DEVELOPMENT OF THE HEAD AND NECK

Placodes and the development of organs of special sense

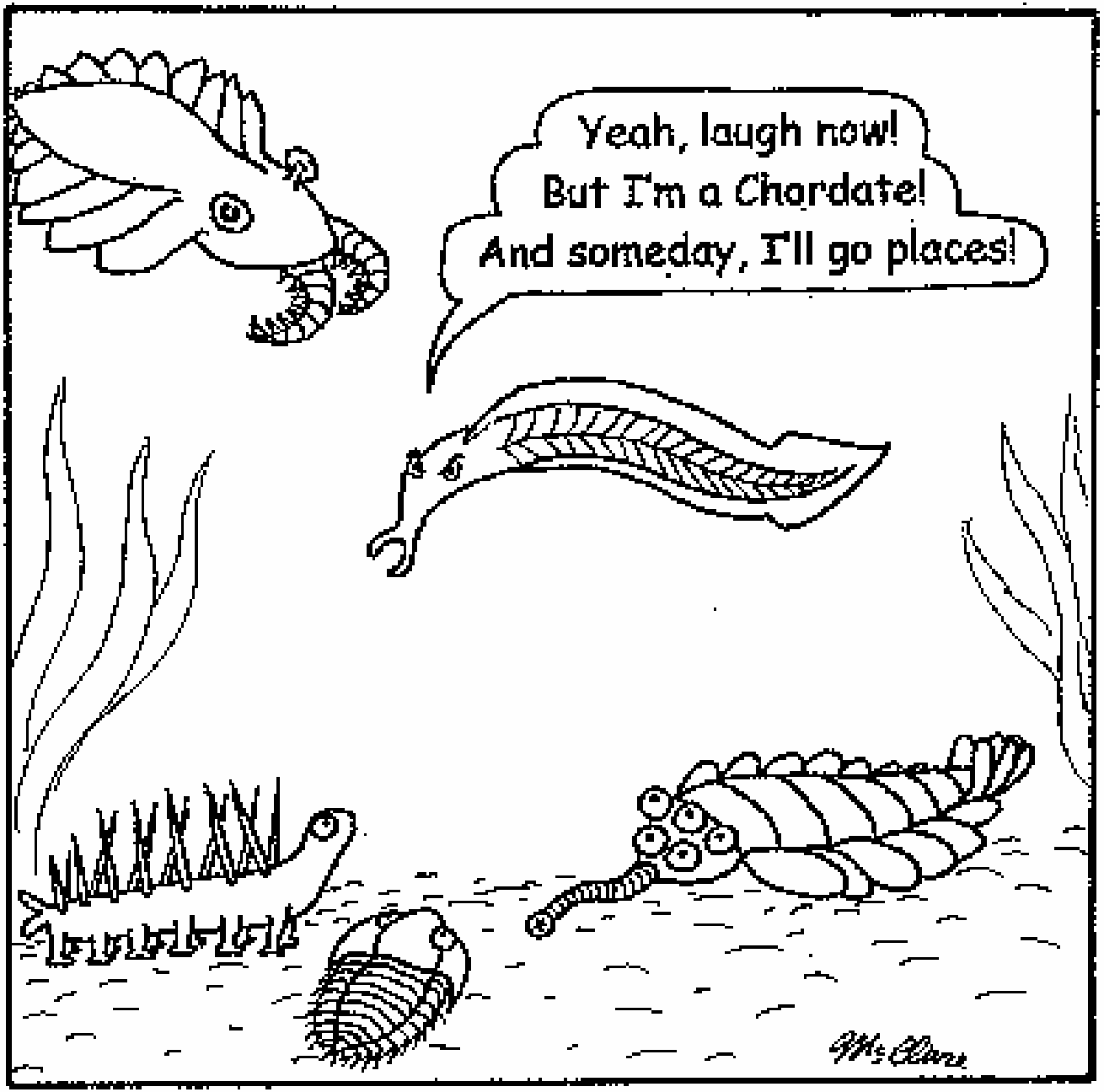
L. Moss-Salentijn

PLACODES

Localized thickened areas of specialized ectoderm, lateral to the neural crest, at the border between neural plate and the future epidermis

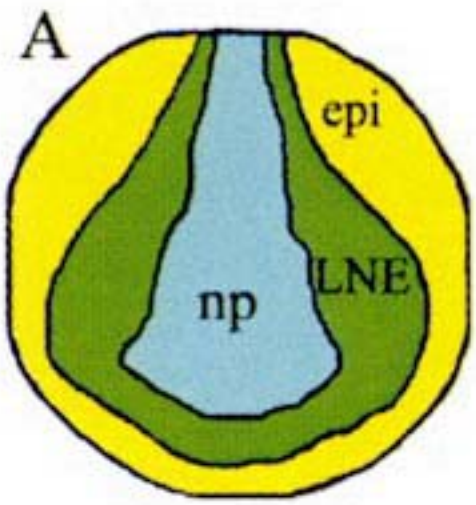
Placodes give rise to several evolutionary novelties in the "new heads" of vertebrates:

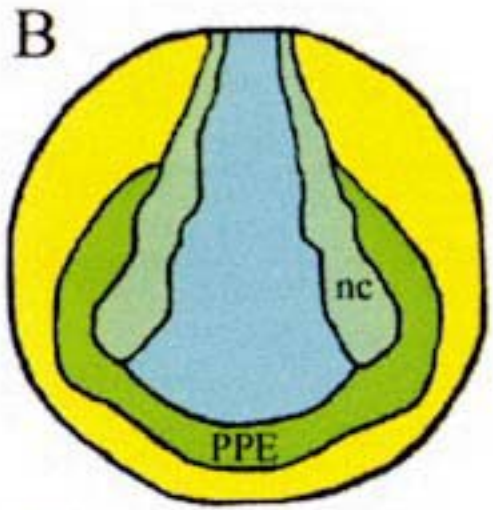
- Specialized paired sense organs. However, structures analogous to placodes are present in non-vertebrate chordates.
- Cranial placodes that will contribute to cranial ganglia of the branchiomeric nerves in pharyngeal arches.

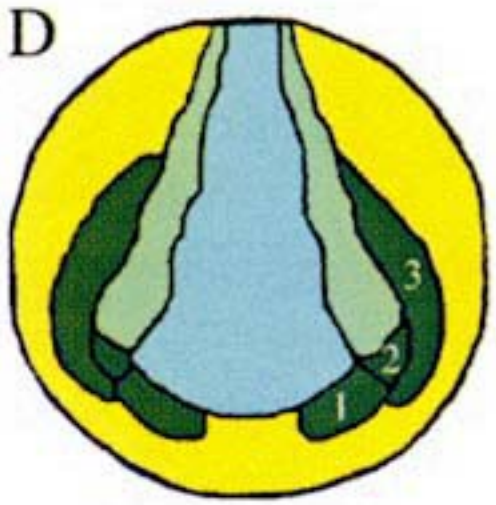


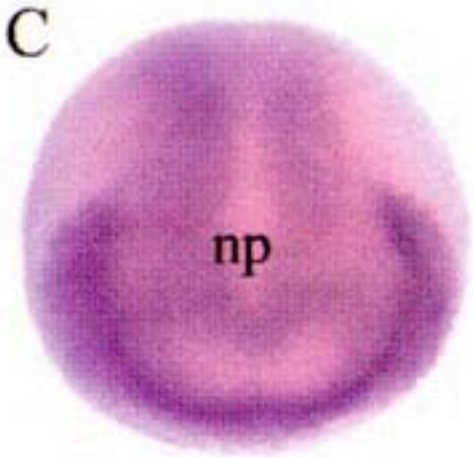
Life in the Lower Cambrian Period

Panplacodal ectoderm







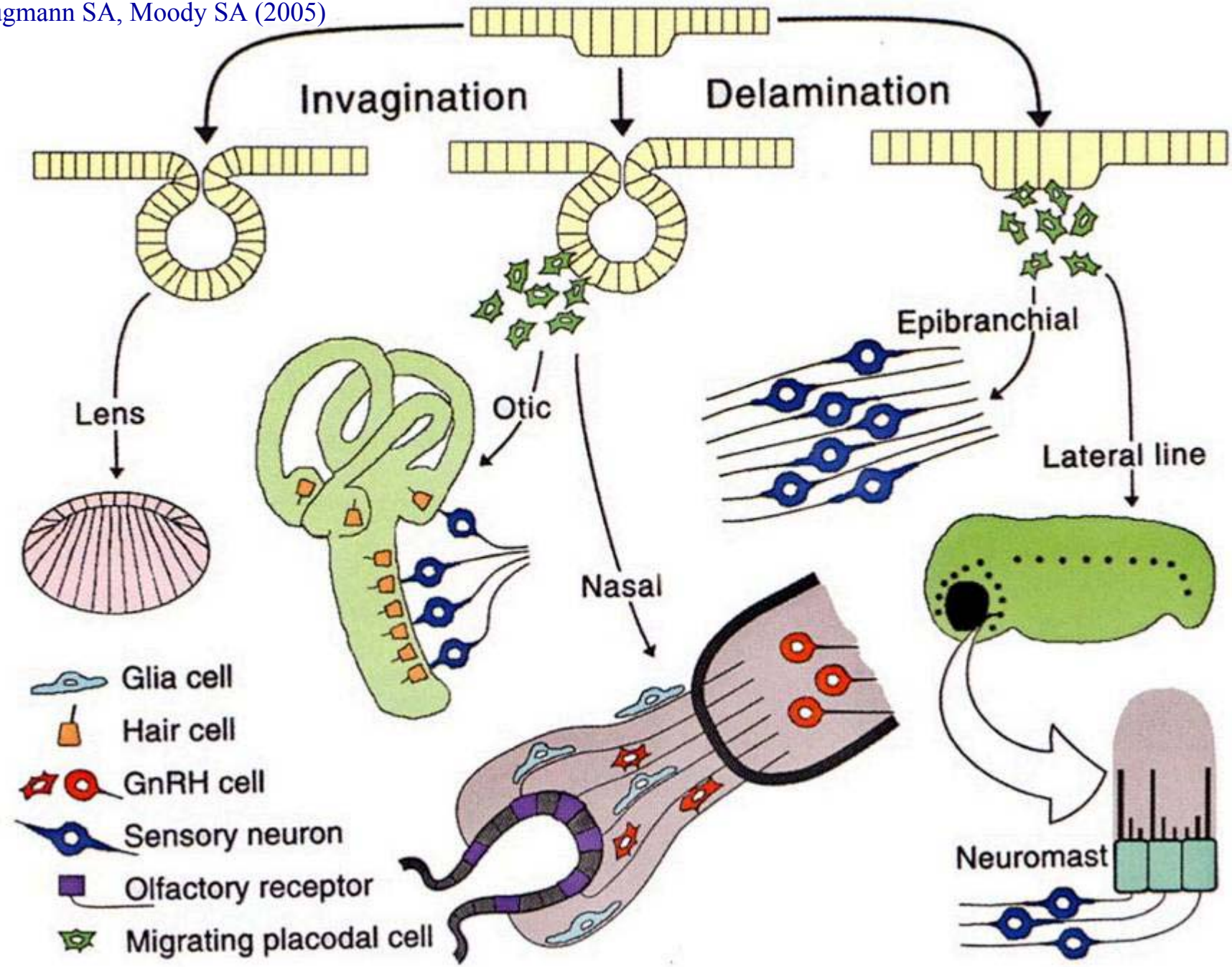


Expression of transcription factors for generic placodal development :

Six1/2, Six4/5, Eya

Brugmann SA, Moody SA (2005)

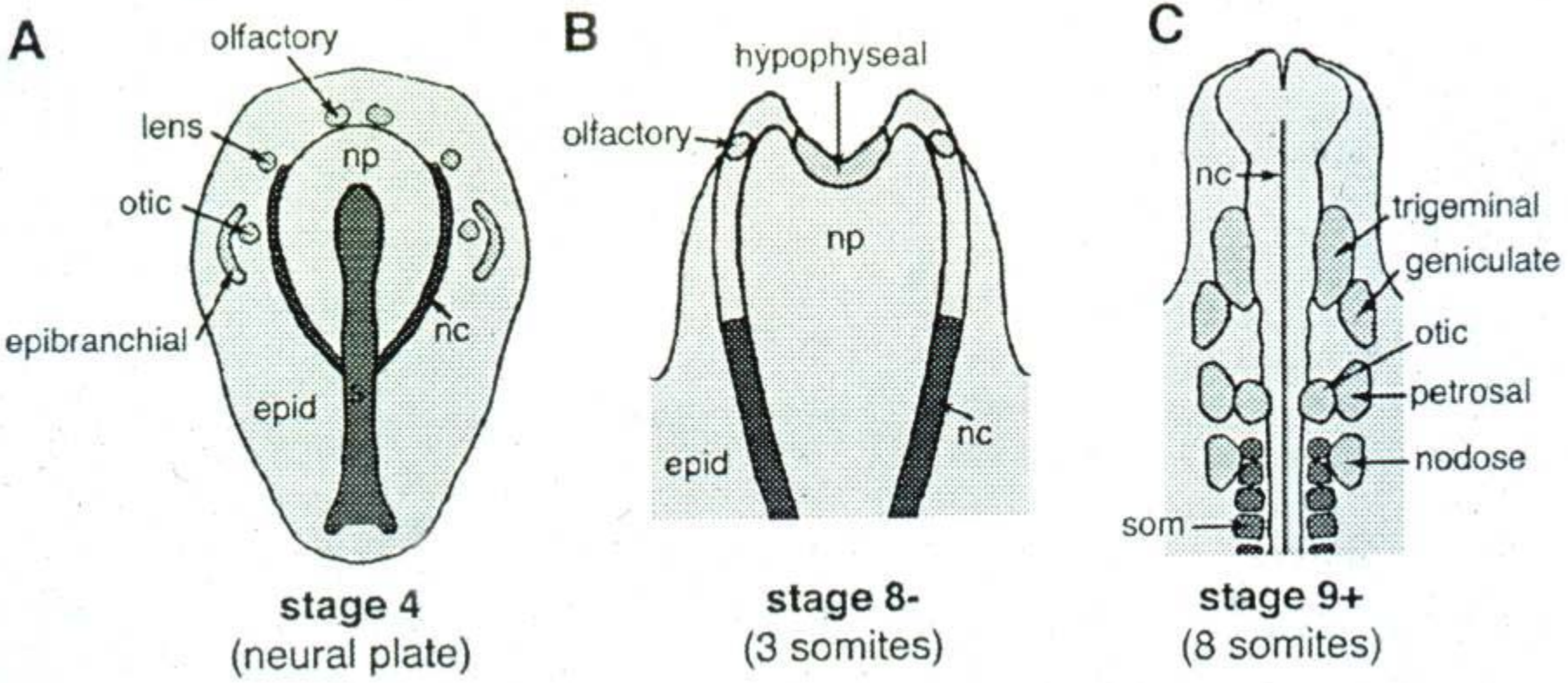
Brugmann SA, Moody SA (2005)



Different kinds of placodes

- Contributing to organs of special sense:
  - Olfactory
  - Lens (only placode that does not have neural fate)
  - Otic
- Contributing to distal ganglia of branchiomeric nerves:
  - Trigeminal (profundal + V 2/3)
  - Epibranchial (3)
- Hypobranchial (2) (contribute to hypobranchial ganglia - frog only; not in chick, mouse, zebrafish)

