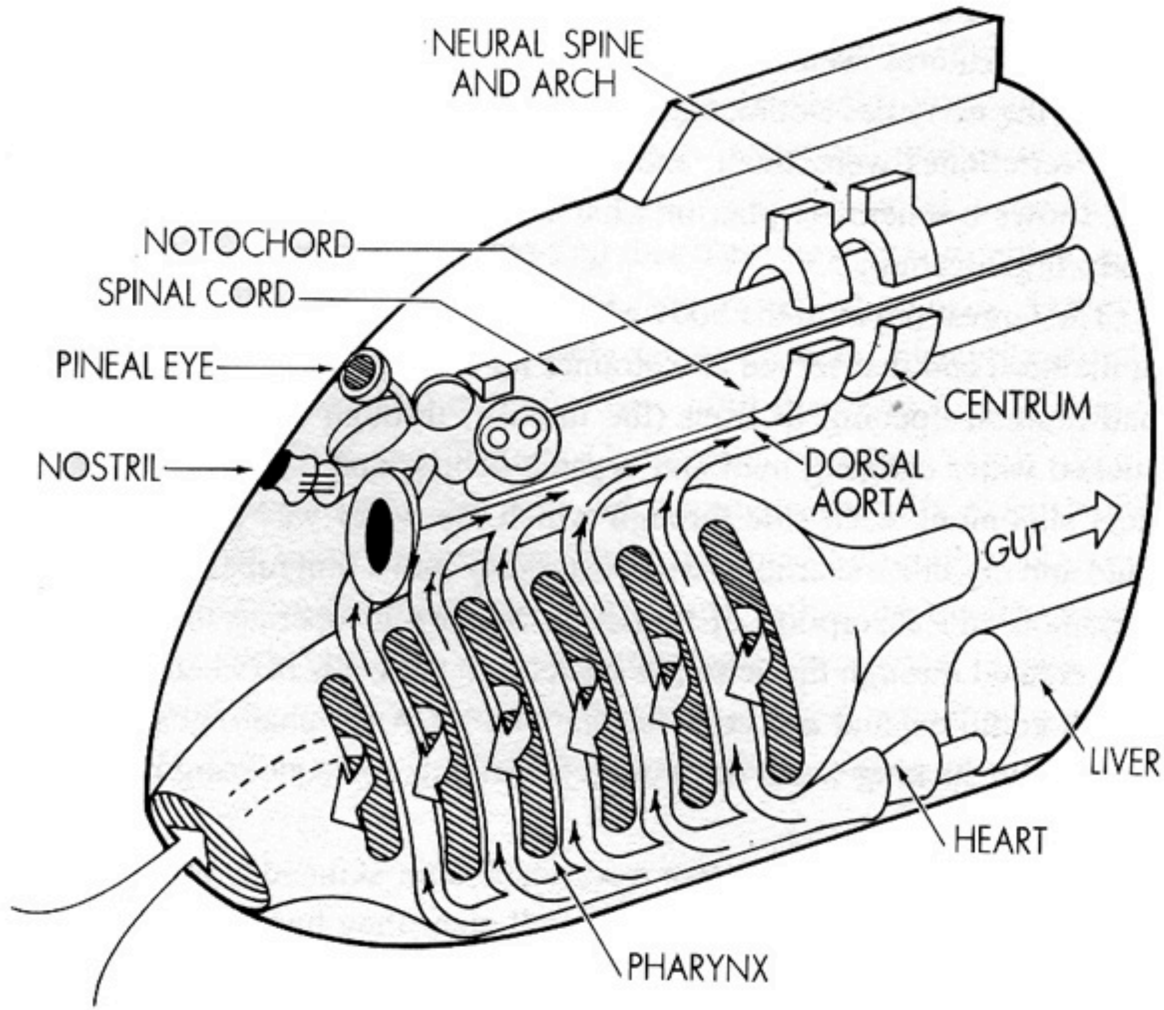
Biology 340
Comparative Embryology
Lecture 11
Dr. Stuart Sumida

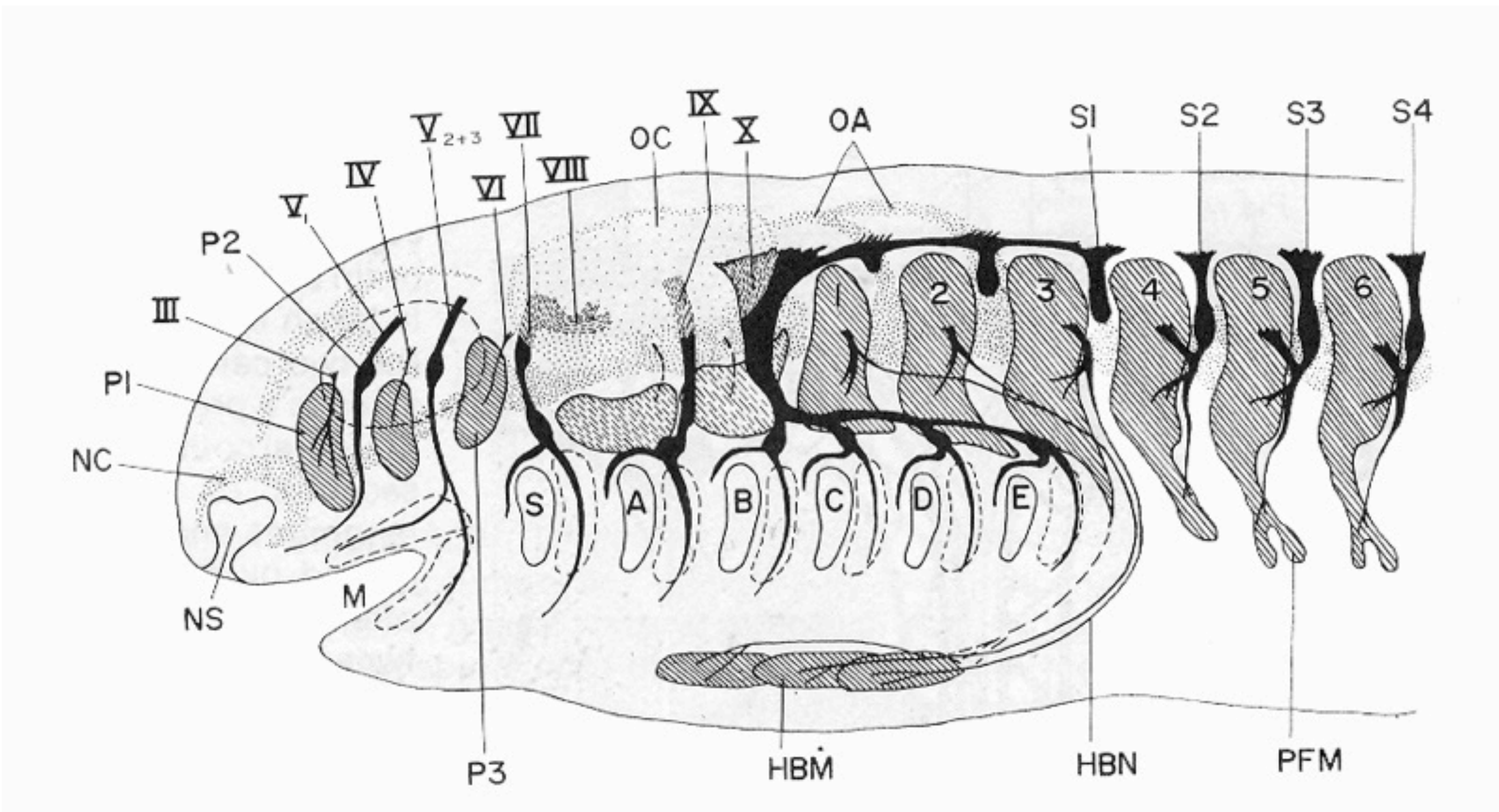
Overview of Embryology of the Vertebrate Skull

Emphasis on Amniota

Initial introduction to components parts of a vertebrate head.

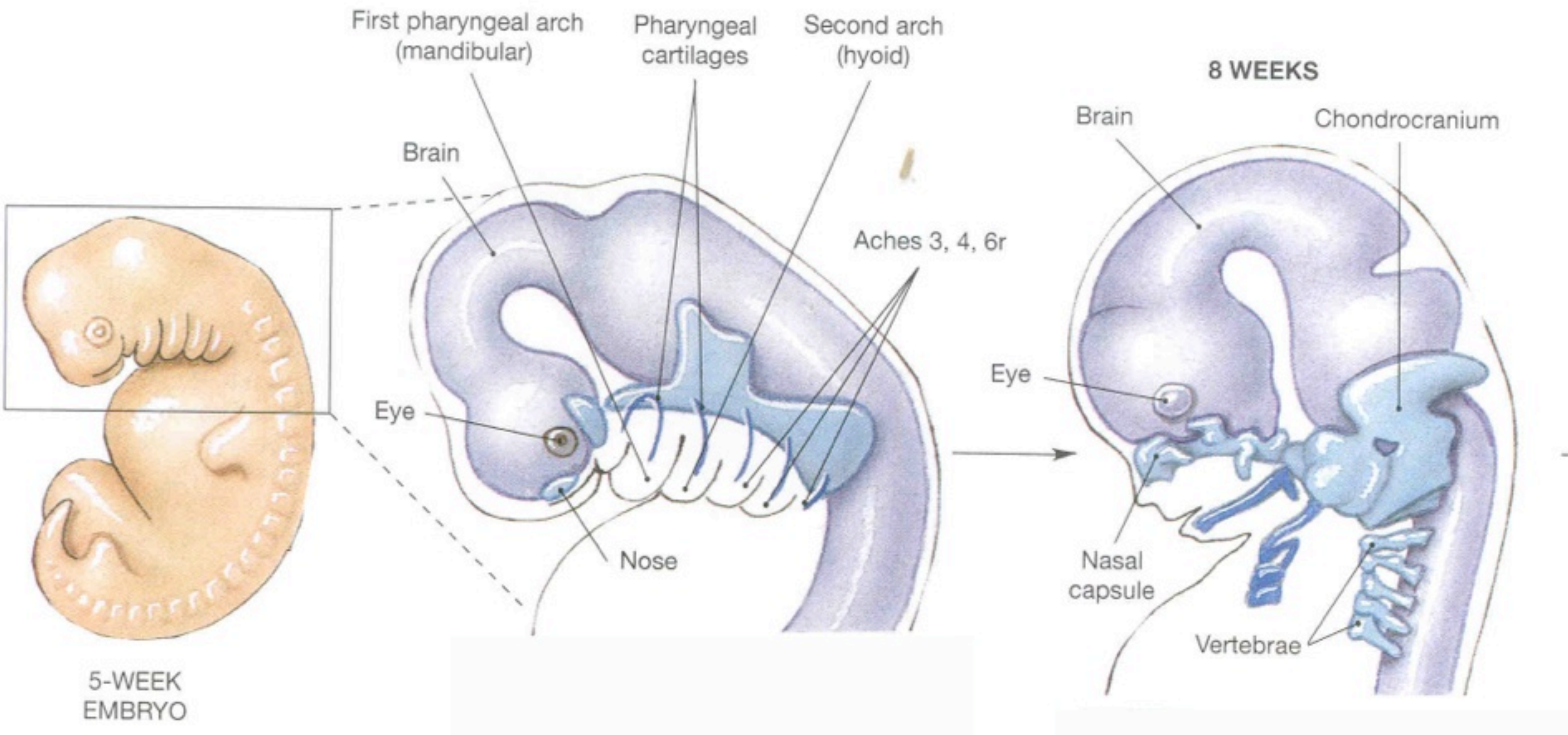


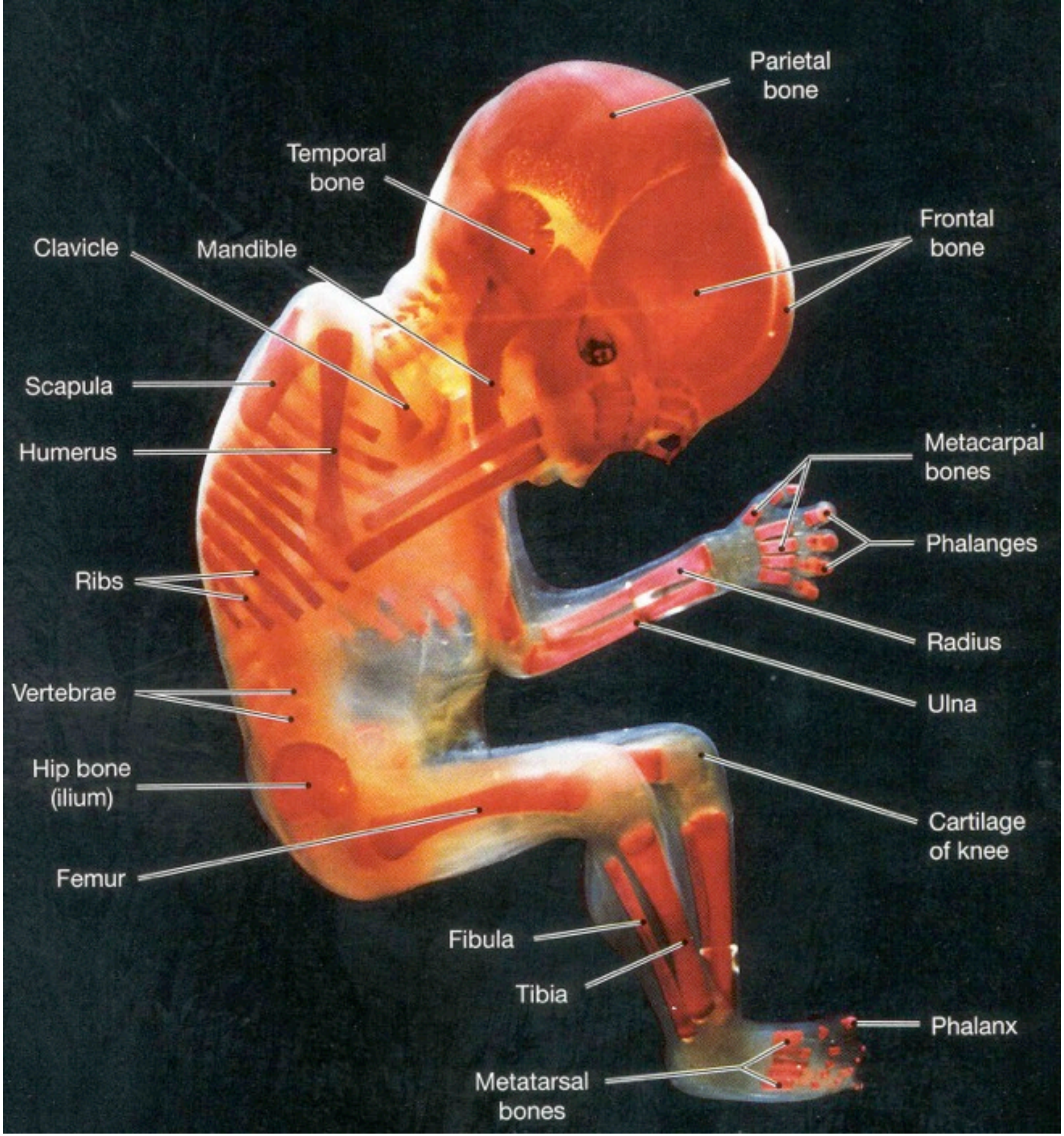
This lecture will revolve around the early embryology of the vertebrate skull. One of the landmark achievments in this was the summary of that topic – based initially the developing embryonic shark head – by Edwin S. Goodrich. Thus it has come to be known as the "Goodrich Diagram".



We will draw our own version of it before we go on to a slide review.

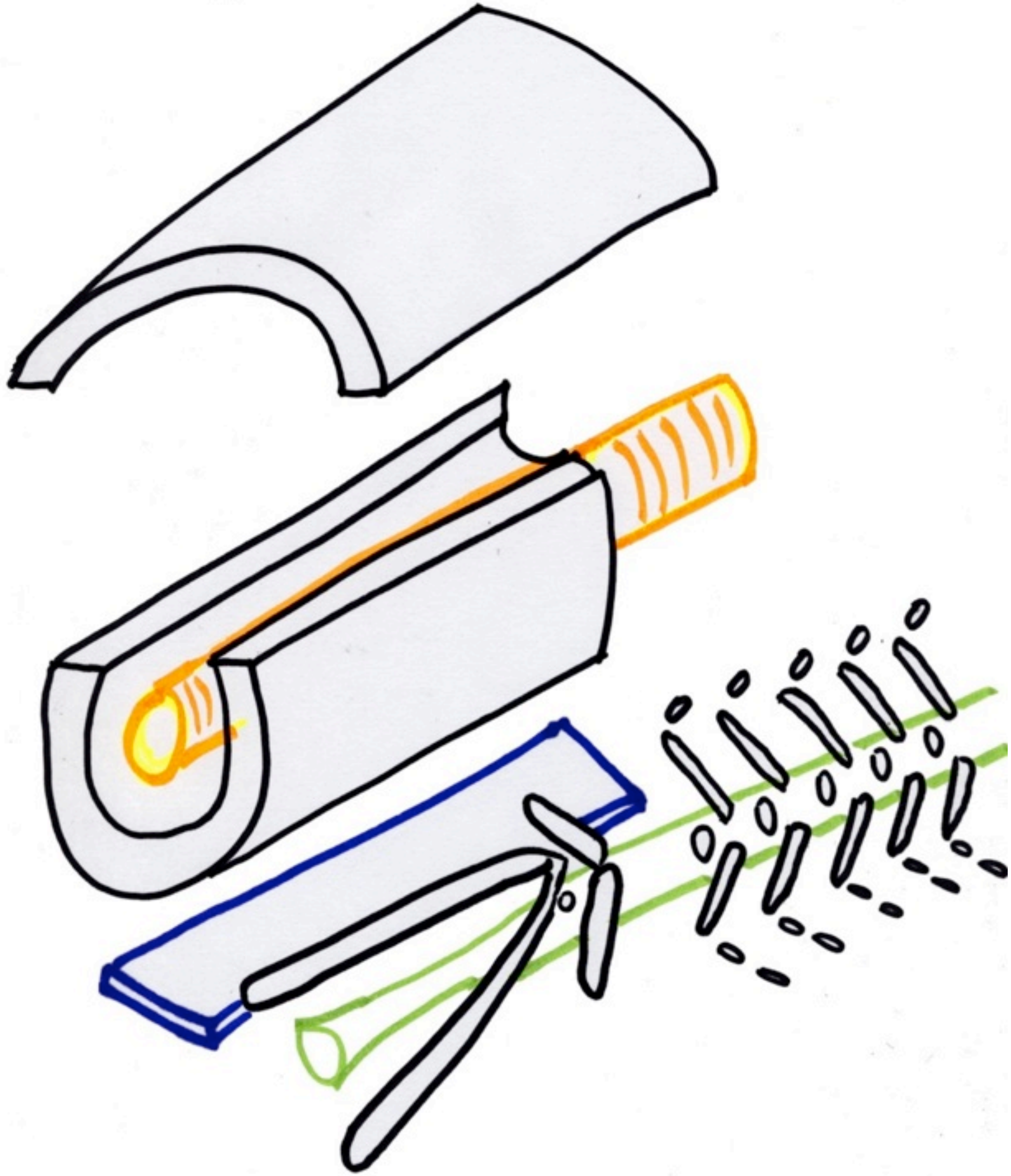
If you’ re working with the PowerPoint files, save space in your notes to draw here.

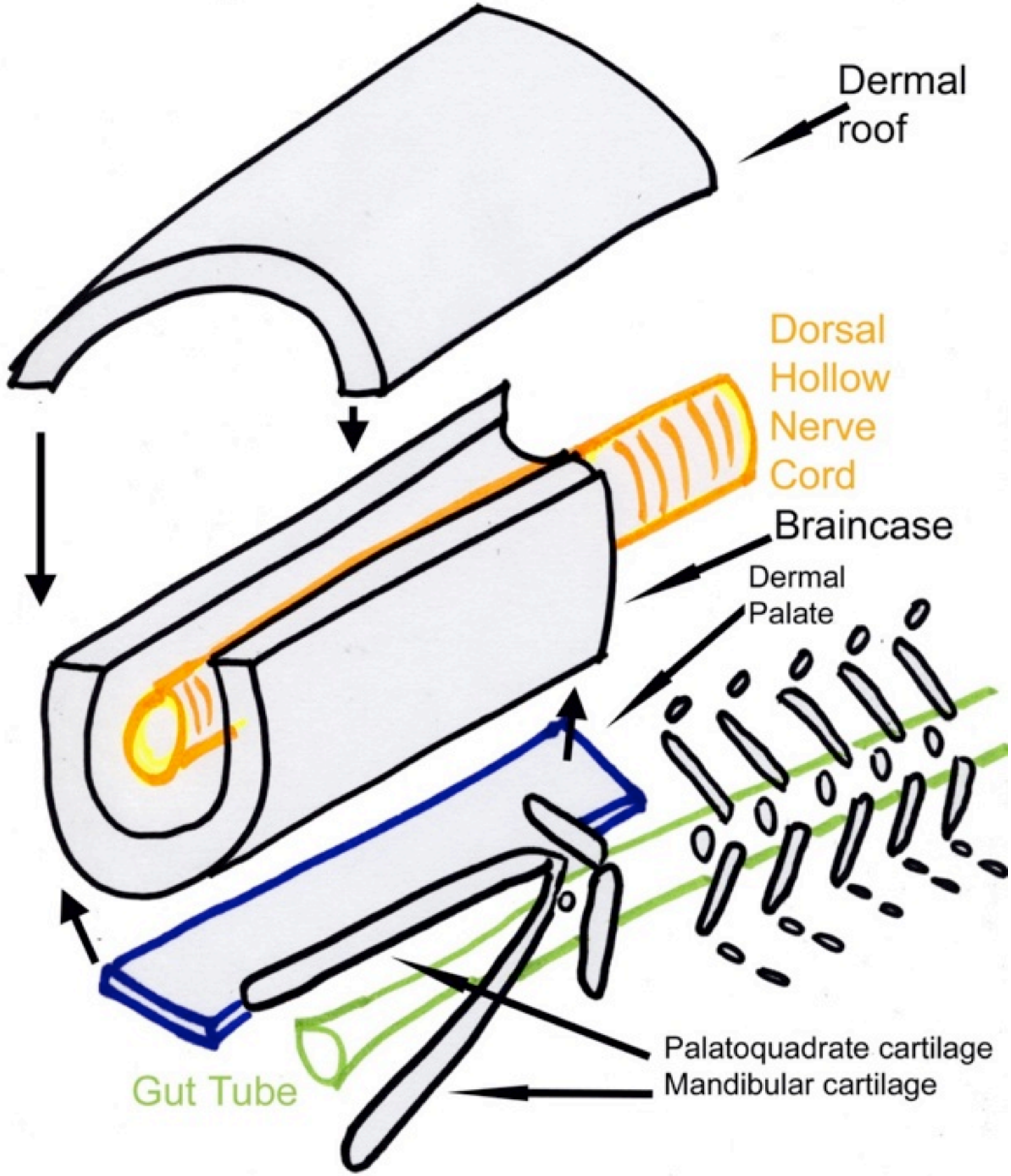

First pharyngeal arch
(mandibular)
Pharyngeal
cartilages
Second arch
(hyoid)
8 WEEKS
Brain
Chondrocranium
Brain
Aches 3, 4, 6r
Eye
Eye
Nose
Nasal
capsule
Vertebrae
5-WEEK
EMBRYO


Parietal bone
Temporal bone
Frontal bone
Clavicle
Mandible
Scapula
Humerus
Metacarpal bones
Phalanges
Ribs
Radius
Vertebrae
Ulna
Hip bone (ilium)
Cartilage of knee
Femur
Fibula
Tibia
Phalanx
Metatarsal bones

