

Branchial Apparatus Development

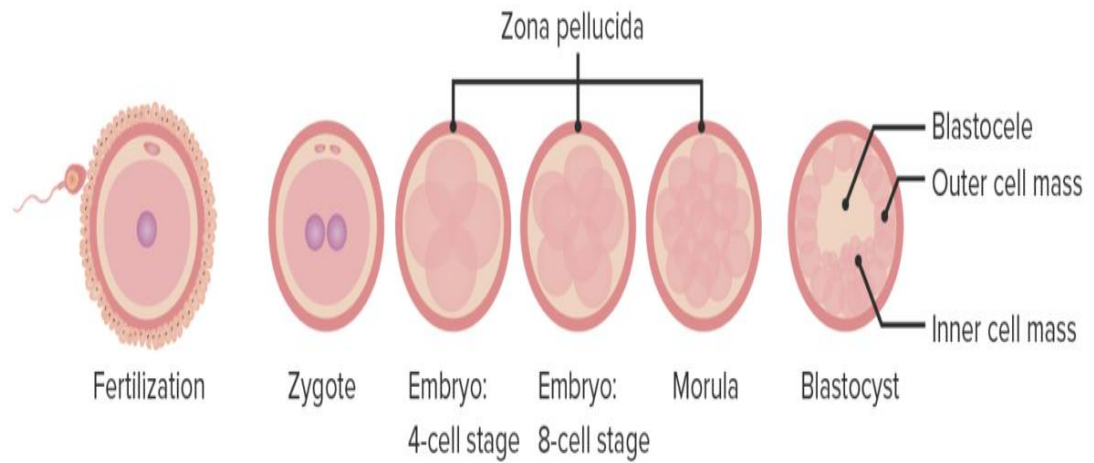
The branchial arches, also known as pharyngeal or visceral arches, are embryonic structures seen in the development of vertebrates that serve as precursors for many structures of the face, neck, and head. These arches are composed of a central core of mesoderm, which is covered externally by ectoderm and internally by endoderm. Indentations between arches are known as the pharyngeal clefts, or grooves, externally and the pharyngeal pouches internally. Each pharyngeal arch contains cartilage and muscular components, which are supplied by a cranial nerve (derived from neural crest cells), and an artery, known as a pharyngeal aortic arch. Some of these aortic arches go on to form the great vessels near the heart.

