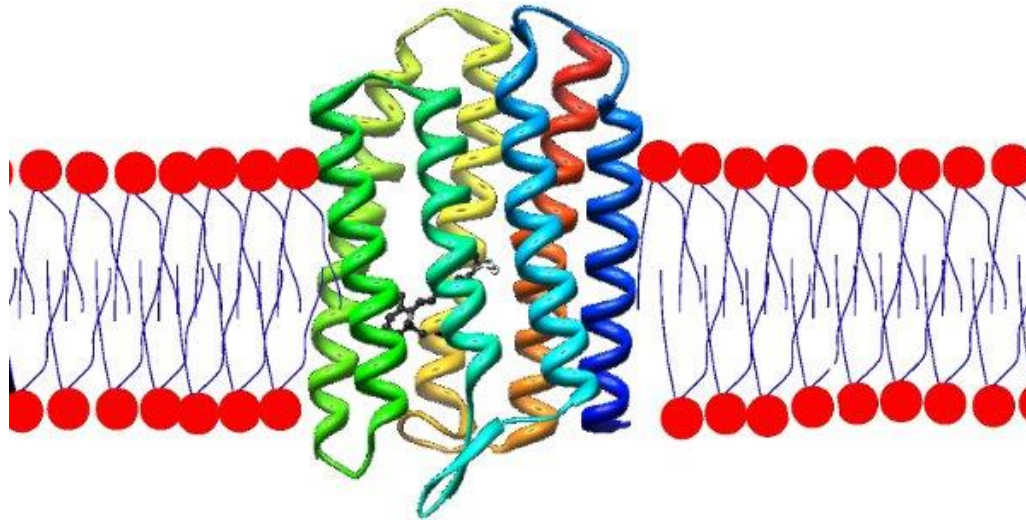


Visual Pigments and Pupil Shape in Various Species

Philip Trammell

Visual Receptors

- G-Protein Coupled Receptors
- Vertebrate opsins - subdivided into Rhodopsin and four types of cone opsins (λ_{\max}) (Takenaka 2007)(Davies 2009)

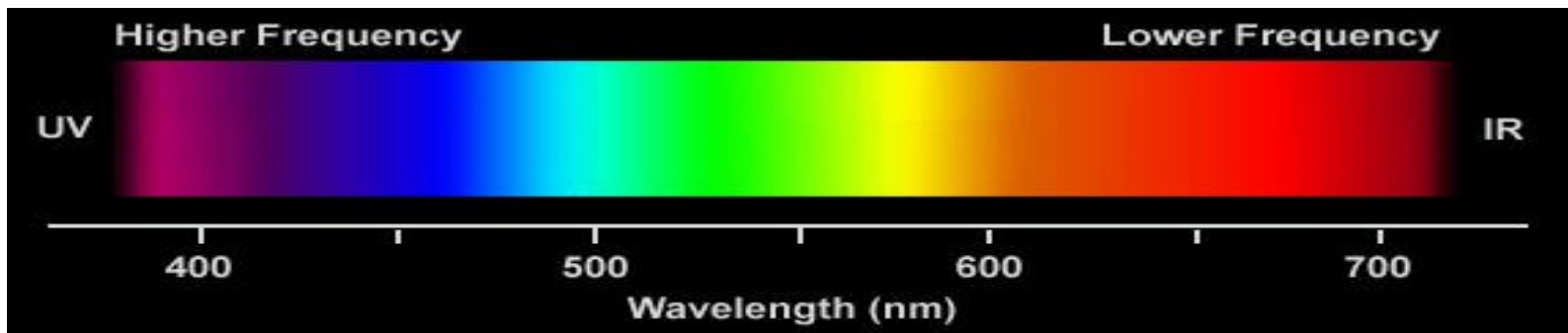


<http://blogs.scientificamerican.com/thoughtomics/2012/11/20/animal-vision-evolved-700-million-years-ago/>

Table 1: Absorption of each class of opsin

Opsin class	λ_{max}	Color
Rho	480-510 nm	Night vision
SWS1	360-430 nm	UV - Blue
SWS2	440-460 nm	Blue
MWS	~ 530 nm	Green
LWS	~ 560 nm	Red

(Takenaka 2007)(Davies 2009)



<http://www.energymedc.com/images/light%20spectrum.jpg>

Opsins can also be categorized by certain conserved amino acids in particular locations.

