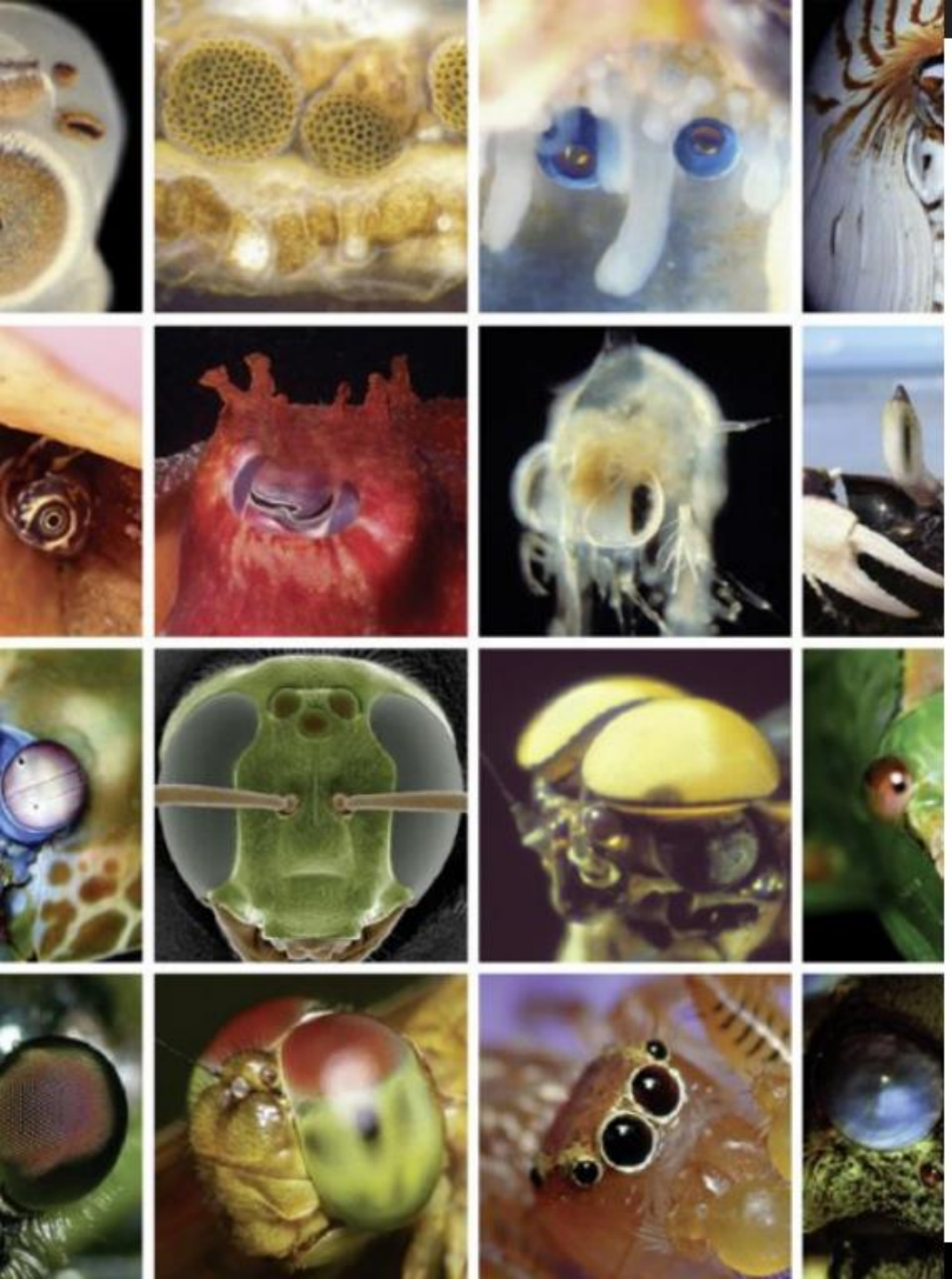
Evolução e Desenvolvimento de olhos

Luiza Saad
Doutoranda

CONTEÚDO



Como olhos se tornaram tão diversificados?

MORFOLÓGICO

FISIOLÓGICO

EMBRIONÁRIO

Uma questão de homologia

Vertebrados

Cefalópodes

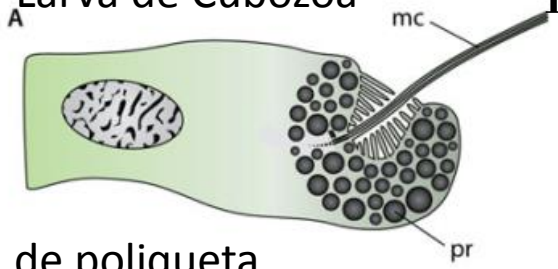
Insetos

Poliquetas

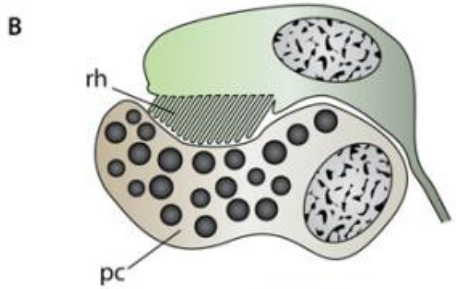
MORFOLÓGICO

Definição do olho

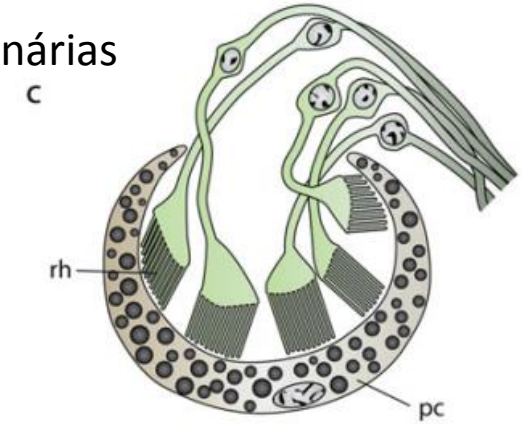
Larva de Cubozoa



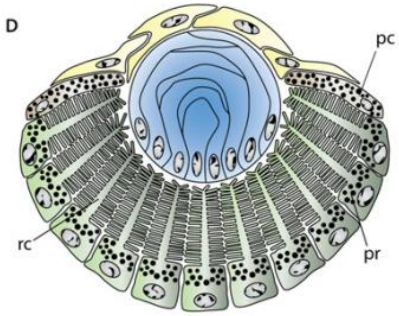
Larva de poliqueta

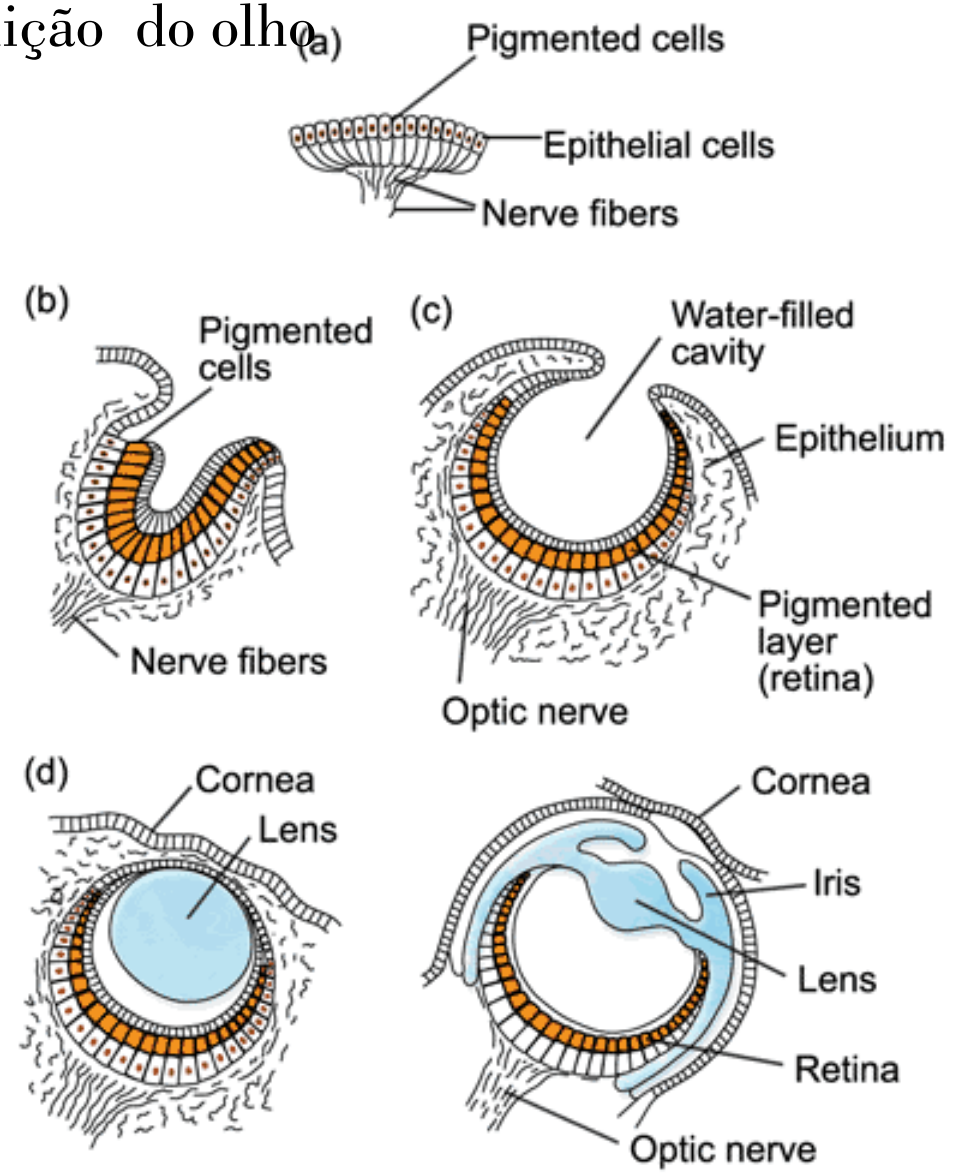


planárias



Agua viva

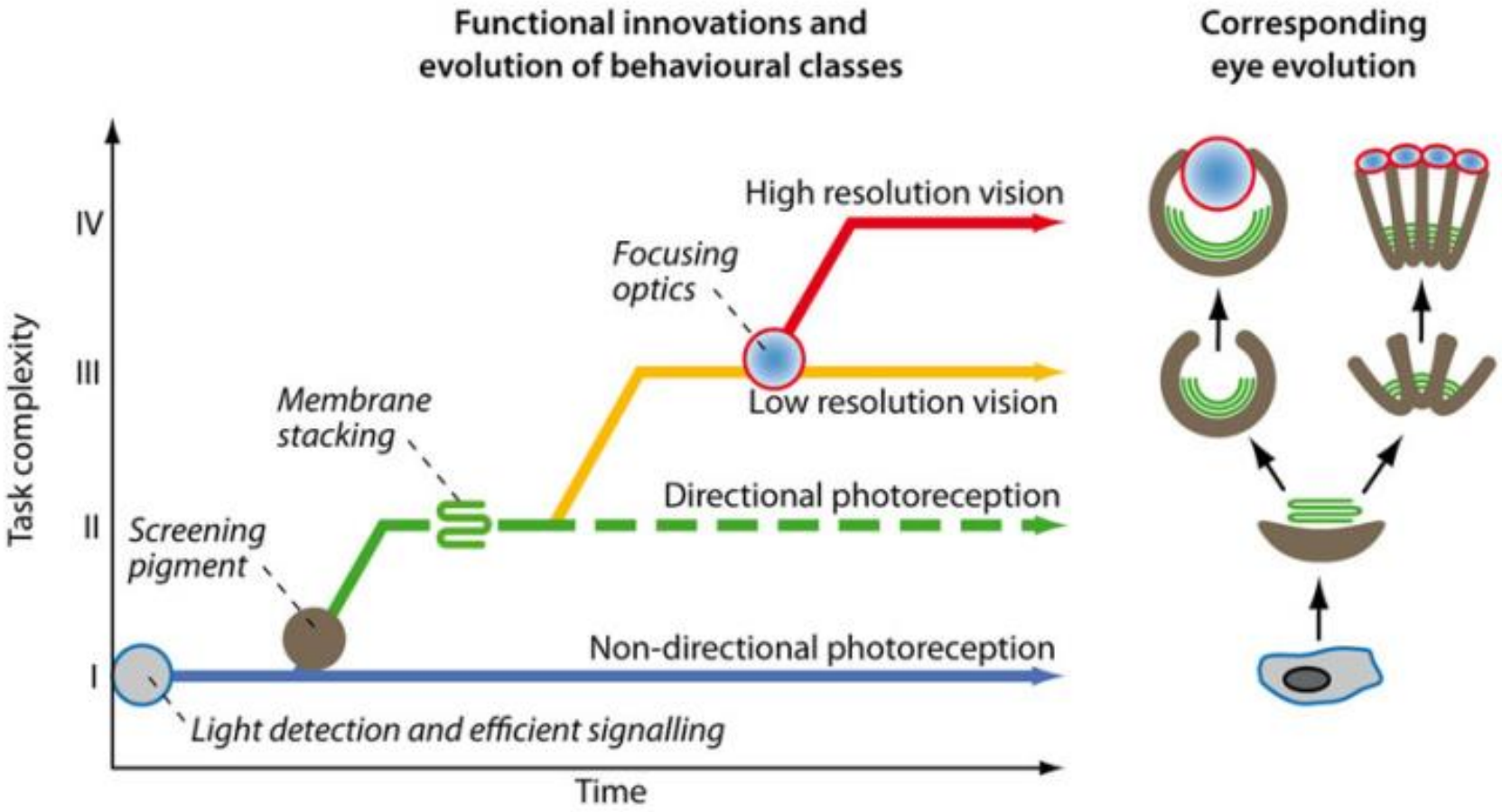




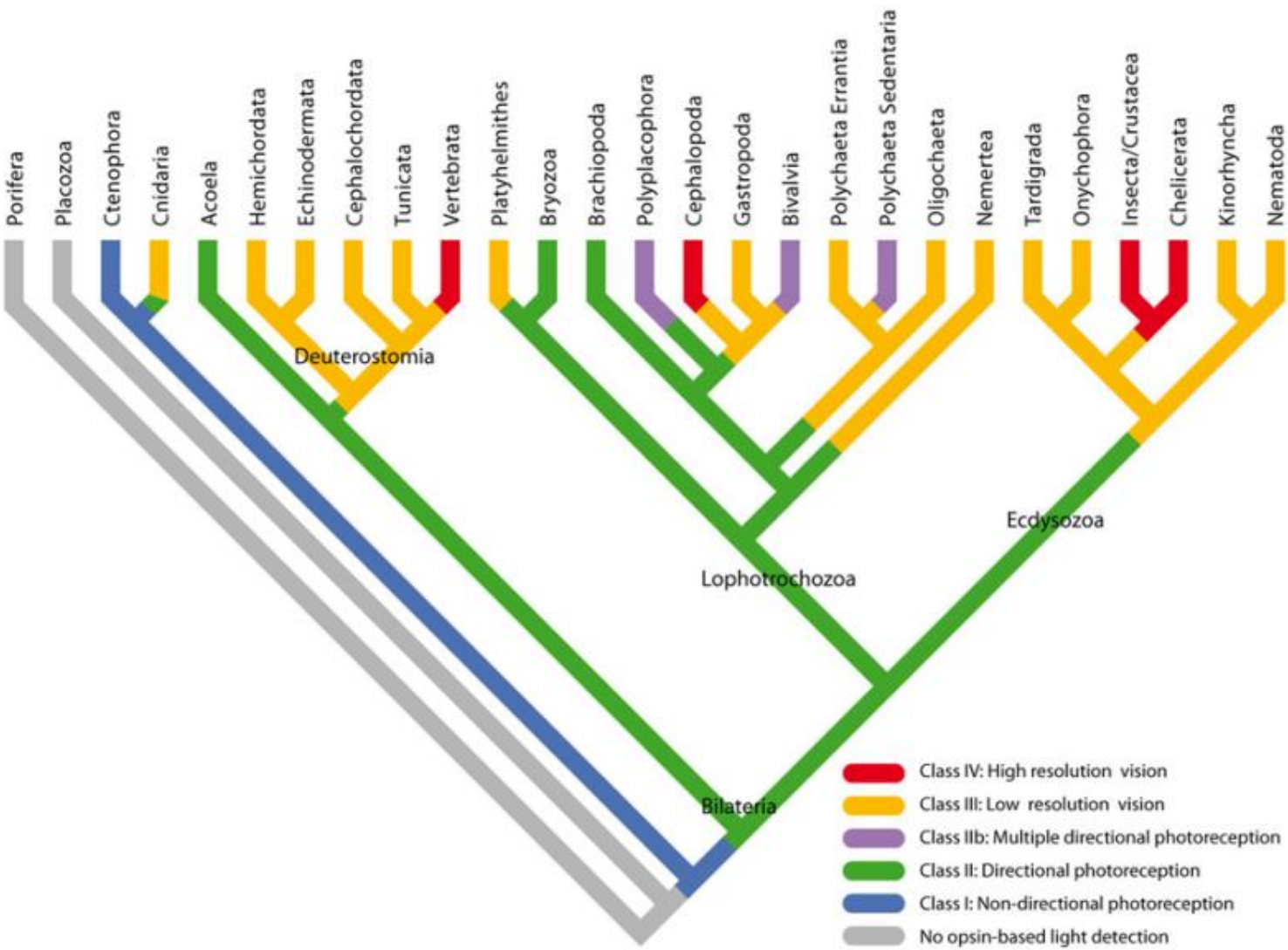
(a) A pigment spot; (b) a simple pigment cup;
(c) the simple optic cup found in abalone;
(d) the complex lensed eye of the marine snail and of the octopus.

Designed according to Ernst Mayr "What evolution is" (2001 p. 206)

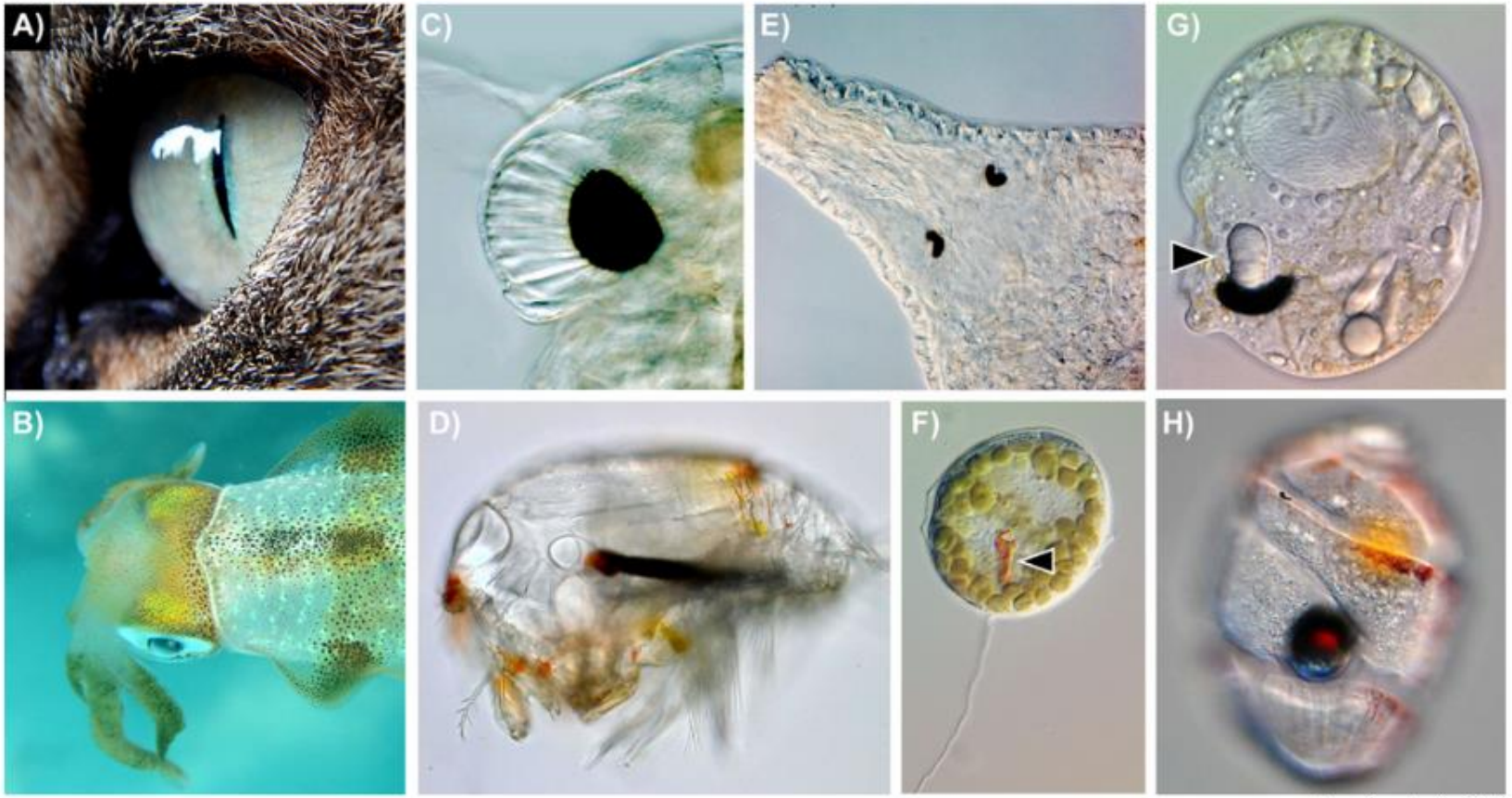
Nilsson, 201



Nilsson, 2013



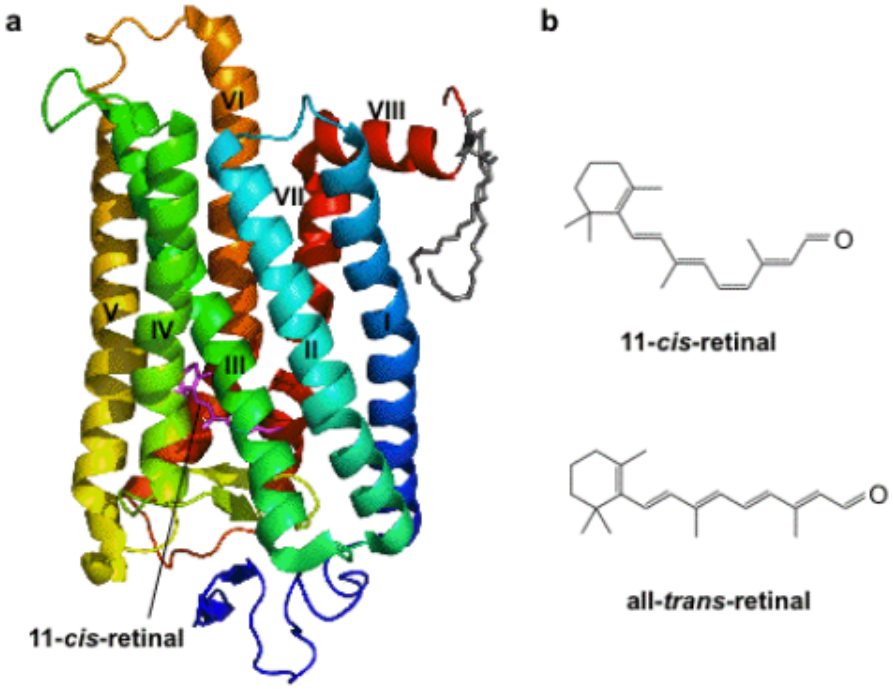
Nilsson, 2013



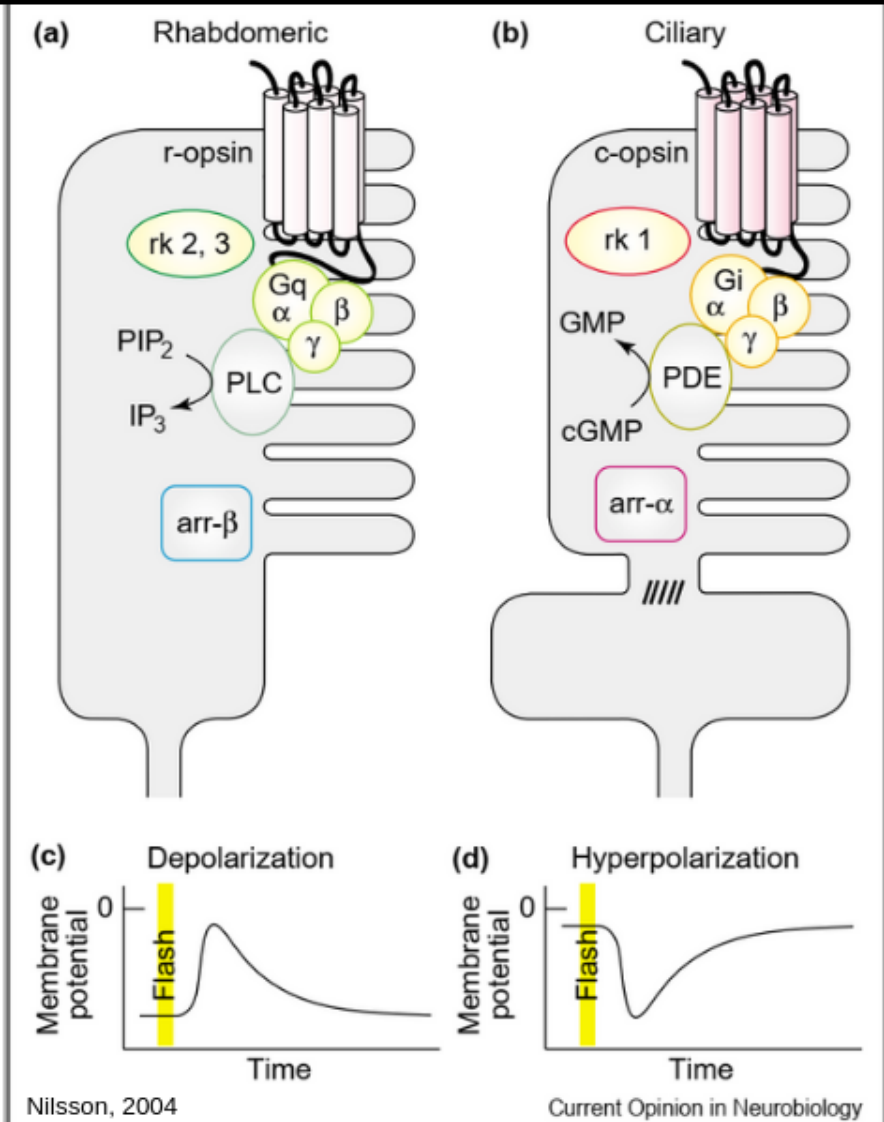
Gavelis, et al., 2017

Todos os olhos compartilham a mesma célula fotorreceptora?