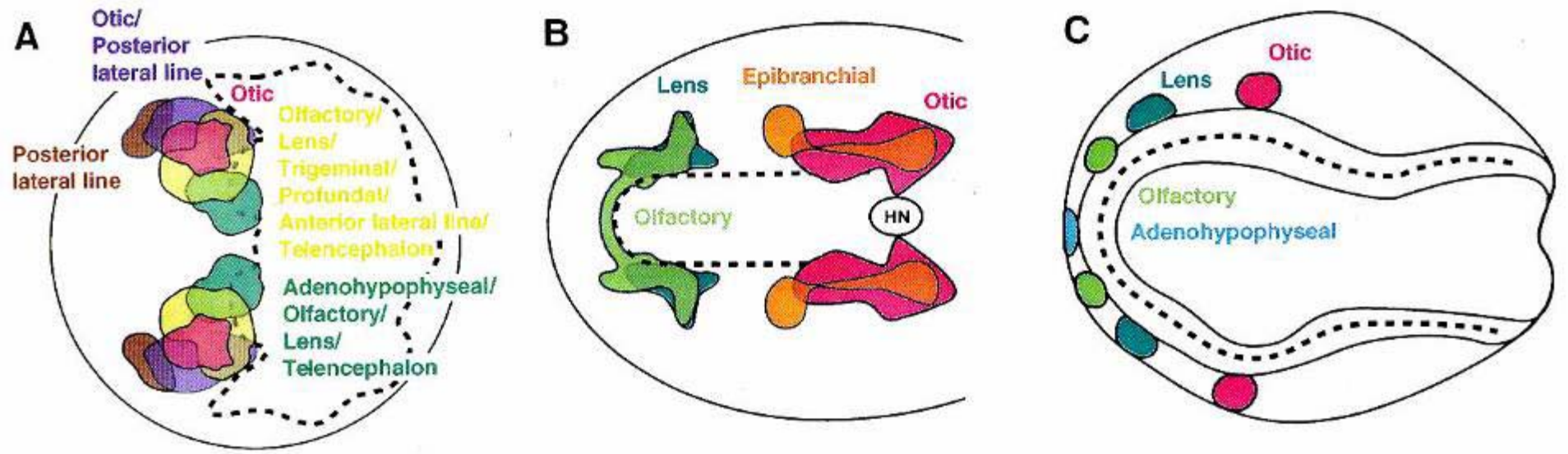
Distribution of placodes at 3 developmental stages



A. Initial induction of placodes in pre-placodal ectoderm field

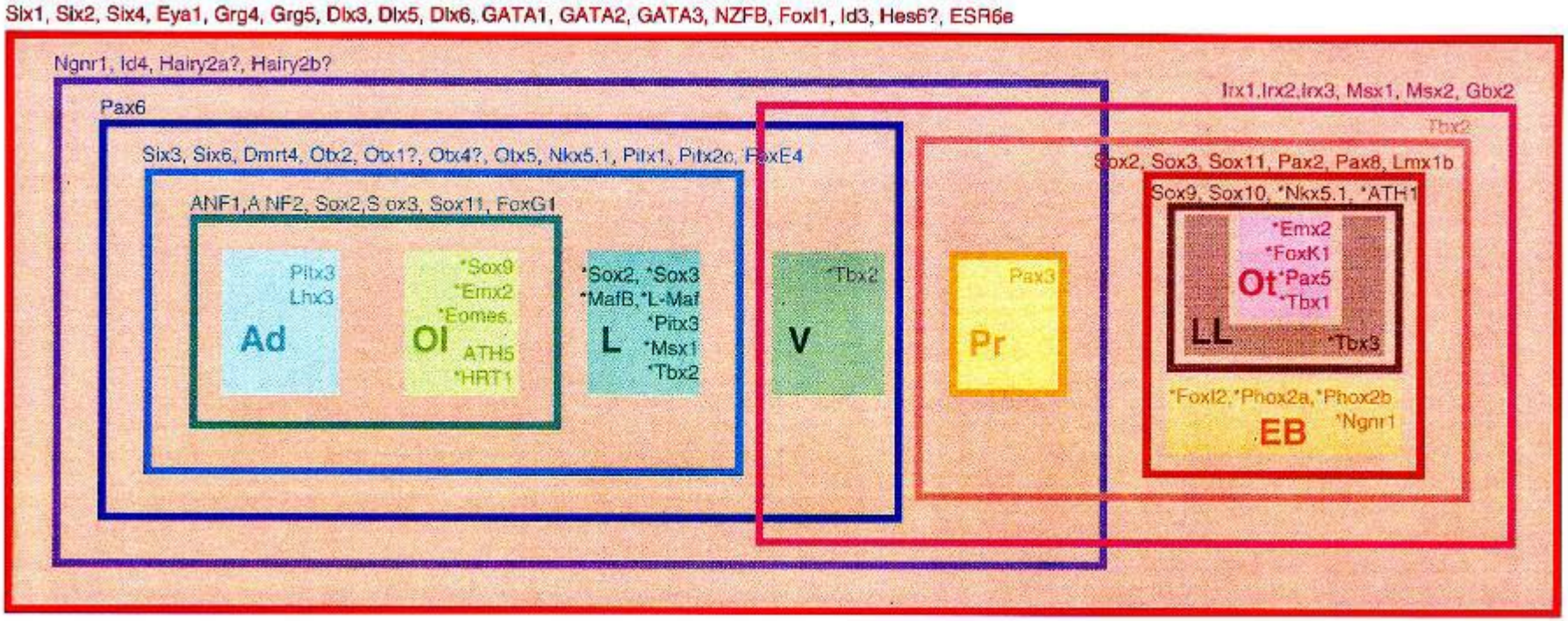
B. Olfactory placodal cells are incorporated in outer folds of anterior neural ridge

Fate maps of cephalic placodes in zebrafish, chick and salamander



Schlosser G (2006)

Transcription factor expression domains in panplacodal primordium



Xenopus

Schlosser G (2006)

Development of placodes: similarities

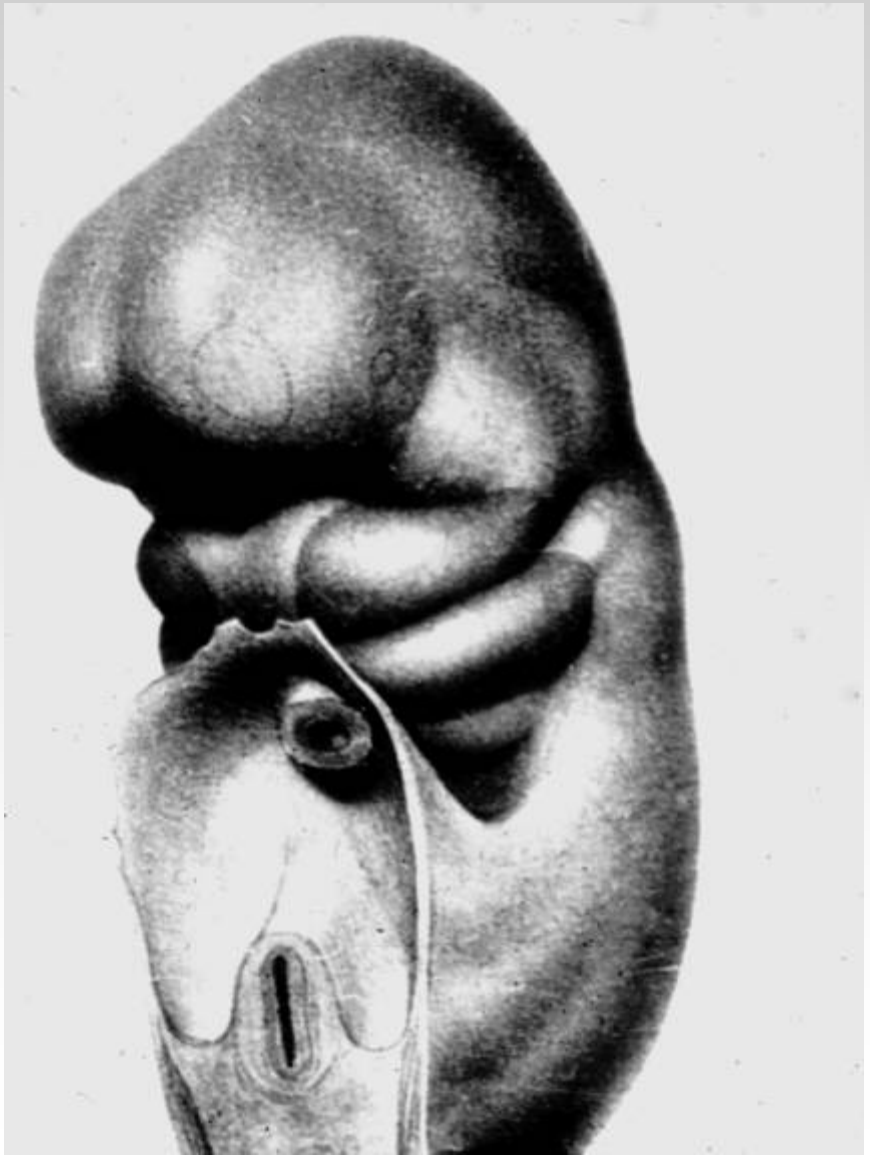
- Under influence of surrounding tissues – no evidence for role of neural crest in this process
- All express one or more members of Pax family as transcription factors early in development

Development of placodes - differences

- Epibranchial placodes: pharyngeal endoderm (BMP-7 signal), Pax2 and Sox3
- Ophthalmic placode of V: neurectoderm of mesencephalon (diffusible signal ?), Pax3
- Otic placode: initially axial and non-axial mesoderm, Pax 8; later hindbrain (FGF-3,-8,-10 signals), Pax2, Sox3, Notch
- Lens placode: forebrain & anterior mesoderm (BMP-4, later BMP-7 signals), Pax6, later Pax2
- Olfactory placode: anterior mesoderm (and forebrain? – no signal identified as yet), Pax6

Location of placodes (1)

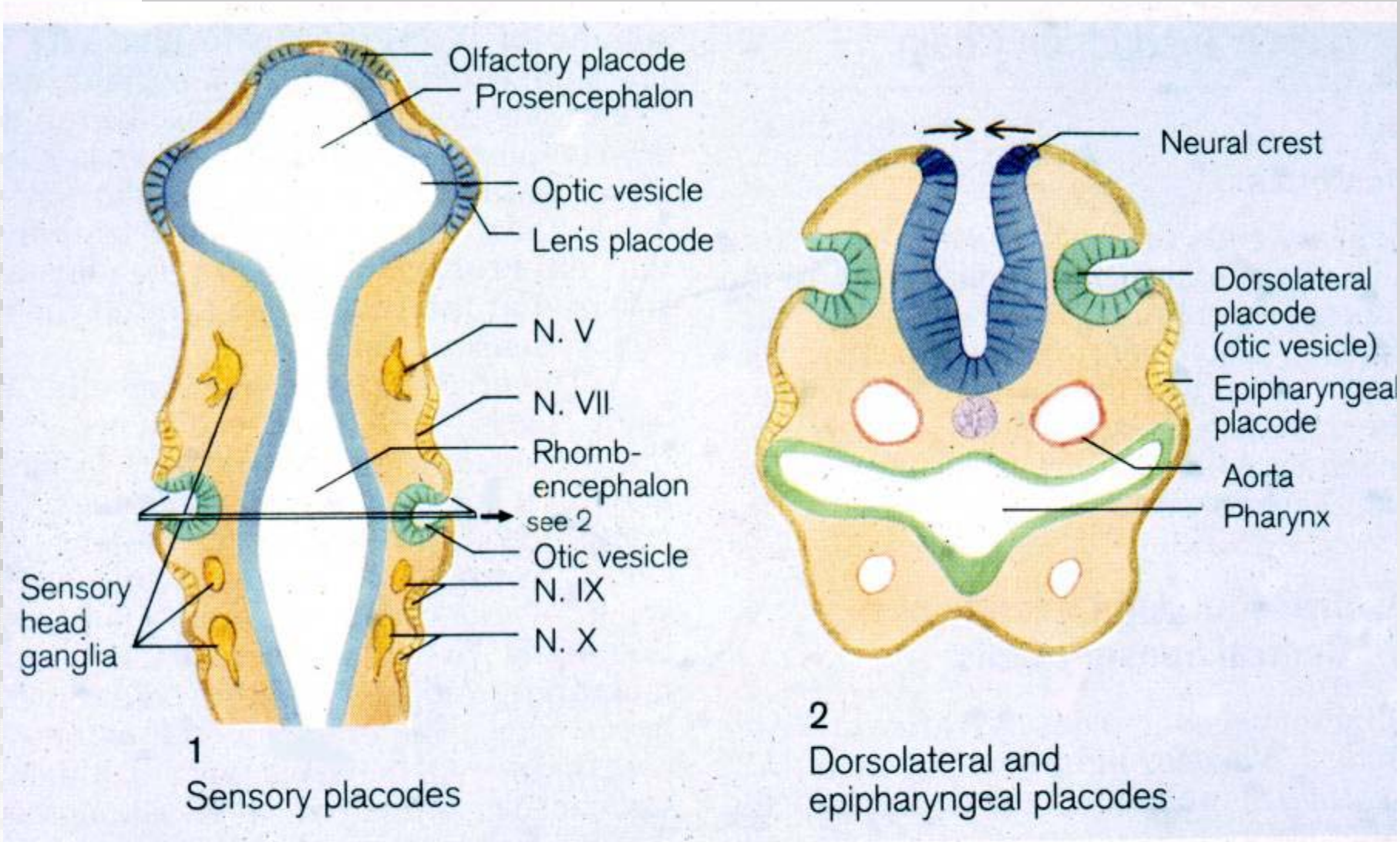
- *Near forebrain* :
  - Olfactory placode
  - Lens placode



Location of placodes (2)

- ***Dorsolateral*** **:**

  Otic placode: related to (= evolved from or having common origin with) lateral line system

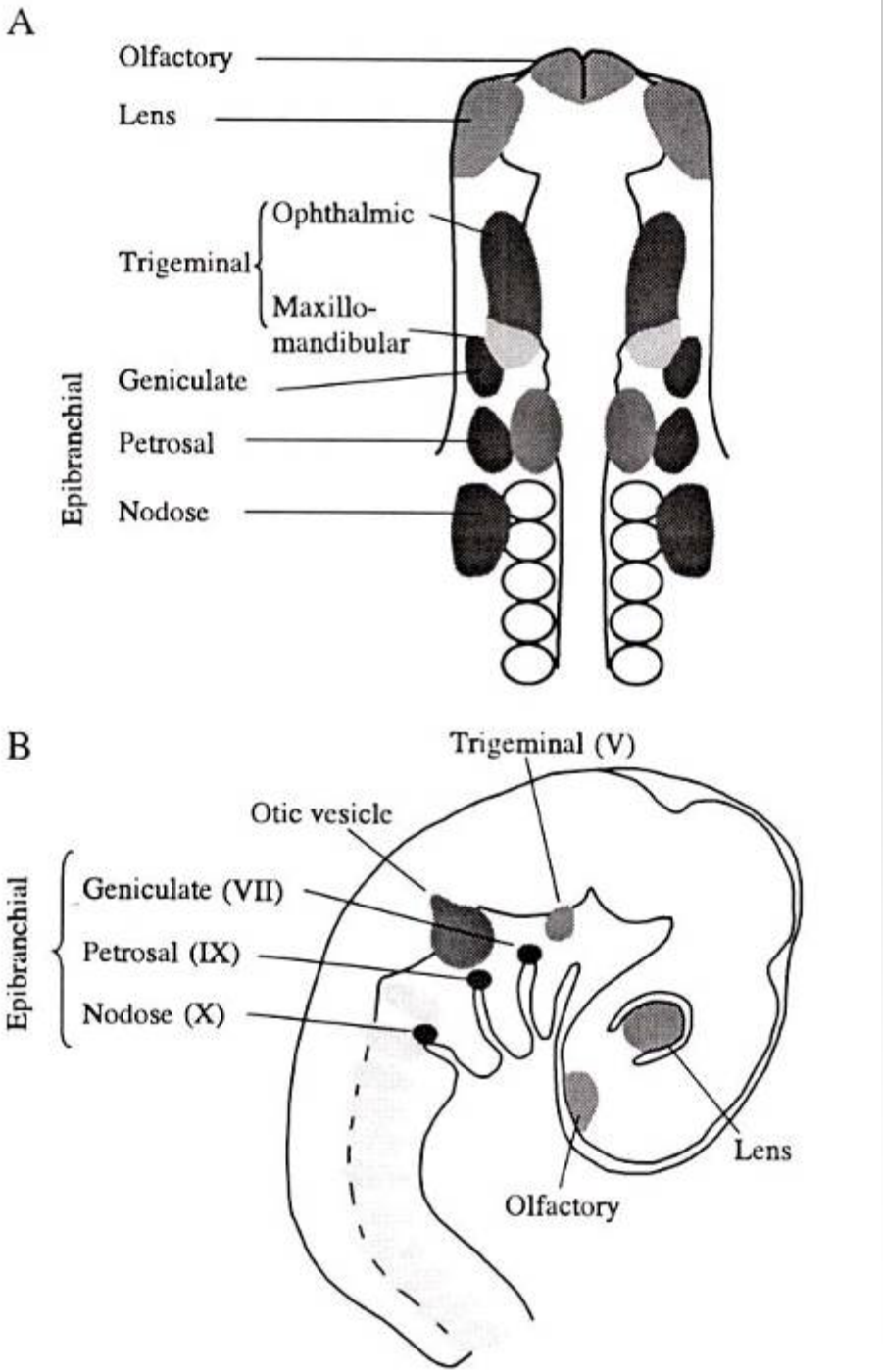


Classification of placodes

Location of placodes (3)