Table 2: Amino acids found to be conserved in each opsin class

Opsin class	Conserved amino acids
Rho	E122, M207, H211, W265, A292, A295
SWS1	L46, F49, T52, F85, A89, T92, A114, S118
SWS2	P91, S94, L122, C127, S211, T261, A292
MWS/LWS	D82, S164, H181, Y261, T269, A292

Figure 1.b: Conserved amino acids in rhodopsin

AC Rh	121	GEMGLWSLVVLAVERYVVIC	KPMSNFRFGETHALIGV	SCTWIMALACAGPPLIGWSRYIP	180
PB Rh	121	GEMALWSLVVLAIER	YVVVCKPMSNFRFTETHAIMGLCFTWIMALACAGPPLVGWSRYIP	180	
OH Rh	121	GEIALWSLVVLAVERYVVIC	KPMSNFRFTETHAIMGVSLTWIMALACAAPPLIGWSRYIP	180	
CP Rh	121	GEIALWSLVVLAIER	YVVVCKPMSNFRFSETHALMGIIFTWVMALACAAPPLFGWSRYIP	180	
TG Rh	121	GEIALWSLVVLAIER	YVVVCKPMSNFRFGENHAIMGVAFSWIMALACAAPPLFGWSRYIP	180	
HS Rh	121	GEIALWSLVVLAIER	YVVVCKPMSNFRFGENHAIMGVAFSTWVMALACAAPPLAGWSRYIP	180	
AC Rh	181	EGMQCSCGVDYYTPTPEVHNESFVIYMF	LVH	FVTPLTIIFFCYGRLVCTVKAAAAQQQES	240
PB Rh	181	EGMQCSCGVDYYTPTPEVHNESFVIYMF	FIVH	FVIPLAVIFFCYGRLVCTVKEAAAQQQES	240
OH Rh	181	EGMQSSCGVDYYTPTPEVHNESFVIYMF	LVH	FITPLTVIFFCYGRLVCTVKEAAAQQQES	240
CP Rh	181	EGLQCSCGIDYYTLKPEVHNESFVIYMF	VVH	FLIPLIIISFCYGRLVCTVKEAAAQQQES	240
TG Rh	181	EGMQCSCGIDYYTLKPEVNNE	SFVIYMFVVH	FMIPLSIIFFCYGNLVCTVKEAAAQQQES	240
HS Rh	181	EGLQCSCGIDYYTLKPEVNNE	SFVIYMFVVH	FTIPMIIFFCYGQLVFTVKEAAAQQQES	240
AC Rh	241	ATTQKAEREVTRMVVIMVISFLVCW	VPYASVAFYIFTHQGSDFGPVFMTIPAFFAKSSAI	300	
PB Rh	241	ATTQKAEKEVTRMVIIMVIAFLICW	VPYASVAFYIFTHQGSDFGPVFMTIPAFFAKSSAI	300	
OH Rh	241	ATTQKAEKEVTRMVIILMVIAFLVCW	VPYASVAFYIFTHQGSDFGPVFMTIPSFFAKSSAI	300	
CP Rh	241	ATTQKAEREVTRMVIIMVISFLVCW	VPYASVAFYIFTHQGSDFGPVFMTIPAFFAKSSAI	300	
TG Rh	241	ATTQKAEKEVTRMVIIMVIAFLICW	VPYASVAFYIFTNQGSDFGPIFMTIPAFFAKSSAI	300	
HS Rh	241	ATTQKAEKEVTRMVIIMVIAFLICW	VPYASVAFYIFTHQGSNFGPIFMTIPAFFAKSAAI	300	

AC= *Anolis carolinensis*

PB= *Python bivittatus*

OH= *Ophiophagus hannah*

CP= *Chrysemys picta bellii*

TG= *Taeniopygia guttata*

HS= *Homo sapiens*

Pupil shape and lifestyle

- Pupils come in various shapes (Banks 2015)
- Correlations have been found between pupil shape and ecological niche (Banks 2015)
- Active vs. Ambush vs. prey

Vertical



Sub-circular



Circular



Horizontal



Research Question

- Do animals with different pupil shapes have different opsin populations?



<http://nextdoornature.org/tag/green-anole>



<http://www.lizardtypes.com/gecko-pictures/tokay-gecko-picture-5/>

Hypotheses

- Opsins in species with vertical pupils will be different than opsins in species with circular pupils.
- If different, which opsins are more likely to be present in species with a given pupil shape?

Methods

- Selected different species with either vertical or circular pupil shape
- Found opsin and rhodopsin AA sequences
- Used *Anolis carolinensis* as query sequence
- Protein BLAST in NCBI and UNIPROT databases
- Aligned sequences with MegAlign and MEGA
- Determined transmembrane domains at Center for Biological Sequence Analysis prediction servers

Methods

- Organized into a table in Excel
- Sequences sent to MEGA and phylogenetic trees were created for each opsin
- Chi square (χ^2) analysis between pupil shape

