Curso de Ictiología Neotropical

PEDECIBA 2022

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El sistema nervioso de los Peces

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¿Que es el sistema nervioso?

¿Cuando se origina?

¿Por que se origina?

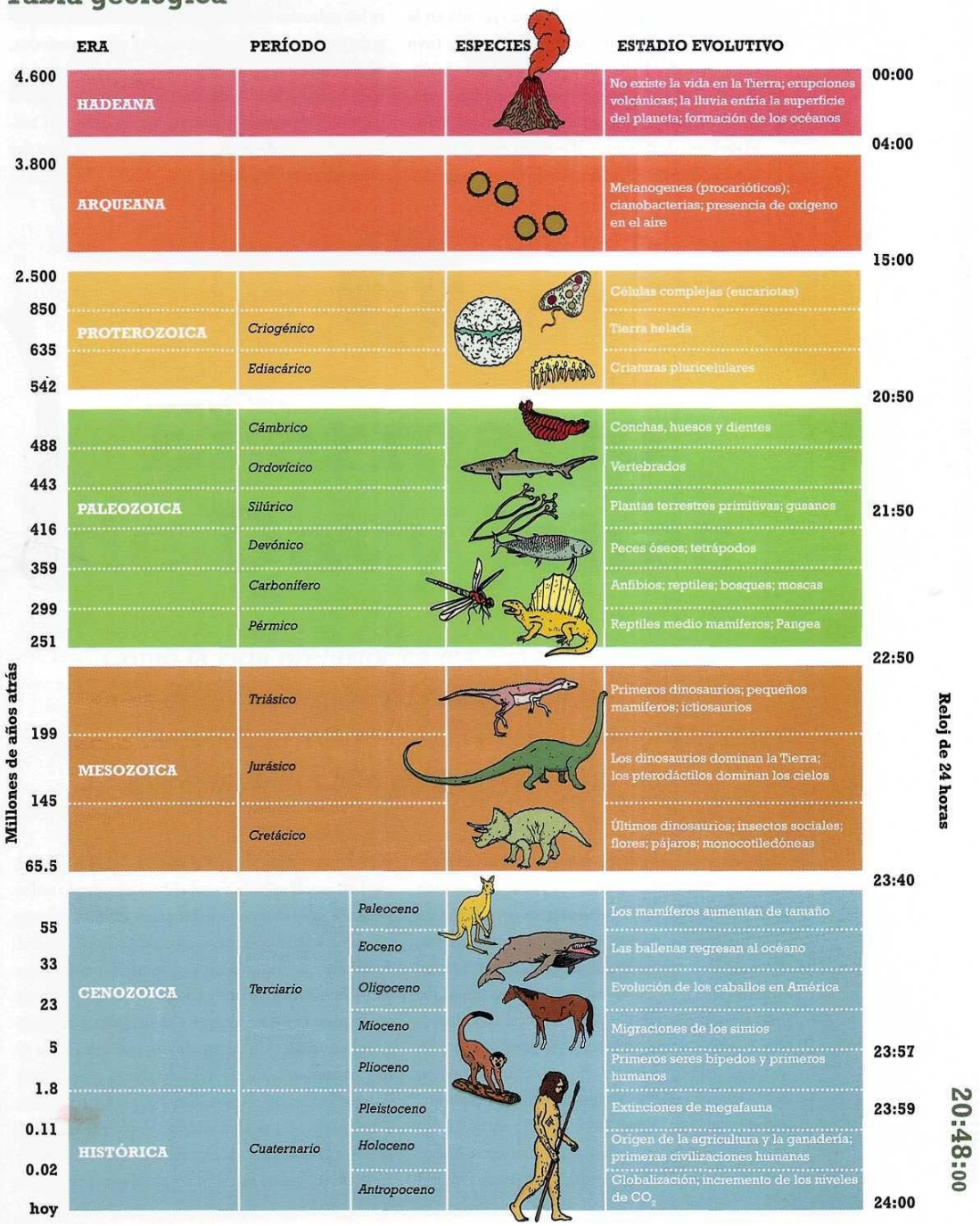
¿Que es el sistema nervioso?

El SISTEMA NERVIOSO : 2 GRANDES FUNCIONES

MANTENER LA HOMEOSTASIS

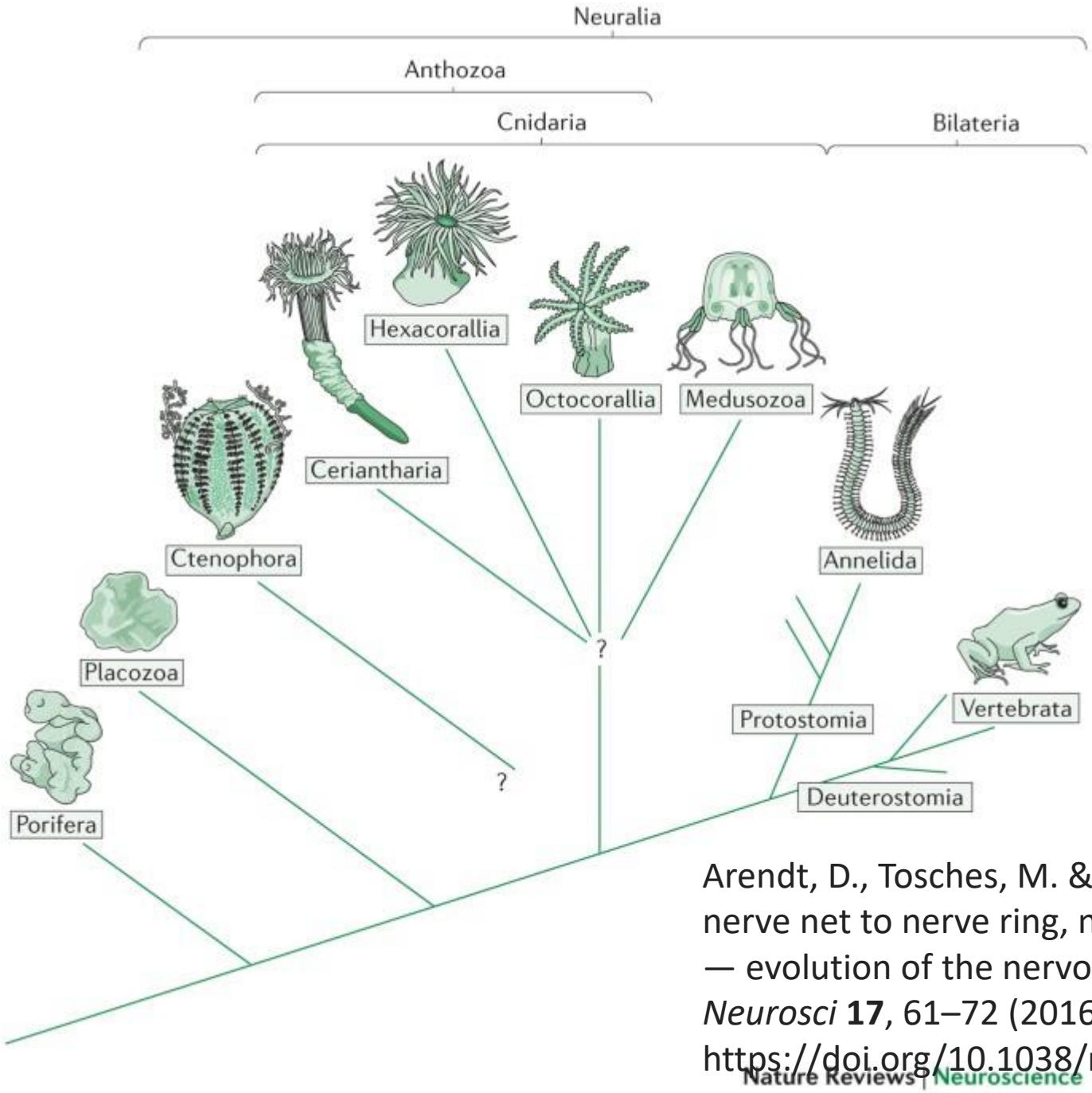
CONTROL DEL COMPORTAMIENTO DEL ANIMAL EN SU MEDIO AMBIENTE

Tabla geológica



¿Cuando se origina?

Animales MULTICELULARES



Arendt, D., Tosches, M. & Marlow, H. From nerve net to nerve ring, nerve cord and brain — evolution of the nervous system. *Nat Rev Neurosci* **17**, 61–72 (2016). https://doi.org/10.1038/nrn.2015.15

¿Por que se origina el sistema nervioso?

El sistema nervioso evolucionó para permitir el movimiento activo de los animales. Para moverse en su entorno con seguridad, una criatura debe anticipar los efectos de cada movimiento en base a la información sensorial entrante. Por lo tanto, la capacidad de predecir es la función cerebral última más probable. Uno podría decir que el Yo es la centralización de la predicción.

(Rodolfo Llinás, I Vortex From neuron to self, 2002, MIT Press).

LA FUNCIÓN CENTRAL DEL SISTEMA NERVIOSO :

1-RECIBIR INFORMACIÓN

Receptores sensoriales generan (ESTIMULO **entrada sensorial)**

2- PROCESAR información (que se origina externa o internamente), de modo de

3- RESPONDER adecuadamente a los estímulos externos y a los internos, manteniendo la homeostasis del organismo. **EFECTOR**

¿Para que un Sistema Nervioso?

"El cerebro existe para procesar información, que permite al animal solucionar problemas, que a su vez contribuyen a su adaptación."

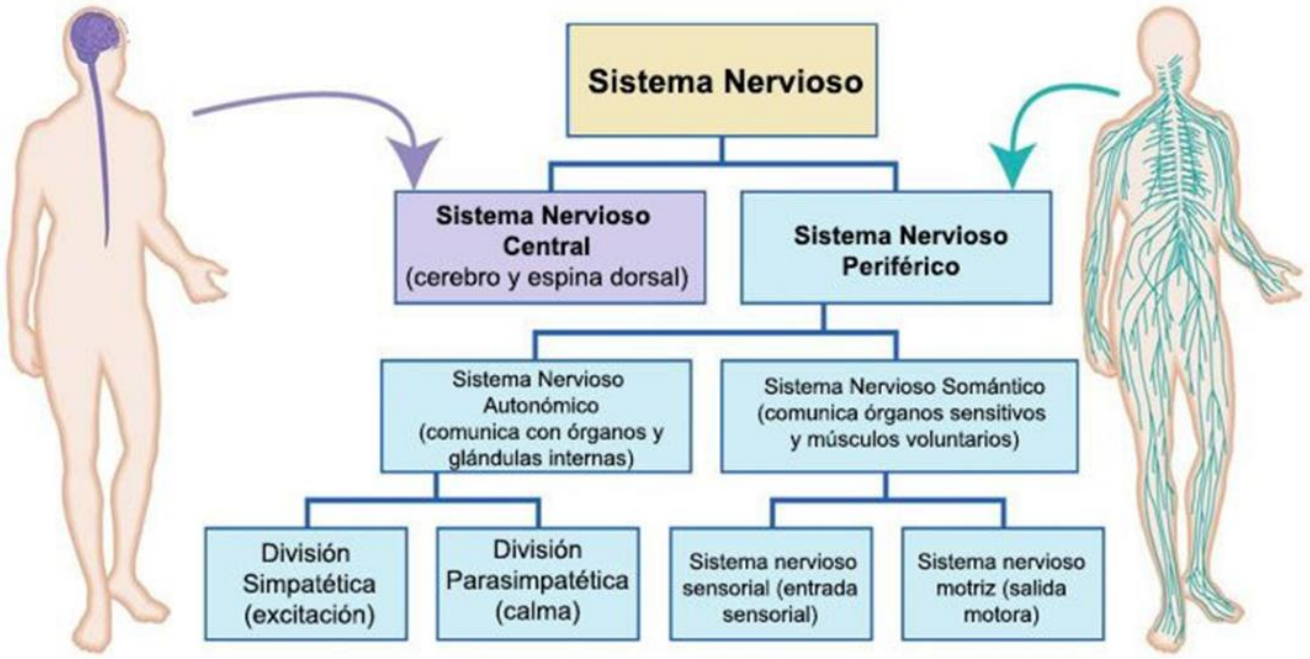
Northcutt, 2002

SISTEMA NERVIOSO CENTRAL

SISTEMA NERVIOSO PERIFÉRICO

Cerebro + Medula Espinal

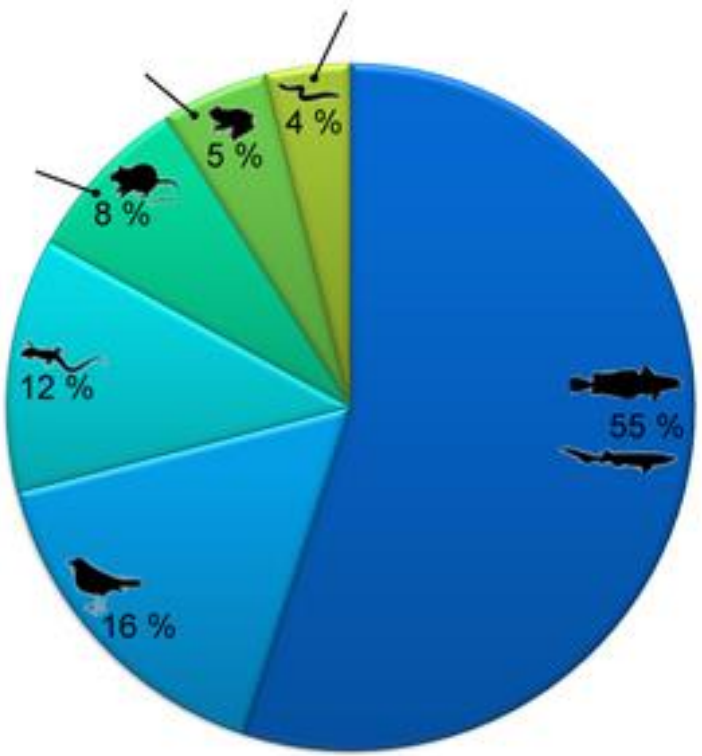
MEDULA ESPINAL



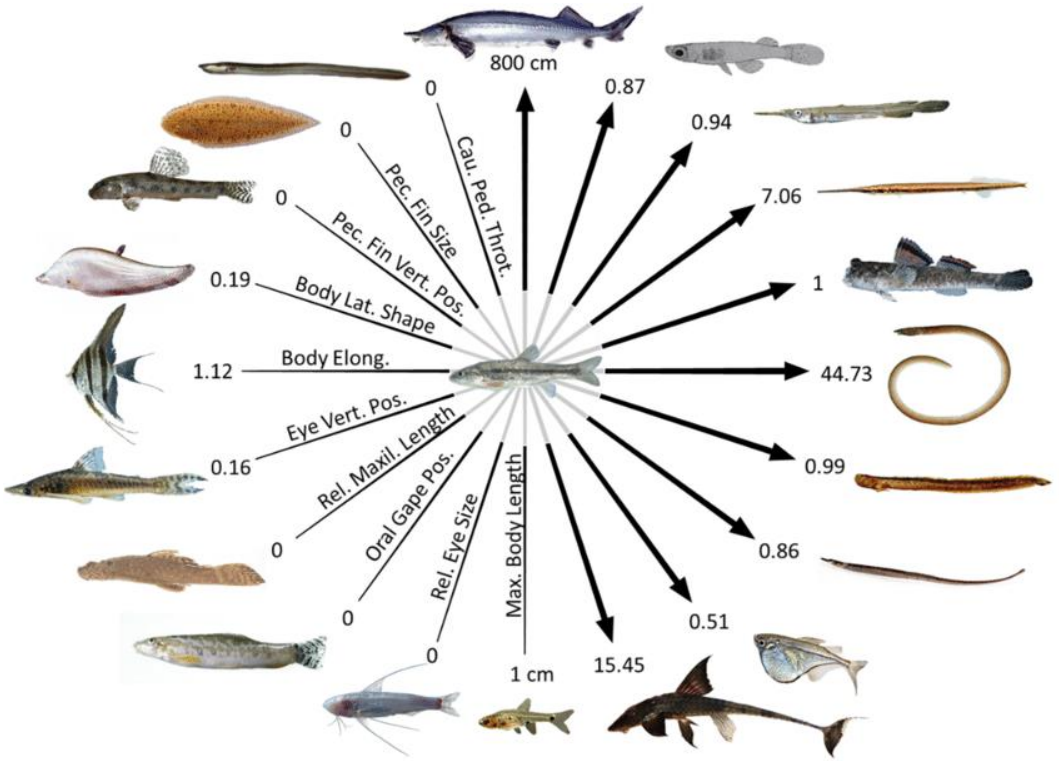
SISTEMA SENSORIAL

SISTEMA MOTOR

Diversidad



35,500 especies*
17,894 de agua dulce

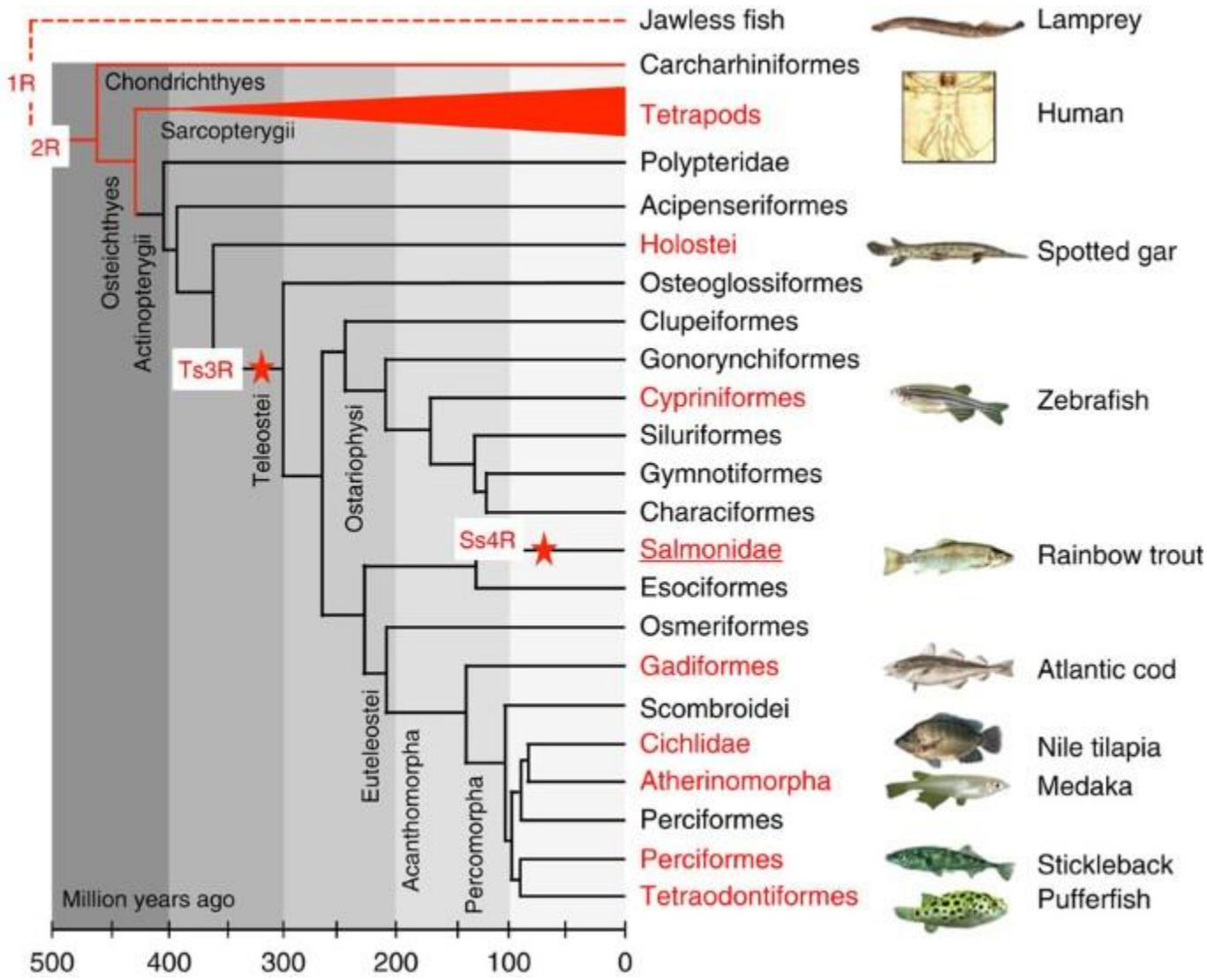


Su et al.., 2019, Figure Supplementary 2

The rainbow trout genome provides novel insights into evolution after whole-genome duplication in vertebrates

•Camille Berthelot,
•Frédéric Brunet,
•Yann Guiguen

Nature Communications **volume 5**, Article number: 3657 (2014)