The developing skull has three component origins:

- **Condrocranium (base of skull / braincase)**
- **Dermatocranium (flat bones of skull)**
- **Splanchnocranium (bones derived from gill arch elements)**



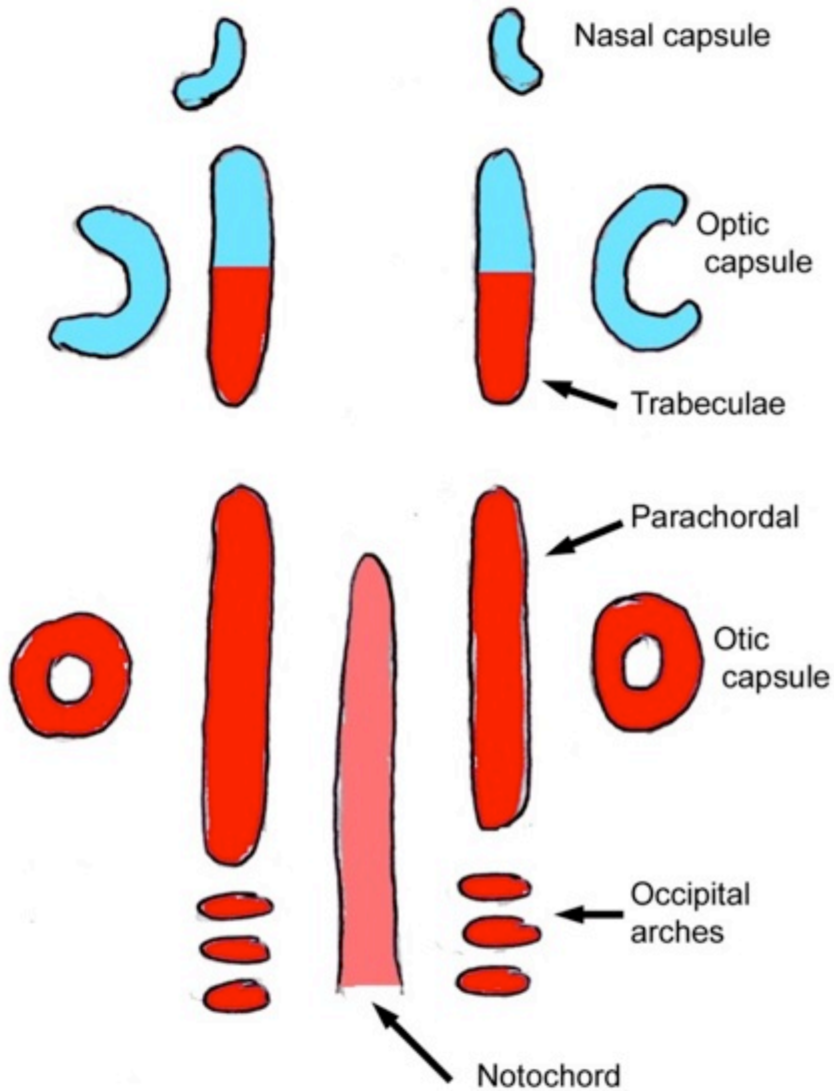


Dermal roof
Dorsal Hollow Nerve Cord
Braincase
Dermal Palate
Palatoquadrate cartilage
Mandibular cartilage
Gut Tube

	Mode of Formation	Germ Layer Origin
Condrocranium	Endochondral	Mesoderm & Neural Crest
Dermatocranium	Intramembranous	Mesoderm & Neural Crest
Splanchnocranium	Endochondral	Neural Crest

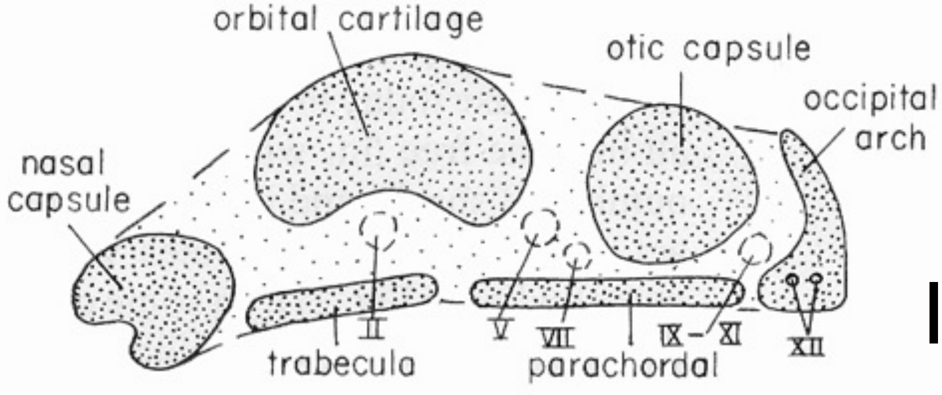
CHONDROCRANIUM: Bones of the base of the skull.

- Most major cranial nerves escape the skull through these.
- Endochondral
- Neural Crest rostrally; Mesodermal caudally
- Include: ethmoid, sphenoid (part), occipital (part) right and left temporal (parts).

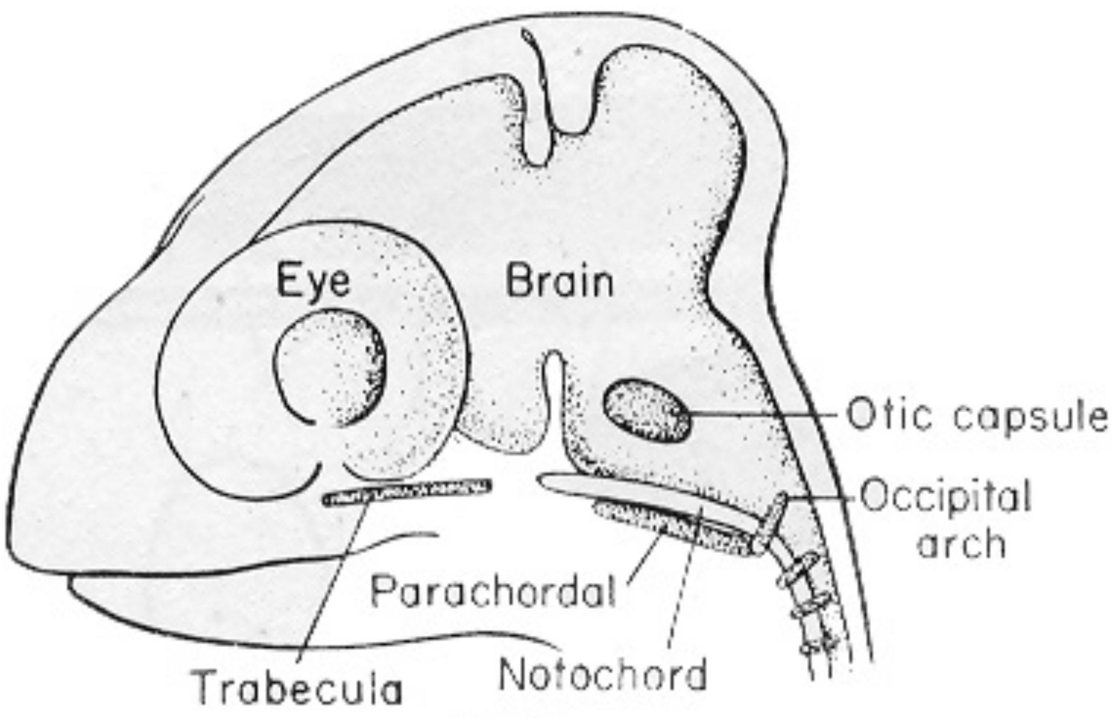


Chondrocranium precursors

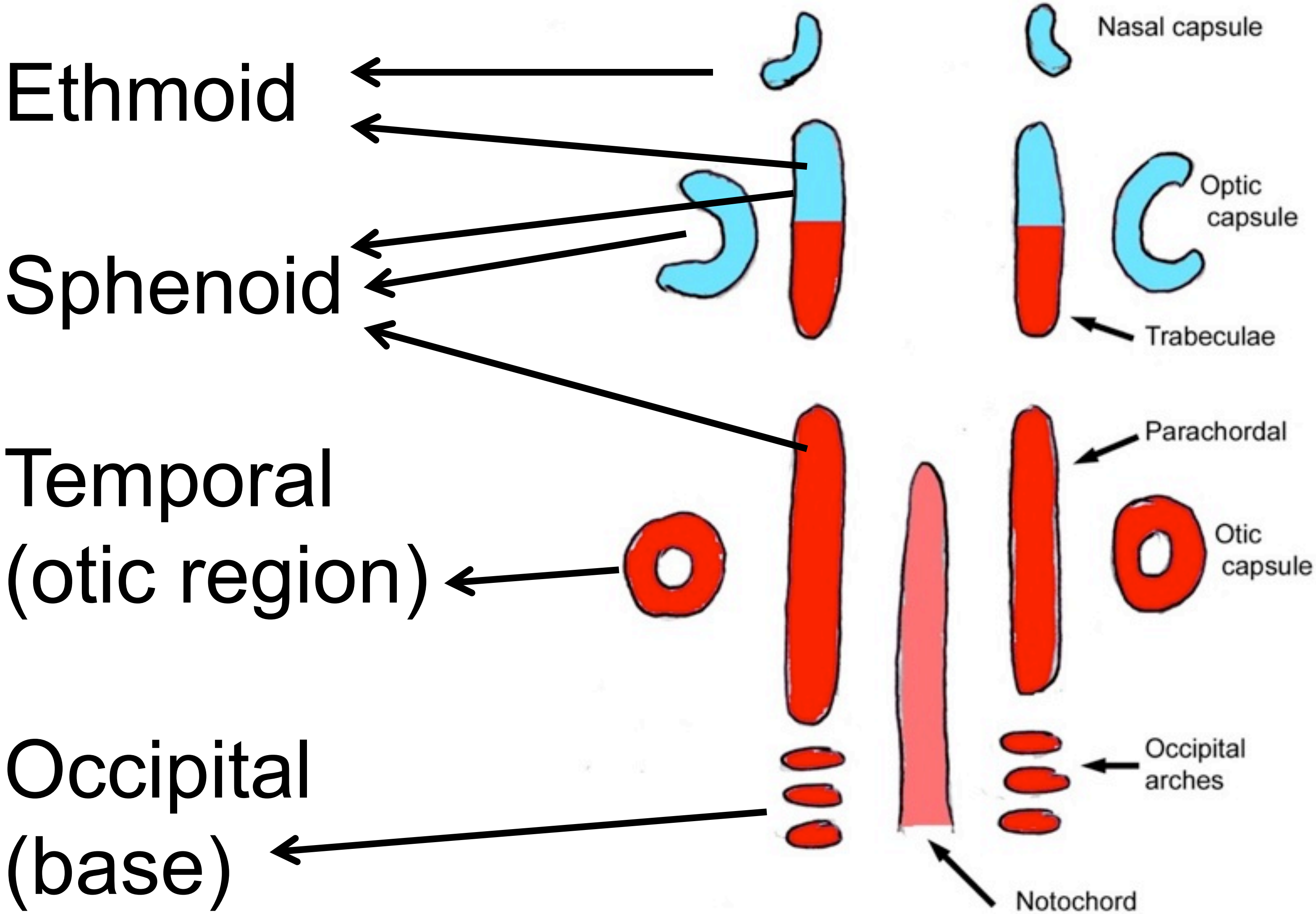
Dorsal view



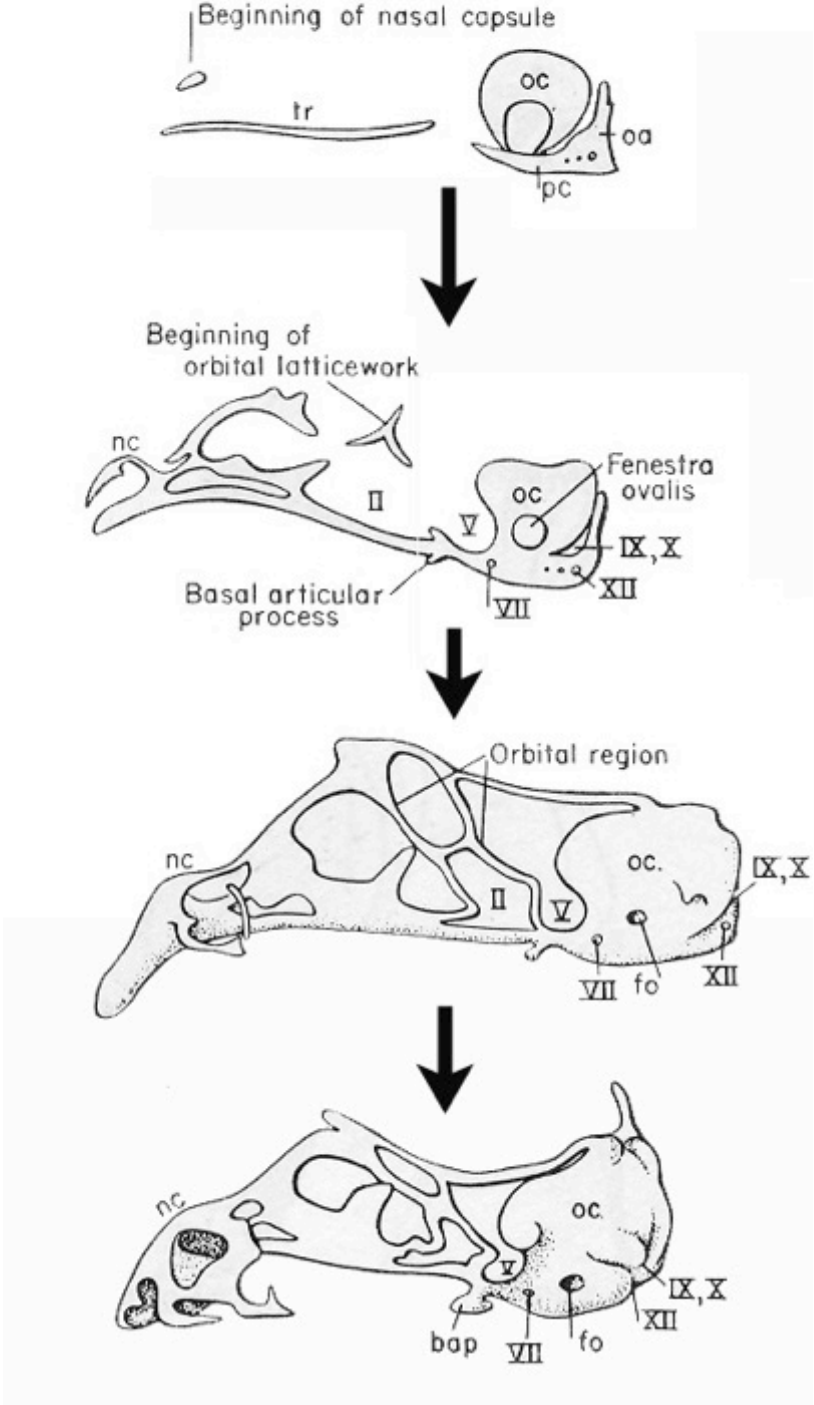
Initial component parts of the vertebrate braincase.



Embryonic Braincase Structure	Embryonic derivation	Adult structure
Nasal capsule	Neural crest	Ethmoid (in part)
Trabeculae		
Anterior trabeculae	Neural crest	Ethmoid in part; anterior part of sphenethmoid
Posterior trabeculae	Mesoderm	Basisphenoid
Optic capsule	Neural crest	
Parachordal cartilage	Mesoderm	Basioccipital
Otic capsule	Mesoderm	Otic capsule and part of basioccipital
Occipital arches	Mesoderm	Basioccipital in part; paired exooccipitals; supraoccipital

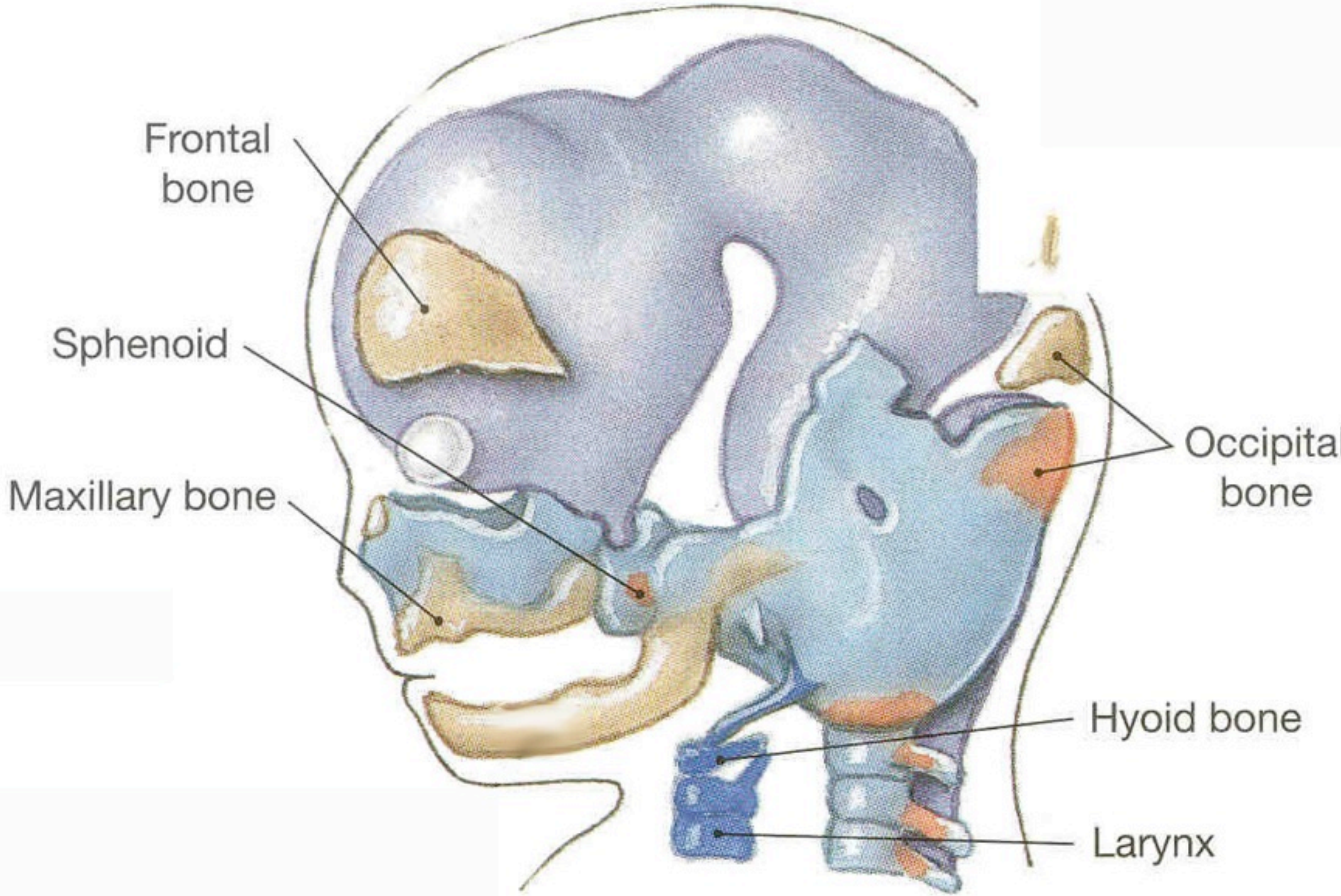


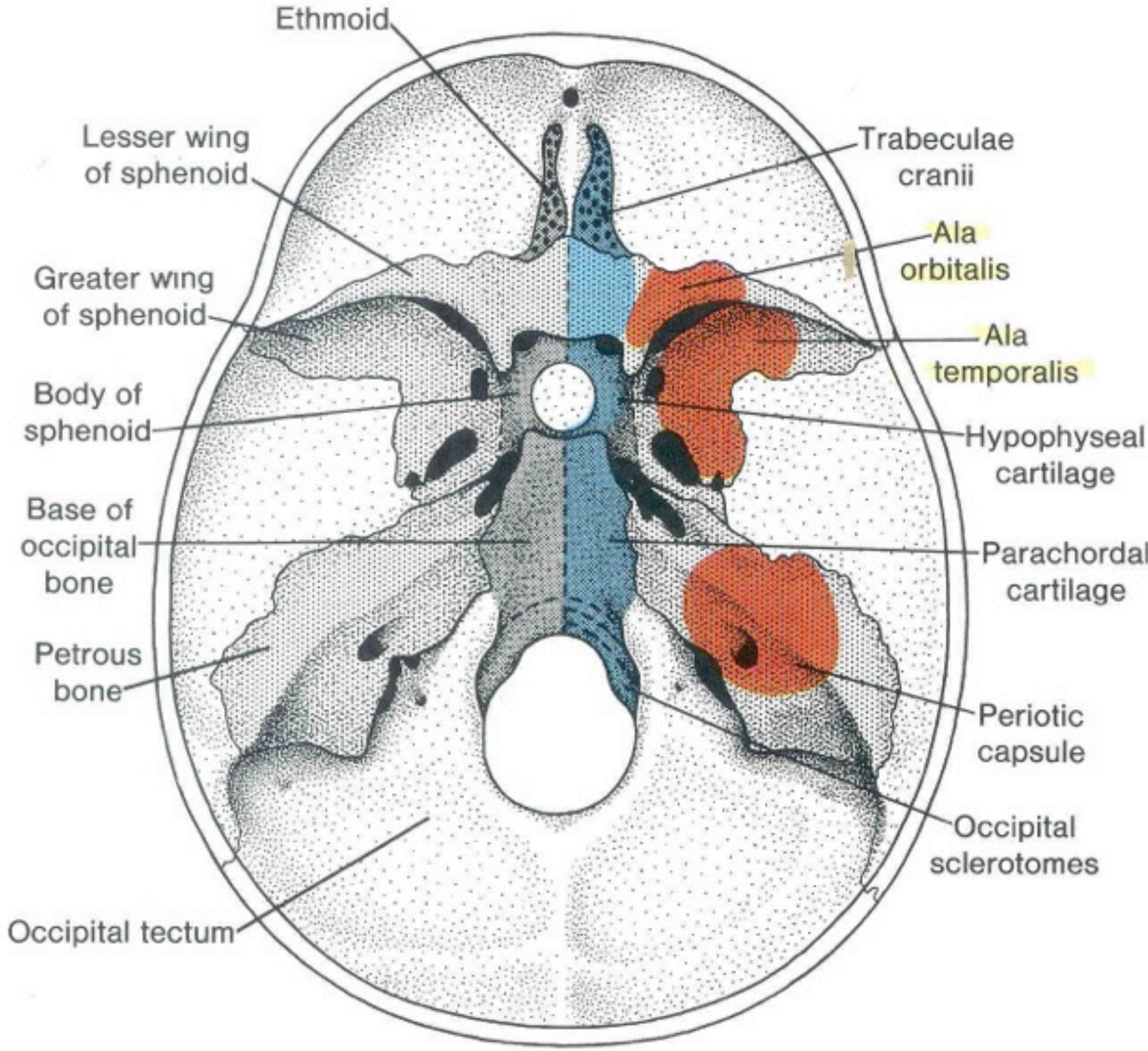
Ethmoid
Sphenoid
Temporal (otic region)
Occipital (base)
Nasal capsule
Optic capsule
Trabeculae
Parachordal
Otic capsule
Occipital arches
Notochord



How the parts of the braincase grow together.

