INSECT EYE (COCKROACH ONLY)

B.SC. ZOOLOGY (H)
SEMESTER- 2
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CORE COURSE: NONCHORDATE II-COELOMATES
TOPIC: INSECT EYE (COCKROACH ONLY)

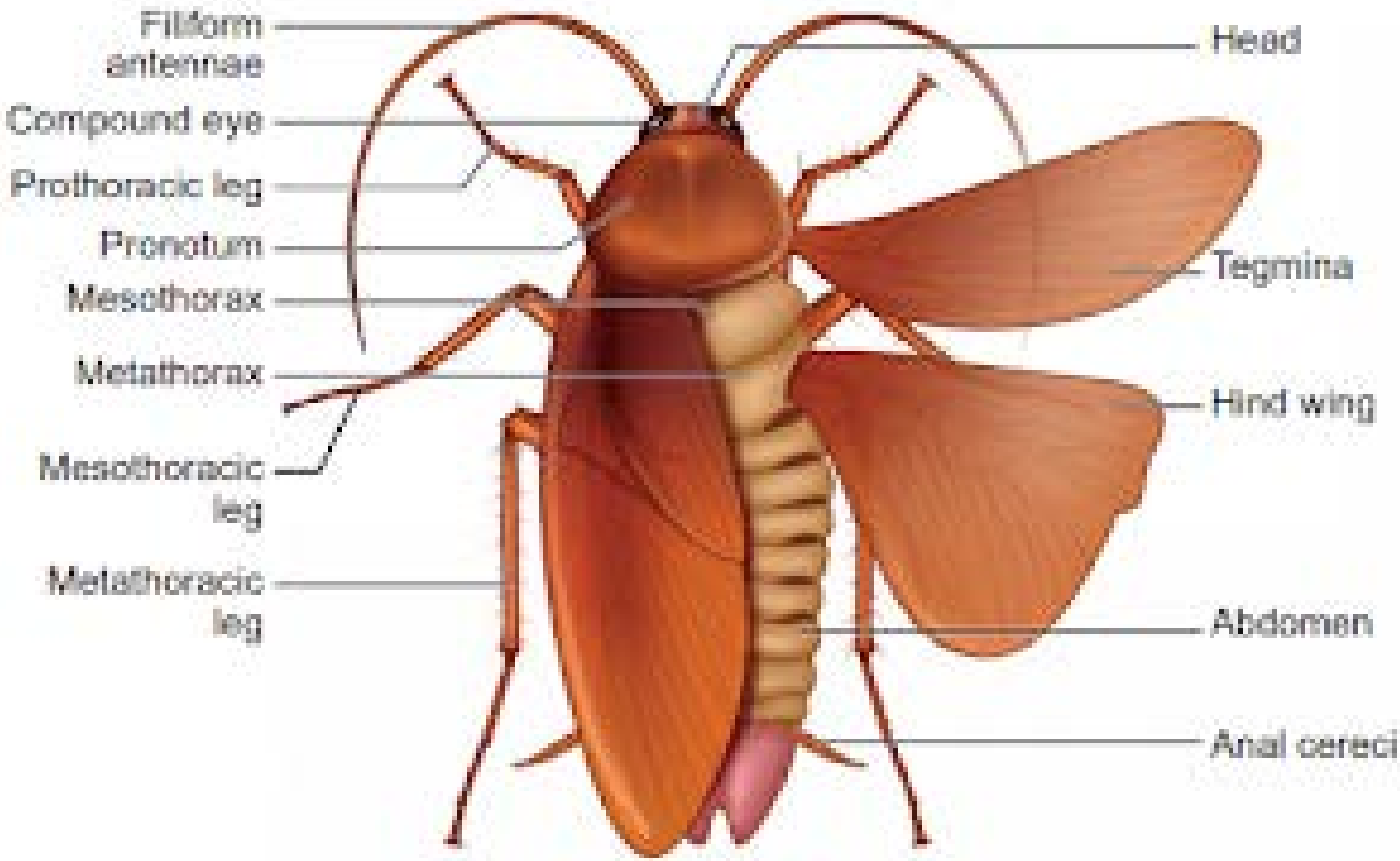
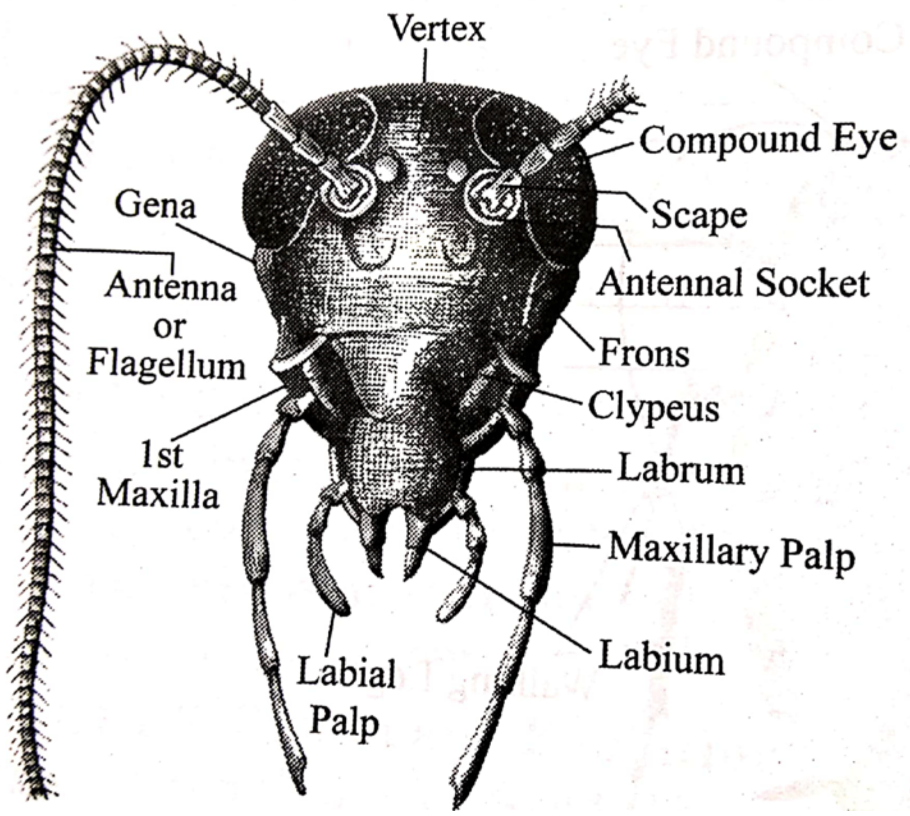