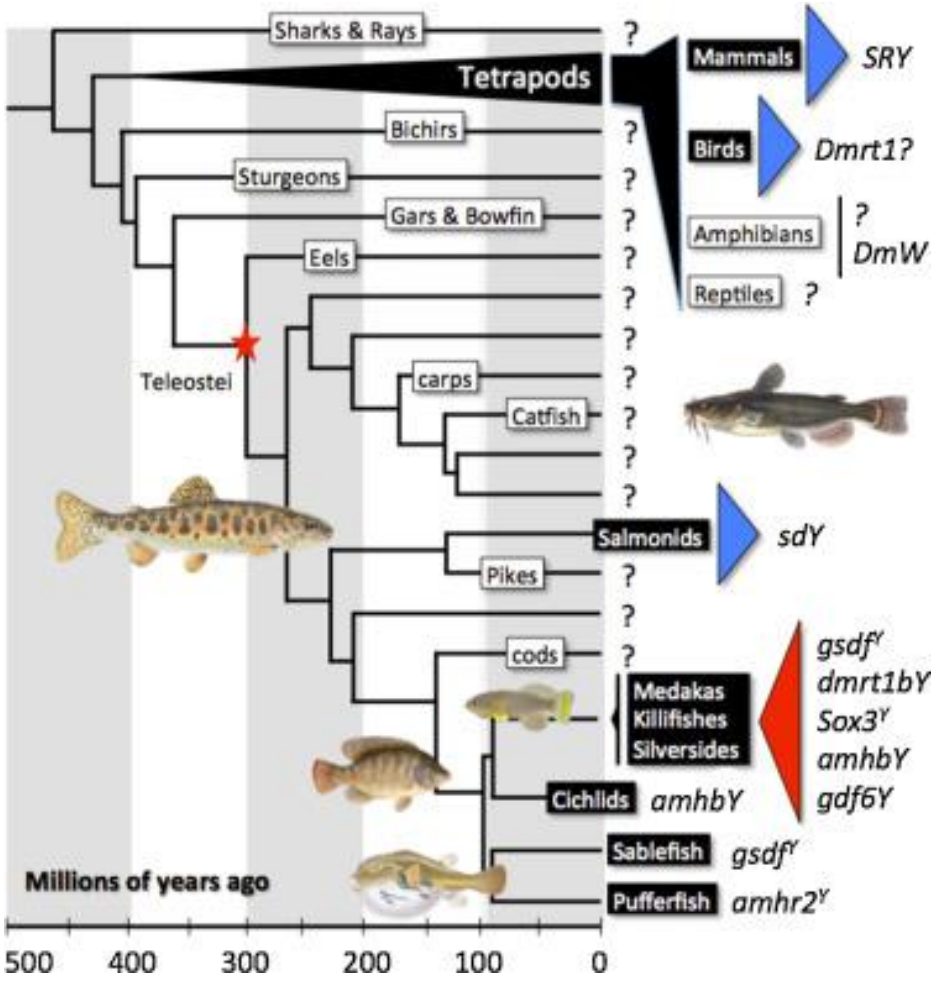
Gran Diversidad Cerebral en Peces

Adaptación al Medio ambiente

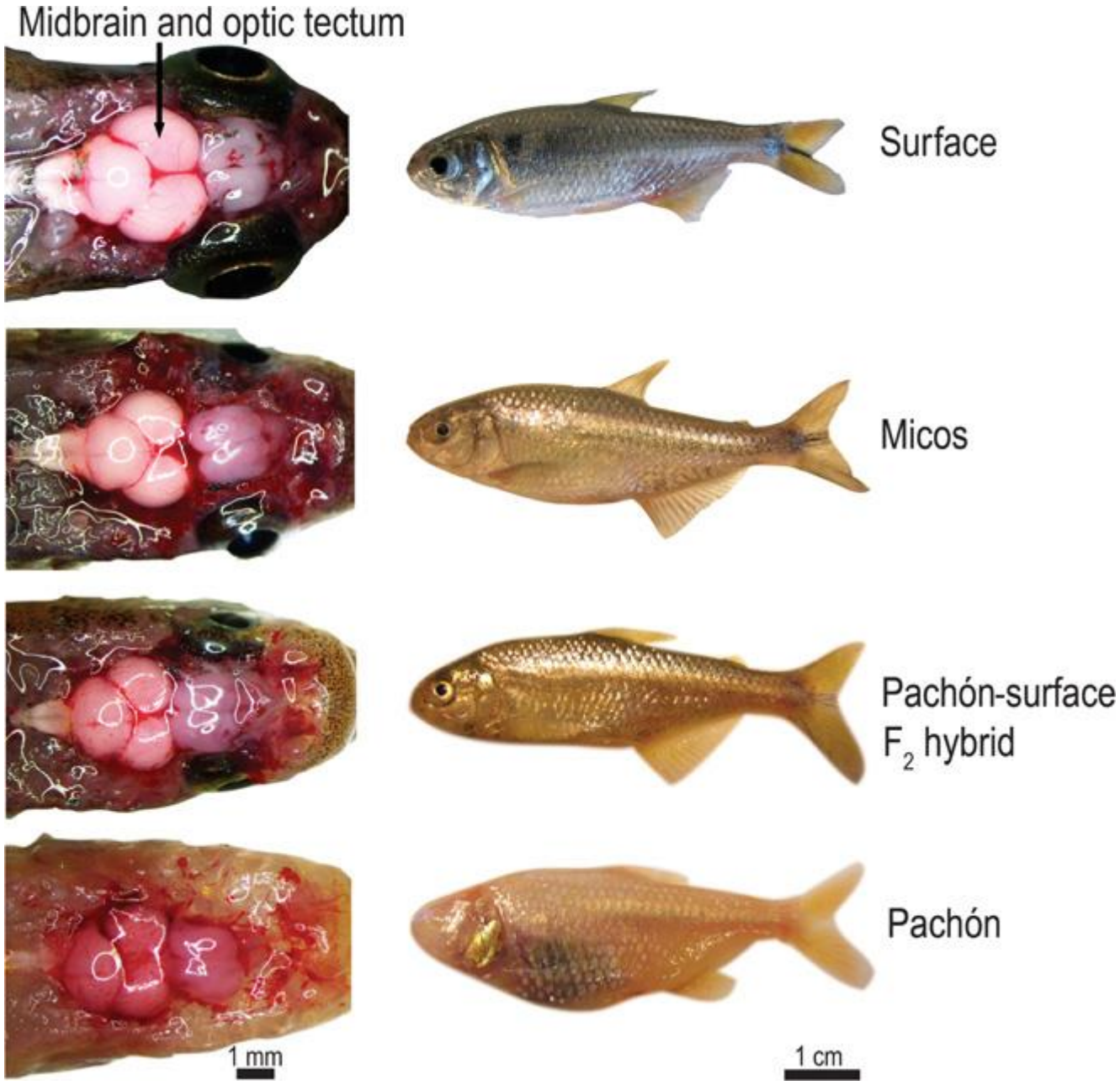
Duplicación del Genoma

- Genes redundantes
- Mas fáciles de mutar
- Regionalización cerebral

PROLIFERACION CELULAR



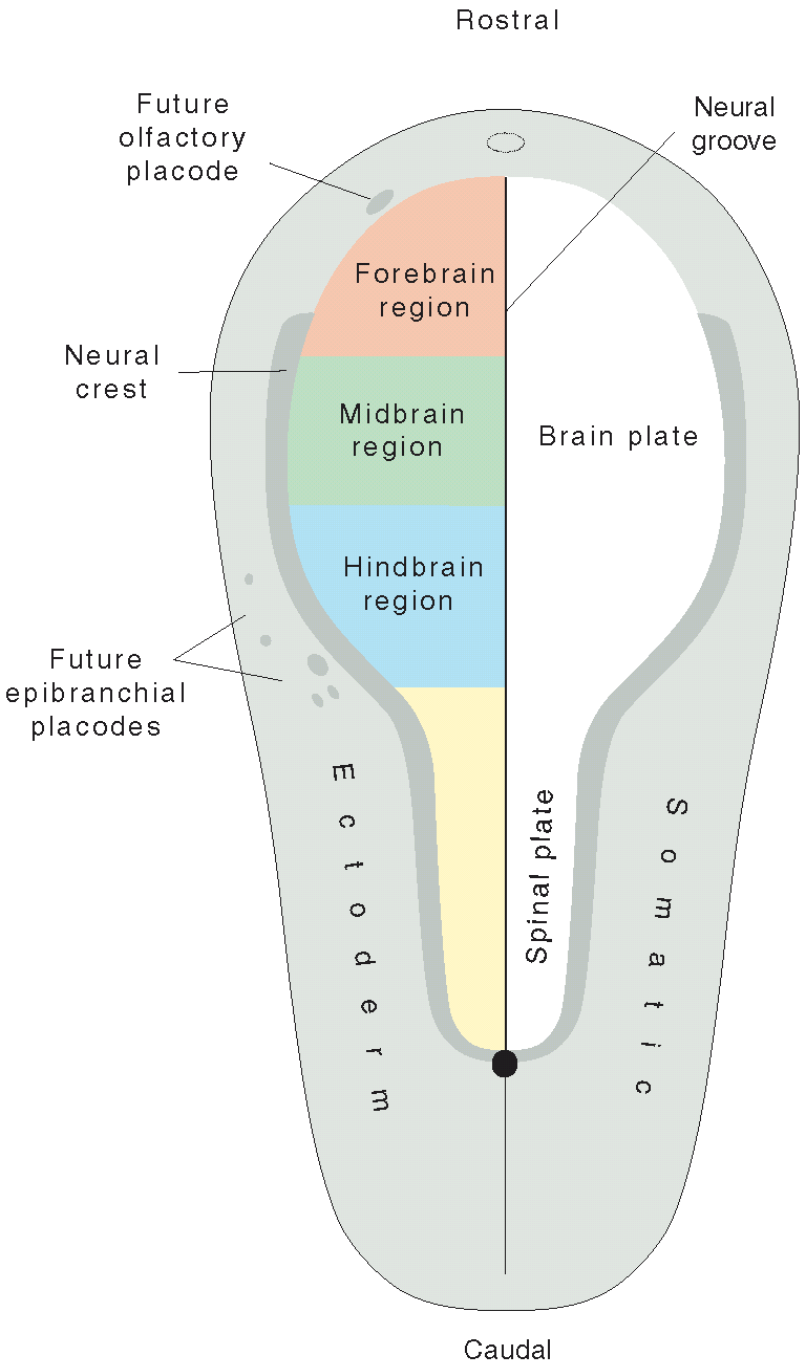
"Por tanto, el cerebro de los teleósteos no es en absoluto un cerebro vertebrado simplificado, sino el reflejo de una enorme diversidad de funciones y adaptaciones que se desarrollan a lo largo de más de 300 millones de años de evolución. Ito, 2007"


Midbrain and optic tectum
Surface
Micos
Pachón-surface
F2 hybrid
Pachón
1 mm
1 cm

Para entender la organización del SN de los vertebrados en necesario comenzar por el desarrollo embrionario.

El desarrollo embrionario en etapas tempranas es común en todos los vertebrados

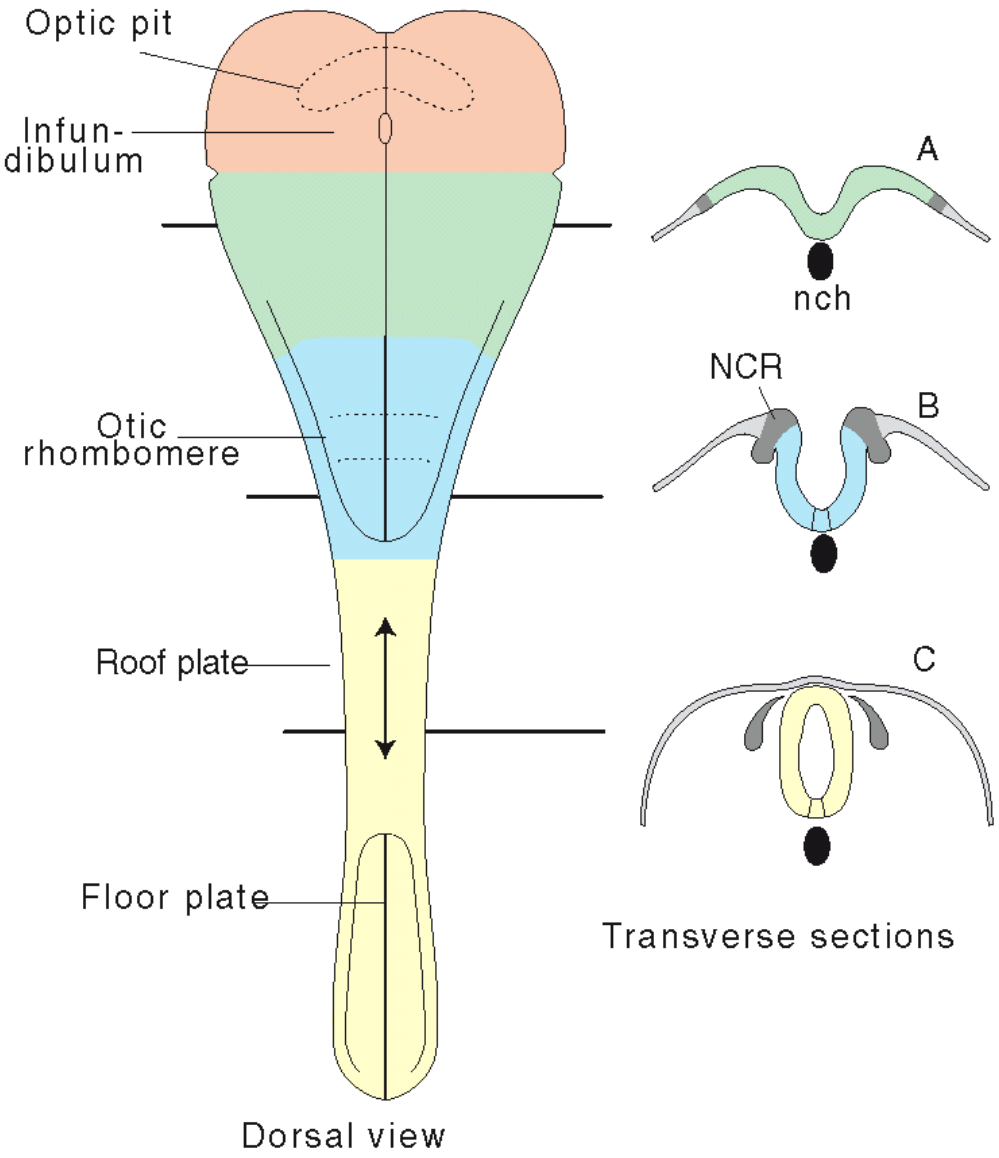
https://www.youtube.com/watch?v=C2q3Dqv9PEA