- ***Intermediate*** **between otic placode and epibranchial placodes :**

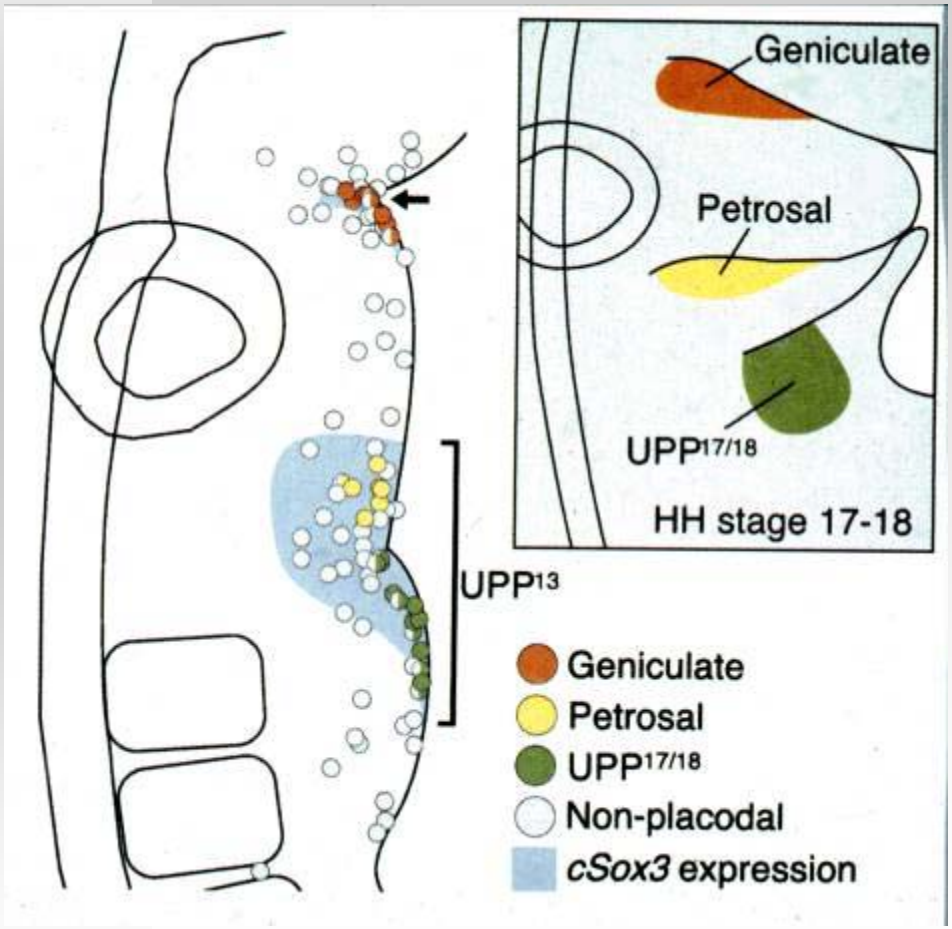
  Ophthalmic (profundal component) and trigeminal placode

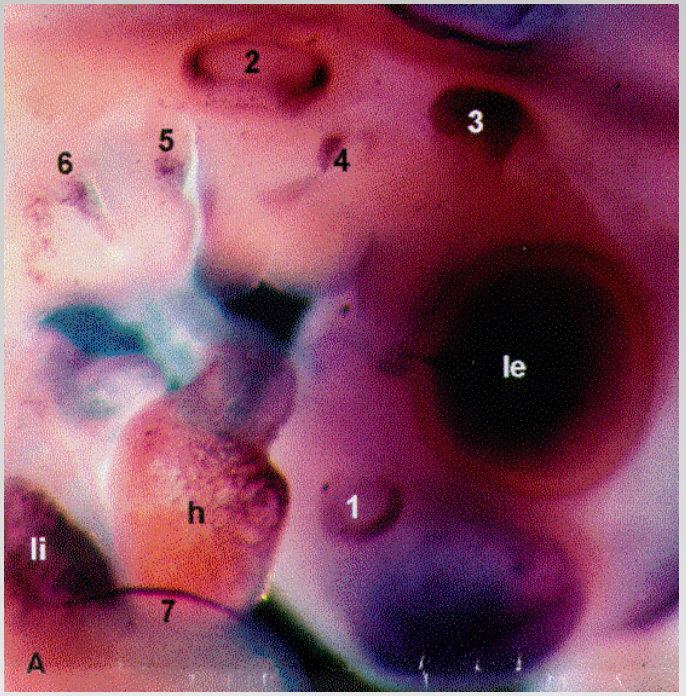


Streit A (2004)

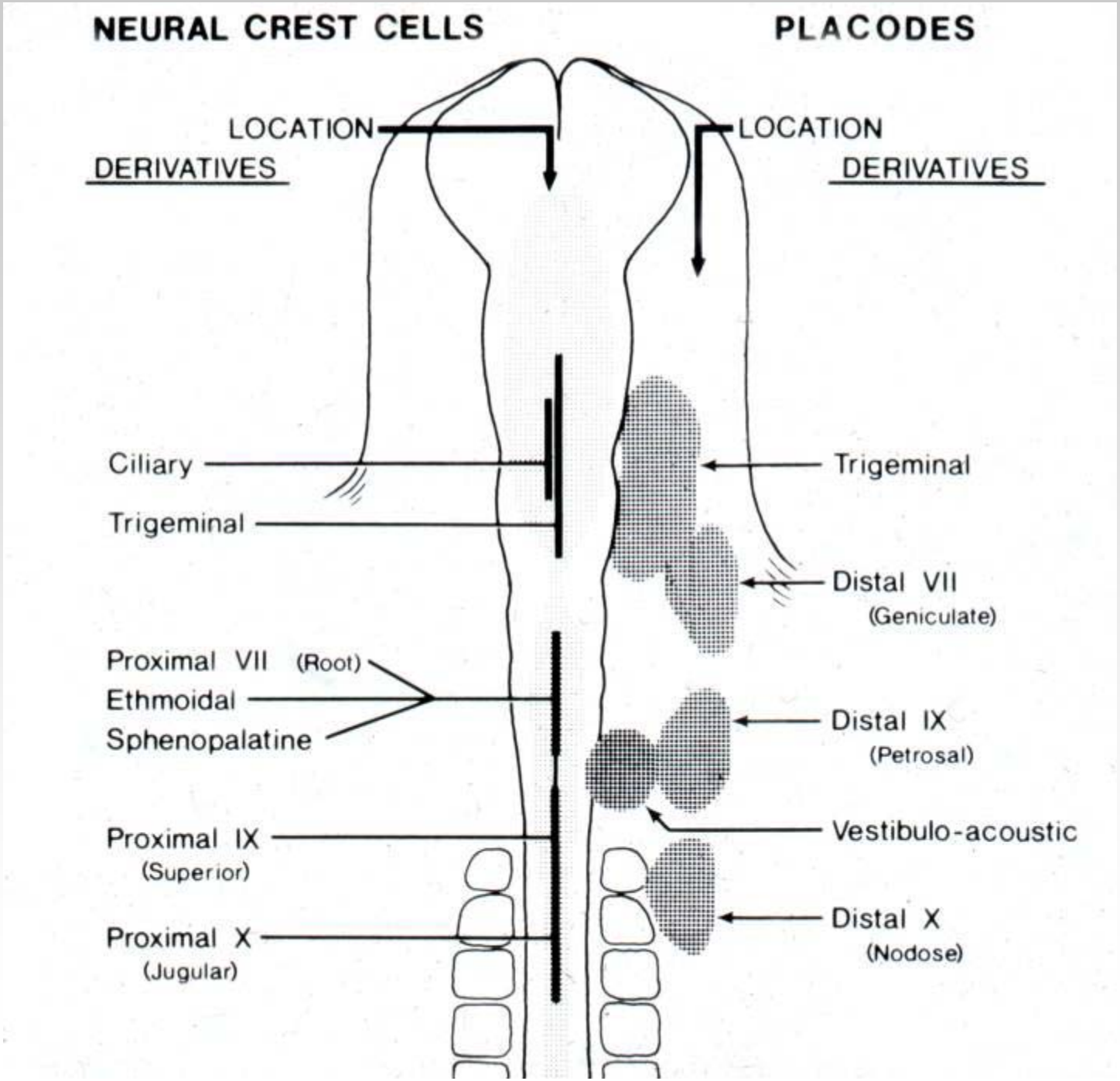
Location of placodes (4)

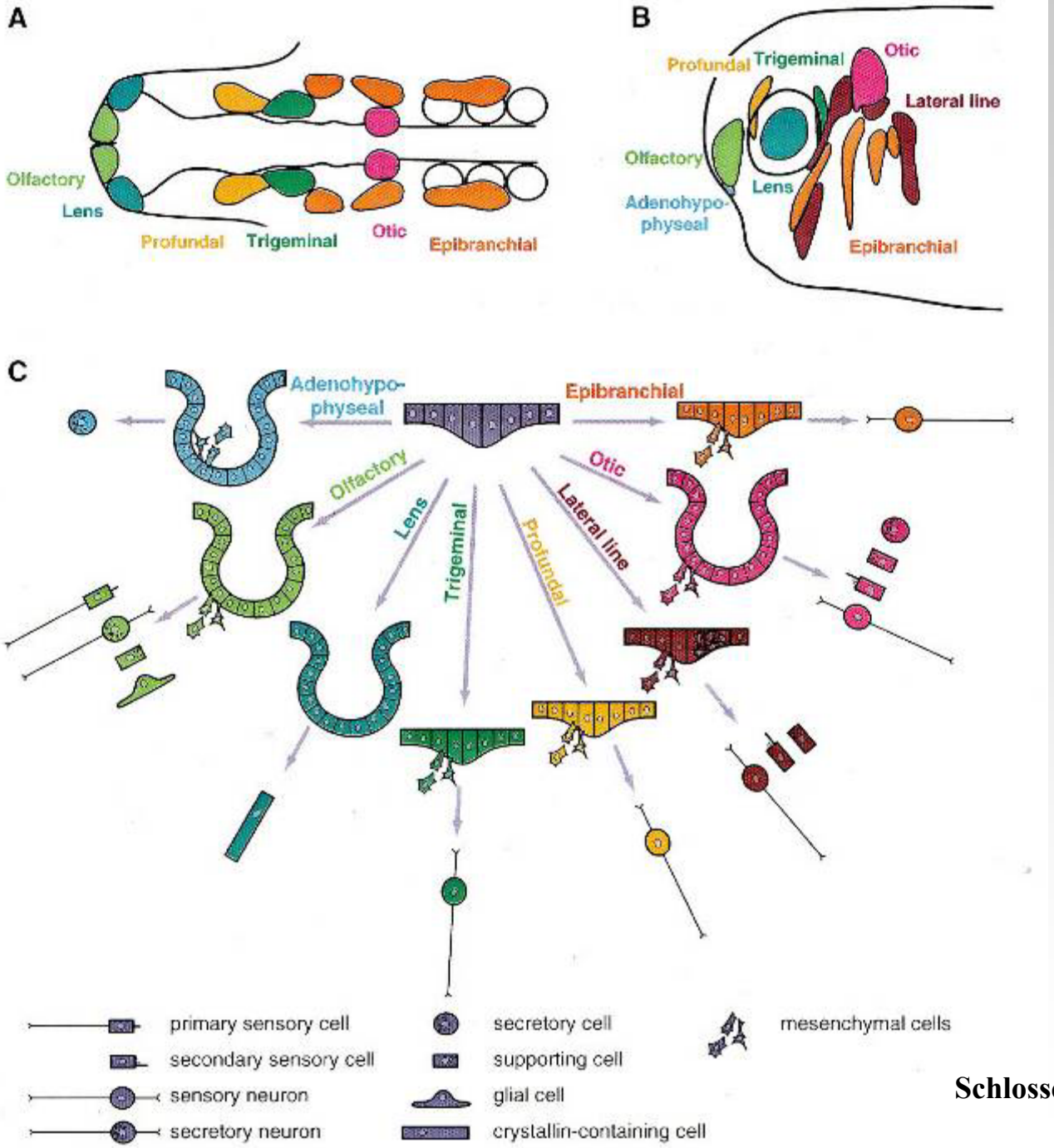
- *Epibranchial series* – dorsal ends of 2nd – 4th pharyngeal grooves
- *Hypobranchial series* in frogs – ventral ends of 2nd – 3rd pharyngeal grooves ?





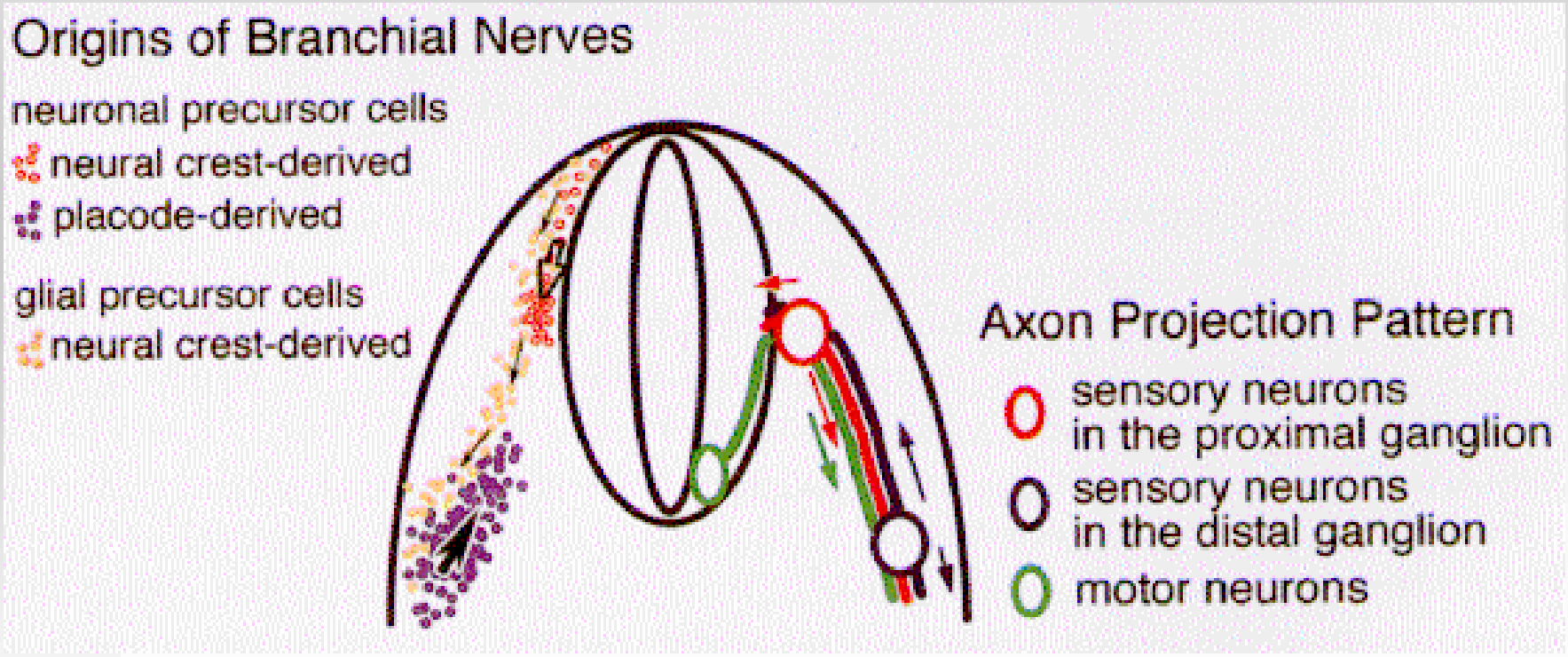
1. Olfactory
2. Otic
3. Trigeminal (V)
4. Facial (VII)
5. Glossopharyngeal (IX)
6. Vagal (X)


NEURAL CREST CELLS
PLACODES
LOCATION
DERIVATIVES
LOCATION
DERIVATIVES
Ciliary
Trigeminal
Proximal VII (Root)
Ethmoidal
Sphenopalatine
Proximal IX
(Superior)
Proximal X
(Jugular)
Trigeminal
Distal VII
(Geniculate)
Distal IX
(Petrosal)
Vestibulo-acoustic
Distal X
(Nodose)