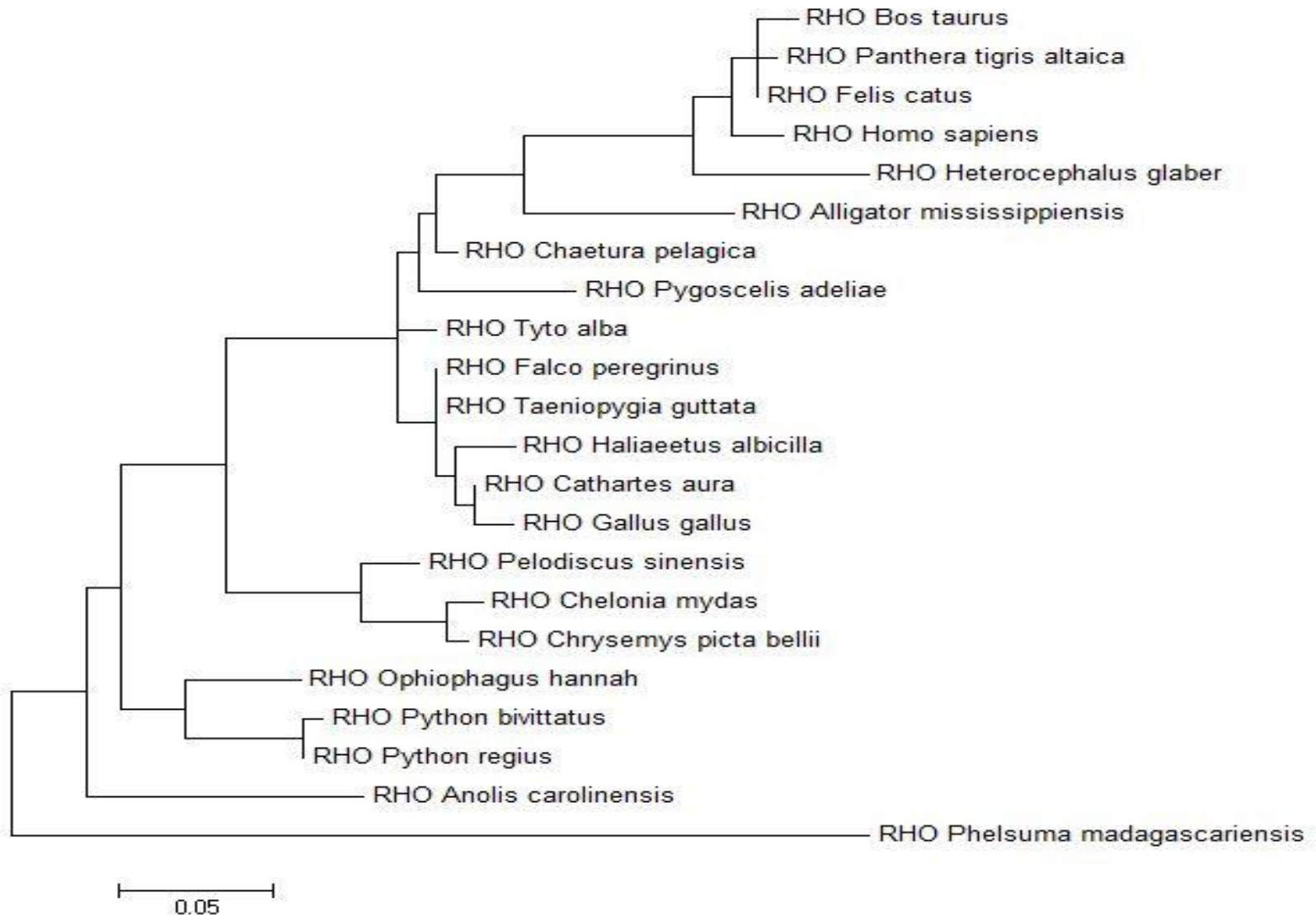
Opsin populations

Species	Common name	Taxa	pupil shape	Rhodopsin	SWS1	SWS2	MWS	LWS
<i>Cathartes aura</i>	turkey vulture	Bird	Circular	1	0*	0*	1	0*
<i>Chaetura pelagica</i>	chimney swift	Bird	Circular	1	0*	0*	1	0*
<i>Falco Peregrinus</i>	Peregrine Falcon	Bird	Circular	1	1	0*	1	0*
<i>Gallus gallus</i>	Chicken	Bird	Circular	1	1	1	1	1
<i>Haliaeetus albicilla</i>	White-tailed Eagle	Bird	Circular	1	0*	0*	1	0*
<i>Pygoscelis adeliae</i>	adelie penguin	Bird	Circular	1	0*	0*	1	0*
<i>Taeniopygia guttata</i>	zebra finch	Bird	Circular	1	1	1	0*	1
<i>Tyto alba</i>	Barn owl	Bird	Circular	1	0*	0*	1	0*
<i>Bos taurus</i>	Cow	Mammal	Circular	1	1	0*	0*	1
<i>Felis catus</i>	House cat	Mammal	Vertical	1	1	0*	0*	1
<i>Heterocephalus glaber</i>	naked mole rat	Mammal	Circular	1	1	1	0*	0*
<i>Homo sapiens</i>	humans	Mammal	Circular	1	1	1	1	1
<i>Panthera tigris altaica</i>	Amur Tiger	Mammal	Circular	1	1	0*	0*	0*
<i>Alligator mississippiensis</i>	American alligator	Reptile	Vertical	1	0*	1	0*	1
<i>Anolis carolinensis</i>	Green anole	Reptile	Circular	1	1	1	0*	1
<i>Chelonia mydas</i>	green sea turtle	Reptile	Circular	1	1	1	0*	1
<i>Chrysemys picta bellii</i>	western painted turtle	Reptile	Circular	1	1	1	0*	1
<i>Gecko gecko</i>	tokay gecko	Reptile	Vertical	0*	1	1	1	0*
<i>Ophiophagus hannah</i>	king cobra	Reptile	Circular	1	0*	0*	0*	1
<i>Pelodiscus sinensis</i>	soft shelled turtle	Reptile	Circular	1	1	1	0*	1
<i>Phelsuma madagascariensis</i>	Day Gecko	Reptile	Circular	1	1	0*	0*	1
<i>Python bivittatus</i>	burmese python	Reptile	Vertical	1	1	0*	0*	1
<i>Python regius</i>	Ball python	Reptile	Vertical	1	1	0*	0*	1

