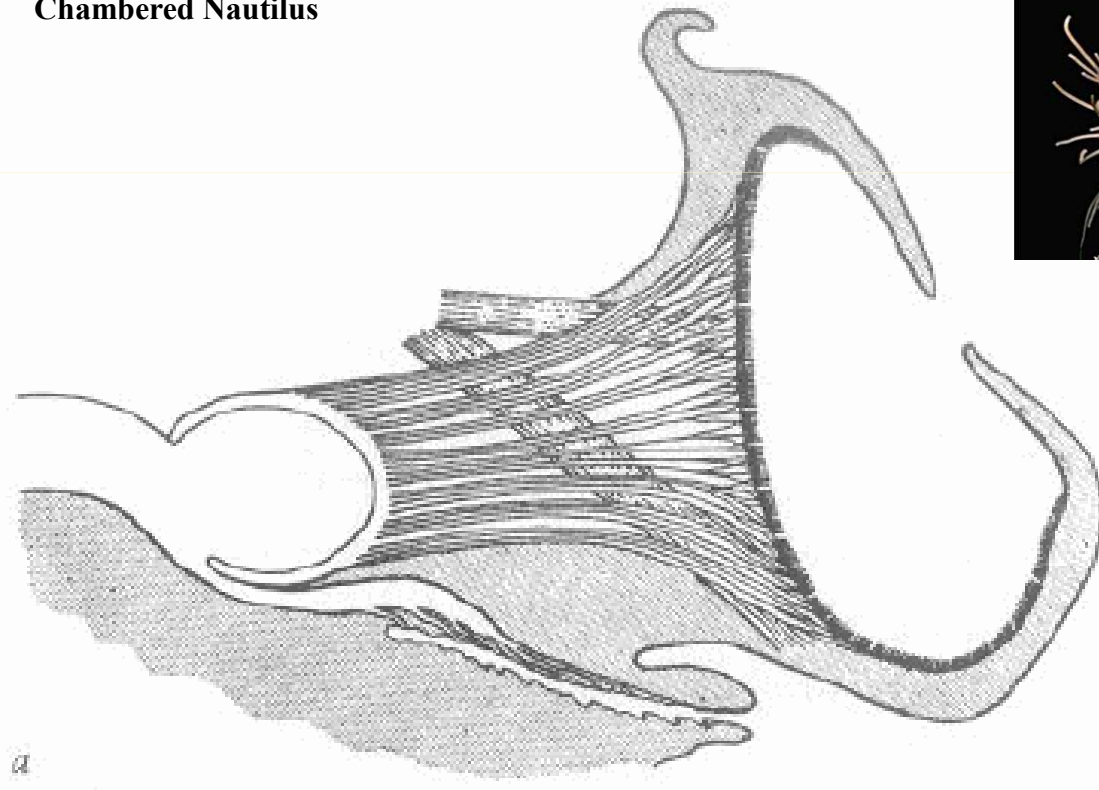




## *The evolution of eyes*

### **V. But where is the image? Toward a pinhole camera eye**

Chambered Nautilus

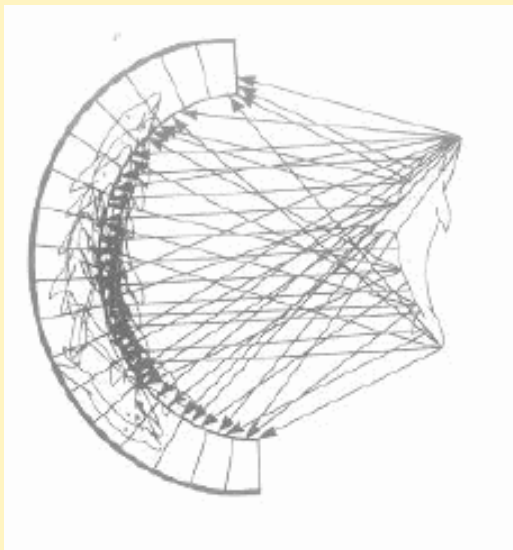