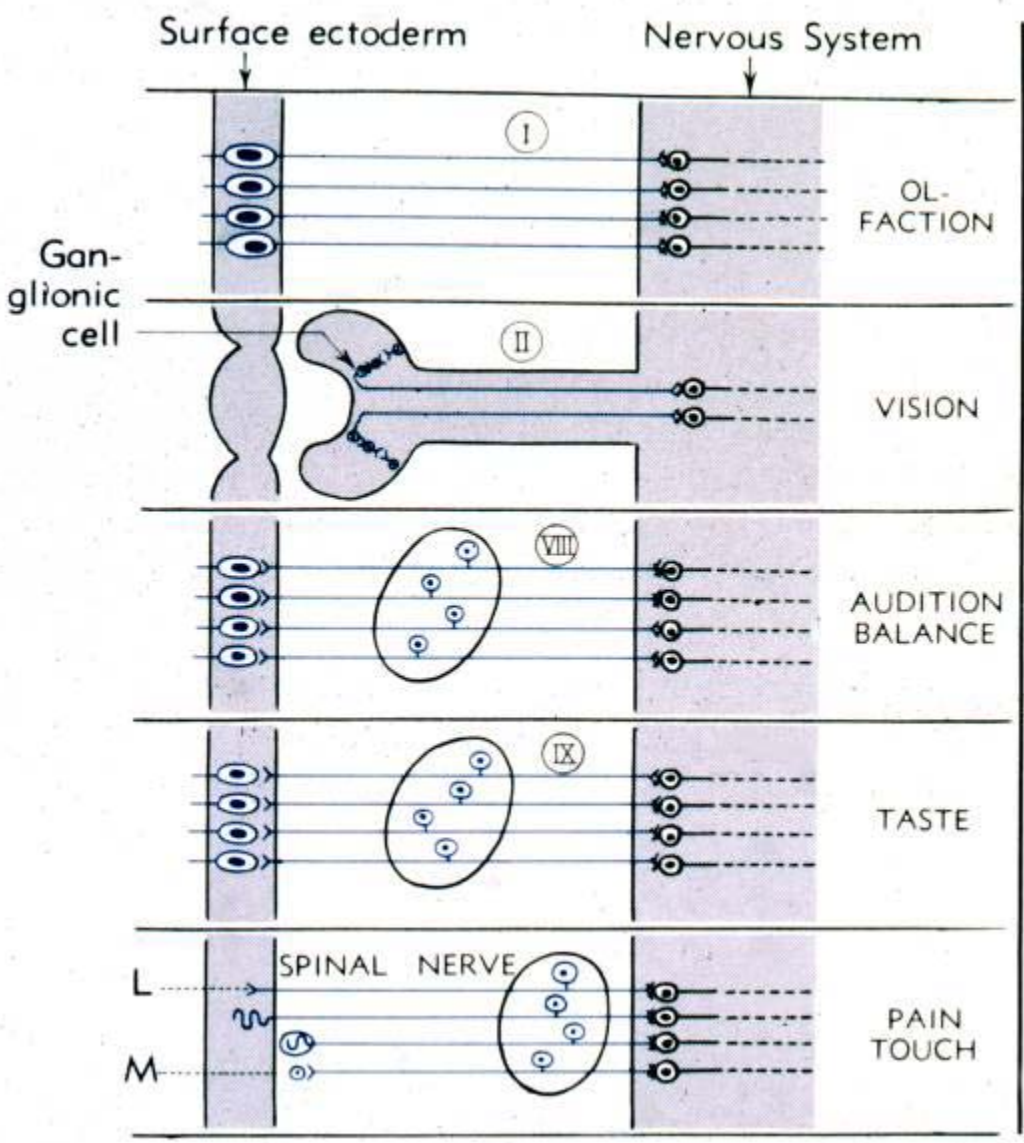


Schlosser G (2006)

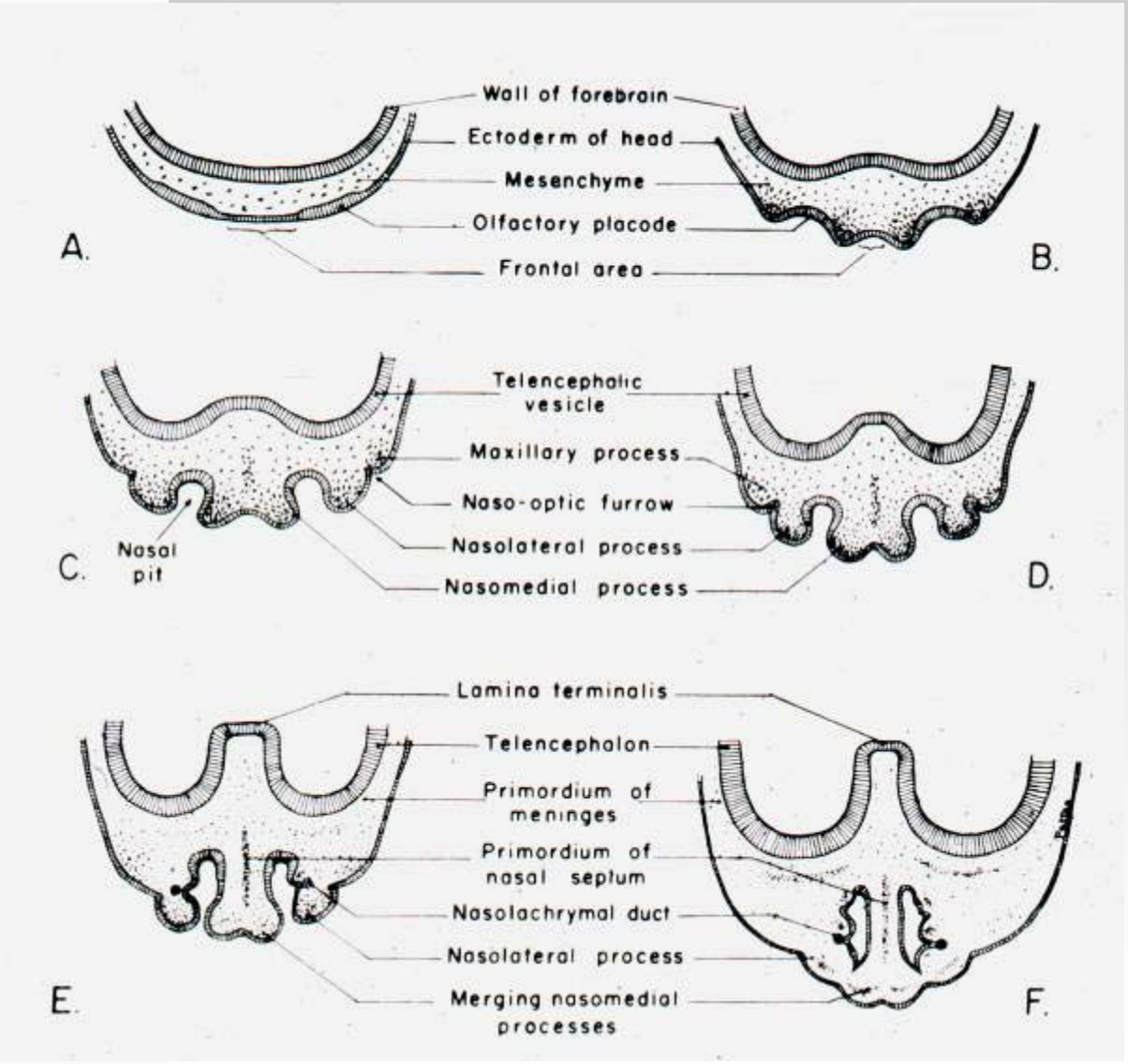
Branchiomeric nerves: origins and axon projection patterns



Development of organs of special sense

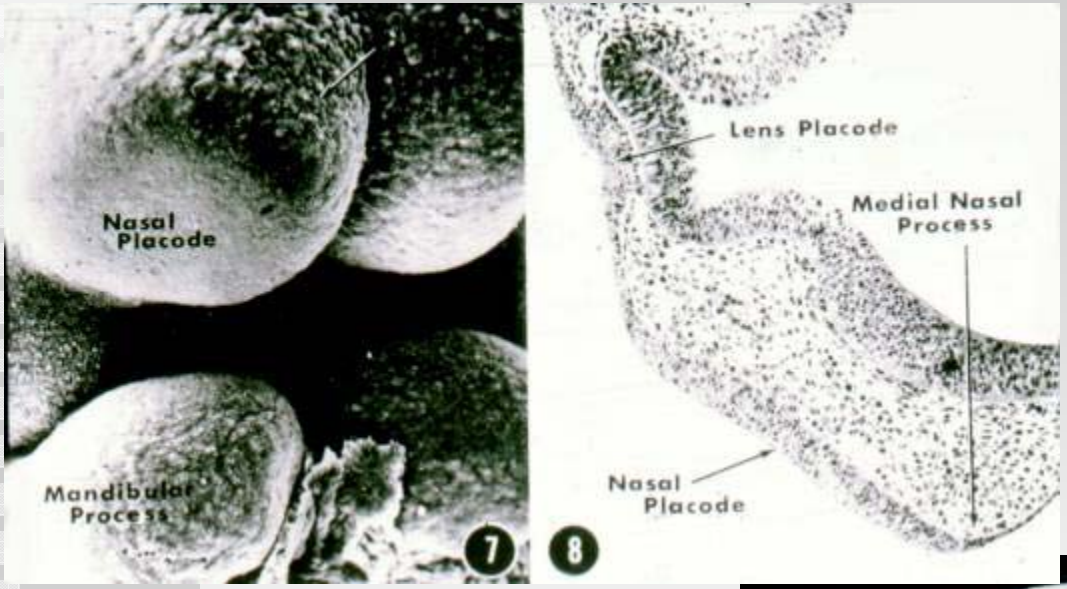


	ORIGIN OF SENSORY ELEMENTS	ORIGIN OF NERVOUS CONDUCTORS
OL-FACTION	Placode	Placode
VISION	Neural tube	Neural tube
AUDITION BALANCE	Placode	Placode
TASTE	Sensory differentiation of certains cells of surface ectodermal covering of tongue	Neural crest (spinal ganglia)
PAIN TOUCH	Free nerve endings (L) : neural crest. Mesenchymal cells (M)	Neural crest (spinal ganglia)

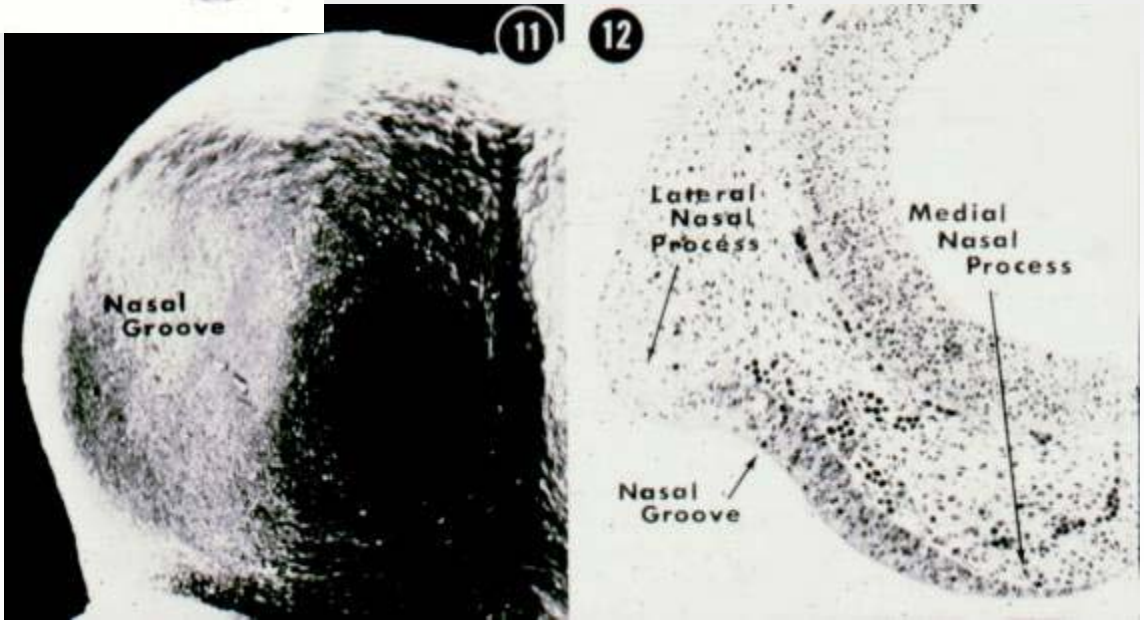


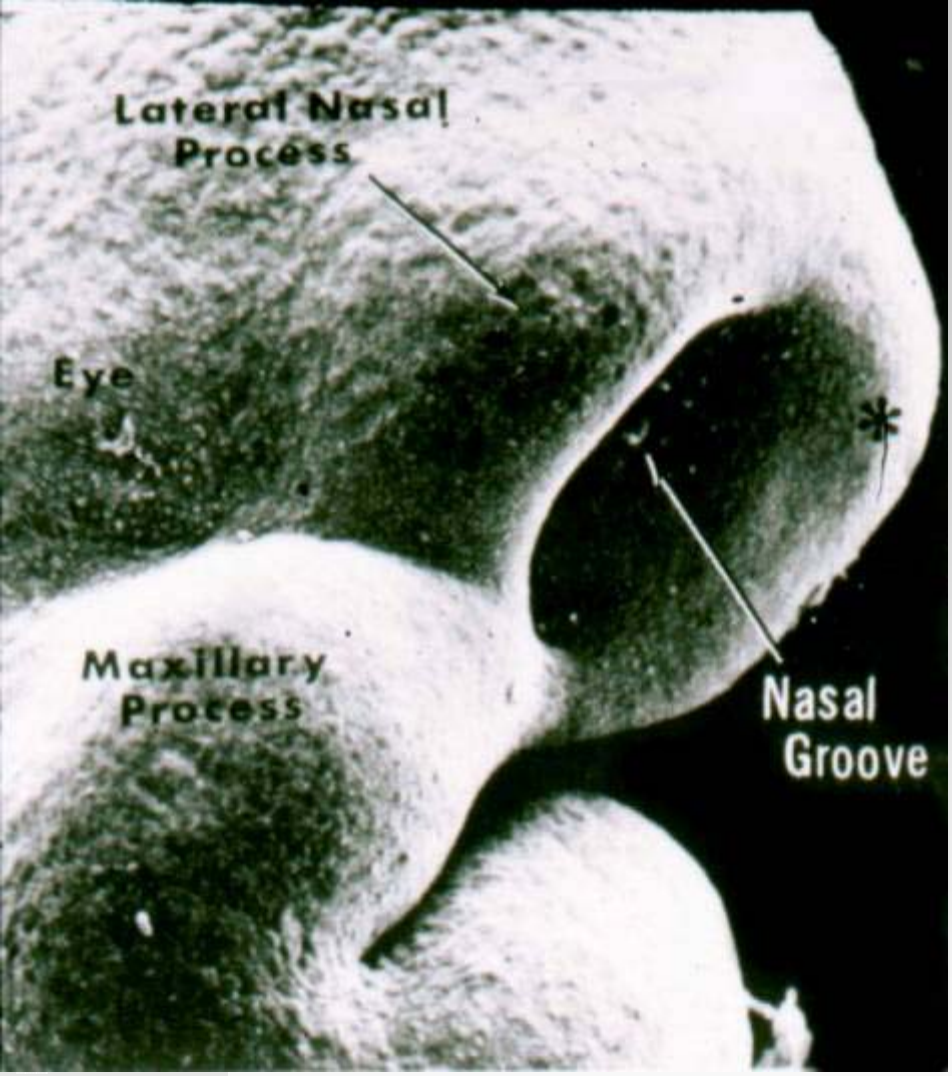
Olfactory epithelium: development of the nose

