

# Eye design



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*Holcocephala fusca* Robber Fly

- Angelique Paulk

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# Insect vision

## *Function:*

*Insects need to deal with the visual world*

- This can require using color cues to find food sources
- Vision can be necessary for finding mates, chasing off rivals, and for detecting moving prey
- Visual cues can be essential for finding oviposition sites, and for maintaining circadian rhythms



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*To perform these functions, the visual organs must receive the information and convey that information to the brain, which then processes the visual world*

# Insect vision

*To perform these functions, the visual organs must receive the information and convey that information to the brain, which then processes the visual world*

The visual system in insects comes in many forms, but the three primary types are:

- Compound eyes
- Ocelli
- Stemmata



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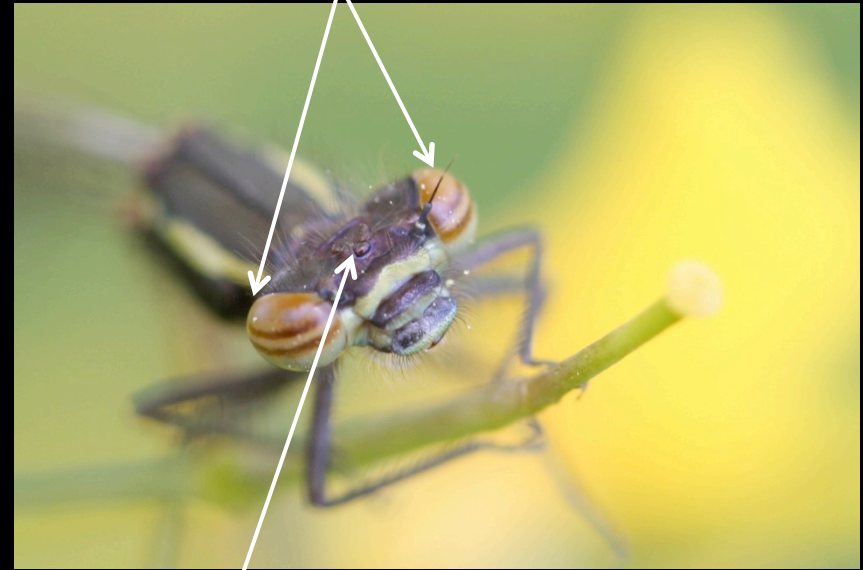
# Insect visual organs

- Compound eyes are paired structures (normally on either side of the head) composed of many units called ommatidia.

Ommatidia are cartridges composed of cuticle, support cells, *photoreceptors* (cells which detect light), and pigment cells

- Ocelli are single-lens eyes often located on the top of the head (where there are normally three near each other)
- Stemmata are also single-lens eyes which are often found in holometabolous larvae on the sides of the head

Compound eyes



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Ocelli

Stemmata



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# Objectives

- Understand the layout of the compound eye
- What are the components of the compound eye?
- Address the diversity of eye designs and their adaptations

# The ommatidial layout: diversity of systems



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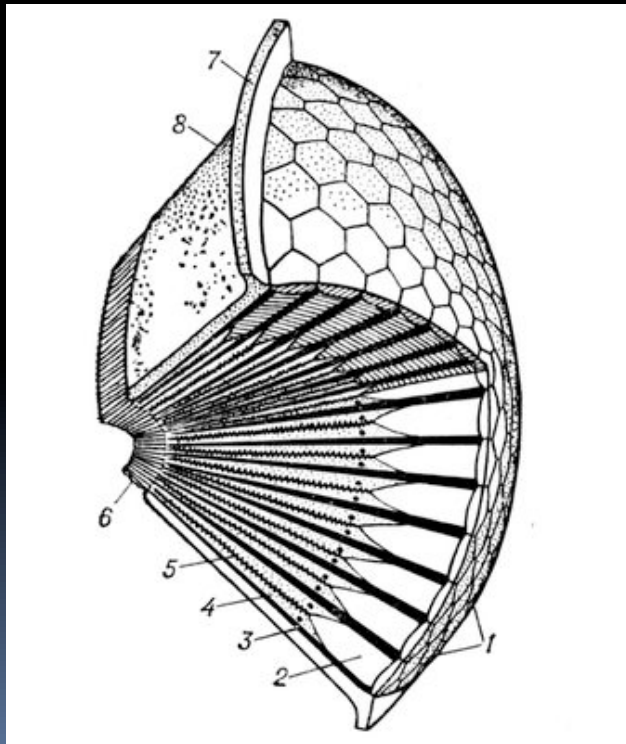
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# The basic layout: the compound eye