FISIOLÓGICO



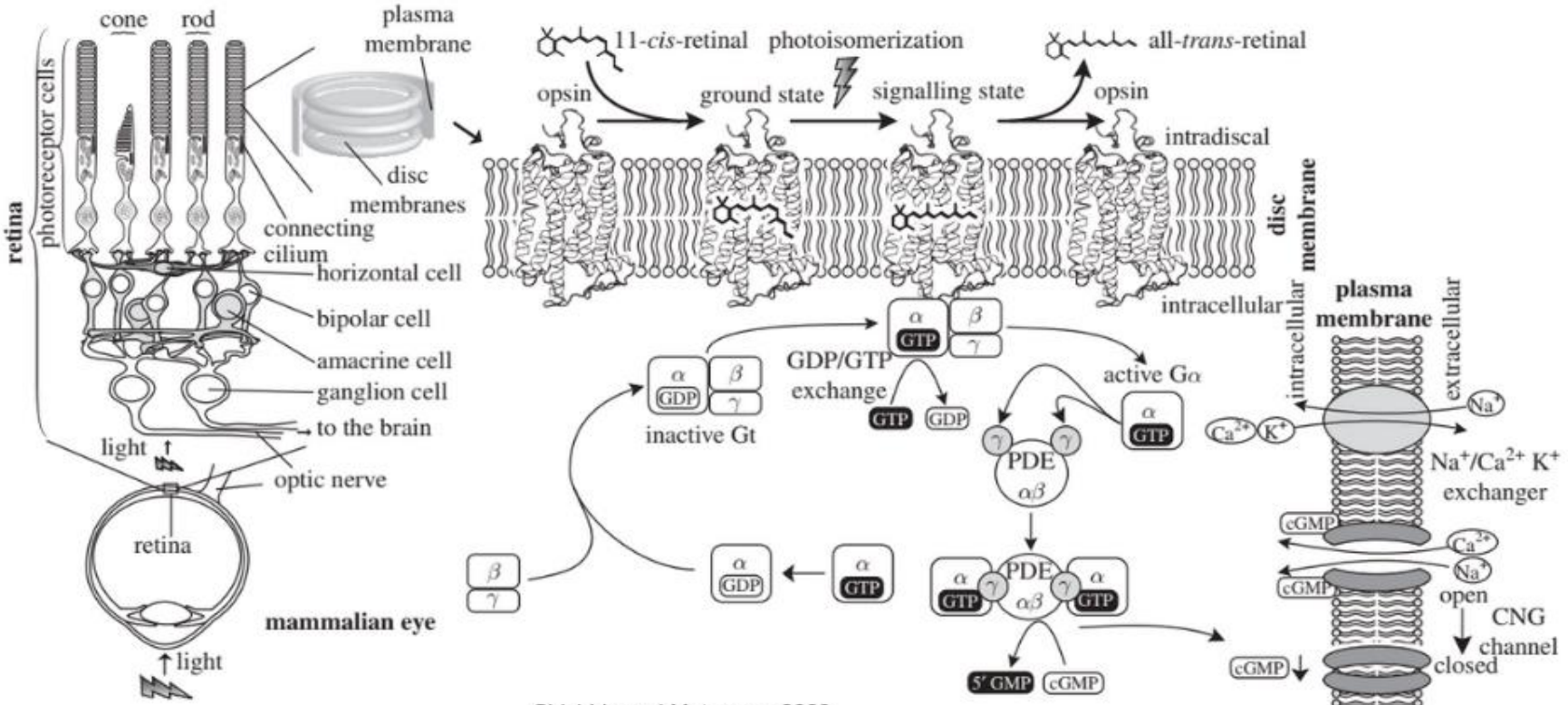
Opsinas - proteínas receptoras



Mesmo caminho de fototransdução

1 - Percepção da luz por rodopsinas
2 - Rodopsina ativa G proteína
3 - G proteína ativa uma cascata de sinalização enzimática
4 - resposta elétrica percebida pelas células fotorreceptoras

Existem 2 tipos de celulas fotorreceptoras
-Ciliares - superfície fotossensível derivada de um cílio.
- Rabdomérico - derivada de microvilosidades da superfície da célula



Shichida and Matsuyam 2009

Randel N, Jekely G. 2016

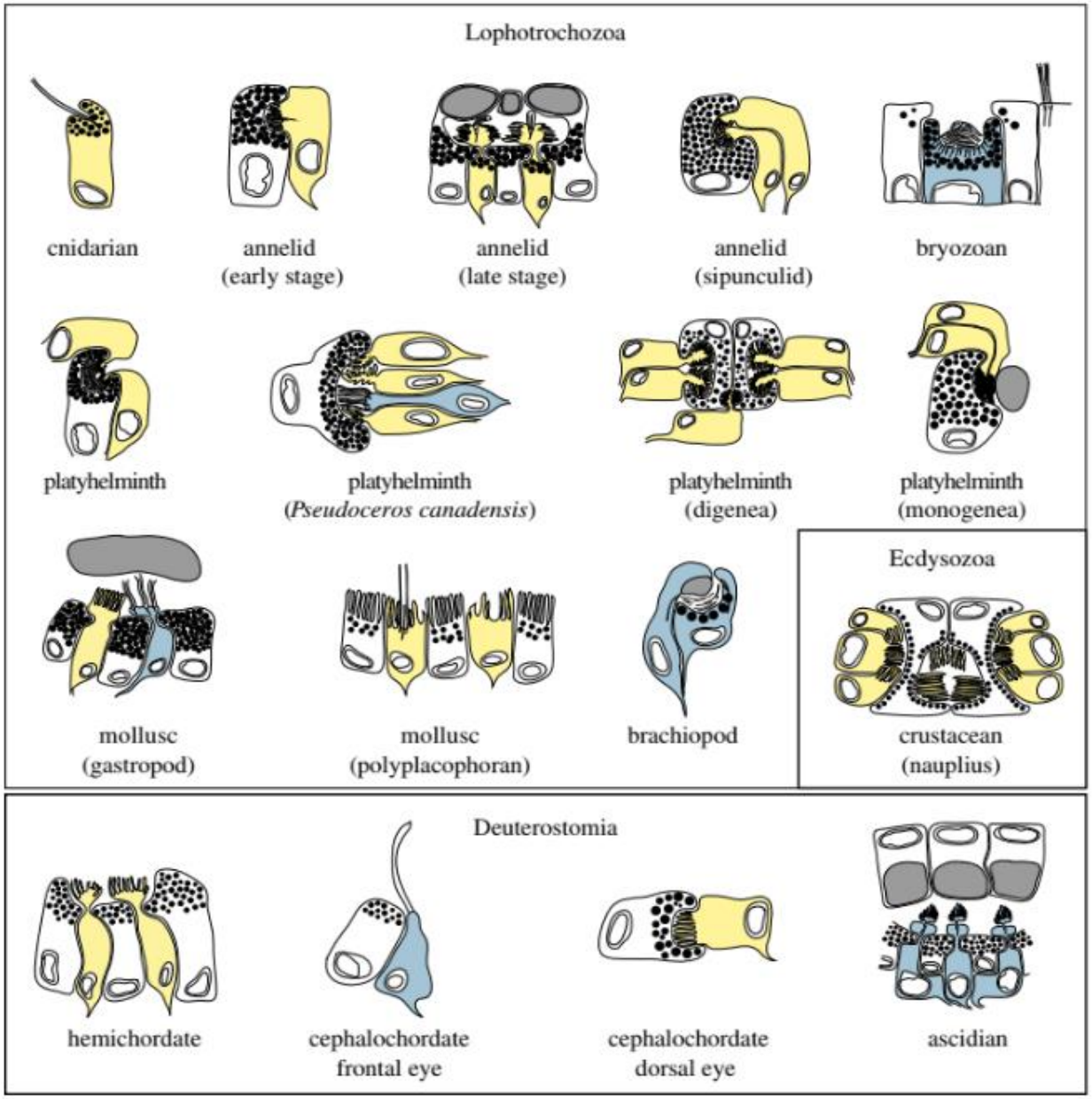


Figure 1. Diversity of simple eyes in planktonic larvae. Schematic drawings of simple eyes from marine invertebrate larvae. Rhabdomeric photoreceptors are shown in yellow, ciliary photoreceptors in blue, lenses in grey and pigment granules in black.

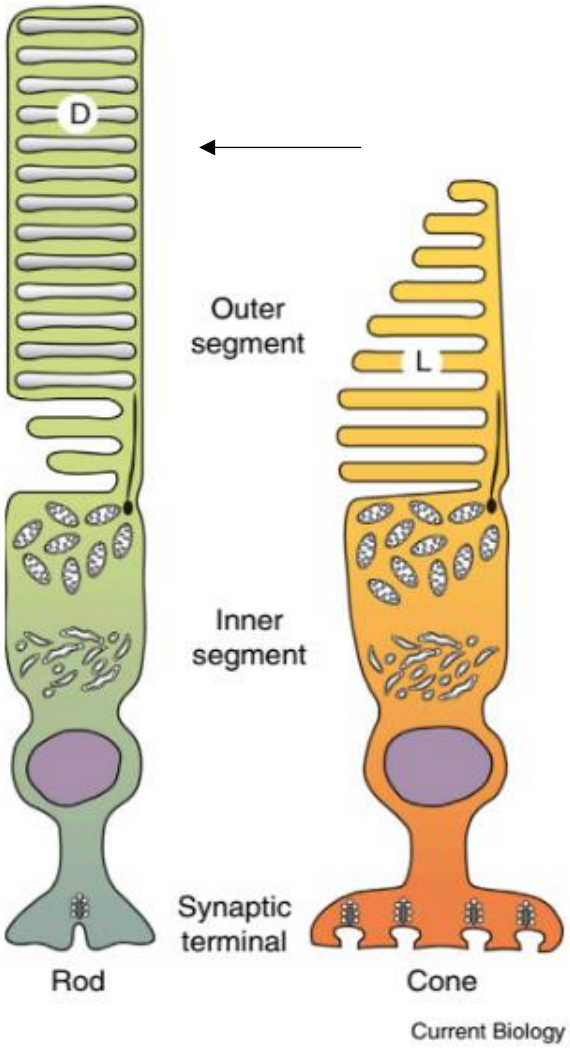


Figure 2. The morphology of rods (left) and cones (right) in modern jawed vertebrates.

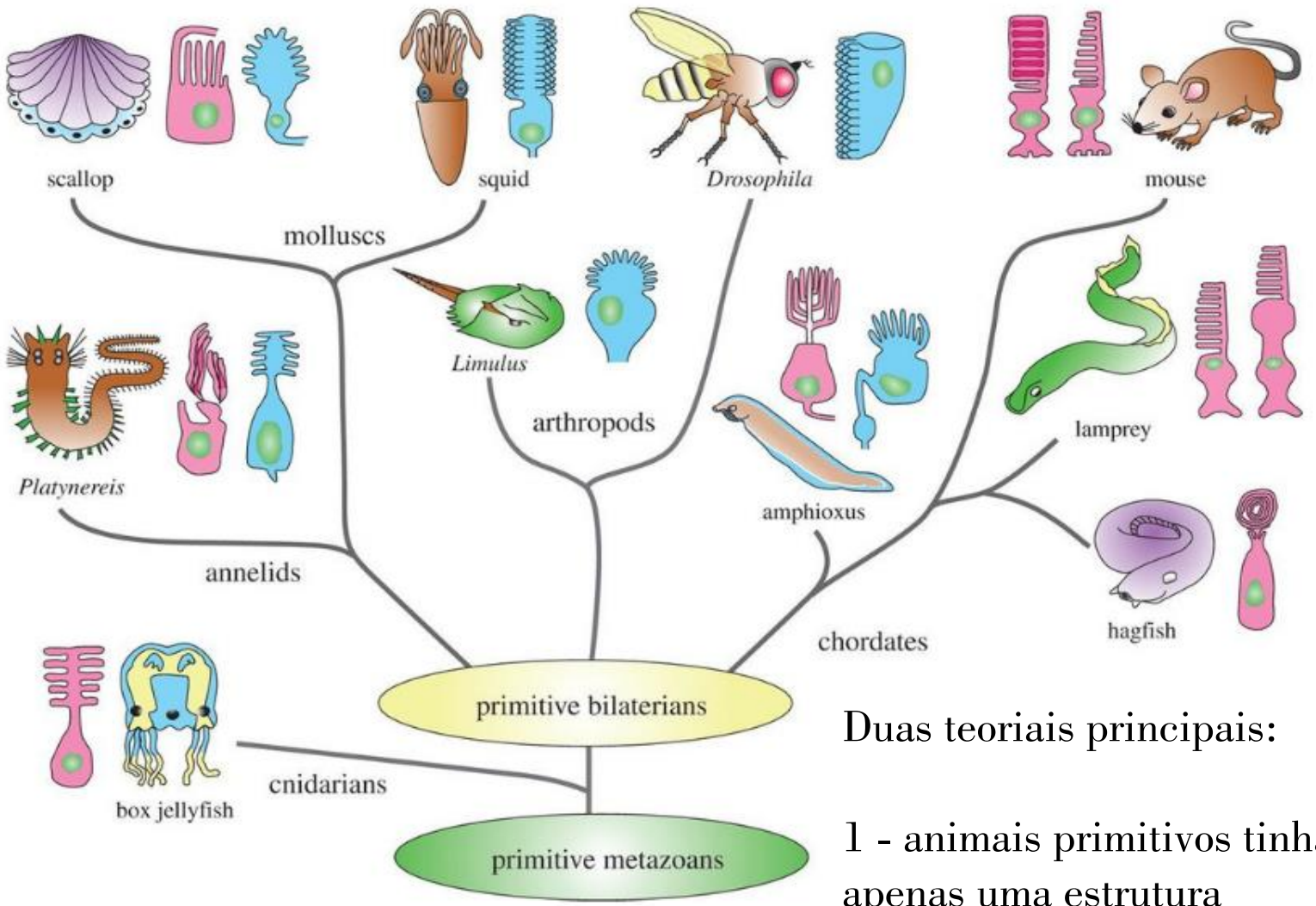
Note the outer segment lamellae (L) and internalised cytosolic disks (D) characteristic of cones and rods, respectively. After [12].

Warrant, 2015

Cones e bastonetes

cone é fisiologicamente muito mais parecido com um bastonete

Histórico das células fotorreceptoras



Duas teoriais principais:

1 - animais primitivos tinham apenas uma estrutura

Morshedian and Fain, 2017

2 – presença de estruturas ciliares, rabdomericas e celulas pigmentares

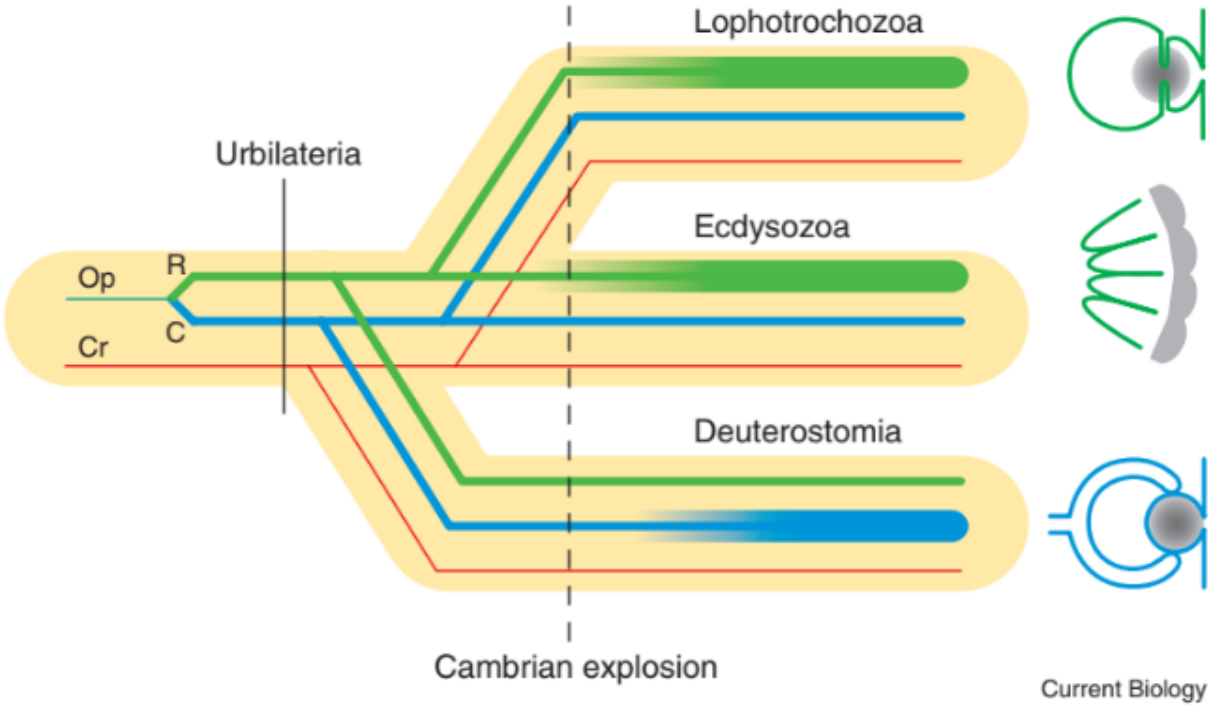


Figure 1. A phylogenetic tree of photoreceptive systems in the main branches of Bilateria.

Então porque considerar uma origem diferente?

Origem independente

MORFOLÓGICO

Origem comum - ressalvas

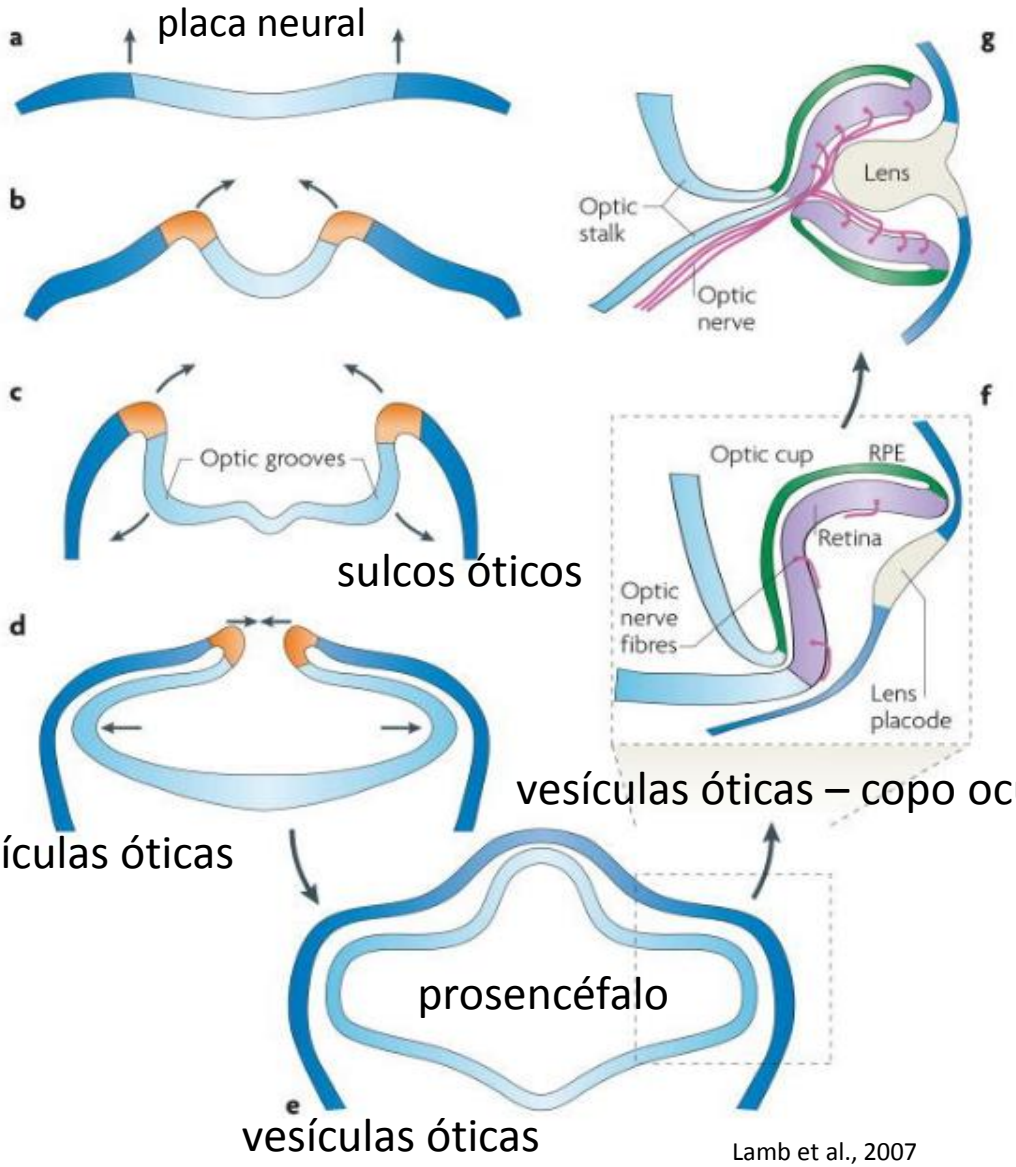
FISIOLÓGICO

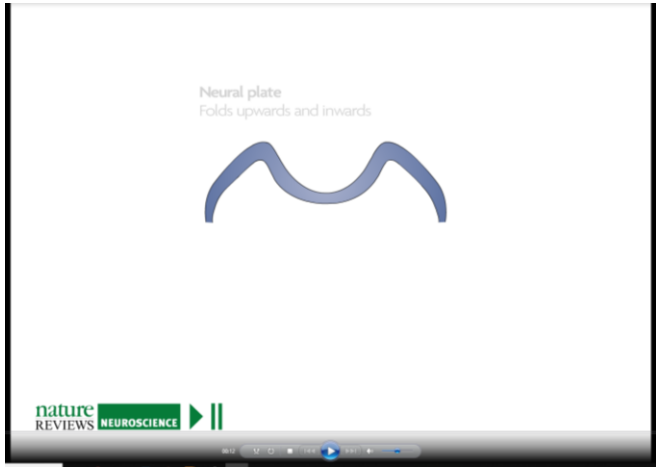
?