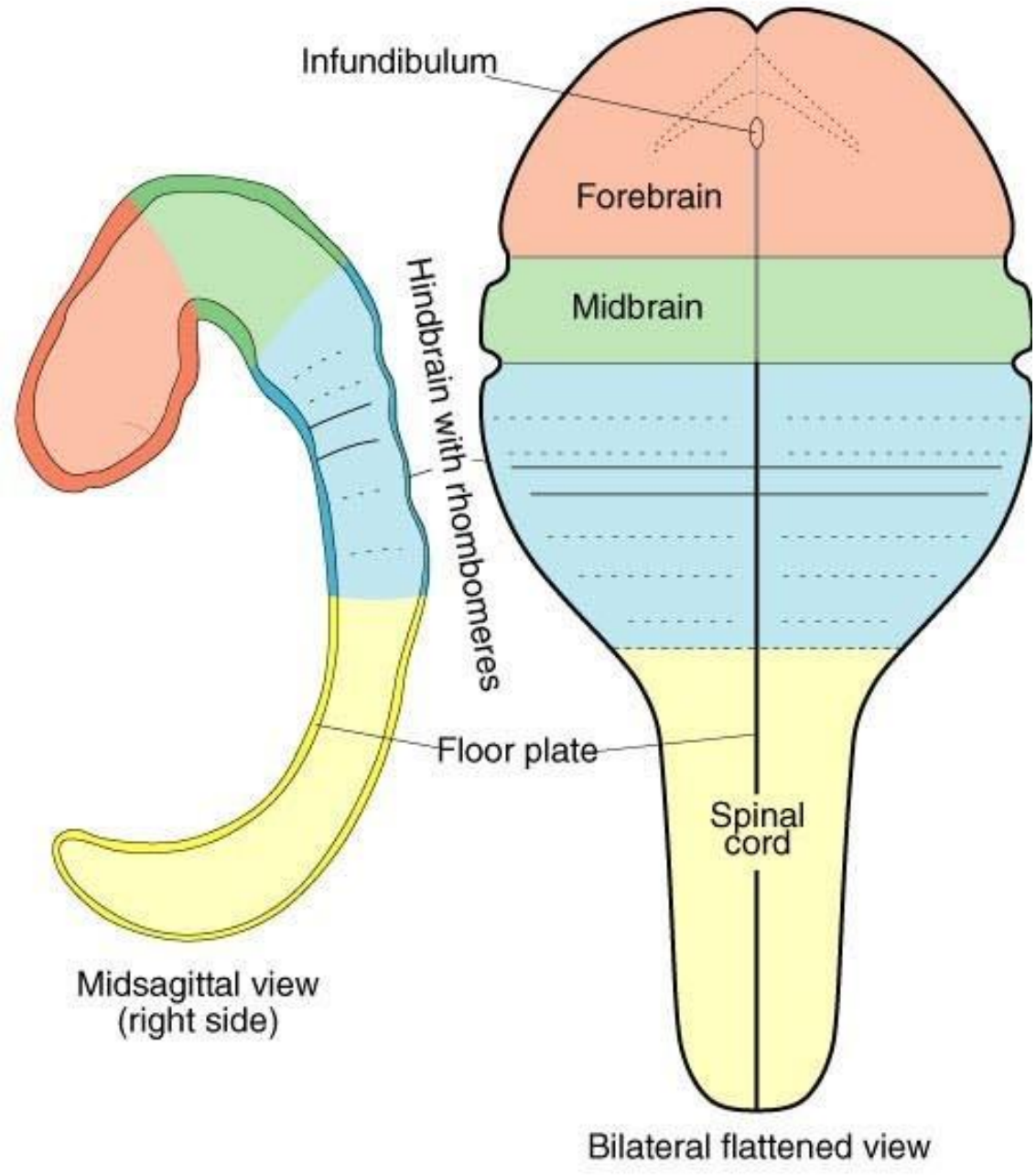
Placa neural

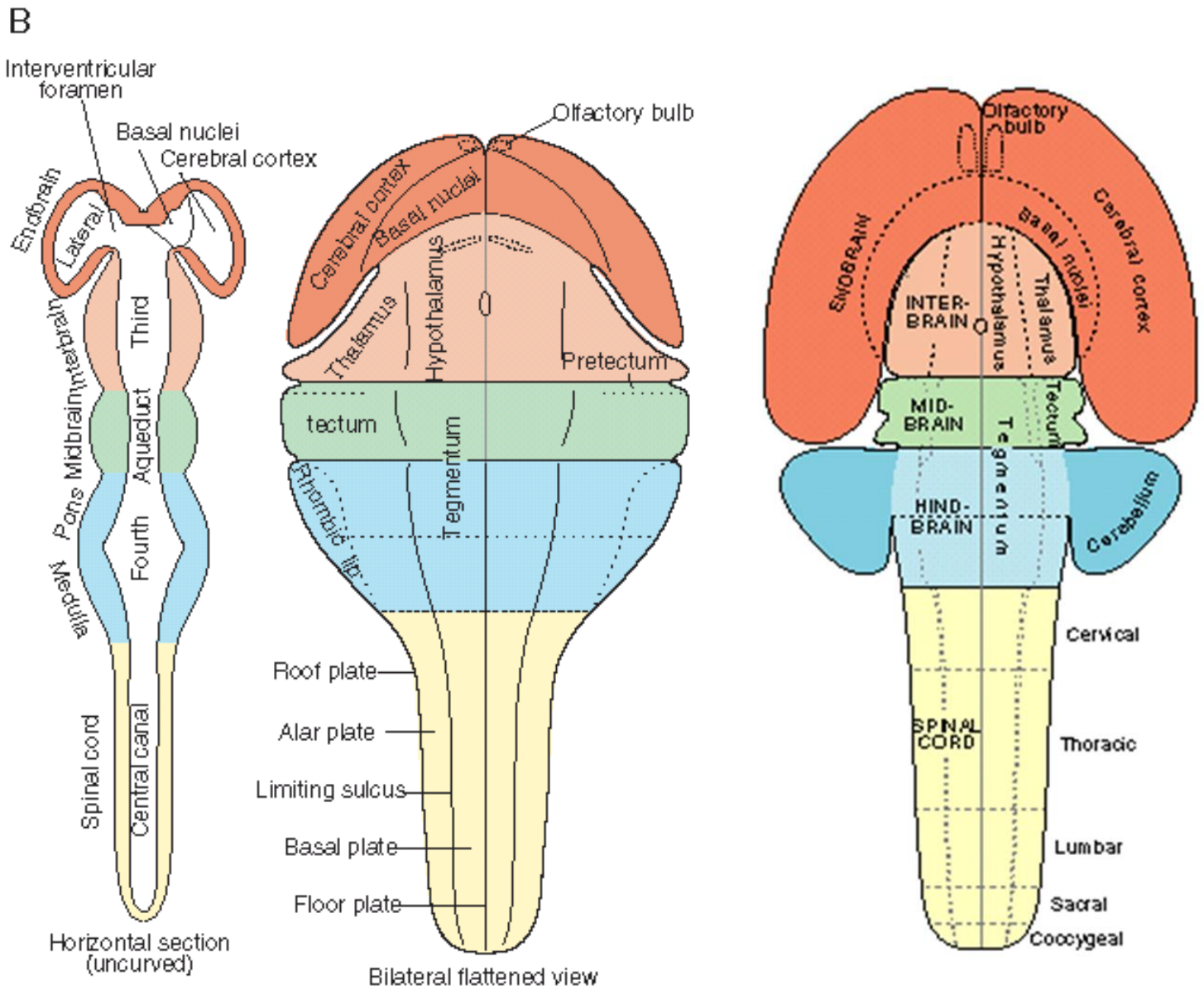
neurulación

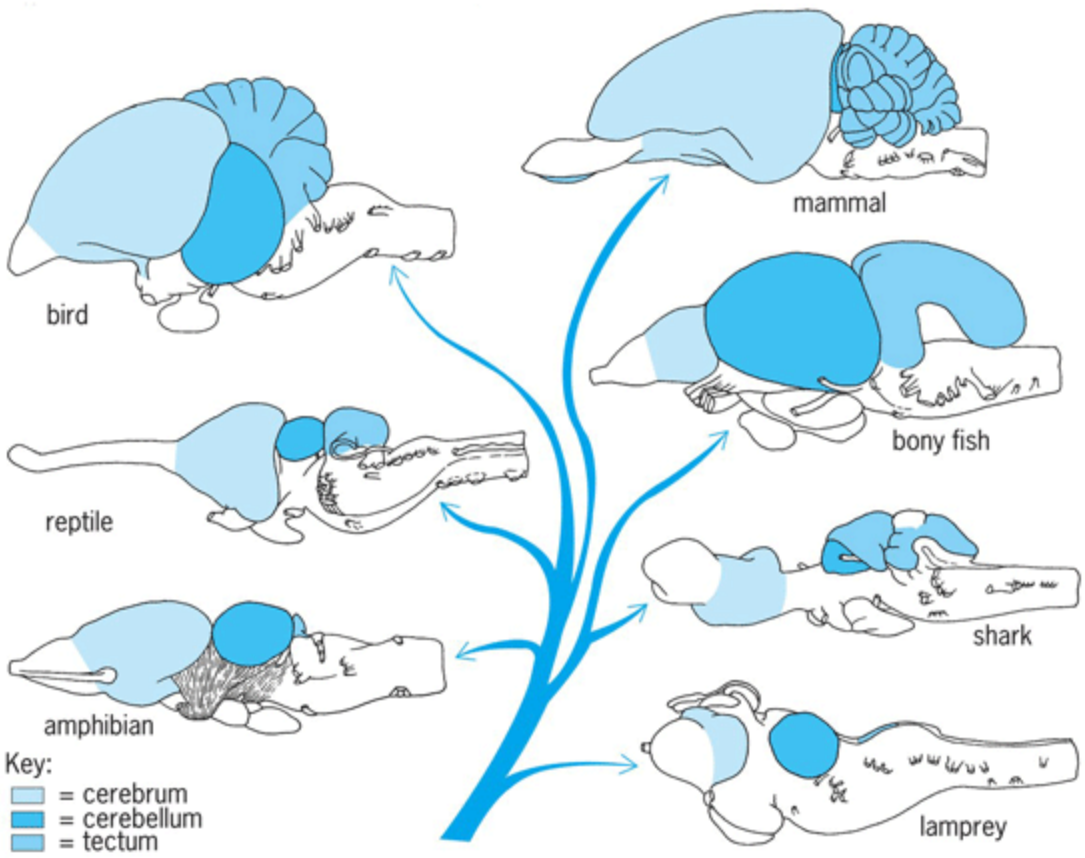
Polarización
Simetría bilateral

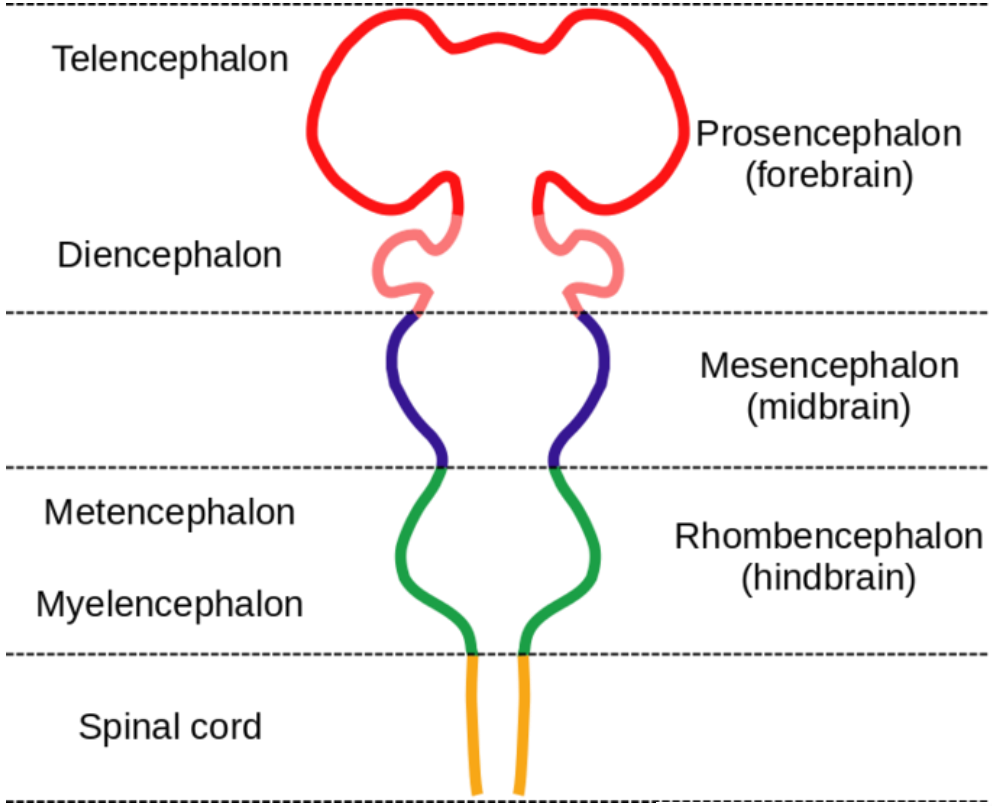

Optic pit
Infun-
dibulum
Otic
rhombomere
Roof plate
Floor plate
Dorsal view
A
nch
NCR
B
C
Transverse sections

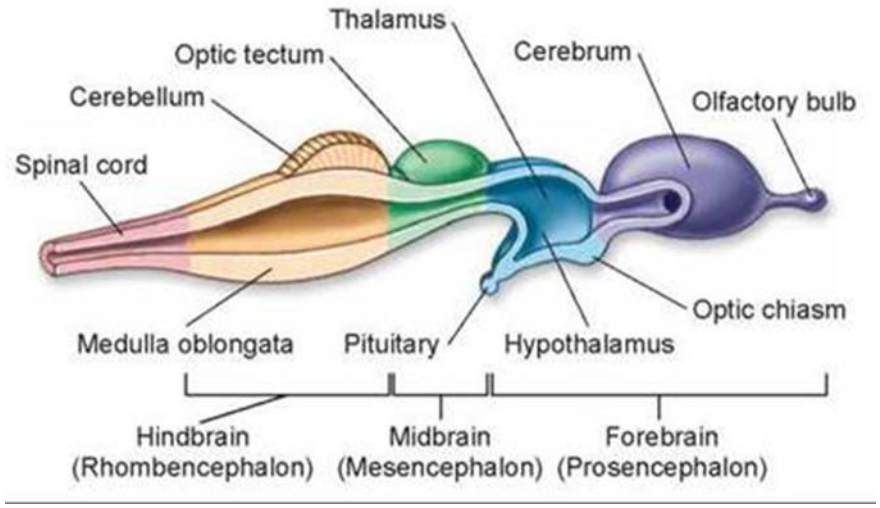
A


Infundibulum
Forebrain
Midbrain
Hindbrain with rhombomeres
Floor plate
Spinal cord
Midsagittal view (right side)
Bilateral flattened view


B
Interventricular foramen
Basal nuclei
Cerebral cortex
Endbrain
Lateral
Third
Midbrain
Interbrain
Aqueduct
Pons
Fourth
Medulla
Spinal cord
Central canal
Horizontal section (uncurved)
Olfactory bulb
Cerebral cortex
Basal nuclei
Thalamus
Hypothalamus
Pretectum
tectum
Tegmentum
Rhombic lip
Roof plate
Alar plate
Limiting sulcus
Basal plate
Floor plate
Bilateral flattened view
Olfactory bulb
Cerebral cortex
Basal nuclei
TELEENCEPHALON
INTER-BRAIN
Hypothalamus
Thalamus
MID-BRAIN
Tectum
Tegmentum
HIND-BRAIN
Cerebellum
SPINAL CORD
Cervical
Thoracic
Lumbar
Sacral
Coccygeal


mammal
bird
bony fish
reptile
shark
amphibian
lamprey
Key:
= cerebrum
= cerebellum
= tectum


Telencephalon
Prosencephalon
(forebrain)
Diencephalon
Mesencephalon
(midbrain)
Metencephalon
Rhombencephalon
(hindbrain)
Myelencephalon
Spinal cord


Thalamus
Optic tectum
Cerebrum
Cerebellum
Olfactory bulb
Spinal cord
Optic chiasm
Medulla oblongata
Pituitary
Hypothalamus
Hindbrain
(Rhombencephalon)
Midbrain
(Mesencephalon)
Forebrain
(Prosencephalon)

EVAGINACIÓN y EVERSIÓN

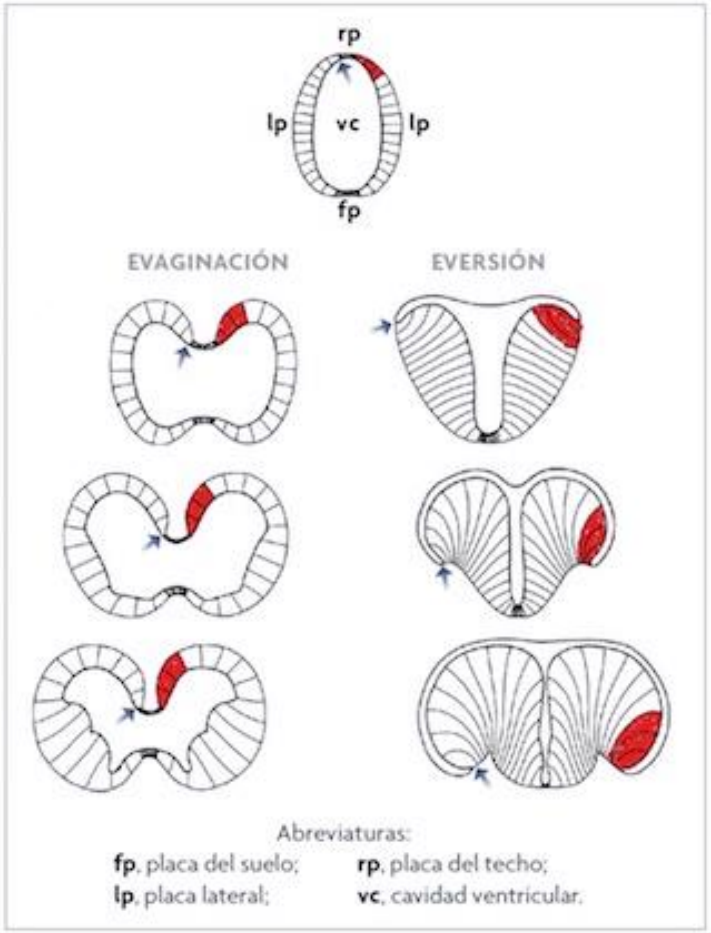


Figura 2. Esquema del desarrollo del cerebro anterior (en particular, el telencéfalo) a partir del tubo neural para mostrar el concepto de topología. Durante la morfogénesis, el telencéfalo puede crecer siguiendo dos procesos diferentes: evaginación (ocurre en la mayor parte de los vertebrados) o eversión (ocurre el peces teleósteos). Como consecuencia, la misma subdivisión del cerebro (como la señalada en rojo) puede terminar ocupando posiciones topográficas diferentes (hacia dentro o hacia fuera), pero su posición topológica es idéntica (en el ejemplo, la estructura en rojo está situada junto a la placa del techo; señalado con una flecha).

Particularidades del desarrollo de los teleosteos

Estructuras Conservados y Nuevas o diferentes

Cerebro anterior

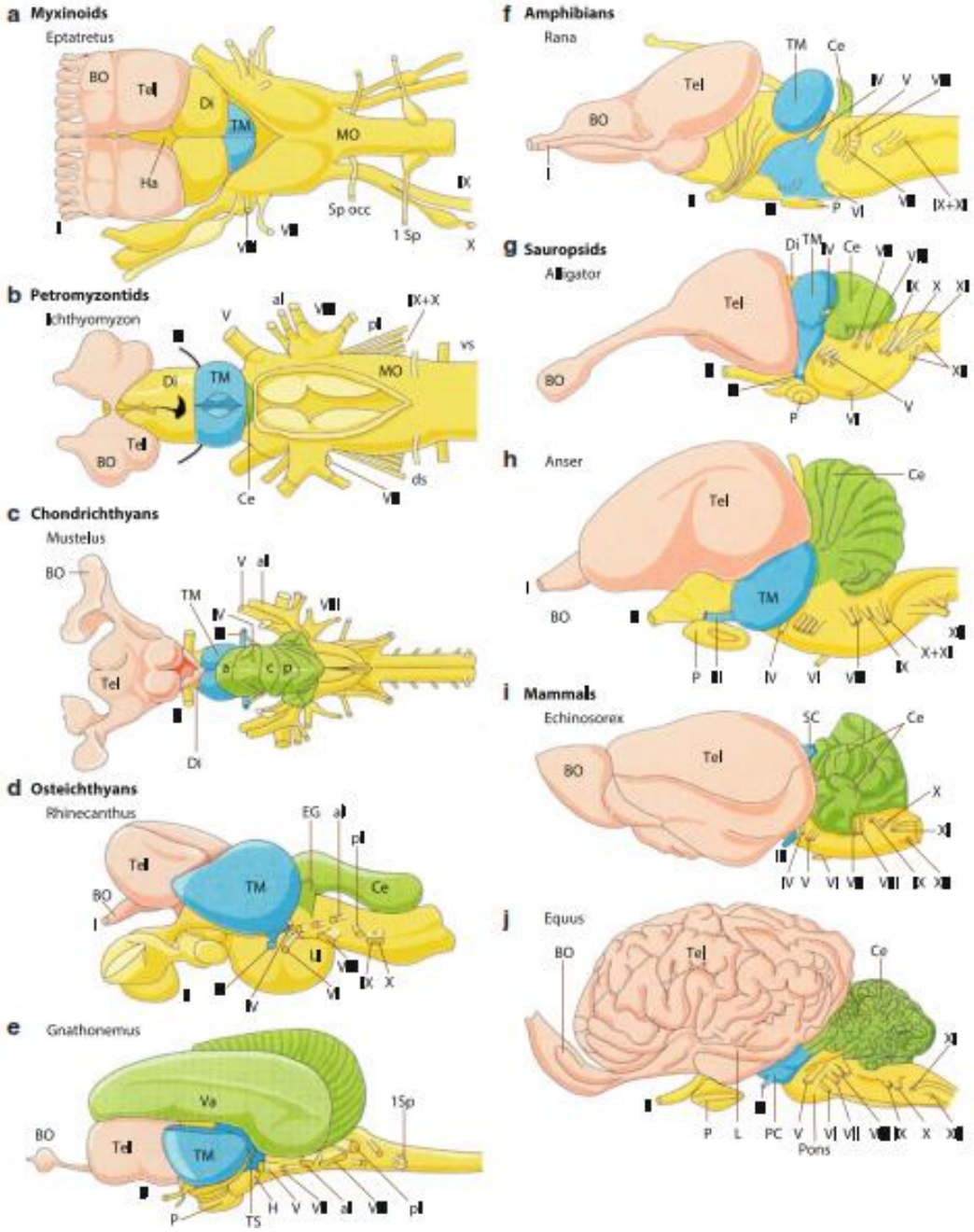
- Telencéfalo Lóbulos olfatorios, corteza cerebral (palio)
- Diencéfalo: Epitálamo, tálamo, hipotálamo

Cerebro medio

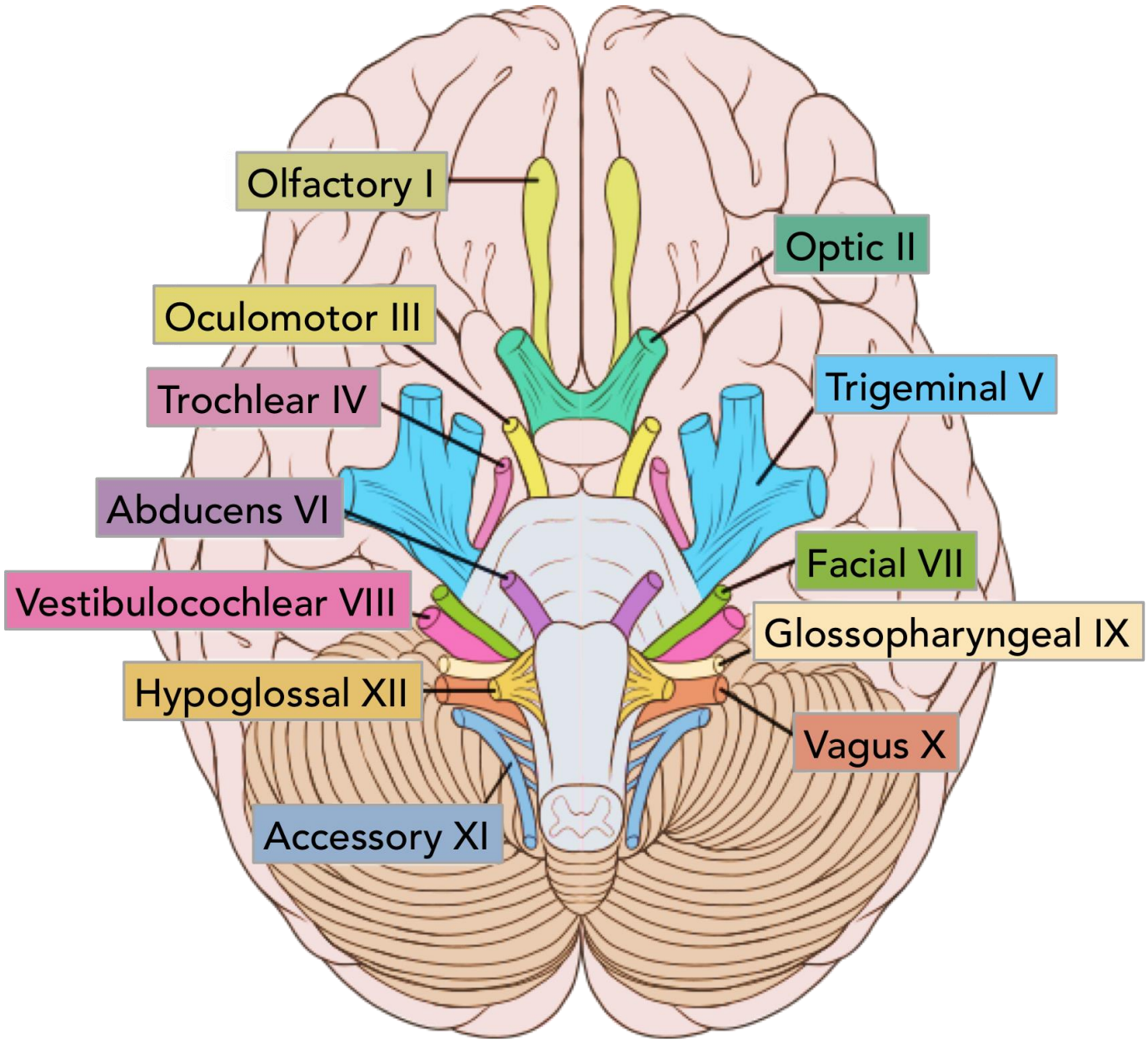
- Lobulos ópticos torus longitudinalis
- Torus semicircularis

Cerebro posterior

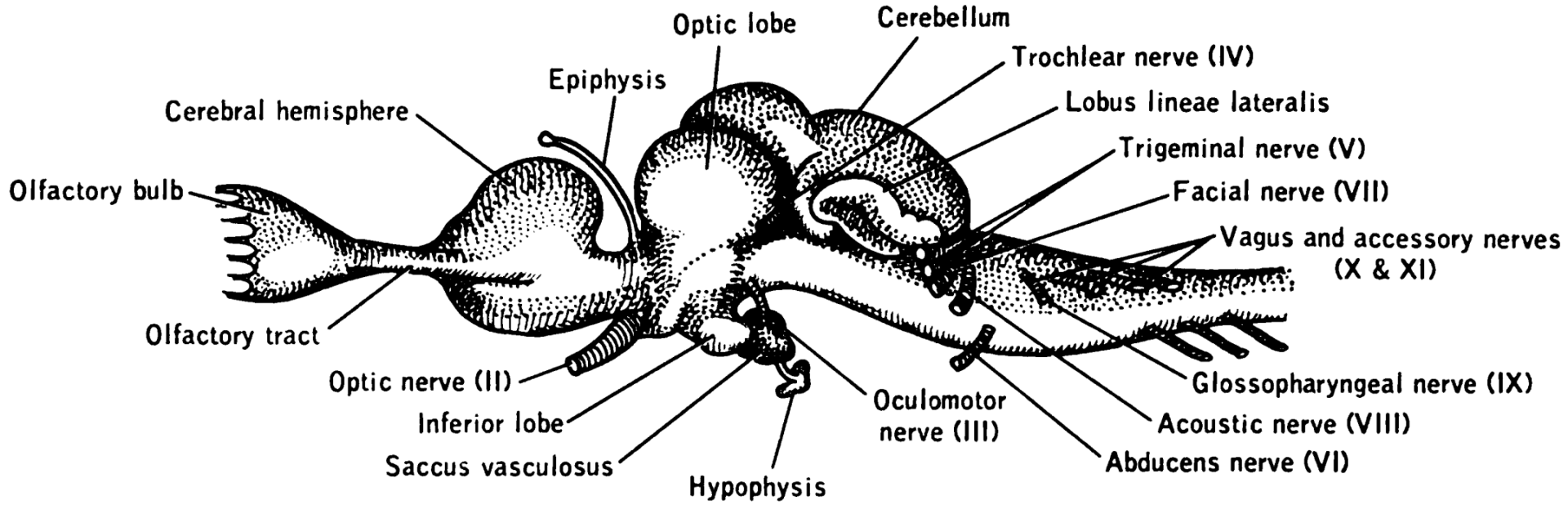
- Metencefalo: parte del bulbo raquideo, cerebelo
- Mielencefalo: mayor parte del bulbo raquideo


a Myxinoids
Eptatretus
BO
Tel
Di
TM
MO
Ha
Sp occ
1 Sp
X
b Petromyzontids
Ichthyomyzon
V
al
pl
IX+X
vs
MO
Di
TM
Tel
BO
Ce
ds
c Chondrichthyans
Mustelus
BO
V
al
TM
IV
VII
a
c
p
Tel
Di
d Osteichthyans
Rhinecanthus
EG
al
pl
Tel
TM
Ce
BO
LI
IV
e Gnathonemus
Va
1Sp
BO
Tel
TM
P
TS
H
V
al
pl
f Amphibians
Rana
TM
Ce
Tel
BO
IV
V
P
VI
IX+X
g Sauropsids
Alligator
Di
TM
IV
Ce
X
XI
Tel
BO
P
VI
V
h Anser
Ce
Tel
TM
BO
P
IV
VI
X+X
i Mammals
Echinosorex
SC
Ce
Tel
BO
X
IV
V
VI
VII
j Equus
BO
Tel
Ce
P
L
PC
V
VI
Pons
X