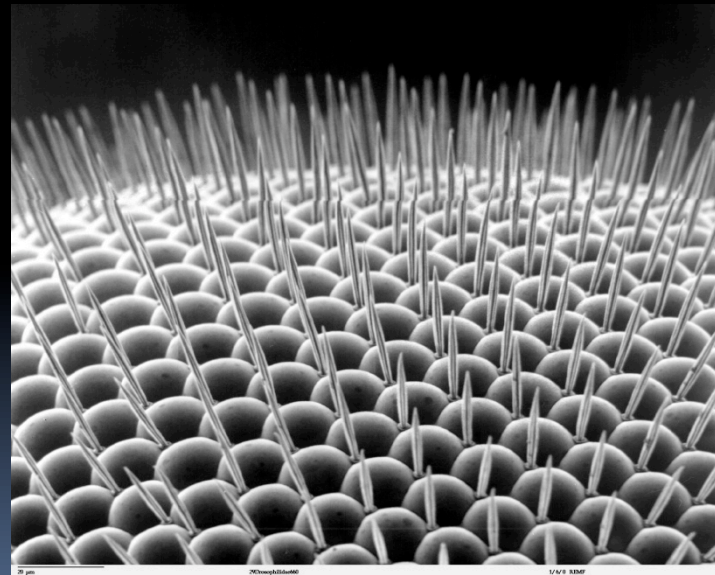
Insects can exhibit a diversity of compound eye types:

From tens of thousands of facets to single facets, to double eyes for living above and below water to single large eyes covering the entire head, insects exhibit massive range of different compound eye designs...



