

S. microcephalus

Greenland shark

Lifespan

~400 yrs

longest-living vertebrate

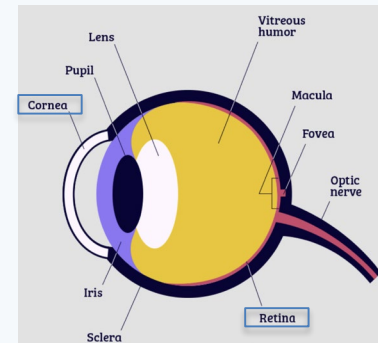
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Paper Presentation | 4-step argument

The visual system of the longest-living vertebrate, the Greenland shark

How a four-step argument overturns the assumption of a degenerating eye

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MOTIVATION

Can a 400-year-old shark still see?

The Greenland shark is the longest-living vertebrate, but lives in one of the harshest sensory environments on Earth: cold, dim, deep, and with a cornea often obscured by parasites. Has its visual system been lost?

PRIOR ASSUMPTION

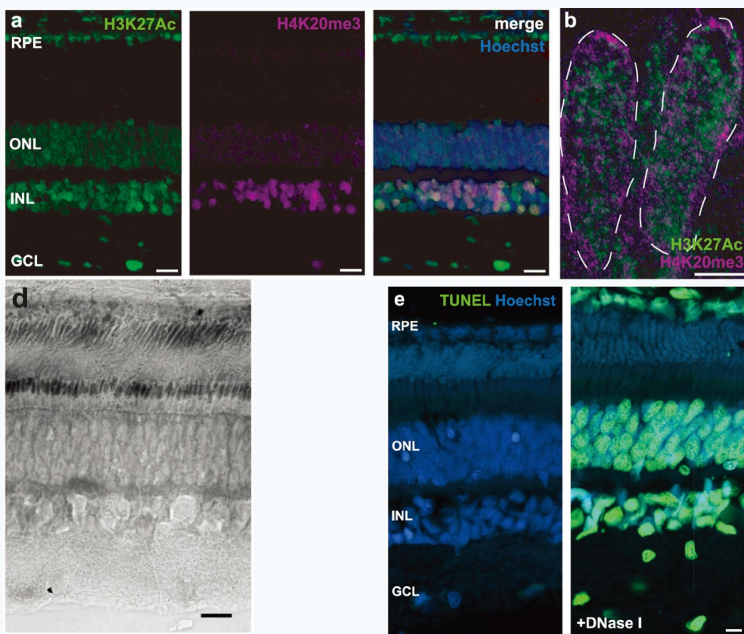
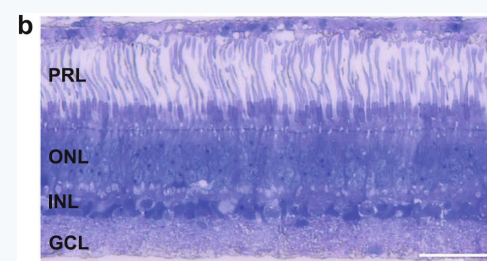
Vision should be lost or degenerating.

- Long time in dim, cold water should erode photoreceptors.
- Corneal parasites (*Ommatokoita elongata*) appear to occlude the eye.
- Cavefish lose vision in darkness; the same might be true here.



Four-step argument: (1) hardware (2) software (3) function (4) longevity

Pure-rod retina: all layers, no degeneration



What the histology and in-site data show

Fig 1b

Retinal cross-section: all layers present in adult sharks > 130 years old.

Fig 2d

RNAscope: rods, Muller glia, bipolar, amacrine and ganglion cells - the complete rod-pathway circuit is there.

Fig 2a, 2b

H3K27Ac (active) and H4K20me3 (repressive) chromatin marks: the retina is metabolically and transcriptionally active.

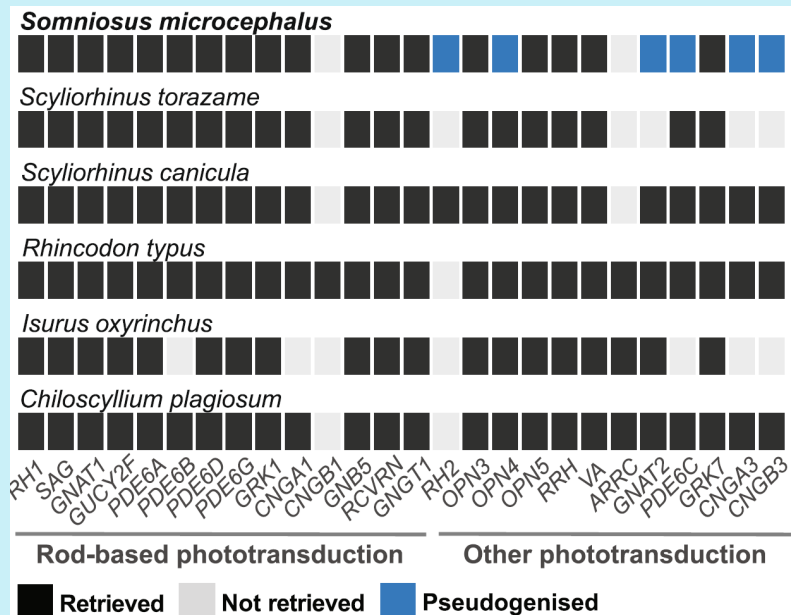
Fig 2e

TUNEL negative: no DNA fragmentation, it is not 'hanging on' in a slow death.