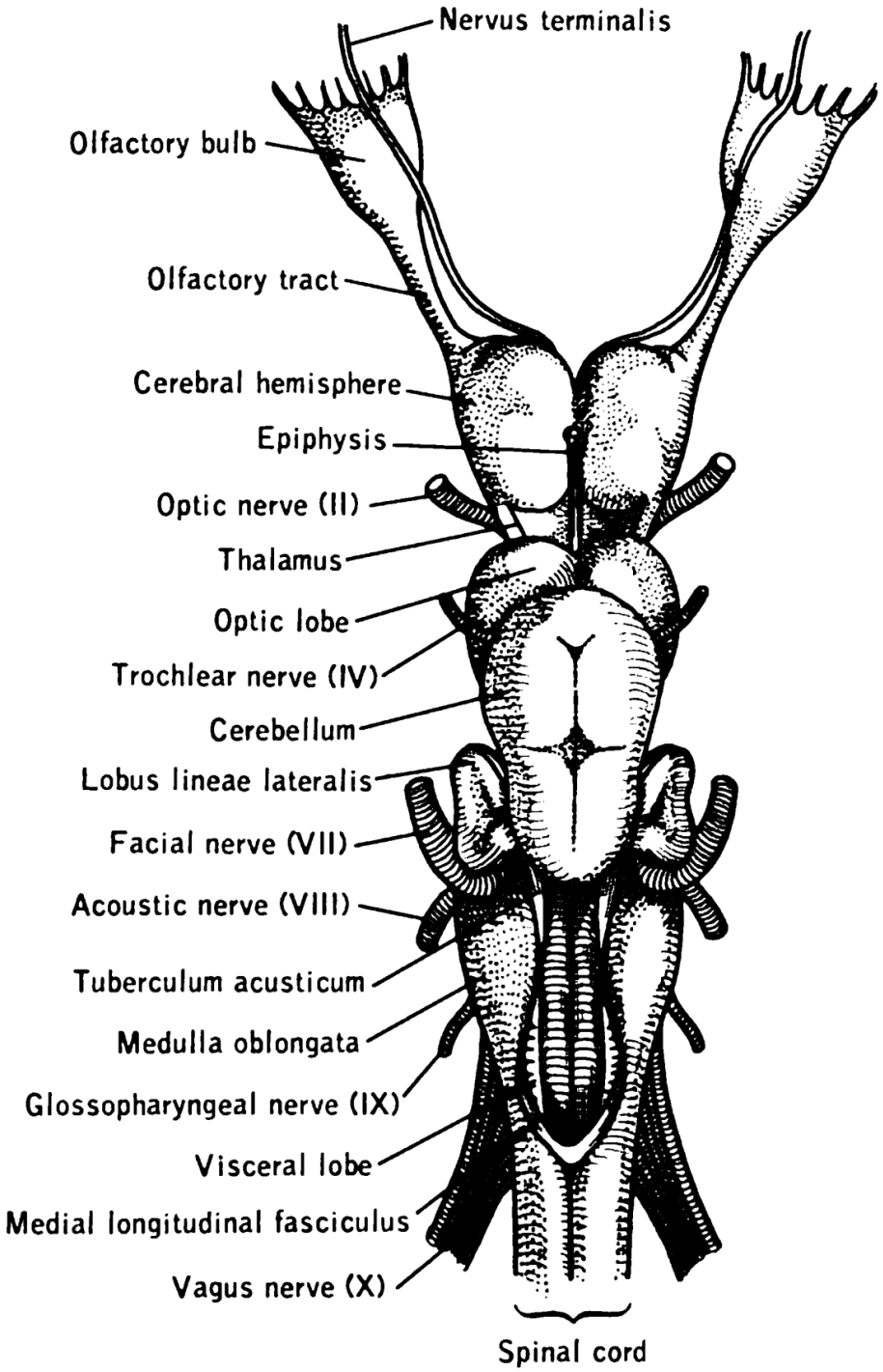
PARES CRANEALES



By House, Earl Lawrence. Pansky, Ben. - A functional approach to neuroanatomy 1960, Public Domain, https://commons.wikimedia.org/w/index.php?curid=31164665

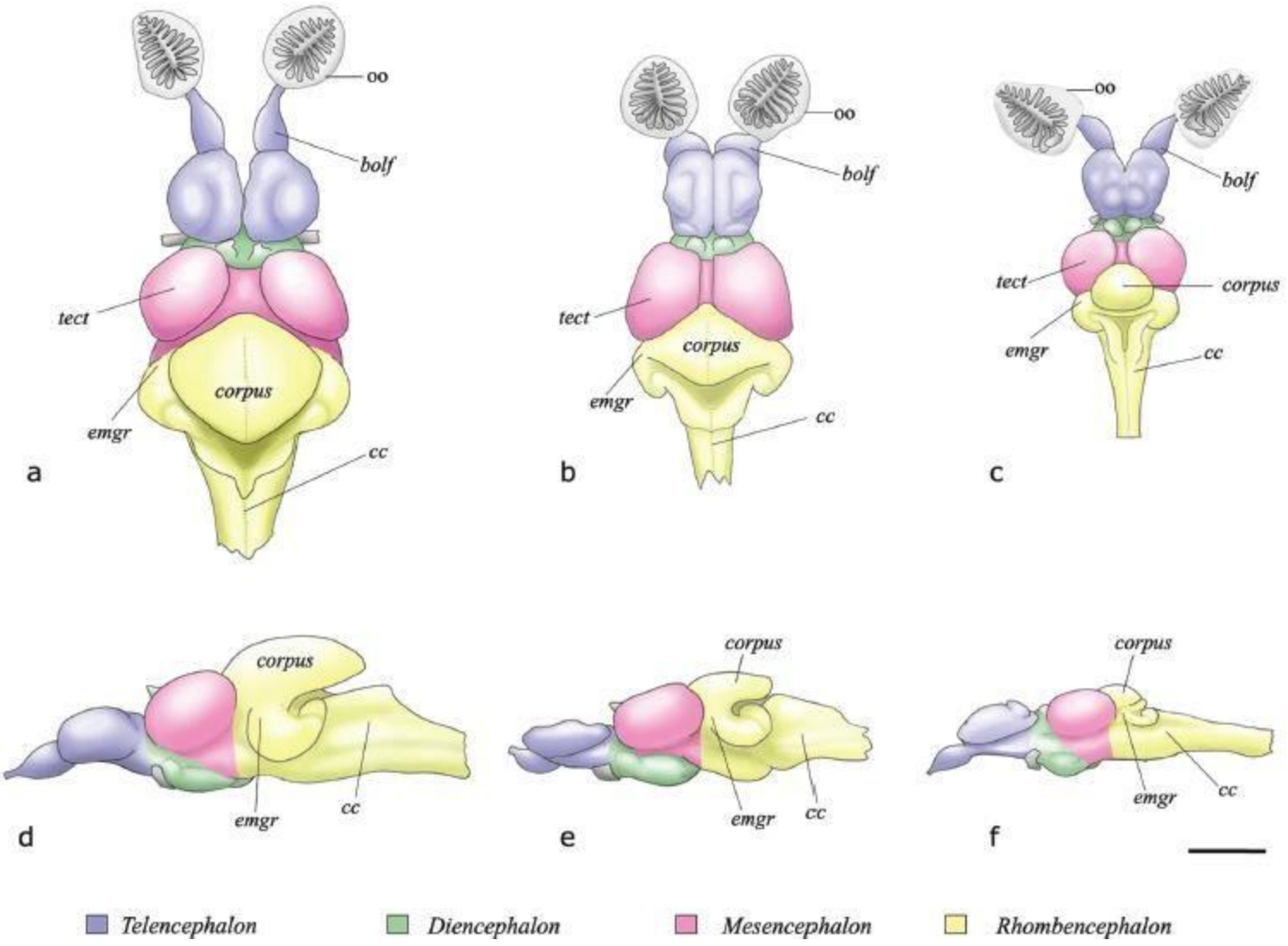


Pares craneales en Peces



#	Name	Nerve type	Function
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Vision
III	Oculomotor	Motor	Most eye movement
IV	Trochlear	Motor	Moves eye
V	Trigeminal	Both	Face sensation, mastication
VI	Abducens	Motor	Abducts the eye
VII	Facial	Both	Facial expression, taste
VII	Vestibulocochlear	Sensory	Hearing, balance
IX	Glossopharyngeal	Both	Taste, gag reflex
X	Vagus	Both	Gag reflex, parasympathetic innervation
XI	Accessory	Motor	Shoulder shrug
XII	Hypoglossal	Motor	Swallowing, speech

PECES


oo
bolf
tect
corpus
emgr
cc
a
b
c
d
e
f
Telencephalon
Diencephalon
Mesencephalon
Rhombencephalon

El cerebro revela las diferentes especialidades funcionales

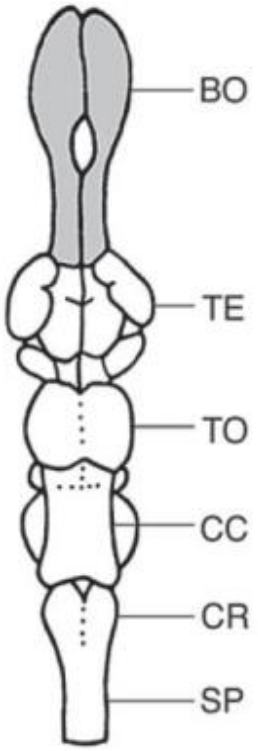
G. kidako Nocturno
olfación

S. cirrhifer,
visión

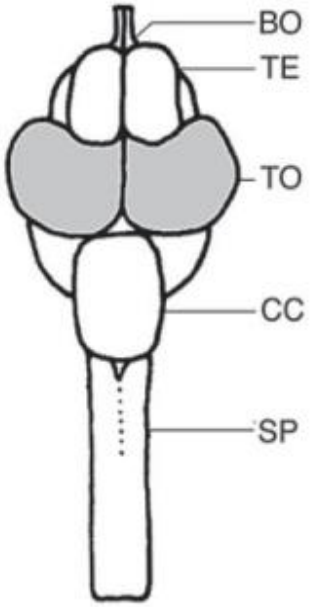
P. scalprus
Coordinación
motora

S. asotus, LLS
(mecano y electro-
recepción)

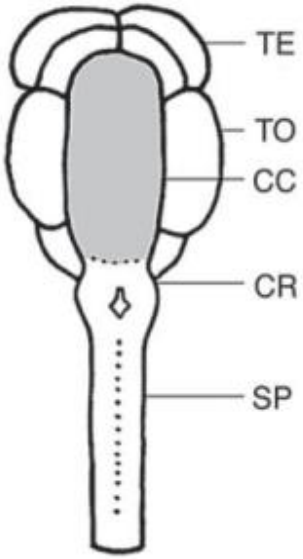
A.argentatus, –
Sistema
vestibular



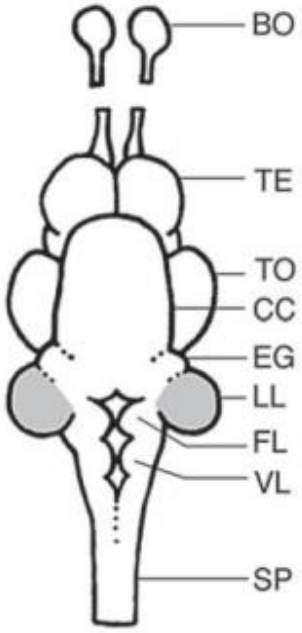
A



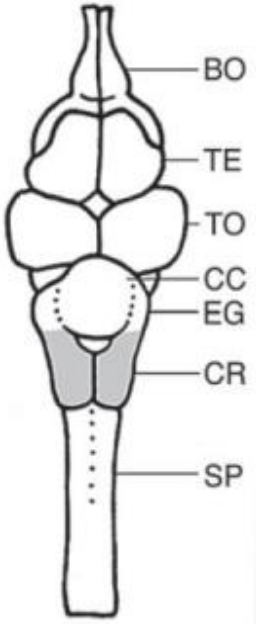
B



C



D



E





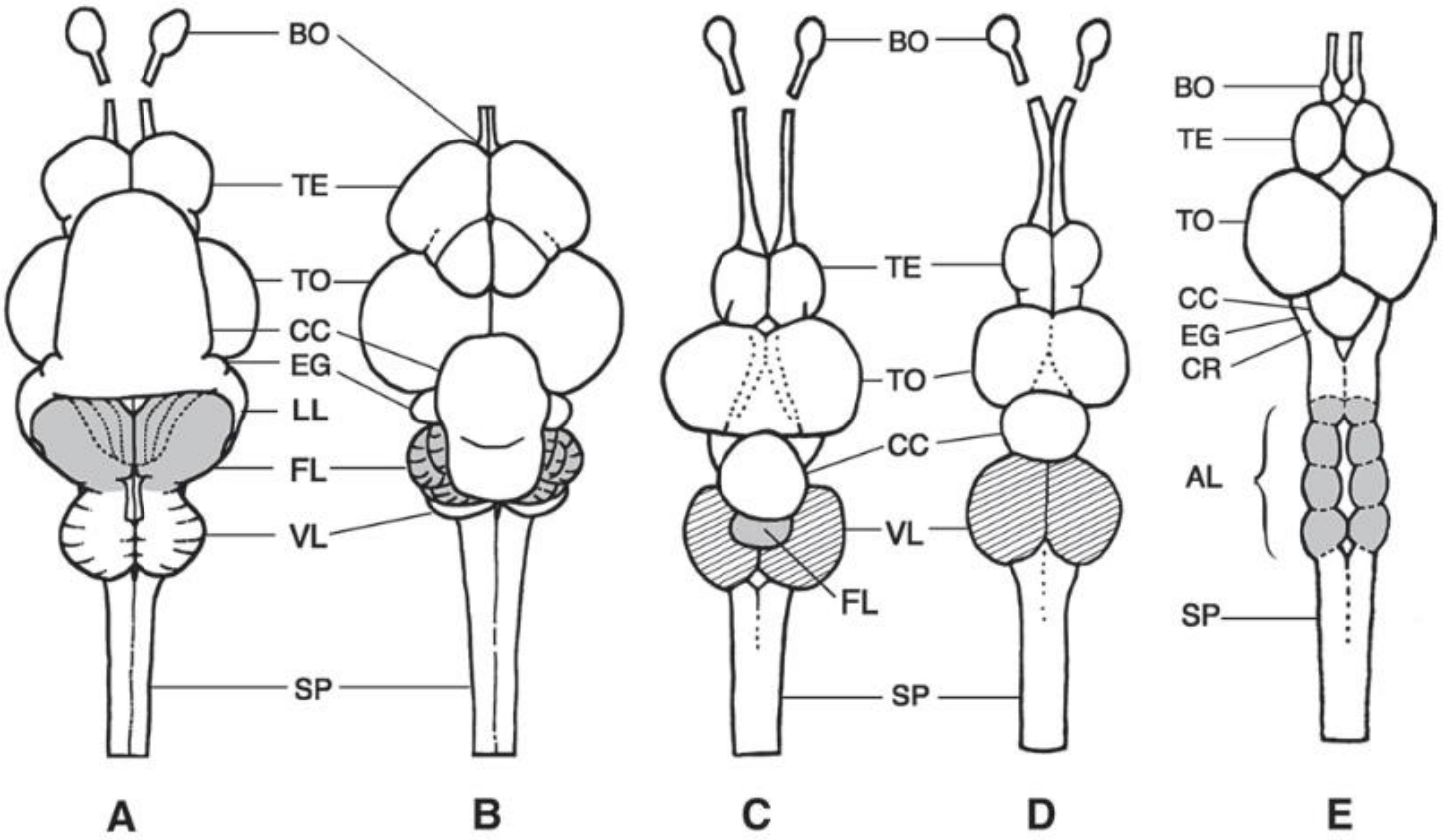
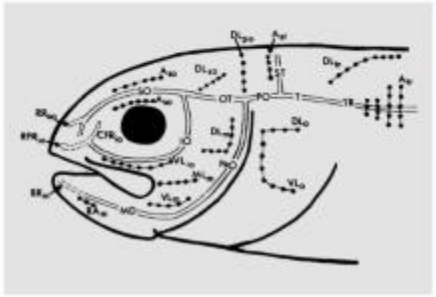


Fig. 4. Dorsal views of brains of A sea catfish (Plotosus lineatus) , B goatfish (Upenensis bensasi) , C common carp (Cyprinus carpio) , D crucian carp (Carassius carassius) , and E sea robin (Prionotus carolinus) .

DIVERSIDAD SENSORIAL

- OLFATO: órganos olfativos- quimiorreceptores
- VISION :Fotorreceptores
- GUSTO: corpúsculos gustativos:
- quimiorreceptores
- AUDICION Y BALANCE: Mecanorreceptores
- MECANORRECEPCIÓN: mecanorreceptores



Gibbs, 2004

G. Omarorum (larva)

Especializaciones Funcionales Electrorecepción

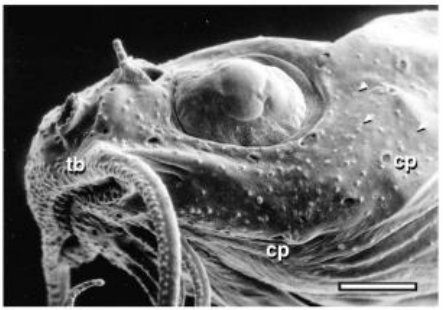
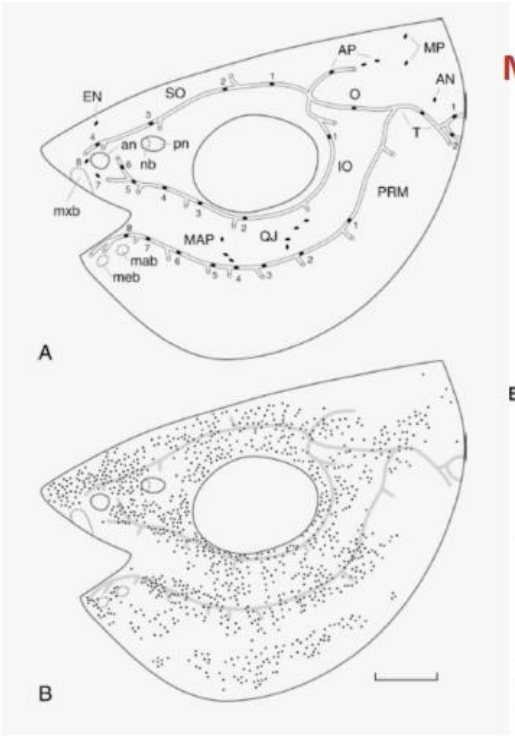


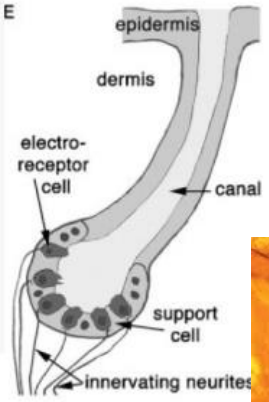
Figure 11. Scanning electron micrograph of the lateral surface of the head of a one-week-old, feeding, larval channel catfish. Note the large number of taste buds on the lips and barbels. Taste buds (tb) also occur in the skin of the head and trunk but can be easily distinguished from the lateral line system. The taste buds form small elevated tubercles, whereas the largest pores are canal pores (cp), and the smaller, more numerous pores are the pores of ampullary organs (denoted by arrowheads). Bar scale equals 500μm.

