Can Complex Adaptations Evolve?

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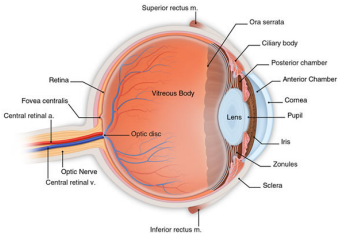
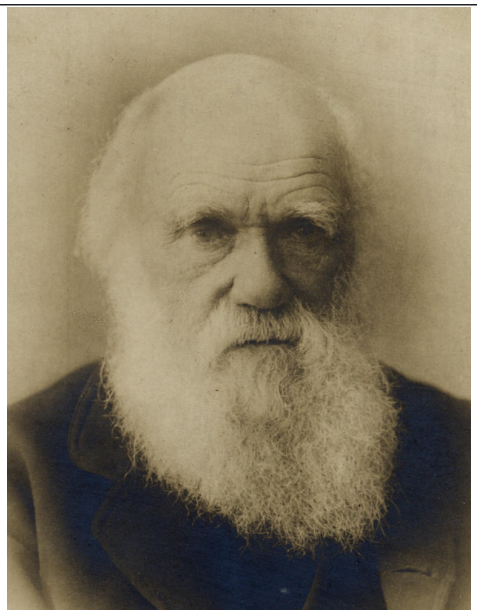
Irreducible complexity



- Lens useless without retina
- Retina useless without lens
- Each part requires the others.
- How does selection favor a partial eye?

Charles Pritchard
(1866)

First to argue that vertebrate eye could not plausibly evolve.



Charles Darwin

First to refute Pritchard's argument (1872).

Yet the argument just won't die.

The weakness of arguments about implausibility

- Pritchard's claim is about plausibility.
- To refute it, we only need to invent a plausible story in which eyes do evolve.
- No evidence is needed.
- The story does not even need to be true.

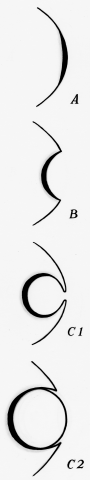
Fleeming Jenkin (1867) argues that complicated organs could not be "useful before fully developed." Yet as he goes on to say,

> *the believer who is at liberty to invent any imaginary circumstances, will very generally be able to conceive some series of transmutations answering his wants. . . . Feeling the difficulty of dealing with adversaries who command so huge a domain of fancy, we will abandon these arguments, and trust to those which at least cannot be assailed by mere efforts of imagination.*

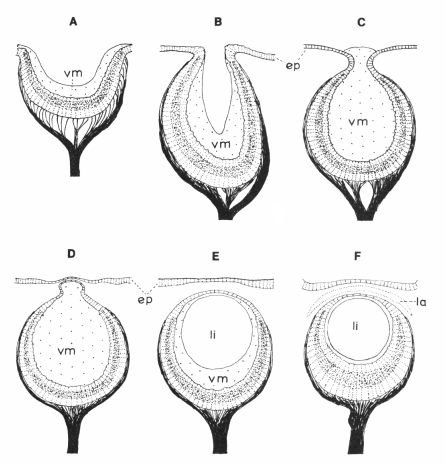
But Jenkin's sneer is misplaced. To demonstrate plausiblity, all we need is a plausible story.

Hypothetical steps in evolution of eye

A eye spot
B eye cup
C1 pin-hole camera eye
C1 primitive lens



Are these steps plausible?



Yes! They can all be found in living organisms today.

Conclusion: eye evolution *is* plausible.

Pritchard was wrong!

But what really happened?

How can we find out?

Darwin's story makes a prediction

1. Retinas evolved early.
2. Lenses evolved late.

We can test this prediction using similarities and differences among the eyes of living animals.

Traces of common descent

We resemble close relatives because of genes we inherited from common ancestors.

It is the same with species.

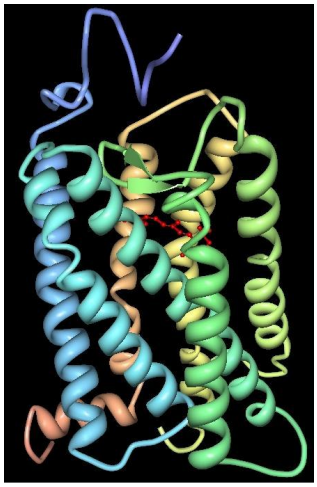
Using such similarities, let us work out the evolutionary history of eyes.

Many eyes resemble ours

But some of this is misleading.

Let's start simple—with proteins.

Opsins: light-sensitive proteins



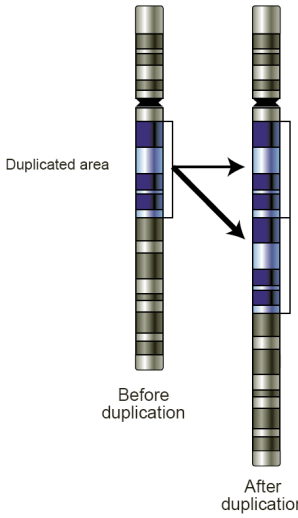
Nature makes several kinds of light-sensitive protein.

Yet all animals that see do so with one type: opsins.

Did all these evolve from a single primordial opsin?

If so, then related species should have similar opsins. Do they?

Why we have several kinds of opsin



When cells divide, the DNA duplicates.

Sometimes the machinery stutters, and some DNA is copied twice.

We may end up with two copies of some gene, and the new copy may evolve a new function.

Eventually, we end up with a family of related genes.

What you have in common with apes and old world monkeys

- One opsin adapted to dim light.
- Three for color vision.

Most mammals only have 2 opsins for color vision.