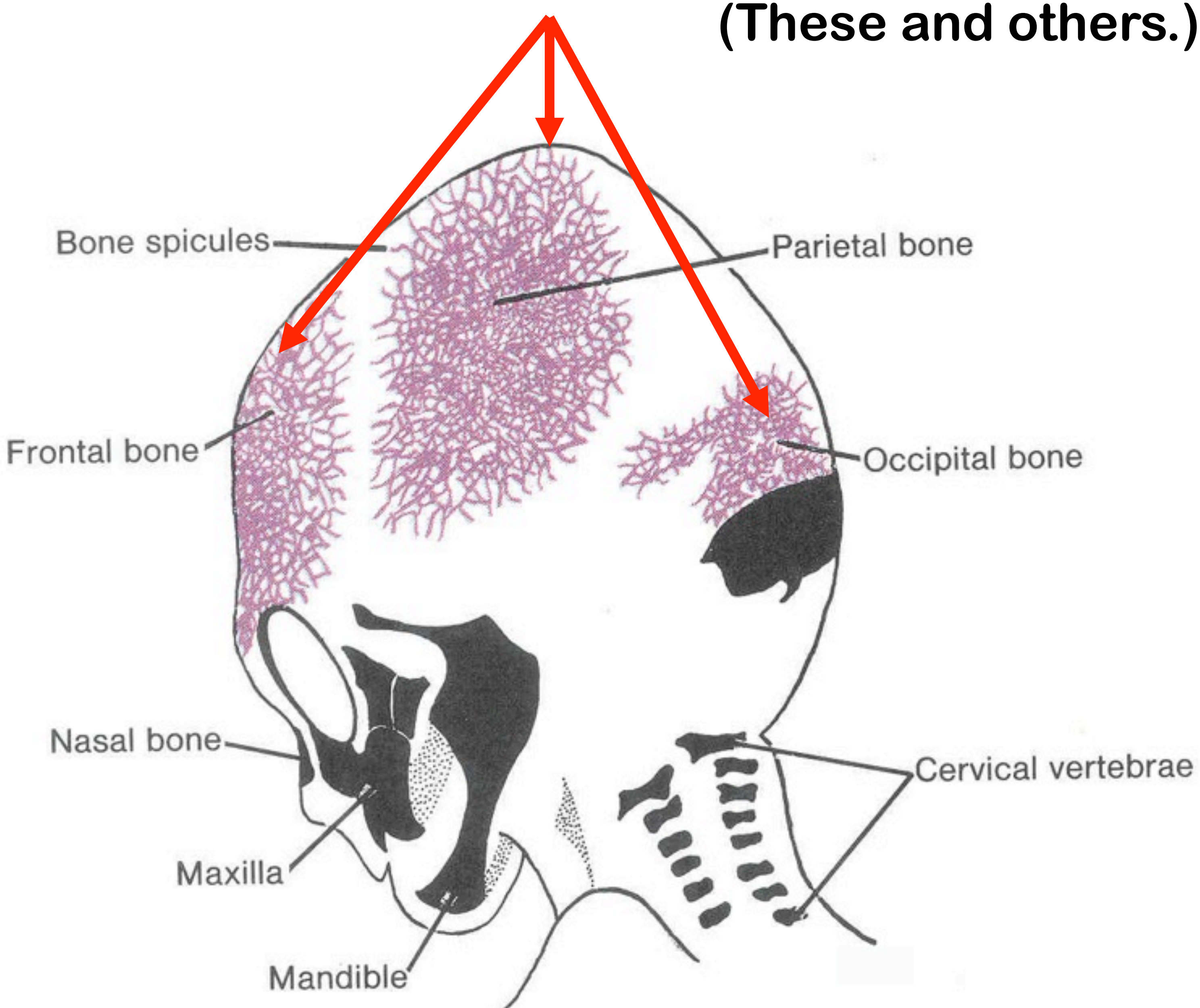
9 WEEKS

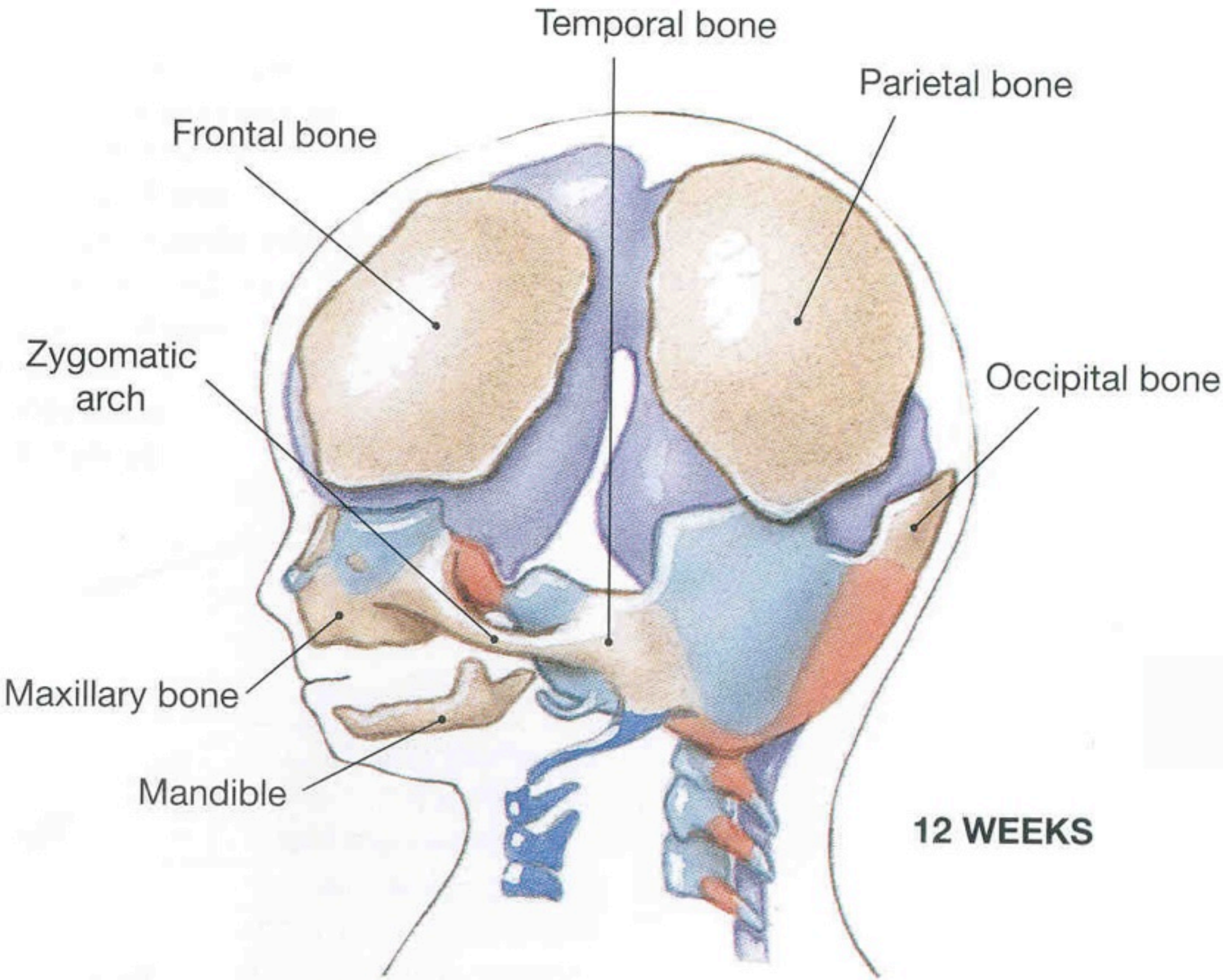

Frontal bone
Sphenoid
Maxillary bone
Occipital bone
Hyoid bone
Larynx



Schematized dorsal view of the chondrocranium or base of the skull in the adult. On the right are indicated in blue the various embryonic components participating in the formation of the median part of the chondrocranium; in red the components for the lateral part of the chondrocranium. On the left are indicated the names of the adult structures.

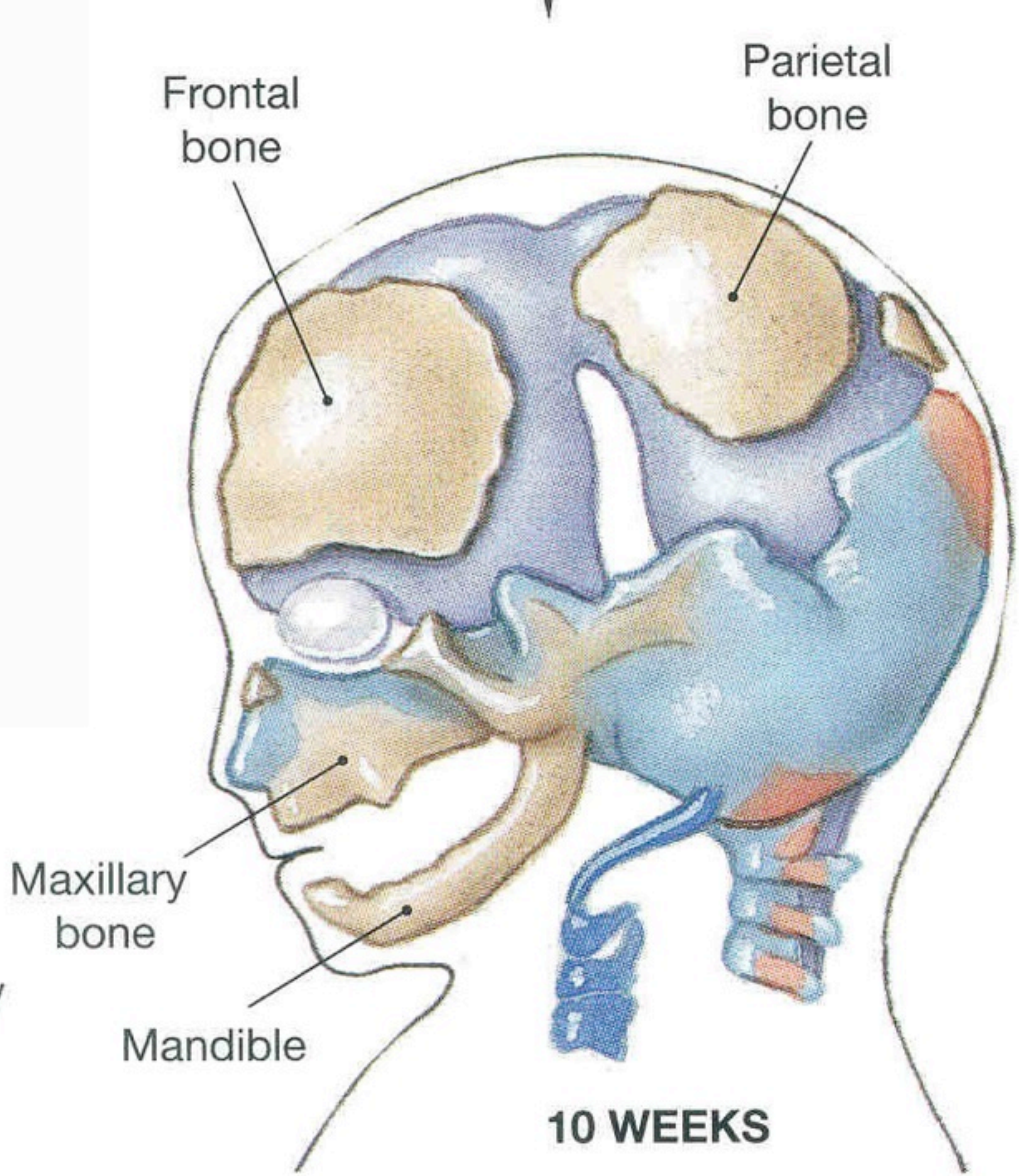
Flat bones of skull: DERMATOCRANIUM
(These and others.)

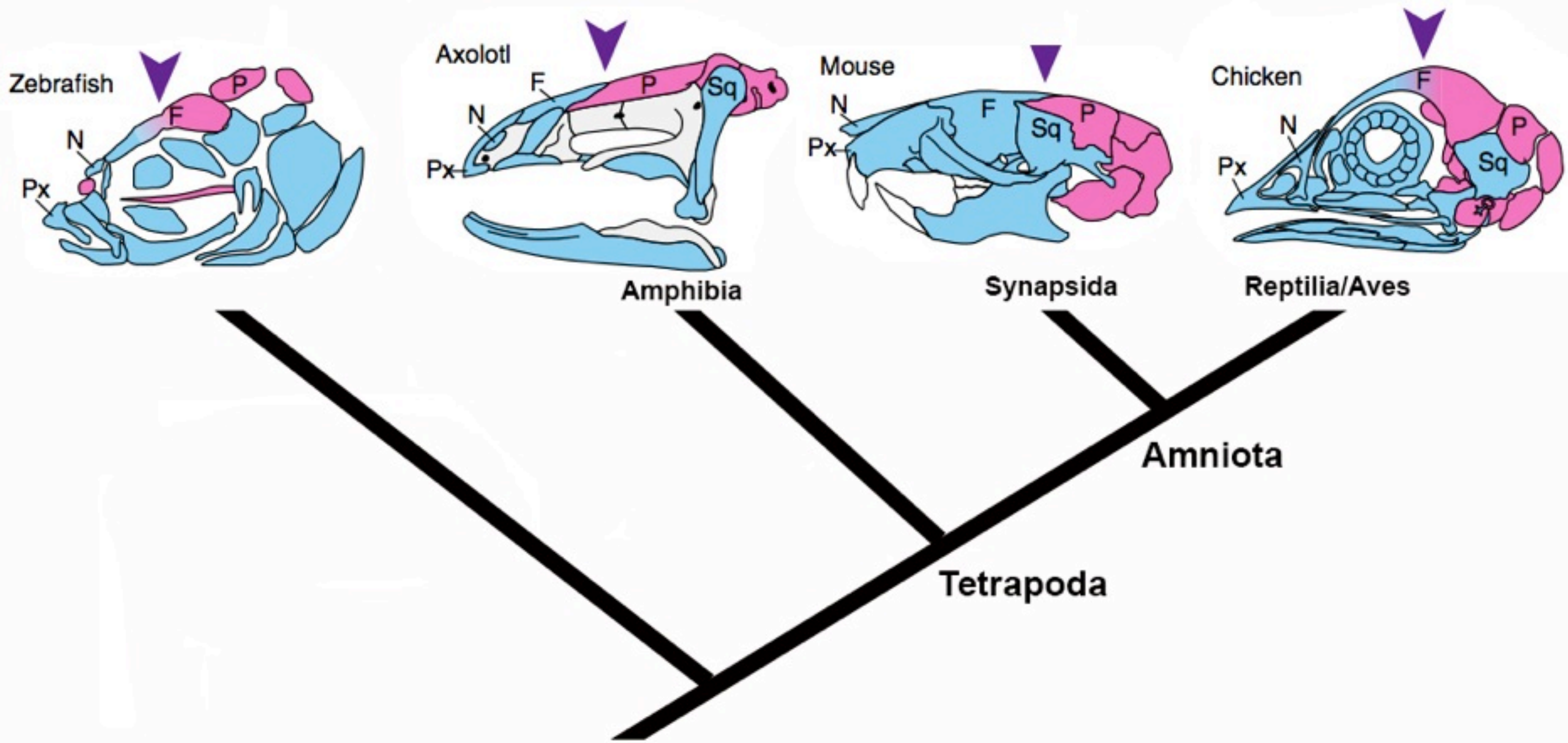




Temporal bone
Parietal bone
Frontal bone
Zygomatic arch
Occipital bone
Maxillary bone
Mandible
12 WEEKS

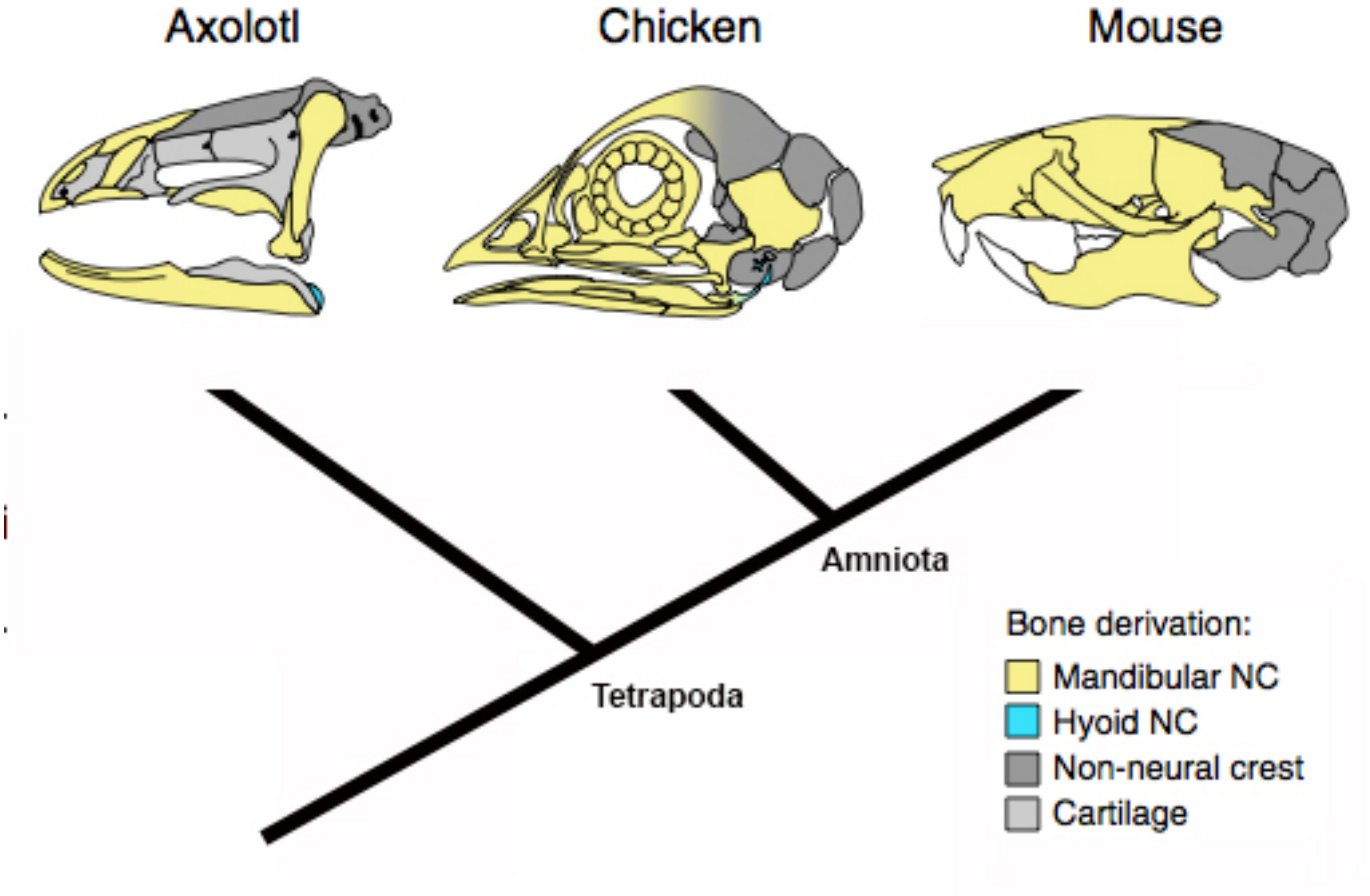
y


Frontal bone
Parietal bone
Maxillary bone
Mandible
10 WEEKS



The junction between neural crest and mesodermal contributions to the dermatocranium has changed through vertebrate evolution.

Generally in region of frontal-parietal complex.