Electroreceptores ampulares

Northcutt, 2003

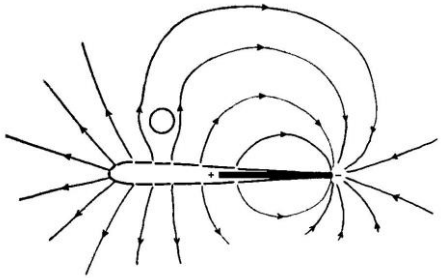


Mecanoreceptores Neuromastos

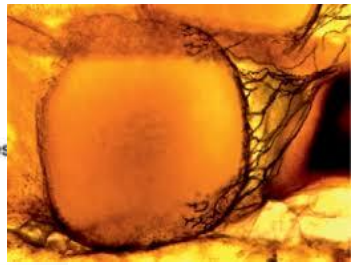


Electrorecepción "pasiva"

ELECTRORRECEPCIÓN «activa»

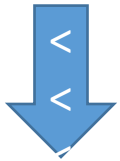


Electroreceptores tuberosos



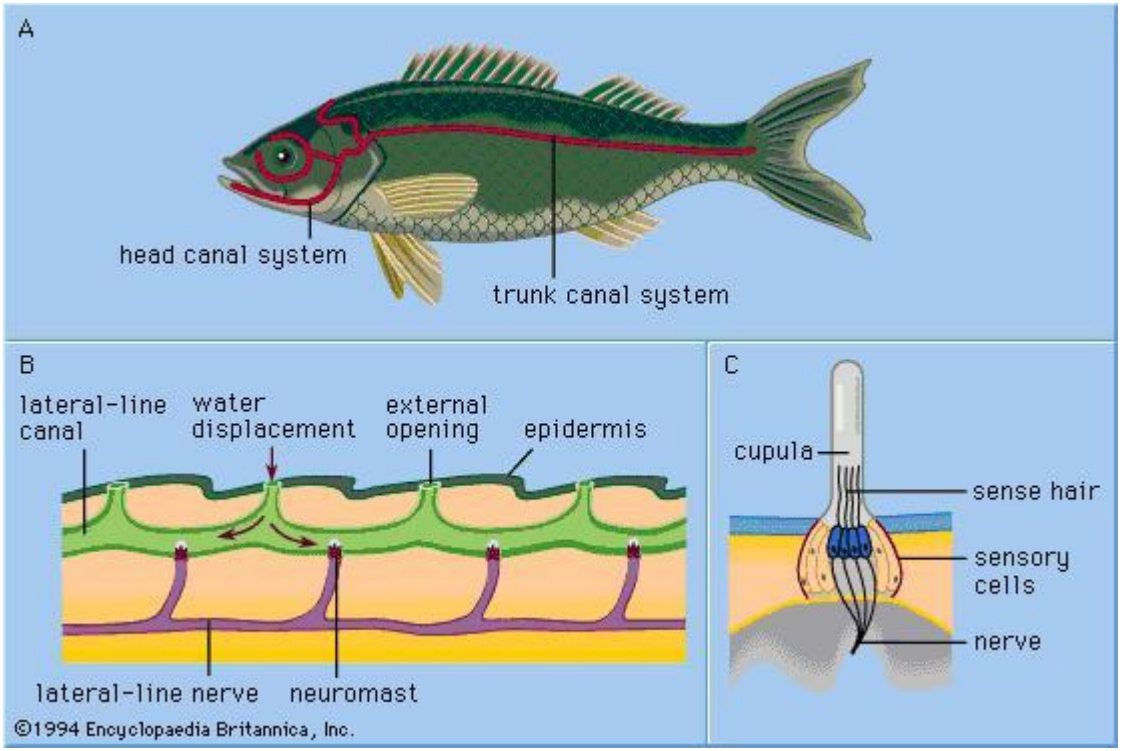
SISTEMA DE LA LINEA LATERAL

PECES Y LARVA DE ANFIBIOS

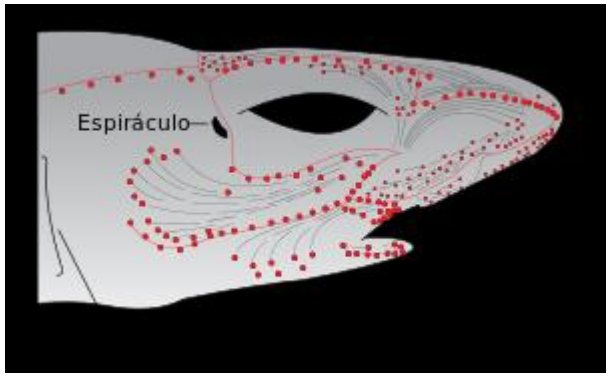


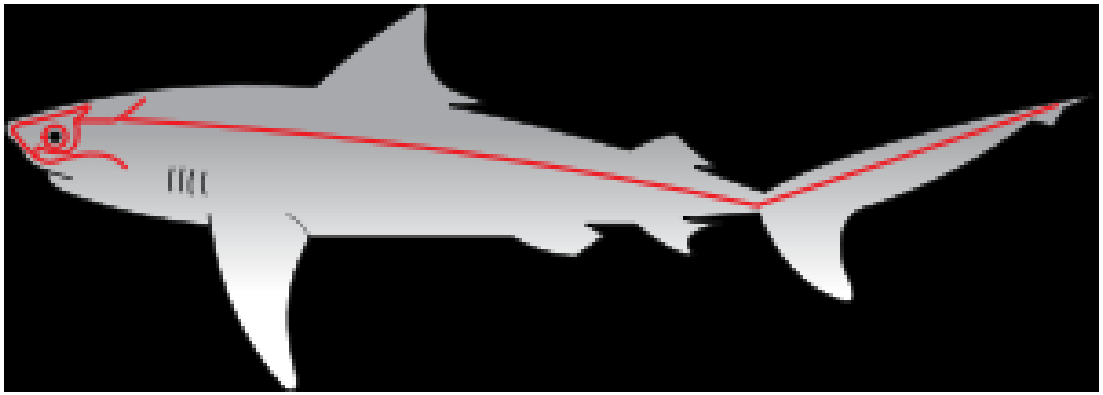
NEUROMASTOS AMPOLLAS DE LORENZINI

CANALES DE LA LÍNEA LATERAL



Especializaciones Sensoriales



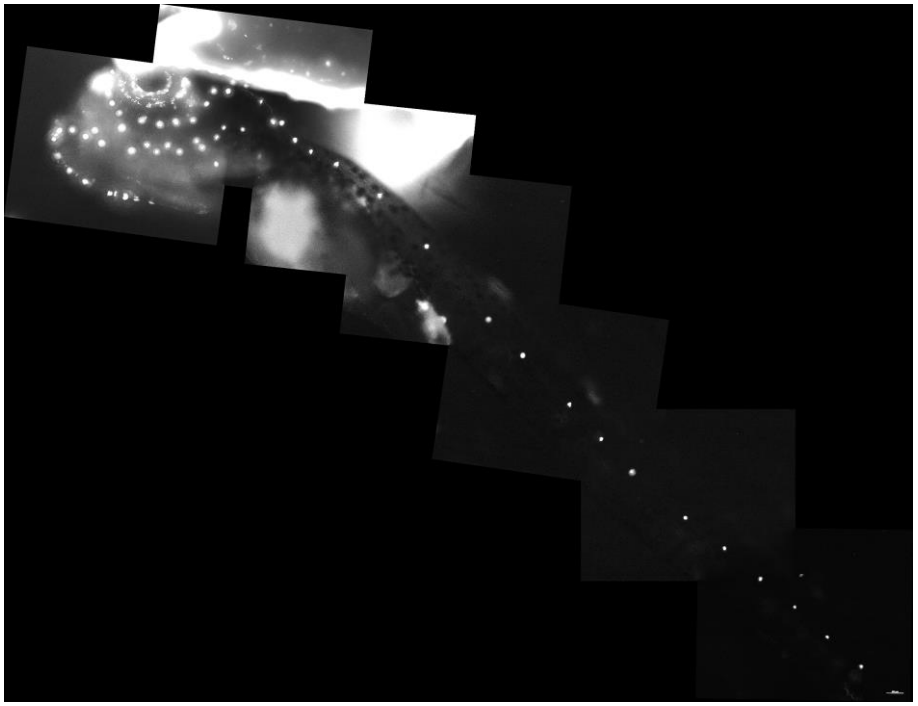


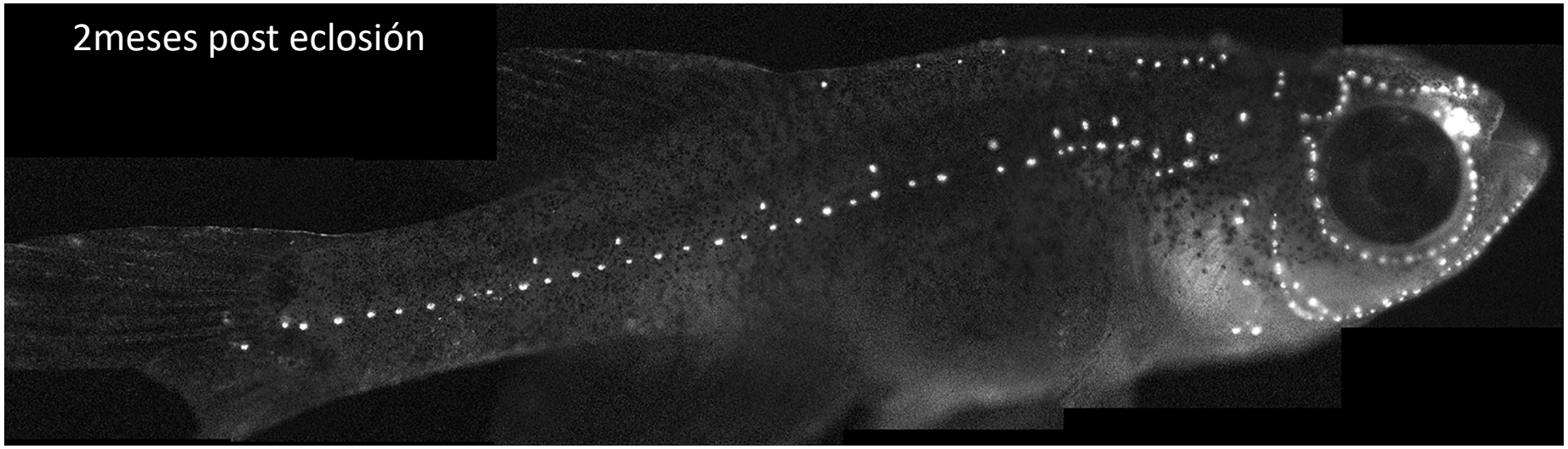
Electrorreceptores (Ampolla de Lorenzini) y los canales de la línea lateral en la cabeza de un tiburón.

Detectan campos electromagnéticos como gradientes de temperatura.

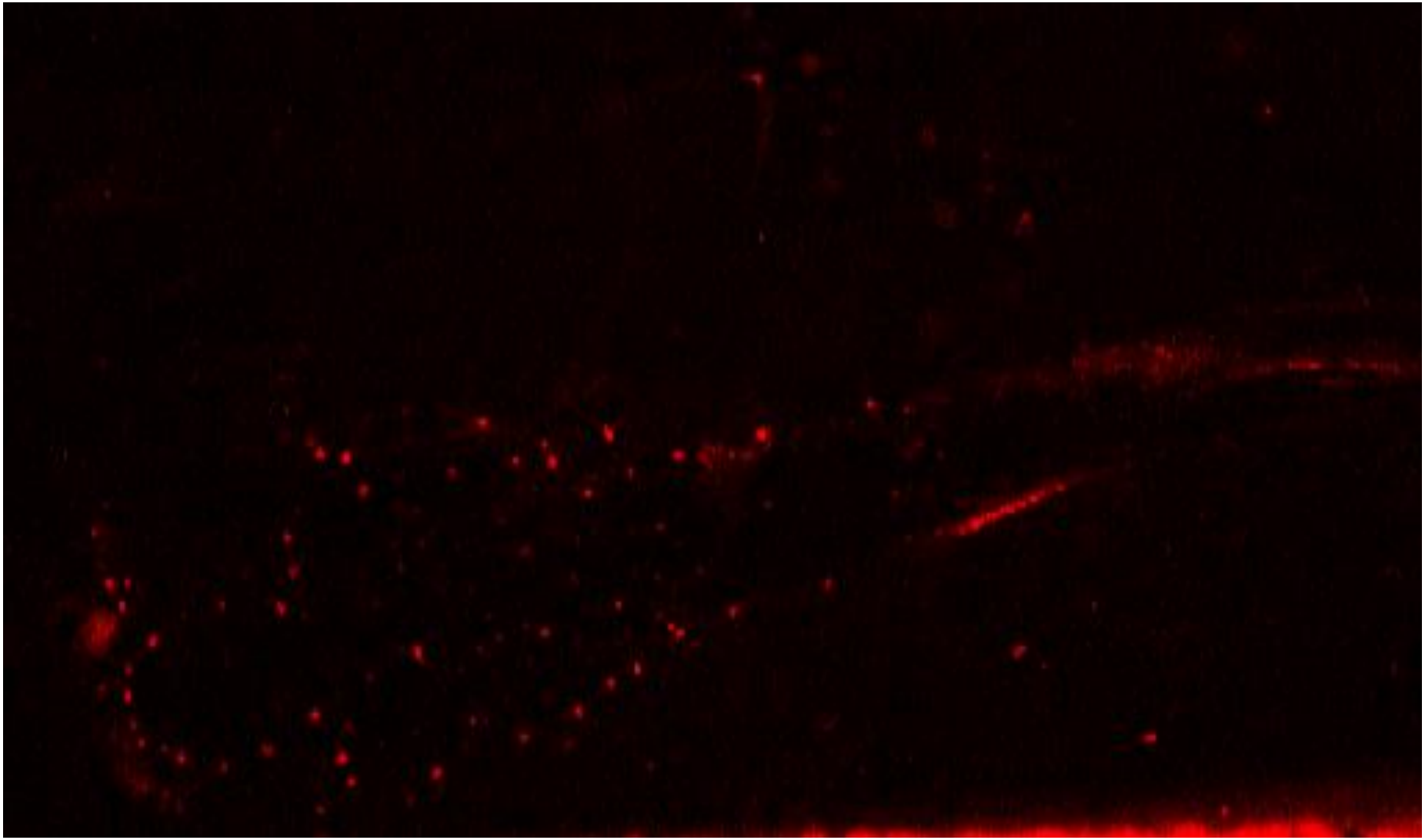
Daspei (neuromastos)

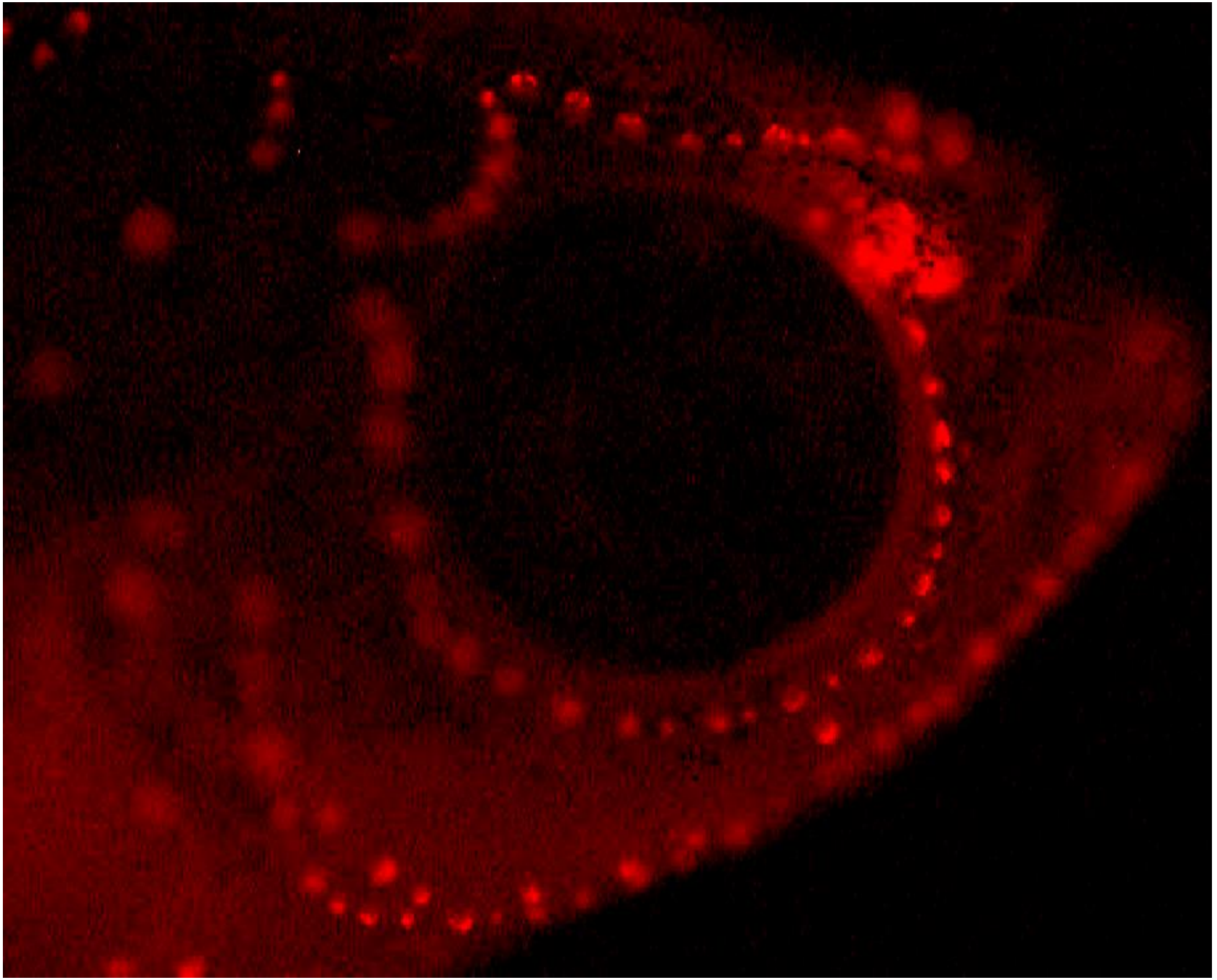
Alevino de 48 hs post eclosión



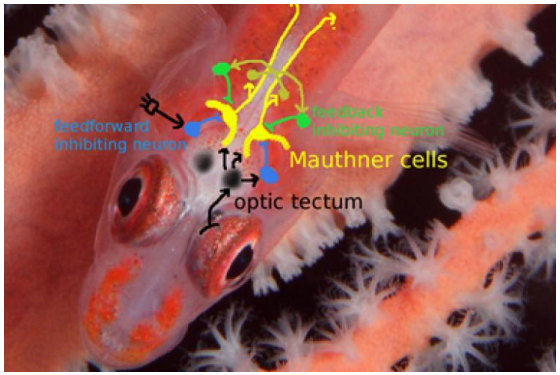


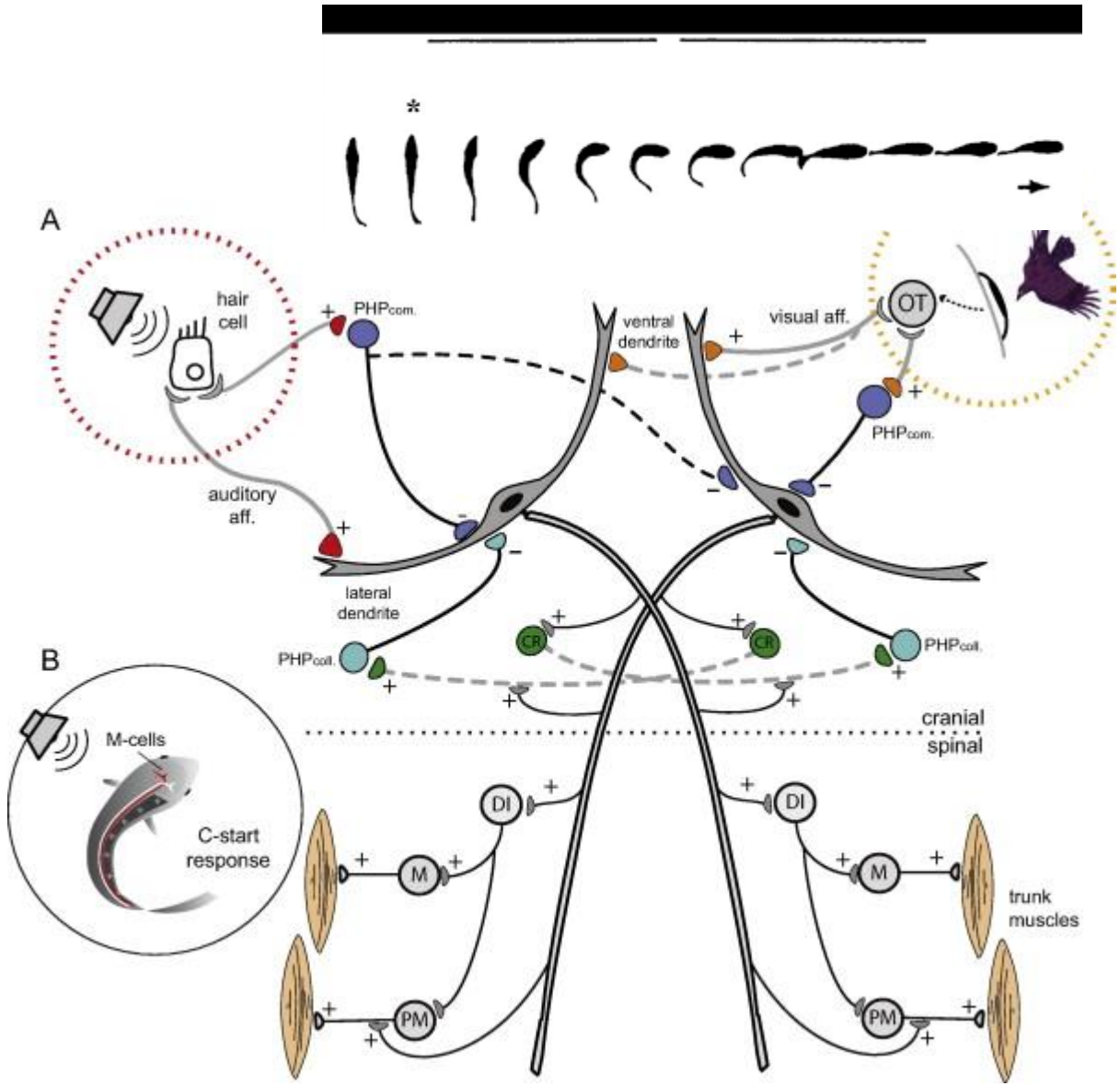
Daspei colorante fluorescente vital en alevines de A. charrua