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*Drosophila* eye

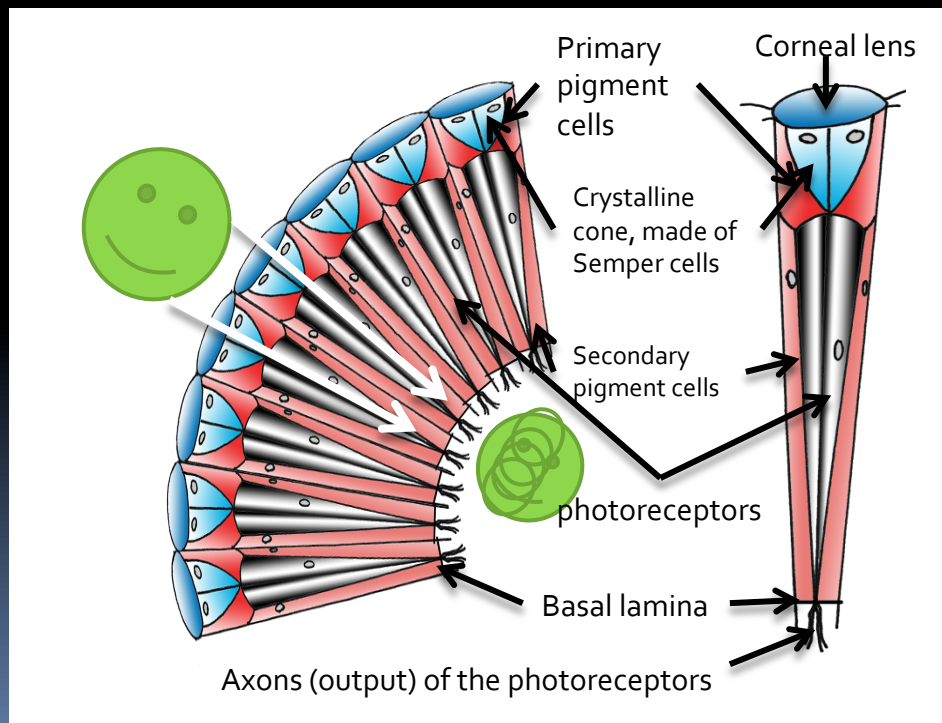


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# The ommatidia layout: The apposition eye

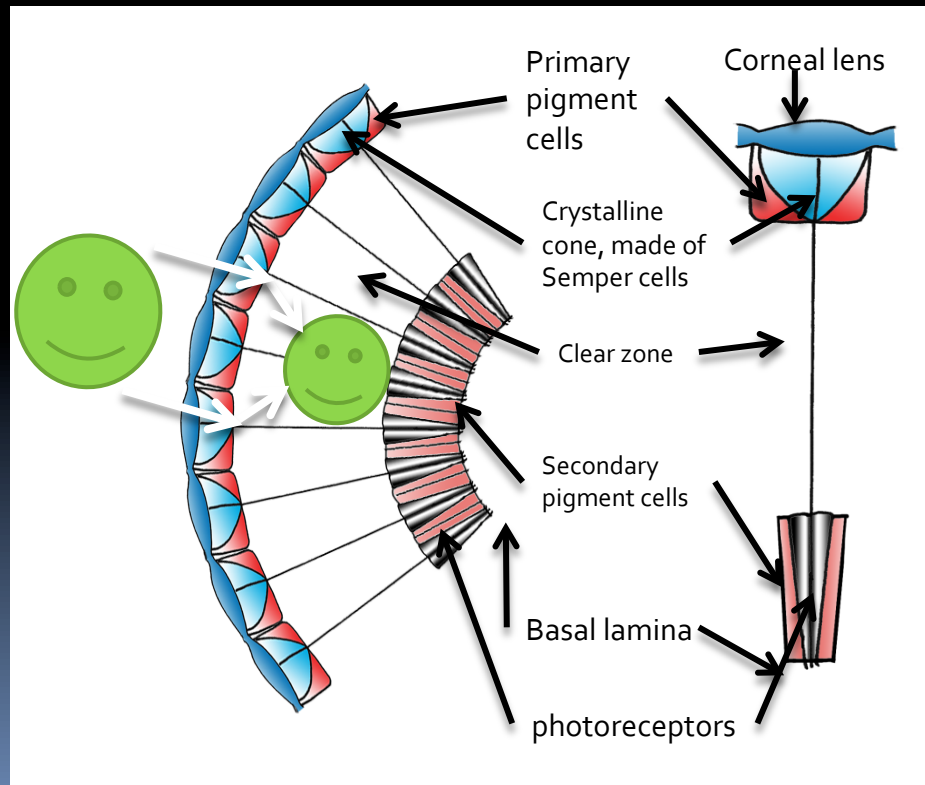
- ❖ The photoreceptors form the core of each ommatidium.
- ❖ They can include up to 8 or 9 photoreceptors (also called retinula cells), which are the cells detecting light in the eye.
- ❖ The photoreceptors have fine microvilli extending into the middle of the facet, which forms the rhabdom of the eye (which is where the light detecting regions of the eye is located)



- ❖ Many insects have apposition eyes, which include bees and flies
- ❖ In this arrangement, photoreceptors form the core of a cartridge of cells which include pigment cells and extend to the crystalline cone.
- ❖ Pigment cells surrounding the photoreceptors block light from straying outside of the cartridge of cells, so that each cartridge received light from its own corneal lens.
- ❖ Therefore, an image is divided into the different views of the facets of the eye