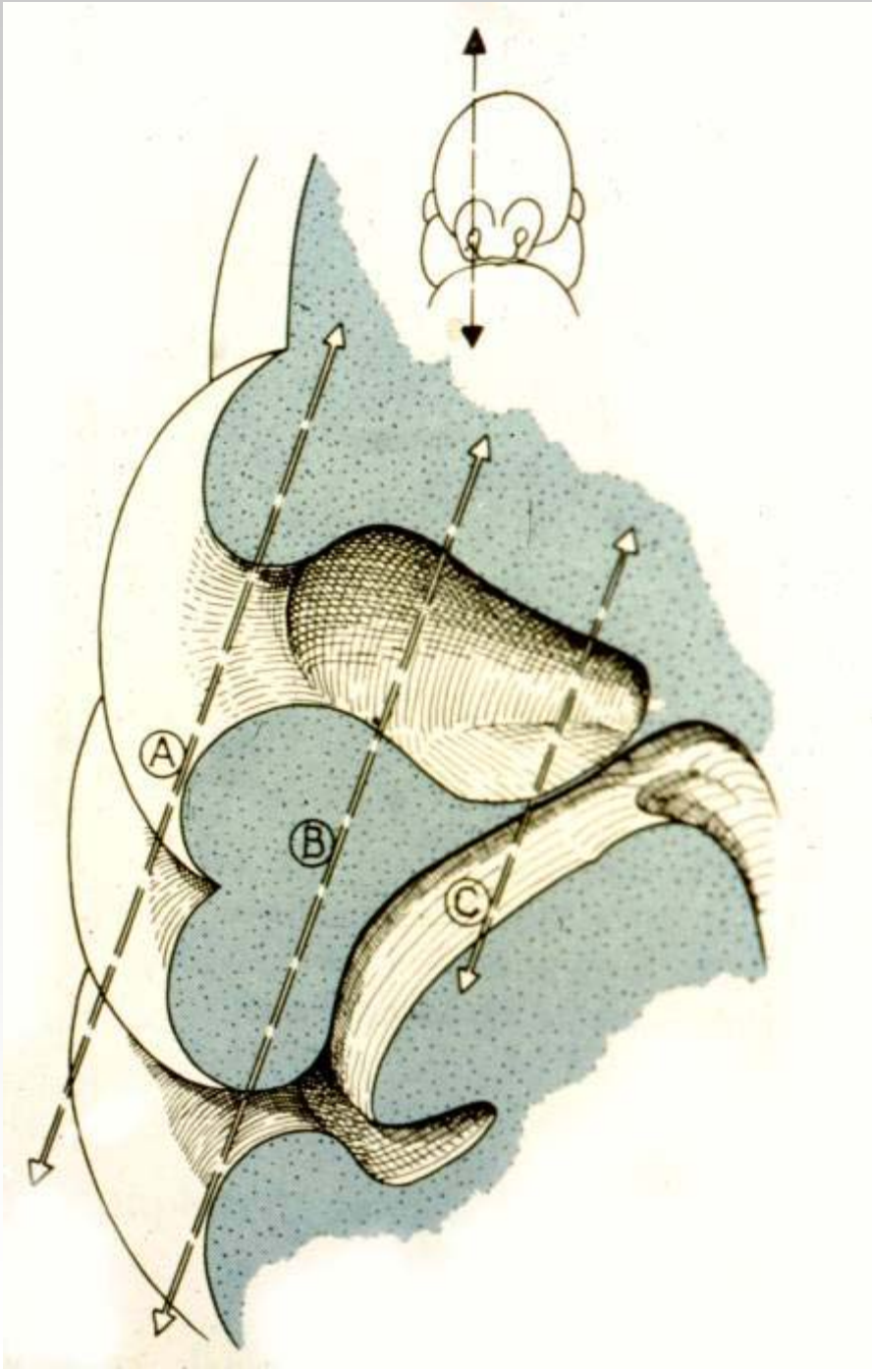
Olfactory epithelium: development of the nose

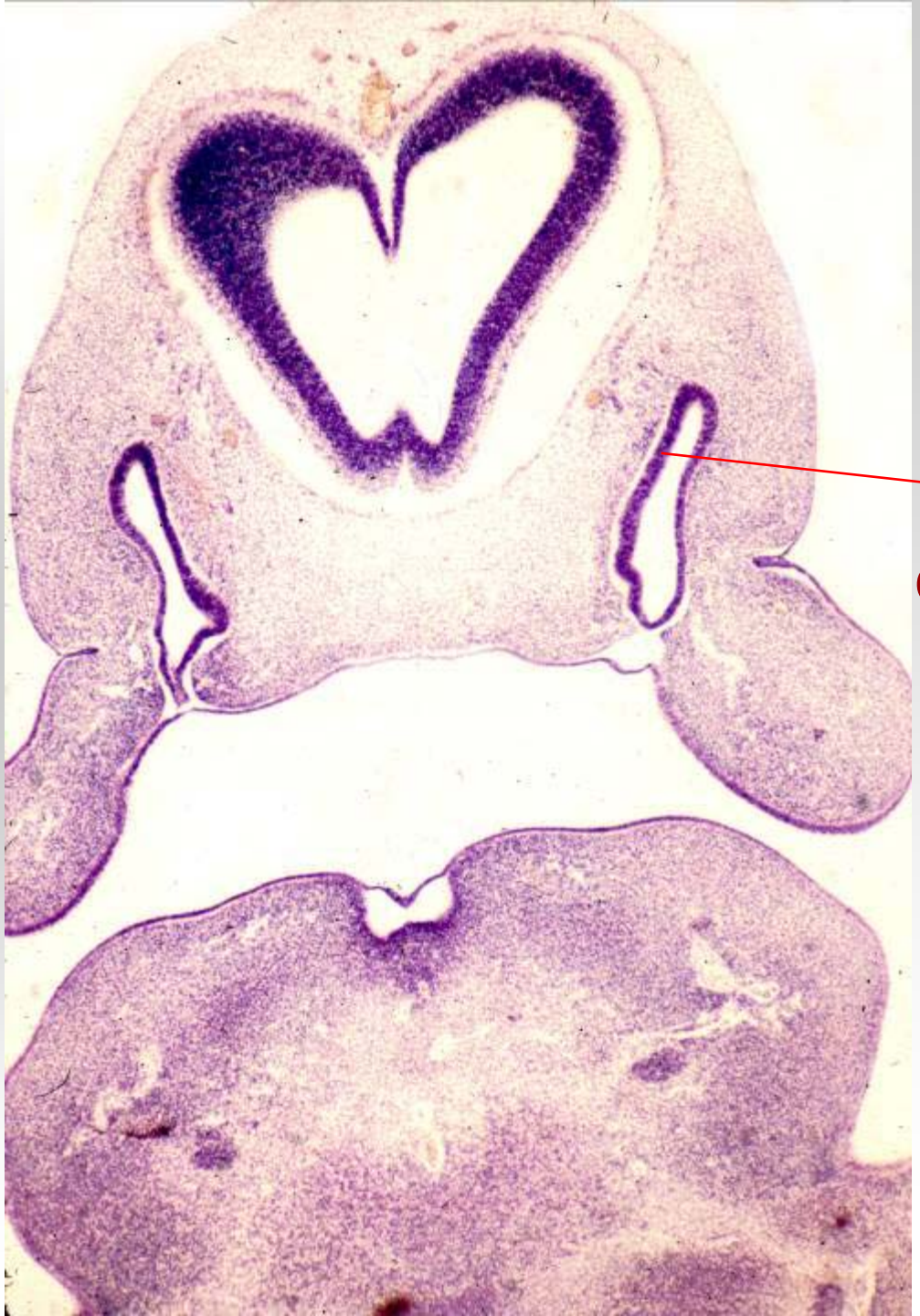


Transient pioneer neurons set up scaffold

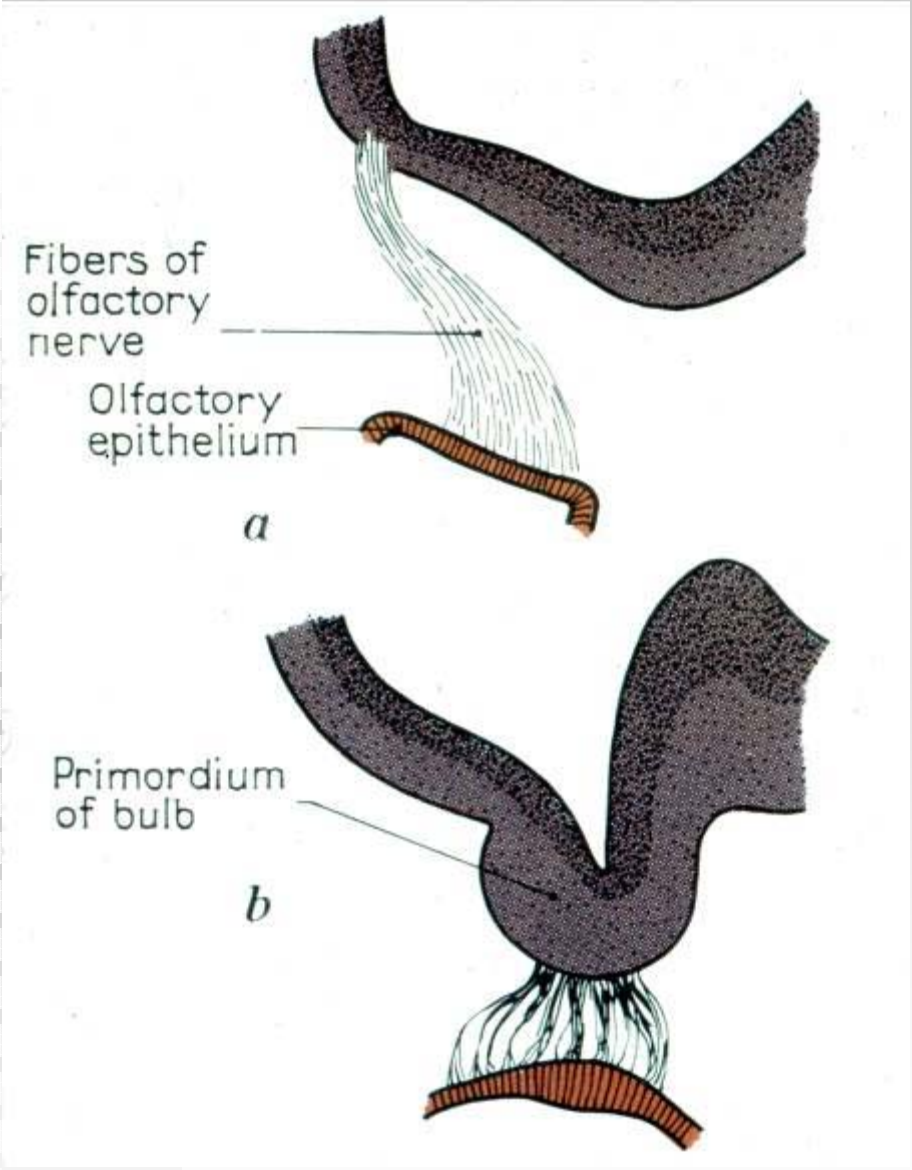



Lateral Nasal Process
Eye
Maxillary Process
Nasal Groove


A
B
C

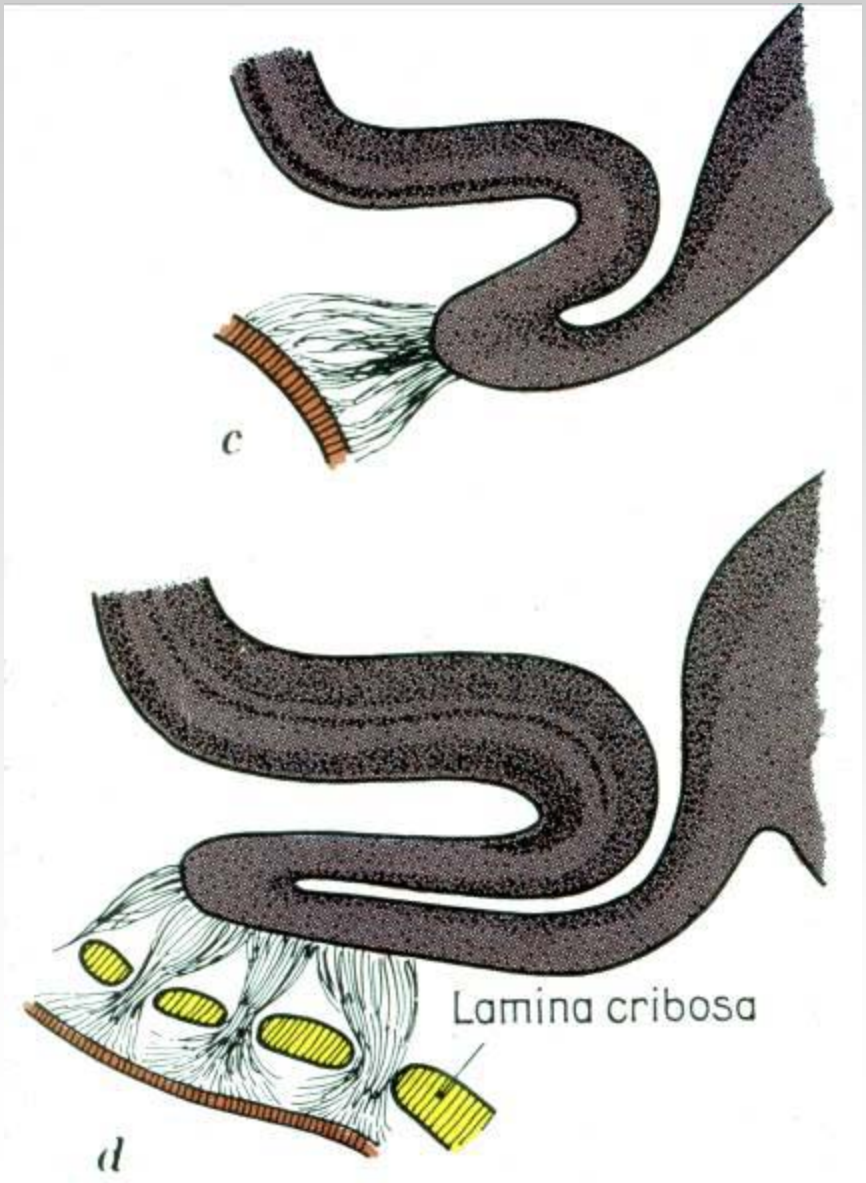


Olfactory epithelium

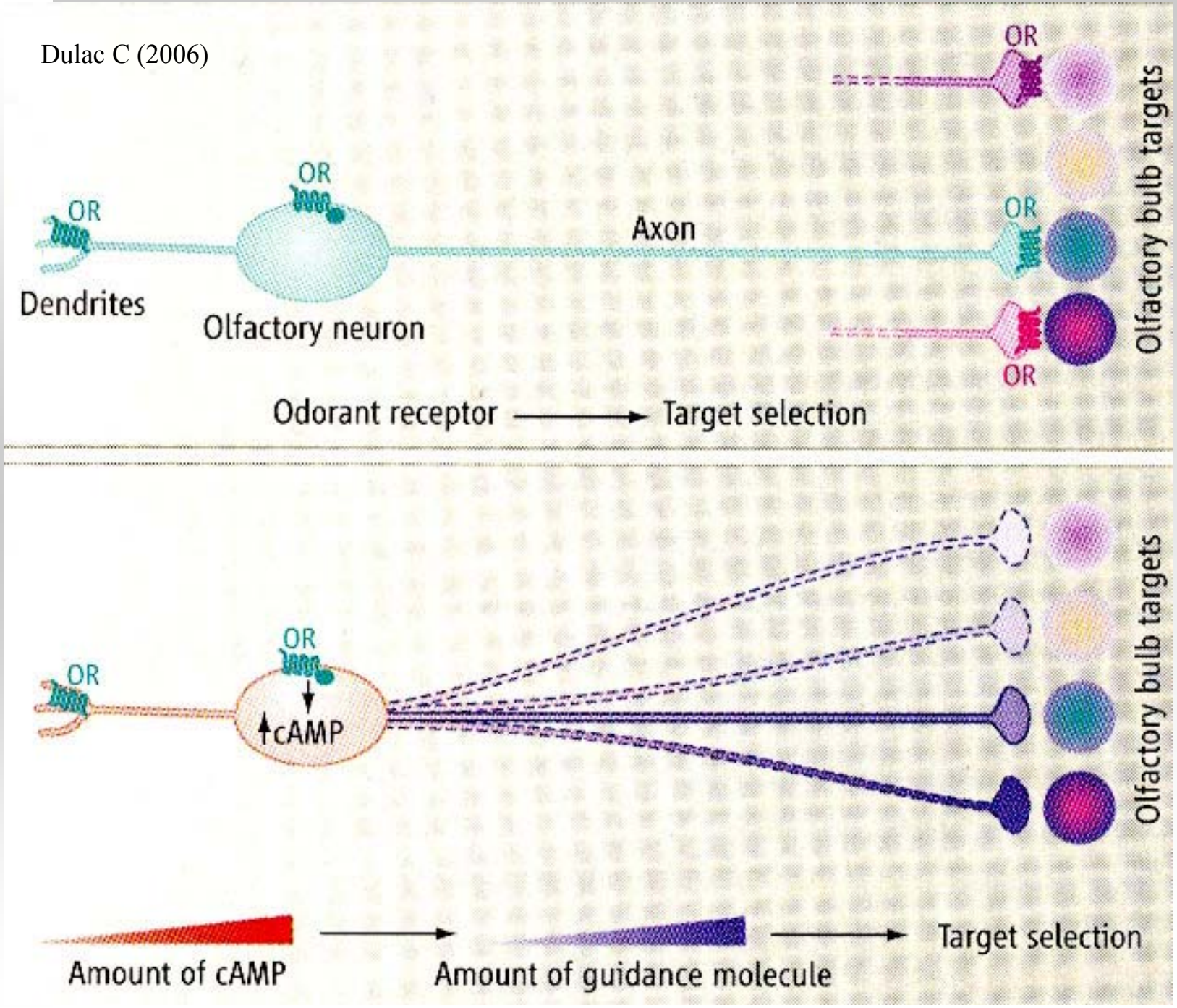


46-54 days

68-84 days



Dulac C (2006)