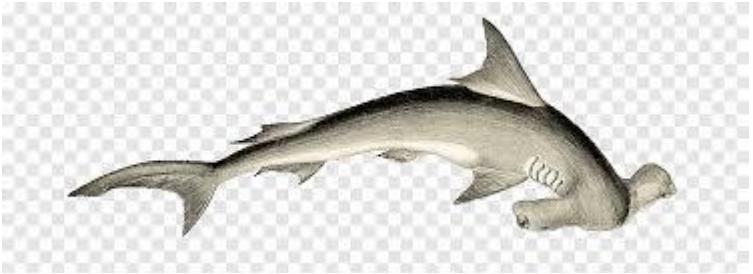


Célula de Mauthner media el reflejo de escape en el pez





Article in Brain Structure and Function · January 2014
DOI: 10.1007/s00429-014-0705-0 · Source: PubMed



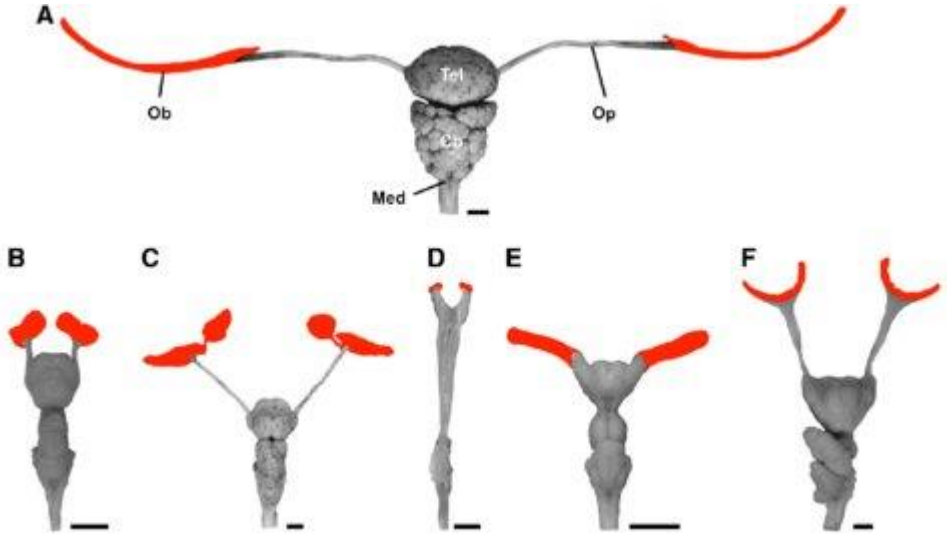
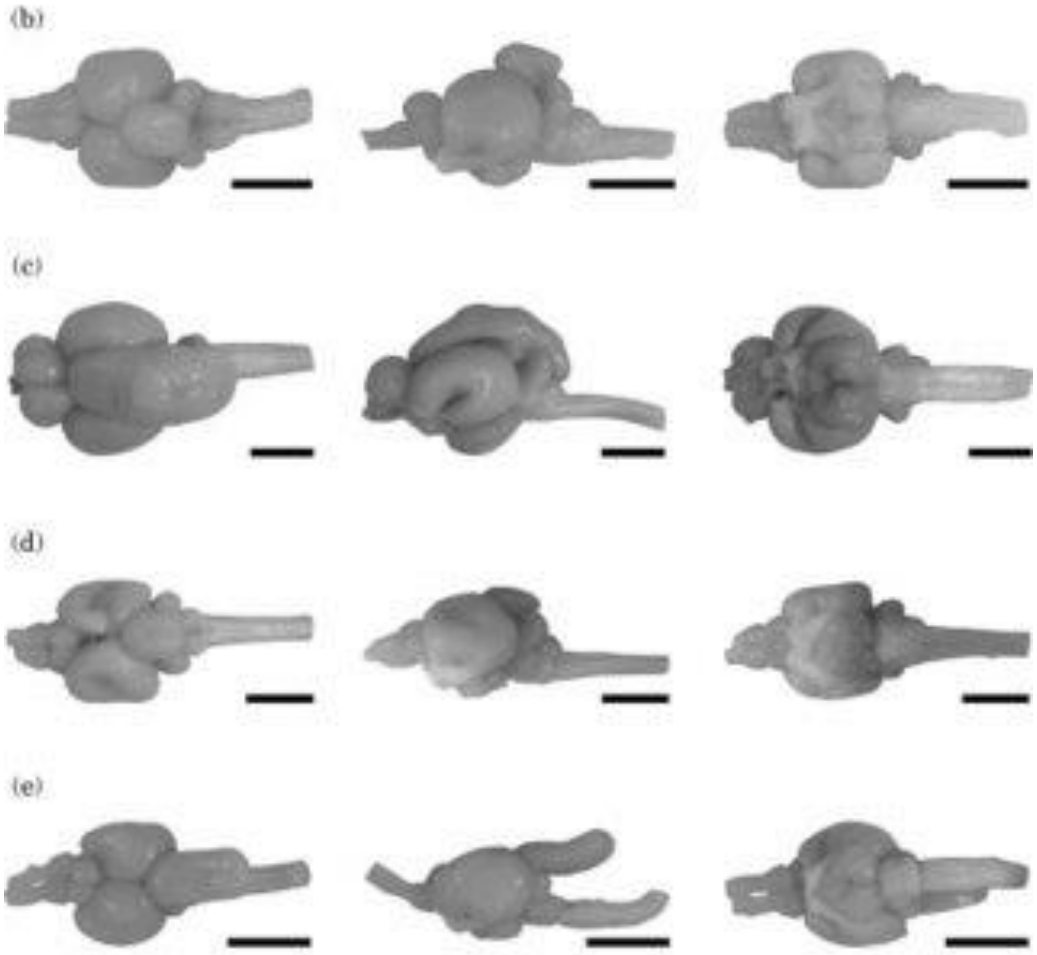


Fig. 1 Vistas dorsales de los cerebros de seis especies representativas de peces cartilaginosos, que ilustran la diversidad en la morfología y tamaño de los bulbos olfatorios (resaltados en rojo) encontrados en este clado. a Tiburón martillo festoneado Sphyrna lewini, b Tiburón charretera Hemiscyllium ocellatum, c Tiburón tigre Galeocerdo cuvier, d Gigante

Variedad de Fenotipos Cerebrales



Austrolebias

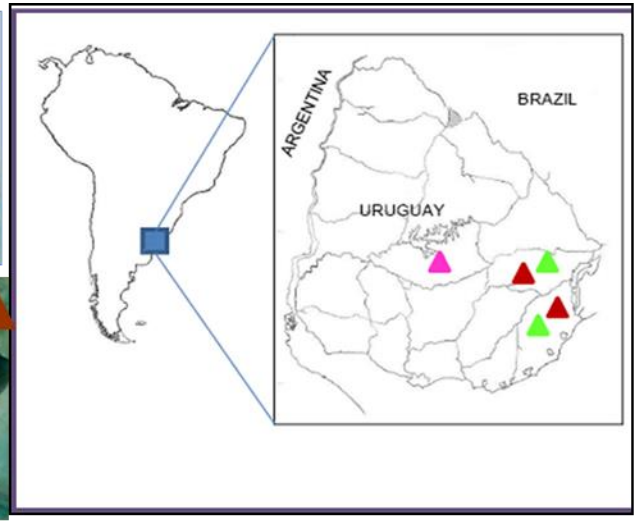
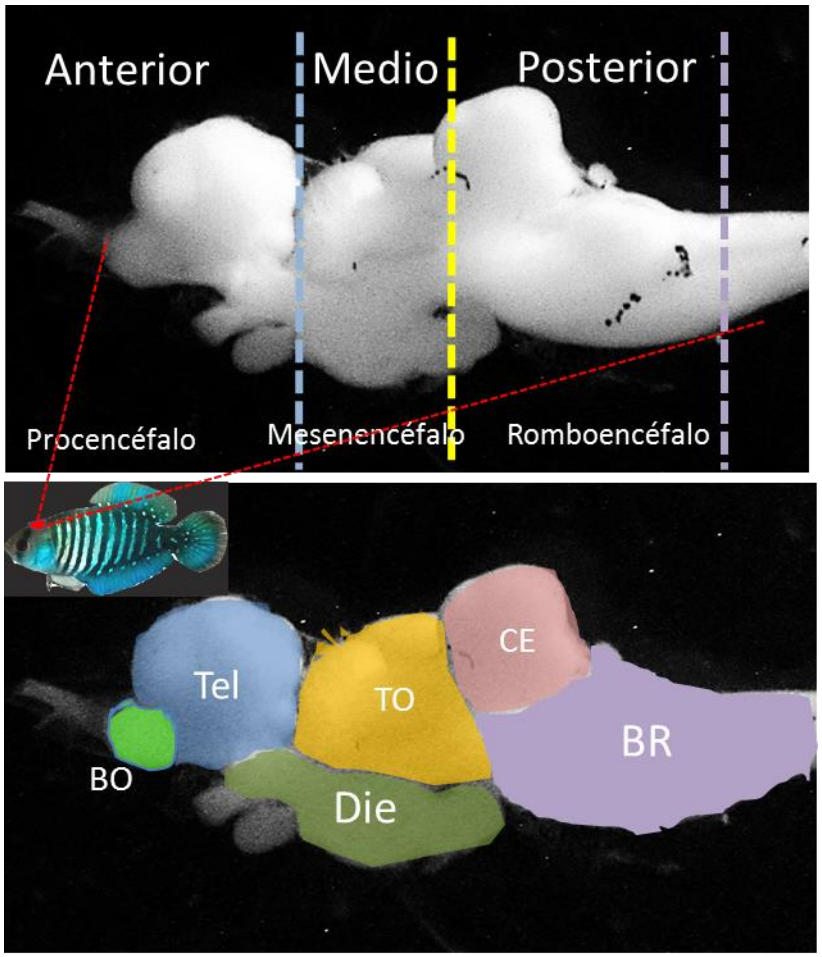
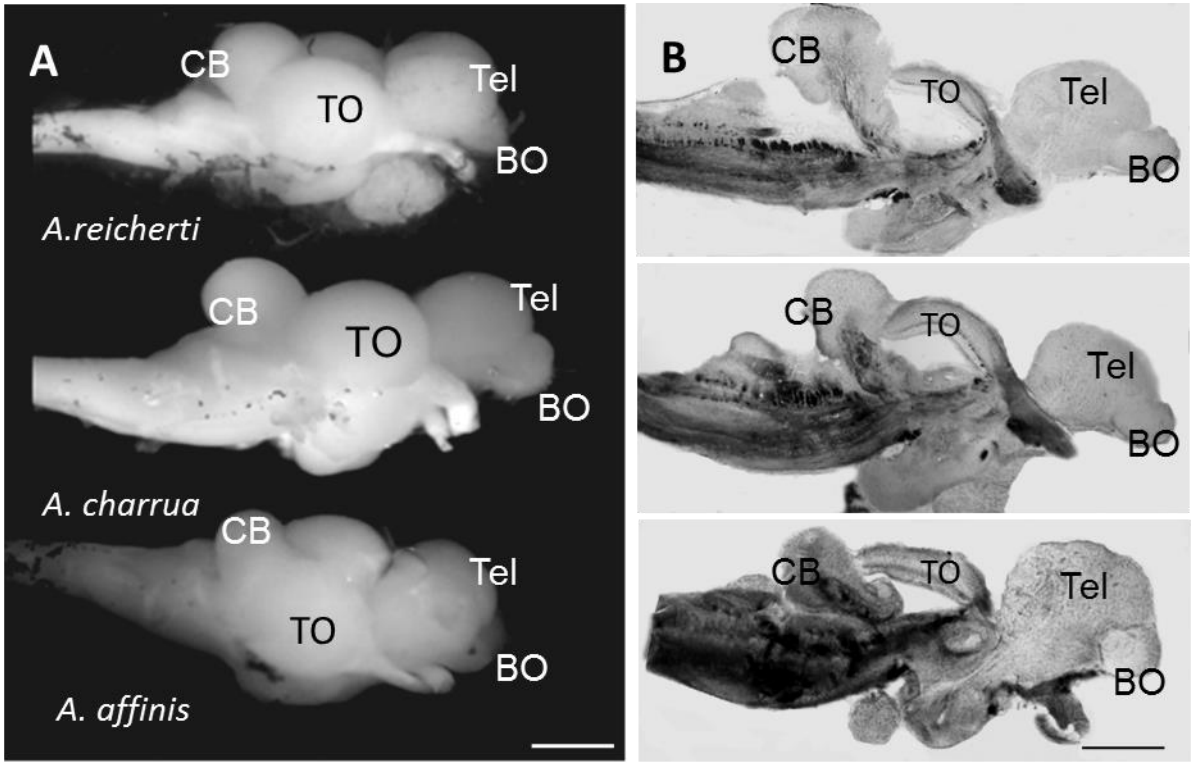


Figura 1. Distribución de las tres especies de *Austrolebias en el Uruguay*. (A) Ejemplares machos adultos que exhiben diferentes patrones de barras o puntos en su cuerpo. (B) El mapa muestra los sitios de colecta de los tres especies, *A. affinis* habita en Durazno, *A. charrua* y *A. reicherti* coexisten en los departamentos de Rocha y Treinta y Tres.

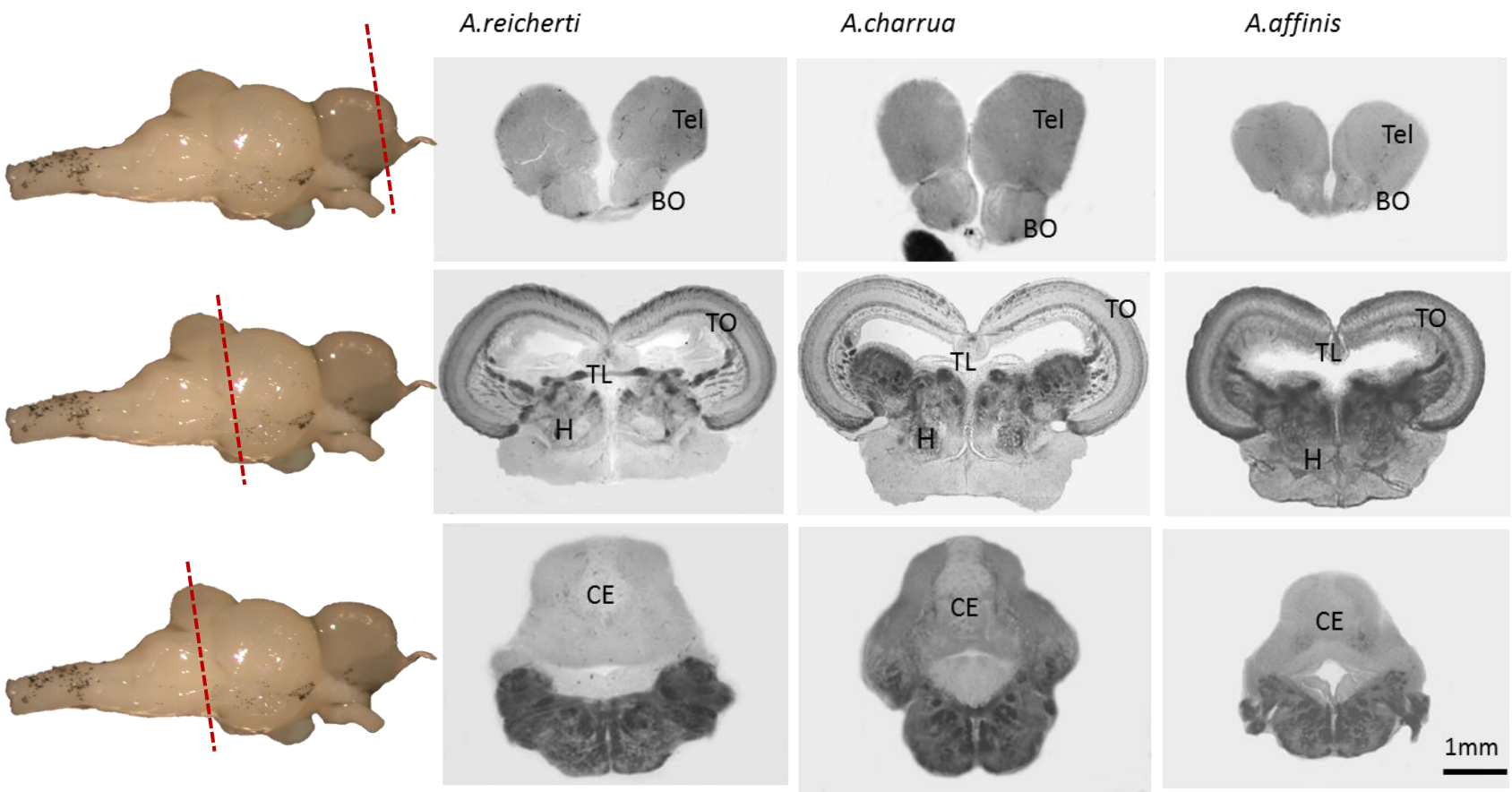
Neuroanatomía de las Austrolebias



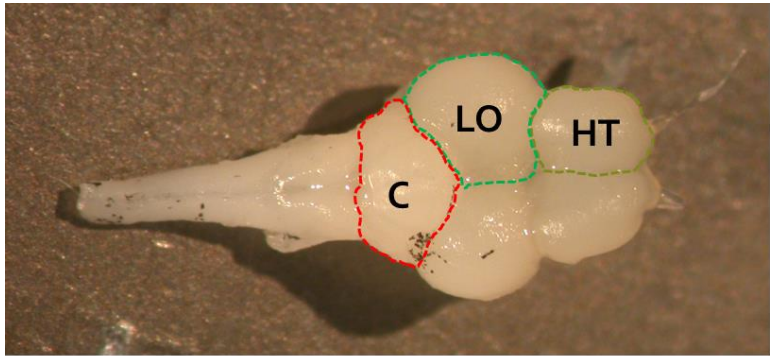
Anatomía del Cerebro de las Austrolebias

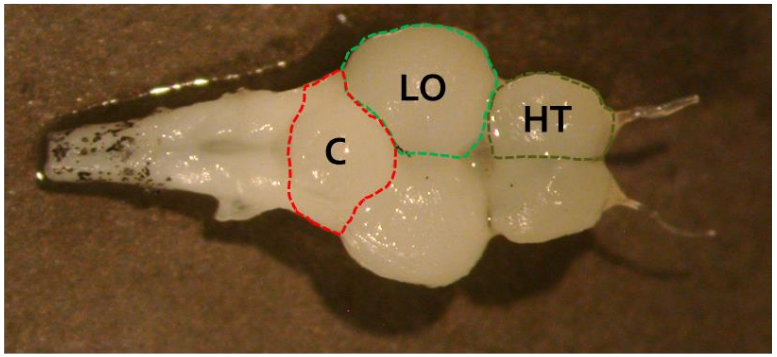


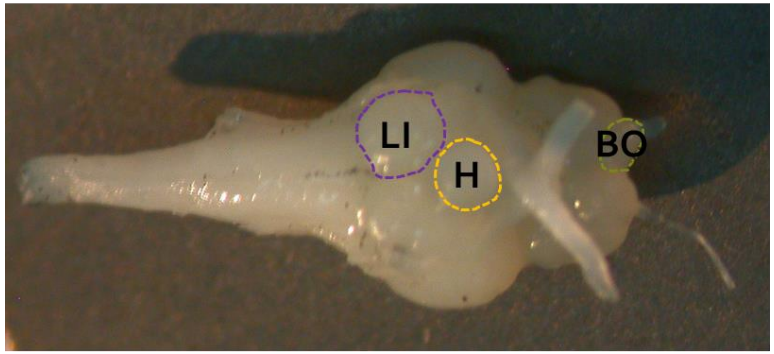
Plasticidad Fenotípica

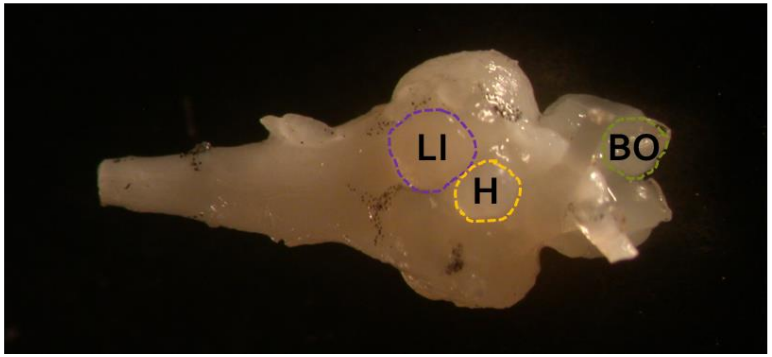


Diferencias Dimórficas









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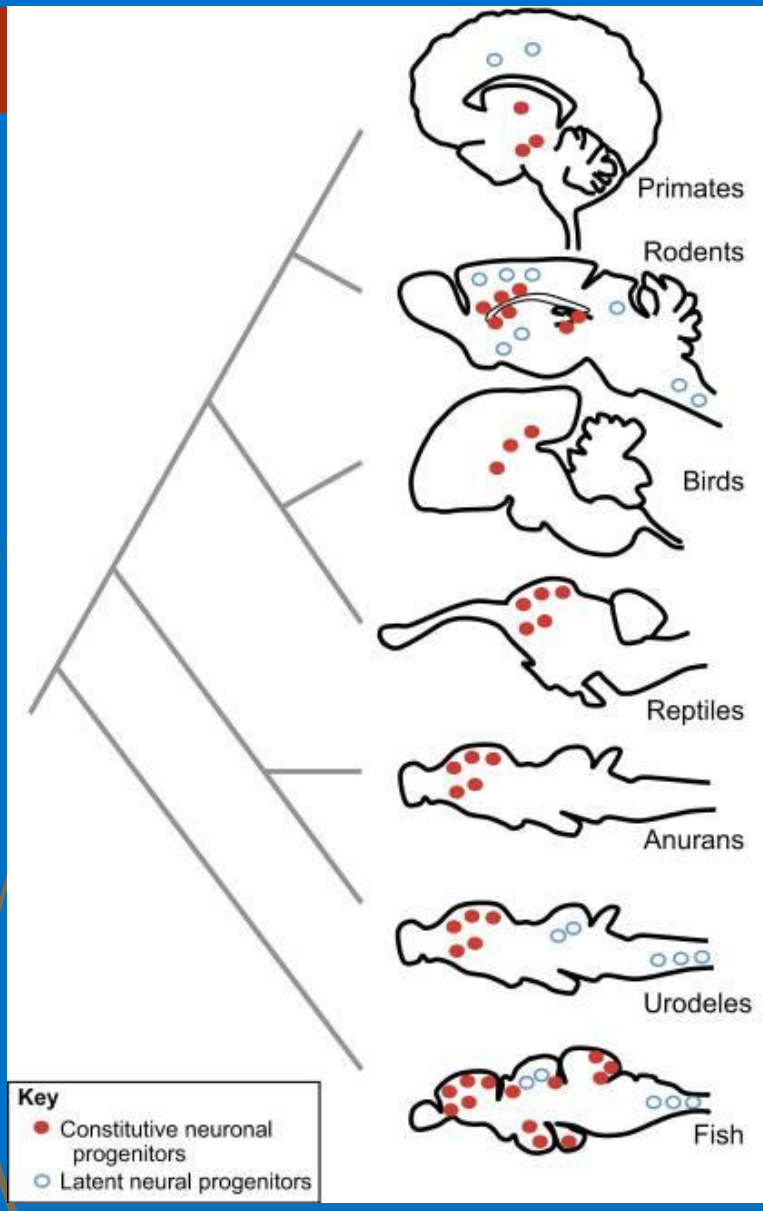
Proliferación y Neurogénesis