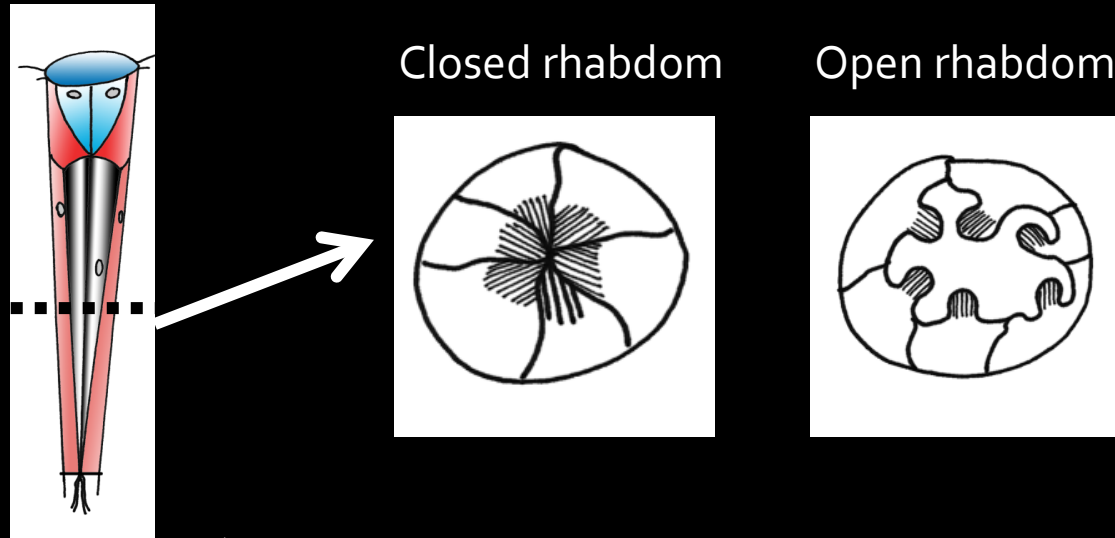
# The ommatidia layout: The superposition eye

- ❖ Many insects have superposition eyes, which include beetles, moths, and butterflies
- ❖ In this arrangement, photoreceptors are located close to the basal lamina.
- ❖ Pigment cells are sequestered to specific areas, allowing light to go through the clear zone to be projected on the rhabdom.



- ❖ Therefore, the image is projected across many photoreceptors and is not divided by the facets of the eye.
- ❖ The clear zone can be made up of clear cells or of areas of the photoreceptor cells without pigment (outside of the rhabdom)
- ❖ The superposition eye can gather more light, which is helpful in nocturnal insects such as moths

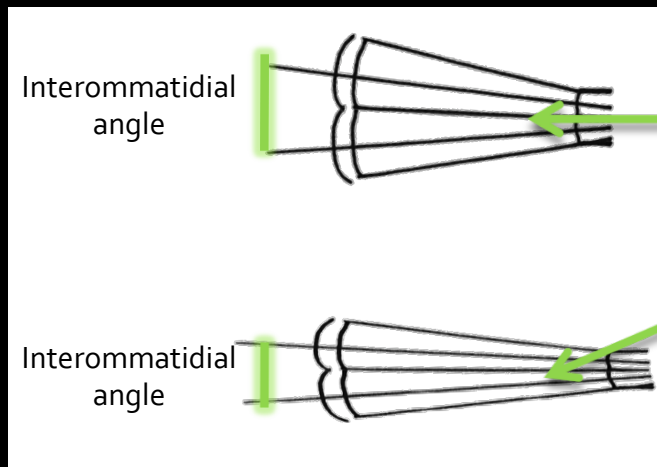
# Photoreceptor layout: different organization patterns



- ❖ The photoreceptors themselves can be arranged in specific ways, where the microvilli (the rhabdom) can be packed together, as is seen in this cross-section of the photoreceptors in the eye (left), called the open rhabdom
- ❖ The microvilli can also be separated (right), which is called the open rhabdom