Review of Early Embryologic Development

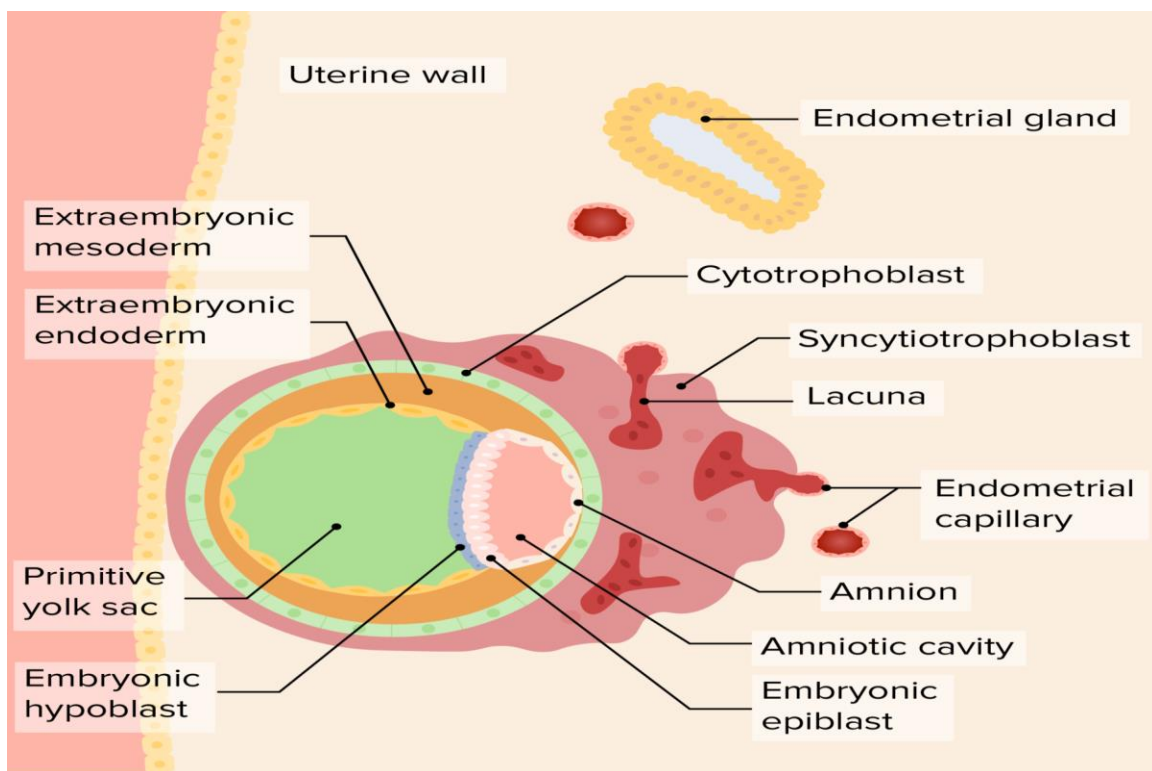
Blastocyst and bilaminar disc

The morula (ball of cells) undergoes a process called blastulation, in which a cavity begins to form. The cells then begin differentiating into outer and inner cell masses.

- **Outer cell mass → trophoblast → placenta and membranes**
- **Inner cell mass → embryoblast → bilaminar disc:**
 - **Epiblast**
 - **Hypoblast**
- **Amniotic sac: cavity of fluid that develops “above” the epiblast (between epiblast and trophoblast)**
- **Primitive yolk sac: cavity that forms “below” the hypoblast (between hypoblast and trophoblast)**



Fertilization, cleavage and blastocyst formation



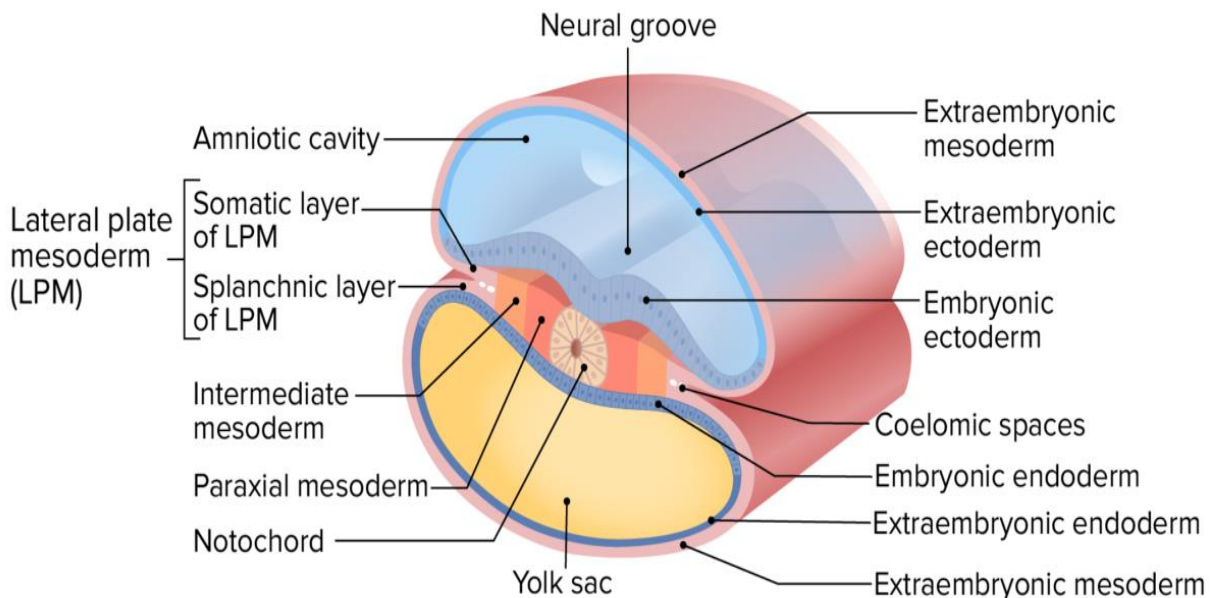
Bilaminar disc and implantation

Tri-laminar disc (gastrulation):