Conclusion 1: the hardware is intact, and it is doing something - not a vestige, a working organ.

Rod genes intact; cone and melanopsin lost

Figure 1c - Phototransduction gene mining across six shark species



A draft genome of *S. microcephalus*

ROD PATHWAY - INTACT

Full complement of rod phototransduction genes retrieved: rh1, sag, gnat1, gucy2f, pde6a/b/d/g, grk1, cnga1, gnb5, rvern, gngt1.

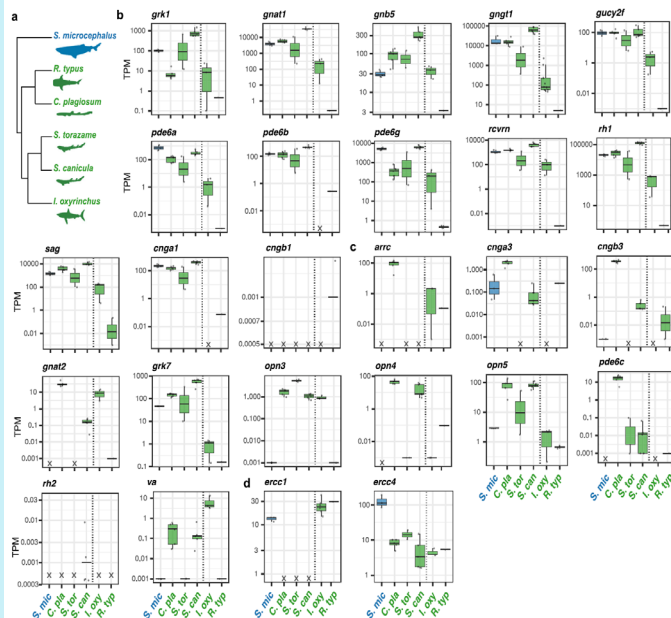
CONE / NON-VISUAL - LOST

Pseudogenized: rh2, gnat2, pde6c, cnga3, cngb3, opn4. Not found: arrc.

Conclusion 2: the genome has committed to a rod-only scotopic visual system - a deliberate dark-adaptation, not a slow breakdown.

Rod genes are highly expressed, cone genes are off

Figure 4b-c - Retinal expression of phototransduction genes across six shark species



Retinal RNA-seq vs. five other sharks

Rod genes - high TPM

rh1, grk1, sag, gnat1, gngt1, pde6a/b/g expressed at levels comparable to other adult elasmobranchs.

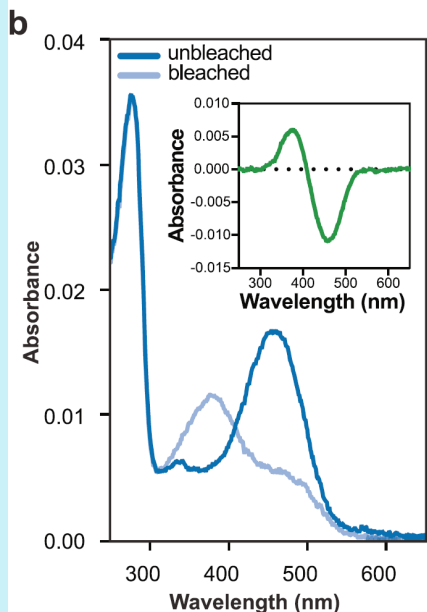
Cone genes - absent or low

No meaningful expression of cone opsins or cone cascade genes, consistent with a pure-rod retina.

Conclusion: the molecular system is not just present, it is on - the rod pathway is the active programme.