# *The evolution of eyes*

## **VI. An evolutionary dilemma**

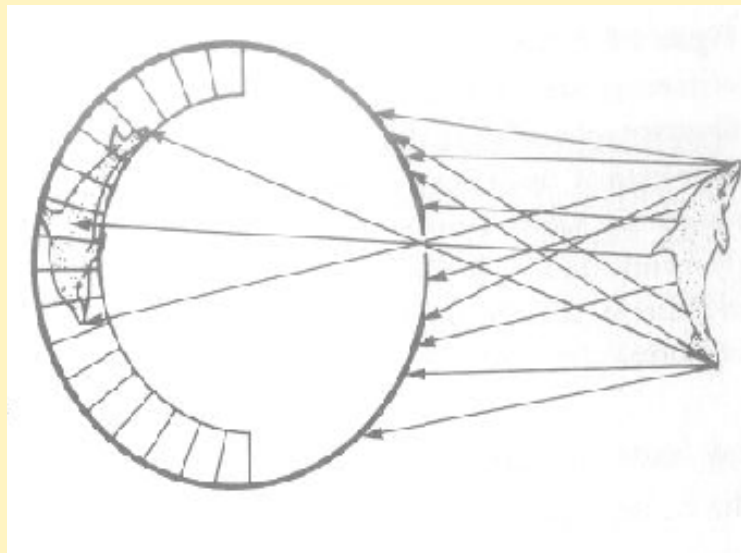
### **Wide aperture:**

- **Bright images**
- **Fuzzy images**



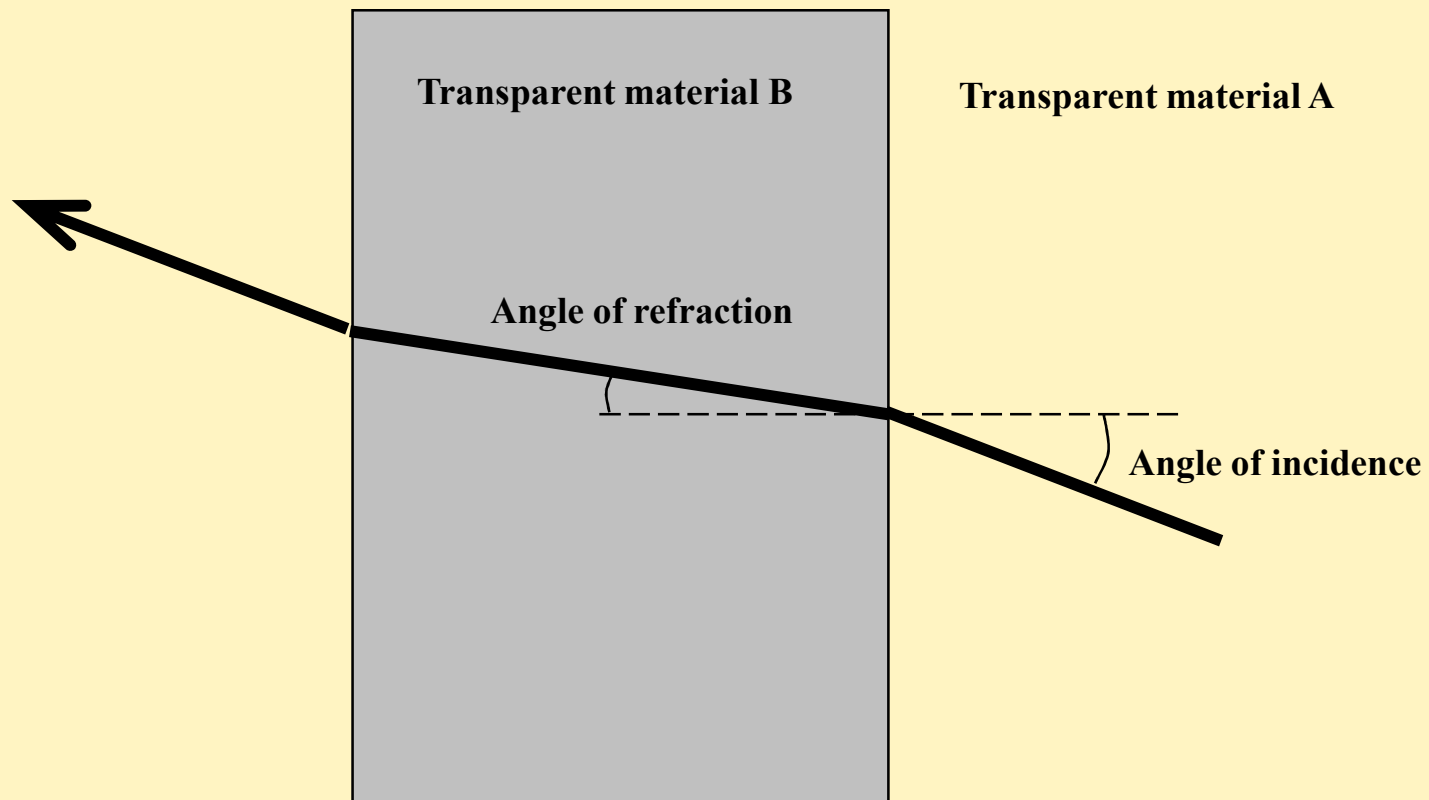