OR
OR
OR
Axon
OR
OR
Dendrites
Olfactory neuron
Olfactory bulb targets
Odorant receptor
Target selection
OR
OR
cAMP
Olfactory bulb targets
Amount of cAMP
Amount of guidance molecule
Target selection

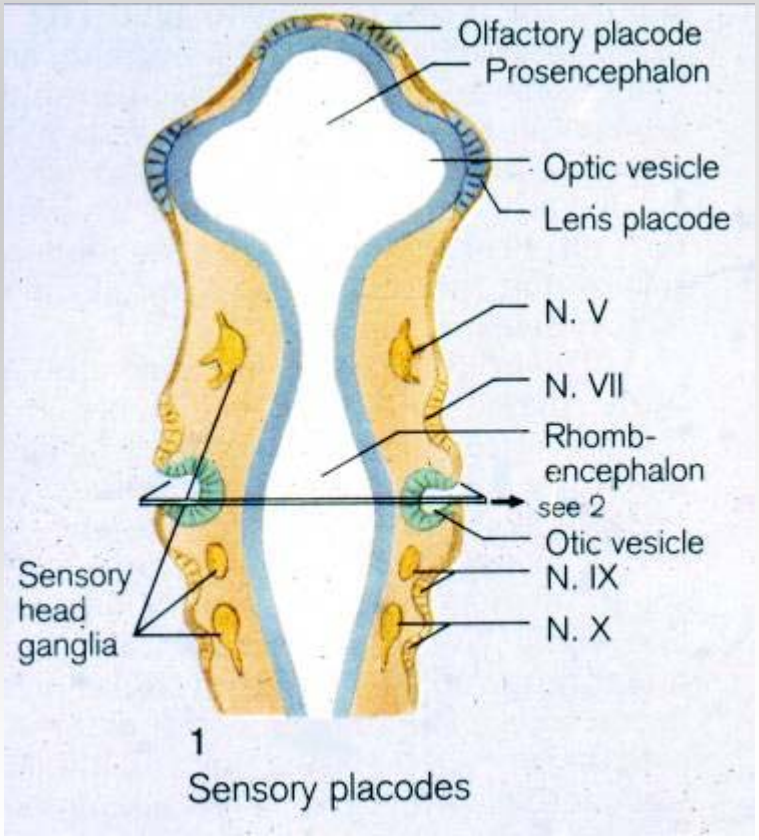
Olfactory placode gives rise to:

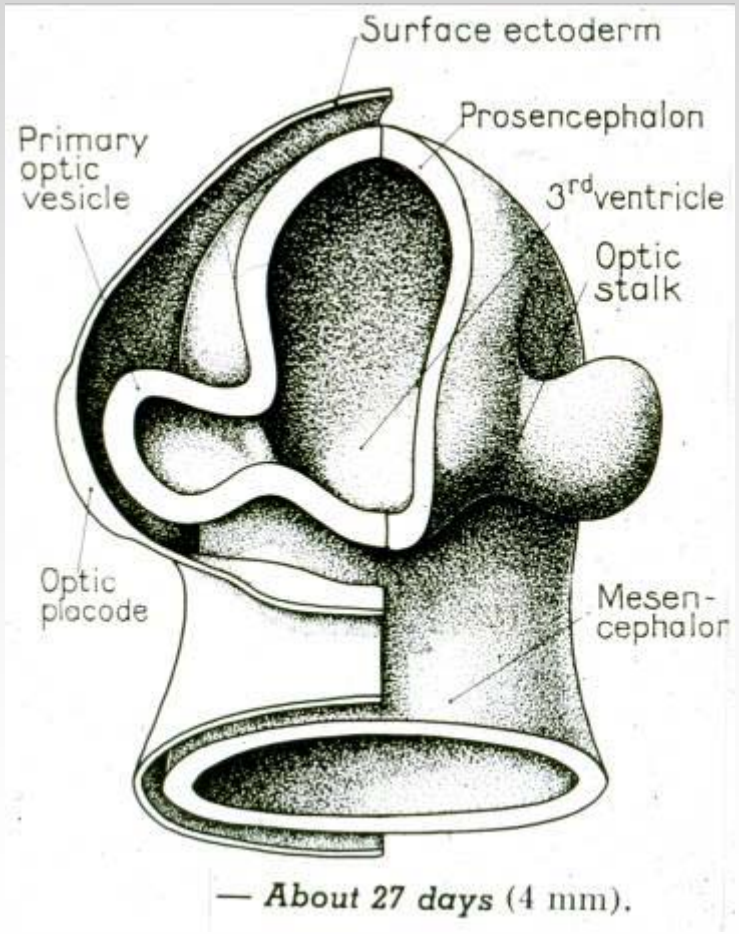
- Sensory receptor cells of olfactory epithelium of the nose (odorant sensing)
- Sensory receptor cells of vomeronasal epithelium (pheromone sensing)
- Basal cells and support cells (olfactory ensheathing cells - glia)

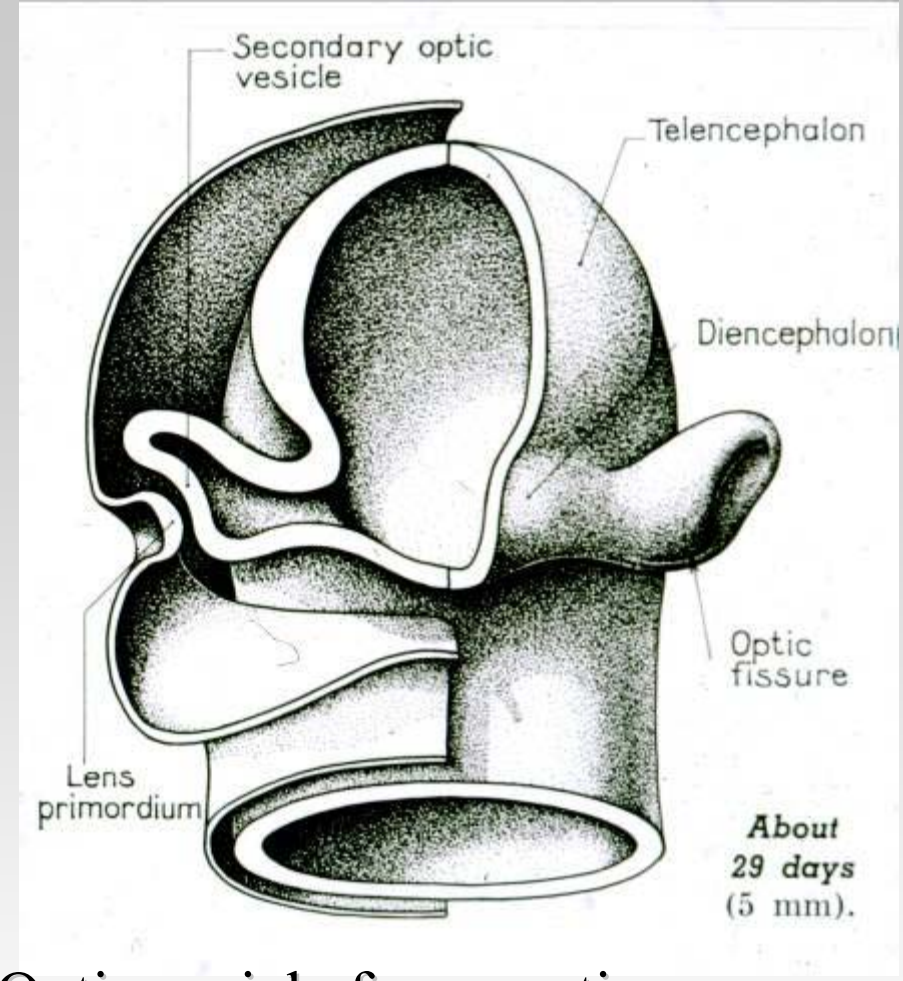
Development of the eye :

1. evagination of forebrain (optic vesicle)

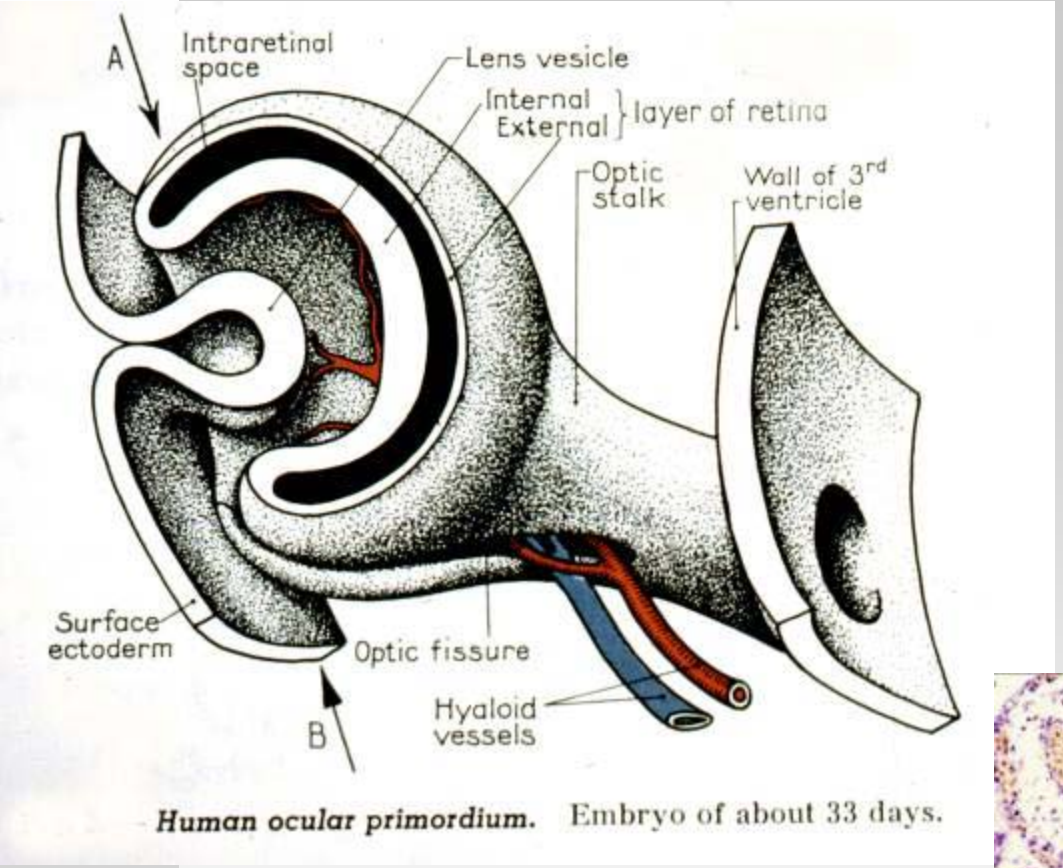
2. invagination of lens placode







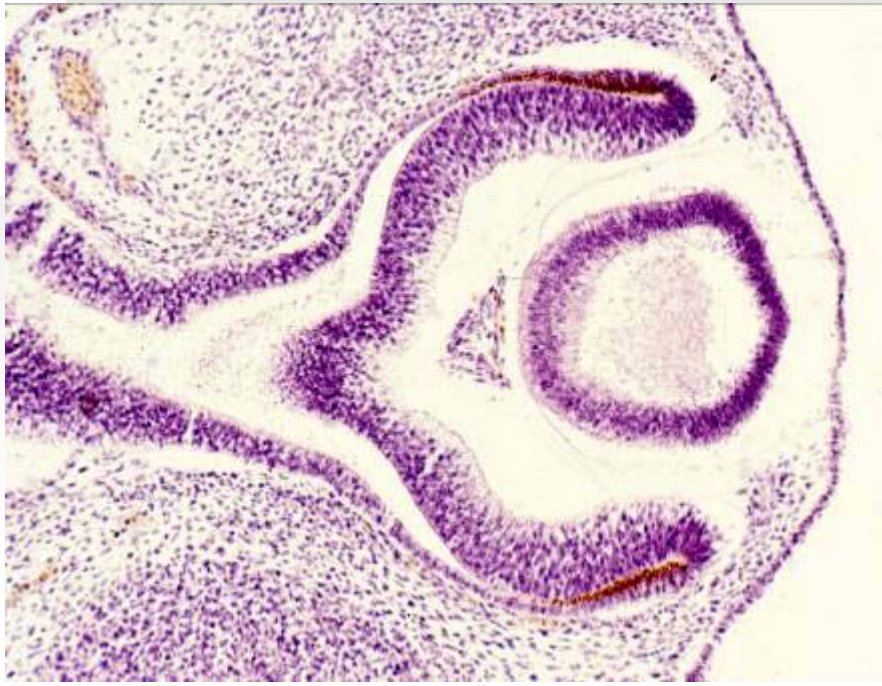
Optic vesicle forms optic cup under influence of lens primordium. Between developing lens vesicle and optic cup : primary vitreous body.



Human ocular primordium. Embryo of about 33 days.

