Evolution of the Eye

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Abstract

'The eyes are the window to the soul.' A philosophical saying reflecting the emotional expression such a small, yet complex organ is capable of. The evolution of the eye has been greatly debated among scientists for centuries, with the eye infamously being used against Charles Darwin's theory of evolution by natural selection. Darwin himself confessed within 'On the Origin of Species' (1859) that it was 'absurd' to claim the eye has evolved via natural selection. '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,' Darwin found it difficult to explain the evolution of such a complex and nuanced organ. The eye serves as the single sensory organ responsible for the detection of light, and ultimately allows us to see. The complex anatomy of the eye, paired with its interactions with the brain to translate electrical signals into images, makes the evolution of the eyes over millenniums, fascinating.

Introduction

The first eyes emerged 541 million years ago during the Cambrian Period; a very important period known for the diversity of lifeforms which emerged during a relatively short time. It marked the first time when major groups of animals first appeared in fossil records. Before this time, many Cambrian ancestors didn't contain eyes at all – This suggests a rapid evolution from lifeforms without eyes, to organisms containing light sensitive organs able to help them survive. The inherent complexity of the eye, through the necessity to assort 6 general components, makes its relatively quick formation extremely unique to other organs. We can also observe the diversity in types of eyes amongst different organisms, with each eye evolved over centuries to adapt to specific environments and lifestyles. The primary categories of eyes include Ocelli, Compound Eyes and Camera-Type Eyes; these will all be examined in depth. With the variation of eyes amongst differing organisms, comes the varying levels of sight. Humans possess 3 types of cones within their eyes: red, blue and green, which allows us to form thousands of shades of colors. Other organism may only contain 2 or even 1 type of cone, which may grant them with other survival advantages such as seeing better at night. This article will begin by detailing the specific function of the eye in addition to its complex structure; this will allow for explaining the mechanism of light detection. It will go on to explore evolution through the first traces of sight, from organisms just having photoreceptive cells, to the modern day, with the great variety of unique eyes possessed by different organisms.

The Anatomy and Function of the Eye

The human eye (A non-compound type of eye) is made up of 6 general components: the cornea, iris, lens, optic nerve, pupil and retina. Initially, light enters through the cornea of the eye; this transparent, dome shaped tissue, refracts light onto the lens. As the light travels towards the lens, it passes through the pupil and past the iris. The iris controls the amount of light which can enter the eye, while the pupil is a hole in the iris allowing light to pass through onto the lens. The lens then bends and focuses this light onto the retina. The retina captures the light and transmits it into electrical and chemical signals. These can form a visual image which are transported to the brain via the optic nerve. The occipital lobe in the brain, then processes these visual signals to convert them into images we can see.

Visualizing objects by continuously producing images, serves as the most important function of the eye. Further functions include the role of the pupils in adjusting the amount of light that enters the eye, as well as the ability for the eye to focus on near and far objects (Accommodation). Pupil dilation (Mydriasis) and pupil constriction (Miosis) are involuntary responses of the eye, crucial in protecting the retina under differing light conditions. During Mydriasis, the pupil enlarges, allowing more light to enter the eye and focus onto the retina. This occurs mainly in low light conditions, or during emotional responses such as the release of adrenaline. Miosis is the opposite of pupil dilation; during constriction, the pupil becomes smaller, reducing the amount of light that enters the eye. This occurs in bright light conditions, which can help minimize damage to the retina.

Eye accommodation is another function of the eye, which allows us to see objects at different distances. It works by adjusting the shape of the lens through the control over the ciliary muscles and the suspensory ligaments. When observing objects near us, a fatter lens is required to allow more refraction of light to focus onto the retina. When observing objects much further away, less refraction is needed, meaning a thinner lens can let the light focus on the retina.

Through the complex nature of both the anatomy of the eye, as well as its many involuntary functions in both protecting the eye and helping us visualize objects, it is clear the evolution from organisms without eyes is a complicated yet intriguing process.

Evolution of the Simple Eye

The precursors to the eye were found in single celled organisms. Over 600 million years ago, certain lifeforms would have had ‘photoreceptive cells,’ allowing them to detect light rather than physically see. The ability to detect light gave these organisms survival advantages, through their ability to orient themselves towards the sun as well as detect predators and food sources.

Around 60 million years later, the Cambrian period brought about organisms with more complex body structures. During this explosion in evolution, the birth of ‘ocelli’ in certain invertebrates began. These very simple eyes still exist in many invertebrates today and consist of a single lens and light sensory cells. They don’t have many complex structures like the human compound eye, and their lack of a retina means they are unable to constantly form complex images. The sole ability for ocelli both during the Cambrian period and even today, is either as a method of light intensity detection, or a way to maintain flight stability.

During this period, the ocelli would further evolve into a cupped shape, and gain pigment cells. The cup shape allowed it easier for organisms to detect the direction of the light, while the pigment cells further enhanced the detection of light intensity.

Emergence of the Compound Eye

Following the development of the ocelli, organisms such as trilobites began showing the formation of newly specialized eyes. This moves from simple to compound eyes, with the lens allowing light to focus onto photoreceptive cells, providing a greater width of vision. This evolutionary advantage allowed trilobites to have a complete view of the ocean flaw, allowing them to forge for food and hide from predators.

During this time, other organisms had begun evolving to form ‘simple camera-type eyes;’ mollusk fossil show us camera-type eyes didn’t just use photoreceptive cells, but also a simple form of a retina. Unlike in compound eyes, where the retina can convert light into electrical signals, camera-type eyes contain retinas as merely layers of photoreceptive cells. Similarly to trilobites, their development of a lens allowed greater focus of light onto their retina, and a more detailed level of image production.

Over time, the further development of structures such as the cornea, iris and macula aided visual acuity for organisms. The more detailed images with a wider range of view allowed longer survival vis natural selection. On top of this, even more intricate structures such as ciliary muscles, suspensory ligaments, circular and radial muscles, all developed to help with pupil movements and accommodation.

Modern Day

Today, the variation of eye types amongst organisms and species is huge. The existence of not just ocelli and compound eyes, but pinhole eyes, mirror eyes, reflector eyes and even having multiple eyes shows Darwin’s theory of evolution by natural selection in real time. With the introduction of climate change, the changing habitats for animals will lead to a necessity for a greater depth and field of vision. Improved color vision paired with greater acuity is expected to help animals survive longer in the changing conditions. Eyes have interestingly been increasingly involved in sexual selection, where certain color iris may help animals attract mates much more easily.

Conclusion

Fundamentally, the evolution of the eyes over millenniums has been fascinating. Its initial structure of only containing photoreceptive cells being able to evolve dramatically in the Cambrian Period to form Ocelli and even compound eyes show the beauty of evolution. Eyes serve as important organs in our daily lives, allowing us the sense of sight which aids us with daily activities as well as survival. The constant evolution of eyes even up to today and into the future will provide our species and other organisms the ability to survive and continue to thrive on this earth.

References

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