### **Pinhole aperture:**

- **Dim images**
- **Sharp images**



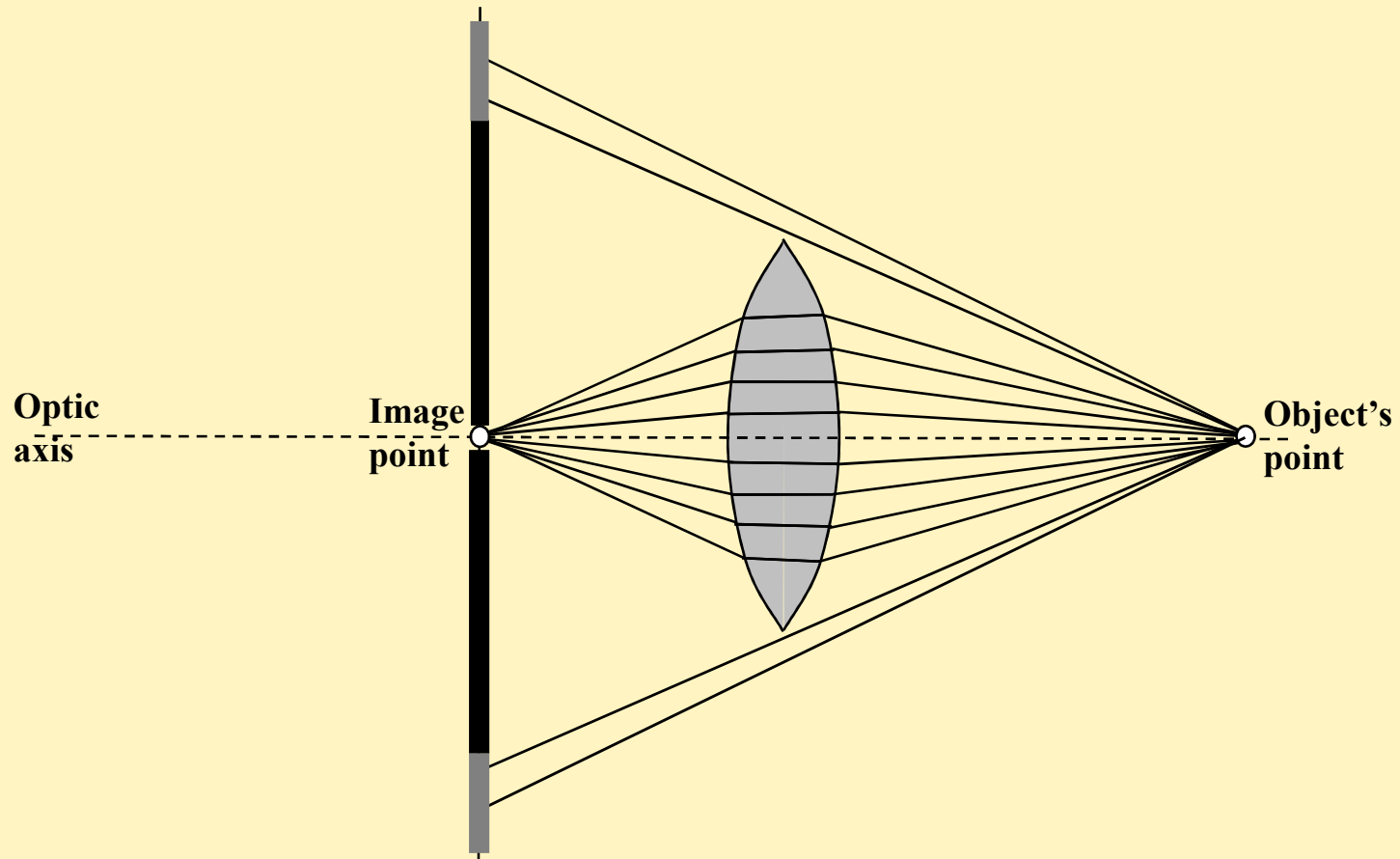
# *The evolution of eyes*

## **VI. An evolutionary dilemma : An ultimate solution**



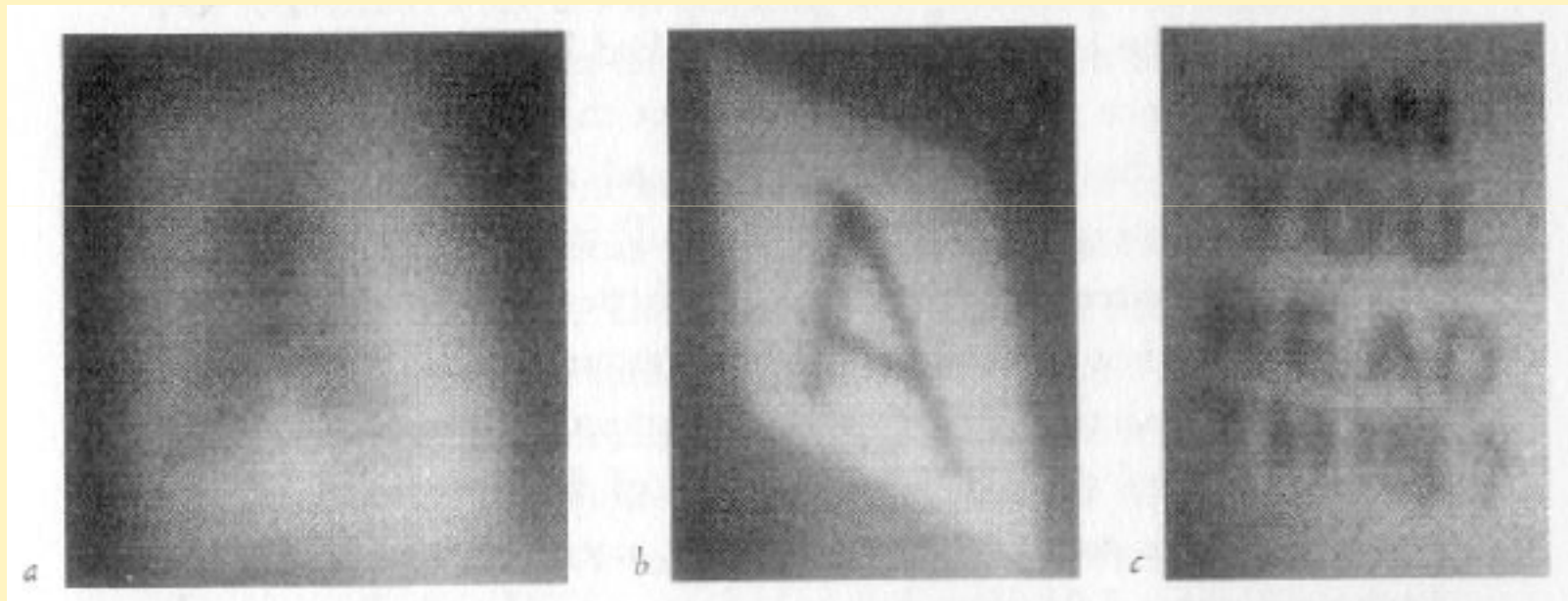
# *The evolution of eyes*

## **VI. An evolutionary dilemma : The formation of lens**



## *The evolution of eyes*

### **VI. An evolutionary dilemma : The formation of lens**



Wide (1cm) “pinhole”