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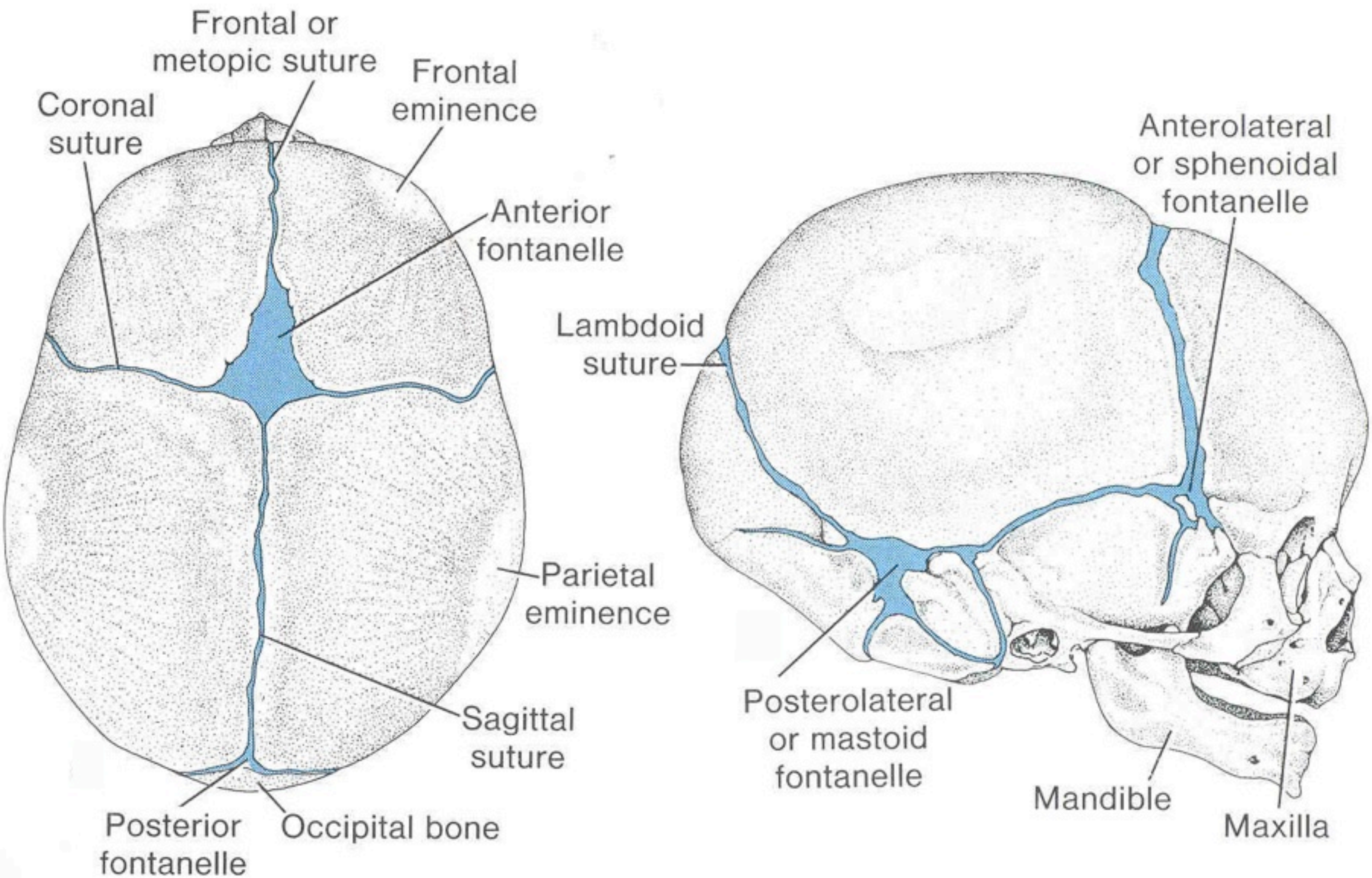
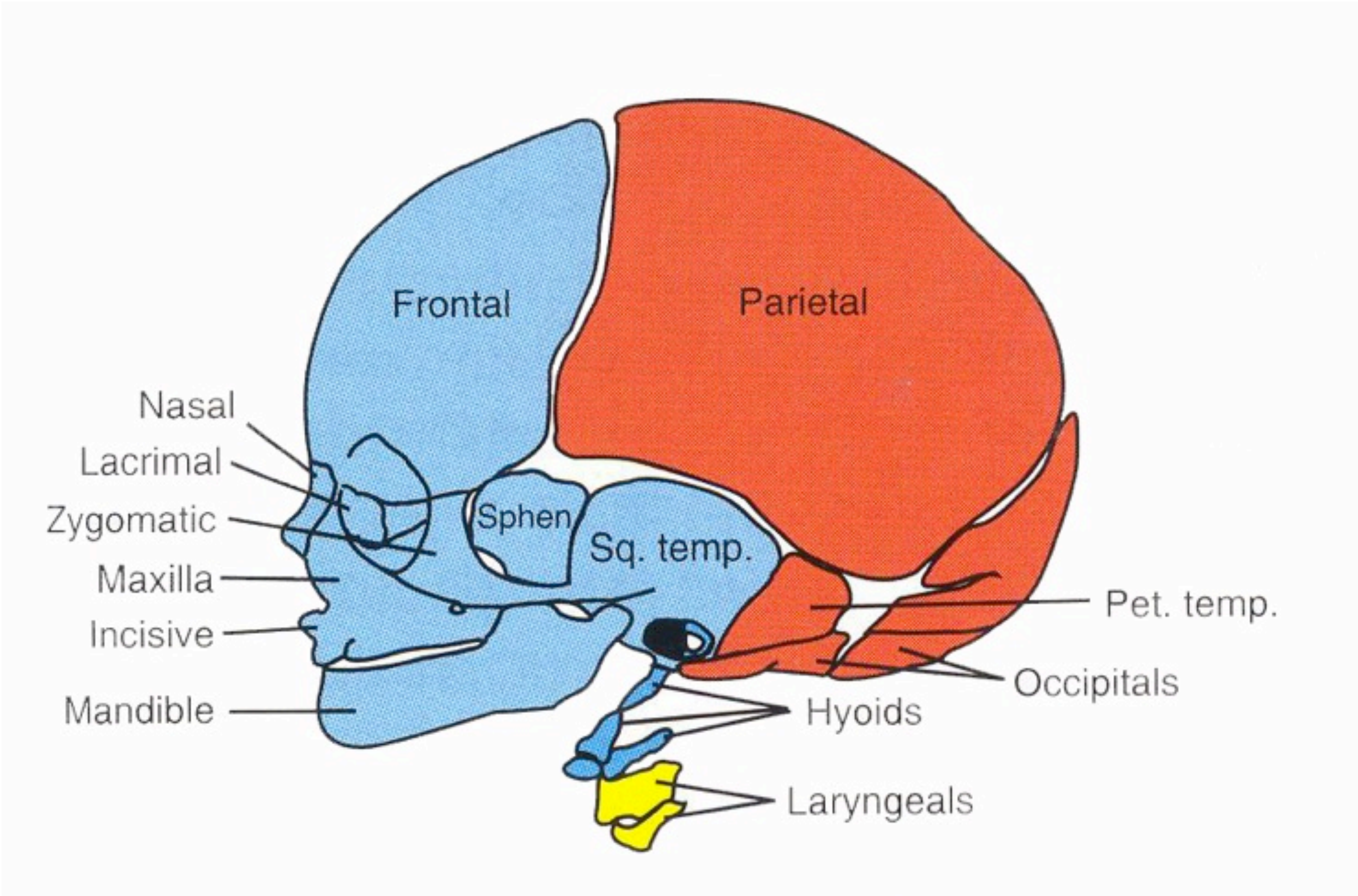
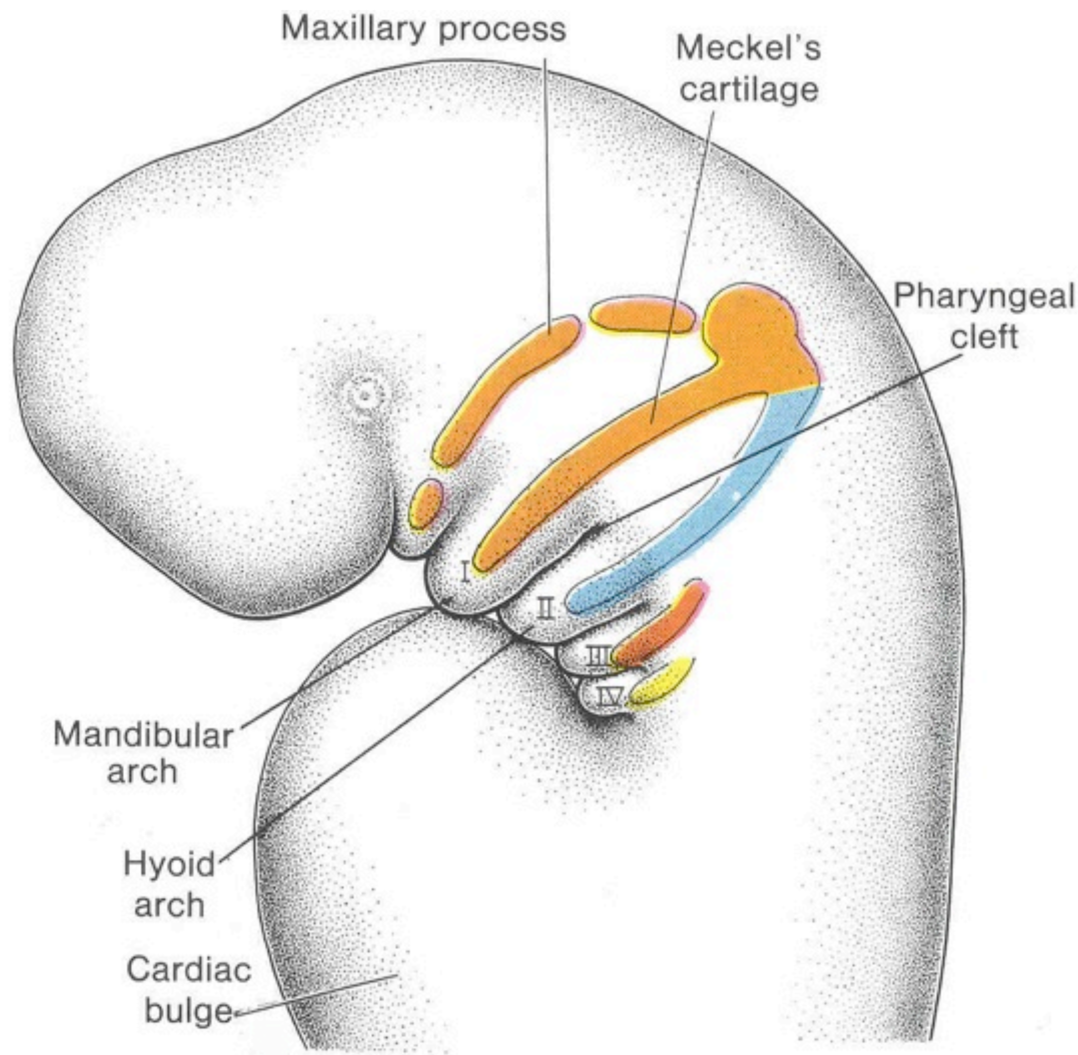
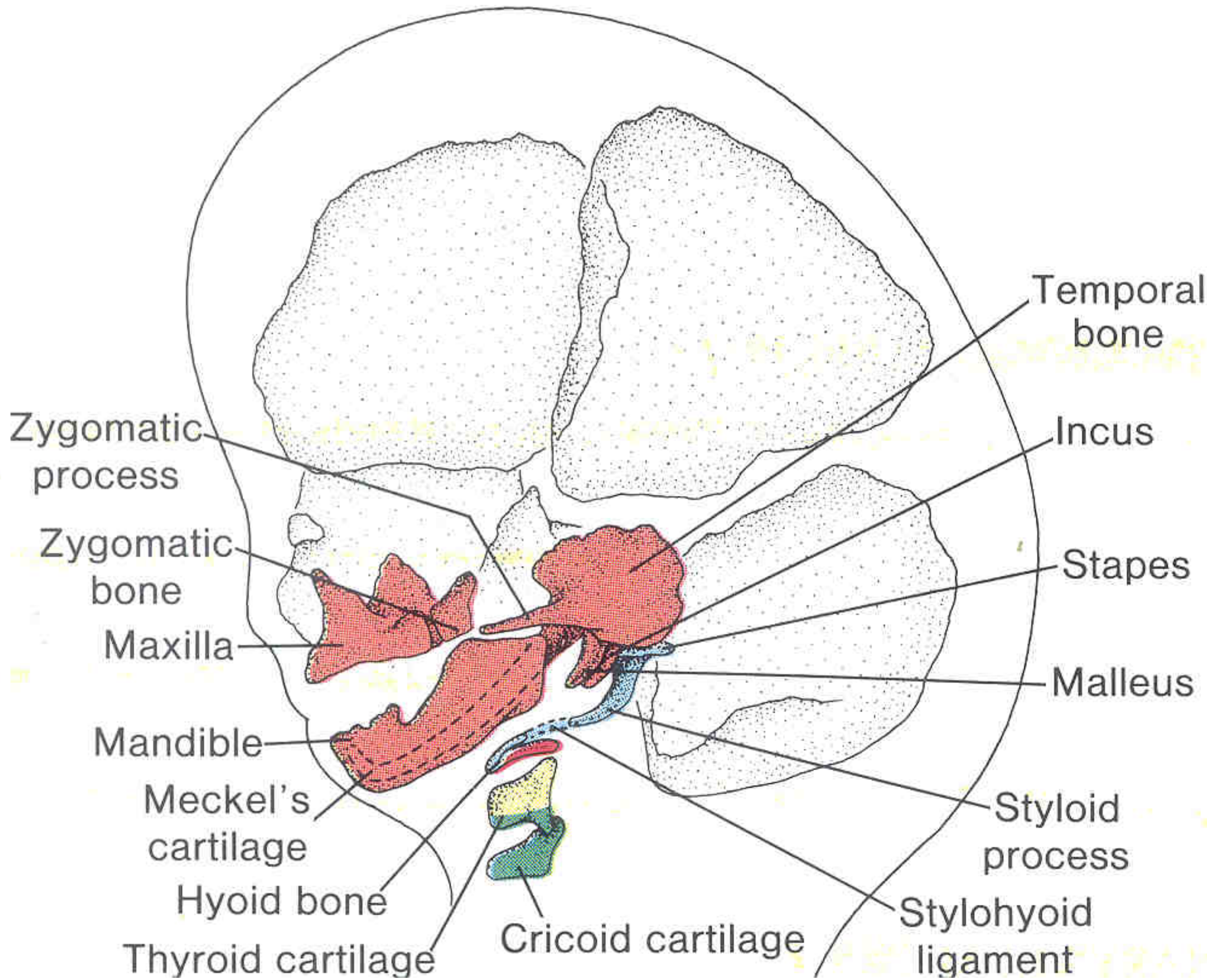

Frontal or metopic suture
Frontal eminence
Coronal suture
Anterior fontanelle
Parietal eminence
Sagittal suture
Posterior fontanelle
Occipital bone
Anterolateral or sphenoidal fontanelle
Lambdoid suture
Posterolateral or mastoid fontanelle
Mandible
Maxilla

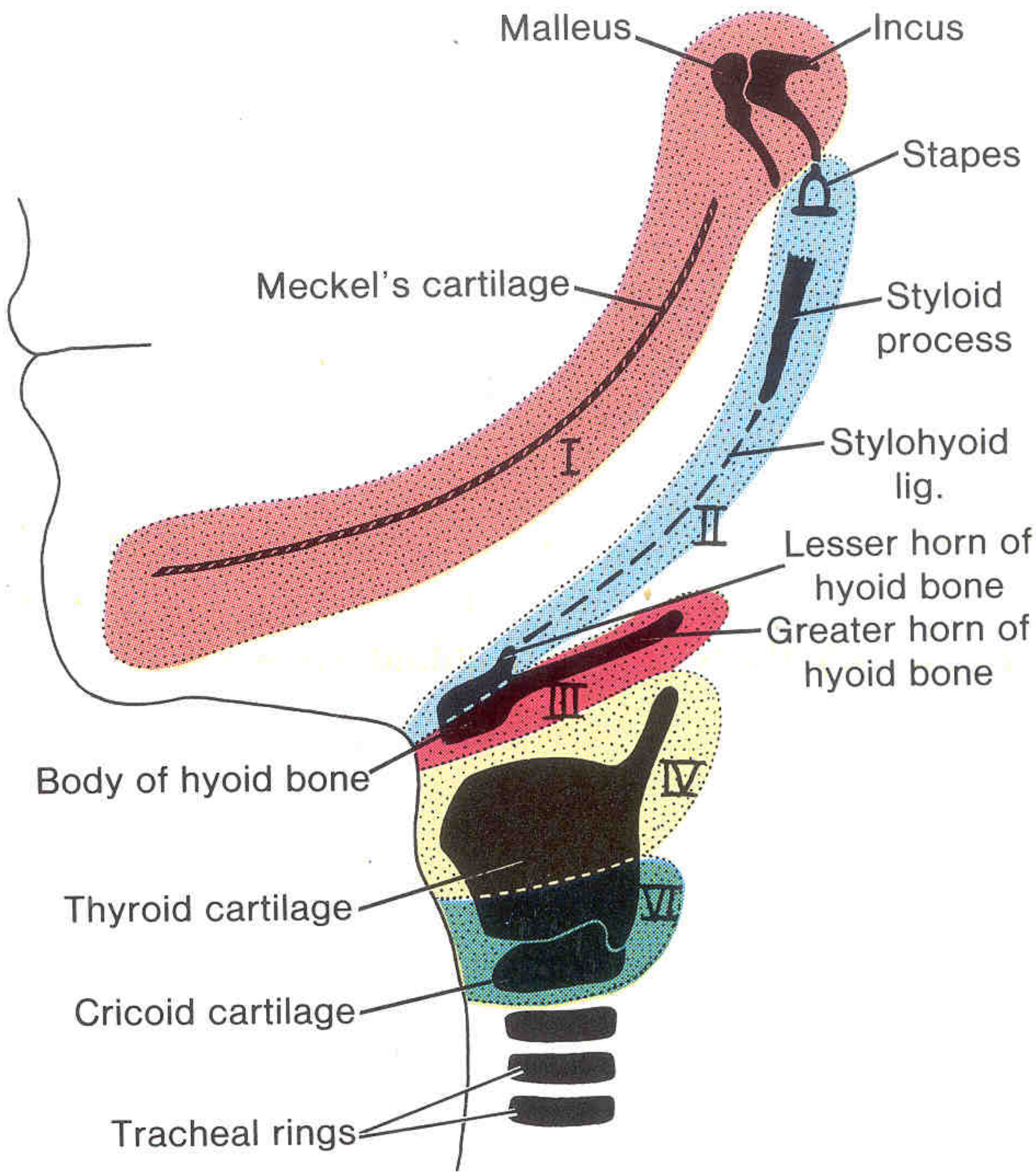


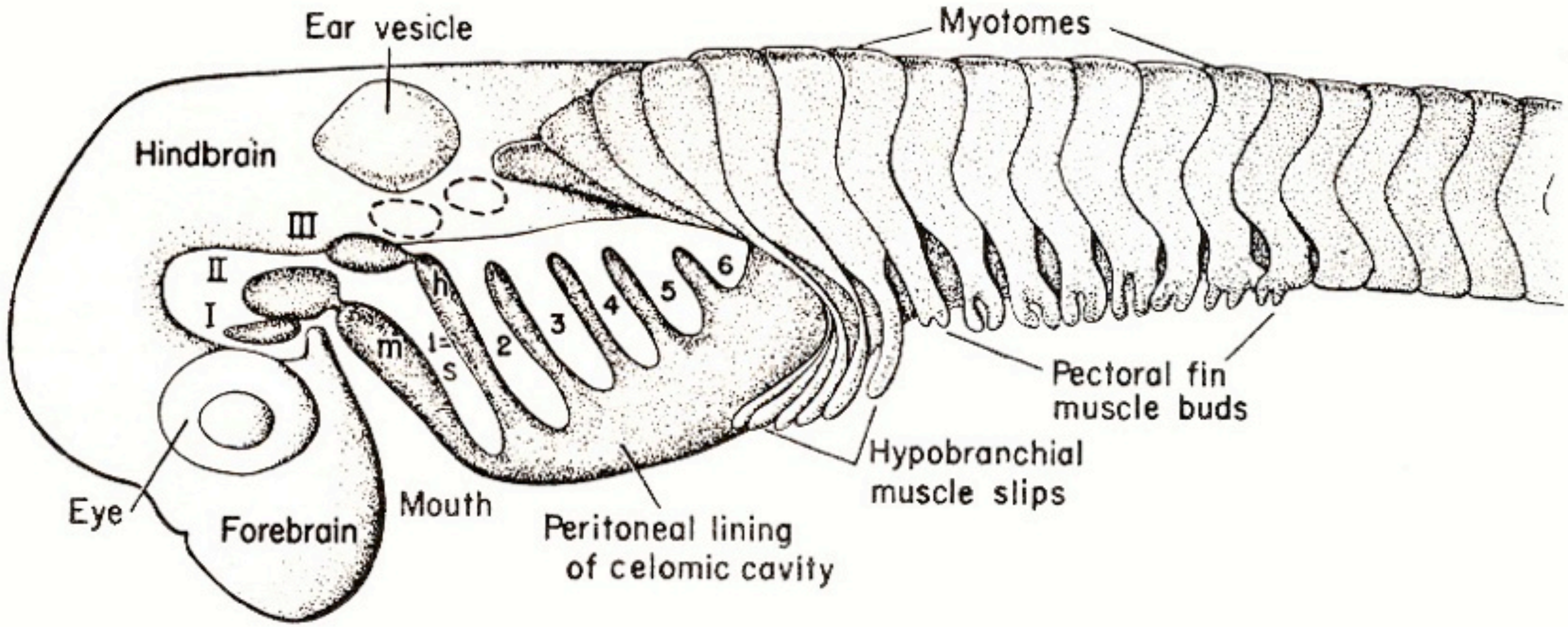
Red: Mesoderm
Blue: Neural crest

Gill slit bones: become SPLANCHNOCRANIUM

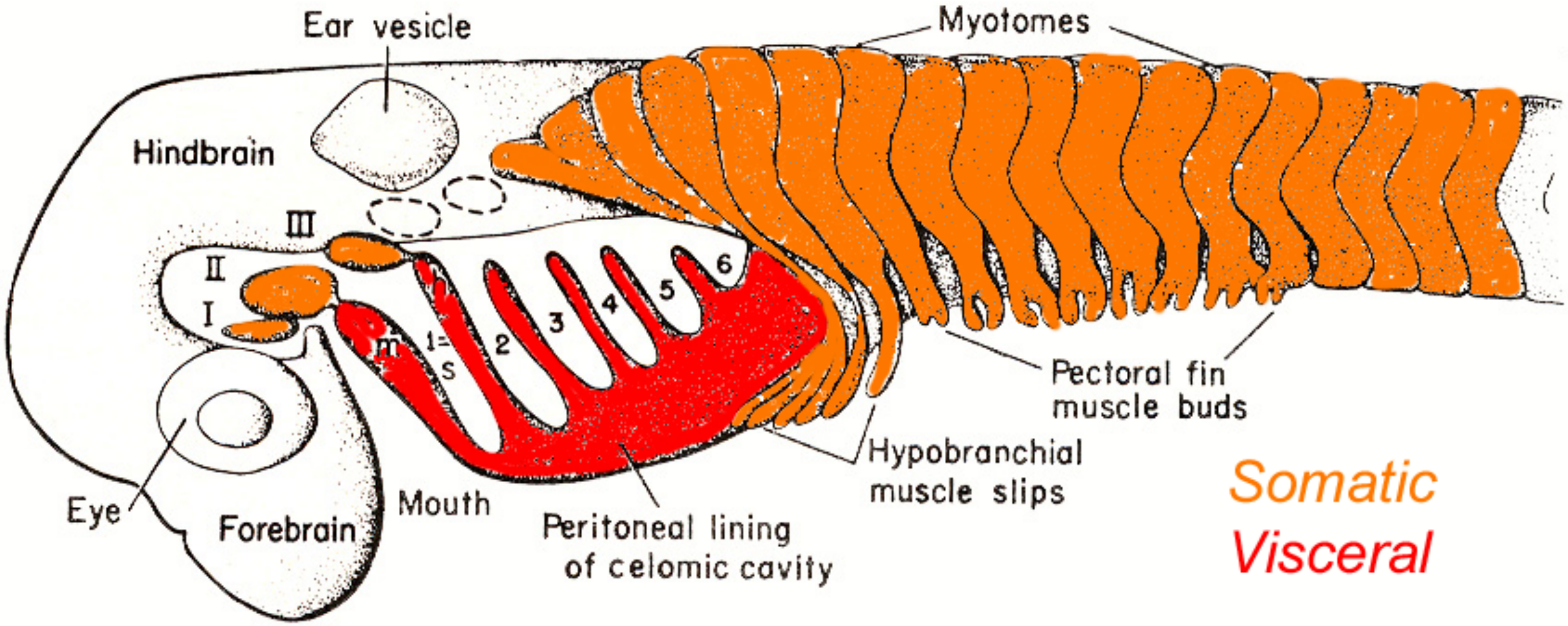



Temporal bone
Zygomatic process
Incus
Zygomatic bone
Stapes
Maxilla
Malleus
Mandible
Meckel's cartilage
Styloid process
Hyoid bone
Stylohyoid ligament
Cricoid cartilage
Thyroid cartilage


Malleus
Incus
Stapes
Meckel's cartilage
Styloid process
Stylohyoid lig.
I
II
Lesser horn of hyoid bone
Greater horn of hyoid bone
III
Body of hyoid bone
IV
Thyroid cartilage
VI
Cricoid cartilage
Tracheal rings



Contribution of somite-derived musculature and gill-slit associated musculature in the vertebrate head.



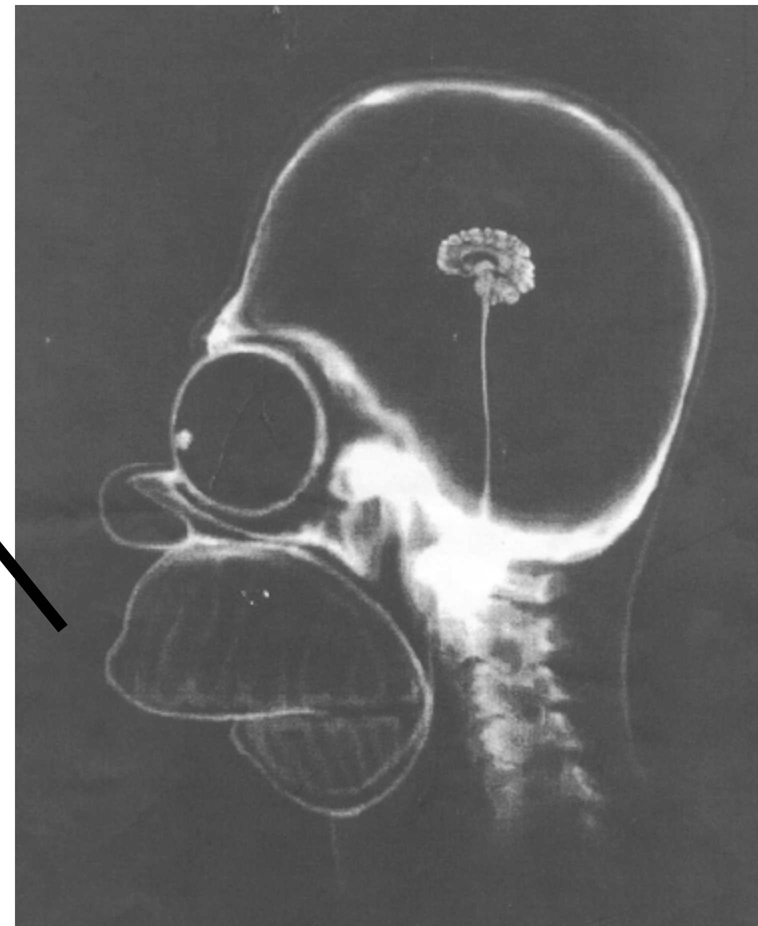
Contribution of somite-derived musculature and gill-slit associated musculature in the vertebrate head.