The bilaminar disc undergoes a process called gastrulation to form the tri-laminar disc. Cells from the epiblast layer migrate downward, replacing the hypoblast (endoderm) and creating a 3rd layer in between (mesoderm).

- Ectoderm (dorsal layer):
 - Continuous with the amnion
 - Formed from cells remaining in the epiblast layer
 - Ectoderm-derived structures:
 - Neural tube → brain and spinal cord
 - Neural crest cells → cranial nerves associated with the branchial arches, PNS
- Mesoderm (middle layer) has several components:
 - Paraxial mesoderm → forms the mesodermal component of the branchial arches
 - Intermediate mesoderm → genitourinary system
 - Lateral plate mesoderm (LPM):
 - Somatic layer of the LPM
 - Splanchnic layer of the LPM → forms primitive heart tube and pharyngeal aortic arches
 - Extraembryonic mesoderm:
 - Surrounds the amniotic cavity → continuous with somatic LPM
 - Surrounds the yolk sac → continuous with splanchnic LPM
- Endoderm (ventral layer):

- Embryonic endoderm (usually just called the endoderm) → becomes the primitive gut tube → most GI organs
- Extraembryonic endoderm → lines the yolk sac
- Folding of the trilaminar disc (folds in 2 directions):
 - Lateral folding:
 - Creates a cylindrical structure surrounded by ectoderm and amniotic cavity
 - Creates primitive gut tube internally from endoderm
 - Cranial–caudal folding:
 - Creates a cranial end and a caudal end (embryo becomes bean-shaped)
 - Forces the yolk sac farther from the body. The elongating stalk connecting the yolk sac to the gut tube is the vitelline duct.



3rd week of development (Gastrulation)

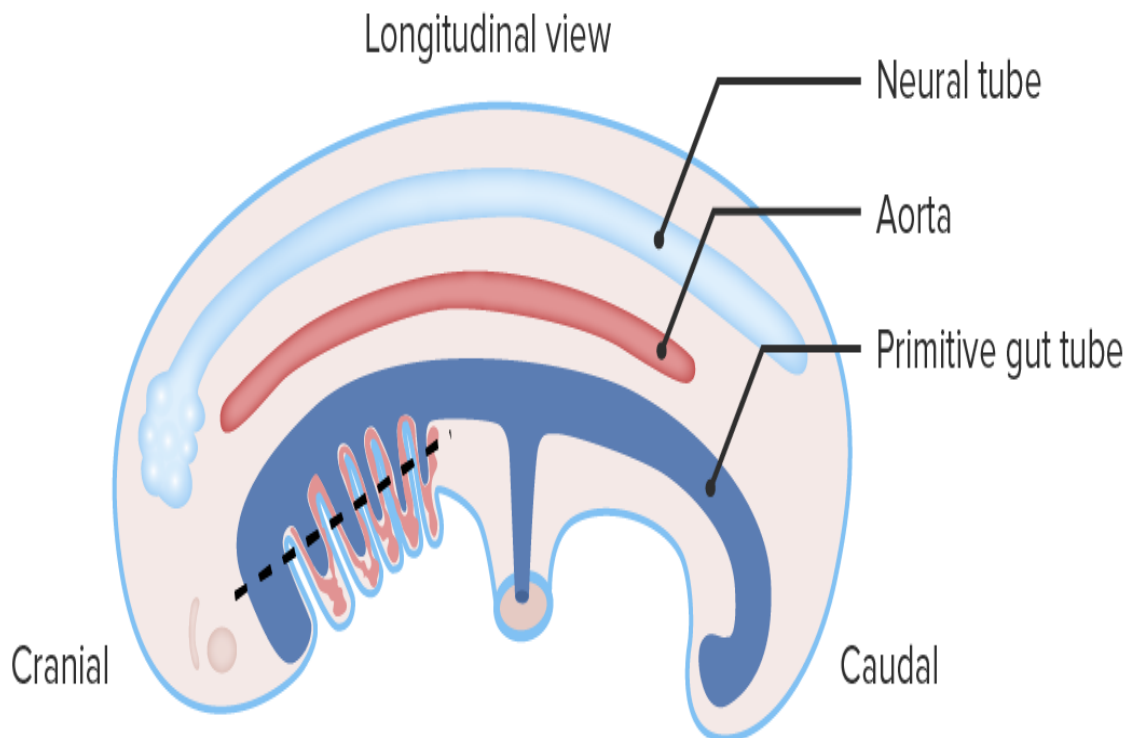
Origin and Structure of the Branchial Apparatus

