# Evolution of Non-visual Opsin Genes Across the Frog Tree of Life

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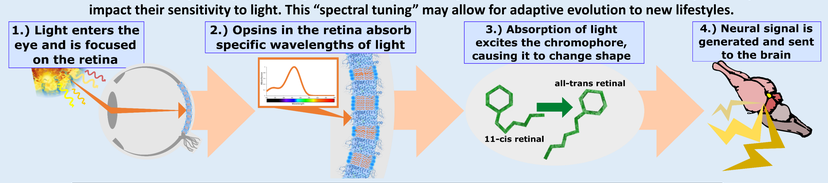
## Opsins & Light Detection

**What are opsins?**

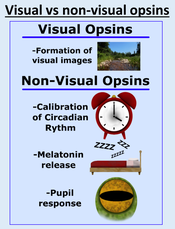
Opsins are transmembrane proteins which encapsulate chromophores. When the opsin absorbs light, the chromophore changes shape, resulting in a neural signal. Changes in the amino acid composition of opsins may impact their sensitivity to light. This "spectral tuning" may allow for adaptive evolution to new lifestyles.




## Intro to Non-visual Opsins

**The function & evolution of non-visual opsins is not well understood in frogs**

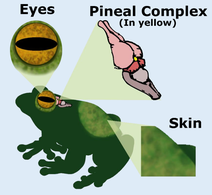
**Visual vs non-visual opsins**




**Non-visual opsin genes found in frogs**

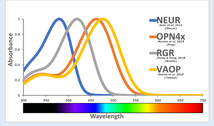
1. NEUR1 (Neuropsin 1)
2. NEUR2 (Neuropsin 2)
3. NEUR3 (Neuropsin 3)
4. NEUR4 (Neuropsin 4)
5. NEUR5 (Neuropsin 5)
6. NEUR6 (Neuropsin 6)
7. OPN4m (mammal-like melanopsin)
8. OPN4x (xenopus-like melanopsin)
9. PAR (Parietopsin)
10. PARA (Parapinopsin)
11. PIN (Pinopsin)
12. RGR (Retinal G-Protein Coupled Receptor)
13. RRH (Peropsin)
14. TMT1 (Teleost Multiple Tissue 1)
15. TMT2 (Teleost Multiple Tissue 2)
16. TMT3 (Teleost Multiple Tissue 3)
17. VAOP (Vertebrate Ancient Opsin)

**Where are these genes expressed?**




**What light are they sensitive to?**

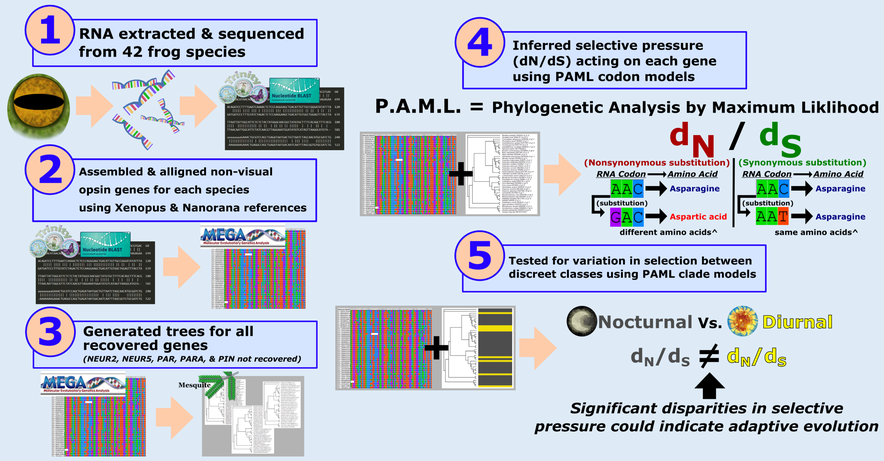
Some information is available regarding the spectral sensitivities of non-visual opsins in vertebrates




## Objectives

1. Identify which non-visual opsin genes are expressed in frog eyes
2. Compare selective pressure between non-visual opsin genes and test for positive selection
3. Test for potential adaptive evolution by comparing selection between discreet lifestyle classes within each gene