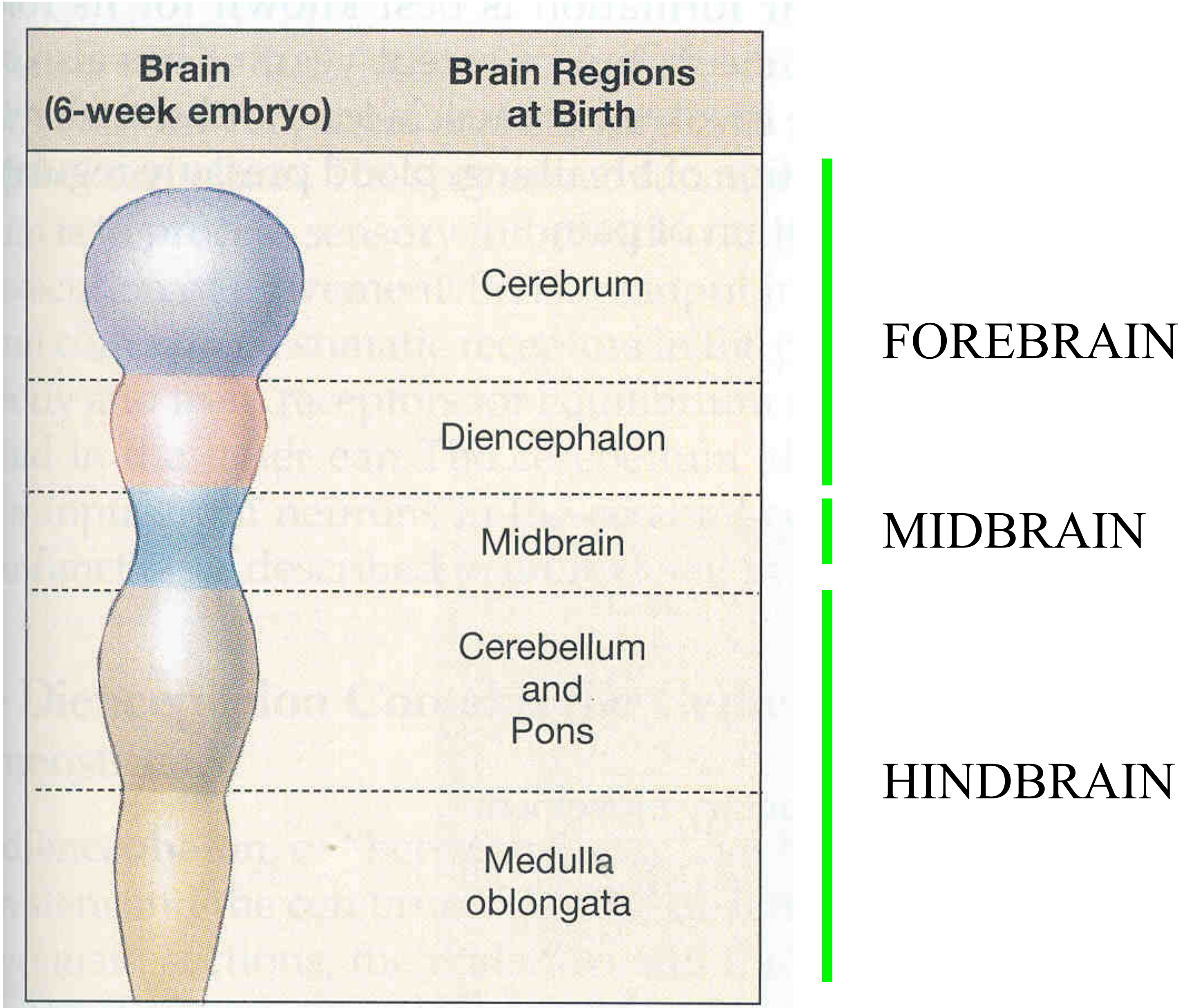
Cranial Nerves and Other Soft Tissues of the Skull

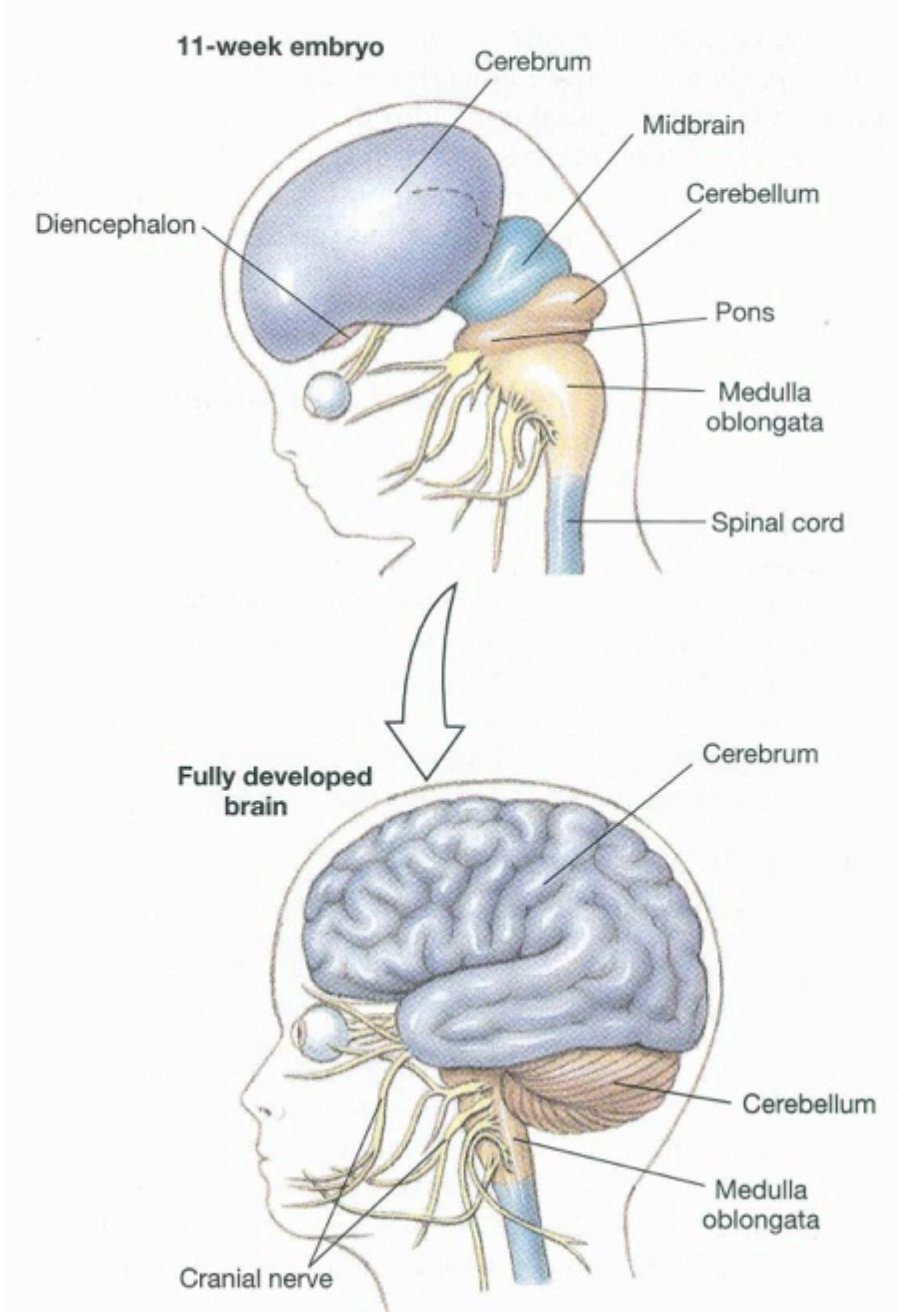
Start with

BRAIN STUFF…

The Brain and Cranial Nerves




Brain
(6-week embryo)
Brain Regions
at Birth
Cerebrum
Diencephalon
Midbrain
Cerebellum
and
Pons
Medulla
oblongata
FOREBRAIN
MIDBRAIN
HINDBRAIN


11-week embryo
Cerebrum
Midbrain
Diencephalon
Cerebellum
Pons
Medulla oblongata
Spinal cord
Fully developed brain
Cerebrum
Cerebellum
Medulla oblongata
Cranial nerve

Forebrain:

Cerebrum – Perception, movement of somatopleure, sensoro-motor integration, emotion, memory, learning.

Diencephalon – Homeostasis, behavioral drives in hypothalamus; sensory relay and modification in thalamus; melatonin secretion in pineal gland.

Midbrain (Mesencephalon)

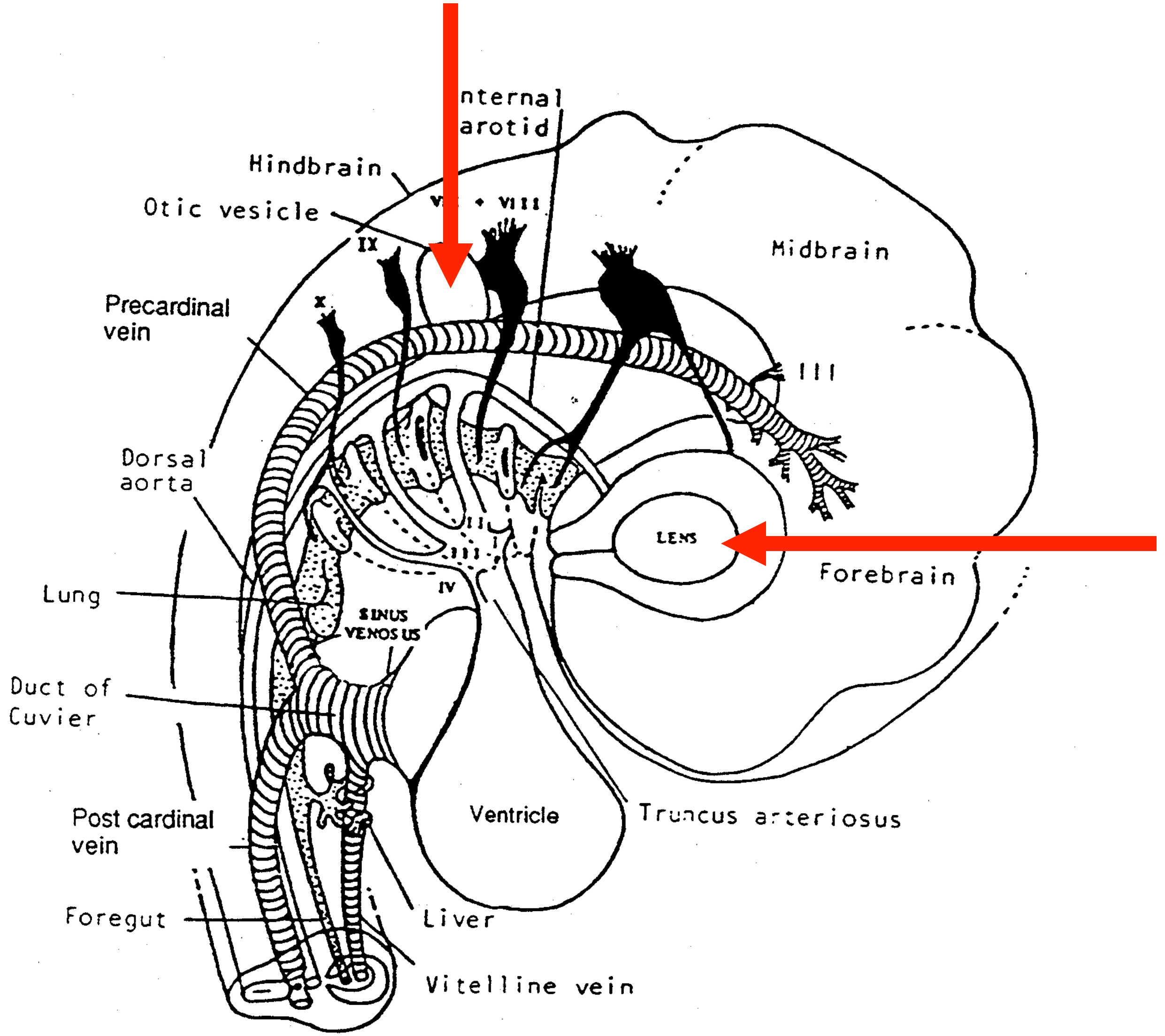
Control of eye movement.

Hindbrain

Cerebellum and Pons – control of movement, proprioreceptive input; relays visual and auditory reflexes in pons.

Medulla Oblongata – Involuntry functions: blood pressure, sleep, breathing, vomiting.

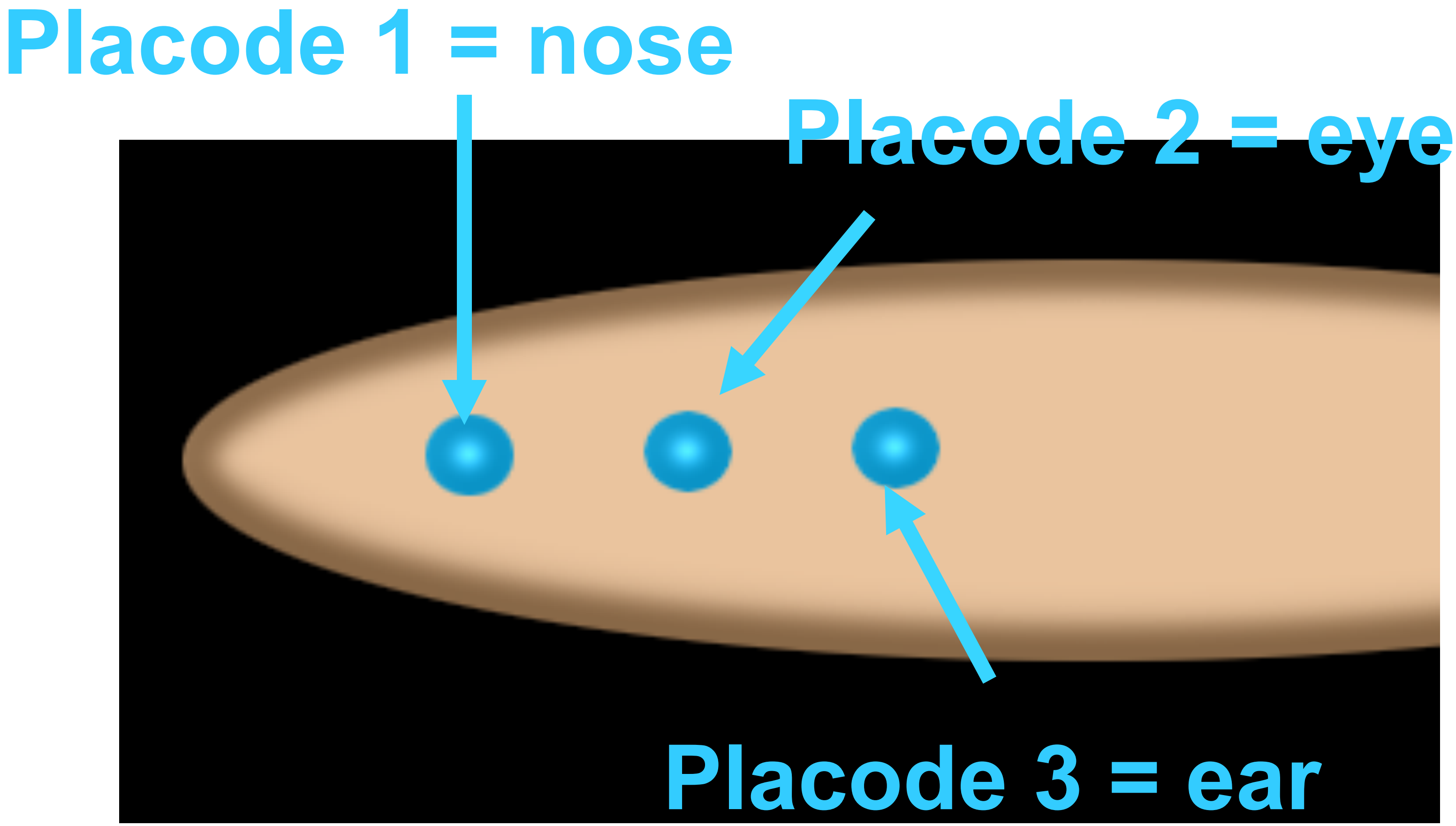
See in Part 3 of your Laboratory Protocols....



Development

- Special Sense organs = nose, eyes and ears, begin as small outcrops of ectoderm called placodes

Development



Development

- In the nose, the ectoderm become nerve cells that send their fibres through the cribriform plate of the ethmoid, back to the brain

- This is Cranial Nerve I = the Olfactory Nerve

Development

- The second placode becomes the lens of the eye.
- It sinks below the surface of the skin, and an outgrowth of the brain wraps around it.
- The outgrowth is the retina, and the stalk connecting it is Cranial Nerve II = The Optic Nerve

Eye starts out as photosensitive lobe of brain underlying surface of skin.

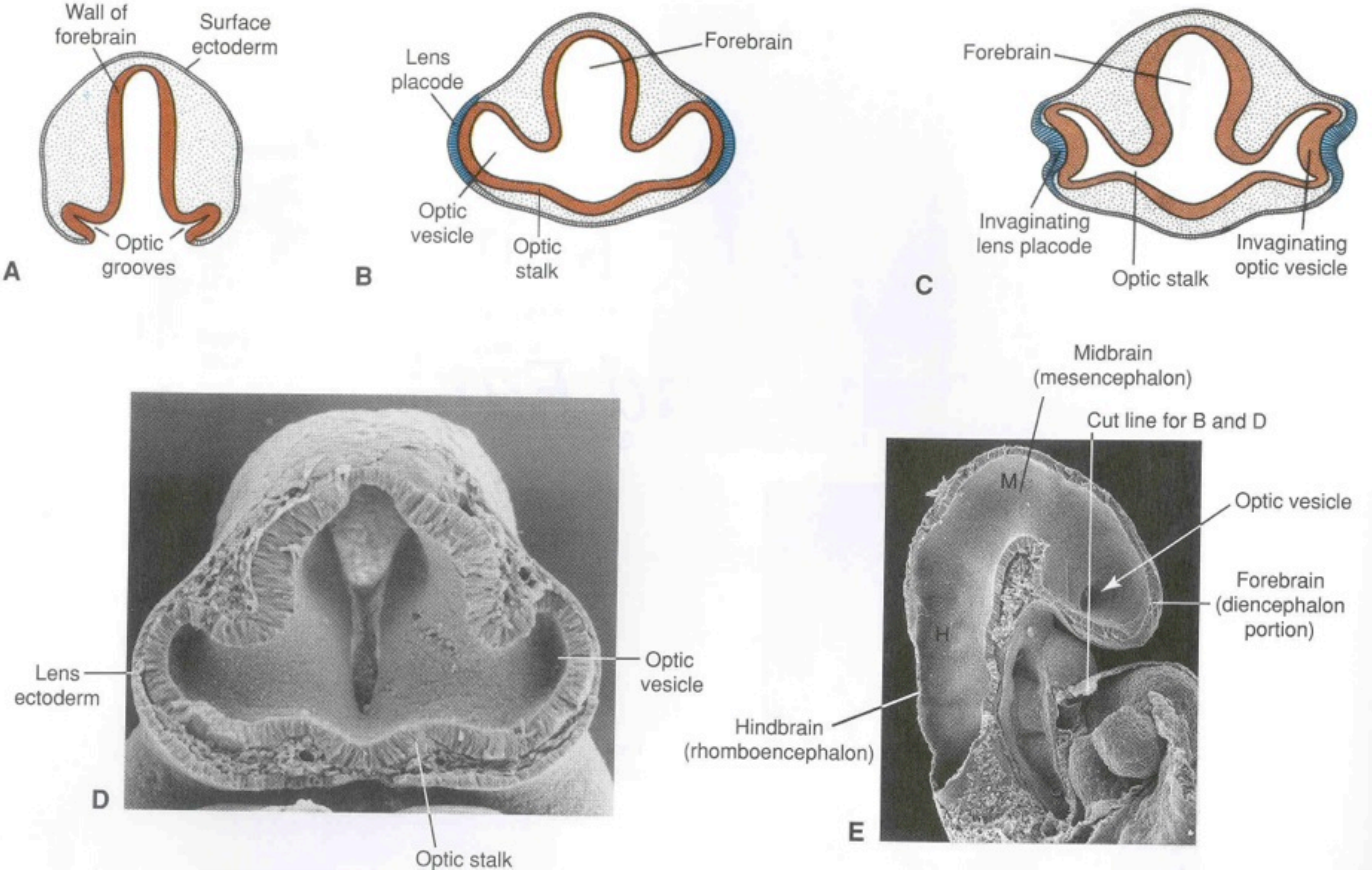
Lobe eventually becomes two-layered cup = retina.

Connected to brain by “stalk” that is the OPITC NERVE (cranial nerve II).

Lens from ectodermal placode.