Development of the branchial apparatus

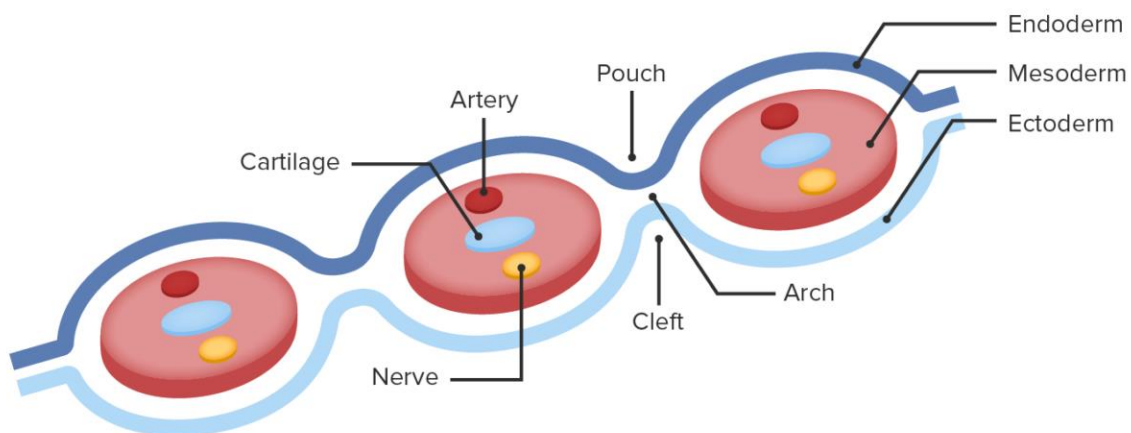
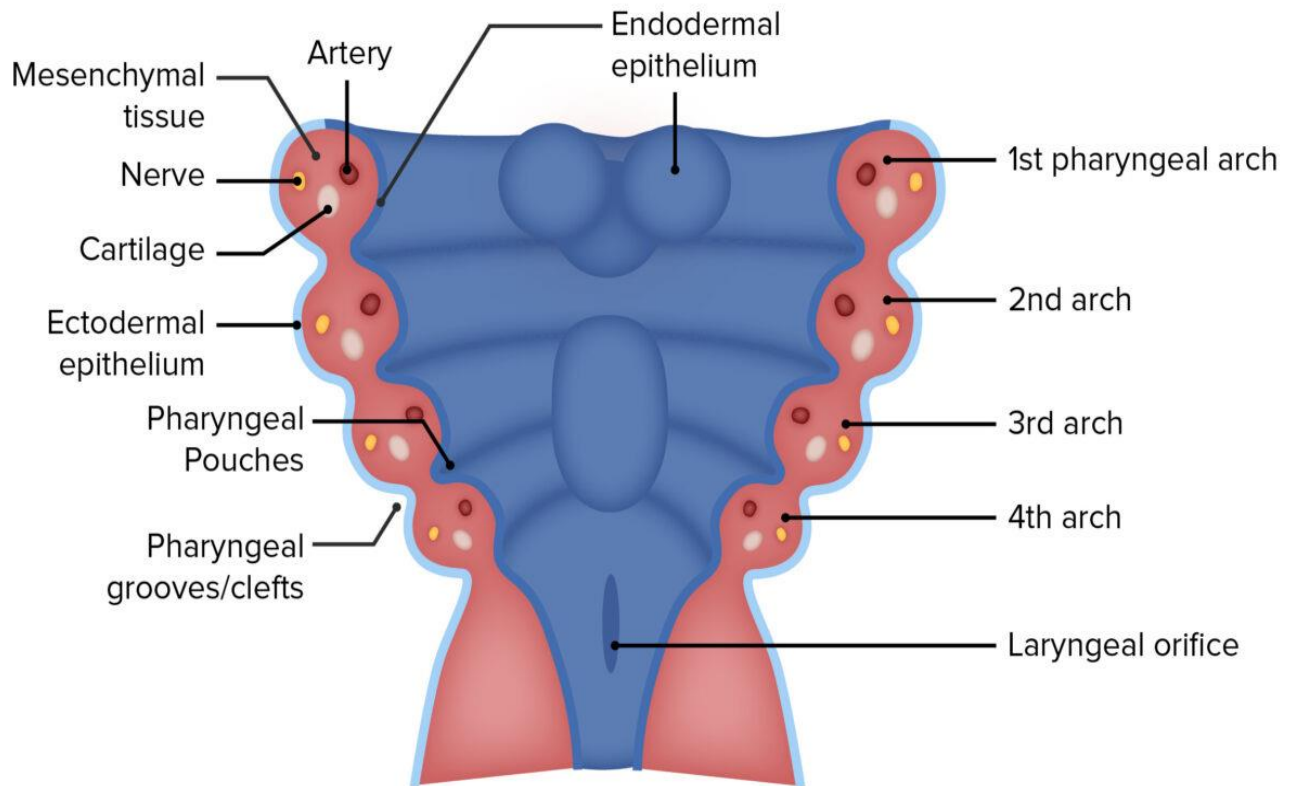
The branchial (meaning “gills”) apparatus is also known as the pharyngeal apparatus in humans.