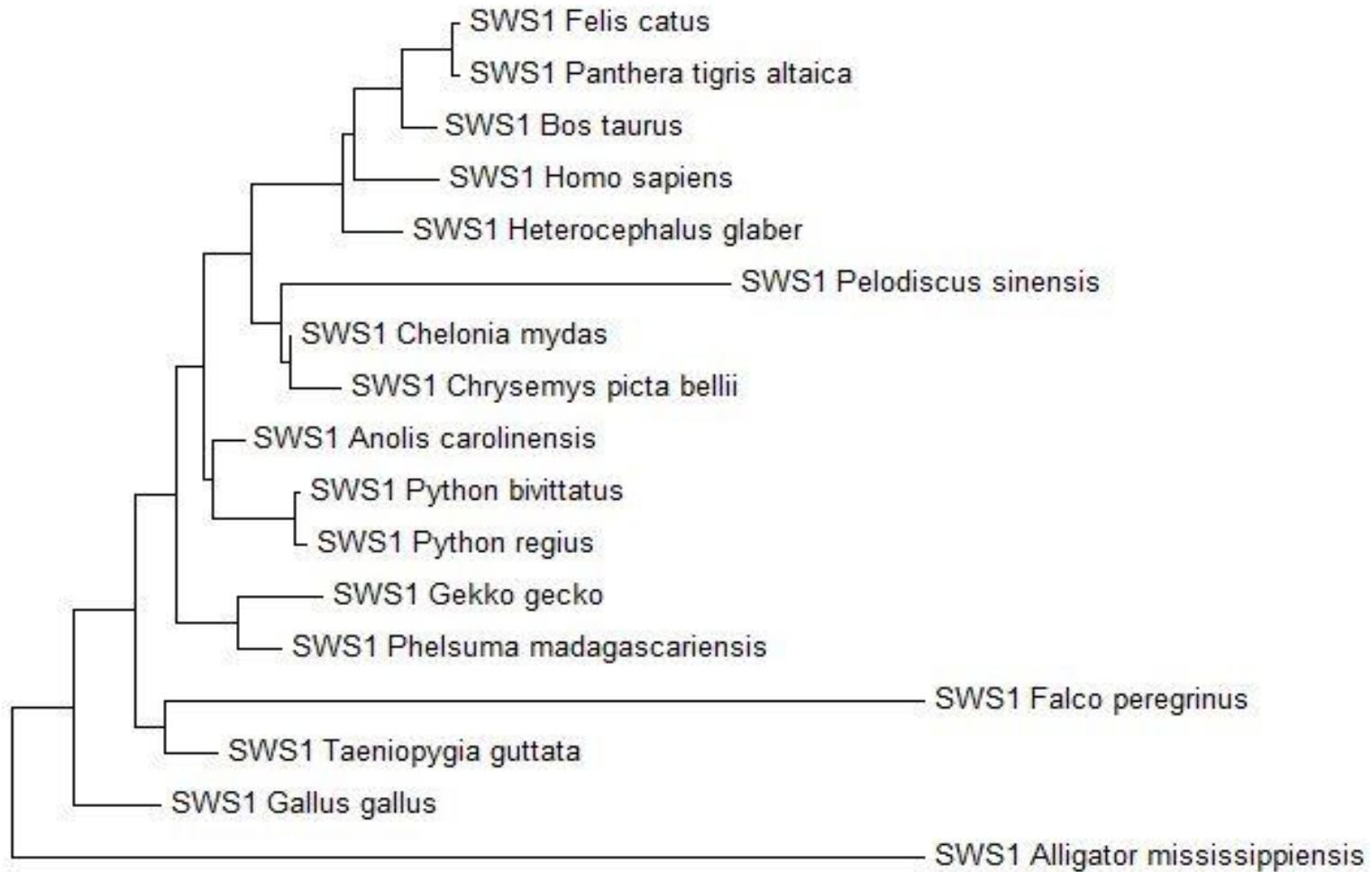
0*=sequence not found on NCBI or UniProt databases

Presence of opsins in each species

Phylogenetic tree (Rhodopsin)