Fig. *Periplaneta* sp. (External Features)

EYES IN COCKROACH:

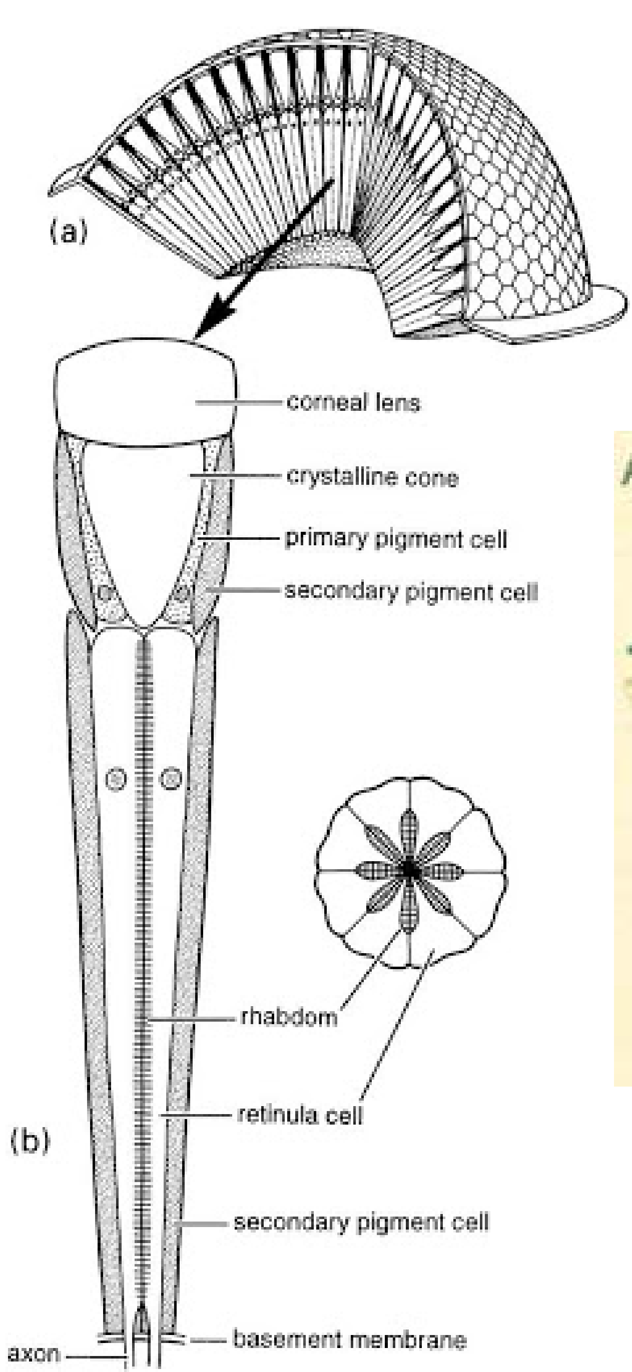


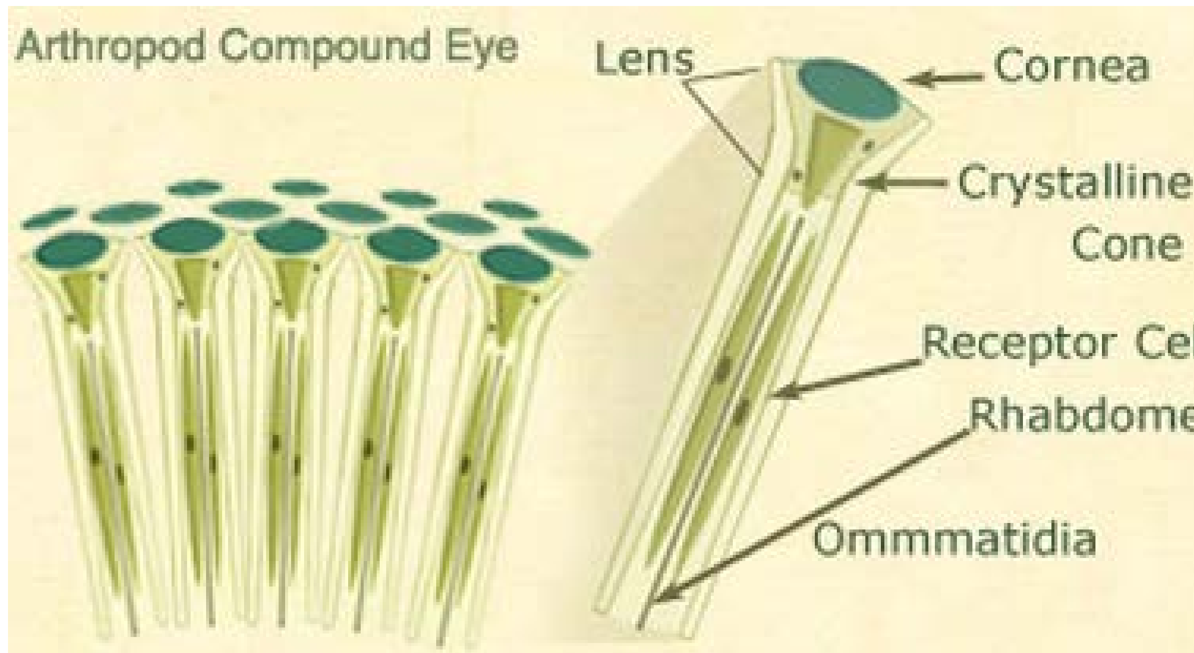
In Cockroach two prominent blackish, kidney shaped compound eyes are situated at the dorso-lateral parts of the head. Each compound