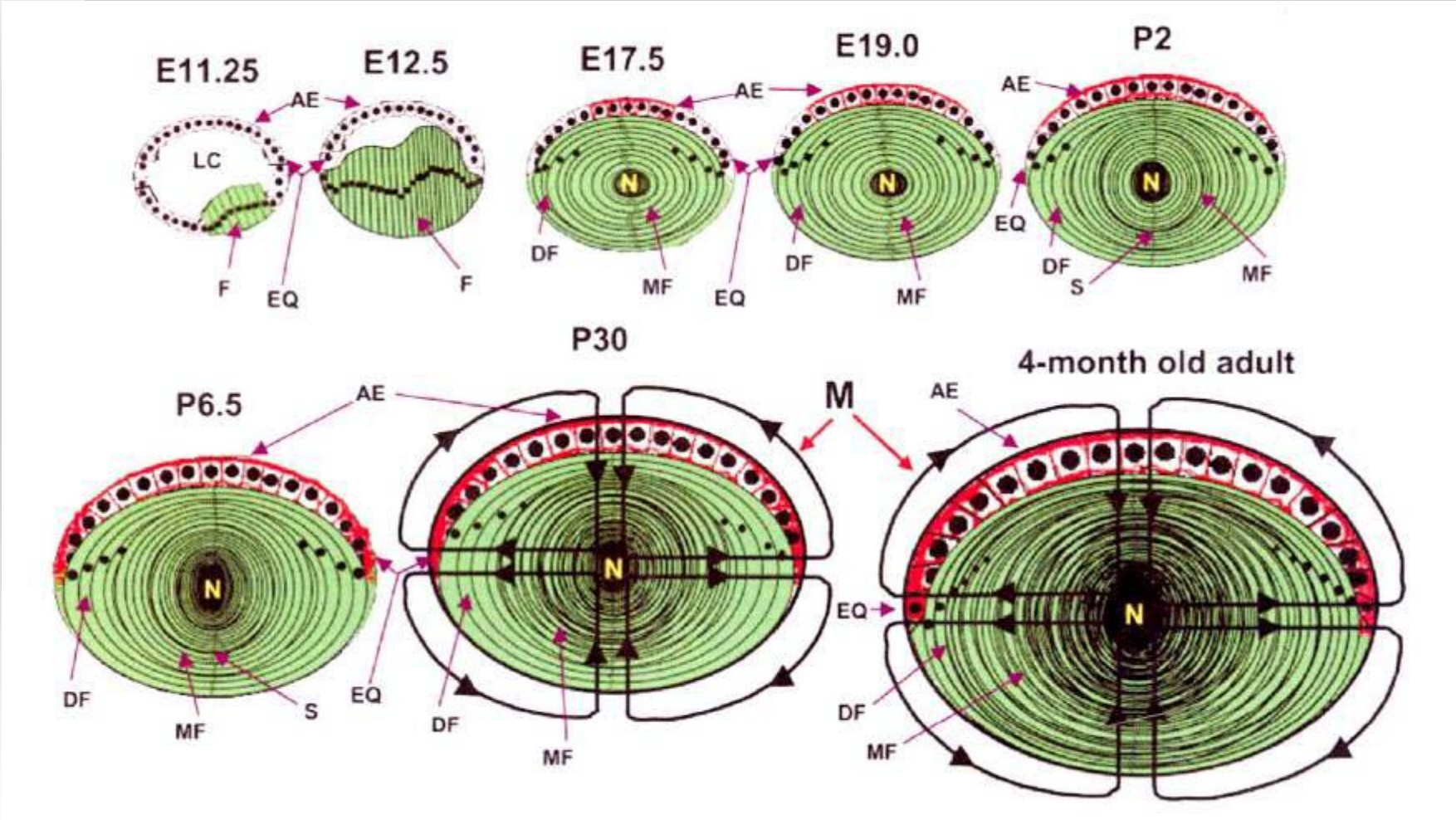
Hyaloid A.: terminal branch of ophthalmic A. (future central artery of retina)

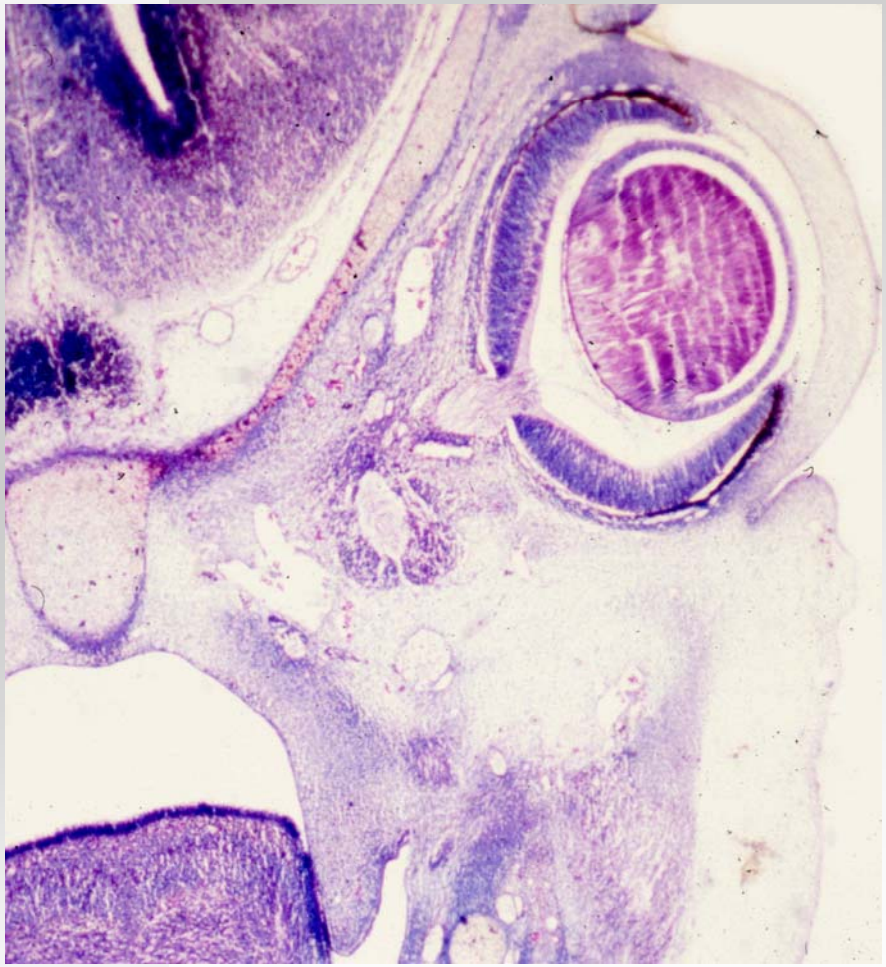
In lens vesicle posterior cells elongate to form primary lens fibers. In third month the equatorial cells of the anterior epithelium form secondary lens fibers (most of mature lens).



Primary and secondary lens fibers

Varadaraj K et al (2007)





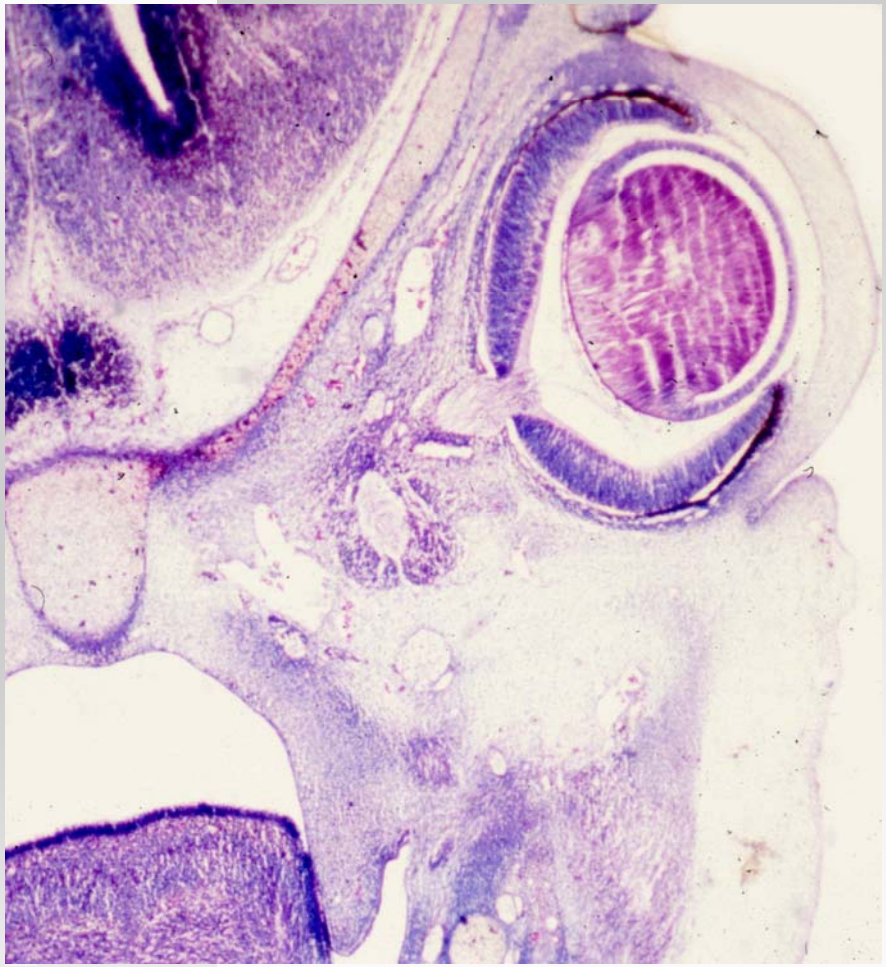
Optic cup:

Inner layer ⟶ neural retina

Outer layer ⟶ pigment retina

Optic stalk:

Axons from neural retina grow through the choroidal fissure to brain ⟶ optic nerve



NC derived mesenchyme around the optic cup:

Thin inner choroid

Outer fibrous sclera

NC derived mesenchyme anterior to lens:

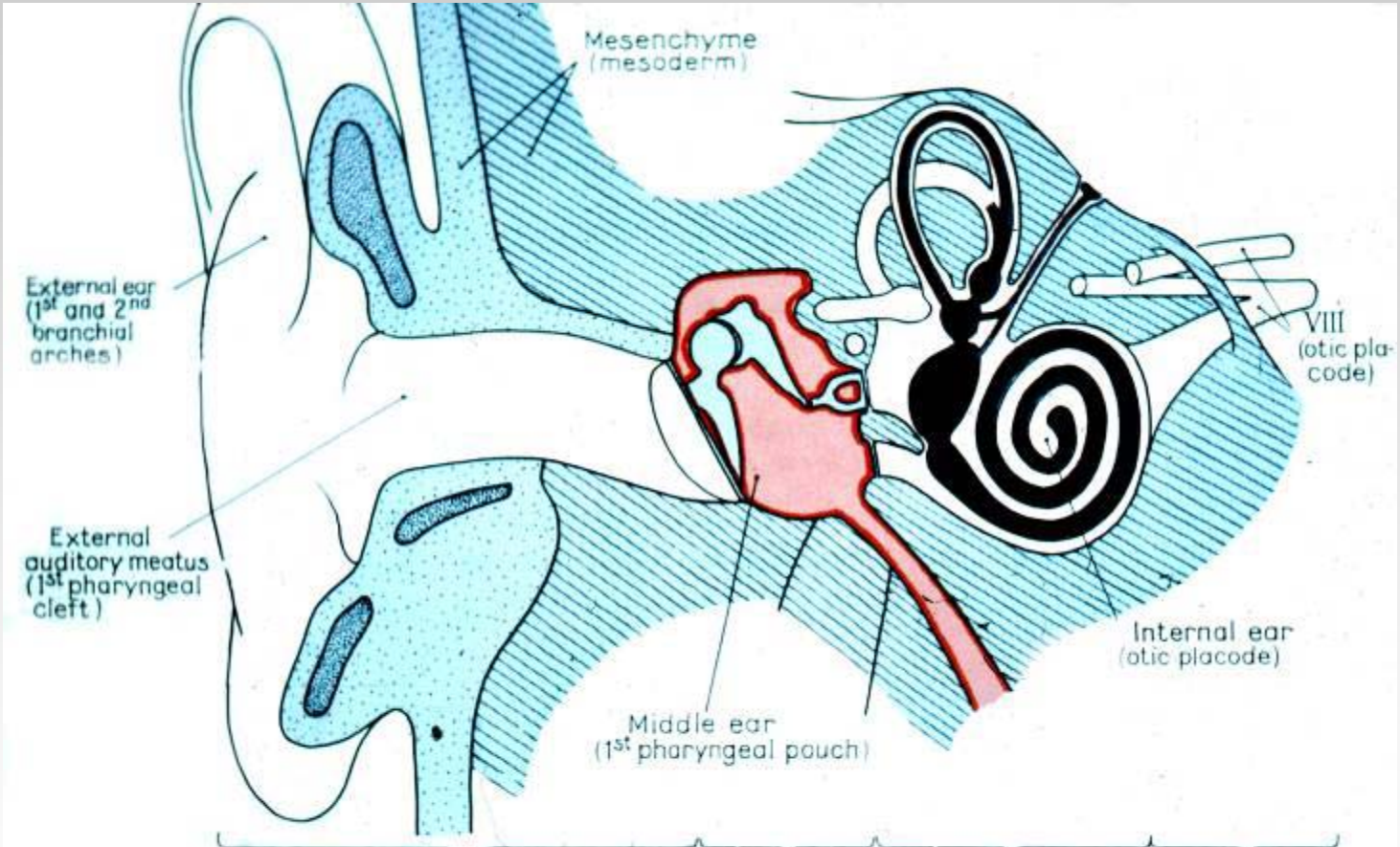
Anterior layer ⟶ contributes to cornea

Posterior layer ⟶ pupillary membrane

Between anterior and posterior layers: anterior chamber of eye

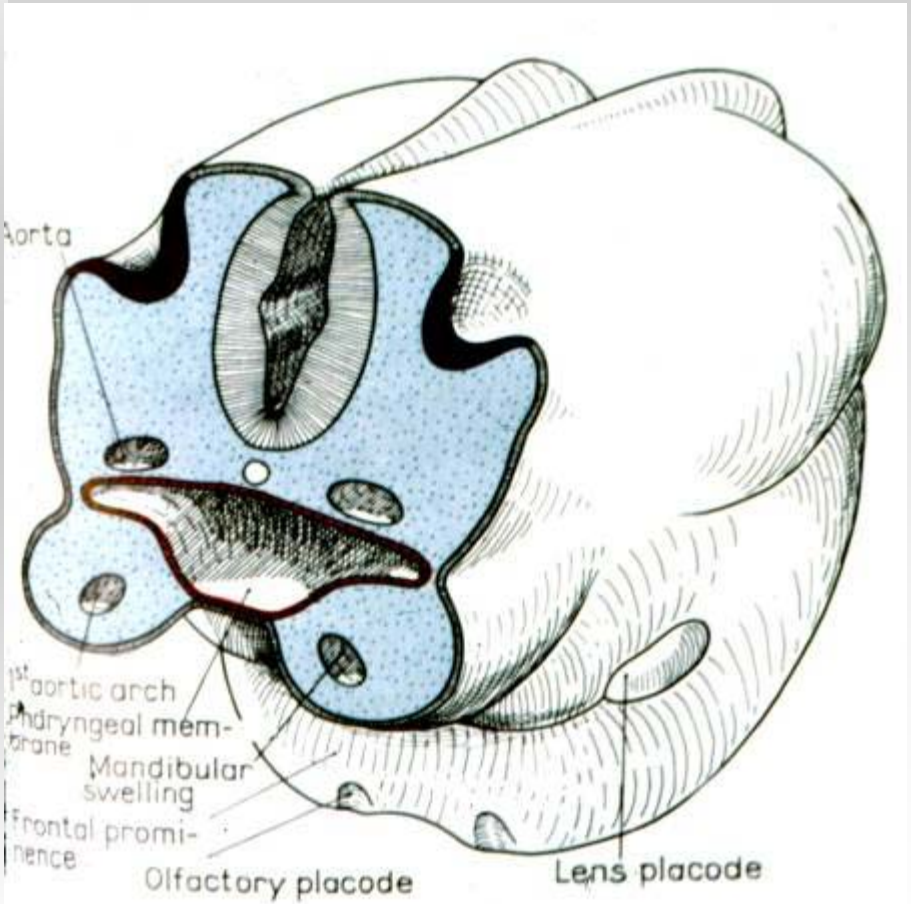
Behind posterior layer: posterior chamber.

Development of inner ear



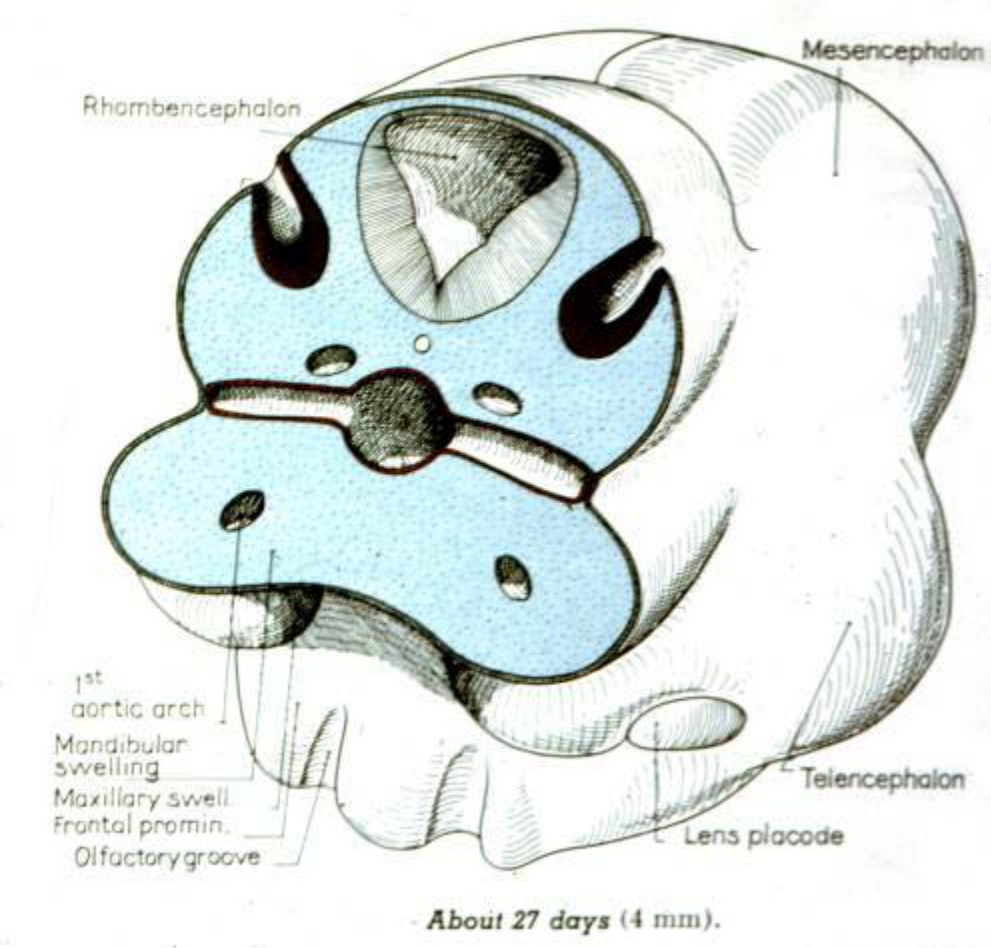
Human adult ear.