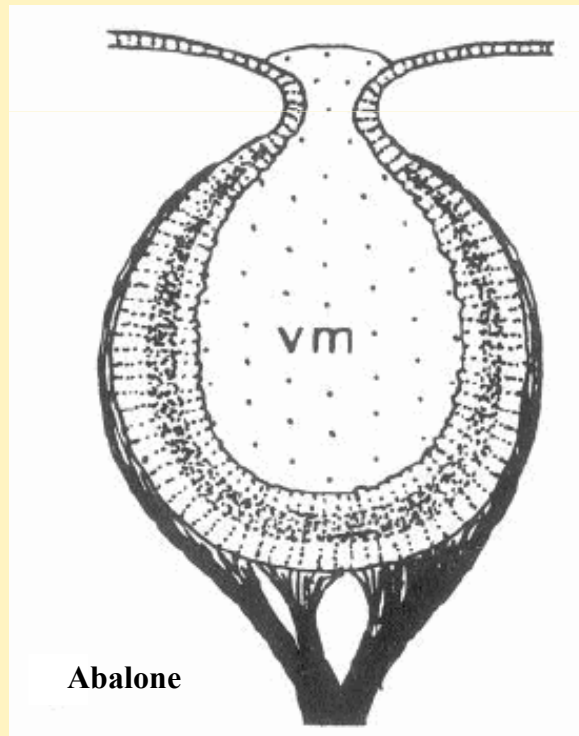
With water filled bag

Water filled wine bottle

# *The evolution of eyes*

## **VI. An evolutionary dilemma : The formation of lens**

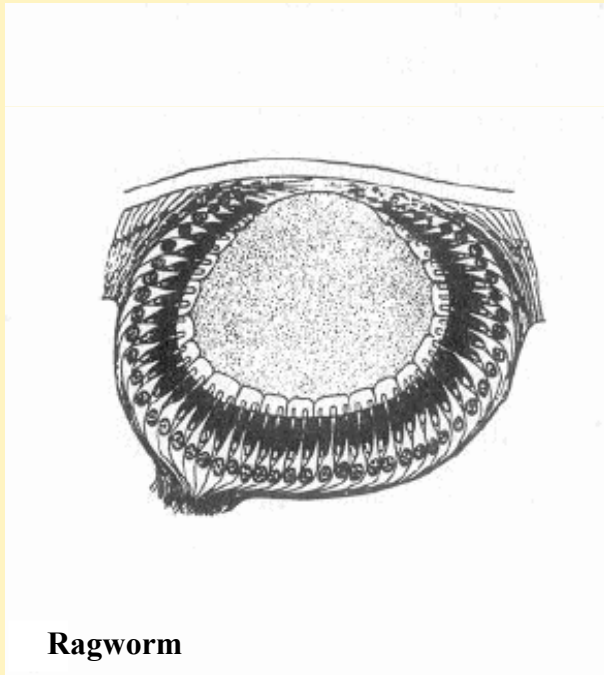
**Naturally forming lens?      Convex reshaping of the vitreous mass**



## *The evolution of eyes*

### **VI. An evolutionary dilemma : The formation of lens**

**Naturally forming lens? Local condensation of a vitreous mass region**



## *The evolution of eyes*

*“To suppose that the eye, with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest possible degree.”*

**The Origin of Species, Charles Darwin 1859**

*“The eye, to this day, gives me a cold shudder, but when I think of the fine known gradations, my reason tells me I ought to conquer that cold shudder.”*

**Letter from Darwin to Asa Gray [a Christian minister], 1860**



# The evolution of eyes

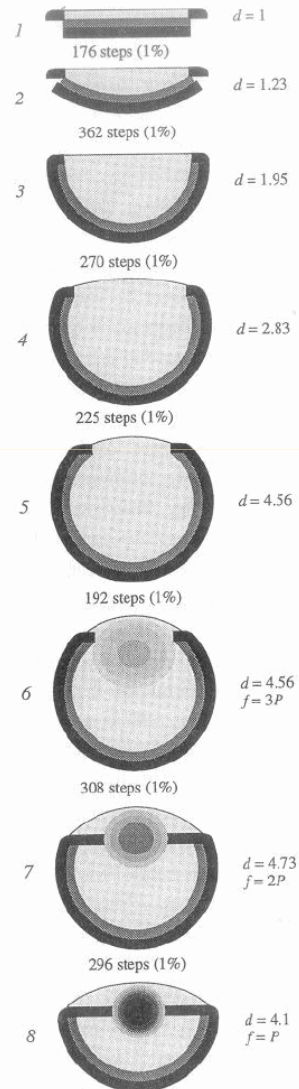


Figure 5.14 Nilsson and Pelger's theoretical evolutionary series leading to a 'fish' eye. The number of steps between stages assumes, arbitrarily, that each step represents a 1 per cent change in magnitude of something. See text for translation from these arbitrary units into numbers of generations of evolution.

**[Nilsson & Pelger 1994]**

## *The evolution of eyes*