eye contain several visual units, known as ommatidium. On the inner side of each compound eye there is a small pale area, known as fenestra or ocellar spot. These are thought to represent simple eyes or ocelli.

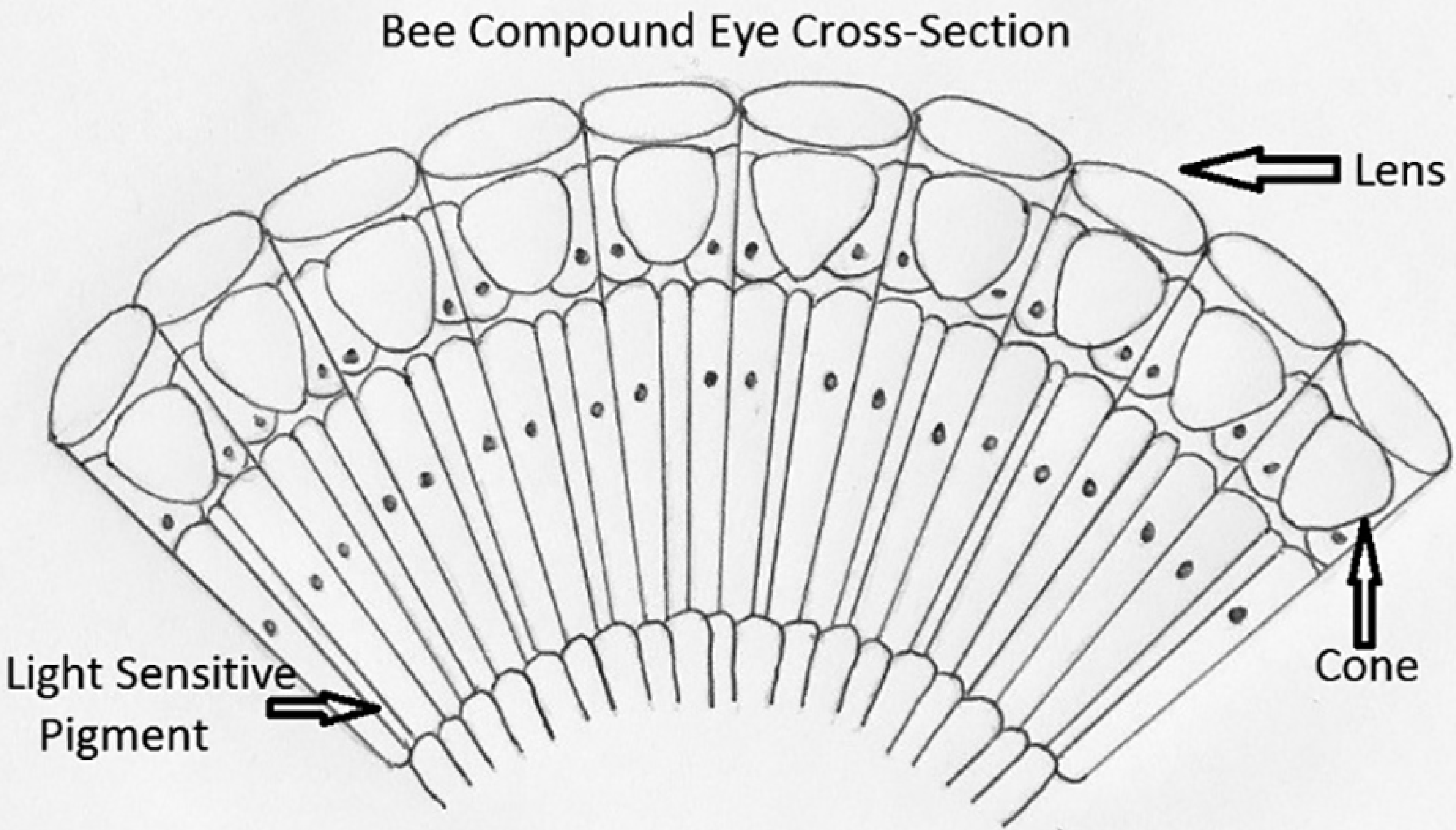
What are compound eyes?