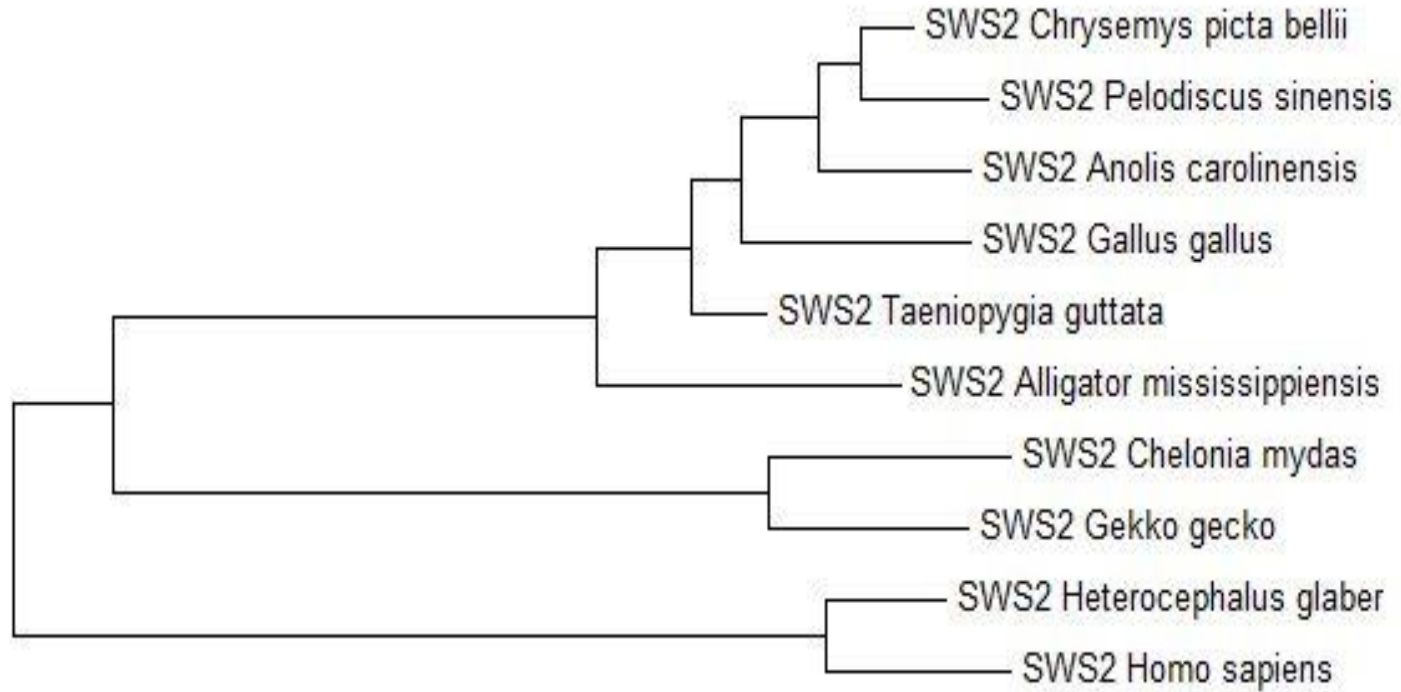


SWS1



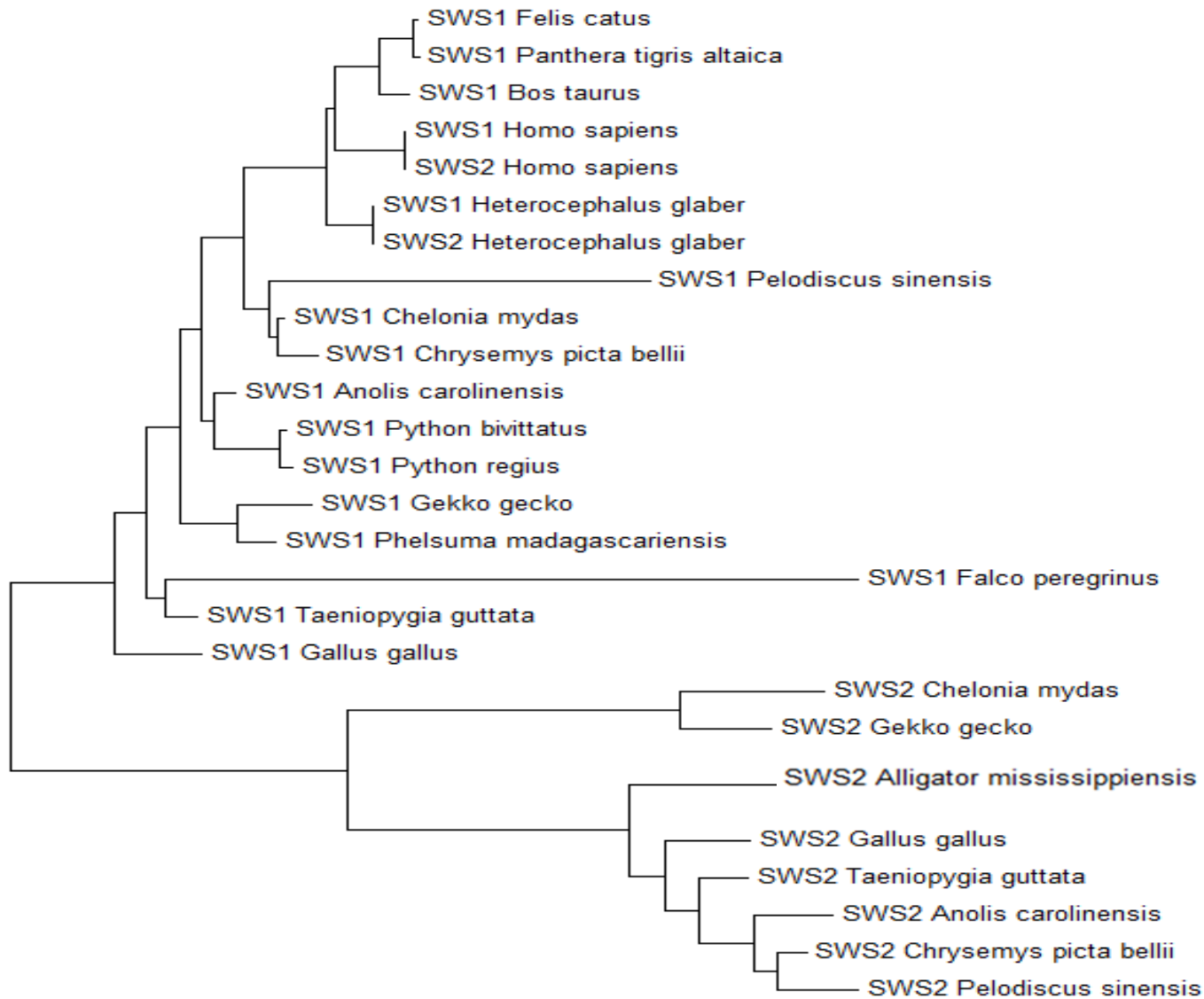
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SWS2