Otic placode invagination: otic pit



About 24 days (3 mm).

Otic pit to otic vesicle

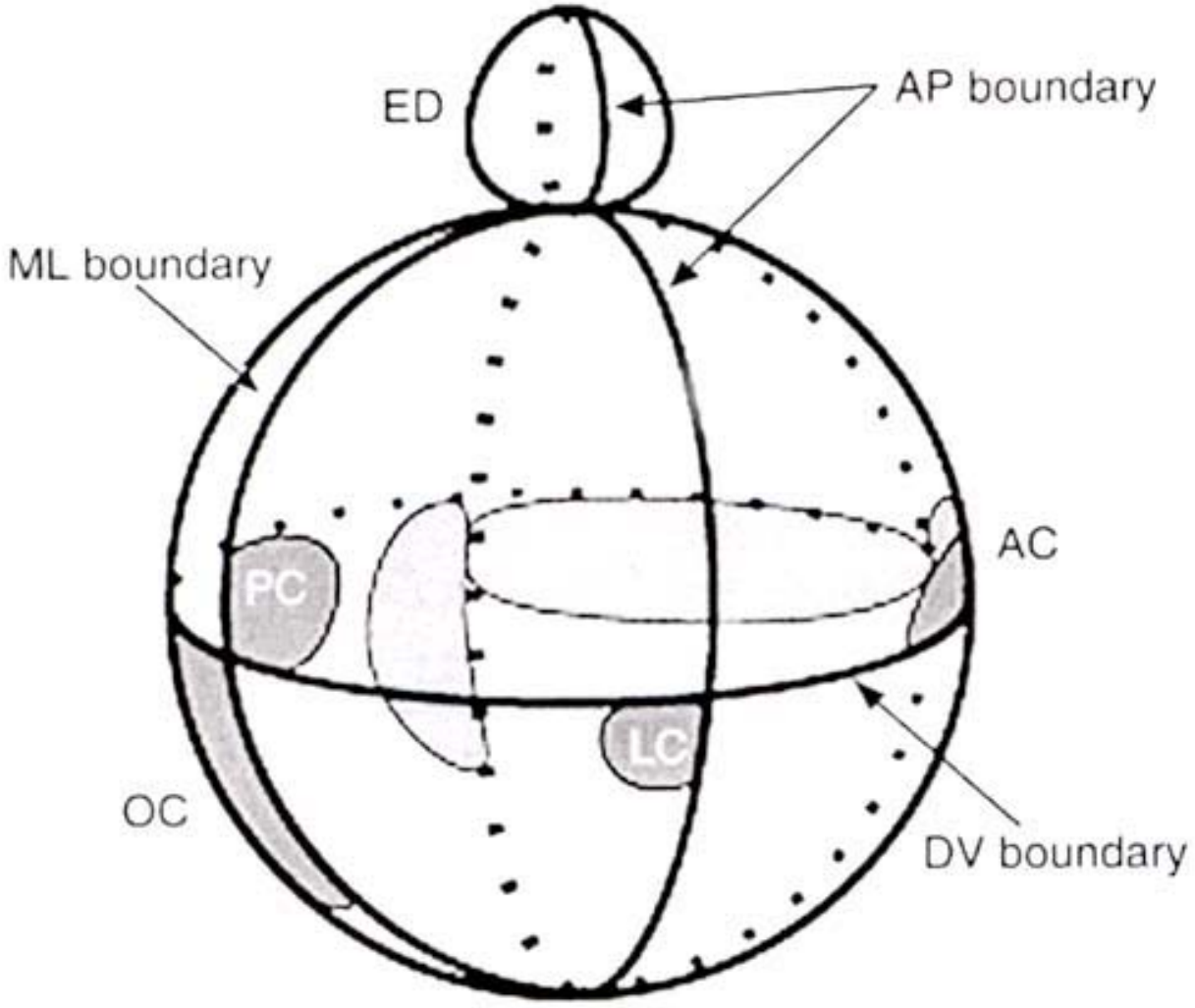


About 27 days (4 mm).

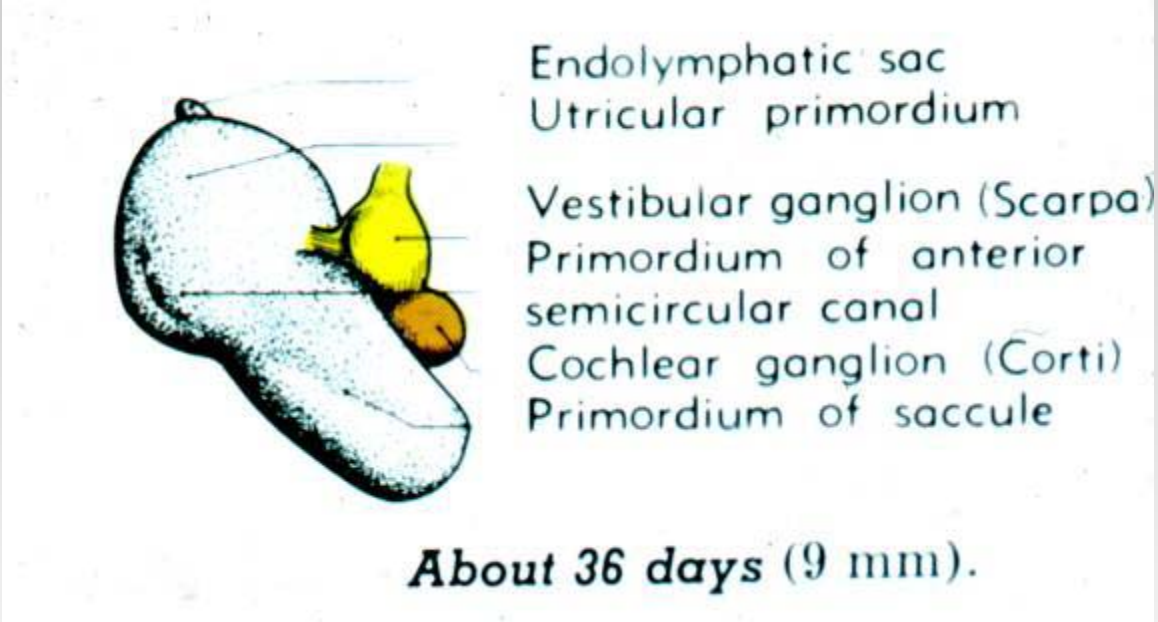
Some placodal cells migrate out of vesicular wall: ⟶ statoacoustic ganglion of CN VIII

Differentiation compartments in the otocyst

Choo, D (2007)

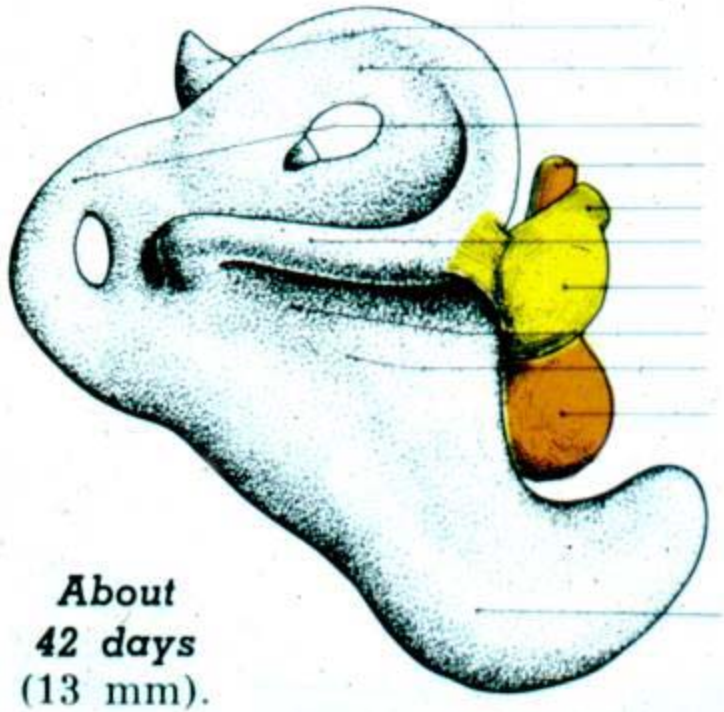


Differential growth of otic vesicle



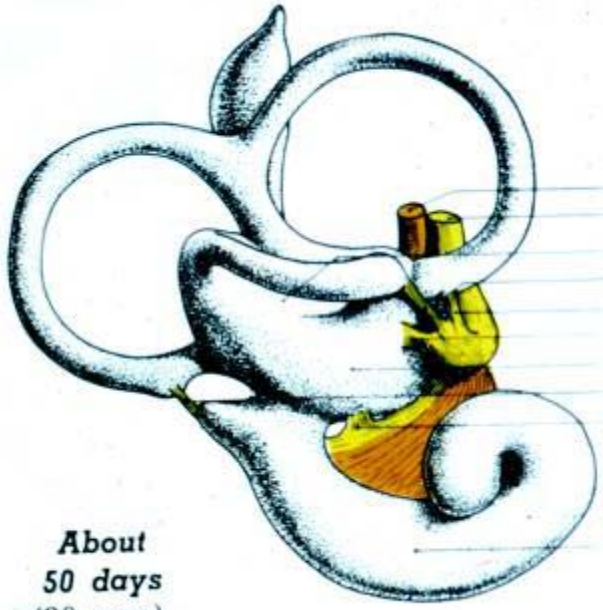
Saccule: ventral, will give rise to mature saccule and cochlea.

Utricle: dorsal, will give rise to mature utricle, semicircular canals and endolymphatic duct.



Endolymphatic sac
Anter-semicircular canal
Poster-semicircular canal
Cochlear nerve
Vestibular nerve
Extern-semicircular canal
Vestibular ganglion
Utricle
Saccule
Cochlear ganglion
Cochlea

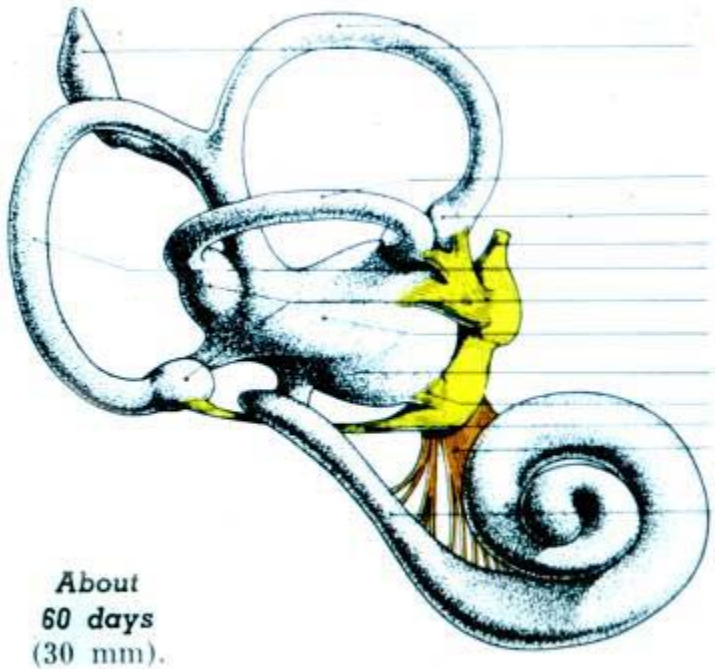
About 42 days (13 mm).



Cochlear nerve
Vestibular nerve
Utricle
External ampullary nerve
Anterior ampullary nerve
Utricular nerve
Saccule
Posterior ampullary nerve
Saccular nerve

Cochlea

About 50 days (20 mm).



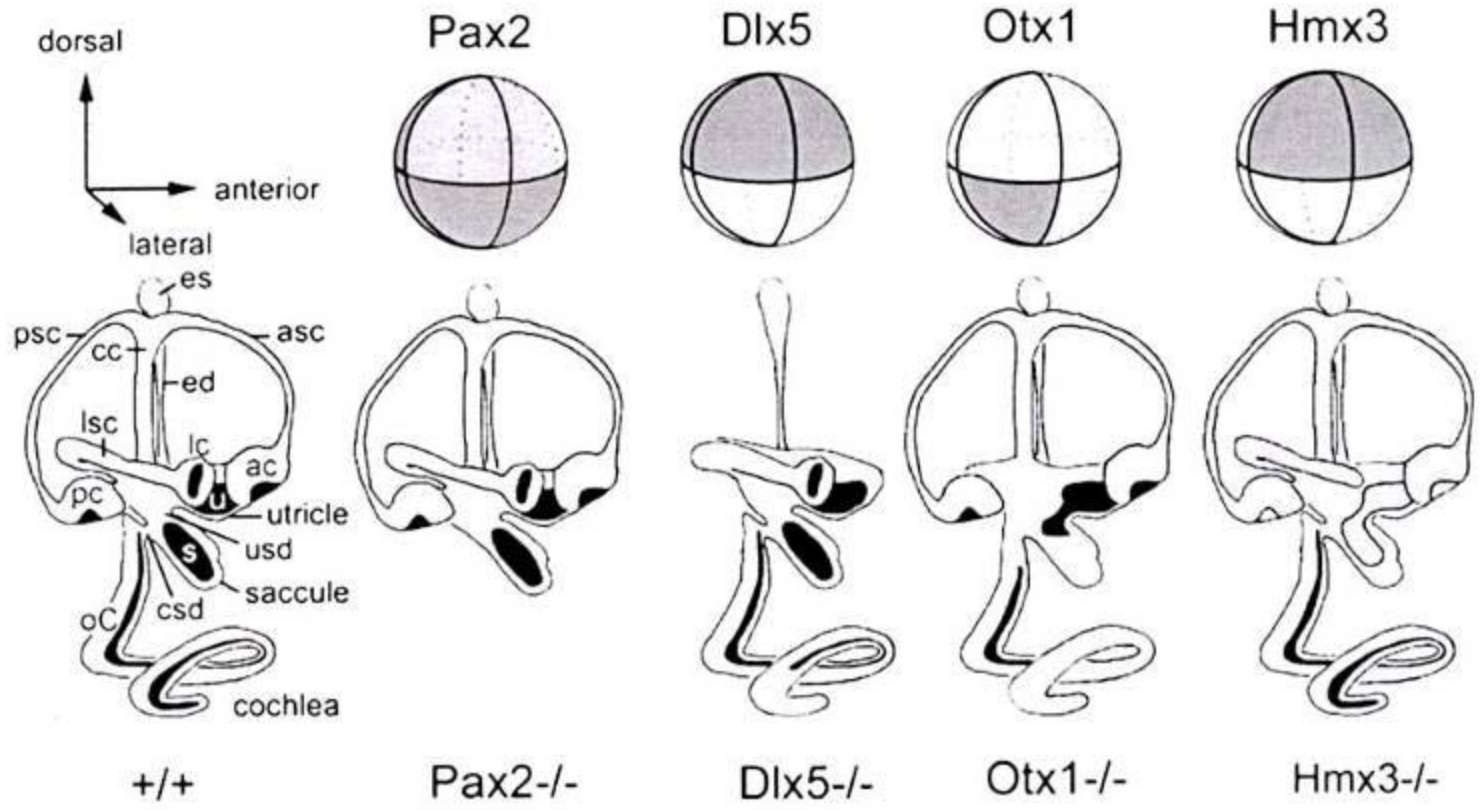
Anter. semicircular canal
Endolymphatic sac

External semicircular canal
Ampulla
Vestibular nerve
Poster. semicircular canal
Ampullae
UTRICLE / VESTIBULE
SACCULE
Saccular nerve
Posterior ampullar nerve
Cochlear nerve

Cochlea

About 60 days (30 mm).

Factors controlling the patterning of the otocyst



Choo, D (2007)

Otic capsule: future petrous part of temporal bone