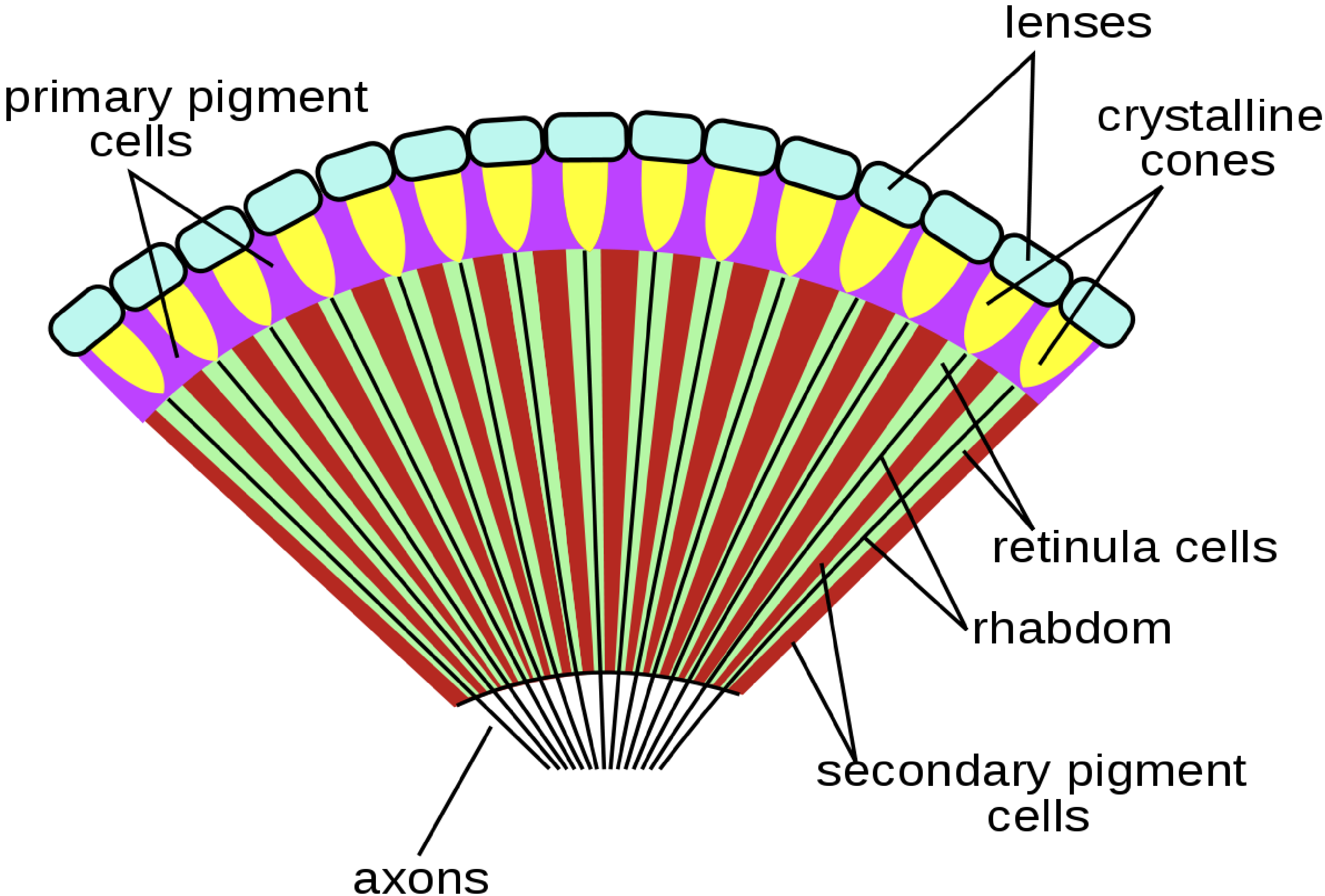
1. Compound eyes are formed by repeating the same basic units of photoreceptors called ommatidia.
2. An ommatidium has a lens and photoreceptive cells mainly, and the pigment cells separate each ommatidium apart from the neighbours.
3. However, compound eyes are capable of detecting motions as well as the polarization of sunlight, in addition to receiving light. The insects, especially honeybees have the ability to understand the time of the day using the polarization of the sunlight from their compound eyes.
4. There are few types of compound eyes known as Apposition, Superposition, Parabolic suspension, and some few more kinds.
5. The information about the images are formed through ommatidia is taken into the brain, and the whole image is combined there in order to understand the object in the apposition eyes.

6. The superposition eyes form the image by reflecting or refracting the light received via mirrors or lenses, and then the image data are transferred into the brain, to understand the object.
7. The parabolic suspension eyes use the principles of both apposition and superposition eyes. Most of the annelids, arthropods, and molluscs have compound eyes, and they can see colours, as well.


