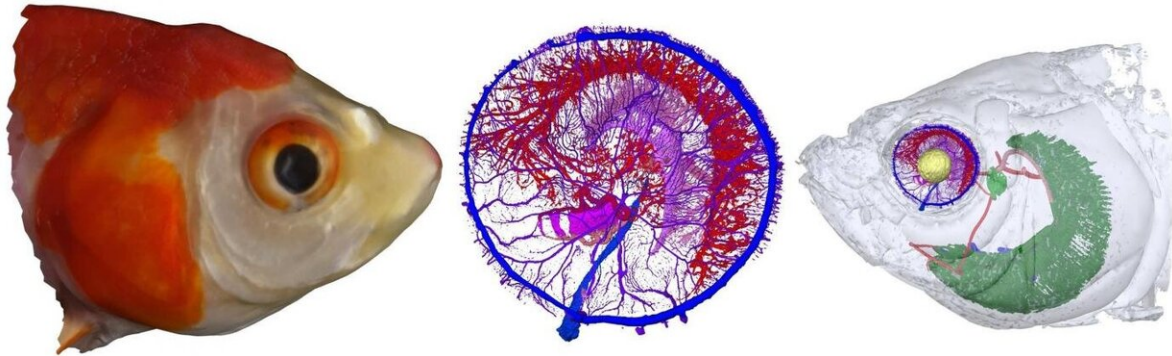


Oxygen shaped the evolution of the eye

December 10 2019



Vascular networks in the retina of a goldfish. The retinal vasculature is divided into the separate layers. Capillaries on the outer side of the retina (red and pink), capillaries on the inner side of the retina (purple and blue), and capillaries inside the retina (not found in the goldfish). For more details, see the interactive model of the goldfish vasculature on Supplementary File 4

<https://doi.org/10.7554/eLife.52153> - Supplementary File 4. Credit: Henrik Lauridsen, AU

Convergent origins of new mechanisms to supply oxygen to the retina were directly linked to concurrent enhancements in the functional anatomy of the eye.

In his *On the Origin of Species*, Darwin used the complexity of the eye to argue his theory of natural selection, and the eye has continued to fascinate and trouble evolutionary biologists ever since.

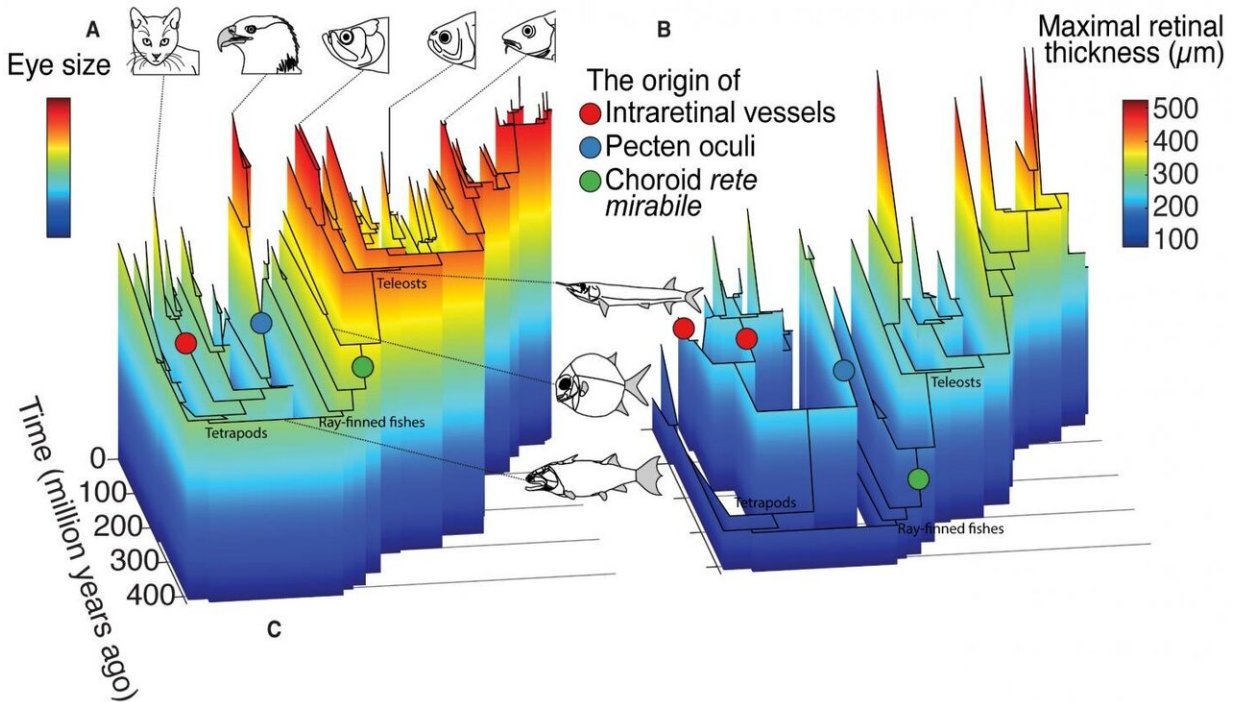
In a paper published today in *eLife*, researchers from Aarhus University teamed up with scientists from eight international institutions to explore the physiological requirements for the [evolution](#) of improved eyesight.