Rhodopsin absorbs maximally at 458 nm

Figure 3b - UV-Vis spectra of purified *S. microcephalus* rhodopsin



Lambda_max

458 nm

bluer than other deep-sea sharks, bluer than most deep-sea fish

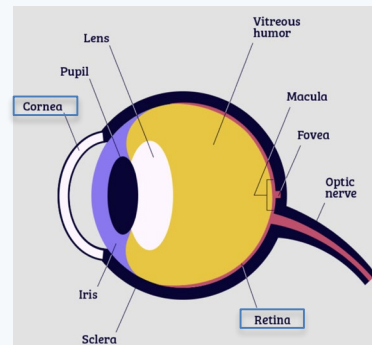
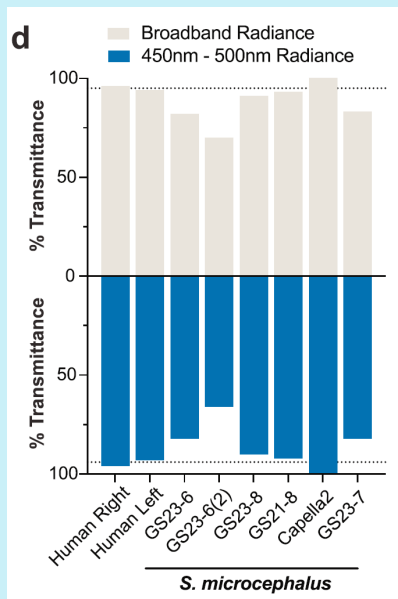
Why blue?

- Shallow-water shark rhodopsins peak near 500 nm - this one is shifted by ~40 nm.
- Arctic deep water transmits predominantly blue light, so the pigment is tuned to the dim environment.
- Reflects adaptive evolution of the rhodopsin gene - a functional response.

Conclusion 3a: the phototransduction protein is biochemically functional and tuned to the local light field.

Cornea transmits 70-100%

Figure 3d - Corneal light transmittance (shark vs. human)



Shark cornea

70-100%

Human cornea

~95%

for reference

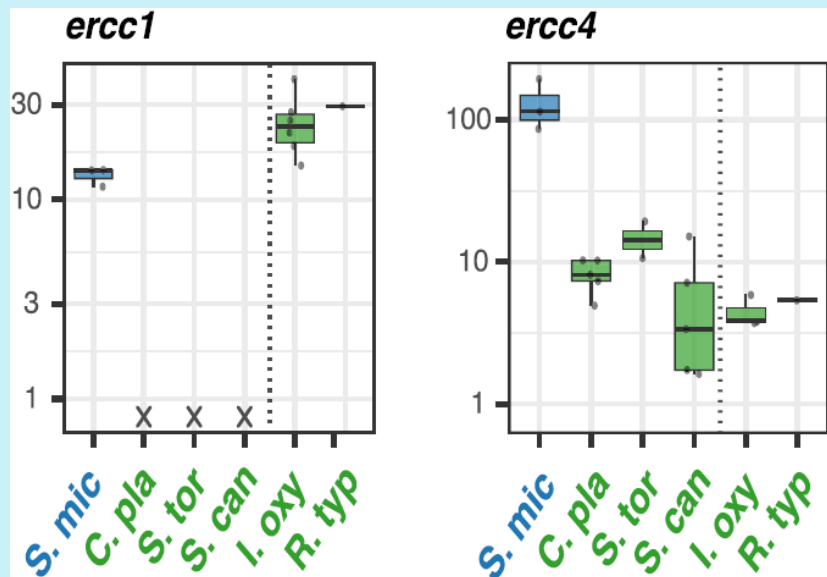
In the blue range (450-500 nm)

Shark corneas transmit 70-100%. The parasites do not block the light - enough photons reach the retina to drive vision.

Conclusion 3b: the entire photon-to-protein pipeline is open - light gets in, rhodopsin responds.

Robust DNA repair: ERCC1 and ERCC4 retained and active

Figure 4d - Retinal expression of DNA-repair genes across shark species



ERCC1-XPF: the smoking gun

Long-lived sharks retain ercc1

Greenland shark and other long-lived species keep an intact ercc1 gene; shorter-lived sharks have lost it.

ercc4 (xpf) is highly expressed

The XPF endonuclease shows elevated retinal expression in *S. microcephalus* compared to other sharks.

Convergent with bowhead whale

Another long-lived Arctic species - the same DNA-repair theme keeps appearing.

Conclusion 4: enhanced DNA repair may be the mechanism that lets the retina survive across centuries.

What this tells us about vision, ageing, and adaptation

Adaptation, not degeneration

Deep-sea sensory systems can be exquisitely tuned, not vestigial - overturning the default 'evolution in the dark equals loss of vision'.

A natural model of retinal longevity

Identifies molecular correlates (DNA repair, lipid composition, intact circuitry) of retinal health across centuries - relevant to age-related eye disease.

FOUR-STEP ARGUMENT

The retina is intact - and built to last.

1. Hardware: retina intact, all layers, no degeneration.
2. Software: rod genes on, cone genes lost.
3. Function: rhodopsin at 458 nm, cornea lets light through.
4. Longevity: DNA repair keeps the tissue alive for centuries.

REFERENCE

Fogg, L. G. et al.

The visual system of the longest-living vertebrate, the Greenland shark.

Nature Communications (2026).

Thank you - questions?

Discussion welcome.