(a)
corneal lens
crystalline cone
primary pigment cell
secondary pigment cell
rhabdom
retinula cell
(b)
secondary pigment cell
basement membrane
axon


Arthropod Compound Eye
Lens
Cornea
Crystalline
Cone
Receptor Cell
Rhabdome
Ommmatidia


Bee Compound Eye Cross-Section
Lens
Cone
Light Sensitive Pigment


lenses
primary pigment cells
crystalline cones
retinula cells
rhabdom
secondary pigment cells
axons

1. The compound eye is based on repetition of many individual units called ommatidia.
2. Each ommatidium resembles a simple stemma: it has a cuticular lens overlying a crystalline cone, which directs and focuses light onto eight (or maybe 6–10) elongate retinula cells.
3. The retinula cells are clustered around the longitudinal axis of each ommatidium and each contributes a rhabdomere to the rhabdom at the center of the ommatidium.
4. Each cluster of retinula cells is surrounded by a ring of light-absorbing pigment cells, which optically isolates an ommatidium from its neighbors.
5. The corneal lens and crystalline cone of each ommatidium focus light onto the distal tip of the rhabdom from a region about 2–5 degrees across. The field of view of each ommatidium differs from that of its neighbors and together the array of all ommatidia provides the insect with a panoramic image of the world. Thus, the actual image formed by the compound eye is of a series of apposed points of light of different intensities, hence the name **apposition** eye.

6. The light sensitivity of apposition eyes is limited severely by the small diameter of facet lenses.
7. Crepuscular and nocturnal insects, such as moths and some beetles, overcome this limitation with a modified optical design of compound eyes, called optical superposition eyes. In these, ommatidia are not isolated optically from each other by pigment cells. Instead, the retina is separated by a wide clear zone from the corneal facet lenses, and many lenses co-operate to focus light on an individual rhabdom (light from many lenses super-imposes on the retina). The light sensitivity of these eyes is thus greatly enhanced.
8. In some optical superposition eyes screening pigment moves into the clear zone during light adaptation and by this means the ommatidia become isolated optically as in the apposition eye. At low light levels, the screening pigment moves again towards the outer surface of the eye to open up the clear zone for optical superposition to occur.
9. Because the light arriving at a rhabdom has passed through many facet lenses, blurring is a problem in optical superposition eyes and resolution generally is not as good as in apposition eyes.

10. Because the light arriving at a rhabdom has passed through many facet lenses, blurring is a problem in optical superposition eyes and resolution generally is not as good as in apposition eyes. However, high light sensitivity is much more important than good resolving power in crepuscular and nocturnal insects whose main concern is to see anything at all.
11. In the eyes of some insects, photon-capture is increased even further by a mirror-like tapetum of small tracheae at the base of the retinula cells; this refects light that has passed unabsorbed through a rhabdom, allowing it a second pass. Light reflecting from the tapetum produces the bright eye shine seen when an insect with an optical superposition eye is illuminated in the flashlight or car headlight beam at night.
12. In comparison with a vertebrate eye, the resolving power of insect compound eyes is rather unimpressive. However, for the purpose of flight control, navigation, prey capture, predator avoidance, and mate-finding they obviously do a splendid job.
13. Bees can memorize quite sophisticated shapes and patterns, and flies and odonates hunt down prey insects or mates in extremely fast, aerobatic flight.

14. Insects in general are exquisitely sensitive to image motion, which provides them with useful cues for avoiding obstacles and landing, and for distance judgment.
15. Insects, however, cannot easily use binocular vision for the perception of distance because their eyes are so close together and their resolution is quite poor. A notable exception is the praying mantid, which is the only insect known to make use of binocular disparity to localize prey.
16. Within one ommatidium, most studied insects possess several classes of retinula cells that differ in their spectral sensitivities; this feature means that each responds best to light of a different wavelength. Variations in the molecular structure of visual pigments are responsible for these differences in spectral sensitivity and are a prerequisite for the color vision of flower visitors such as bees and butterflies.
17. Some insects are pentachromats, with five classes of receptors of differing spectral sensitivities, compared with human di- or trichromats. Most insects can perceive ultraviolet light (which is invisible to us) allowing them to see distinctive alluring flower patterns visible only in the ultraviolet.

18. Light emanating from the sky and reflected light from water surfaces or shiny leaves is polarized, i.e. it has greater vibration in some planes than in others. Many insects can detect the plane of polarization of light and utilize this in navigation, as a compass or as an indicator of water surfaces. The pattern of polarized skylight changes its position as the sun moves across the sky, so that insects can use small patches of clear sky to infer the position of the sun, even when it is not visible.
19. In like manner, an African dung beetle has been shown to orientate using polarized moonlight in the absence of direct sighting of the moon, perhaps representing a more general ability amongst nocturnal insects.
20. The microvillar organization of the insect rhabdomere makes insect photoreceptors inherently sensitive to the plane of polarization of light, unless precautions are taken to scramble the alignment of microvilli.
21. Insects with well-developed navigational abilities often have a specialized region of retina in the dorsal visual field, the dorsal rim, in which retinula cells are highly sensitive to the plane of polarization of light.
22. Ocelli and stemmata also may be involved in the detection of polarized light.