EMBRIONÁRIO


EMBRIONÁRIO

Vertebrados



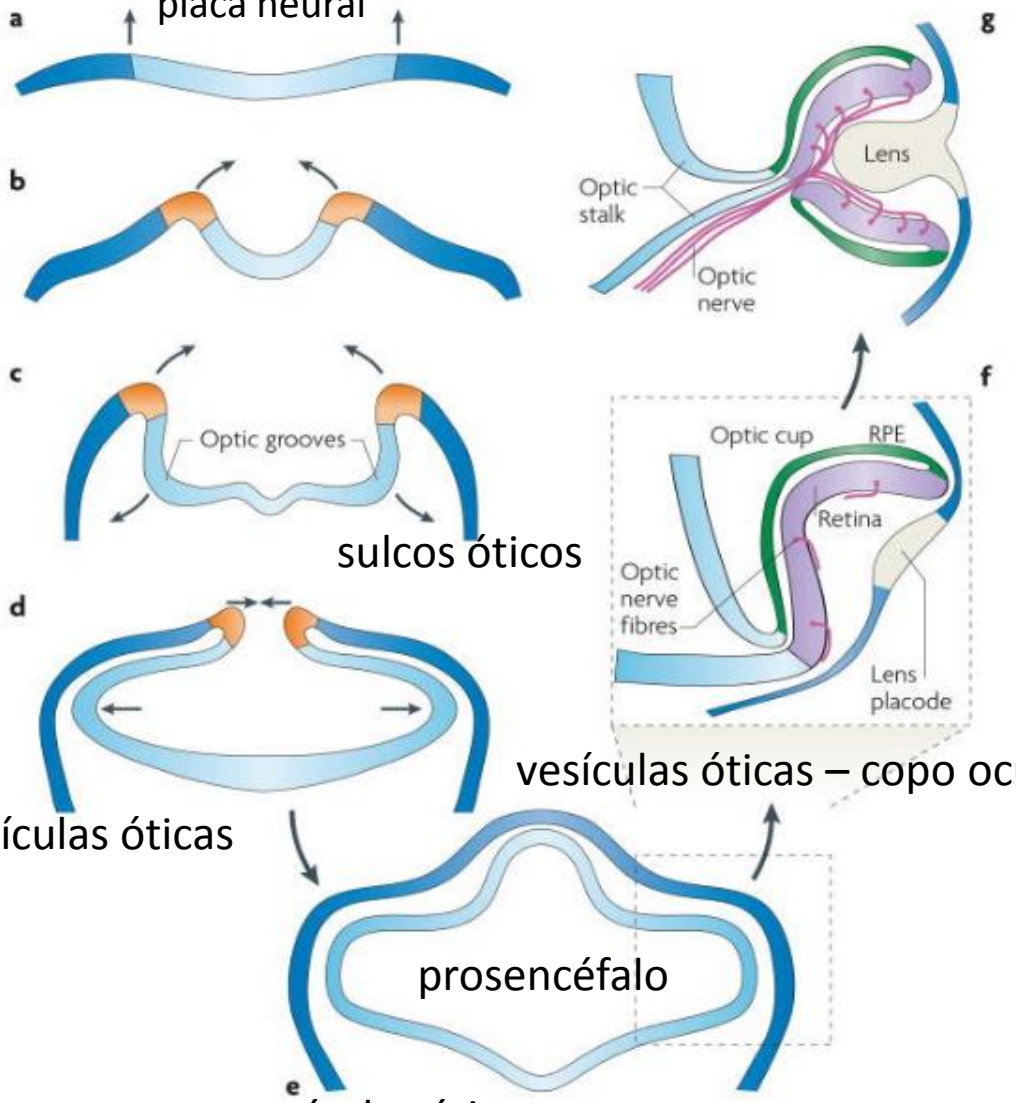


https://www.youtube.com/watch?v=C4fPBYvx17Y

Lamb et al., 2007

Vertebrados

placa neural



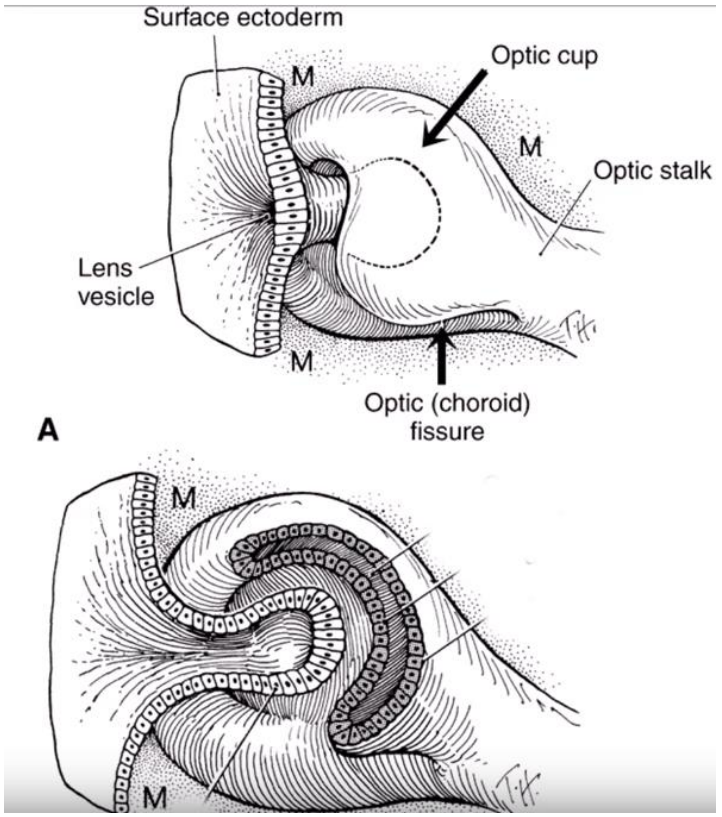
sulcos óticos

vesículas óticas – copo ocular

vesículas óticas

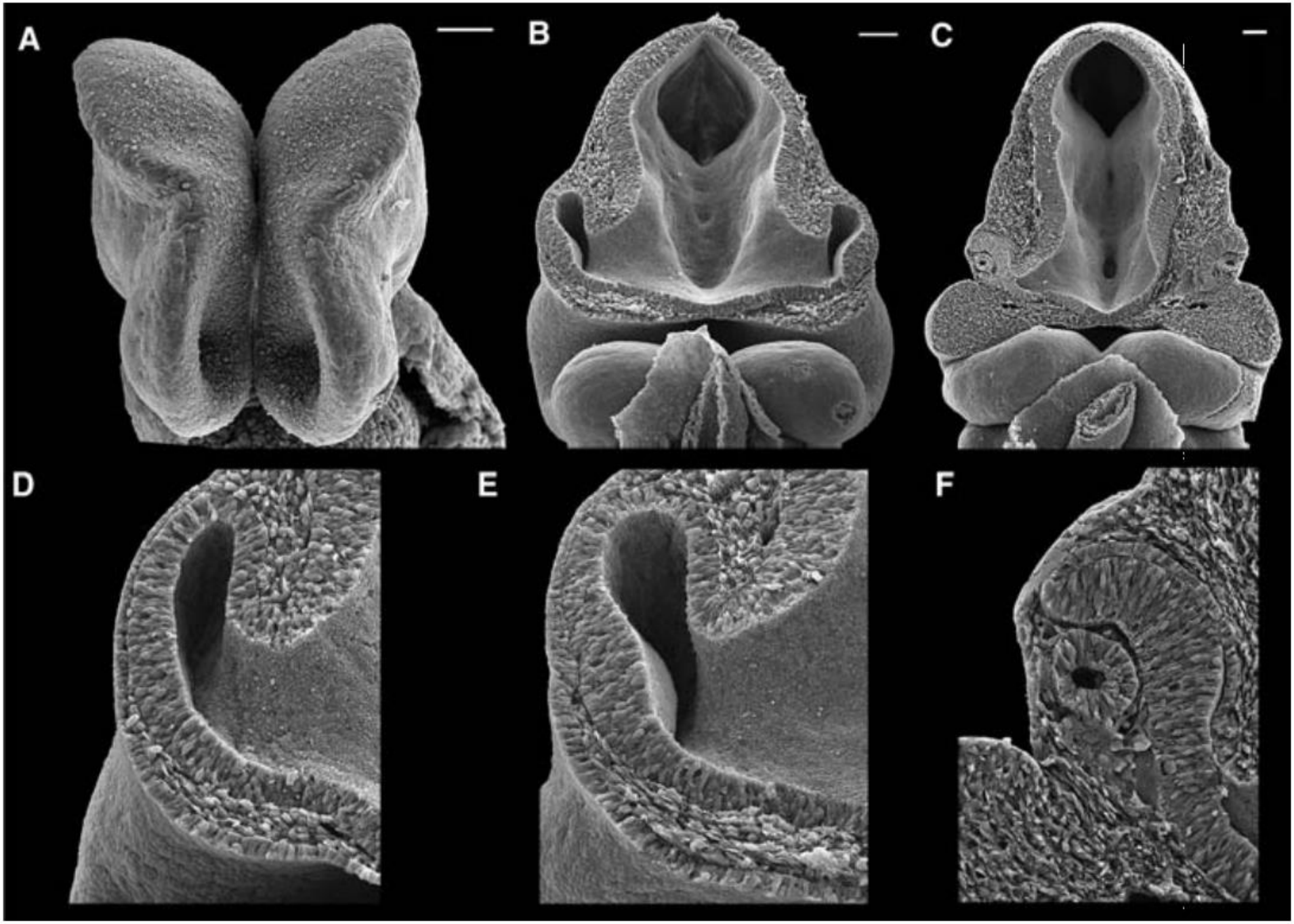
prosencéfalo

vesículas óticas

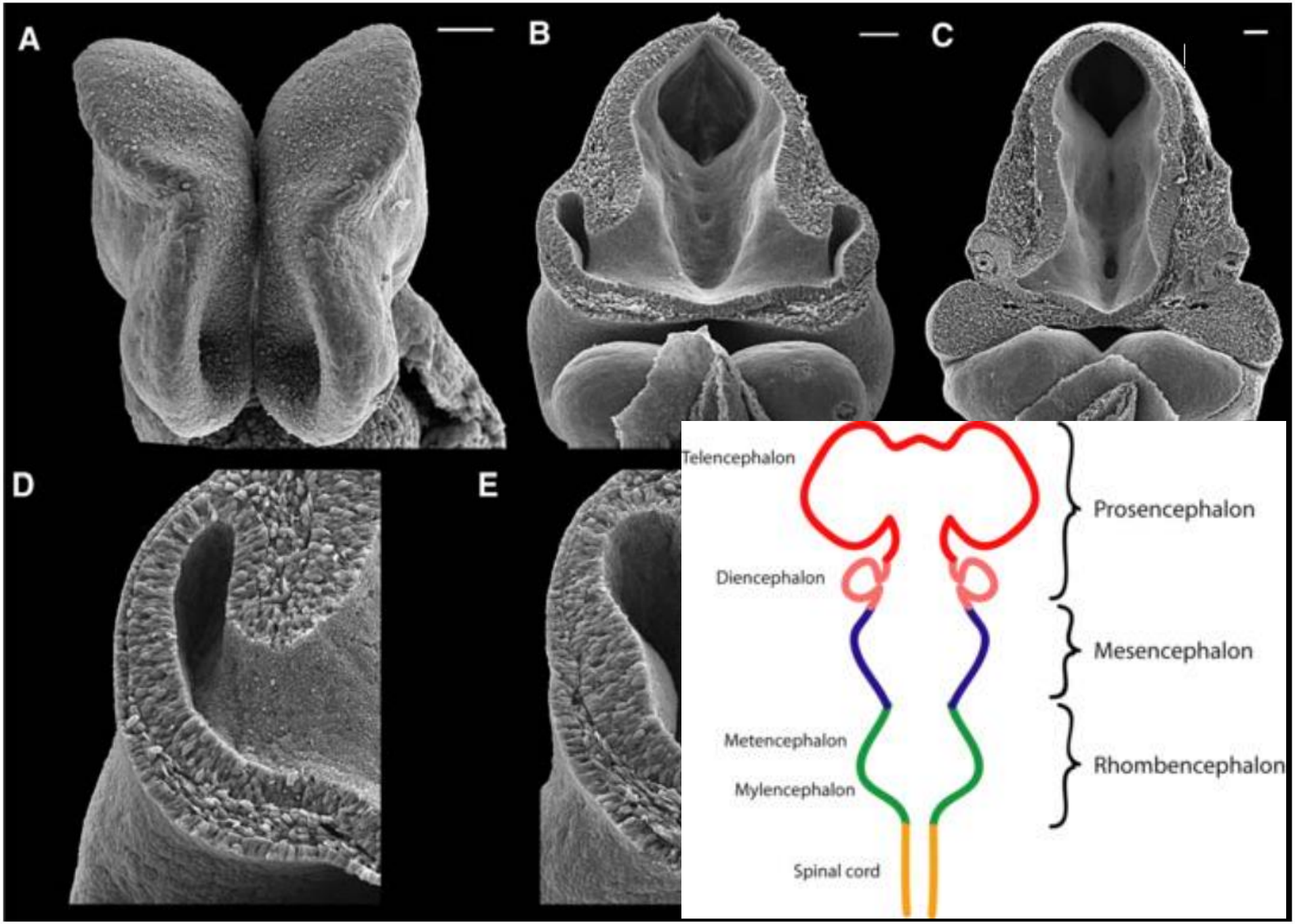


https://www.youtube.com/watch?v=C4fPBYvx17Y

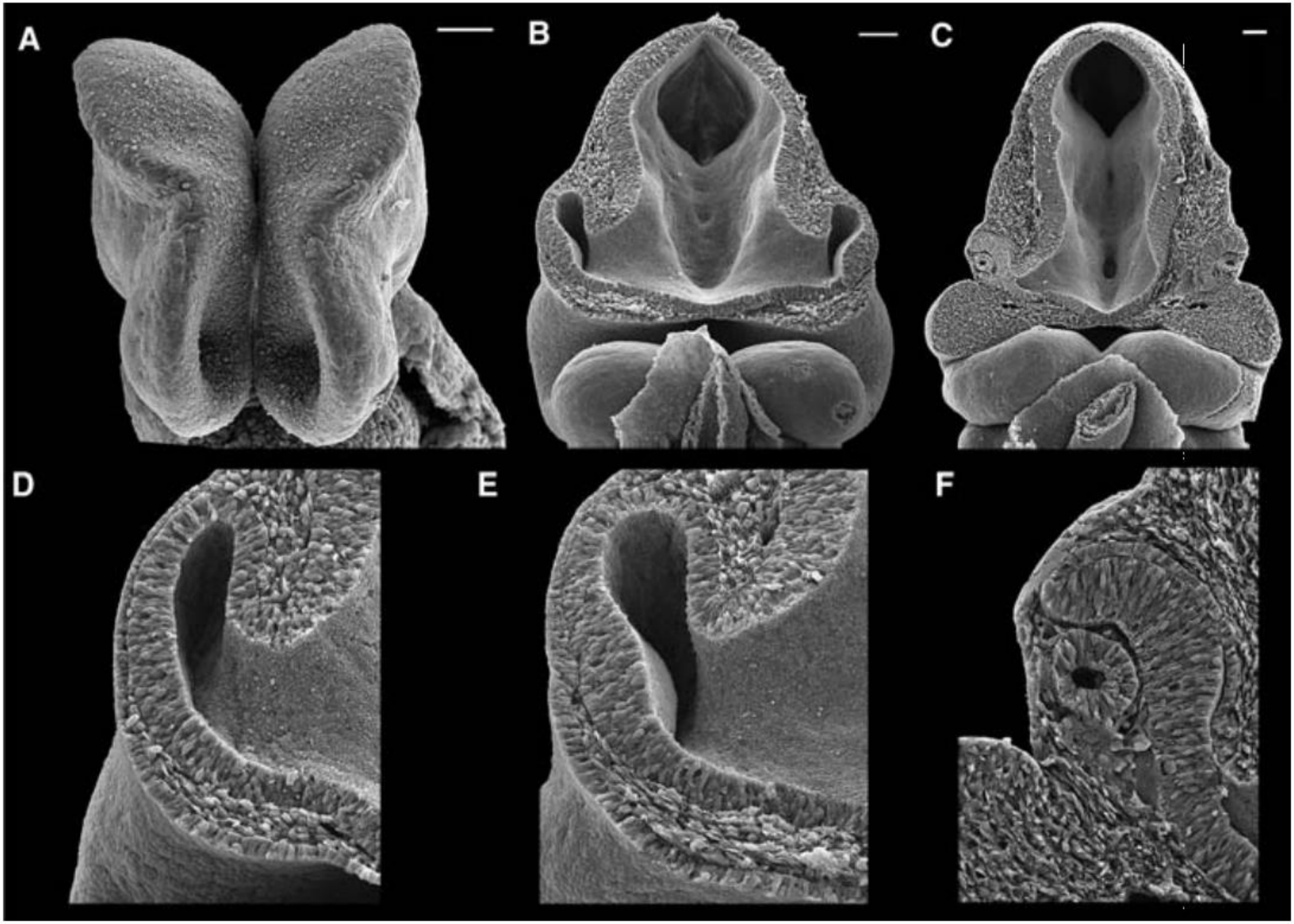
Lamb et al., 2007



Heavner and Pevny 2012



Heavner and Pevny 2012



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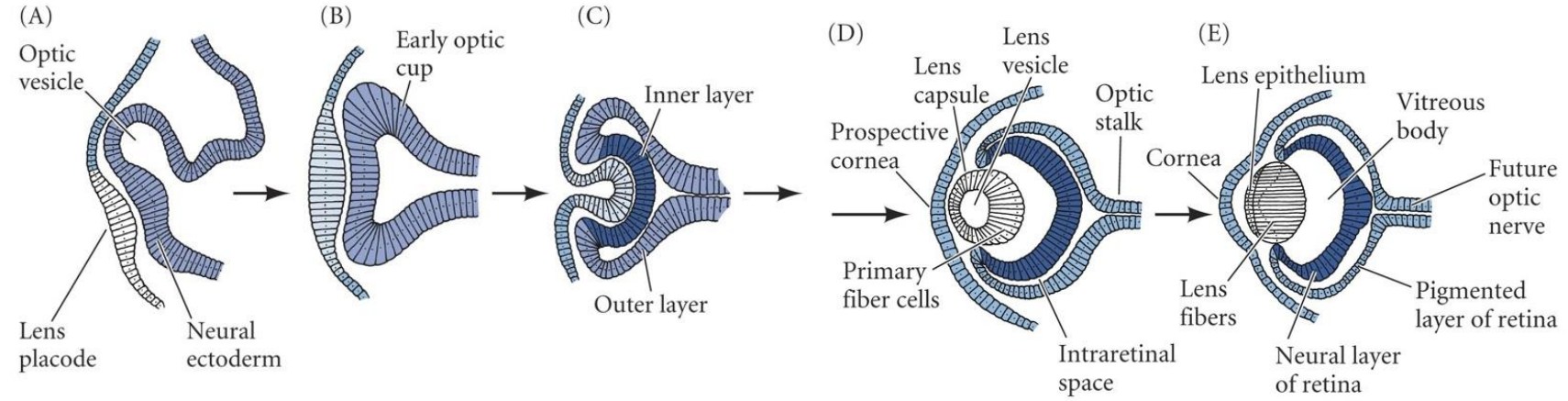


(F)