Crecimiento Cerebral y regionalización

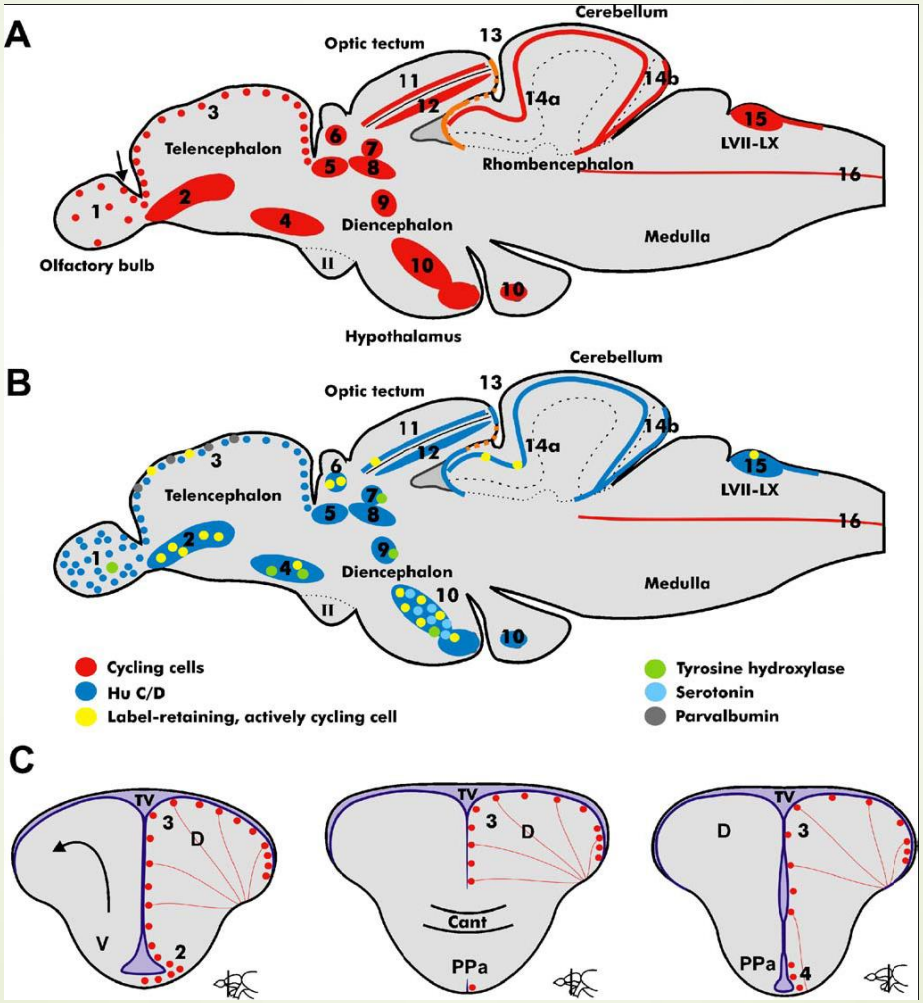
PROLIFERACIÓN Y NEUROGENESIS COMPARATIVA



	Adult neurogenesis	Latent progenitors	Reparative neurogenesis
F	+	+	–
M	–	?	–
Sc	–	?	–
R	–	?	–
F	+	+	–
M	–	+	–
Sc	–	+	–
R	–	+	+/–
F	+	?	+
M	–	–	–
Sc	–	–	–
R	–	+	+
F	+	?	+
M	–	?	–
Sc	–	?	–
R	–	–	–
F	+	?	–
M	?	?	–
Sc	–	?	–
R	+	+	+
F	+	?	+
M	–	+	+
Sc	+	?	+
R	+	+	+
F	+	?	+
M	+	?	?
Sc	–	+	+
R	+	+	+

Alessandro Alunni and Laure Bally-Cuif* 2016

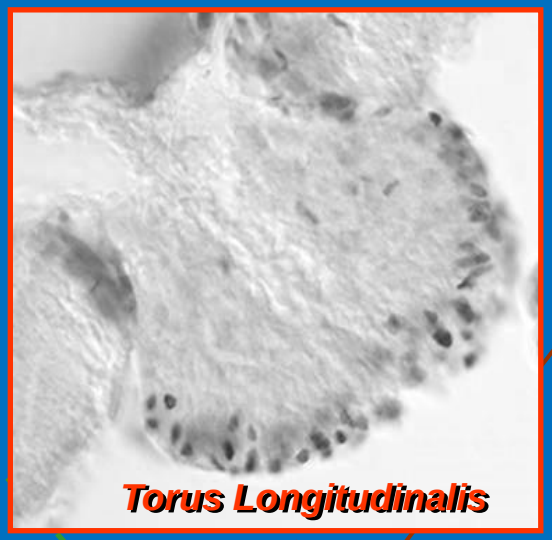
PEZ CEBRA



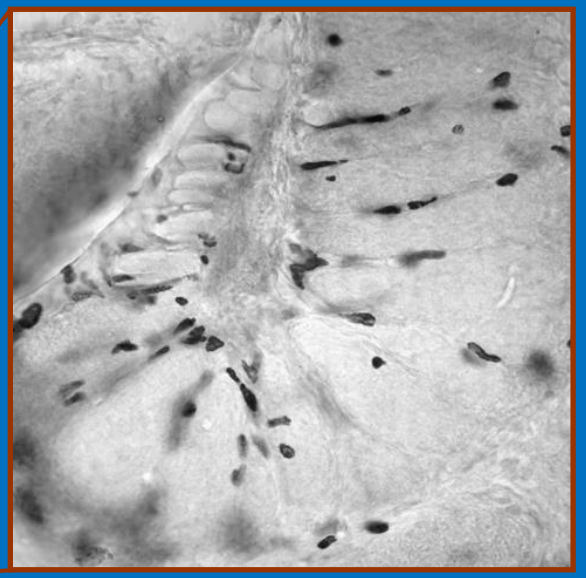
Grandel et al 2006

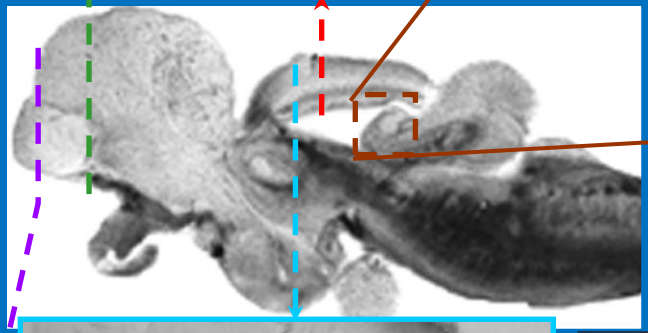
Células BrdU+ en cinco zonas proliferativas del cerebro de *Austrolebias sp. adulta*

Pared Ventricular del Telencéfalo

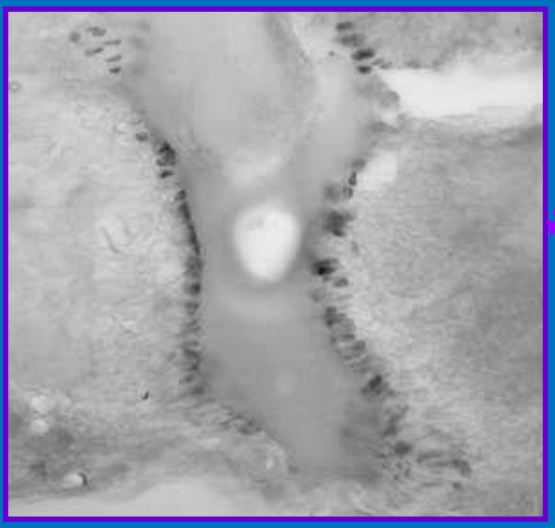


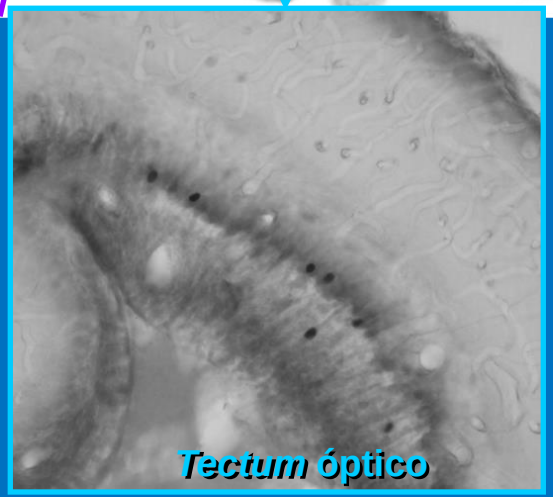
Cerebelo

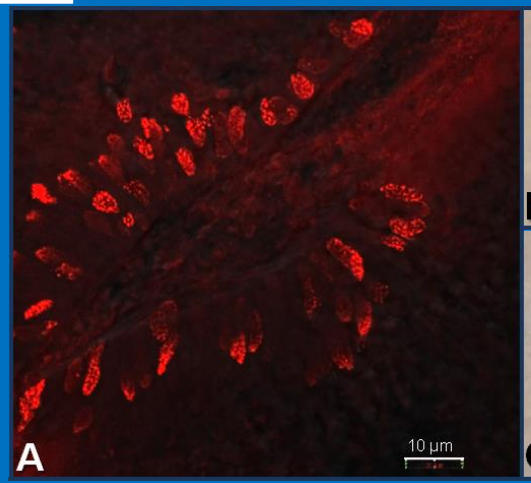


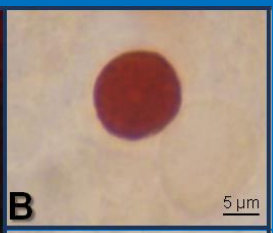


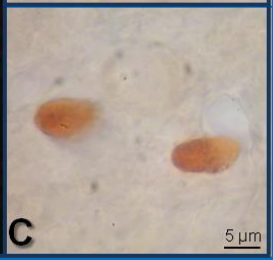
Bulbo olfatorio







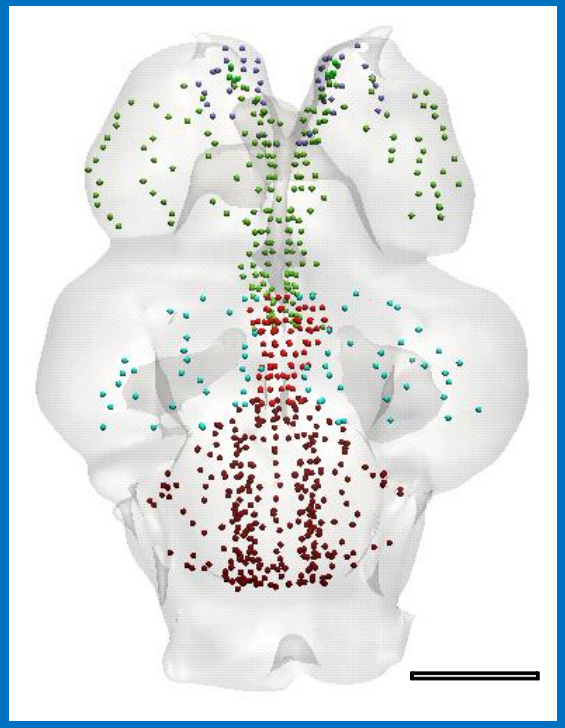


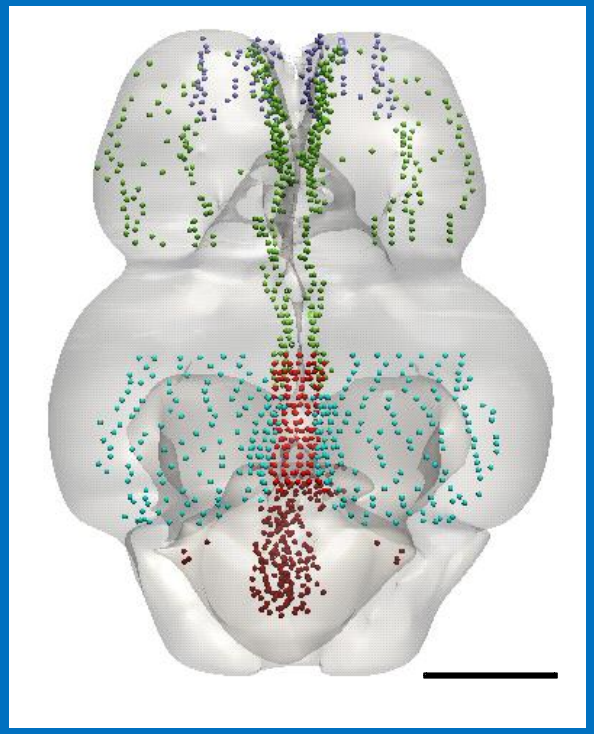


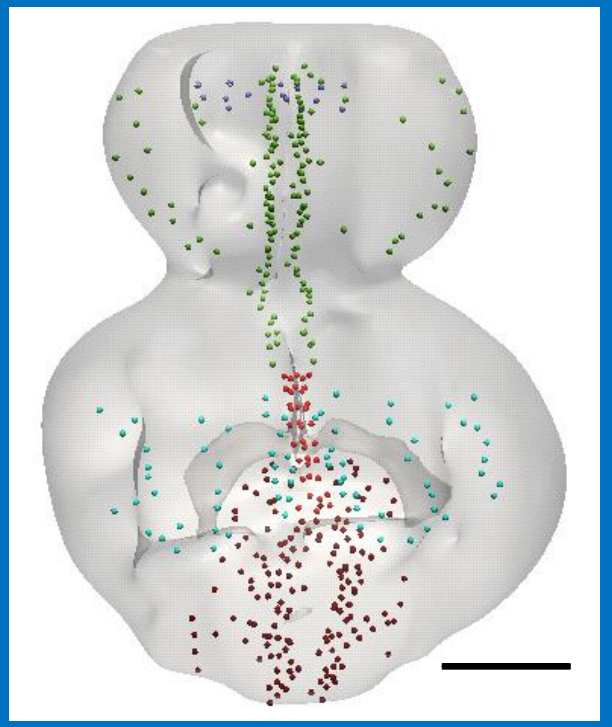
Biovis3D para el mapeo de regiones proliferativas.

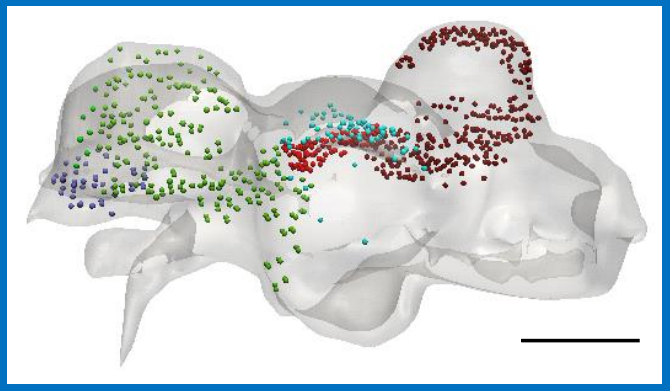
Rosillo, 2010

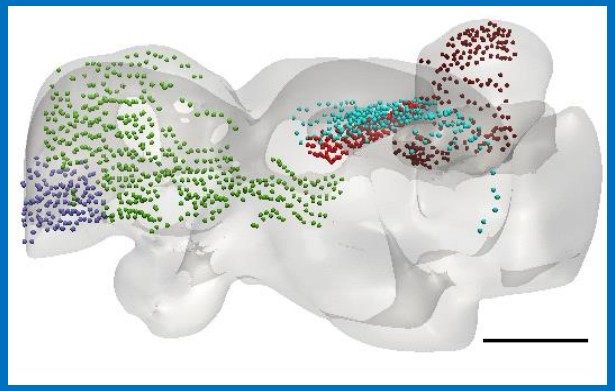
A.reicherti ***A.charrua*** ***A.affinis***

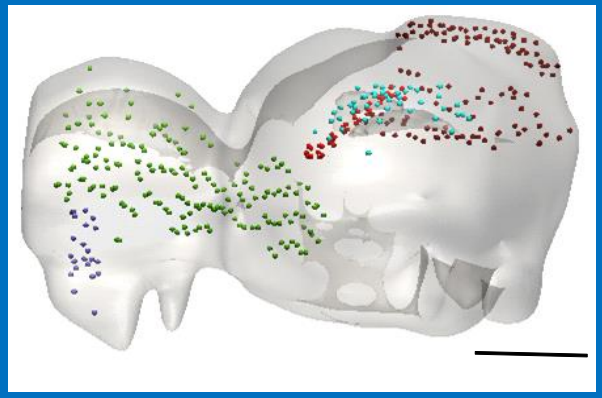






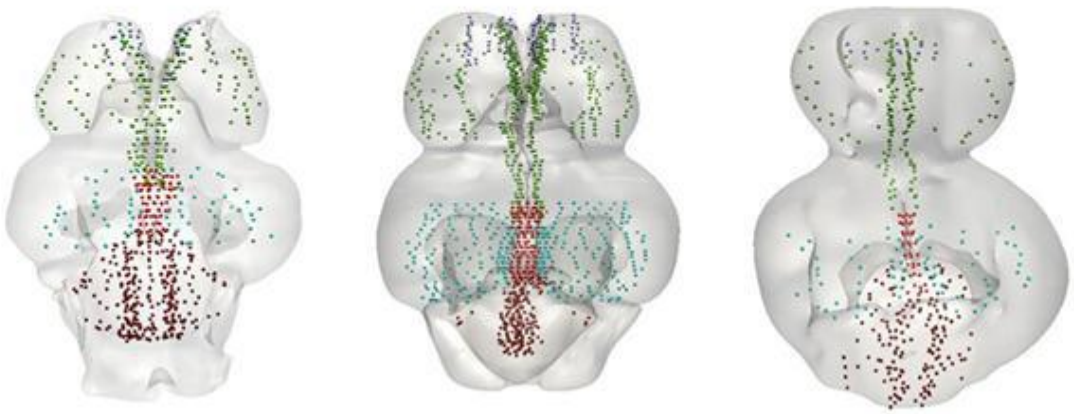




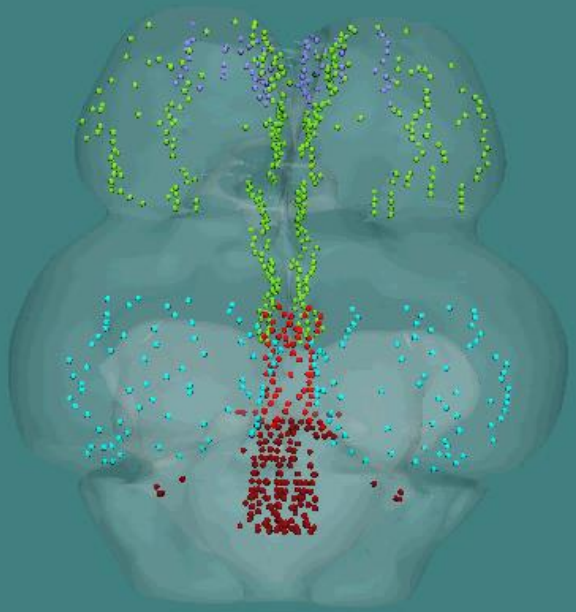


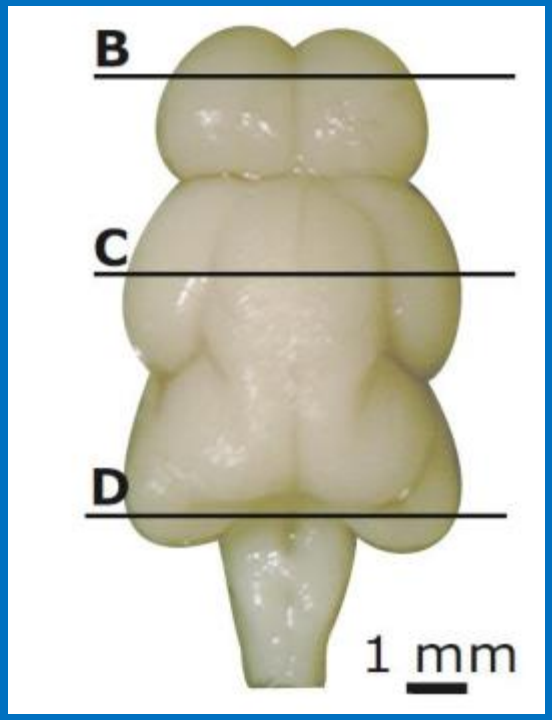
Mapeo de las zonas proliferativas Bio Vis 3D