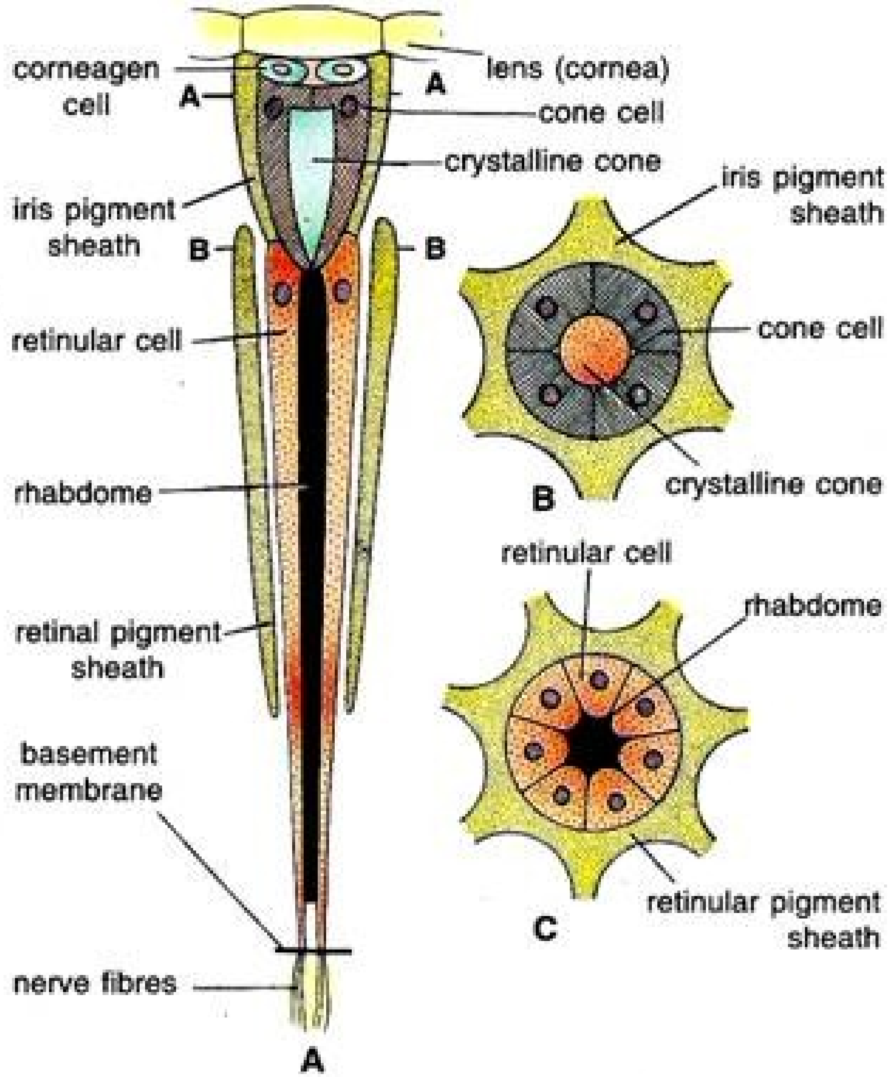


Fig. 73.30. *Periplaneta.* A—L.S. of an ommatidium ; B—T.S. through cone at A—A ; C—T.S. through rhabdome at B—B.