Early gastrula | Late gastrula | Early neurula | Mid to late neurula

Chordamesoderm

Prospective ectoderm

Prospective neural plate

Prospective optic cup

Optic vesicle

Optic cup

Pigmented retina

Neural retina

Prospective epidermis

Prospective lens ectoderm

Lens placode

Lens vesicle

Lens

Prospective pharynx

Prospective heart

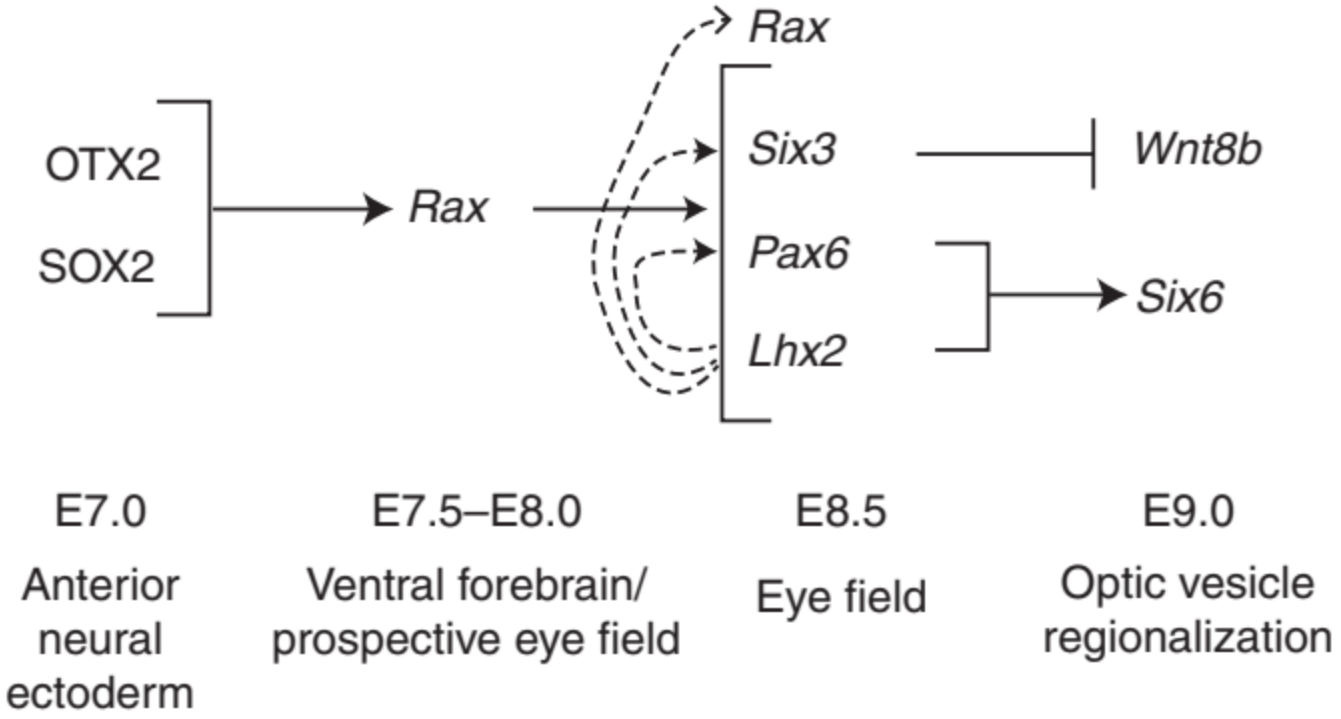
Prospective cornea ectoderm

Cornea

Gilbert, S. Developmental Biology

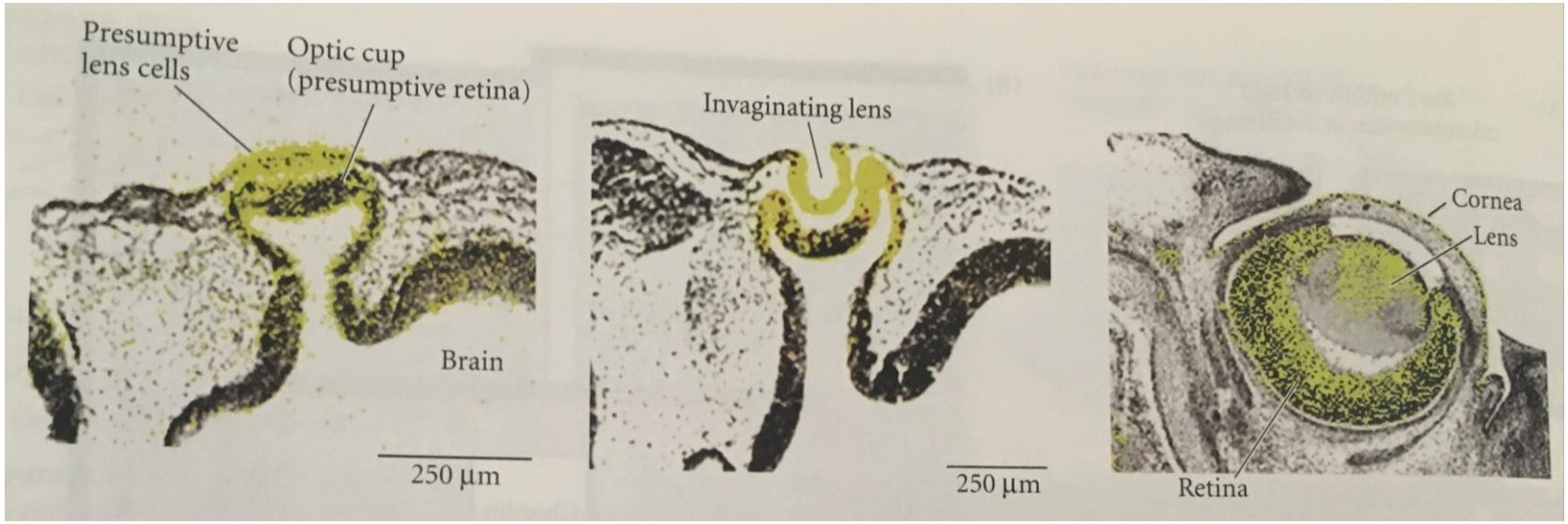
Expressão Genética

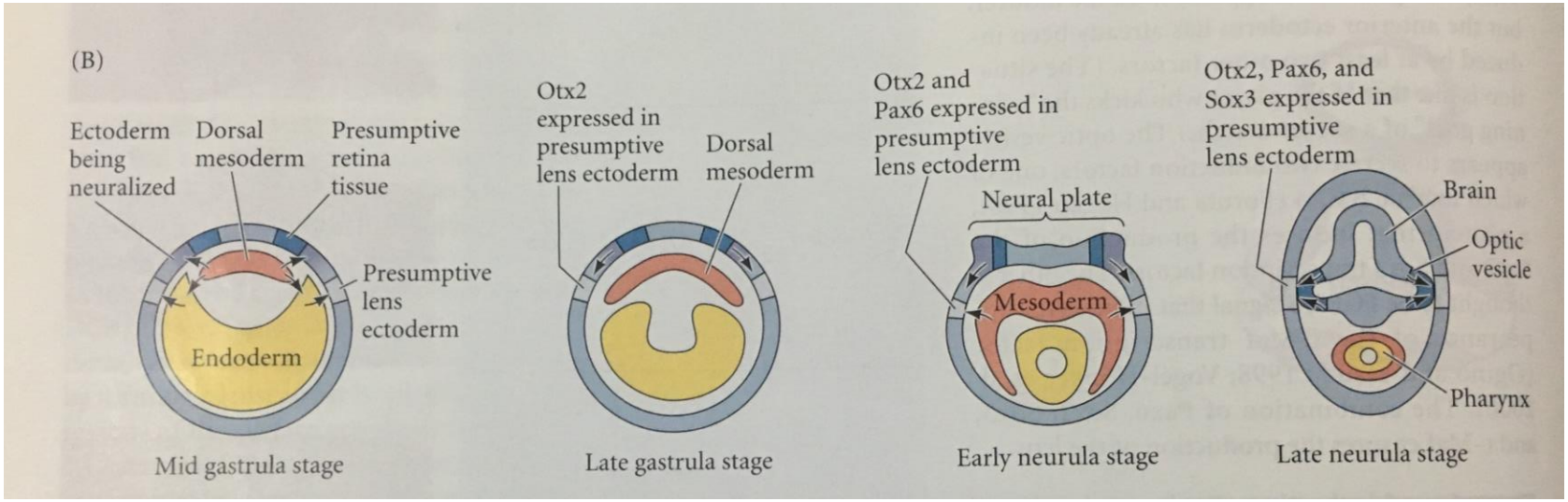
Fatores de transcrição



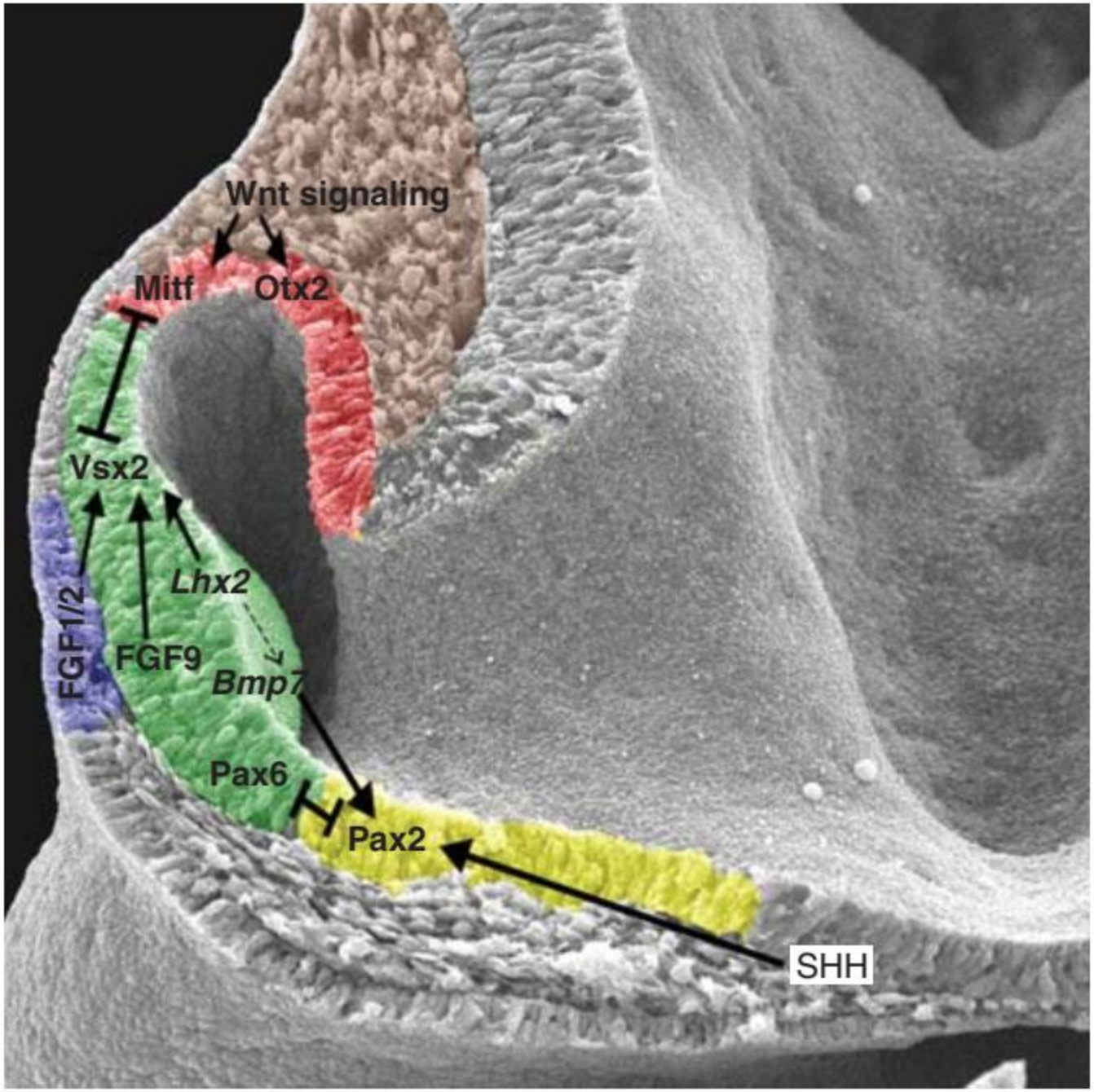
Indução progressiva

Heavner and Pevny 2012

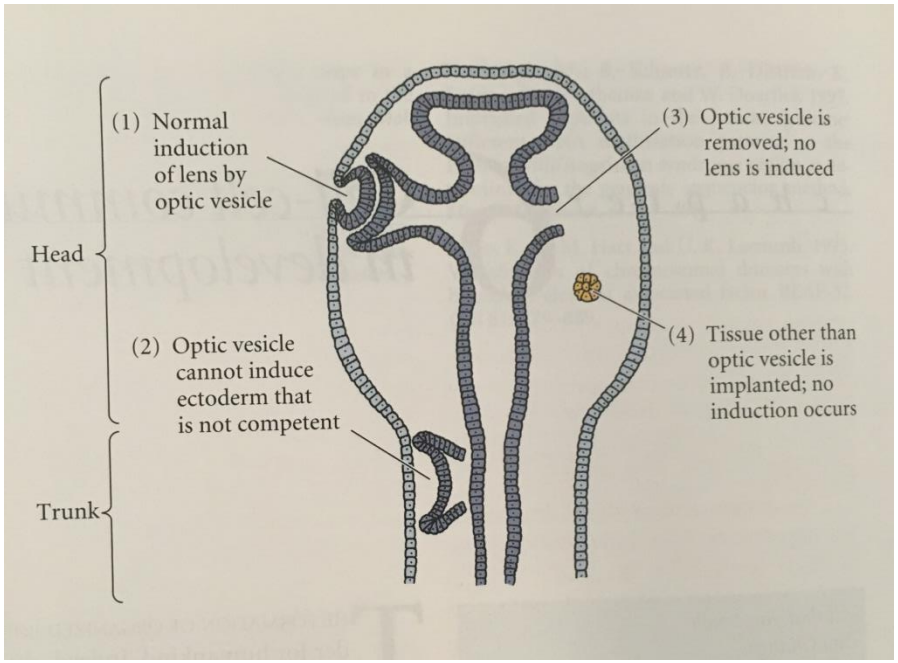




Gilbert, S. Developmental Biology



Heavner and Pevny 2012



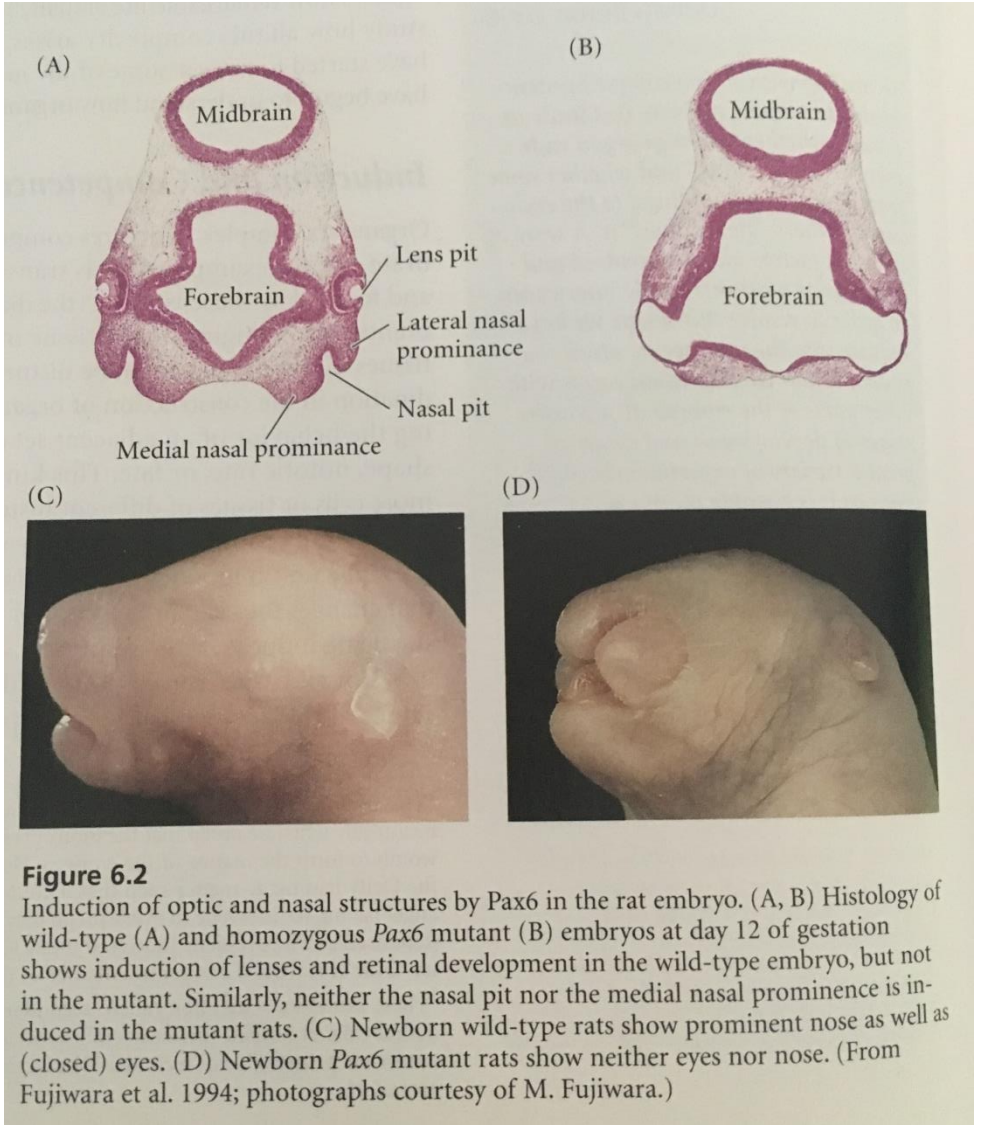
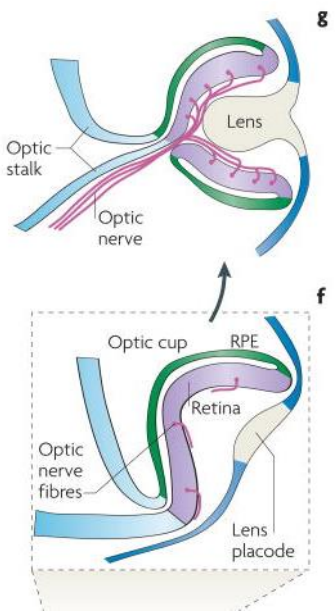
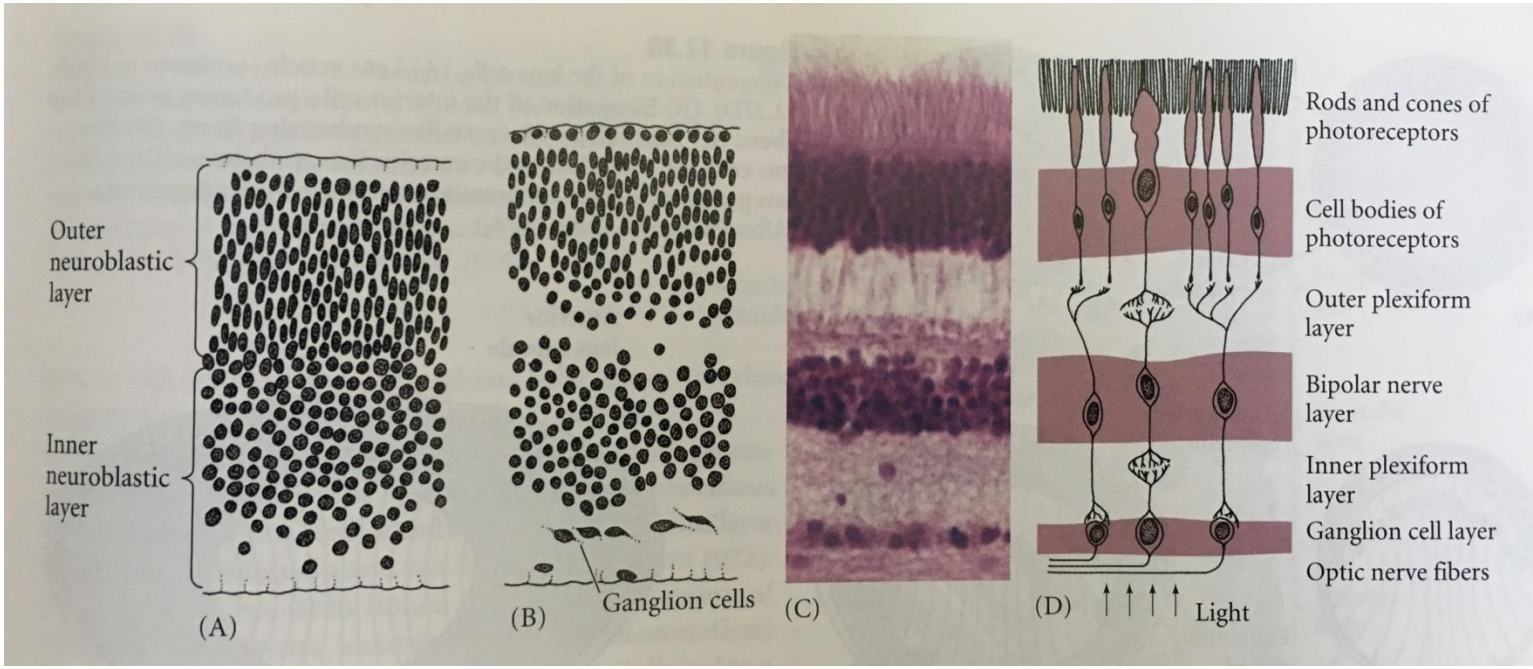


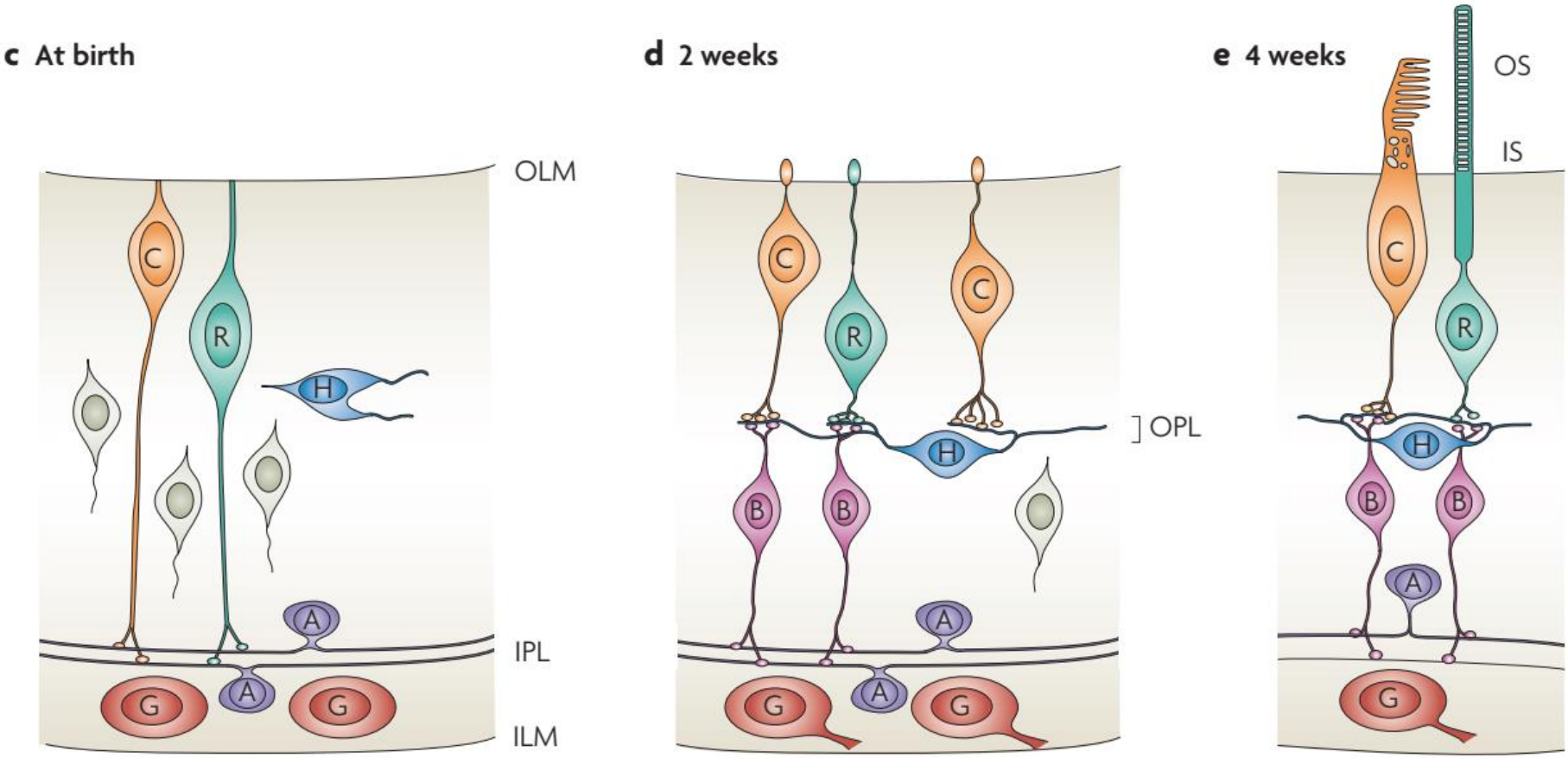
Figure 6.2
Induction of optic and nasal structures by Pax6 in the rat embryo. (A, B) Histology of wild-type (A) and homozygous *Pax6* mutant (B) embryos at day 12 of gestation shows induction of lenses and retinal development in the wild-type embryo, but not in the mutant. Similarly, neither the nasal pit nor the medial nasal prominence is induced in the mutant rats. (C) Newborn wild-type rats show prominent nose as well as (closed) eyes. (D) Newborn *Pax6* mutant rats show neither eyes nor nose. (From Fujiwara et al. 1994; photographs courtesy of M. Fujiwara.)

Formação da retina e células fotorreceptoras





Gilbert, S. Developmental Biology



Lamb et al., 2007

Formação da lente

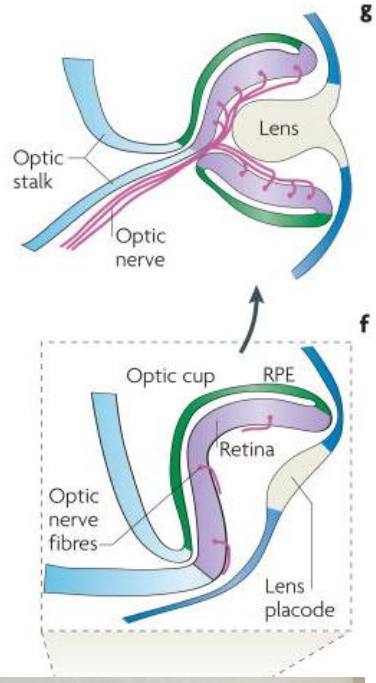


Figure 12.30
Differentiation of the lens cells. (A)
12.27D). (B) Elongation of the inte
fibers. (C) Lens filled with crystallin
lens cells are derived from the ante
lens grows, new fibers differentiate,
(After Paton and Craig 1974.)

Gilbert, S. Developmental Biology

Optic vesicles	Surface ectoderm	Lens induction
Wild-type	Wild-type	Yes
Pax6^{-}/*Pax6*$^{-}$	Wild-type	?
Wild-type	*Pax6*$^{-}$/*Pax6*$^{-}$	?
Pax6^{-}/*Pax6*$^{-}$	*Pax6*$^{-}$/*Pax6*$^{-}$	?

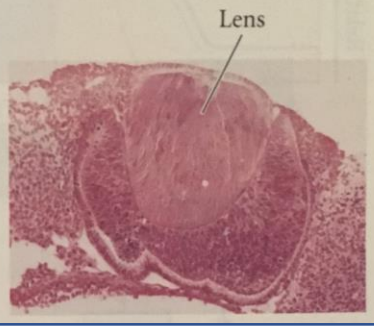
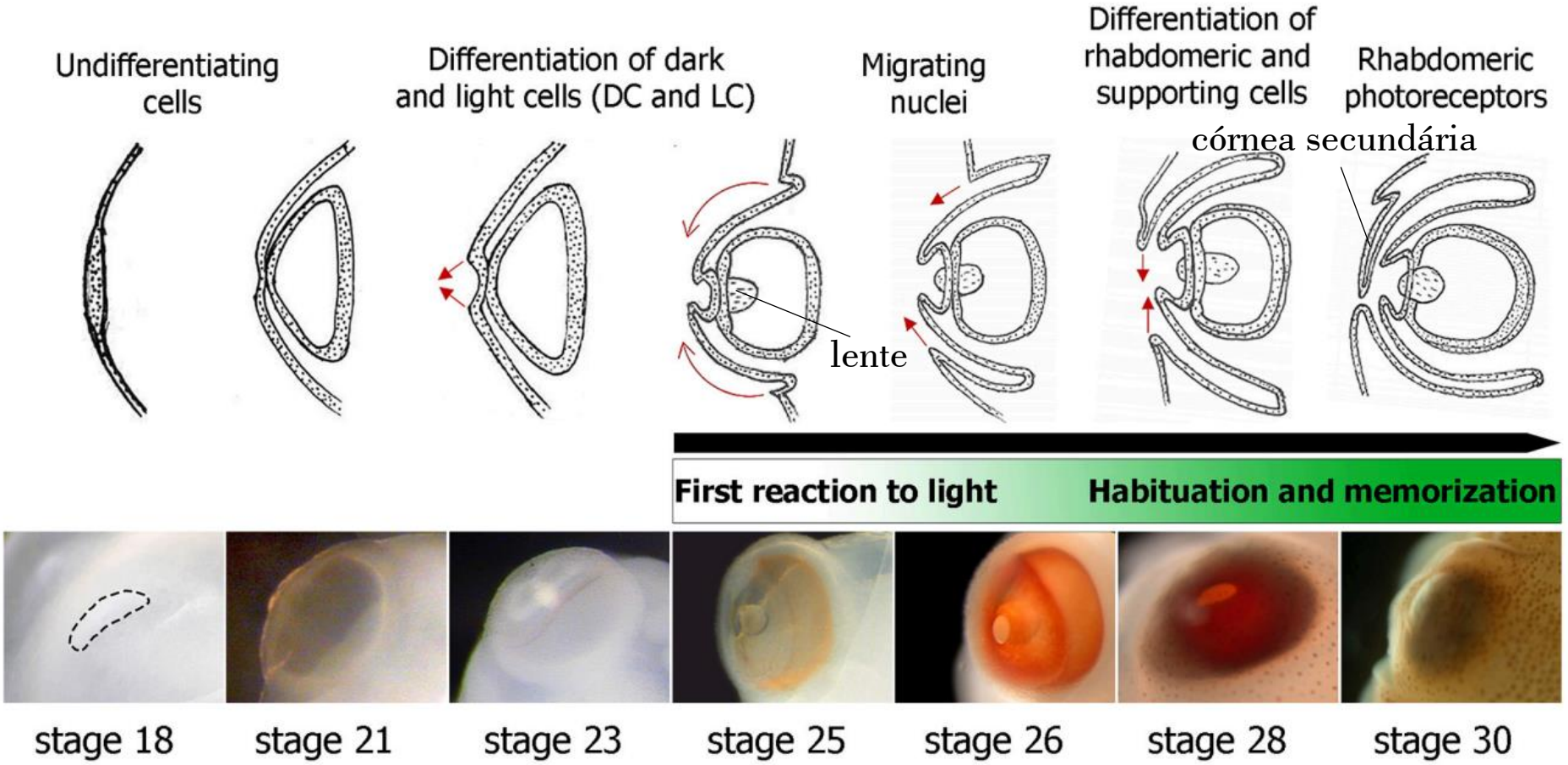


Figure 6.3
Recombination experiments show that the induction deficiency of *Pax6*-deficient rats is caused by the inability of the surface ectoderm to respond to the optic vesicle. (Photographs courtesy of M. Fujiwara.)