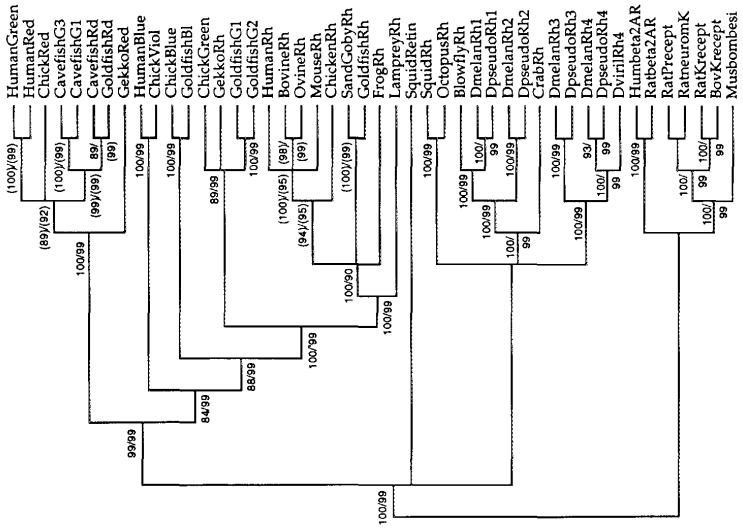
One of these must have duplicated in the common ancestor of apes, humans, and old world monkeys.

The usual mammalian condition

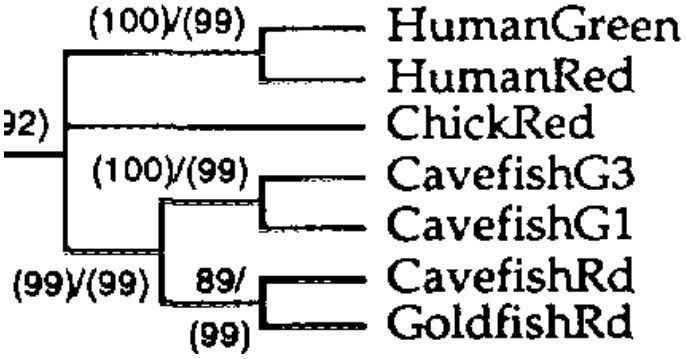
Most mammals only have 2 opsins for color vision.

Yet most other vertebrates have 4.

2 must have been lost in common ancestor of all mammals.



A branch of the opsin tree



(Chang, Crandall, Carulli, and Hartl, 1995)

Traces of common descent in opsins

Closely related species have closely similar opsin molecules.

They are also similar in the number of types of opsin.

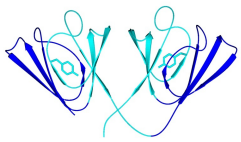
This pattern of nested similarities goes all the way back to the original opsin.

Our opsins have similarities with those of insects and cephalopods.

All opsins show evidence of common descent.

All eyes had a single origin.

Crystallins: lens proteins



Transparent proteins used in lens and cornea.

If lenses evolved early, then humans and insects should have similar crystallins.

But if lenses evolved late, . . .

Traces of common descent in crystallins

- Evidence of common descent throughout vertebrates.
- Yet insects have very different crystallins.
- So do cephalopods.

It appears that lenses evolved late.

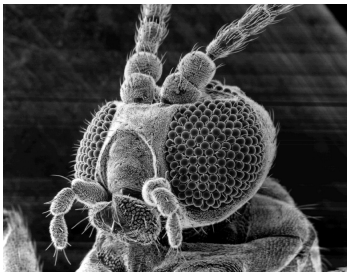
What about eye morphology?

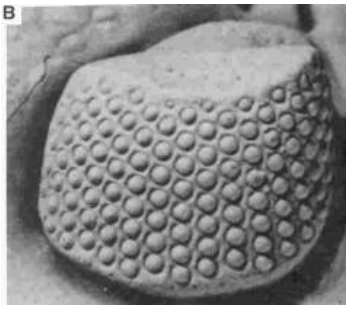
All vertebrates have eyes like cameras.

Canis familiaris

Pempheris japonica

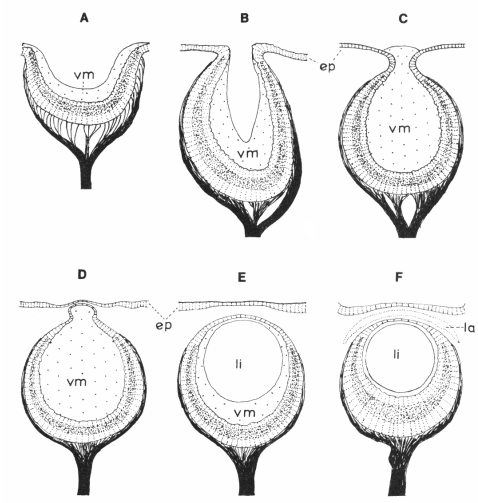
All arthropods have compound eyes.





Even this trilobite.

Yet snails have an amazing variety of eyes.



Heteropod sea snails

Have eyes like slits.

Field of vision 180° wide but just a few degrees high.

Eye scans rapidly up and down to assemble image.

Traces of common descent in eye morphology

Closely related animals have closely similar eyes.

Yet these resemblances do not extend back as far as with opsins.

Like lens proteins, eye morphology evolved relatively recently.

Darwin's "just so" story

It seems that retinas evolved early, and that lenses and complex eyes evolved late, just as Darwin suggested.

Complex adaptations can evolve in small individually-adaptive steps.

Conclusions

Much of the public is still skeptical about evolution of complex adaptations.

Yet evidence is now strong.

Many early objections have faded in importance.

Perhaps this one will too.