# Resolution and the eye: all about structure



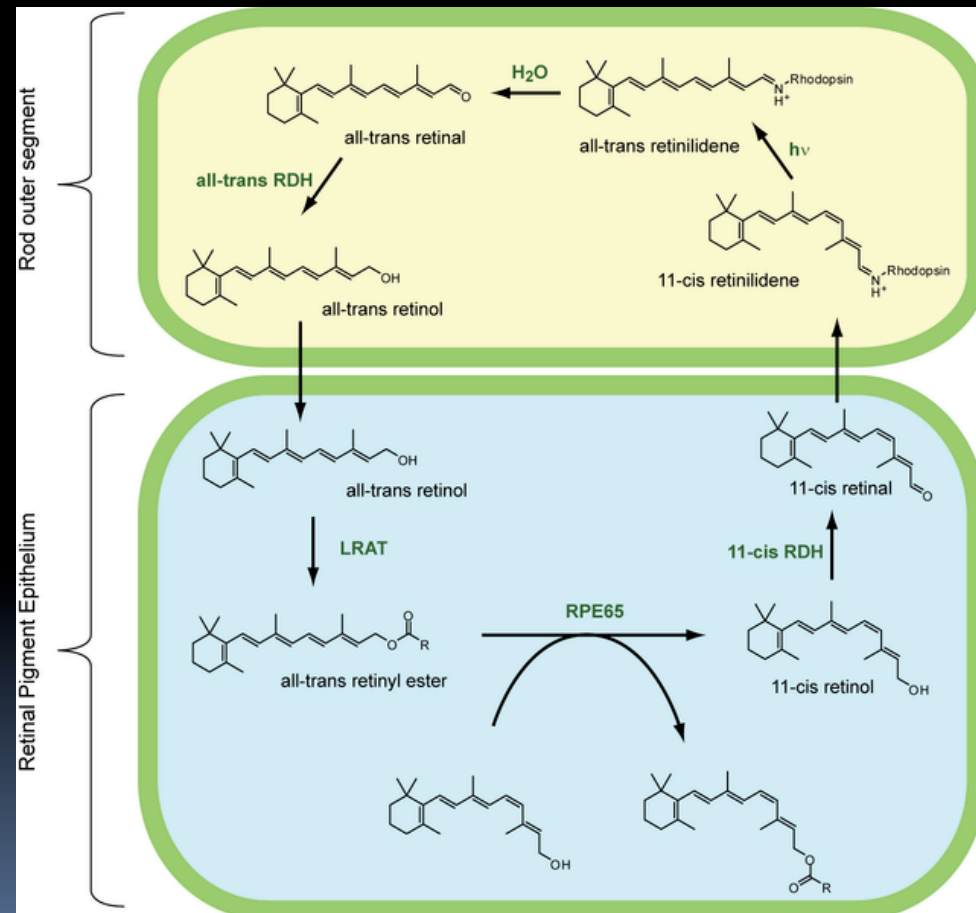
- The resolution of the eye depends on the angle between the facets of the compound eye (the interommatidial angle and whether the eye facets are facing the same direction).
- Many insects have high resolution areas, similar to the vertebrate fovea, where the interommatidial angle is low (nearly 1 degree), with the rest of the eye with low resolution (and an increased interommatidial angle)

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*Holcocephala fusca* Robber Fly