Cefalópodes

4 dobras ectodérmicas sucessivas

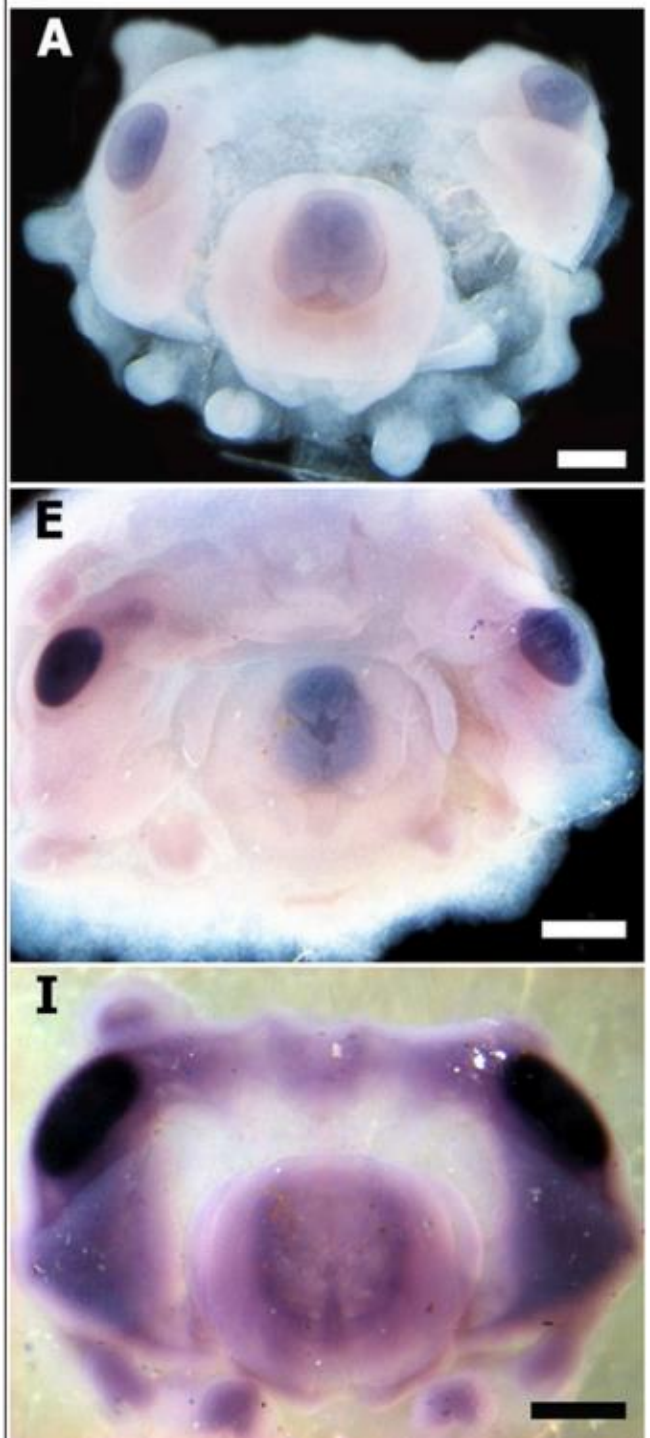


Imarazene et al., 2017

Sof-eya

Sof-dac

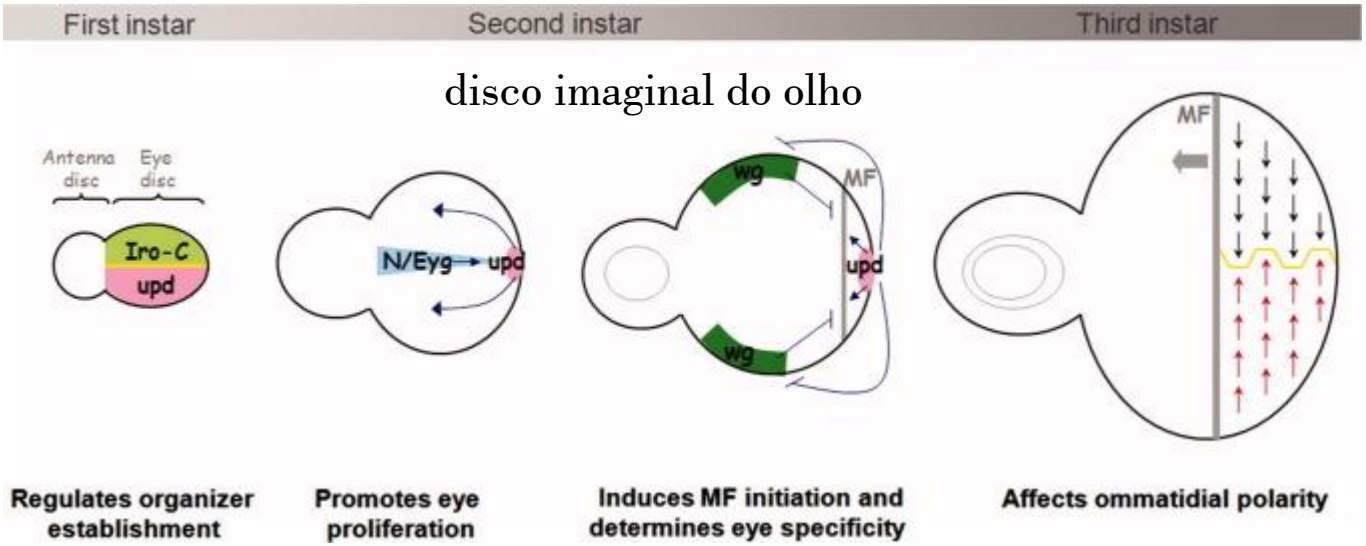
Sof-otx

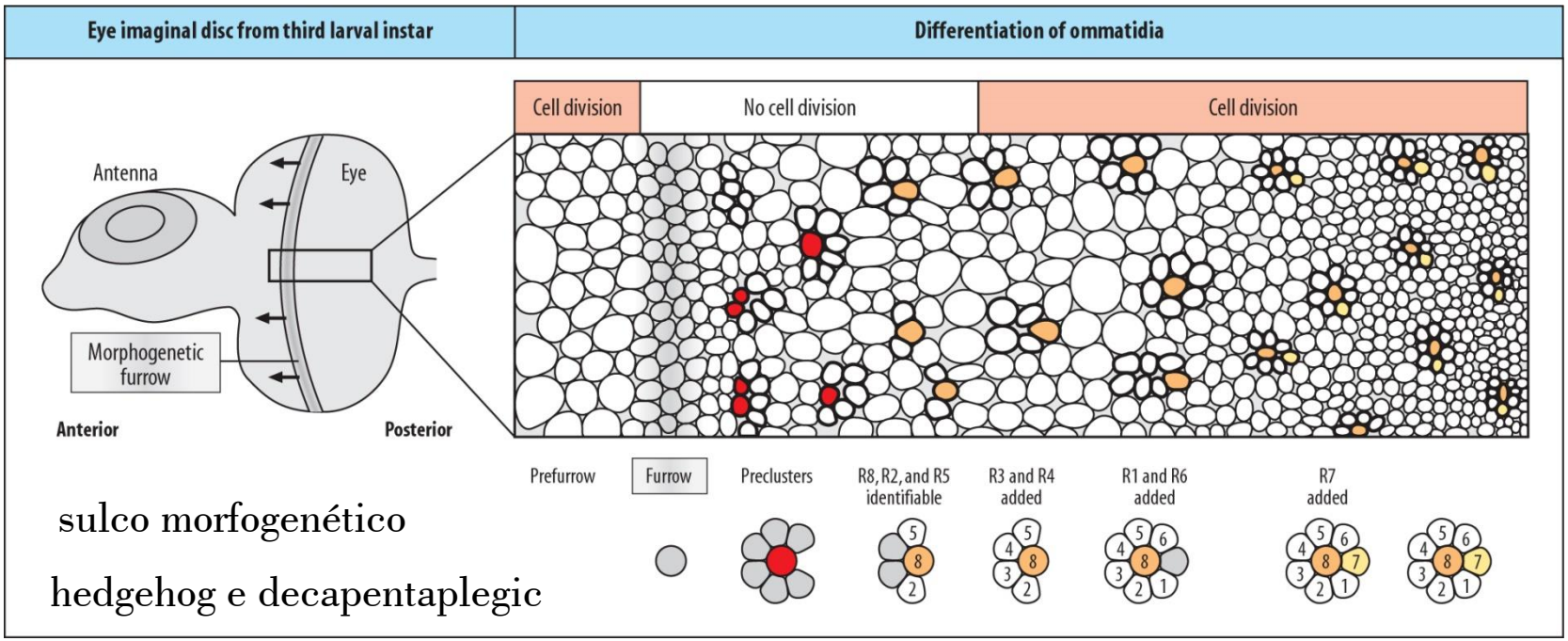


Drosophila

750 omatidia

disco imaginal do olho



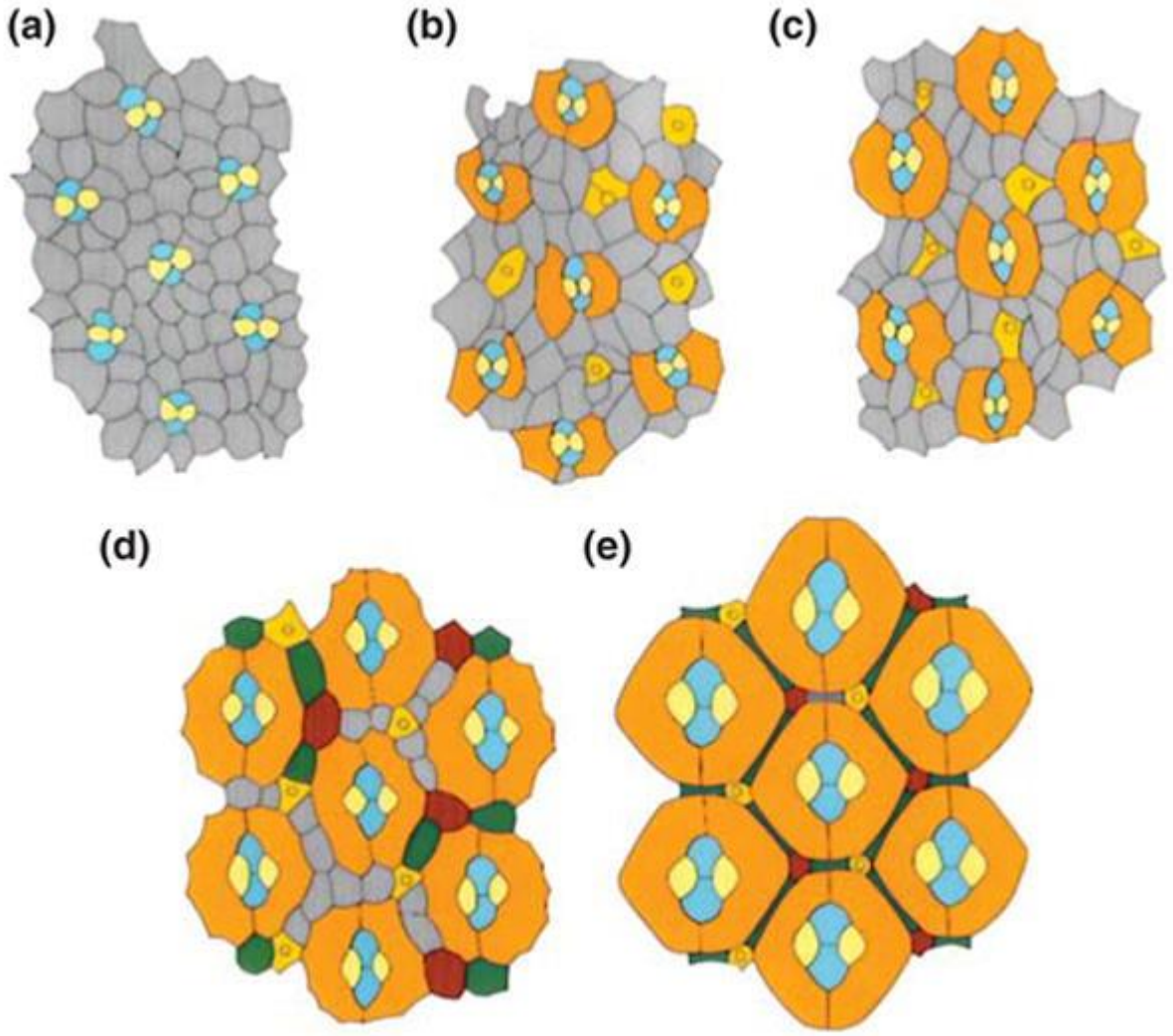


sulco morfogenético

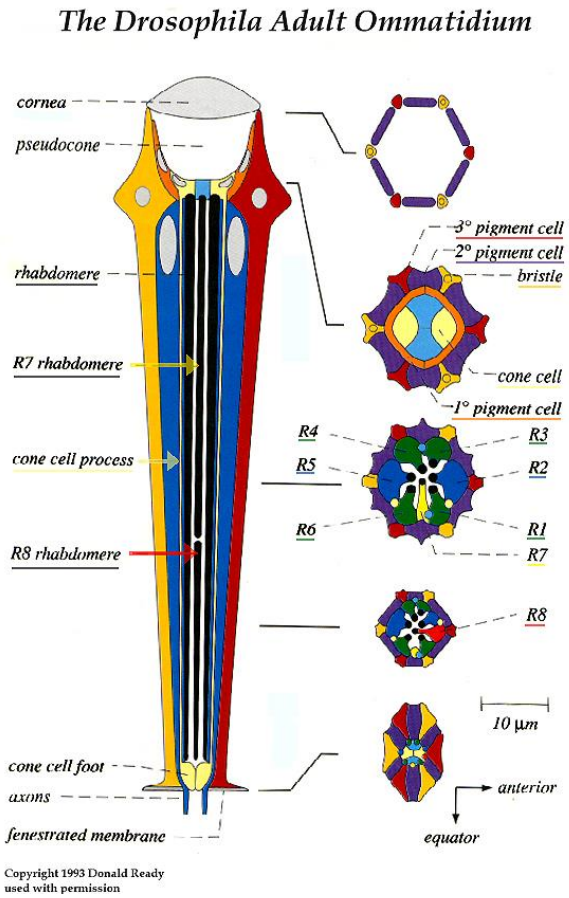
hedgehog e decapentaplegic

diferenciação dos neurônios fotorreceptores R8

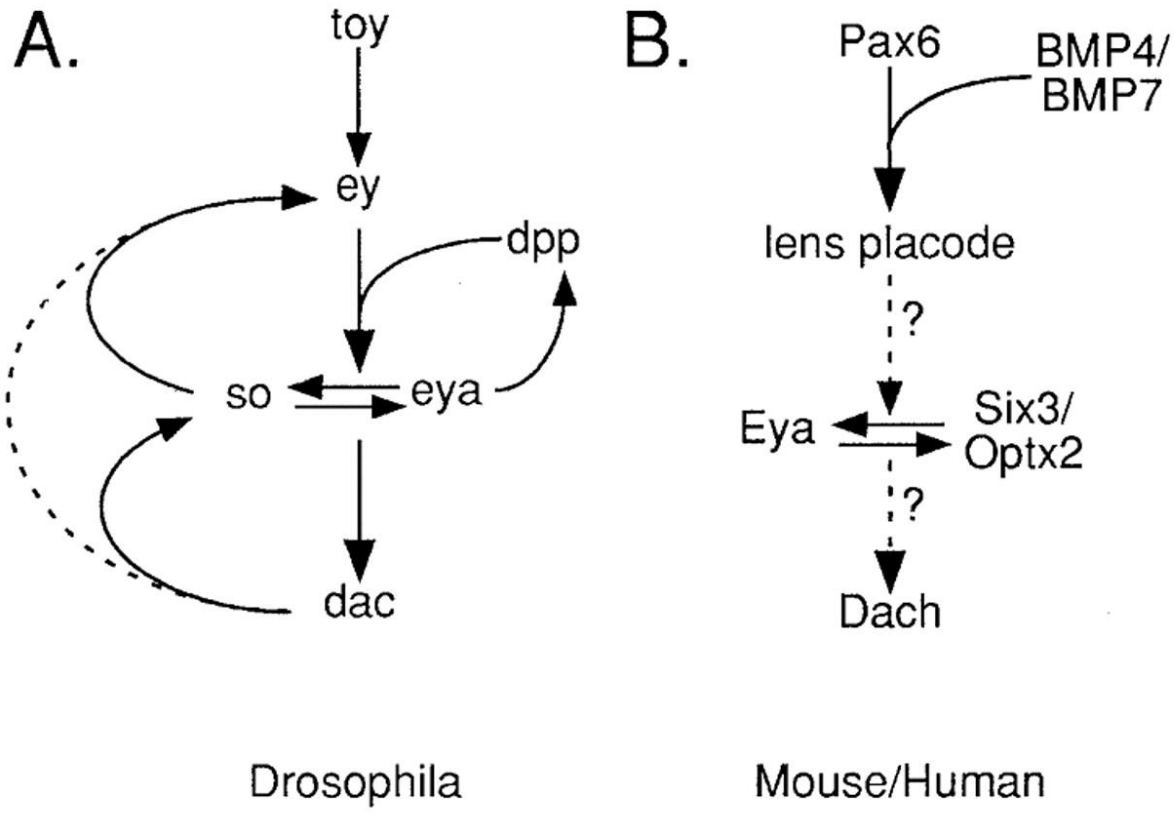
- 20 células arranjadas
-8 dessas células são fotorreceptores
- restantes são lentes



Current Opinion in Genetics & Development



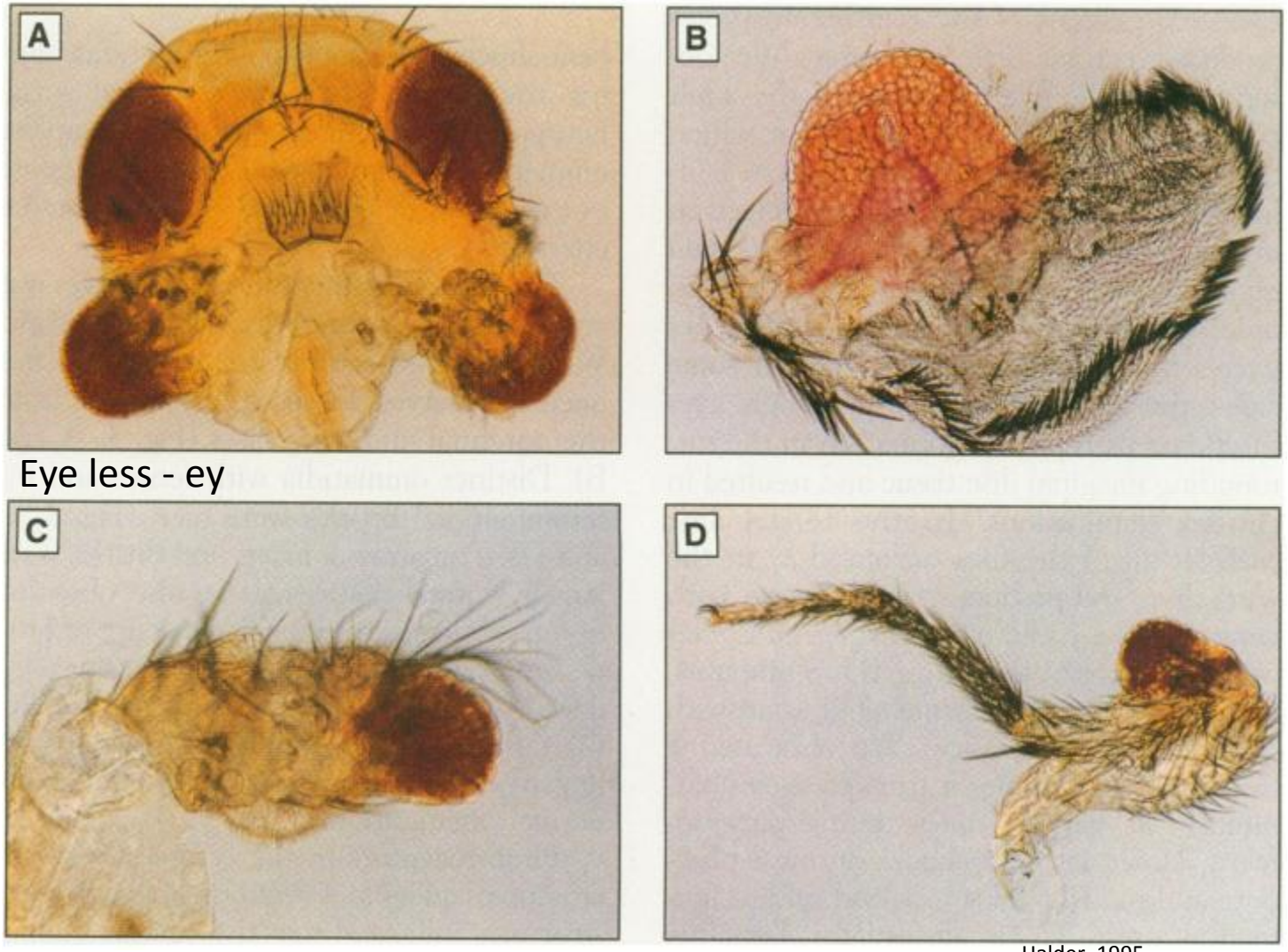
Expressão Genética



Human Molecular Genetics, Volume 9, Issue 6, 2000, Pages 917–925, https://doi.org/10.1093/hmg/9.6.917