A. reicherti *A charrua* *A affinis*

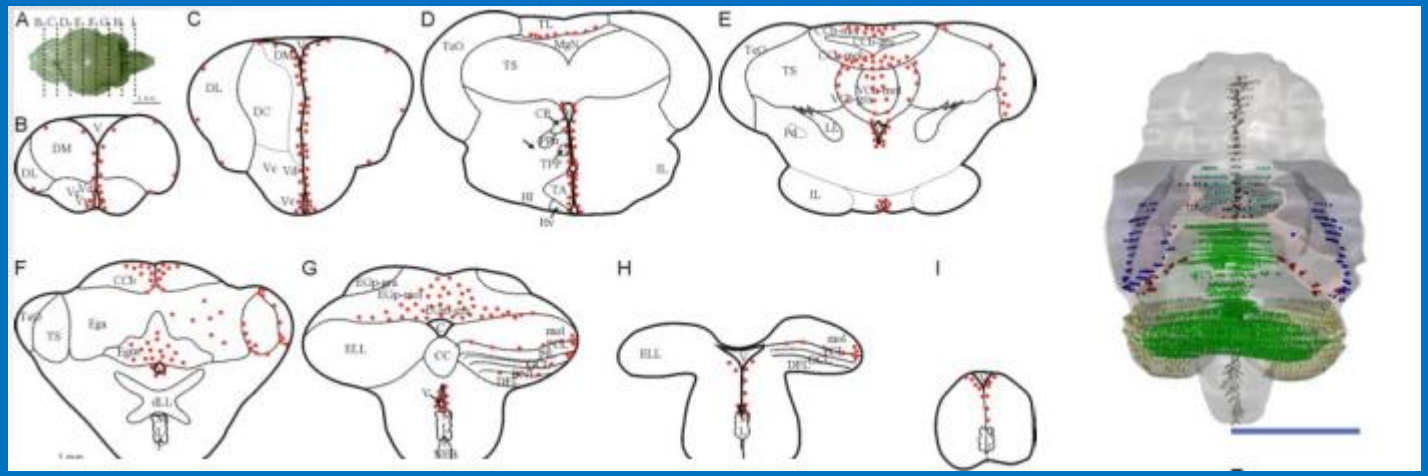


	TASA DE PROLIFERACION (Nº de núcleos BrdU+/mm³)		
	A. reicherti	***A. charrua***	***A. affinis***
BO	947	643	444
TO	54	76	108
TL	3000	1400	4000
CB	264	269	329



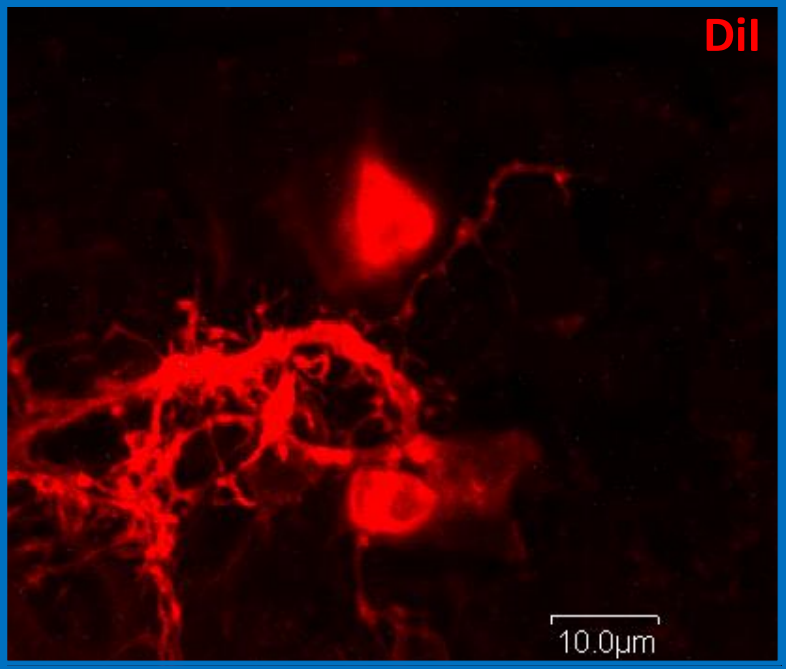


Gymnotus omarorum



Castelló et al 2017

Nervio terminal: Vínculo entre los sistemas visual y olfatorio (Experimentos con sustancias trazadoras)



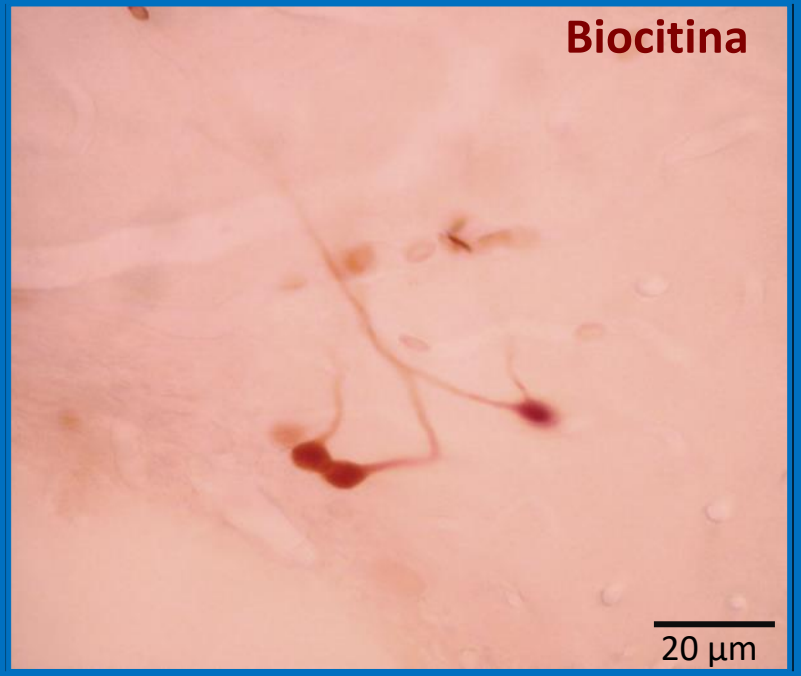
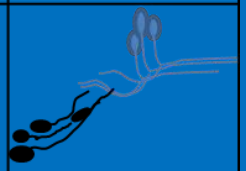
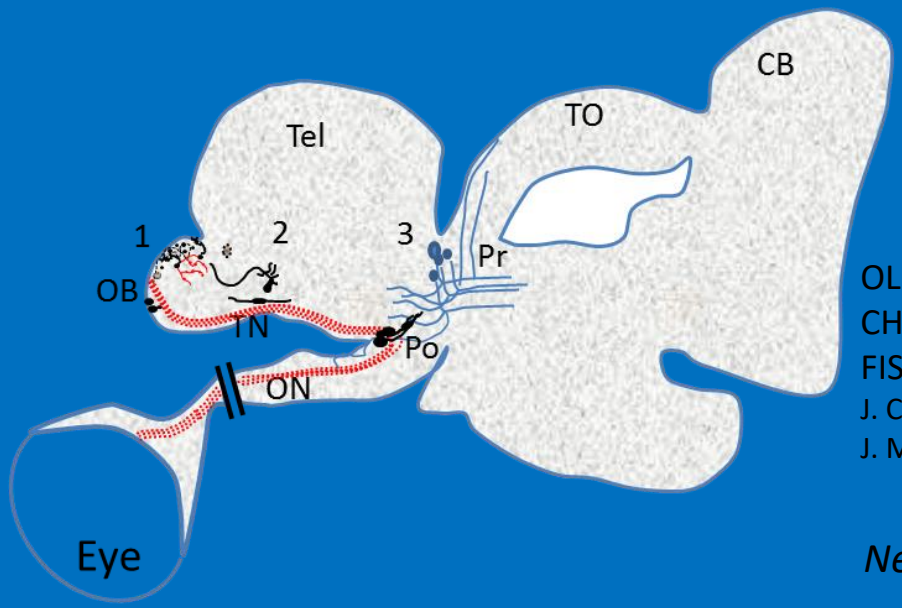


Fig. 7

A LOCATION AND CELLS TYPES LABELED WITH THE DIFFERENT DYES EMPLOYED

		DiI	HRP	Biocytin-DAB	Biocytin-Alexa 488	Cellular types
1	OB	Rostral Dorsal	Rostral		Rostral Dorsal Ventral	
2	Tel	OB-Tel Transition	OB-Tel Transition	OB-Tel Transition	OB-Tel Transition	
3	Dien	Pretectal	Pretectal	Pretectal	Preoptic Pretectal	

B

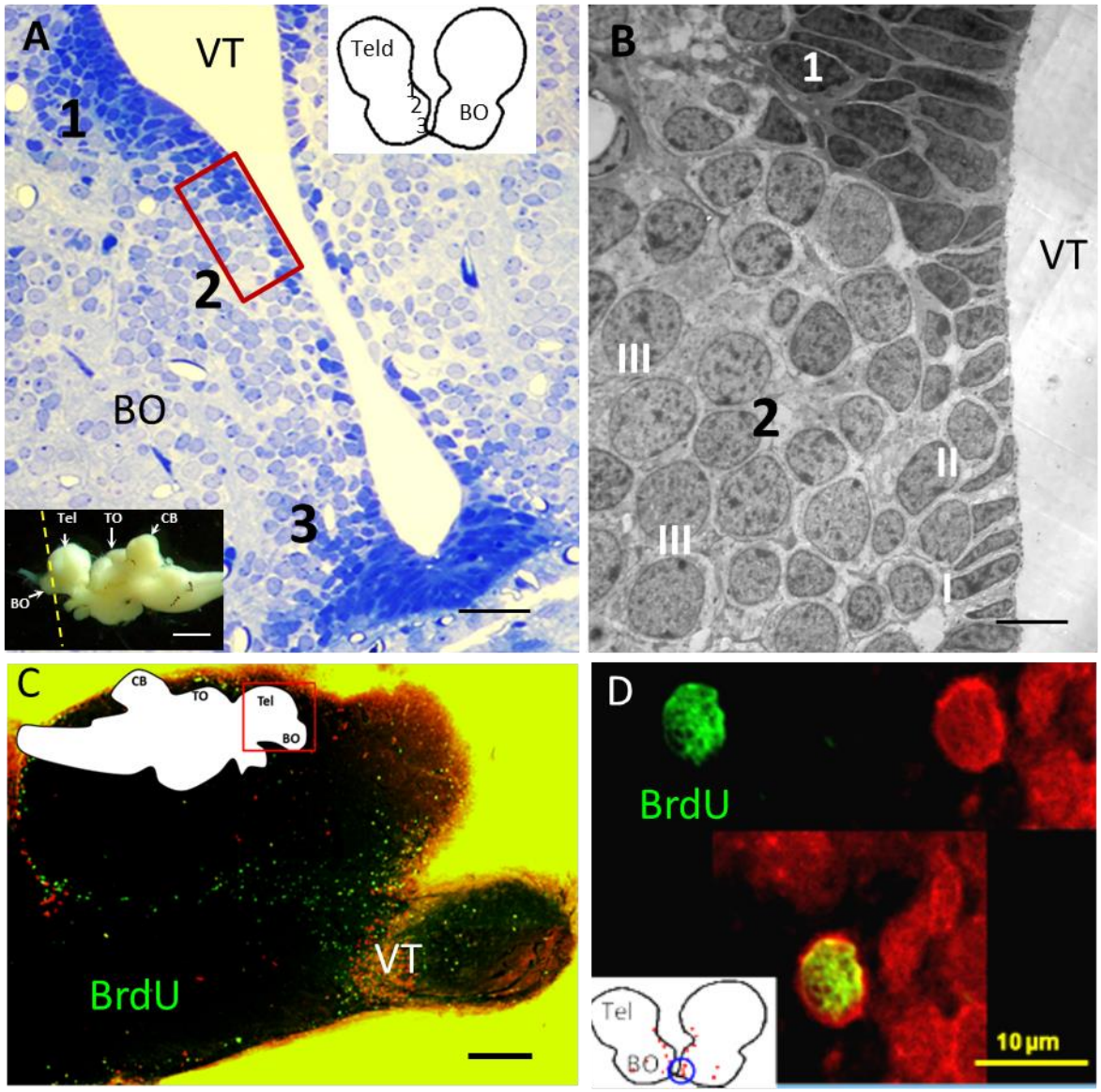


OLFACTO-RETINALIS PATHWAY IN AUSTROLEBIAS CHARRUA FISHES: A NEURONAL TRACER STUDY

J. C. ROSILLO, S. OLIVERA-BRAVO, G. CASANOVA, J. M. GARCIA-VERDUGO AND A. S. FERNANDEZ

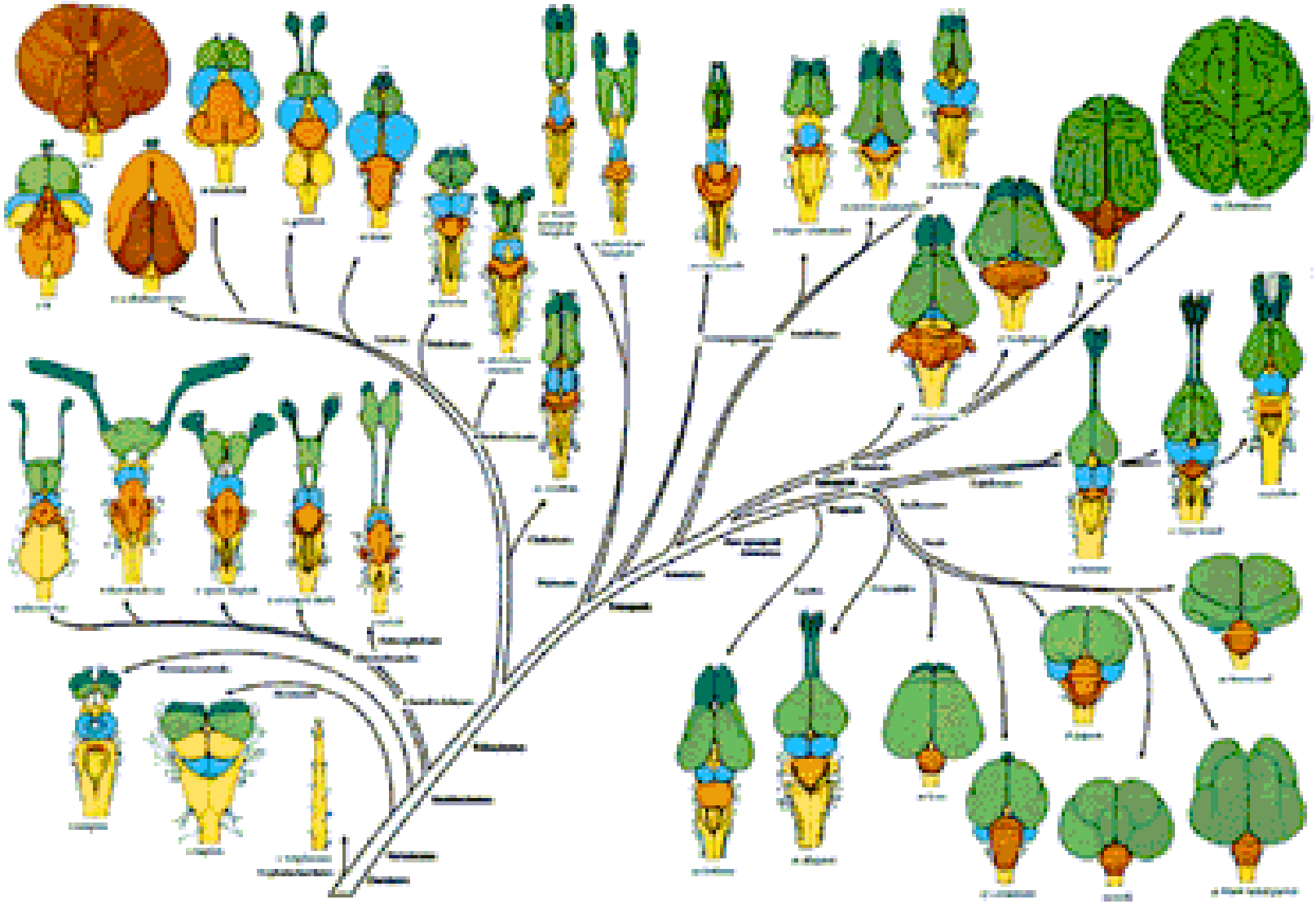
Neuroscience 253 (2013) 304–315

Nuerogenesis en el Bublo Olfactorio



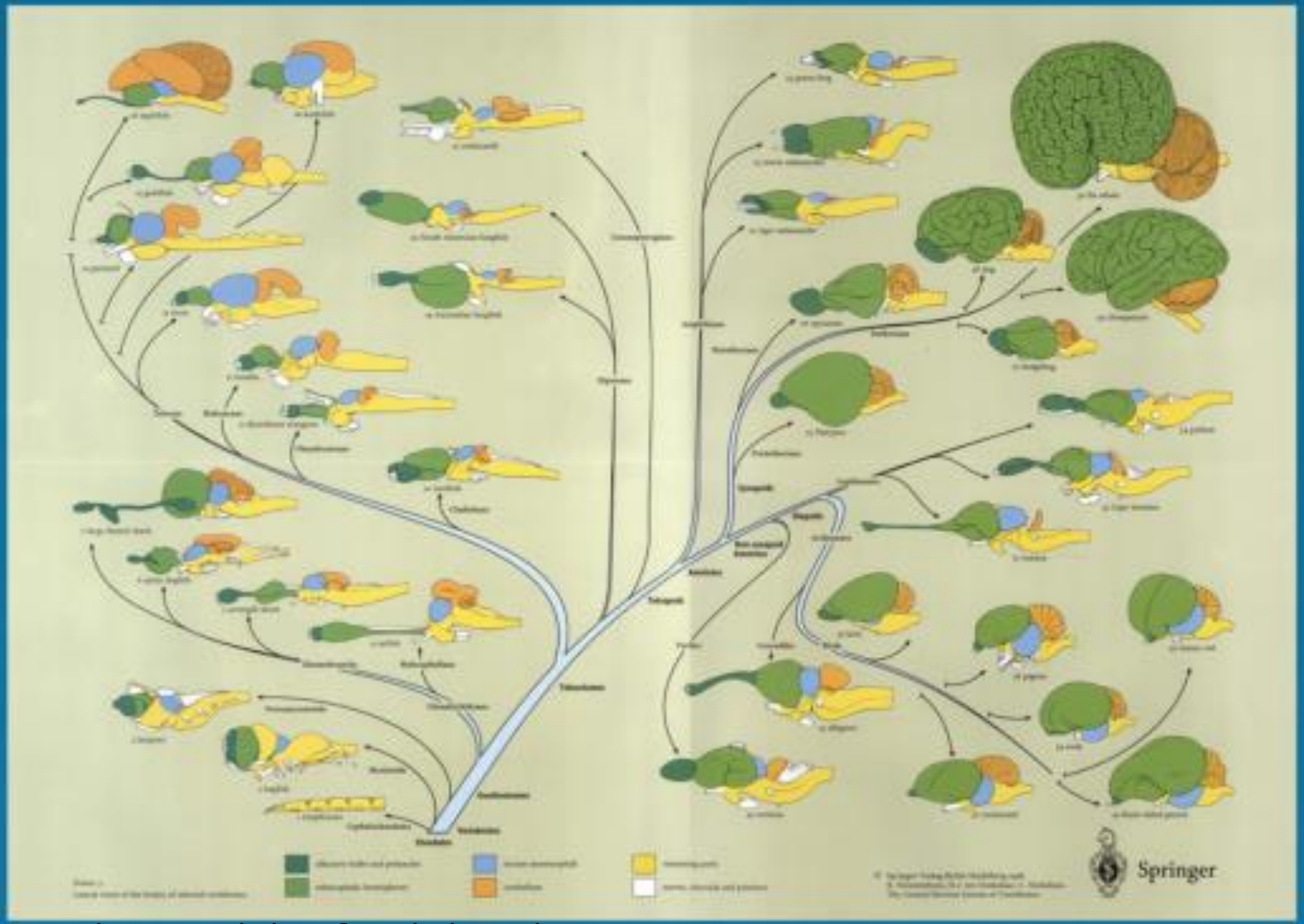
Rosillo et al 2016 Neurosc.

¡GRACIAS!



Nieuwenhuys, Donkelaar & Nicholson The Central Nervous System of Vertebrates (1989)

Excursion 4: Biodiversity



Nieuwenhuys, Donkelaar & Nicholson The Central Nervous System of Vertebrates (1989)