# How light is converted into a neural signal

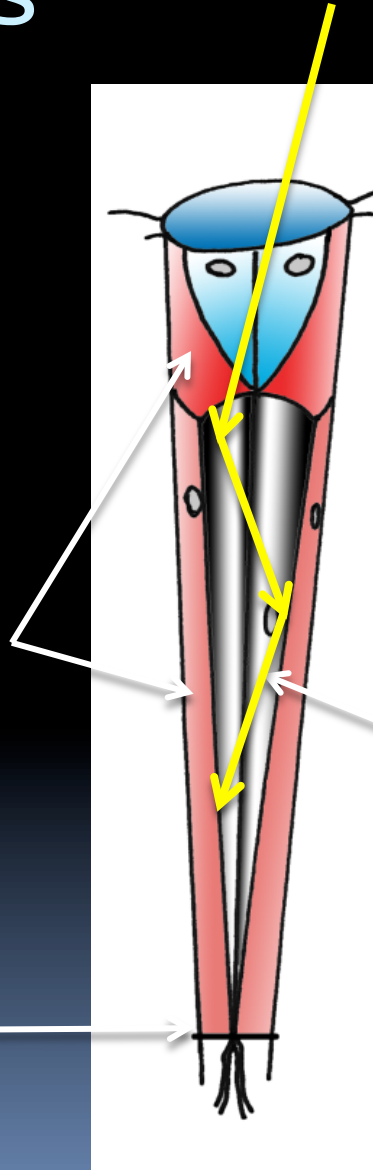
- ❖ The phototransduction mechanism is a series of reactions, where a molecule, retinal, changes shape with the introduction of light (in the process to the right).
- ❖ This conformational change is then translated into enzymatic changes (see Figure 22.8 in *Insects: Structure and Function*)
- ❖ These enzymatic changes induce a G-protein cascade, leading to the opening of channels and depolarization (or excitation) of the photoreceptors



# Dark and light adaptation: multiple ways

Redistribute pigment in the pigment cells:  
In light adapted eyes, the pigment is increased along the cartridge.  
Dark adapted eyes may have less pigment lining the pigment cells

Additional tracheation  
(forming a structure called a tapetum) is used in nocturnal insects to reflect photons into the photoreceptors and increase sensitivity



- Since insects have to experience a wide range of light conditions, the eye can have a series of adaptations to deal with strong light (called light adaptation) or dim conditions (dark adaptation)
- These adaptations are varied, with some adaptations involving mostly nocturnal insects.

Pigment in the photoreceptors can also be redistributed, to receive more or less light.



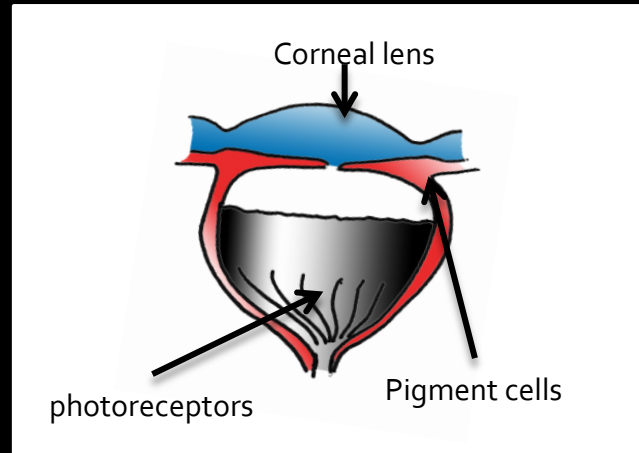
# The structure of the ocelli

Ocelli are single-lens eyes normally located on the top of the head (where there are normally three near each other)



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- Since the focus depth for most ocelli indicate they should not form images, ocelli are thought to be primarily light detectors, possibly to detect changes in the horizon.
- However, recent recordings in dragonfly ocelli have indicated they can be directionally selective, in an article entitled: Directional Selectivity in the Simple Eye of an Insect, by Joshua van Kleef, Richard Berry, and Gert Stange, in *The Journal of Neuroscience*, 28(11):2845-2855