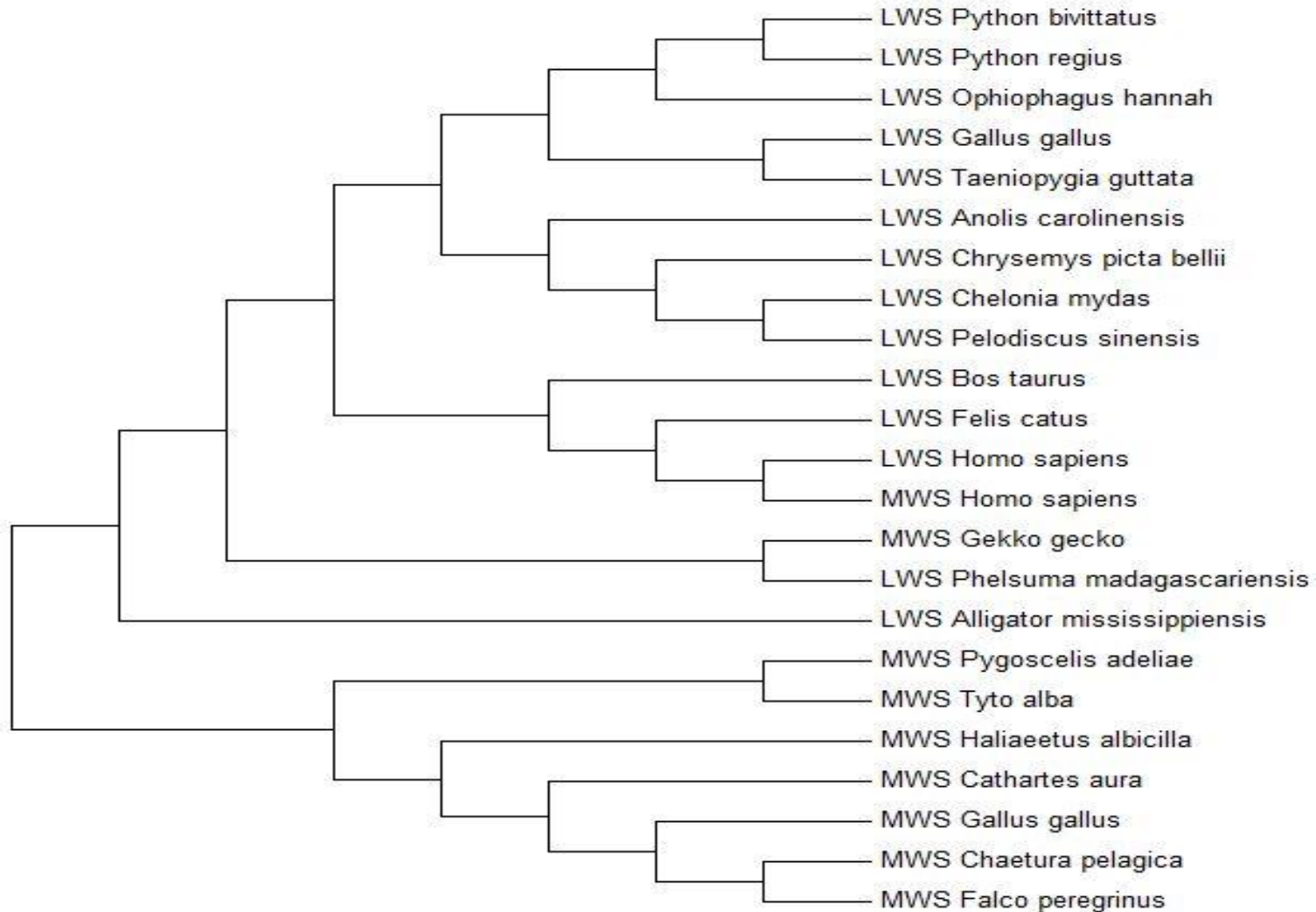
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SWS2 vs SWS1