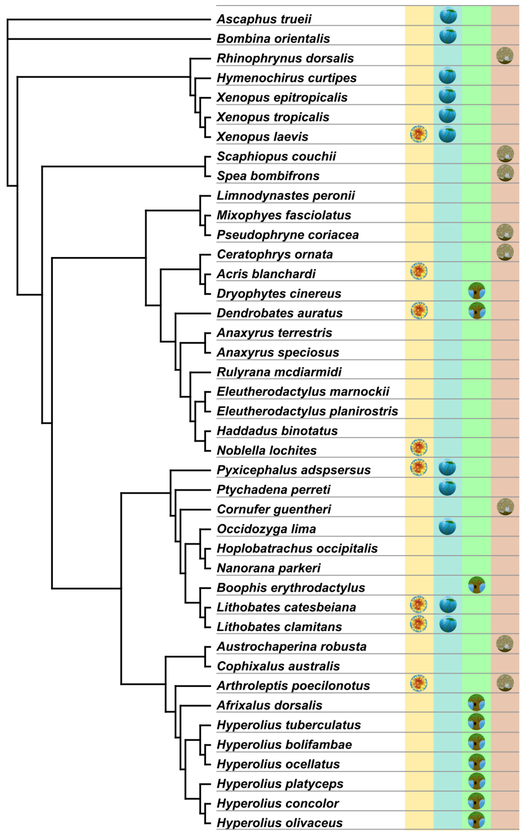
## Methods




## Species Sampling


**Discreet Lifestyle Classes**

| | YES | NO |
|---|---|---|
| DIURNAL | | |
| SCANSORIAL | | |
| AQUATIC/ SEMIAQUATIC | | |
| SECRETIVE/ FOSSORIAL | | |



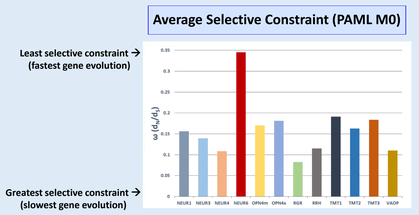

## Selection Analyses

$d_N/d_S > 1$: positive selection { *Higher proportion of non-synonymous substitutions; Suggests adaptive evolution*

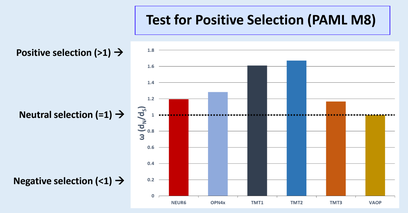
$d_N/d_S = 1$: neutral selection

$d_N/d_S < 1$: negative selection { *Lower proportion of non-synonymous substitutions; Suggests strong selective constraint; Most functional genes are subject to selective constraint*

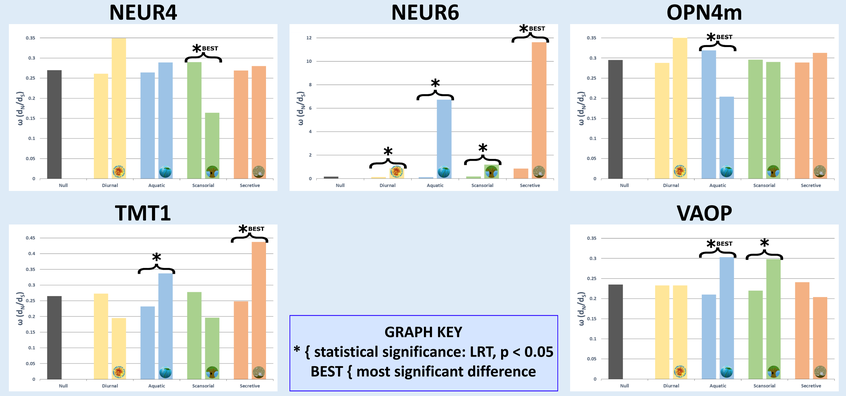
**Average Selective Constraint (PAML M0)**




**Test for Positive Selection (PAML M8)**




**Comparing Selection Between Lifestyle Classes (PAML Clade Model Analyses)**




GRAPH KEY
* { statistical significance: LRT, p < 0.05
BEST { most significant difference

(No evidence for variation in selection between lifestyle classes was found in NEUR1, NEUR3, OPN4x, RGR, RRH, TMT2, or TMT3)

## Summary

- 12 of the 17 non-visual opsin genes were consistently recovered across frog species
- Selective constraint was similar across non-visual opsins with the exception of NEUR6, which displayed elevated $d_N/d_S$
- Positive selection in 5 genes suggests potential adaptive evolution
- Environmental light variations associated with lifestyle appear to have influenced the evolution of 5 non-visual opsins and may reflect functional adaption in these genes

## Acknowledgements

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