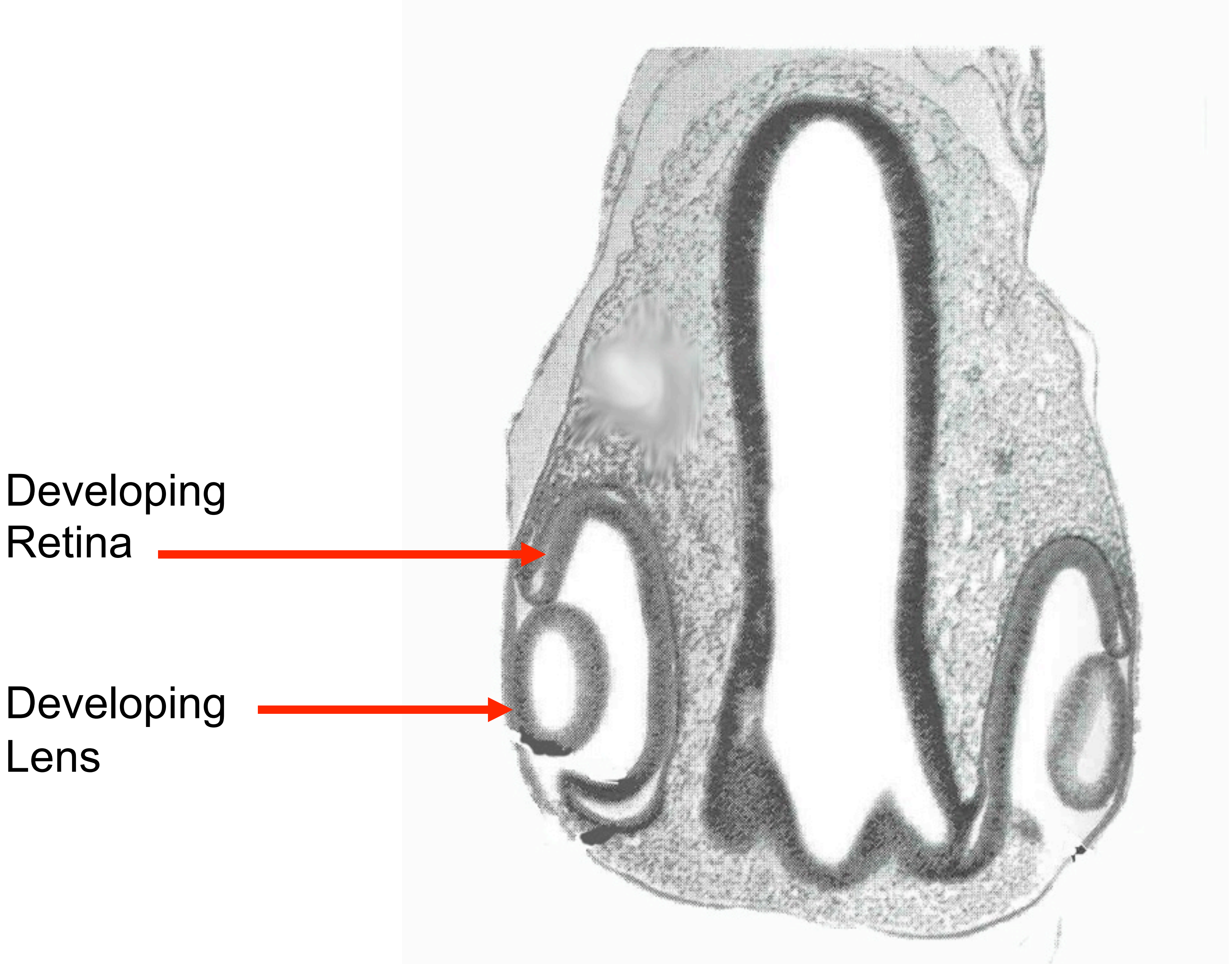
Marginal cells of retina become specialized as MUSCLE CELLS that regulate opening of pupil:

- Sphinctor pupillae (parasympathetically regulated)
- Dilator pupillae (sympathetically regulated)



Wall of forebrain
Surface ectoderm
Optic grooves
A
Lens placode
Forebrain
Optic vesicle
Optic stalk
B
Forebrain
Invaginating lens placode
Optic stalk
Invaginating optic vesicle
C
Lens ectoderm
Optic vesicle
Optic stalk
D
Midbrain (mesencephalon)
Cut line for B and D
M
Optic vesicle
Forebrain (diencephalon portion)
H
Hindbrain (rhomboencephalon)
E


8
7
2
3
3
5



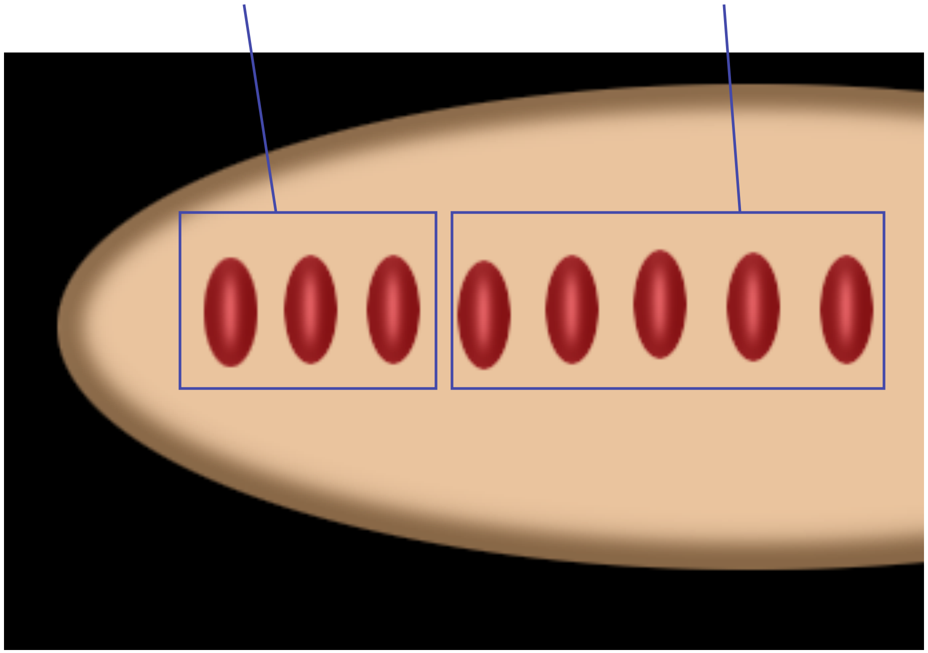
Developing Retina
Developing Lens

Ventral Root Cranial Nerves

Somite Associated

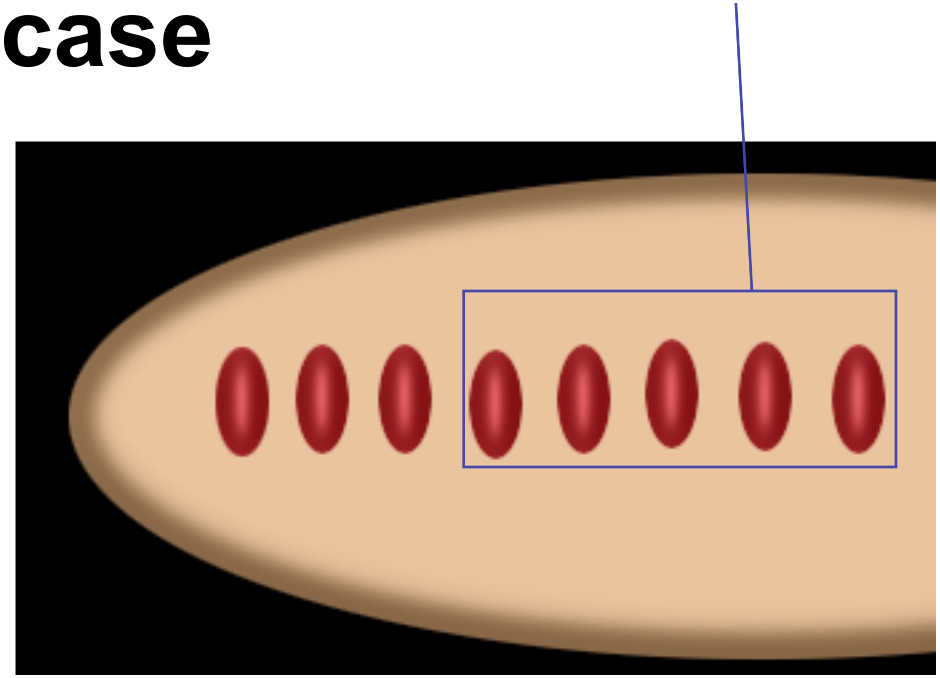
Development

- Head somites can be divided into 2 sets. Pre-otic and post-otic



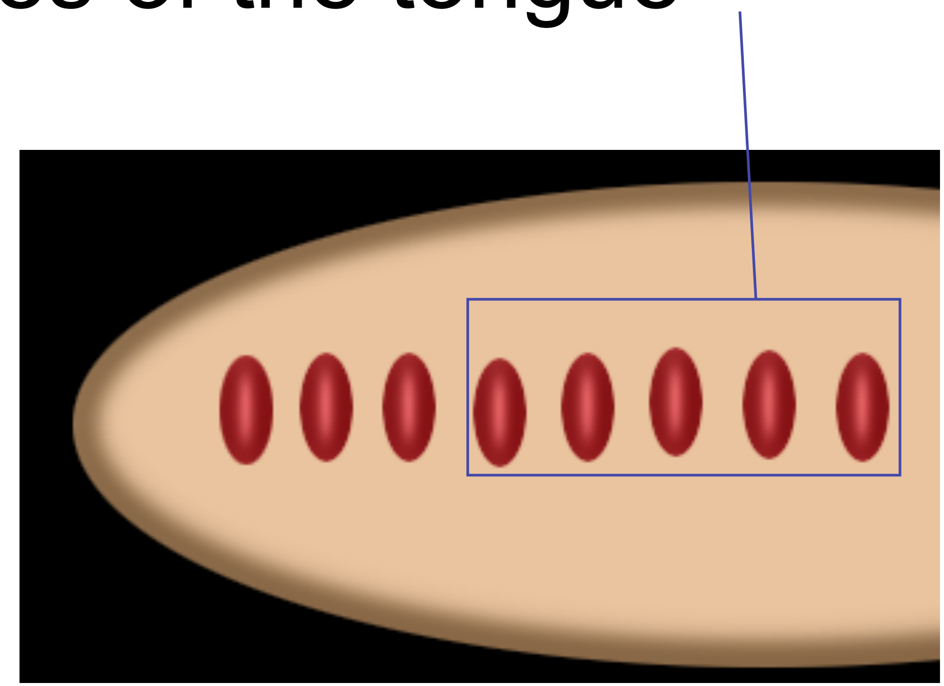
Development

- The sklerotomes of the post otic somites form the floor of the brain case



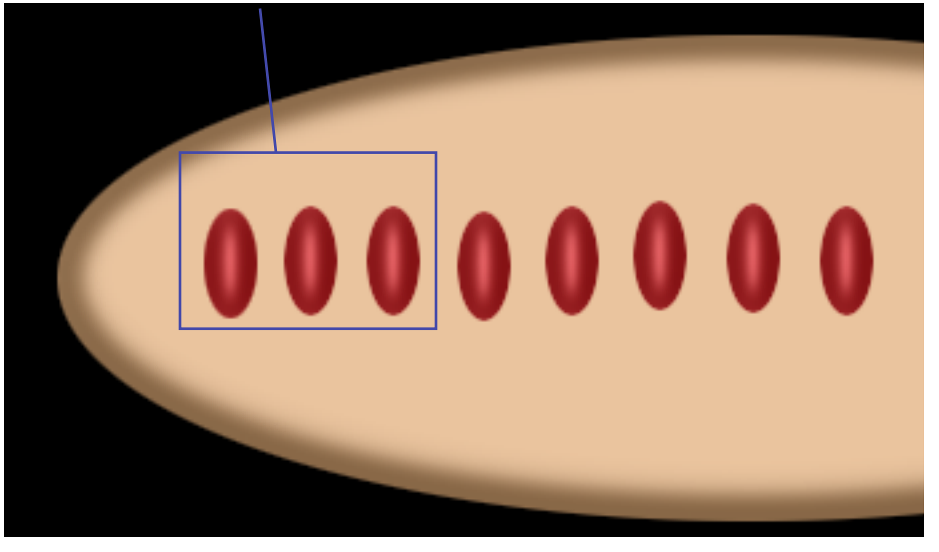
Development

….and their myotomes develop into muscles of the tongue



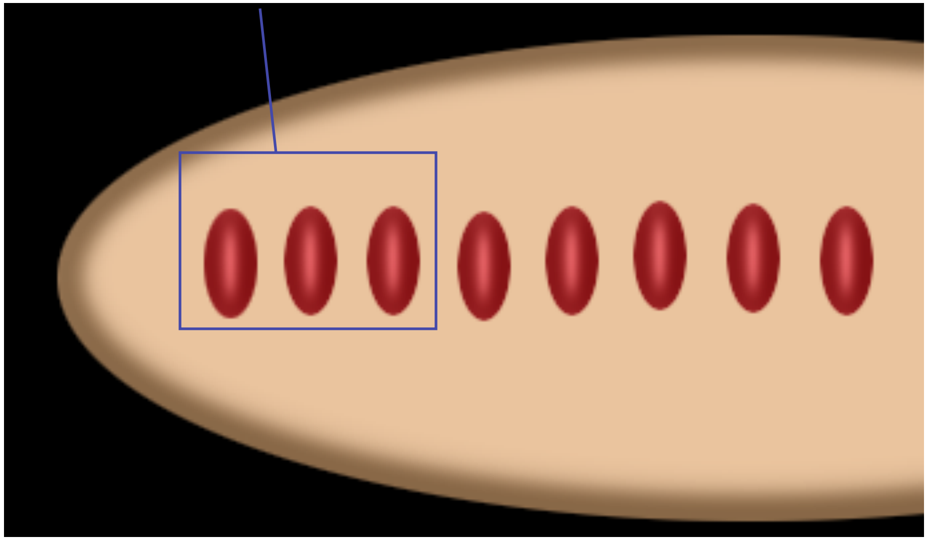
Development

The myotomes of the pre-otic somites form the muscles that move the eyeballs.



Development

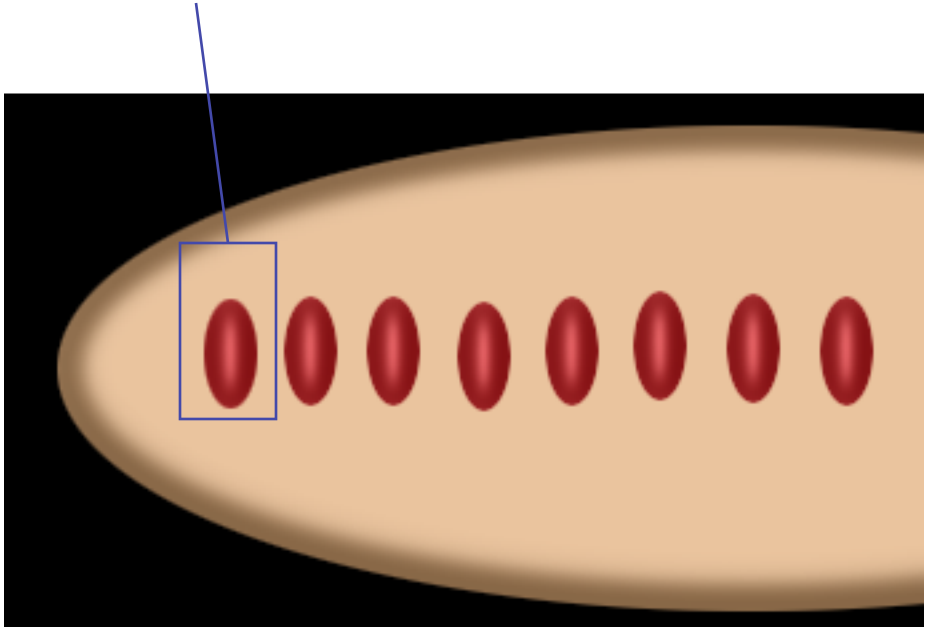
Each is supplied by a different cranial nerve:



Development

Cranial Nerve III =

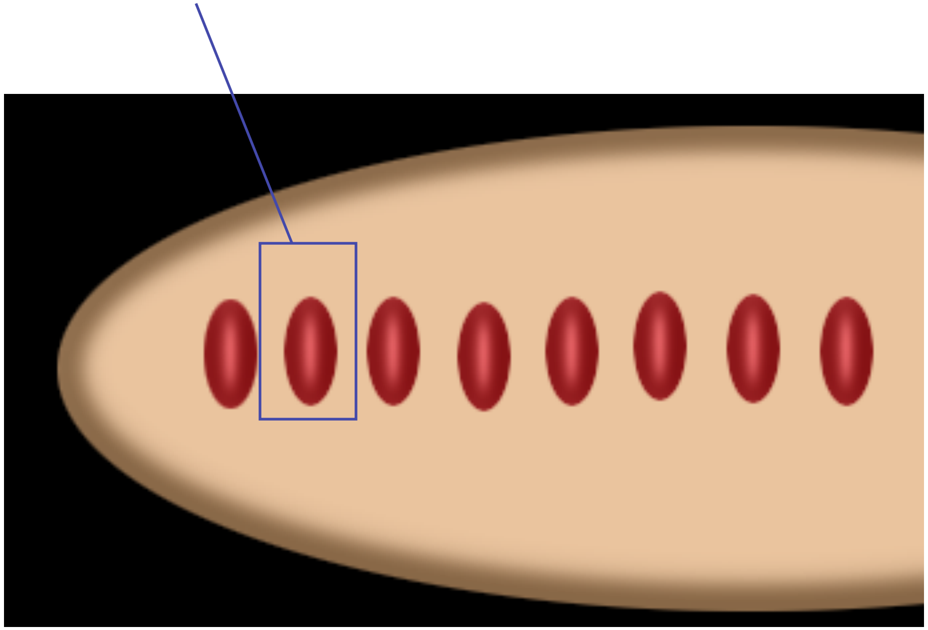
Occulomotor Nerve



Development

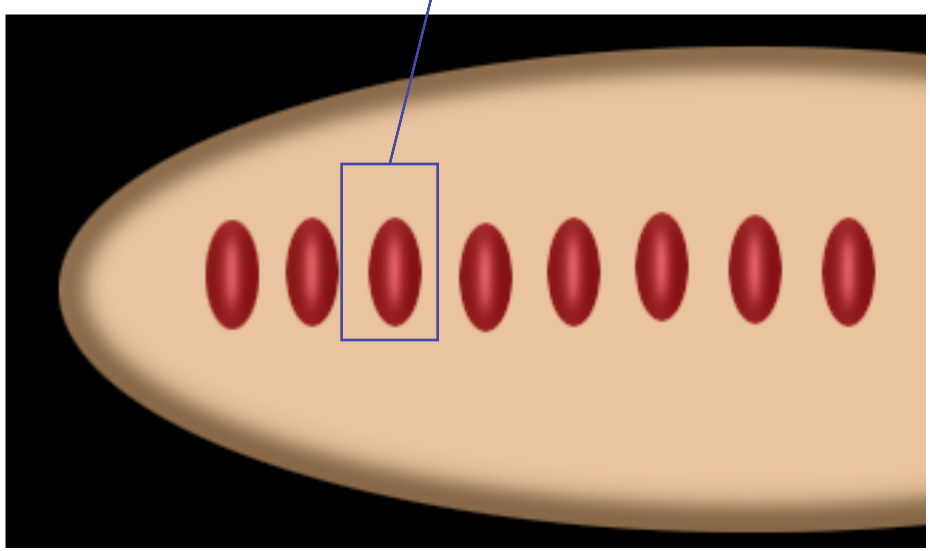
Cranial Nerve IV =

Trochlear Nerve



Development

Cranial Nerve VI = Abducens Nerve



EYEBALL MOVING MUSCLES:

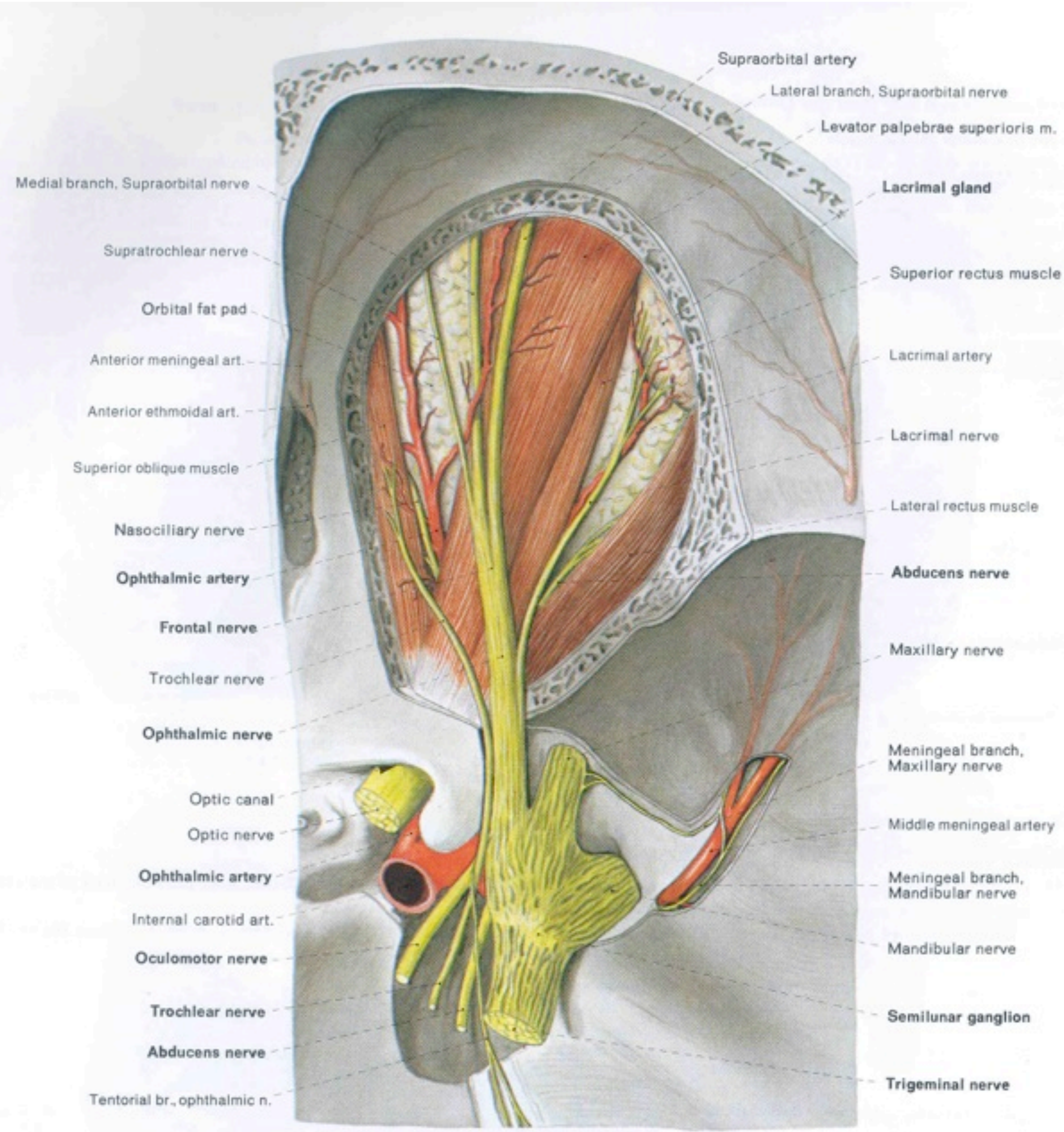
Rectus Muscles

- Superior rectus - III
- Inferior rectus - III
- Lateral rectus - VI
- Medial rectus - III