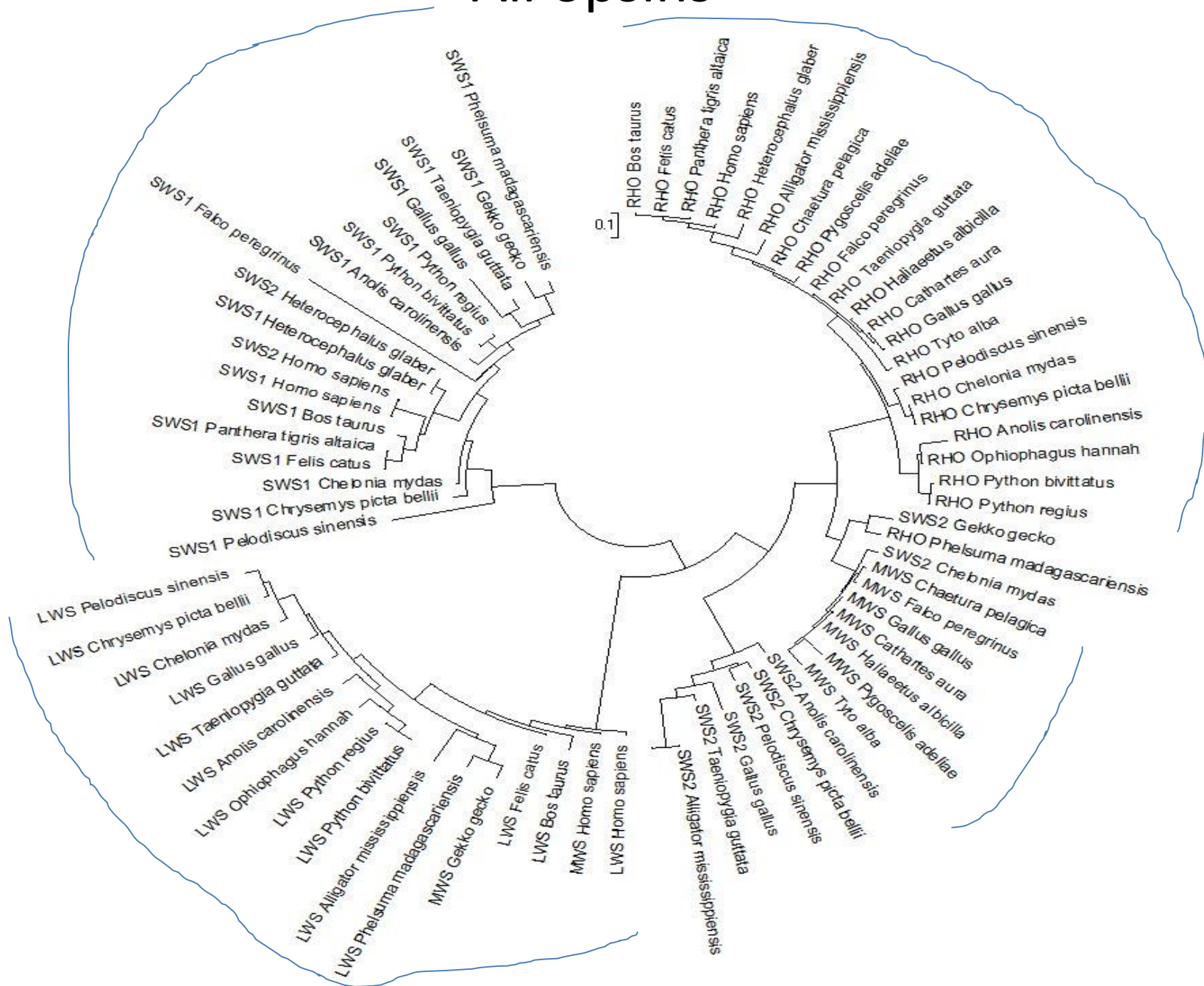


0.1

MWS/LWS



All opsins



χ^2 between pupil shapes

Species	Common name	Taxa	pupil shape	Rhodopsin	SWS1	SWS2	MWS	LWS
<i>Cathartes aura</i>	turkey vulture	Bird	Circular	1	0*	0*	1	0*
<i>Chaetura pelagica</i>	chimney swift	Bird	Circular	1	0*	0*	1	0*
<i>Falco Peregrinus</i>	Peregrine Falcon	Bird	Circular	1	1	0*	1	0*
<i>Gallus gallus</i>	Chicken	Bird	Circular	1	1	1	1	1
<i>Haliaeetus albicilla</i>	White-tailed Eagle	Bird	Circular	1	0*	0*	1	0*
<i>Pygoscelis adeliae</i>	adelie penguin	Bird	Circular	1	0*	0*	1	0*
<i>Taeniopygia guttata</i>	zebra finch	Bird	Circular	1	1	1	0*	1
<i>Tyto alba</i>	Barn owl	Bird	Circular	1	0*	0*	1	0*
<i>Bos taurus</i>	Cow	Mammal	Circular	1	1	0*	0*	1
<i>Heterocephalus glaber</i>	naked mole rat	Mammal	Circular	1	1	1	0*	0*
<i>Homo sapiens</i>	humans	Mammal	Circular	1	1	1	1	1
<i>Panthera tigris altaica</i>	Amur Tiger	Mammal	Circular	1	1	0*	0*	0*
<i>Anolis carolinensis</i>	Green anole	Reptile	Circular	1	1	1	0*	1
<i>Chelonia mydas</i>	green sea turtle	Reptile	Circular	1	1	1	0*	1
<i>Chrysemys picta bellii</i>	western painted turtle	Reptile	Circular	1	1	1	0*	1
<i>Ophiophagus hannah</i>	king cobra	Reptile	Circular	1	0*	0*	0*	1
<i>Pelodiscus sinensis</i>	soft shelled turtle	Reptile	Circular	1	1	1	0*	1
<i>Phelsuma madagascariensis</i>	Day Gecko	Reptile	Circular	1	1	0*	0*	1
<i>Felis catus</i>	House cat	Mammal	Vertical	1	1	0*	0*	1
<i>Alligator mississippiensis</i>	American alligator	Reptile	Vertical	1	0*	1	0*	1
<i>Gecko gecko</i>	tokay gecko	Reptile	Vertical	0*	1	1	1	0*
<i>Python bivittatus</i>	burmese python	Reptile	Vertical	1	1	0*	0*	1
<i>Python regius</i>	Ball python	Reptile	Vertical	1	1	0*	0*	1

0*=sequence not found on NCBI or UniProt databases

$\chi^2 = 1.73618$, 5 degrees of freedom, $P=0.865836$

χ^2 between pupil shapes and taxon

Species	Common name	Taxa	pupil shape	Rhodopsin	SWS1	SWS2	MWS	LWS
<i>Cathartes aura</i>	turkey vulture	Bird	Circular	1	0*	0*	1	0*
<i>Chaetura pelagica</i>	chimney swift	Bird	Circular	1	0*	0*	1	0*