Wawersik and Maas, 2000

Expressão Genética

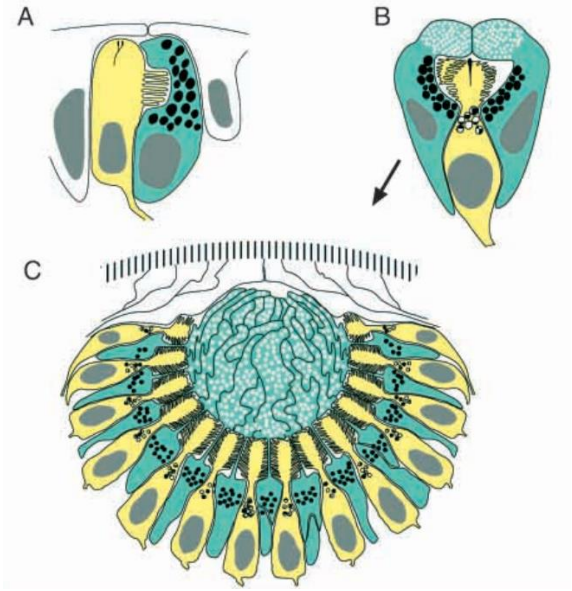


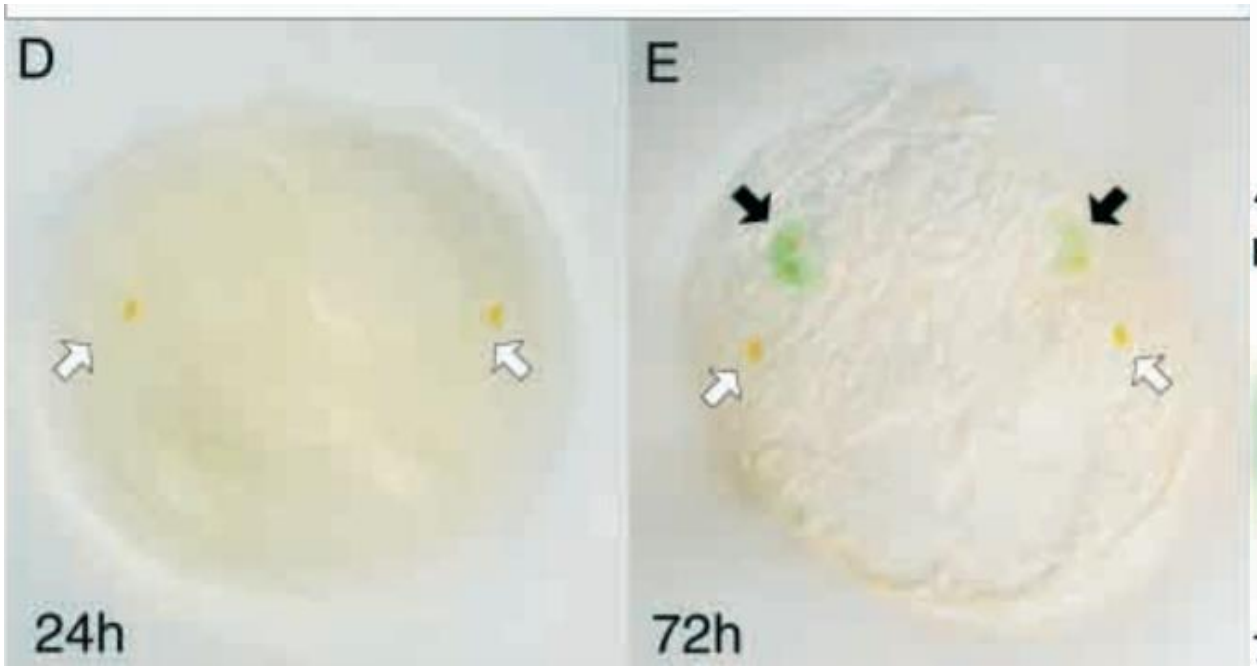
Eye less - ey

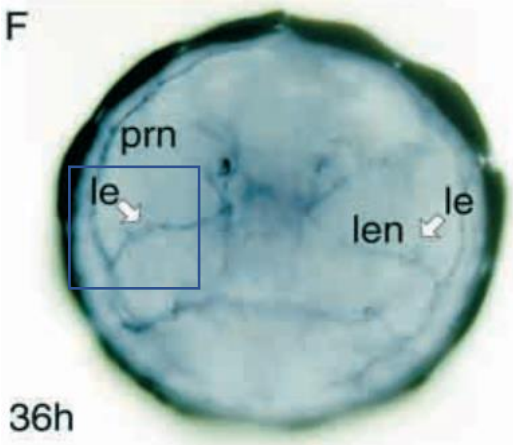
Halder, 1995

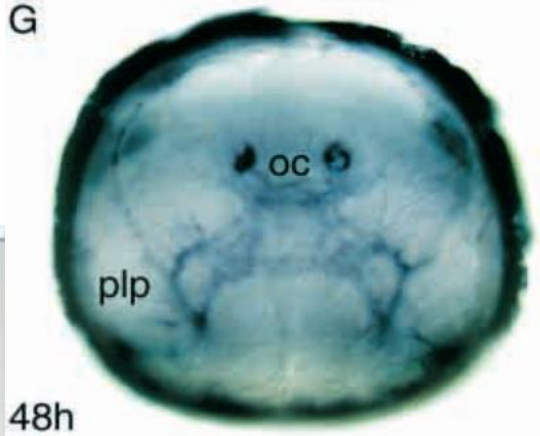
Arendt, et al., 2002

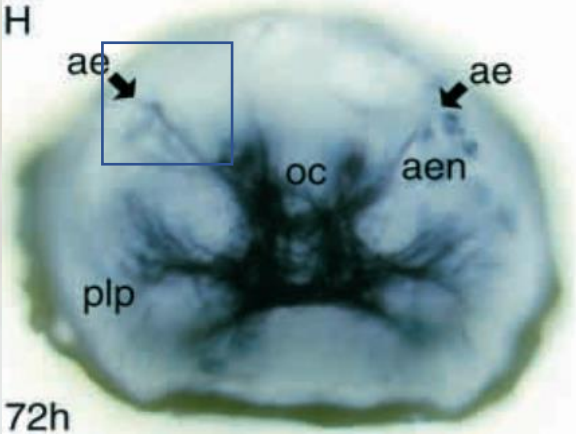
Poliqueta



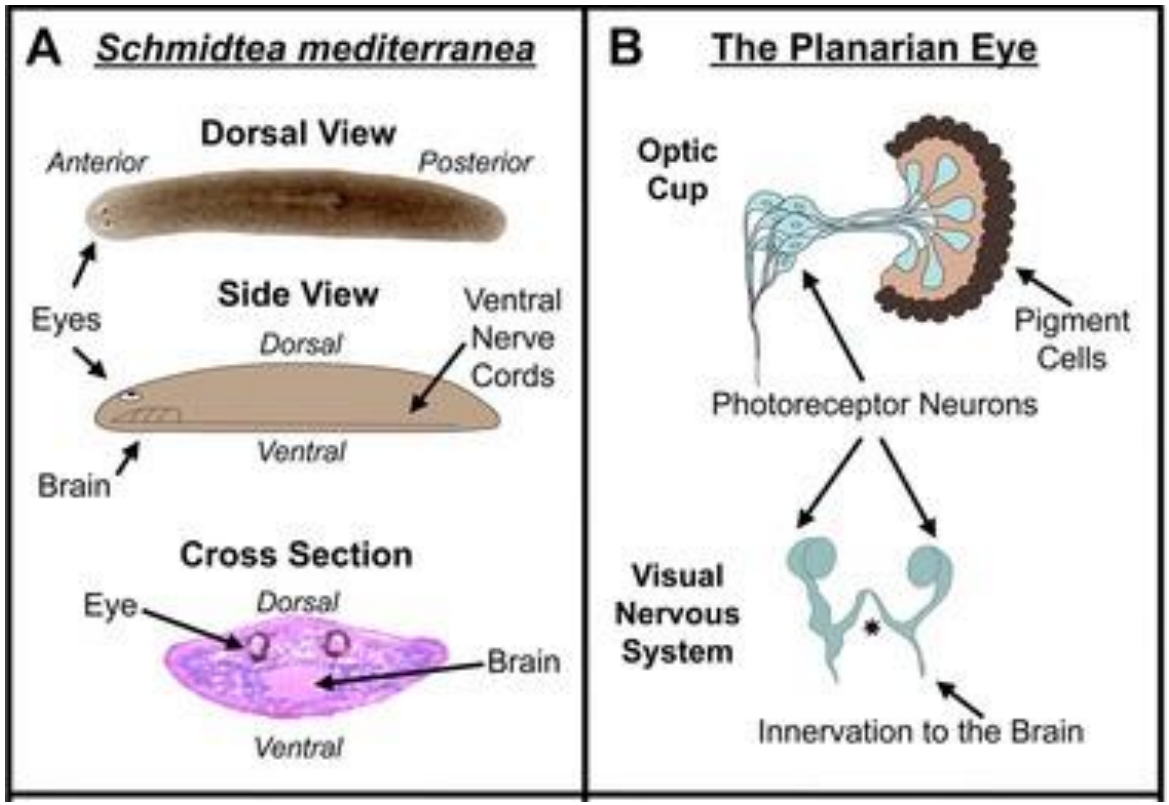






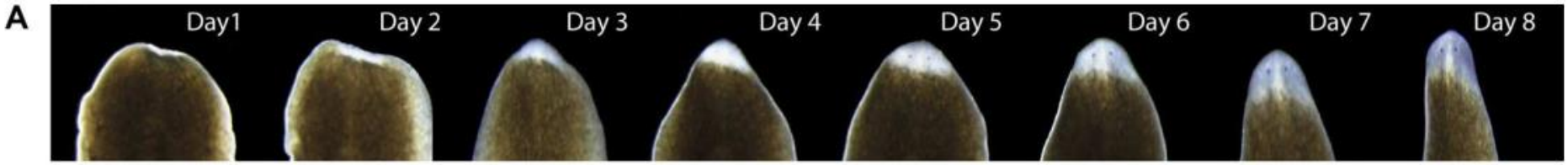


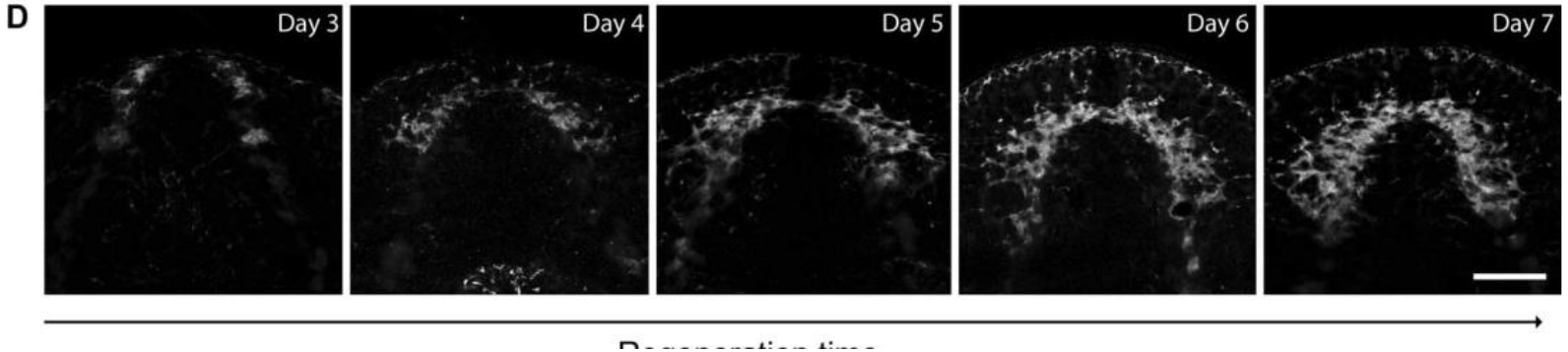
Planária



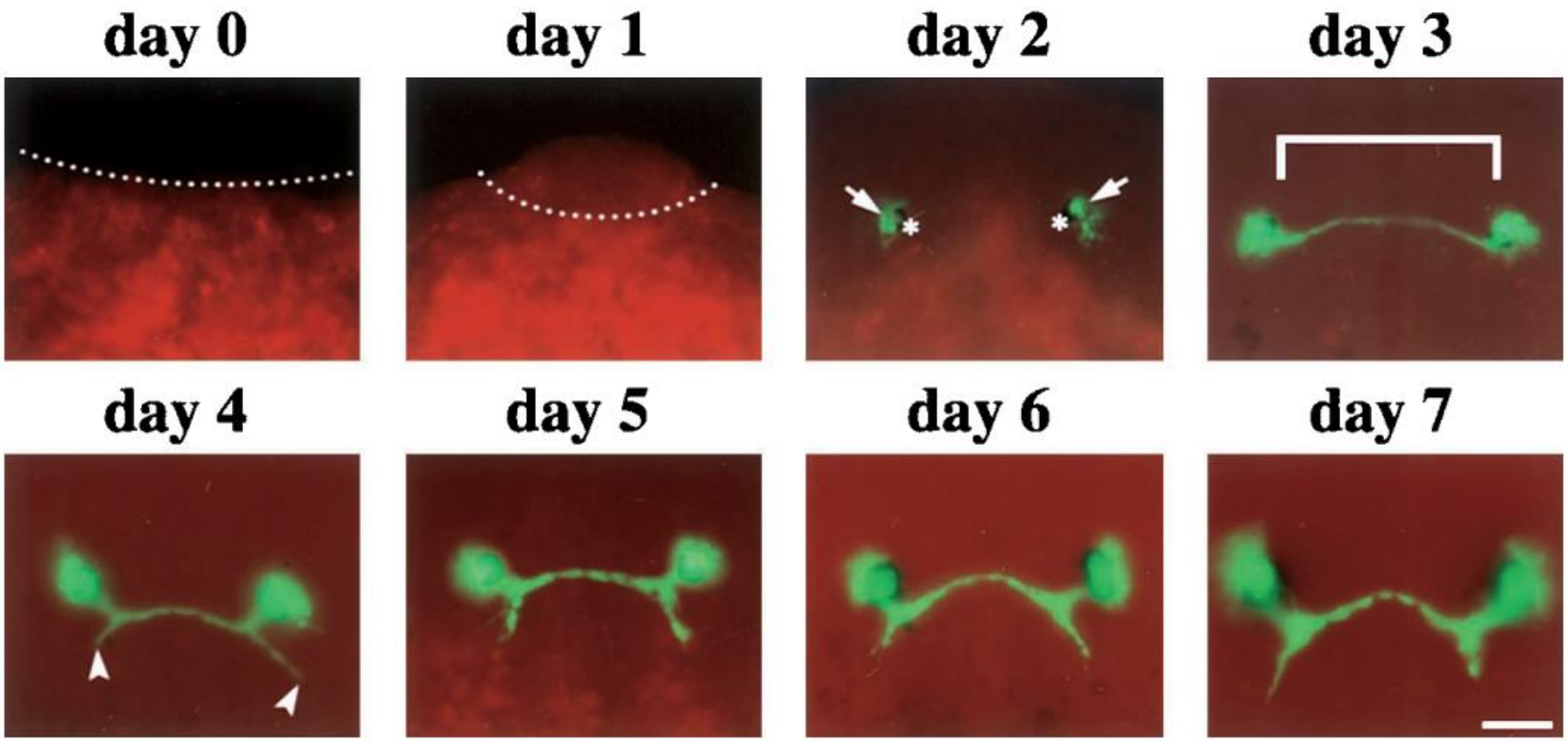
Deochand et al., 2016

Planária

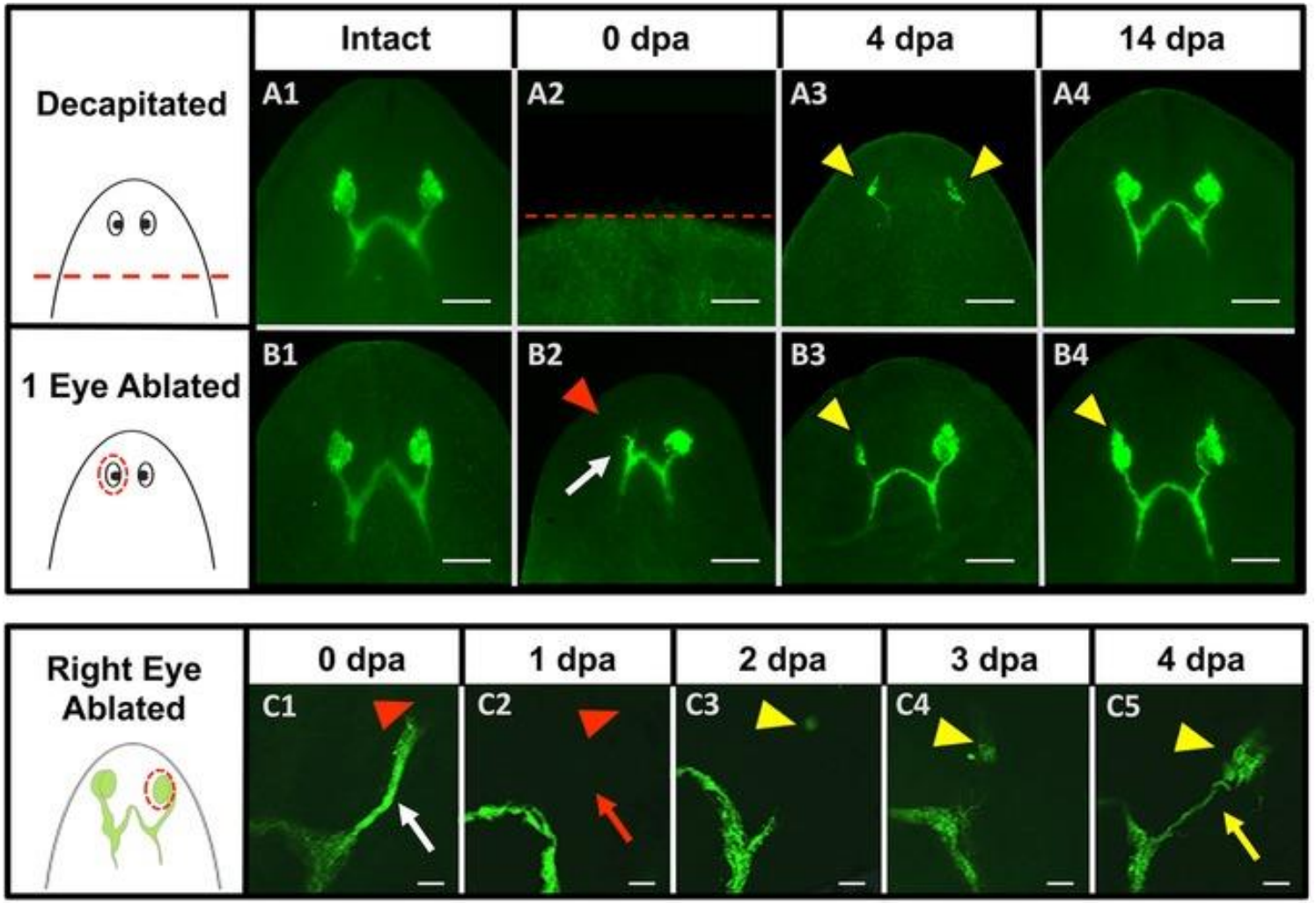




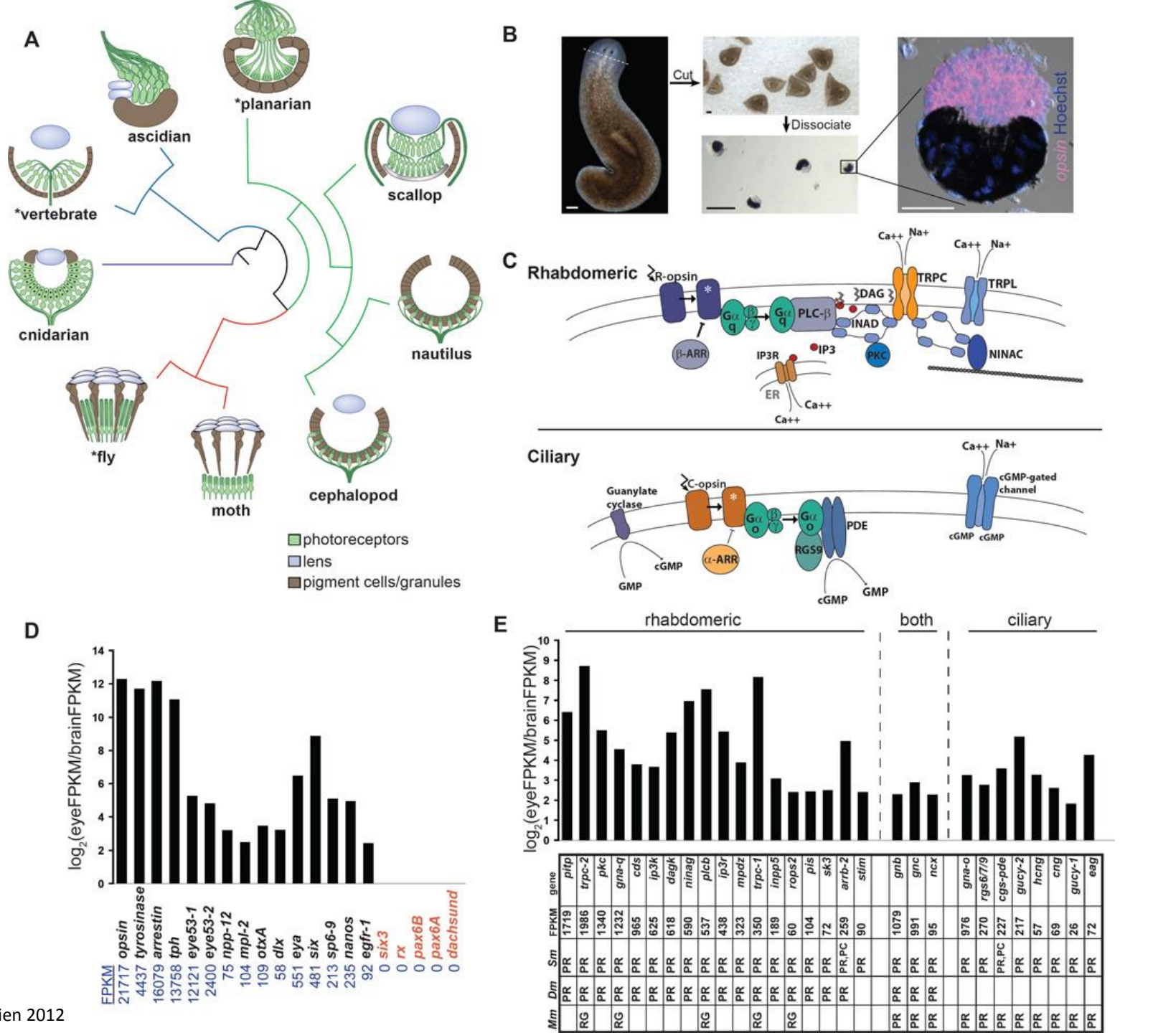
Deochand et al., 2016



Inoue et al., 2004



Deochand et al., 2016



Lapan and Reddien 2012

Origem independente

MORFOLÓGICO

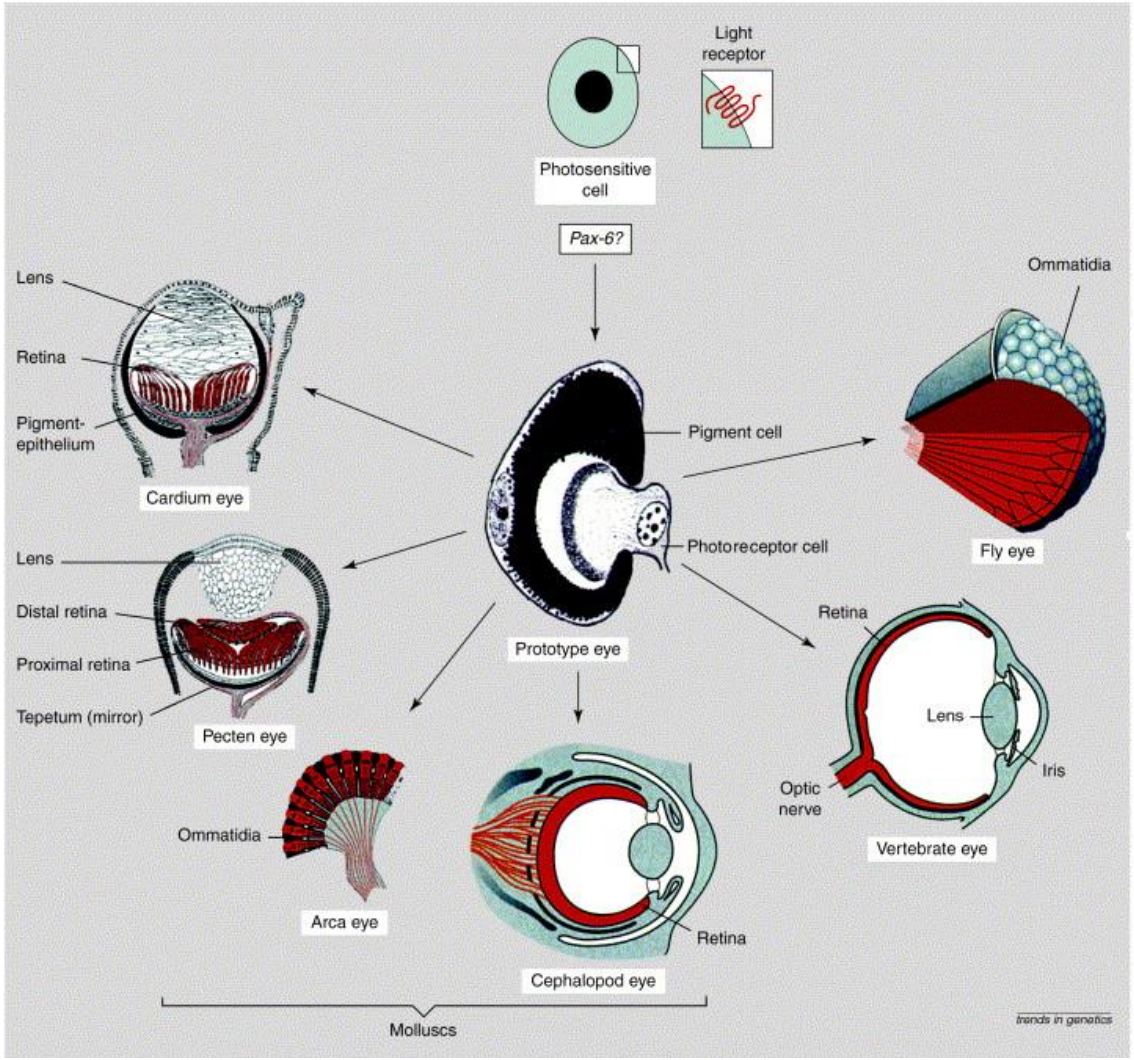
Origem comum - ressalvas

FISIOLÓGICO

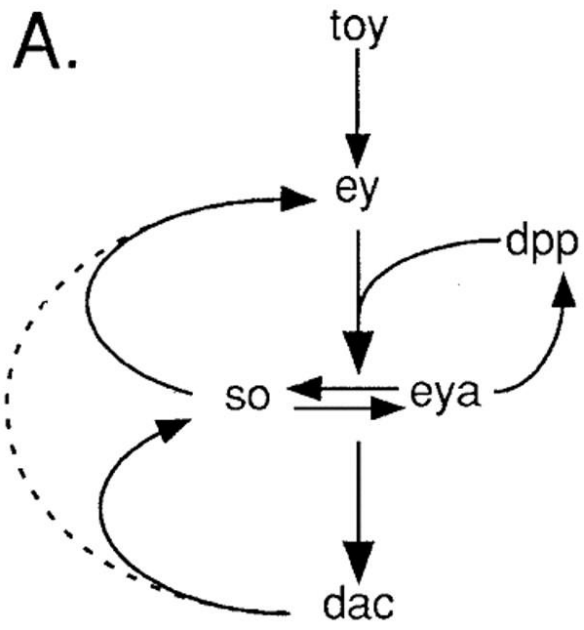
Estruturas diferentes

EMBRIONÁRIO

O que possuem em comum?



Não apenas Pax6



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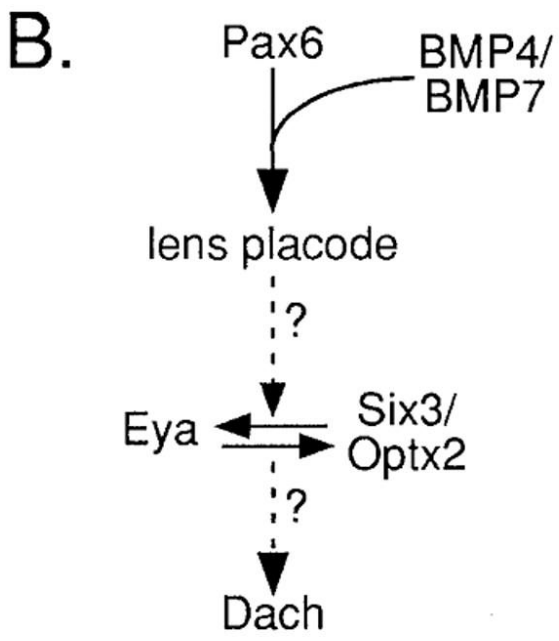
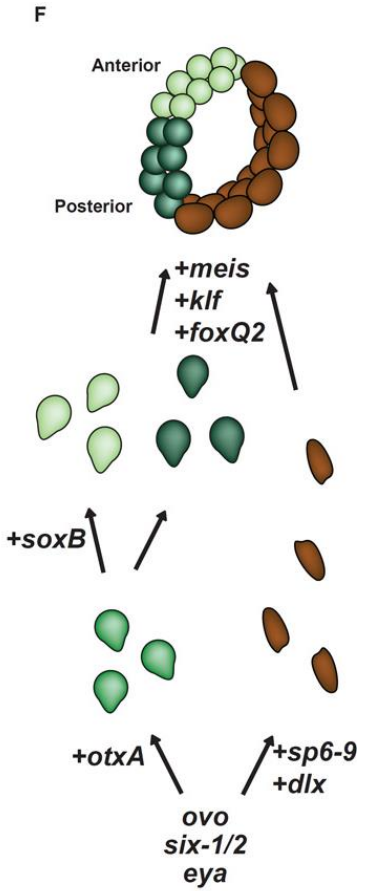


Mouse/Human



Planária

Lapan and Reddien 2012 Wawersik and Maas, 2000

Origem independente

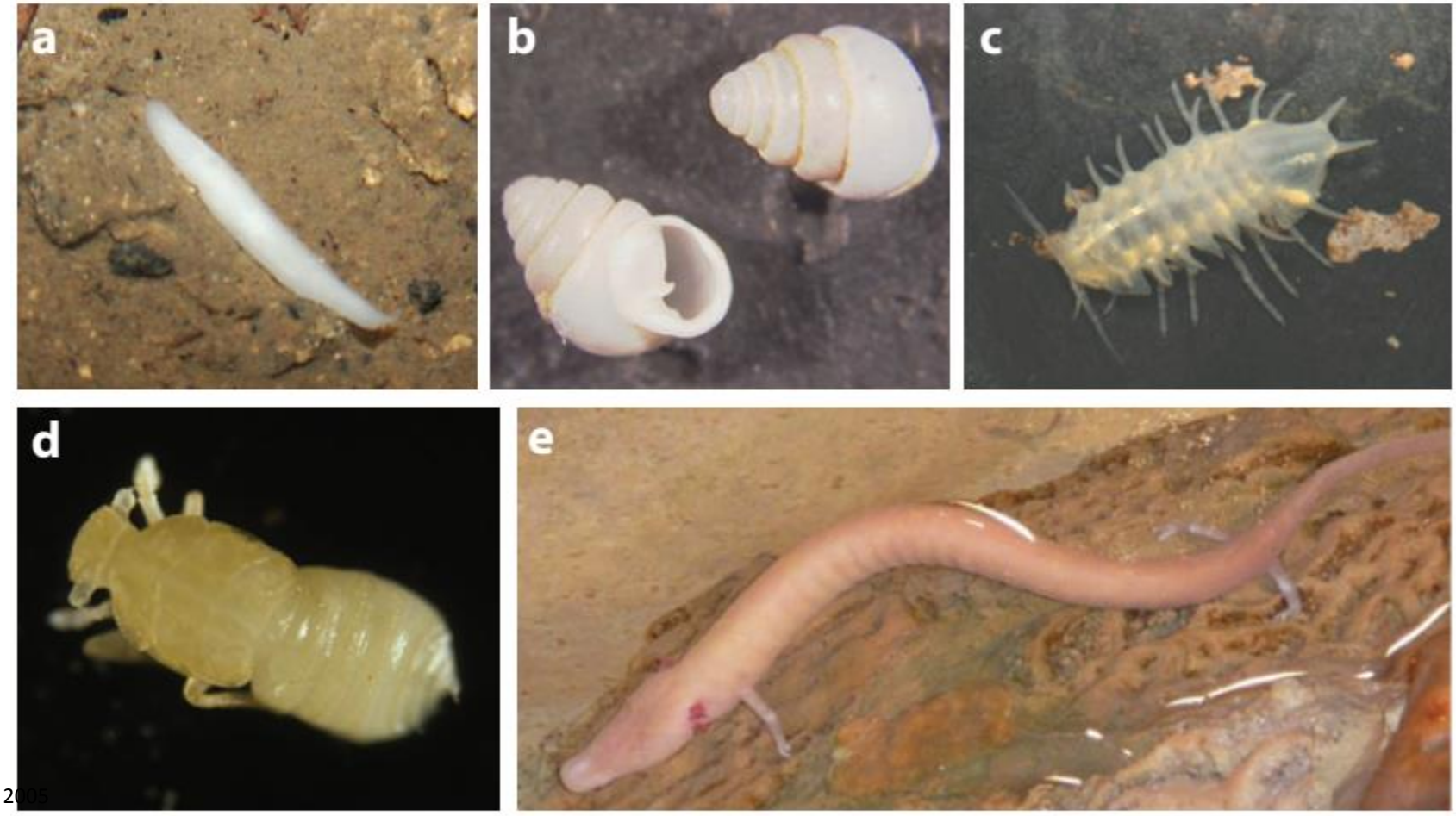
MORFOLÓGICO

Origem comum - ressalvas

FISIOLÓGICO

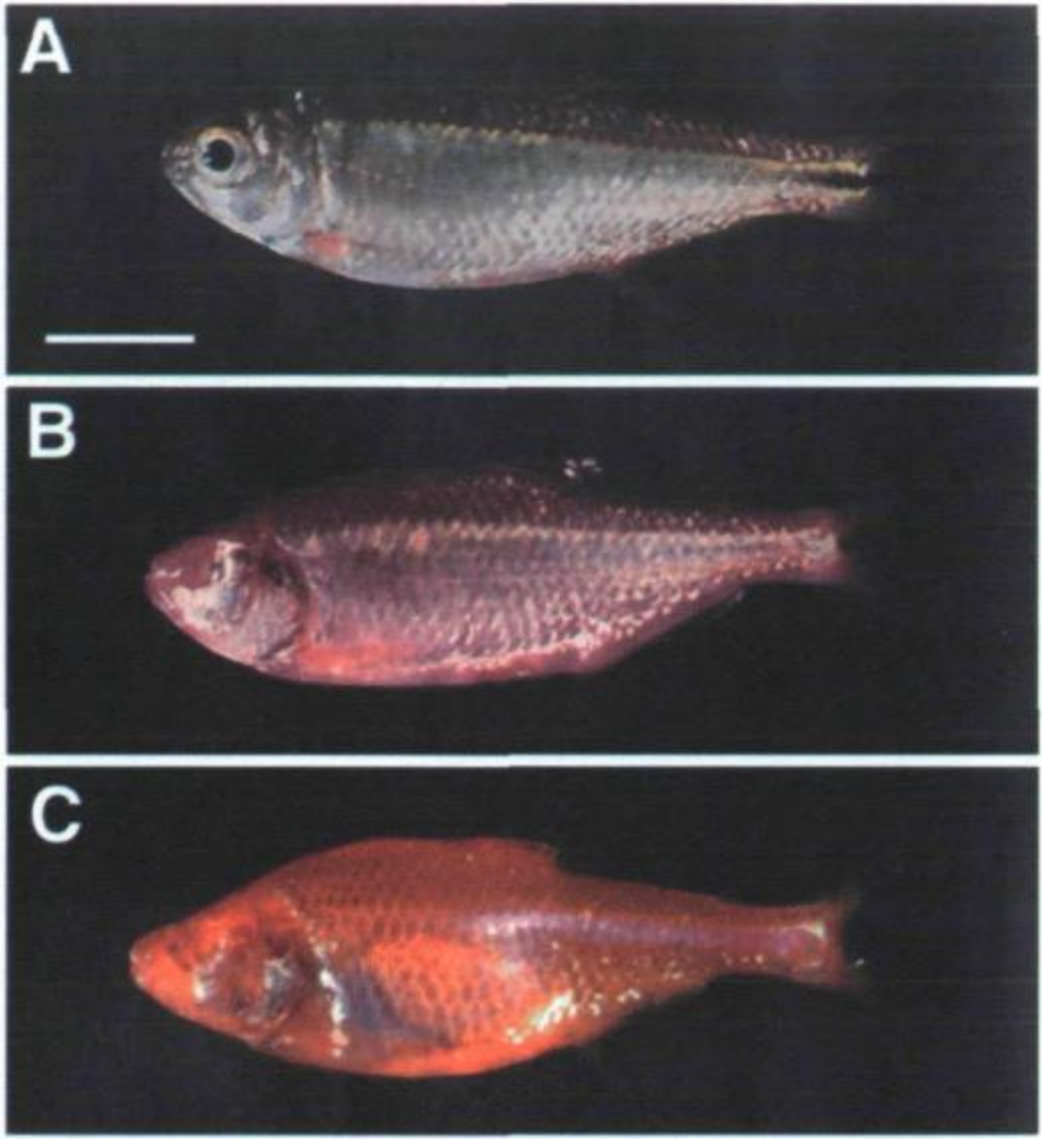
Estruturas diferentes
Mesmo fatores de transcrição envolvidos

EMBRIONÁRIO



Jeffery , 2005

PERDA DA VISÃO ?