# The structure of the stemmata

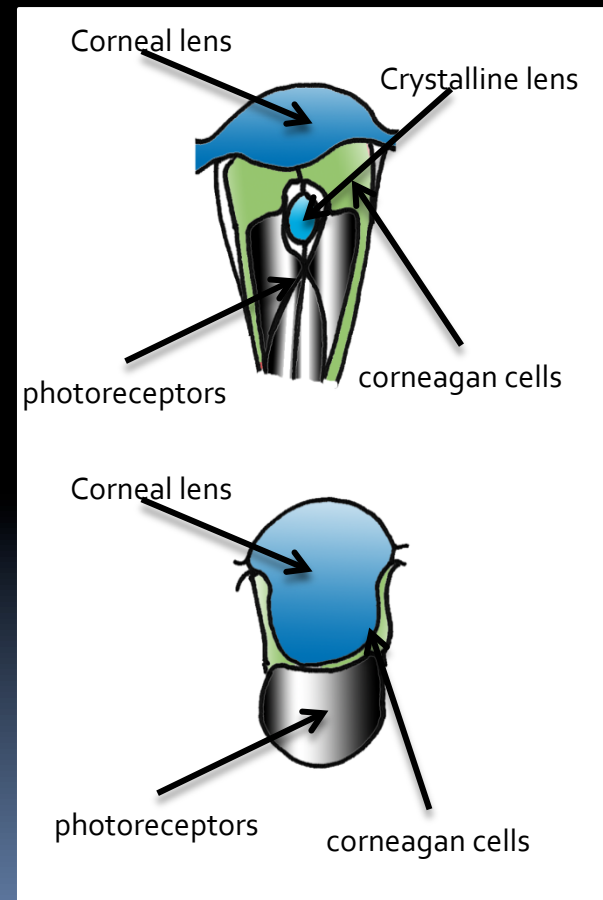
Stemmata are also single-lens eyes which are often found in holometabolous larvae on the sides of the head

Stemmata

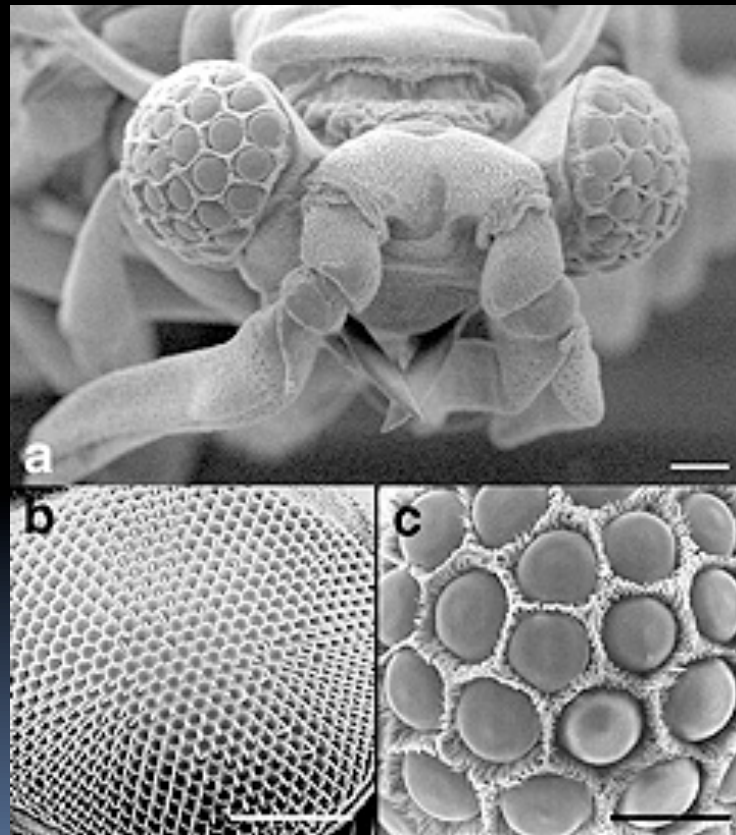


Thomas Shahan, <http://www.flickr.com/photos/opoterser/>

- Stemmata are also thought to be poorly developed for image formation, but can be used to detect light



Diversity of systems:  
there's not just one way to  
build an eye!



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<http://www.biology.uc.edu/faculty/buschbeck/elke.htm>