<i>Falco Peregrinus</i>	Peregrine Falcon	Bird	Circular	1	1	0*	1	0*
<i>Gallus gallus</i>	Chicken	Bird	Circular	1	1	1	1	1
<i>Haliaeetus albicilla</i>	White-tailed Eagle	Bird	Circular	1	0*	0*	1	0*
<i>Pygoscelis adeliae</i>	adelie penguin	Bird	Circular	1	0*	0*	1	0*
<i>Taeniopygia guttata</i>	zebra finch	Bird	Circular	1	1	1	0*	1
<i>Tyto alba</i>	Barn owl	Bird	Circular	1	0*	0*	1	0*
<i>Bos taurus</i>	Cow	Mammal	Circular	1	1	0*	0*	1
<i>Heterocephalus glaber</i>	naked mole rat	Mammal	Circular	1	1	1	0*	0*
<i>Homo sapiens</i>	humans	Mammal	Circular	1	1	1	1	1
<i>Panthera tigris altaica</i>	Amur Tiger	Mammal	Circular	1	1	0*	0*	0*
<i>Felis catus</i>	House cat	Mammal	Vertical	1	1	0*	0*	1
<i>Anolis carolinensis</i>	Green anole	Reptile	Circular	1	1	1	0*	1
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<i>Ophiophagus hannah</i>	king cobra	Reptile	Circular	1	0*	0*	0*	1
<i>Pelodiscus sinensis</i>	soft shelled turtle	Reptile	Circular	1	1	1	0*	1
<i>Phelsuma madagascariensis</i>	Day Gecko	Reptile	Circular	1	1	0*	0*	1
<i>Alligator mississippiensis</i>	American alligator	Reptile	Vertical	1	0*	1	0*	1
<i>Gecko gecko</i>	tokay gecko	Reptile	Vertical	0*	1	1	1	0*
<i>Python bivittatus</i>	burmese python	Reptile	Vertical	1	1	0*	0*	1
<i>Python regius</i>	Ball python	Reptile	Vertical	1	1	0*	0*	1

0*=sequence not found on NCBI or UniProt databases

$\chi^2 = 13.58917$, 8 degrees of freedom, $P=0.093122$

$\chi^2 = 6.36$, 2 degrees of freedom, $P<0.05$

Conclusion

- No significant correlation between opsin distribution and pupil shape. $P > 0.8$
- Between all taxa, significant different at $P = 0.1$
- There is significant different between birds and reptiles in distribution of SWS2 and MWS $P < 0.05$

In the future?

- Sequence more genomes
 - Fill in missing opsins with current species (?)
 - Check databases in the future
 - Add more species to databases
 - Black skimmer: bird with vertical pupils

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