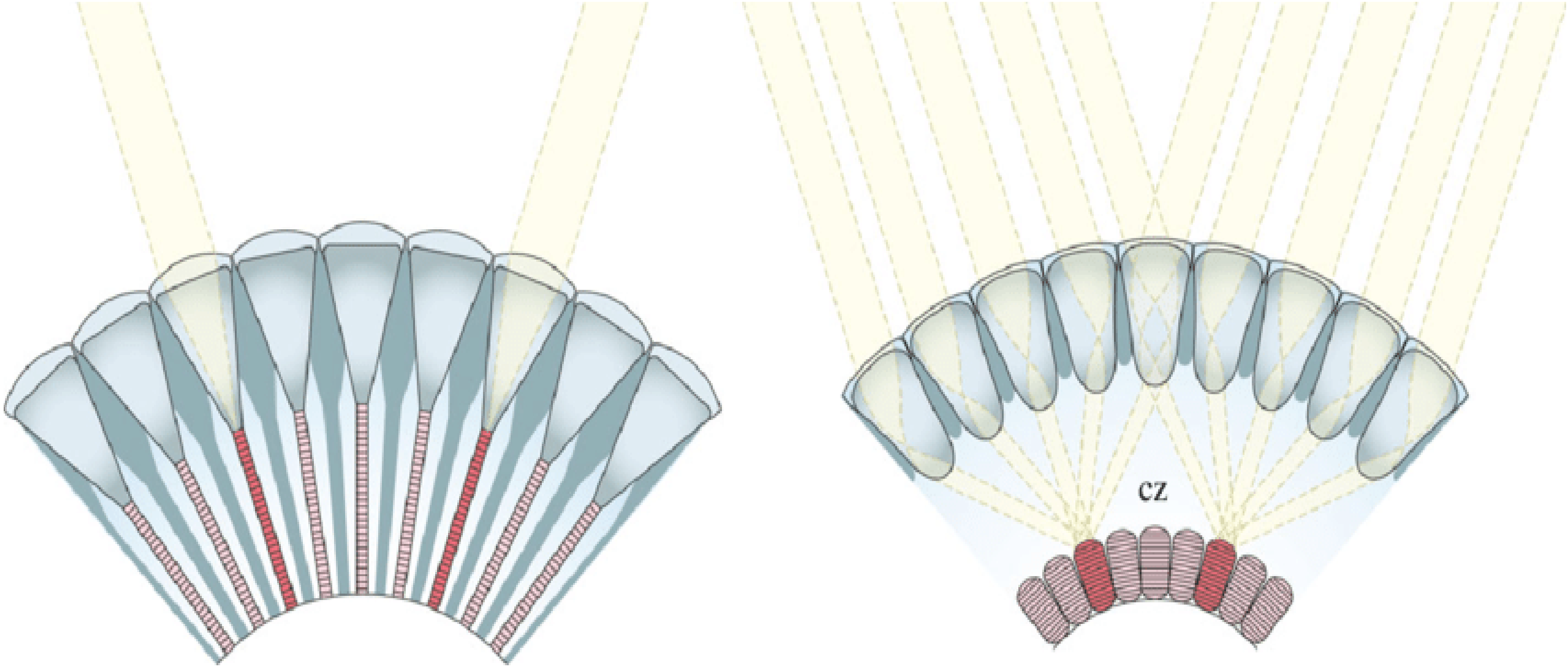


Fig. Comparison of Apposition & Superposition eyes/ images

Distribution of Compound Eye:

1. The absence of compound eyes in most of the Apterygota.—
2. Typically insects possess both ocelli and compound eyes; when either kind of eyes is wanting it is evidently due to a; loss of these organs and not to a generalized condition.
3. Although compound eyes are almost universally absent in the Apterygota-in the few cases where they are present in this group they are of a highly developed type and not rudimentary; the compound eyes of Machills, for example, are as perfect as those of winged insects.

Why compound eyes are absent in 1arvae?

1. The absence. of compound eyes in larva is evidently a secondary adaptation to their particular mode of life, like the internal development of wings in the same forms.
2. In the case of the compound eyes of larva, the development of the organs is retarded, taking place in the pupal stage instead of in an embryonic stage, as is the case with nymphs and naiads.
3. While, the development of the compound eyes as a whole is retarded in larva, a few ommatidia may be developed and function as ocelli during larval life.

What are simple eyes?

1. Although the name suggests some simplicity, the simple eyes are not simple in photosensitivity and accuracy but only in the structure.
2. Simple eyes are found in many phyla of the animal kingdom including the vertebrates and invertebrates.
3. There are few types of simple eyes known as Pit eyes, Spherical lens eyes, Multiple lenses, Refractive cornea, and Reflector eyes.
4. Pit eyes are the most primitive of all types of eyes, and there is a small depression with a collection of photoreception cells. It is important to notice that pit vipers have pit eyes to sense the infrared radiation of their prey animals.
5. The spherical lens eyes have a lens in the structure, but the focal point is usually behind the retina, causing a blur image to detect the intensity of light.
6. Multiple lenses simple eyes are an interesting type with more than one lens in the eye, which enables them to enlarge the picture and get a sharp and focused image. Certain predators such as spiders and eagles are good examples for this type of lens arrangement.

7. The eyes with a refractive cornea have an outer layer of a light penetrating substance, and the lens is not usually spherical, but its shape could be changed according to the focal lengths.
8. Reflector eyes are a wonderful phenomenon that provides a common communication platform for other organisms, as well. The image formed in one's eye is reflected onto another place so that the other organisms could see it.
9. All these types of simple eyes function in taking the information with regard to light to sustain the body. Despite all these being simple eyes, all the higher vertebrates including humans have simple eyes.