They argue that the evolution of high-acuity vision in ancestral animals was constrained by the ability to deliver sufficient amounts of [oxygen](#) to cells in the retina. Their study uncovered a fascinating pattern of mechanisms to improve retinal oxygen supply capacity that evolved in concert with enhanced retinal morphology to improve vision. The model fits across all bony vertebrates from fish through to birds and mammals. These findings add an additional component to our understanding of the evolution of the eye, which has fascinated and troubled evolutionary biologists for centuries.

The rises and falls of retinal oxygen supply

The study took advantage of the diversity in the physiology and anatomy among eyes from 87 [animal species](#), including fishes, amphibians and mammals. By placing these species on the tree of life, the authors unravelled the evolutionary history of the eye from a 425 million-year-old extinct ancestor of modern vertebrates to current day animals. They identified three distinct physiological mechanisms for retinal oxygen supply that are always associated with improved vision. Thus, in fishes, mutations in haemoglobin were associated with the ability to deliver oxygen to the retina at exceptionally high oxygen partial pressures to overcome the significant diffusion distance to the retinal cells.

The authors show that the origin of this mechanism around 280 million years ago was associated with a dramatic increase in eye size and retinal thickness that directly links to improved light sensitivity and spatial resolution. This mechanism in hemoglobin was subsequently lost several times, possibly to avoid oxidative damage and gas bubble formation in the eye.



The evolution of the size of the eye (A) and retina (B). The evolution of structures to supplement retinal oxygen supply to tightly coupled to the evolution of large eyes and a thick retina. The pectens oculi is a vascular structure found in the eyes of birds, the choroid rete mirabile is a gas-gland found in the eyes of fishes, and intra-retinal capillaries are found in some mammals, including humans. Credit: Christian Damsgaard, AU

Warm blooded dinosaurs shaped the vision of mammals

The authors show that increased reliance on vision in mammals was associated with the evolution of capillary beds inside the retina despite the potential trade-off to [visual acuity](#) imposed by the bending of light by red blood cells.

Retinal capillaries in mammals originated around 100 million years ago

when dinosaurs evolved endothermy. Endothermy allowed these Mesozoic dinosaurs to hunt at night, which forced the previously nocturnal mammals into a diurnal lifestyle with an increased reliance of vision.

The new model on eye evolution shows that the evolution of intra-retinal capillaries coincided precisely with the improvements in vision around 100 million years ago. Further, it shows that some mammals lost retinal capillaries when they became less reliant on [vision](#) (e.g., echolocating bat).

Oxygen and vision go hand in hand

Overall, this analysis shows that the functional morphology of the eye has changed dynamically throughout animal evolution. It shows that eye morphology goes hand in hand with parallel changes in retinal oxygen supply, and they are likely driven by different tradeoffs to retinal oxygen supply. These tradeoffs appear acceptable in place of the improved visual acuity available when the thickness of the retina was allowed to increase.

Overall, this study shows that adaptations to ensure oxygen delivery to the retina were a physiological prerequisite for the functional evolution of the eye.

More information: Christian Damsgaard et al, Retinal oxygen supply shaped the functional evolution of the vertebrate eye, *eLife* (2019). [DOI: 10.7554/eLife.52153](https://doi.org/10.7554/eLife.52153)

Provided by Aarhus University

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