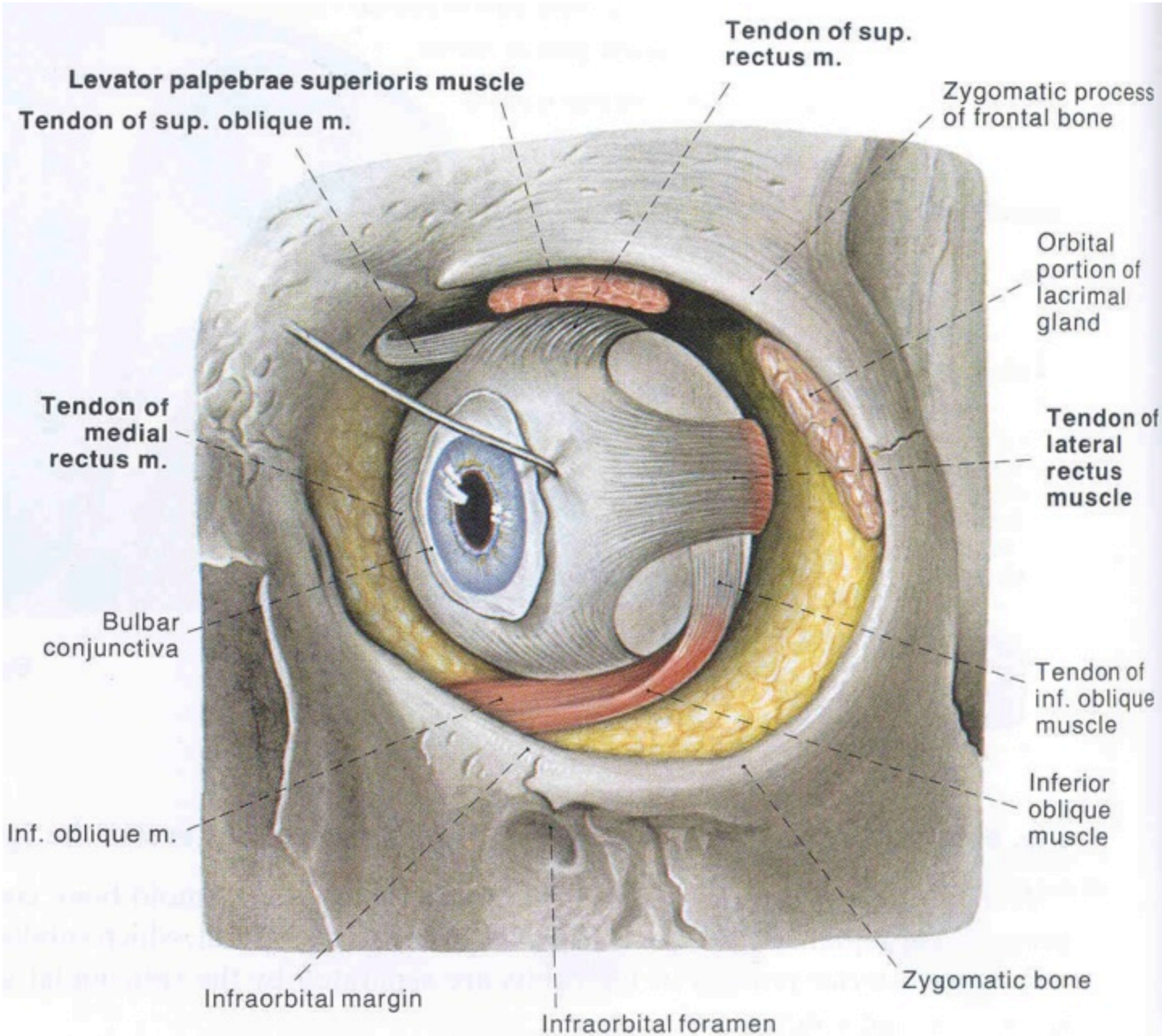
Oblique muscles

- Superior oblique - IV
- Inferior oblique - III

Lavator palpebrae superioris - III



Supraorbital artery
Lateral branch, Supraorbital nerve
Levator palpebrae superioris m.
Medial branch, Supraorbital nerve
Lacrimal gland
Supratrochlear nerve
Superior rectus muscle
Orbital fat pad
Anterior meningeal art.
Lacrimal artery
Anterior ethmoidal art.
Lacrimal nerve
Superior oblique muscle
Lateral rectus muscle
Nasociliary nerve
Ophthalmic artery
Abducens nerve
Frontal nerve
Maxillary nerve
Trochlear nerve
Ophthalmic nerve
Meningeal branch, Maxillary nerve
Optic canal
Optic nerve
Middle meningeal artery
Ophthalmic artery
Meningeal branch, Mandibular nerve
Internal carotid art.
Oculomotor nerve
Mandibular nerve
Trochlear nerve
Semilunar ganglion
Abducens nerve
Tentorial br., ophthalmic n.
Trigeminal nerve



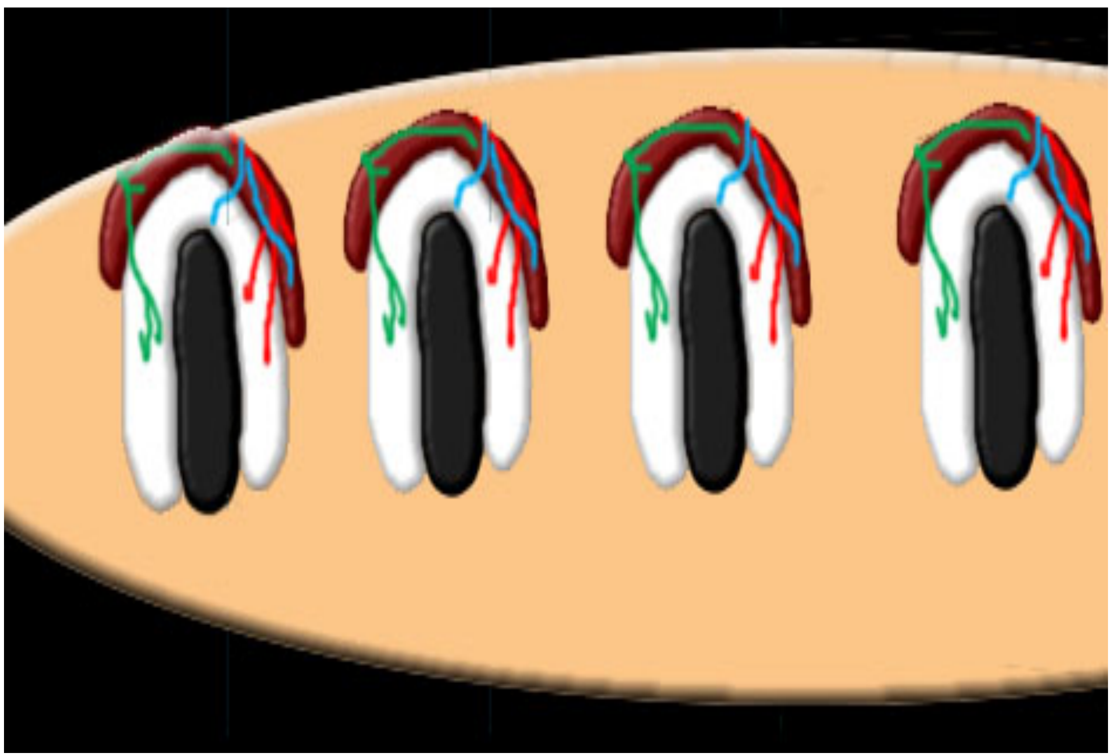
Tendon of sup. rectus m.
Levator palpebrae superioris muscle
Tendon of sup. oblique m.
Zygomatic process of frontal bone
Orbital portion of lacrimal gland
Tendon of medial rectus m.
Tendon of lateral rectus muscle
Bulbar conjunctiva
Tendon of inf. oblique muscle
Inferior oblique muscle
Inf. oblique m.
Zygomatic bone
Infraorbital margin
Infraorbital foramen

Dorsal Root Cranial Nerves

Gill Slit Associated

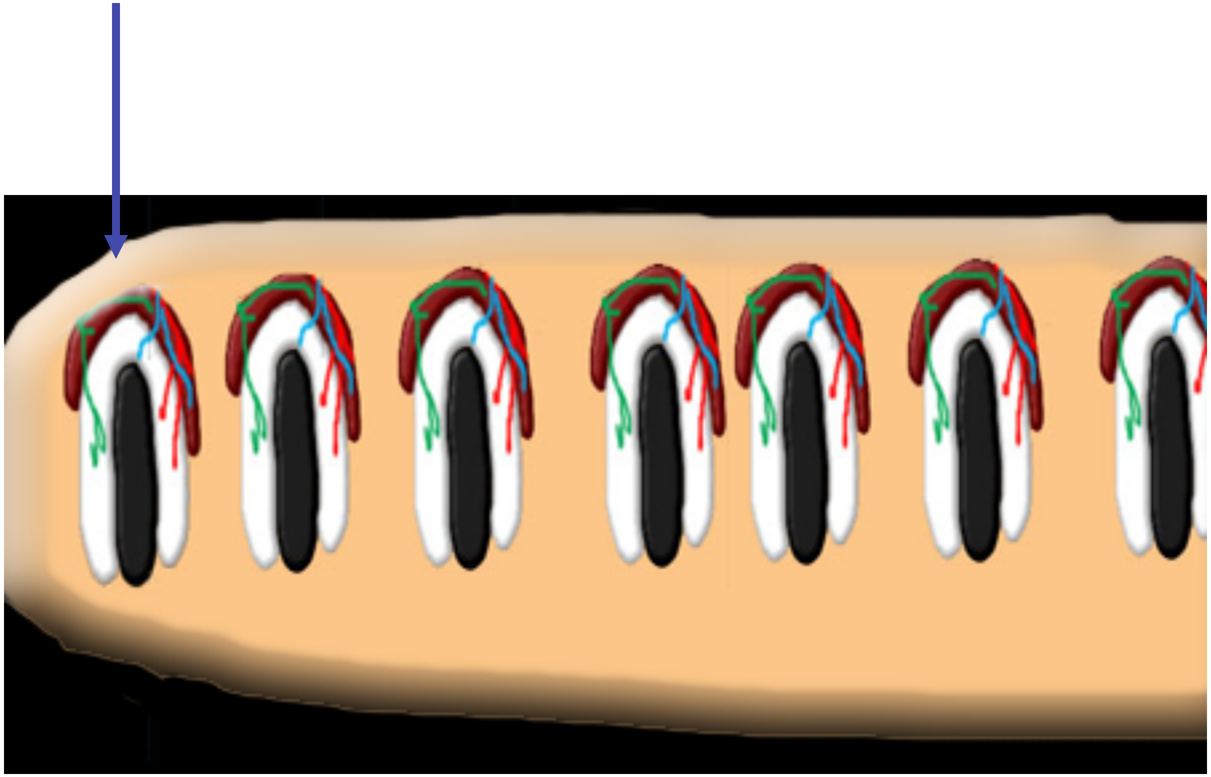
Development

Gill Arch Derivatives



Development

Mandibular arch

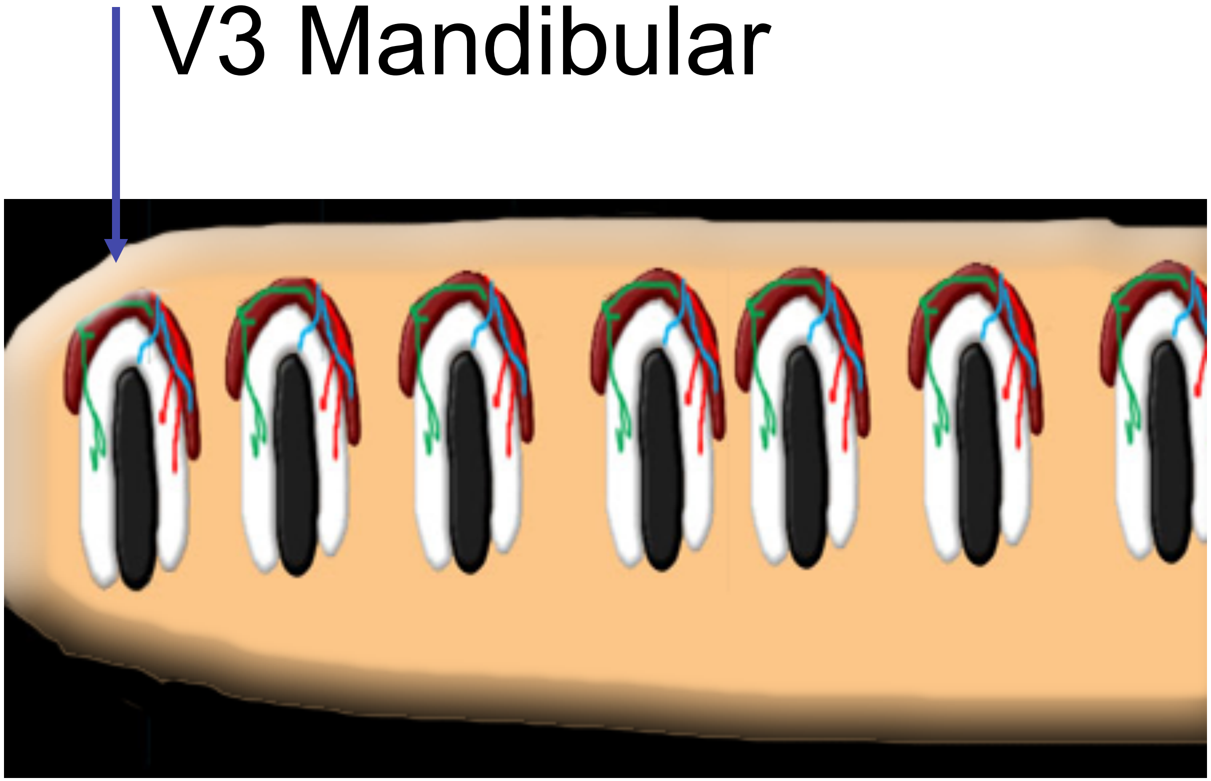


Cranial Nerve V: The Trigeminal Nerve (3 branches)

V1 Opthalmic ,

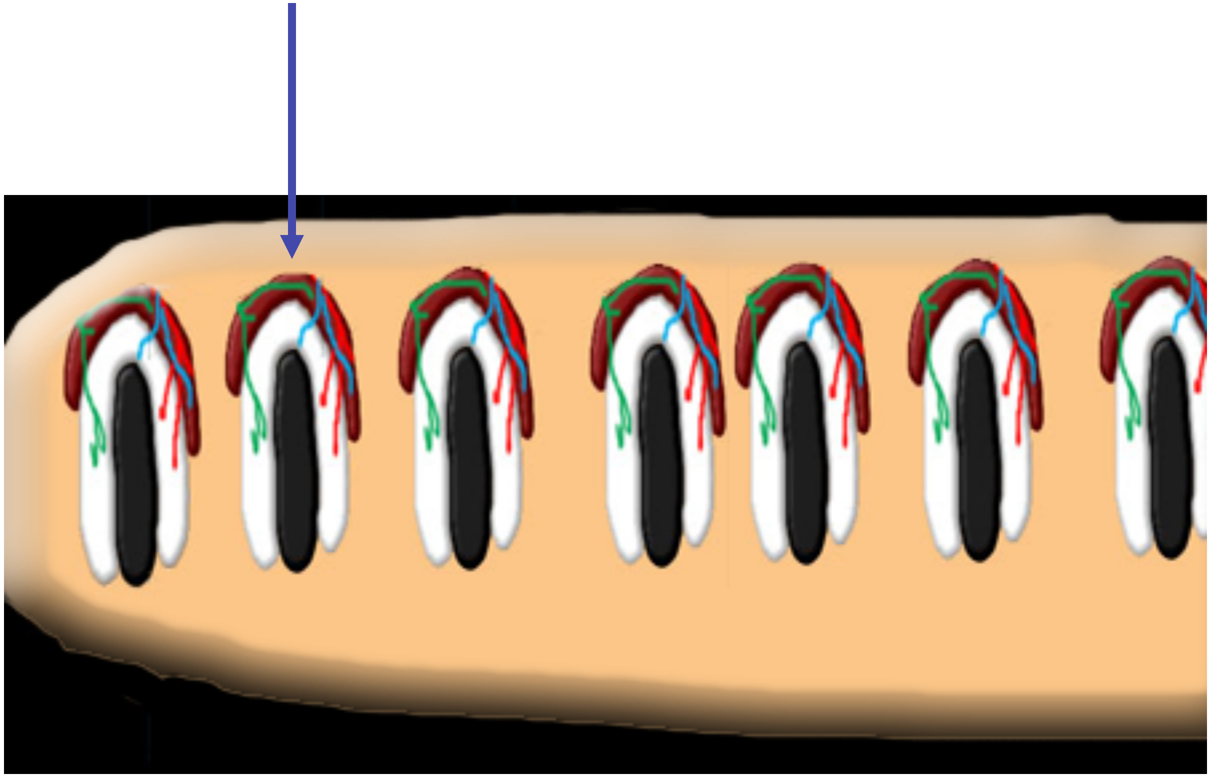
V2 Maxillary,

V3 Mandibular

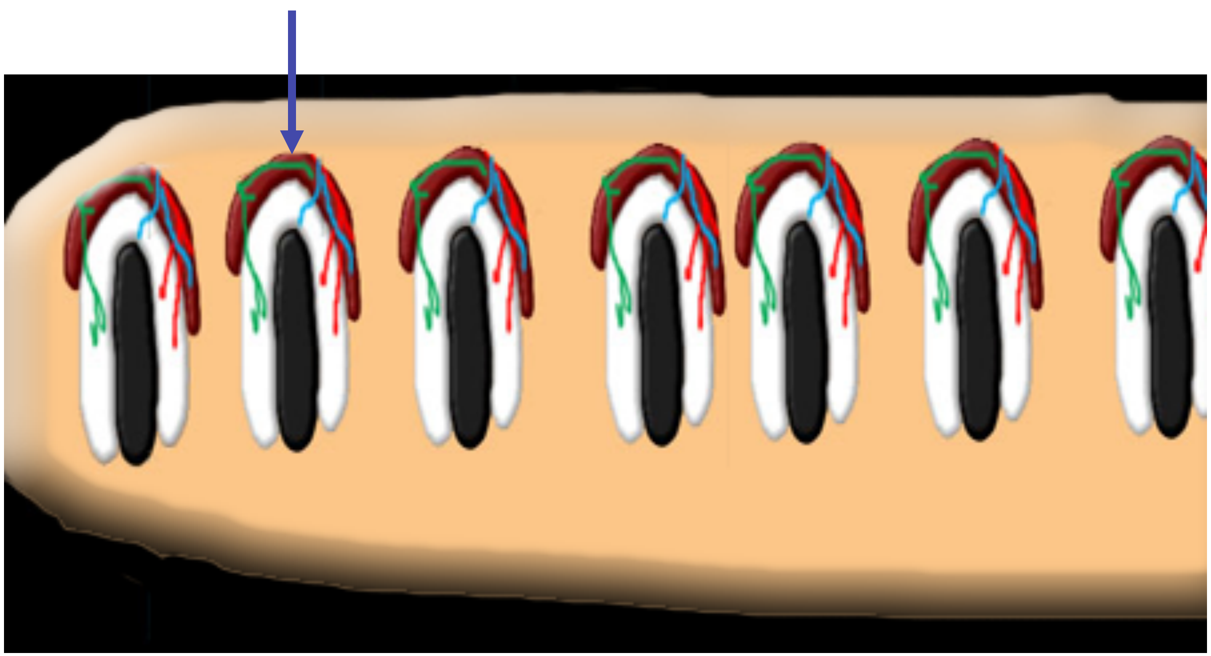


Development

Hyoid arch



Cranial Nerve VII:
Facial nerve

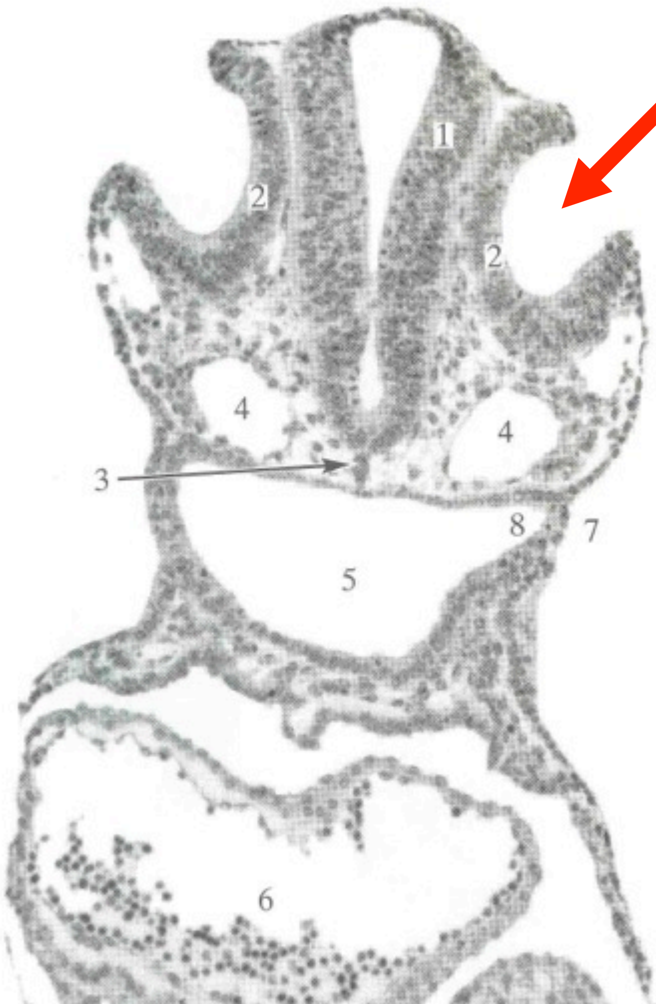


Development

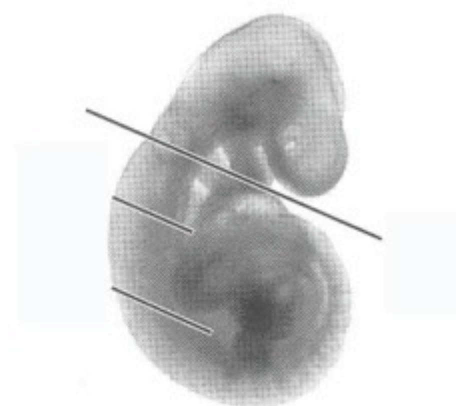
- The Inner ear starts out as a lens, but turns into a fluid filled sac
- Receptor organs of hearing and balance.
- Cranial Nerve VIII = Auditory or Vestibulocochlear Nerve

Cranial Nerve VIII
Vestibulocochlear Nerve
(Evolutionary branch of VII)