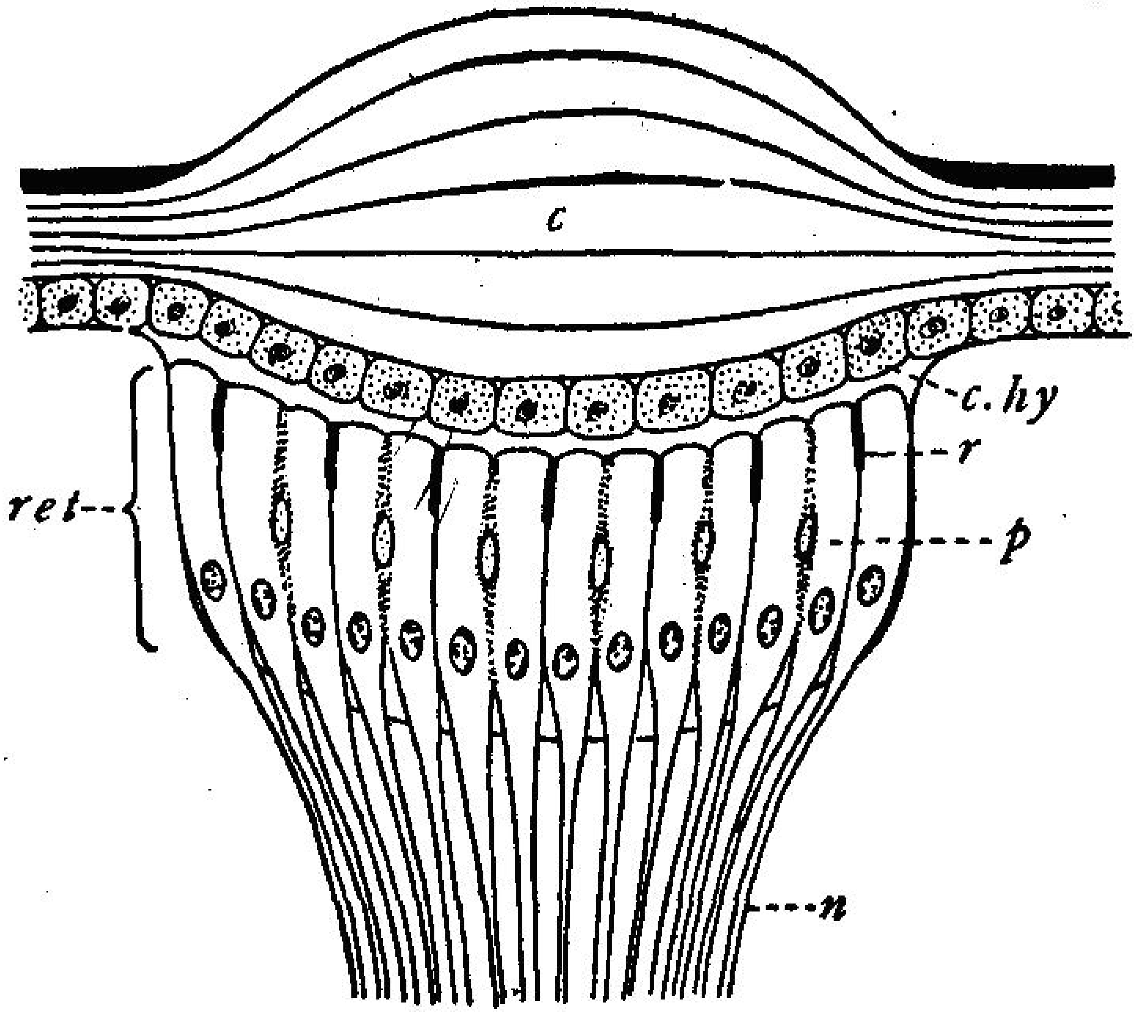


Fig. 154.—A diagram illustrating the structure of a primary ocellus; *c*, cornea; *c. hy*, corneal hypodermis; *ret*, retina; *n*, ocellar nerve; *p*, accessory pigment cell; *r*, rhabdom.

Ocelli

1. Many adult insects, as well as some nymphs, have dorsal ocelli in addition to compound eyes. These ocelli are unrelated embryologically to the stemmata. Typically, three small ocelli lie in a triangle on top of the head.
2. The cuticle covering an ocellus is transparent and may be curved as a lens. It overlies transparent epidermal cells, so that light passes through to an extended retina made up of many rhabdoms (Fig. 4.9).
3. Individual groups of retinula cells that contribute to one rhabdom or the complete retina are surrounded by pigment cells or by a reflective layer.
4. The focal plane of the ocellar lens lies below the rhabdoms so that the retina receives a blurred image.
5. The axons of the ocellar retinula cells converge onto only a few neurons that connect the ocelli to the brain.
6. In the ocellus of the dragonfly *Sympetrum*cells converge onto one large neuron, two medium-sized neurons, and a few, some 675 receptor small ones in the ocellar nerve.

7. The ocelli thus integrate light over a large visual field, both optically and neurally. They are very sensitive to low light intensities and to subtle changes in light, but they are not designed for high-resolution vision. They appear to function as “horizon detectors” for control of roll and pitch movements in flight and to register cyclical changes in light intensity that correlate with diurnal behavioral rhythms.

No. of Ocelli usually present in insect

1. Typically two pairs of ocelli; but almost invariably the members of one pair of ocelli are united and form a single median ocellus.
2. The median ocellus is absent in many insects that possess the other two ocelli.

	Compound Eyes	**Simple Eyes**
1.	Made up of clusters of ommatidia	Made up of only one single unit of eye
2.	Found in most of the Arthropods, Annelids and Mollusc	Found among many types of organisms including most of the higher vertebrates.
3.	Cover a wider angle compared to simple eyes	Lesser angle covered
4.	Less diversified	More diversified
5.	Polarization of sunlight could be understood via compound eyes	Polarization not understood
6.	Crystaline cone is present, corneal hypodermis absent	Crystaline cone is absent, corneal hypodermis present
7.	Function in image formation both in diurnal and nocturnal insects.	Eyes function in taking the information with regard to light to sustain the body, not in image forming

Stemmata

1. The only visual organs of larval holometabolous insects are stemmata, sometimes called larval ocelli. These organs are located on the head, and vary from a single pigmented spot on each side to six or seven larger stemmata, each with numerous photoreceptors and associated nerve cells.
2. In the simplest stemma, a cuticular lens overlies a crystalline body secreted by several cells. Light is focused by the lens onto a single rhabdom. Each stemma points in a different direction so that the insect sees only a few points in space according to the number of stemmata.
3. Some caterpillars increase the field of view and fill in the gaps between the direction of view of adjacent stemmata by scanning movements of the head.
4. Other larvae, such as those of sawflies and tiger beetles, possess more sophisticated stemmata. They consist of a two-layered lens that forms an image on an extended retina composed of many rhabdoms, each receiving light from a different part of the image. In general, stemmata seem designed for high light sensitivity, with resolving power relatively low.

THE END