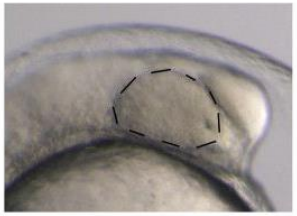


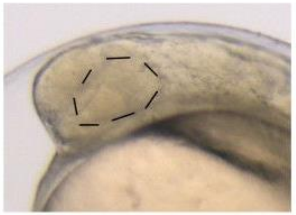
Astyanax mexicanus

Jeffery and Martasian, 1998

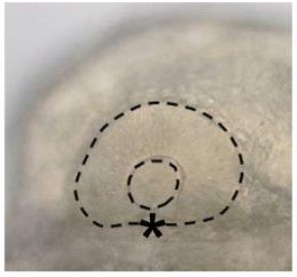
surface

cave

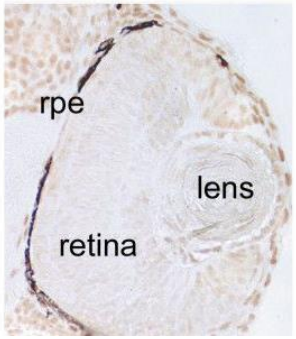


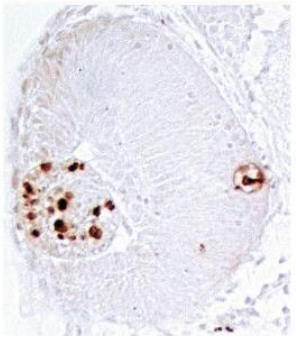


18hpf,
embryonic
eye vesicle

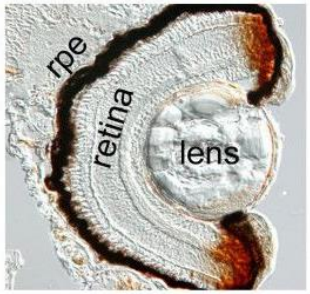


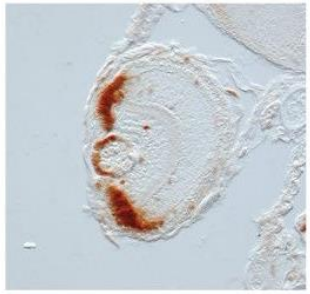
24hpf,
larval eye
morphology



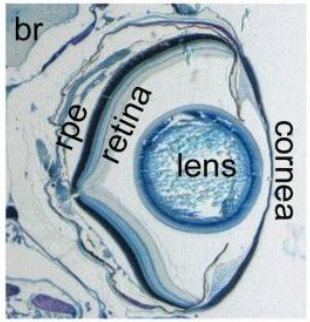


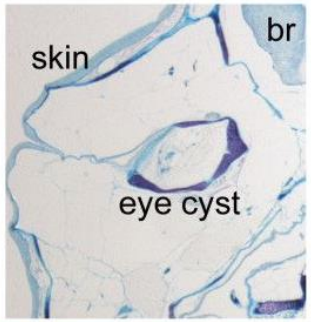
48hpf,
lens and retir
apoptosis
(TUNEL)





5dpf,
progenitor
proliferation
(PCNA)



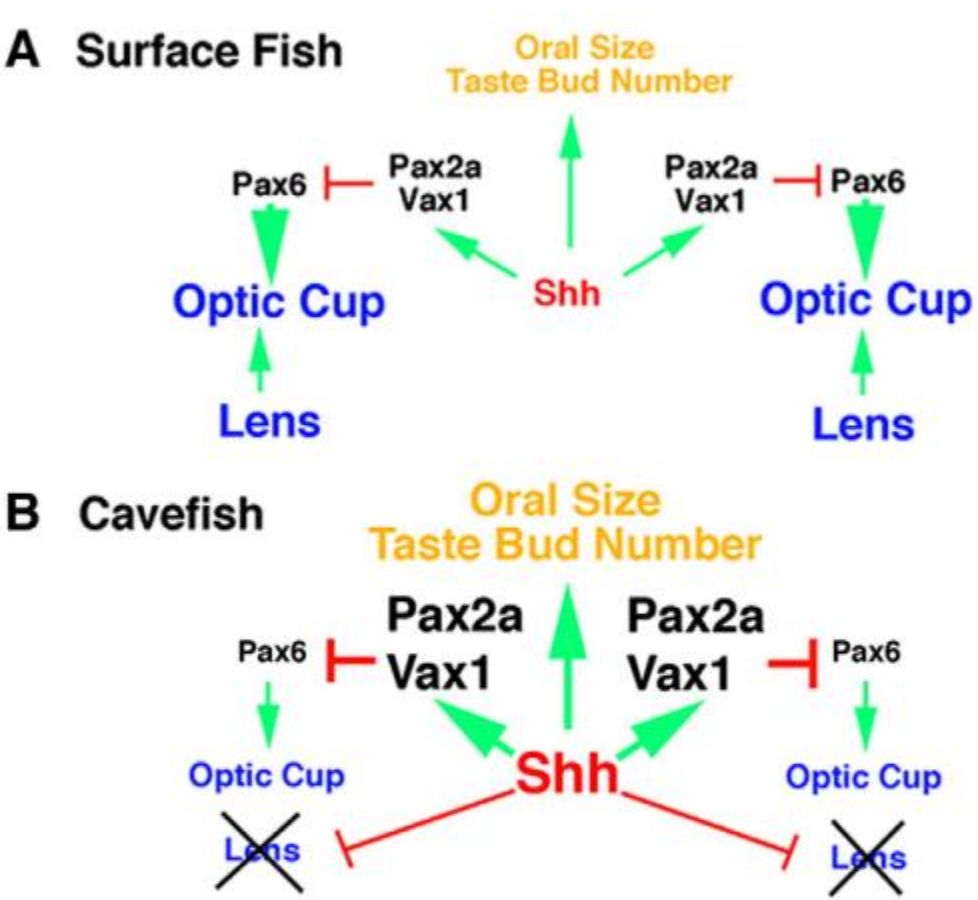


adult,
eye
morphology

adult,
head
morphology

Rétaux and Casane 2013

Yamamoto et al., 2005



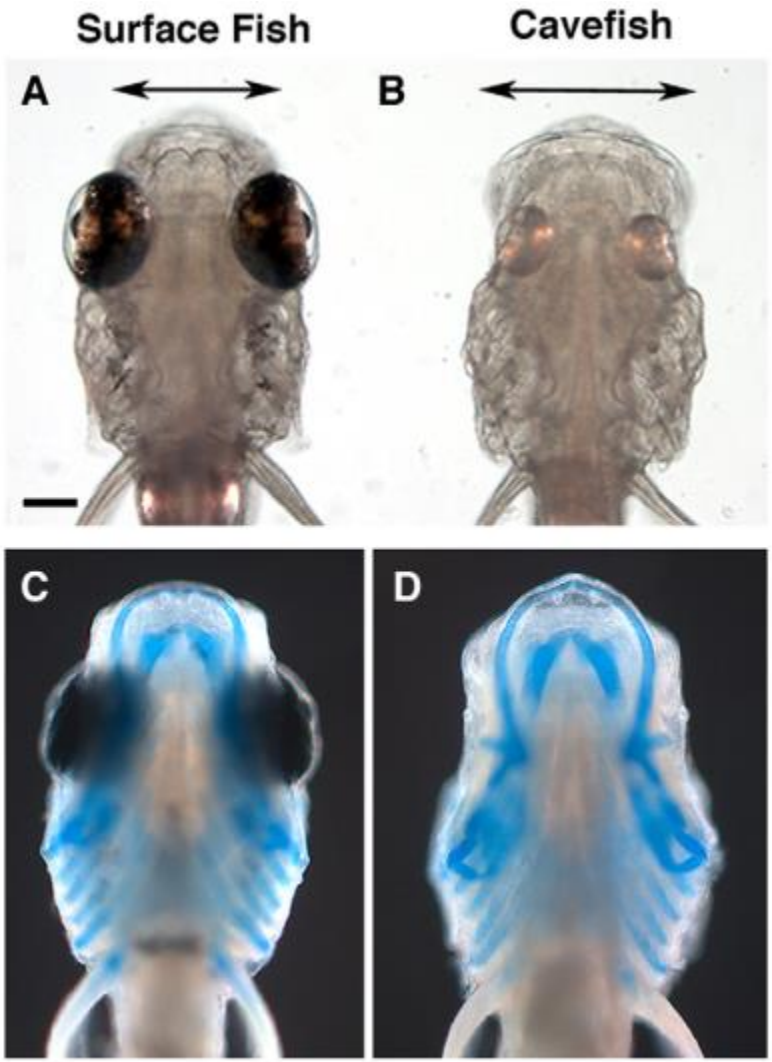


Fig. 7. The relationship between Shh signaling, oral–pharyngeal constructive traits, and eye degeneration in *Astyanax* surface fish (A) and cavefish (B) indicating the effects of Shh signaling on oral–pharyngeal, lens, and optic cup development. Letter size indicates relative increase or decrease in cavefish compared to surface fish. See text for other details.

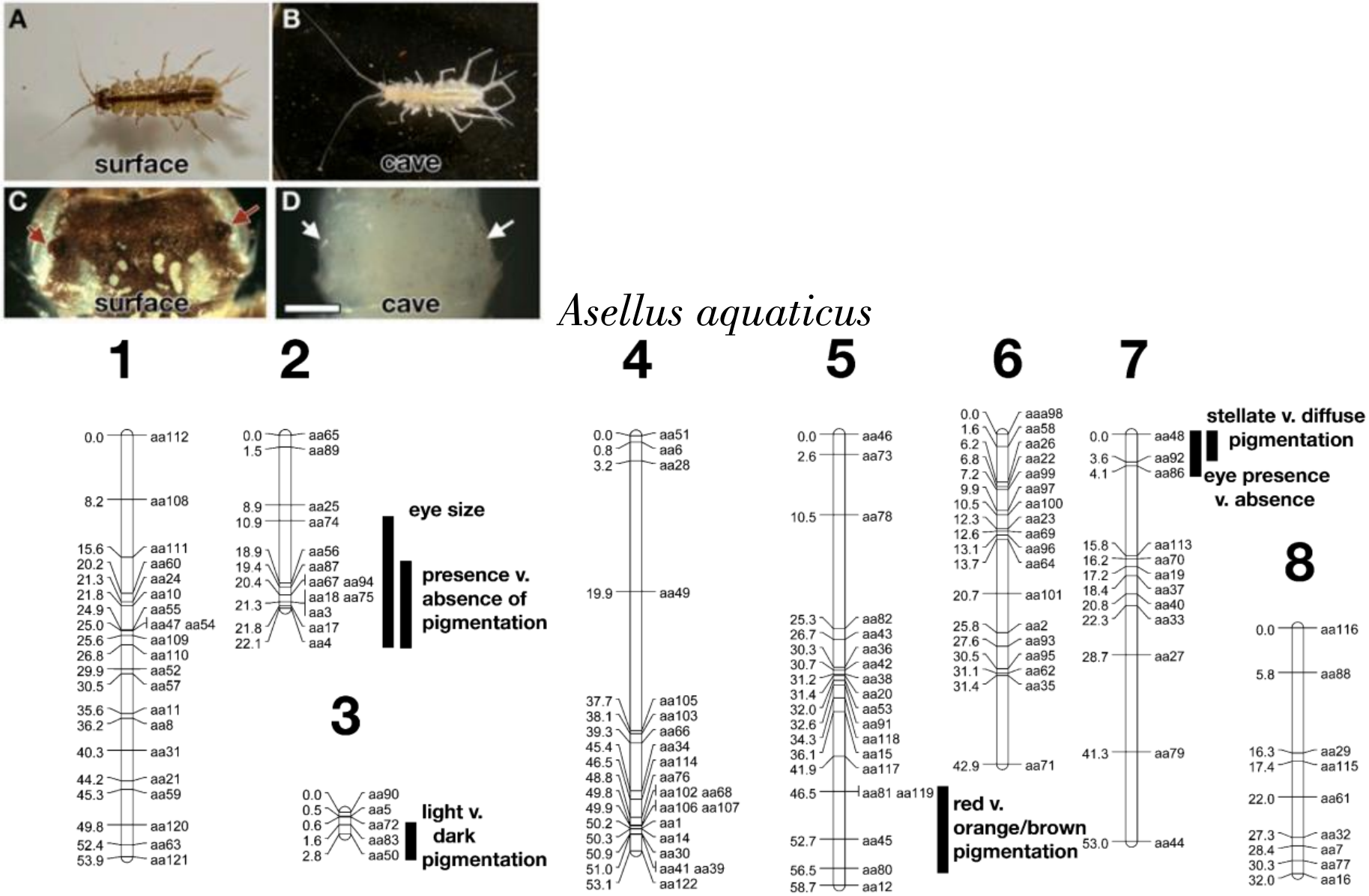
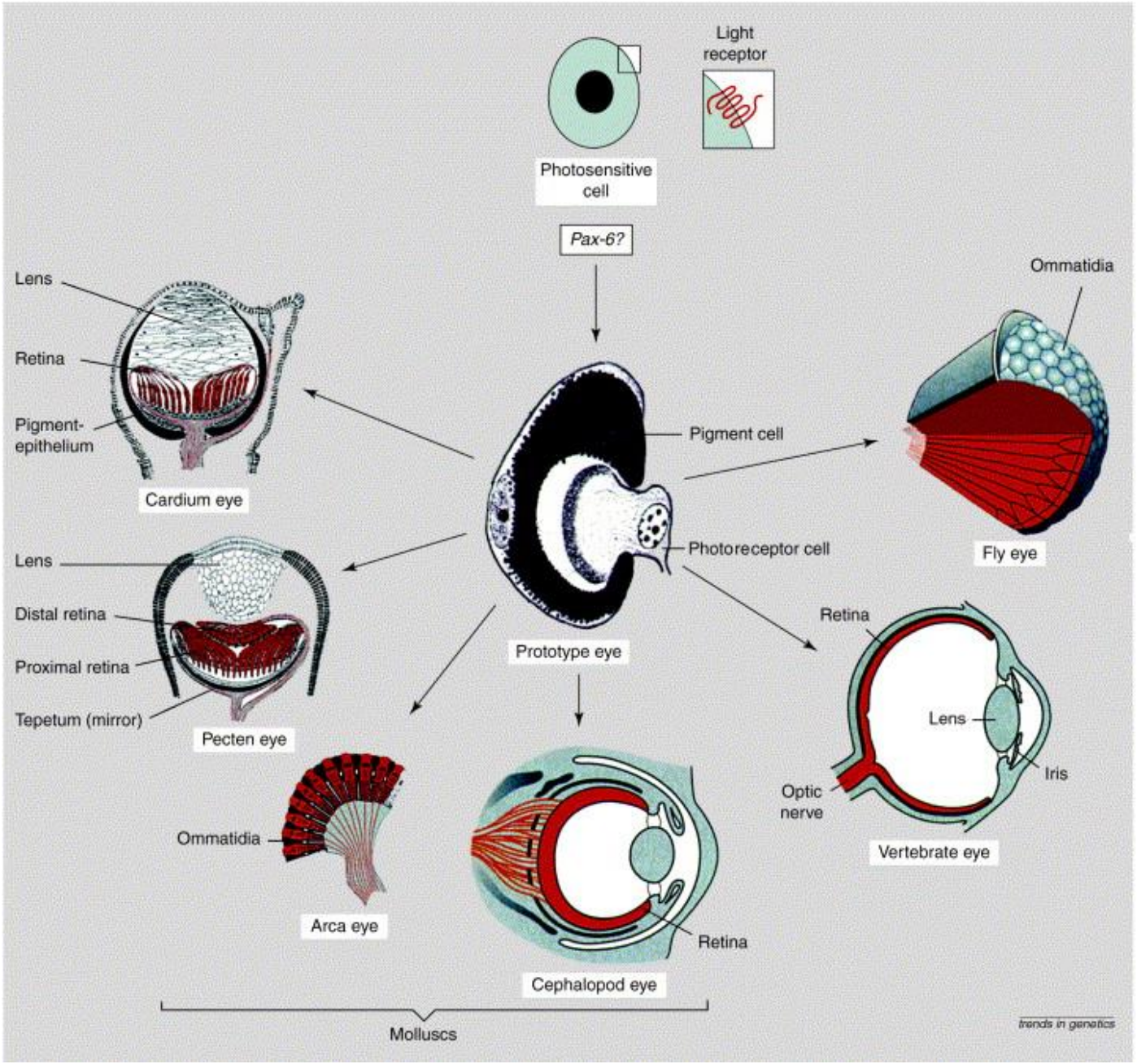


Fig. 2. Linkage map of *A. aquaticus*. Linkage group (LG) number is listed above each linkage group diagram. Placement in centimorgans is to the left and marker name to the right. The 1.5 LOD support intervals for each trait are shown with black vertical bars.

Locus de característica quantitativa QTL

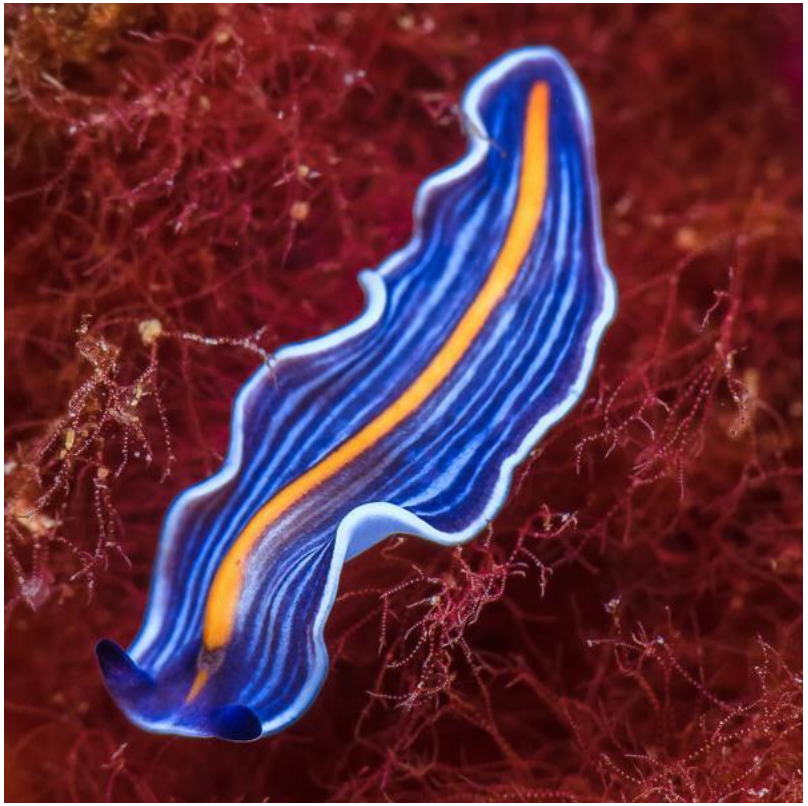
FROM LIGHT TO DARKNESS:

evolutionary history of the photosensory system in planarians

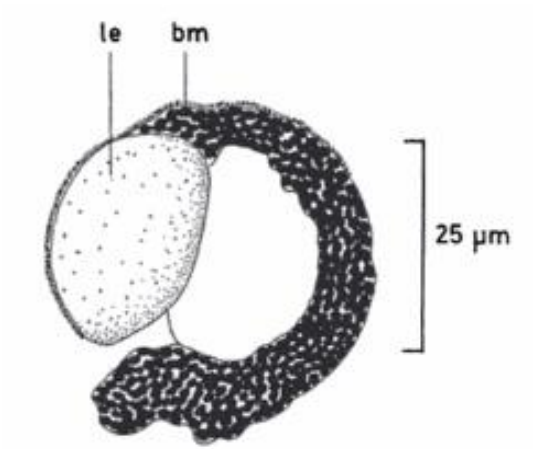

Light receptor
Photosensitive cell
Pax-6?
Lens
Retina
Pigment-epithelium
Cardium eye
Ommatidia
Pigment cell
Photoreceptor cell
Fly eye
Lens
Distal retina
Proximal retina
Tepetum (mirror)
Pecten eye
Prototype eye
Retina
Lens
Iris
Optic nerve
Vertebrate eye
Ommatidia
Arca eye
Retina
Cephalopod eye
Molluscs
trends in genetics

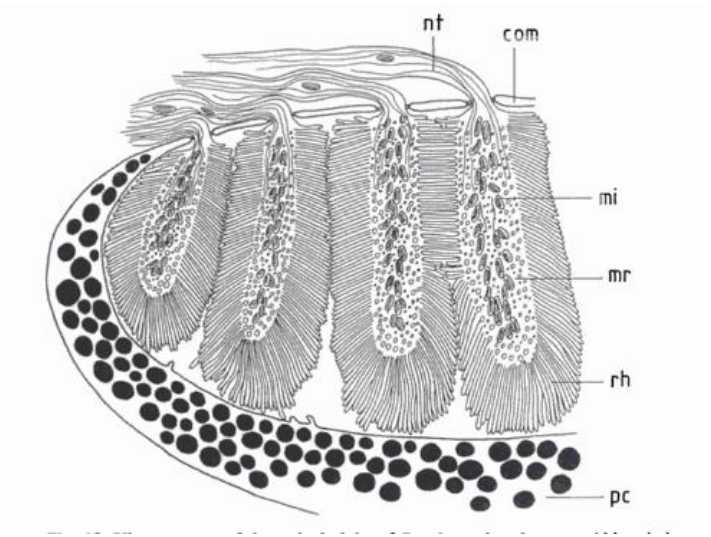


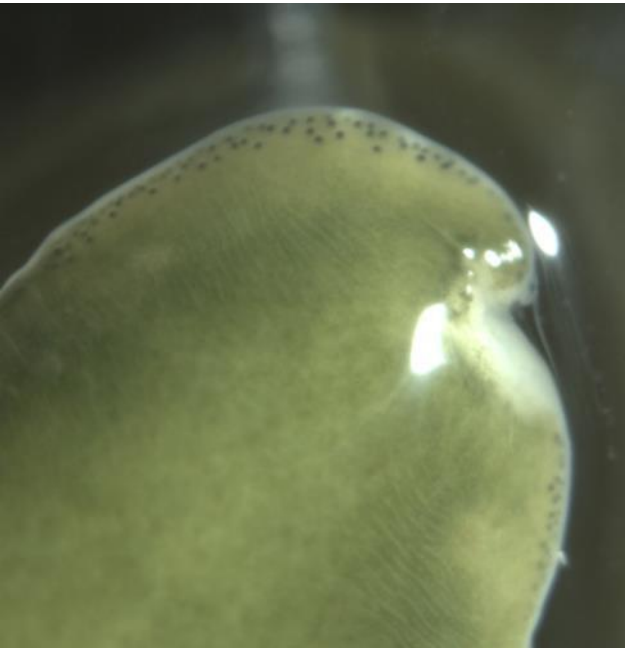


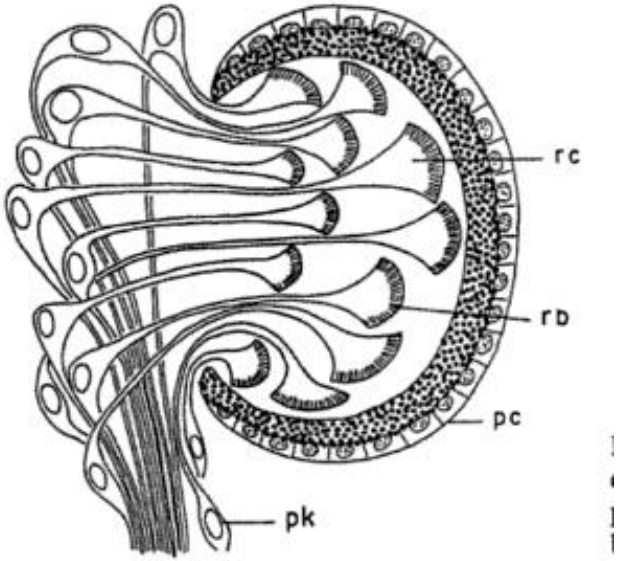


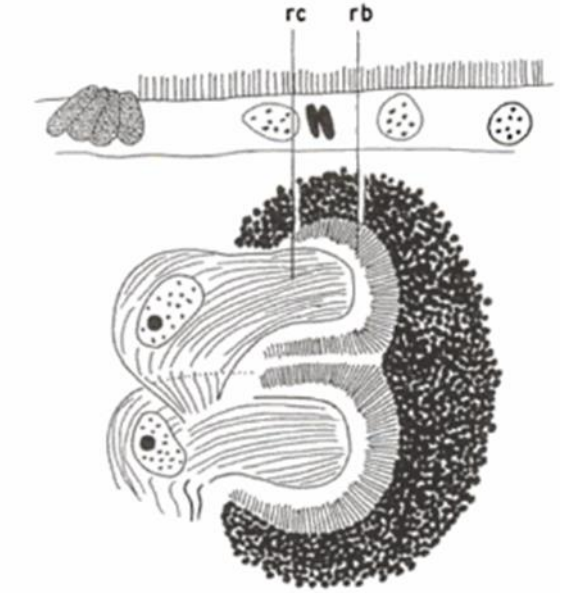

C

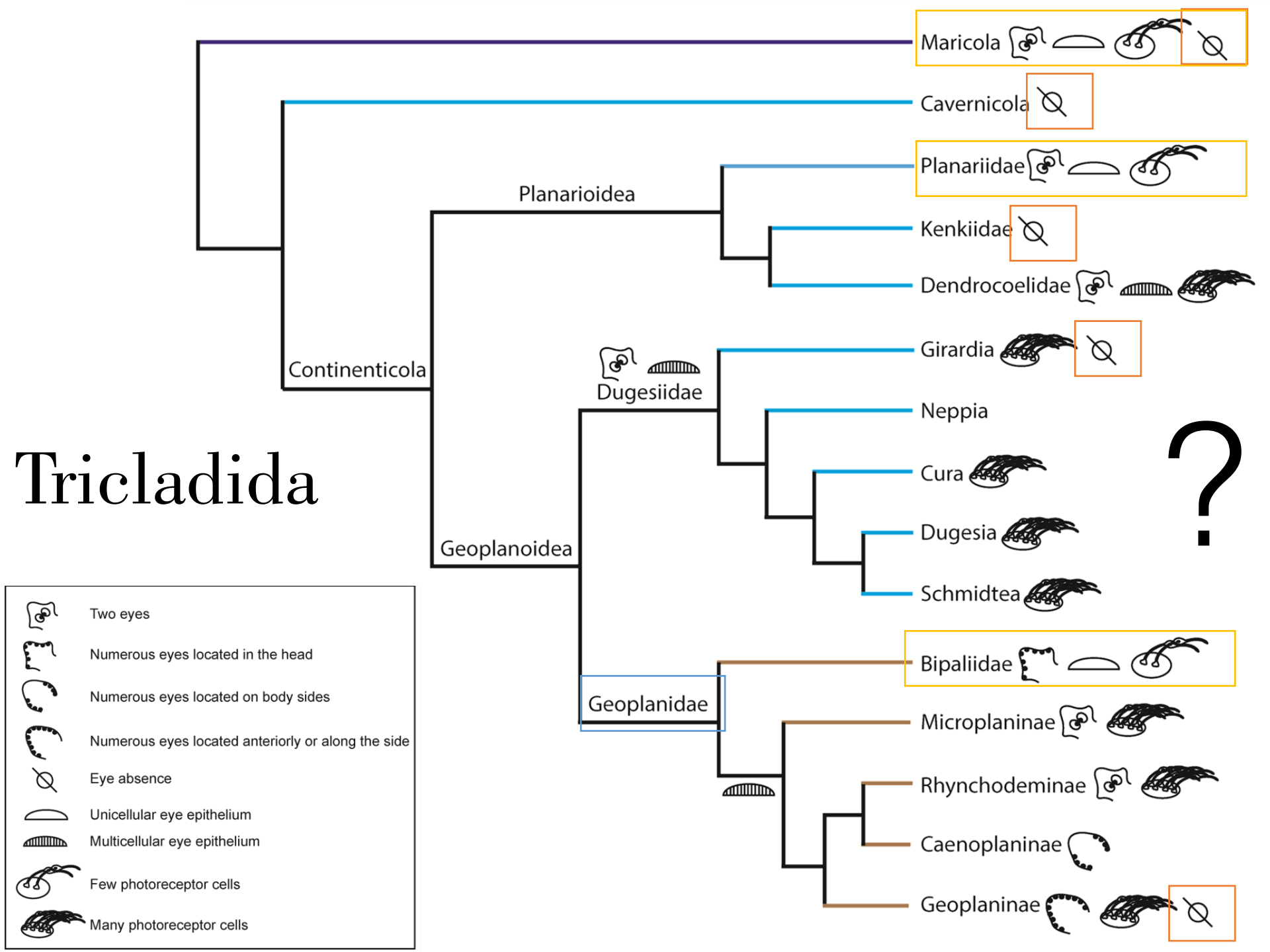

le
bm
25 µm


nt
com
mi
mr
rh
pc




rc
rb
pc
pk


rc
rb


Tricladida
Maricola
Cavernicola
Planariidae
Planarioidea
Kenkiidae
Dendrocoelidae
Continenticola
Girardia
Dugesiidae
Neppia
Cura
Dugesia
Schmidtea
Geoplanoidea
Geoplanidae
Bipaliidae
Microplaninae
Rhynchodeminae
Caenoplaninae
Geoplaninae
?
Two eyes
Numerous eyes located in the head
Numerous eyes located on body sides
Numerous eyes located anteriorly or along the side
Eye absence
Unicellular eye epithelium
Multicellular eye epithelium
Few photoreceptor cells
Many photoreceptor cells