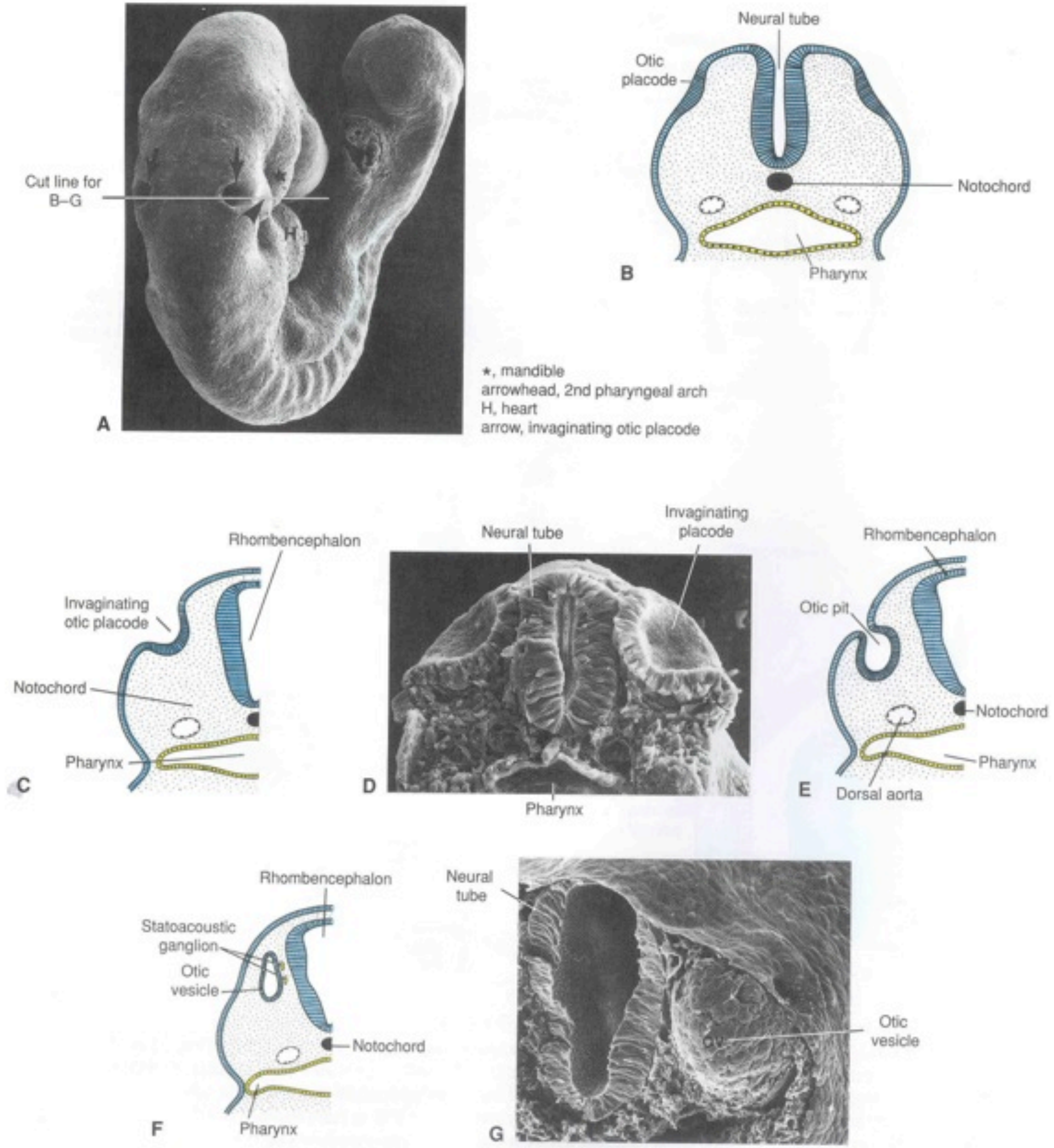
Otic Vesicle



4.59



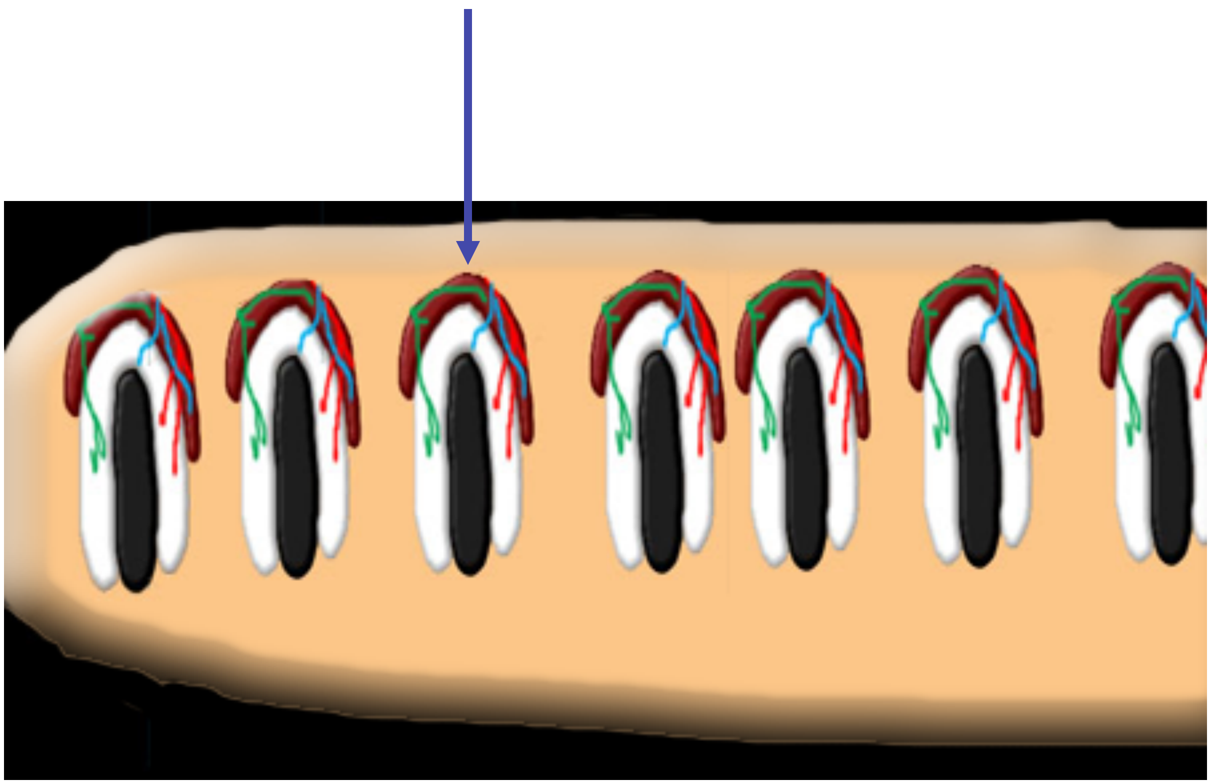
Early Development of the Ear



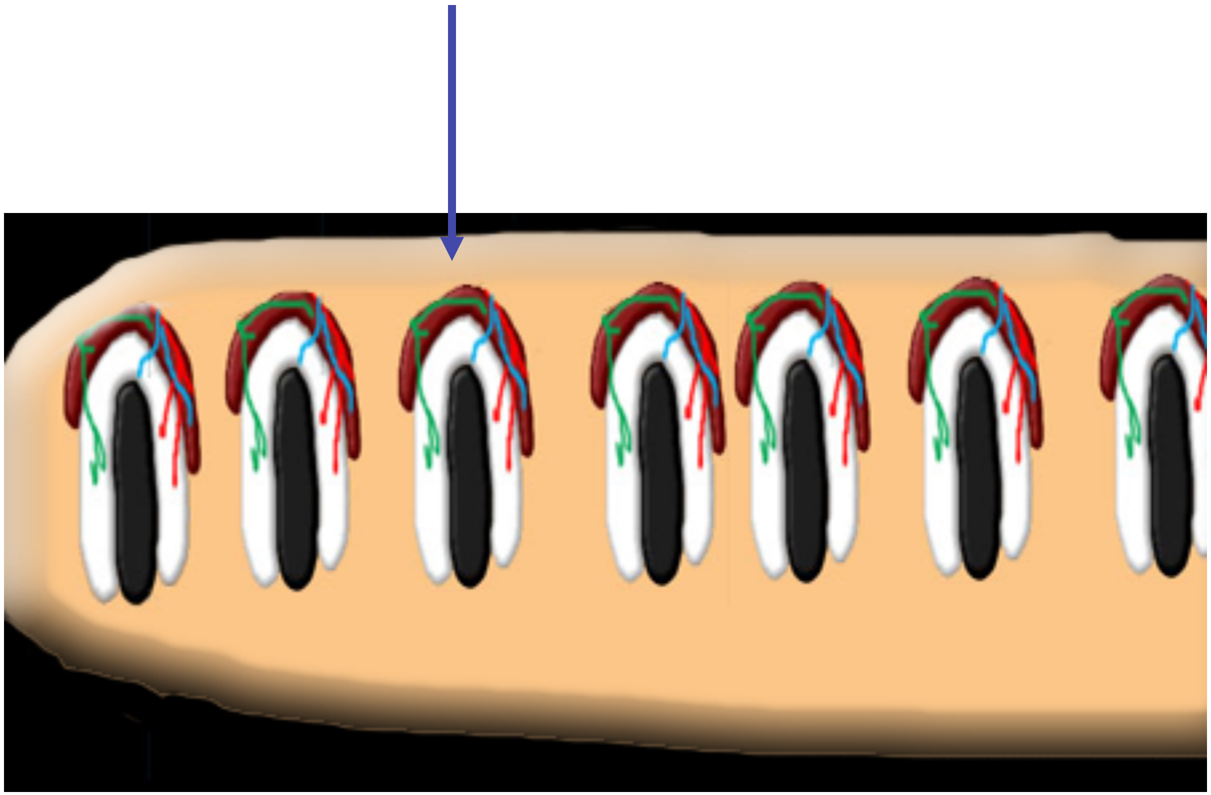
The ear consists of three different parts: the **external ear**, **middle ear**, and **internal ear**. The internal ear forms from **otic placodes (thickened ectoderm)** that develop on both sides of the hindbrain during the 4th week of development (**A** and **B**). These placodes invaginate to form otic vesicles (**C–G**).

Development

Next arch

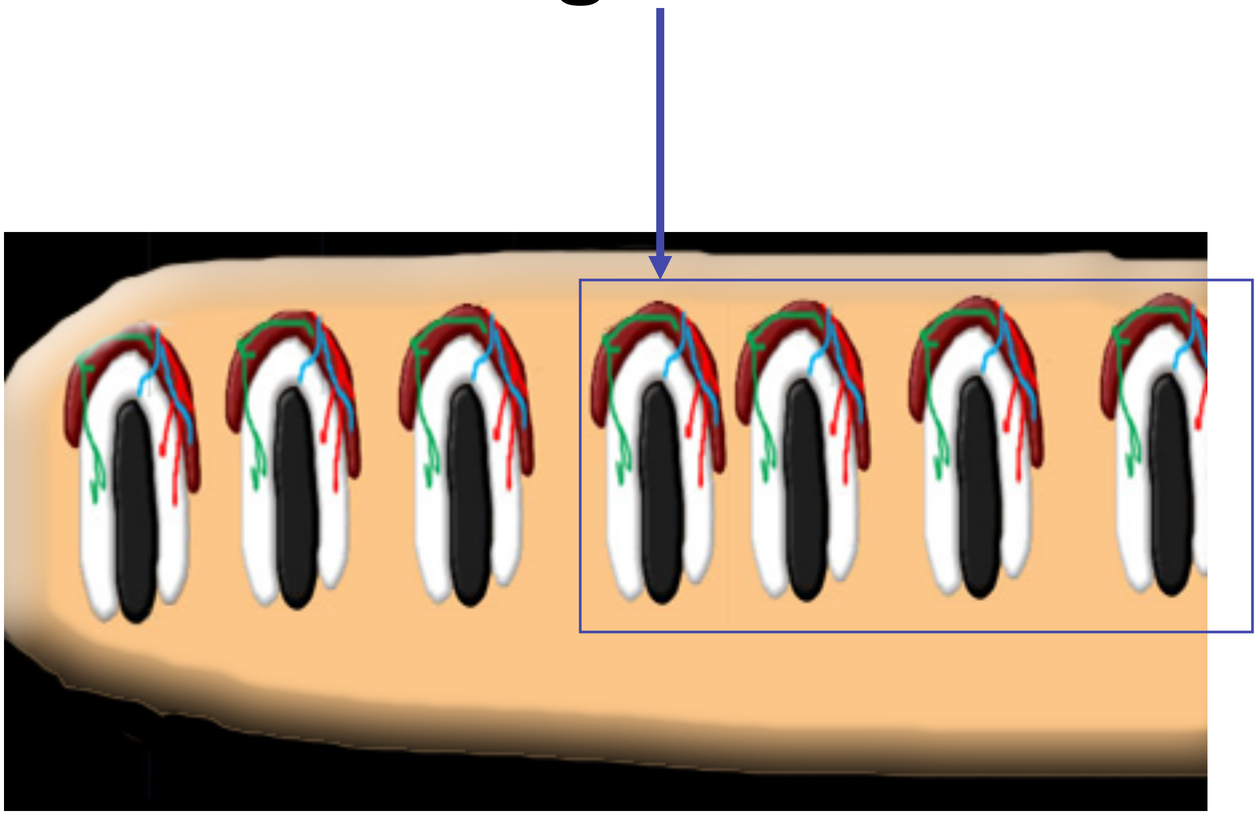


Cranial nerve IX:
Glossopharyngeal Nerve

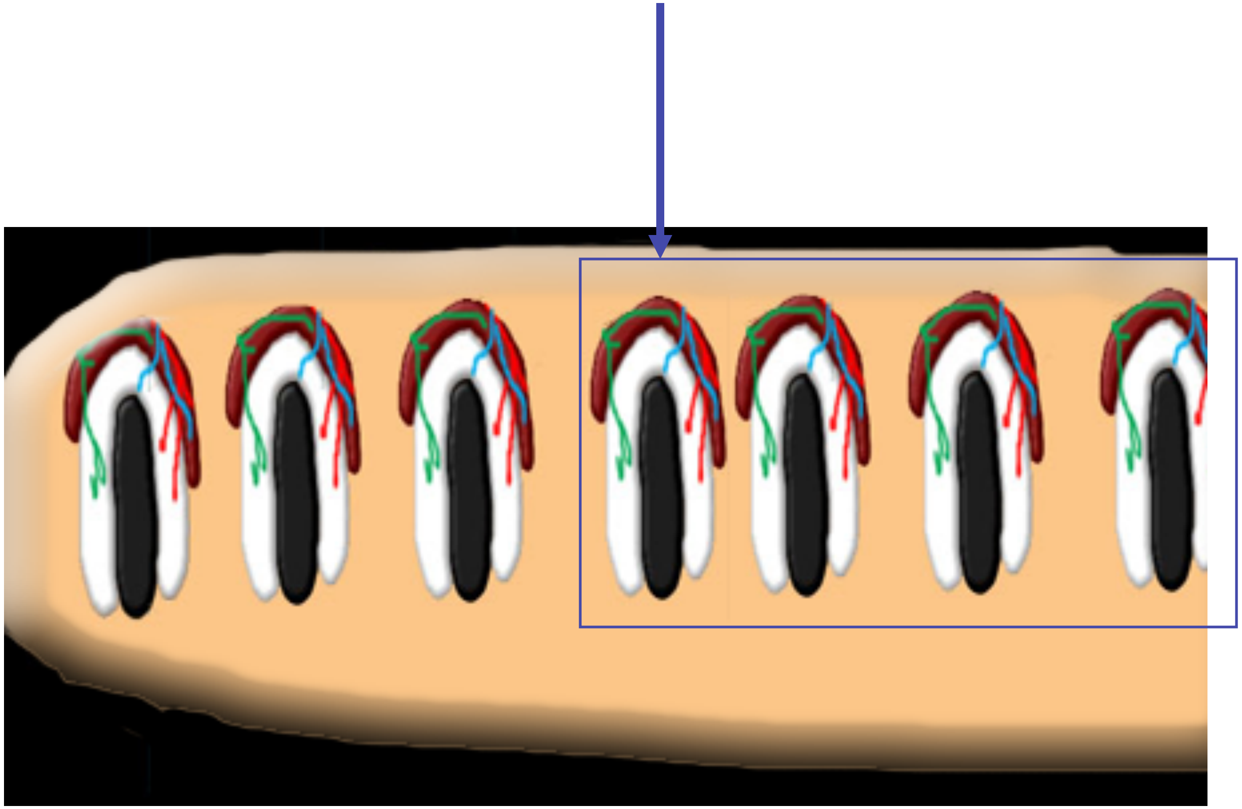


Development

Remaining arches



Cranial nerve X:
The Vagus Nerve



Is there a "#0" nerve?

The *Nervus Terminalis* (Nerve Zero) has been suggested as a primitive vertebrate structure serving the vomeraonasal organ.

I	Olfactory			
II	Optic			
III	Occulomotor			
IV	Trochlear			
V	Trigeminal			
VI	Abducens			
VII	Facial			
VIII	Vestibulochochlar			
IX	Glossopharyngeal			
X	Vagus			
XI	Accessory			
XII	Hypoglossal			

Motor, sensory, or both

I	O	Sensory		
II	O	Sensory		
III	O	Mainly motor		
IV	T	Mainly motor		
V	T	Both		
VI	A	Mainly motor		
VII	F	Both		
VIII	A	Sensory		
IX	G	Both		
X	V	Both		
XI	A	Mainly motor		
XII	H	Mainly motor		

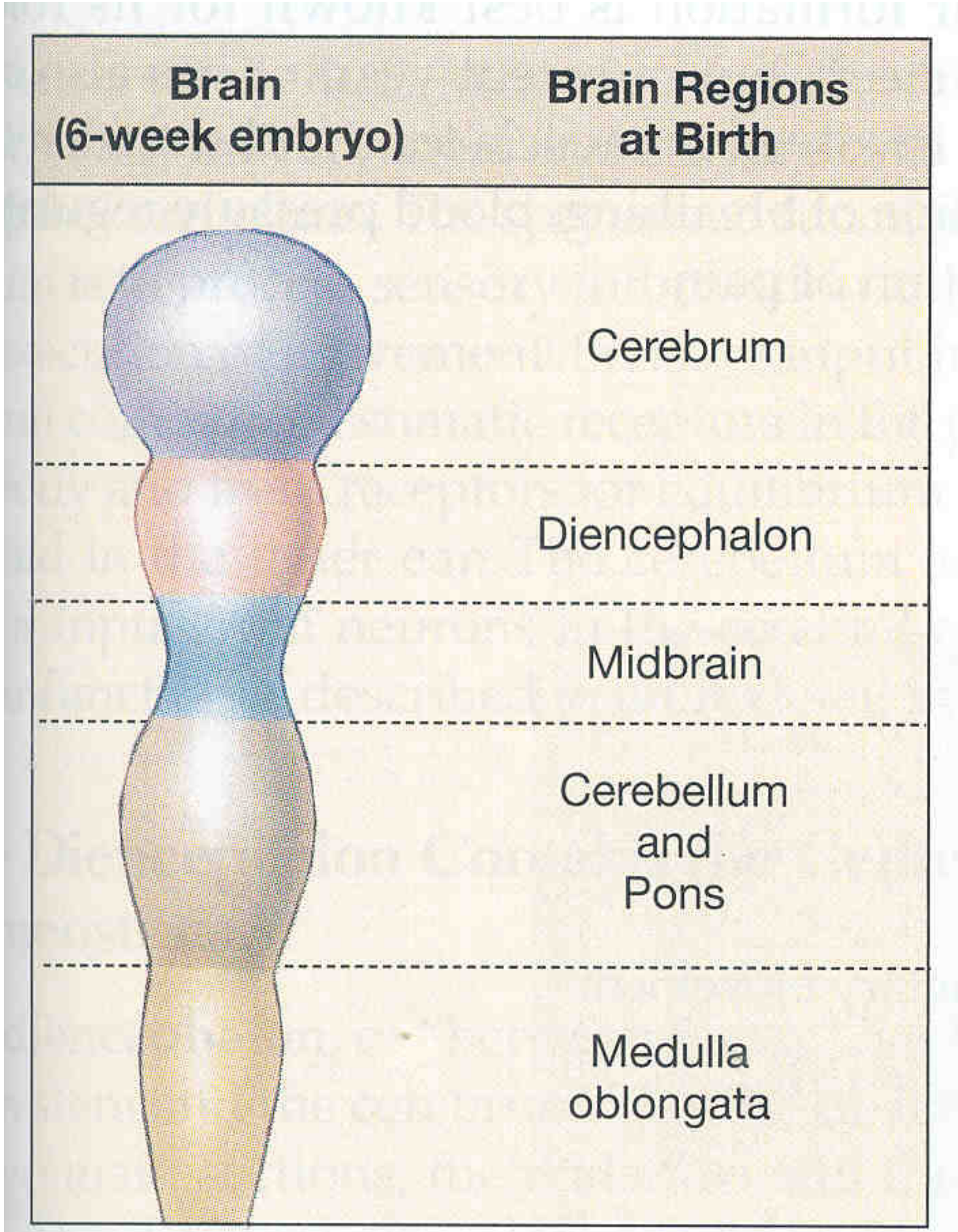
For YEARS developmental biologists tried to figure out the correspondence between specific head somites and specific pharyngeal gill slits.

Eventually, it was thought that somites and gill slits were such fundamentally different types of primary organizing segmentation that one could not be ties to the other.

However, in the mid 1990s on, the study of structures of the brain called BRAIN NEUROMERES – serial swellings of the dorsla hollow nerve cord - showed that:

1) Certain somites of the head – were associated with certain neuromeres, thus certain ventral root cranial neves were associated with certain neurmeres.
2) Certain gill slits were also associated with certain neuromeres.
3) Thus, although somites and gill slits are not causally related to one another, they do follow an even more primal head segmentation, that of the neuromeres of the brain.

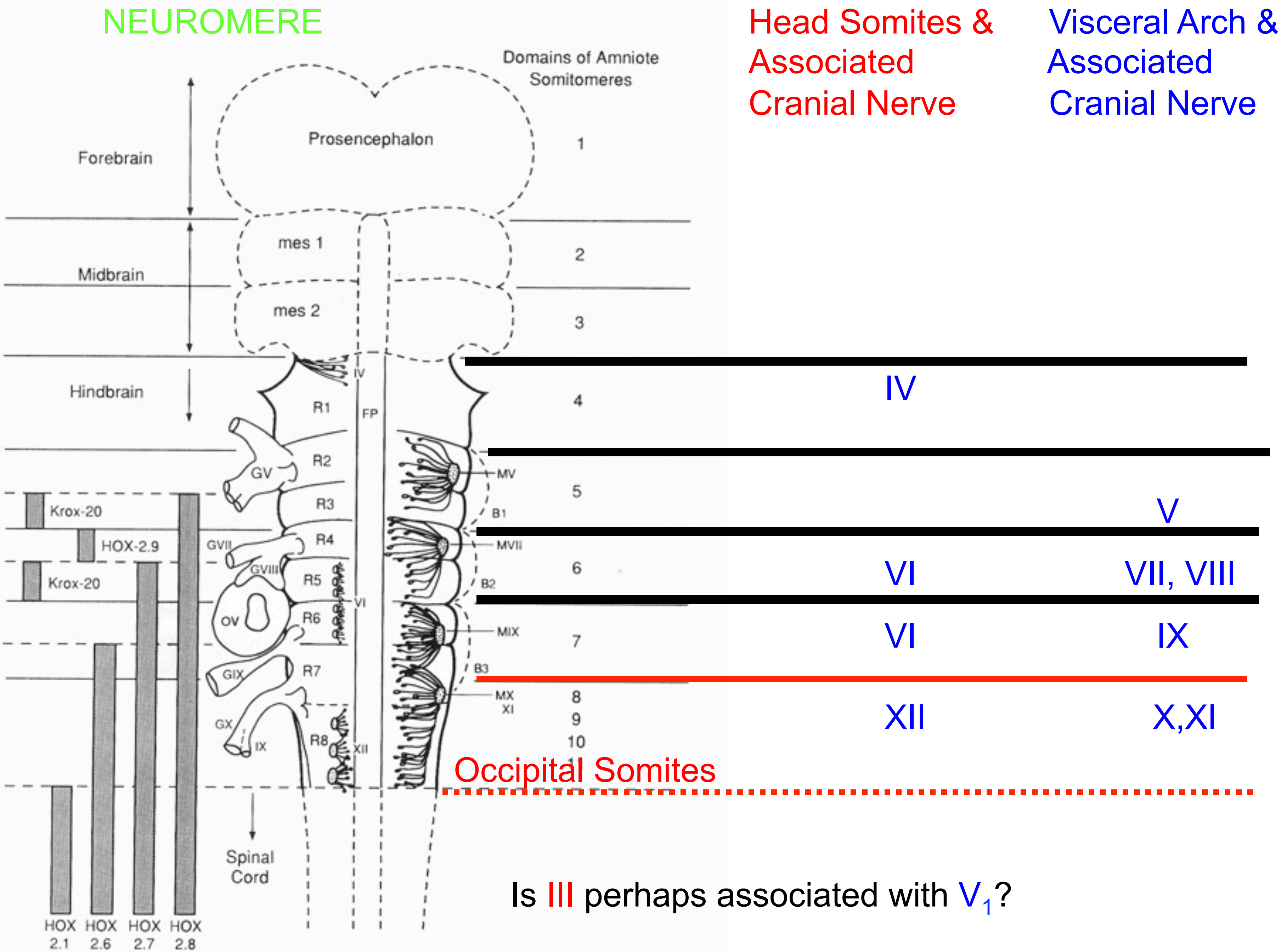
Recall….



FOREBRAIN

MIDBRAIN

HINDBRAIN


NEUROMERE
Head Somites & Associated Cranial Nerve
Visceral Arch & Associated Cranial Nerve
Domains of Amniote Somitomeres
Prosencephalon
Forebrain
Midbrain
Hindbrain
mes 1
mes 2
1
2
3
4
5
6
7
8
9
10
R1
R2
R3
R4
R5
R6
R7
R8
FP
IV
VI
XII
GV
GVII
GVIII
GIX
GX
IX
OV
MV
MVII
MIX
MX
XI
B1
B2
B3
Krox-20
HOX-2.9
Krox-20
HOX 2.1
HOX 2.6
HOX 2.7
HOX 2.8
Spinal Cord
IV
V
VI
VII, VIII
VI
IX
XII
X,XI
Occipital Somites
Is III perhaps associated with V1?