Perda de olhos

Girardia tigrina

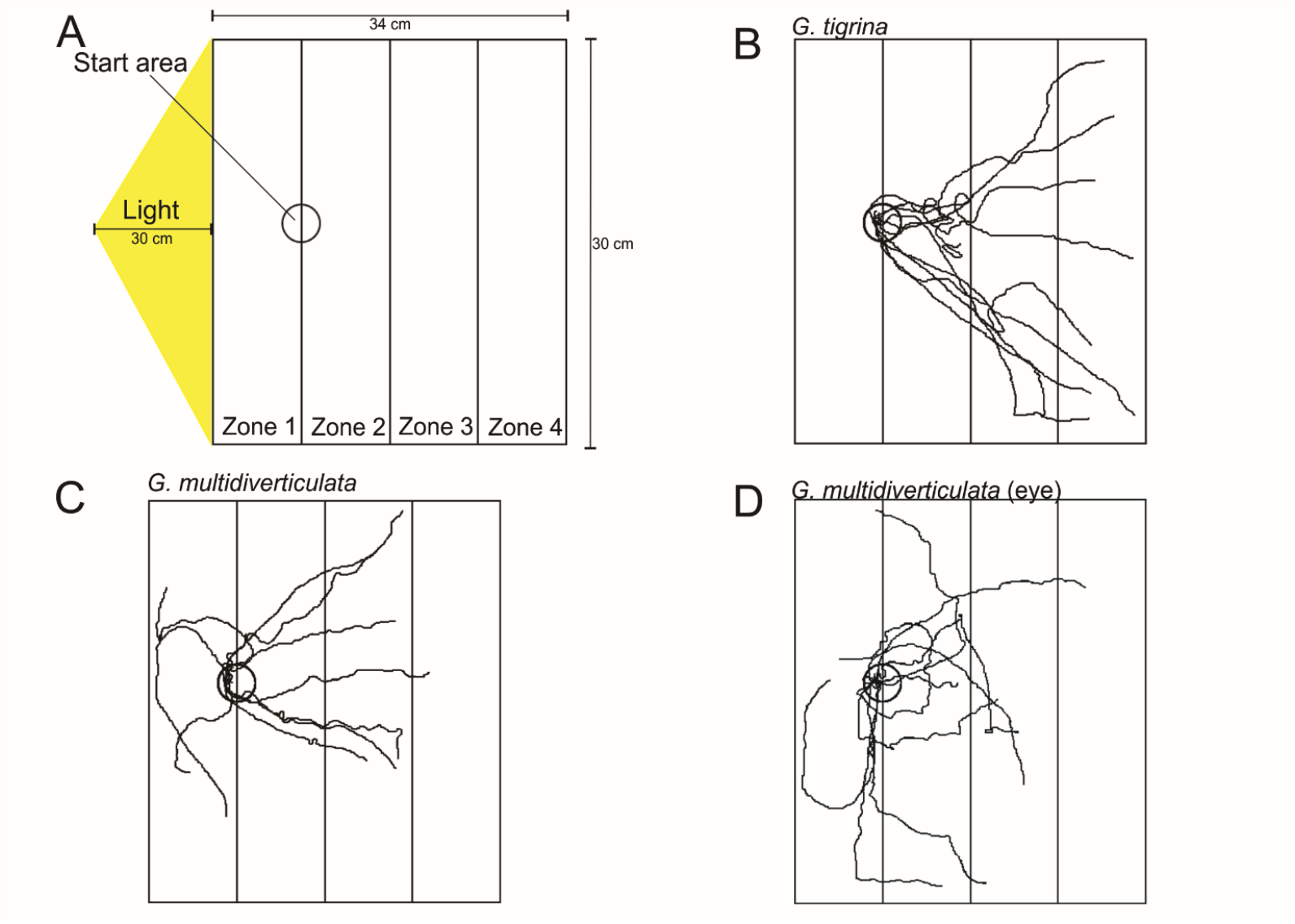
Girardia multiverticulata

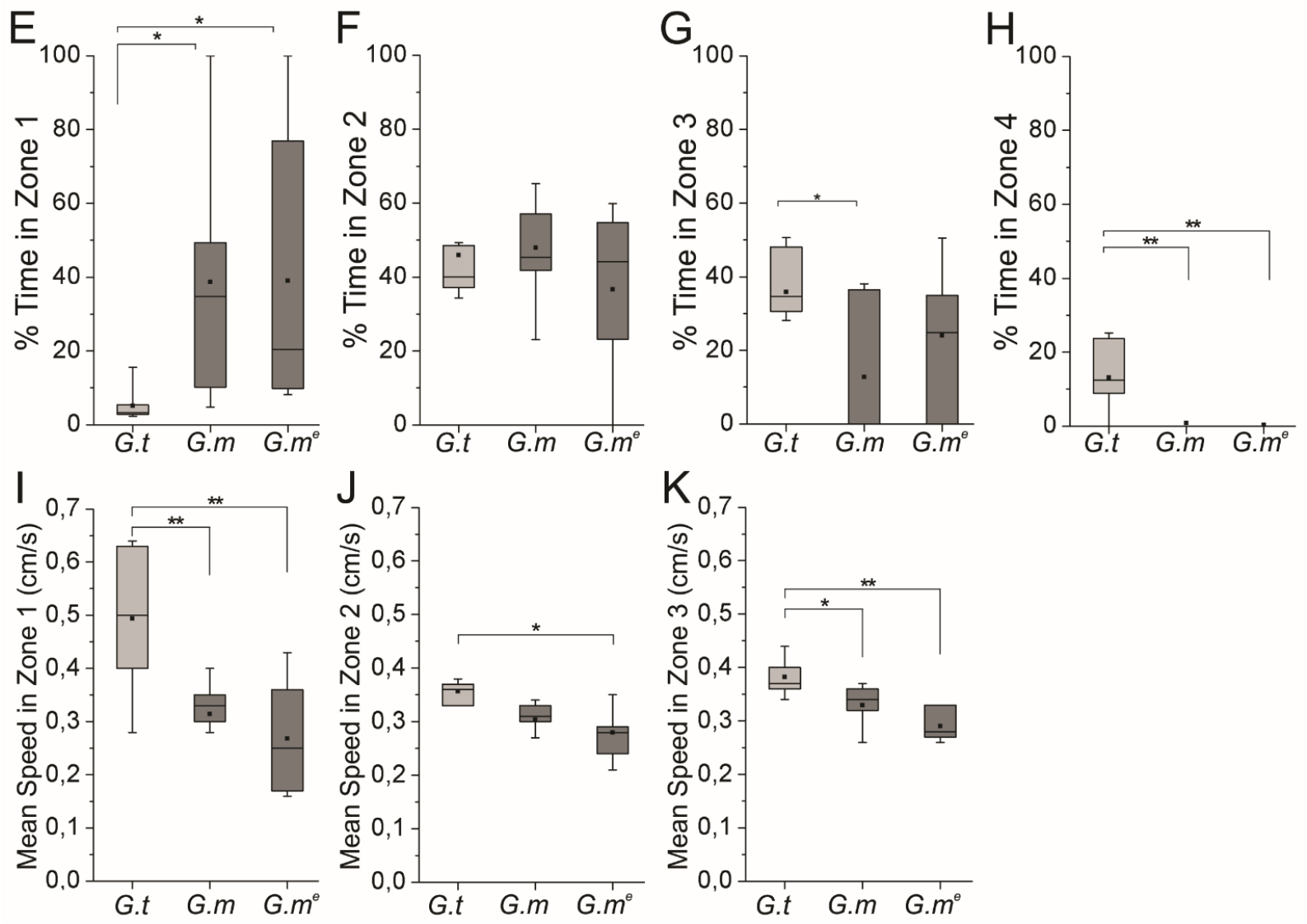
Perda de olhos

Girardia tigrina

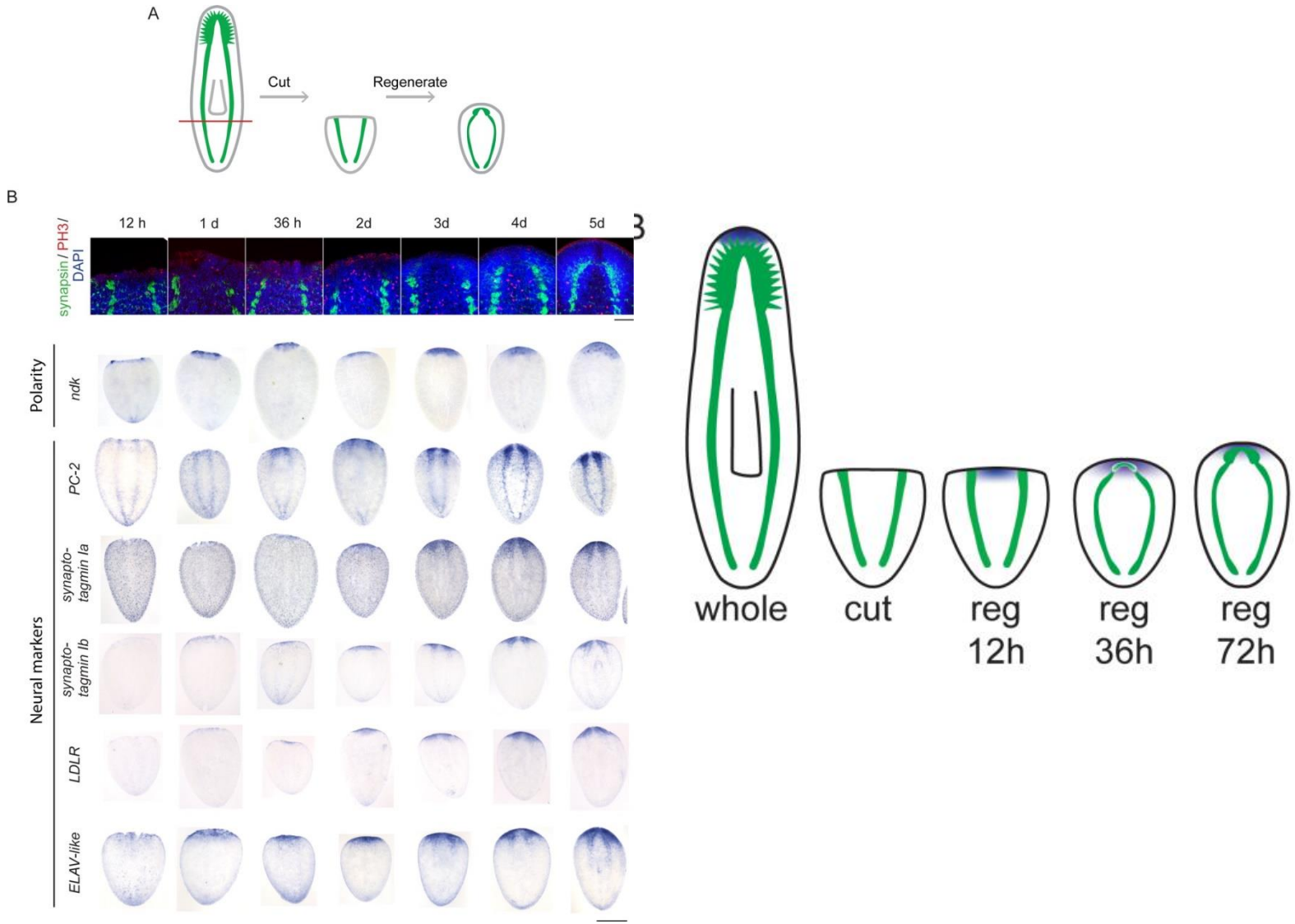
Girardia multiverticulata

Girardia multiverticulata


A
34 cm
Start area
Light
30 cm
30 cm
Zone 1
Zone 2
Zone 3
Zone 4
B
G. tigrina
C
G. multidiverticulata
D
G. multidiverticulata (eye)


E
% Time in Zone 1
F
% Time in Zone 2
G
% Time in Zone 3
H
% Time in Zone 4
I
Mean Speed in Zone 1 (cm/s)
J
Mean Speed in Zone 2 (cm/s)
K
Mean Speed in Zone 3 (cm/s)
G.t
G.m
G.m^e

Quais mecanismos moleculares envolvidos?

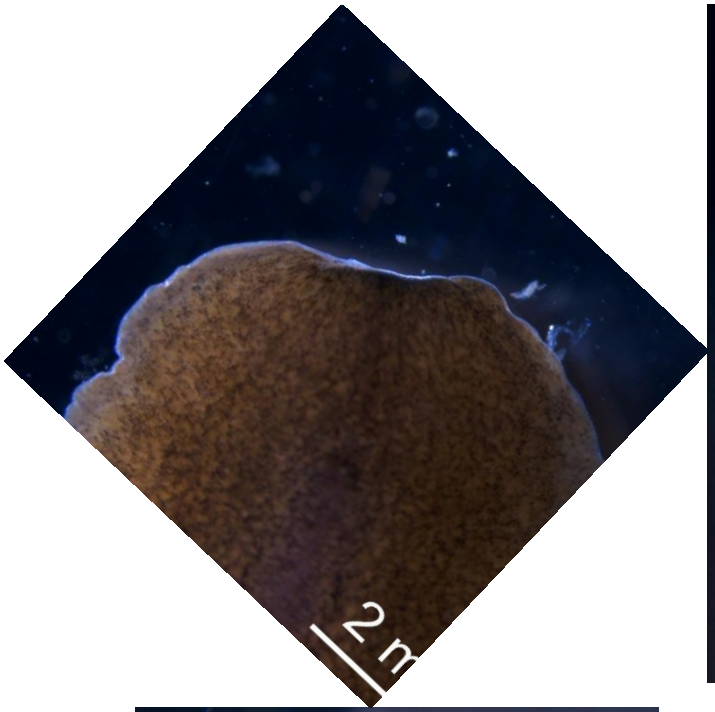


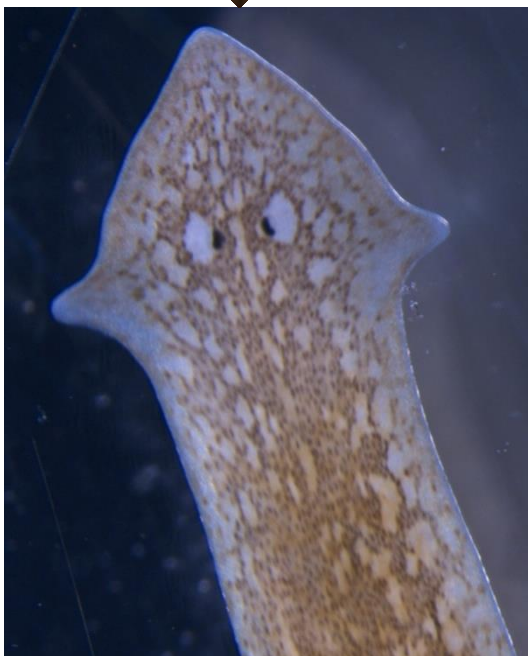
Prática

OBJETIVO

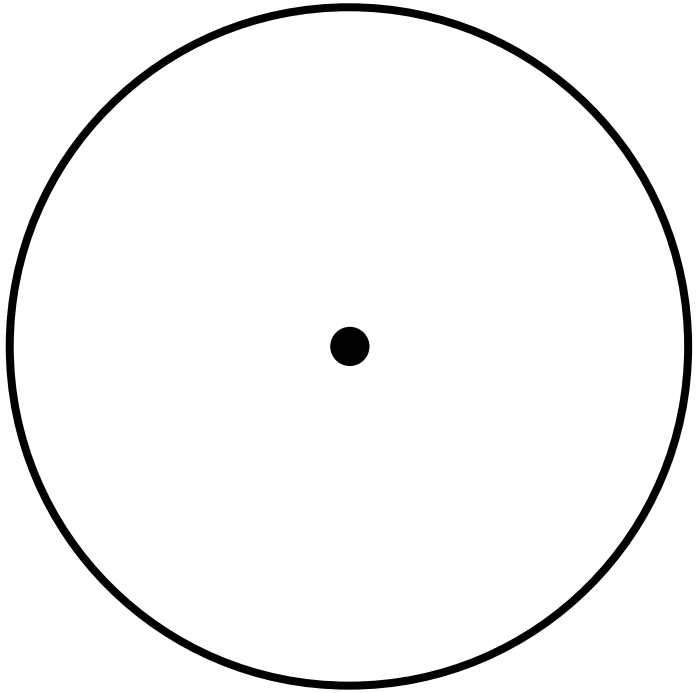
1) Compreender as etapas do desenvolvimento dos olhos das planárias

2)Realizar experimento simples de recuperação mecanica

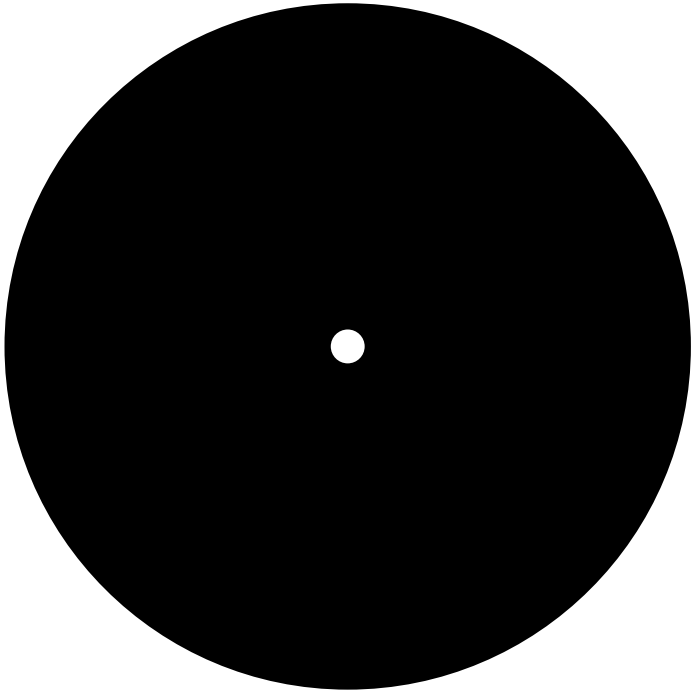

2
B



Tratamento no claro



Tratamento no escuro

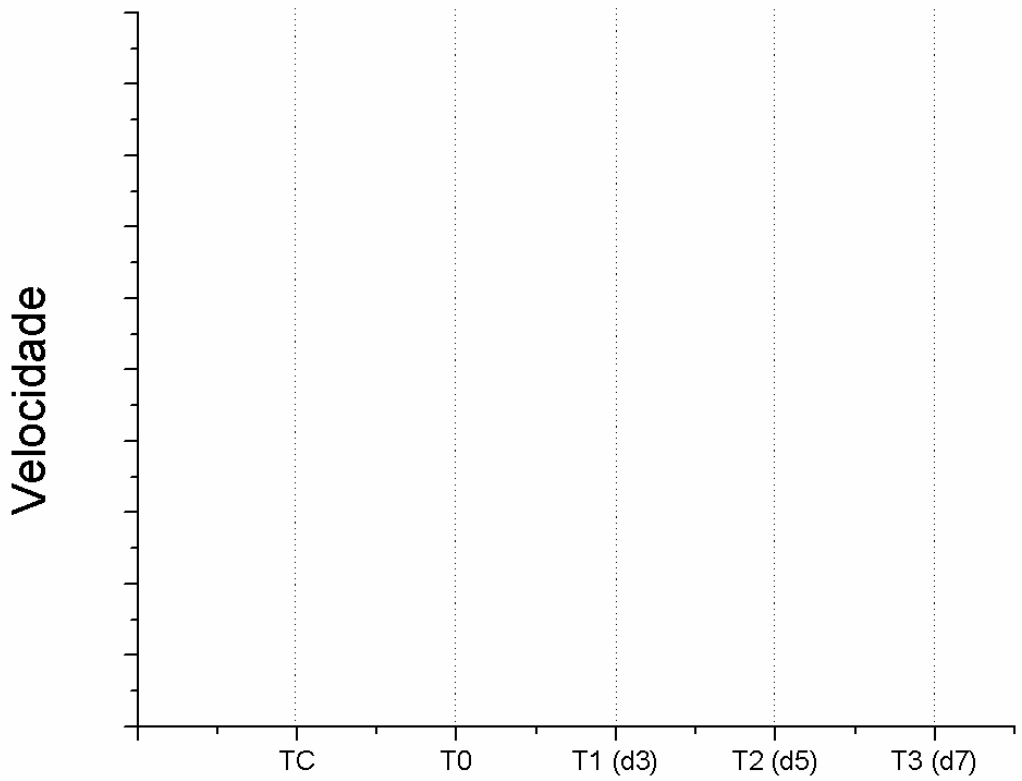


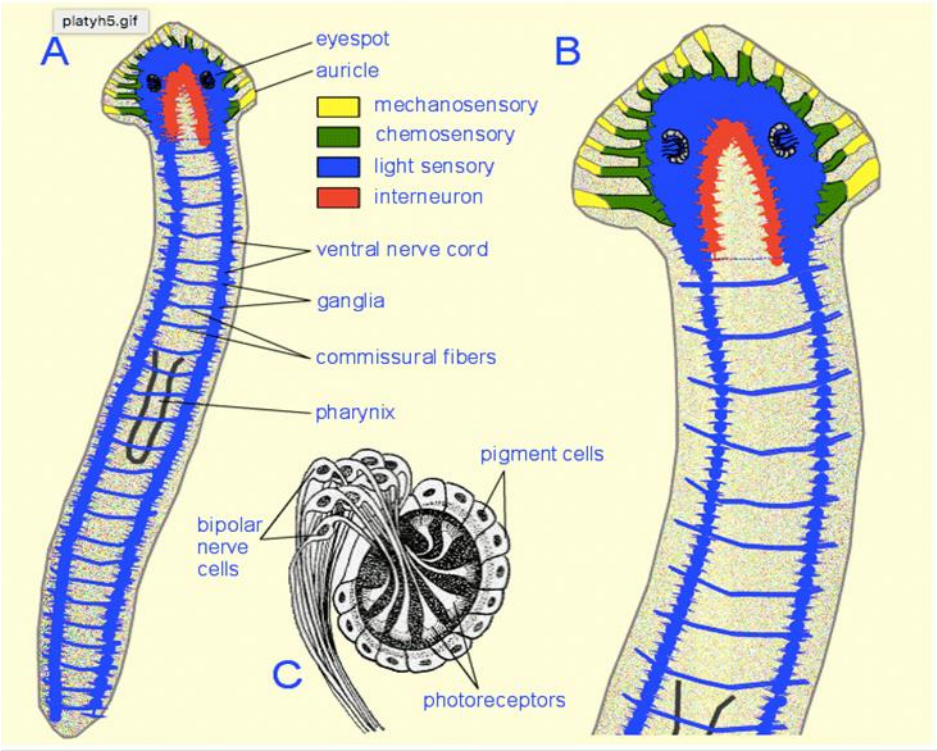
Por 1 minuto ou até permanecer na borda

$$Vm = \frac{Espaço(S)}{Tempo(t)}$$

Tratamento no claro

Tratamento no escuro





Controle = 0 dias

Corte t1=3 dias

Corte t2=5 dias

Corte t3=7 dias