- Occurs in the 4th–5th embryonic week
- In humans, 5 arch-shaped bulges or folds form off the ventral side of the foregut (part of the primitive gut tube) in the region that will become the head and neck.
 - Named branchial arches I–VI
 - Arches I, II, III, IV, and V exist in humans
 - Arch VI does not exist in humans; it is a structure in other vertebrates (e.g., fish).
 - 4th and 6th arches fuse → results in 4 total pharyngeal arches
 - Each of the arches consists of all 3 germ layers:
 - Endoderm: internal layer
 - Mesoderm: central core
 - Ectoderm: external layer
- Mesenchymal cells migrate downward (ventrally) from the paraxial mesoderm, surrounding the endoderm-derived foregut:
 - Form the lateral wall of the digestive tract
 - Continue to proliferate in the cranial portion of the tube forming the mesodermal core of the branchial arches
- Associated with each arch is:
 - A cranial nerve (nerve supply)
 - A pharyngeal aortic arch (blood supply)

- Arches are separated:
 - Externally by pharyngeal clefts, also called pharyngeal grooves:
 - Made from indentations of ectoderm
 - Groove/cleft I is below arch I.
 - Internally by pharyngeal pouches
 - Made from indentations of endoderm, directly across from the grooves
- Pouch I is below arch I.
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- Different segments of the tube have different patterns of gene expression → triggers various differentiations of each groove/arch/pouch



Embryonic Folding



Structure and derivatives of the branchial apparatus

- Pharyngeal clefts (also called pharyngeal grooves):
 - 4 indentations of ectoderm located on the external surface of the structure
 - Becomes external epithelium
- Pharyngeal arches:

- 4 cores of mesoderm located in the middle of the structure
- Become:
 - Cartilage and connective tissue
 - Muscle
 - Bones
- Also contain:
 - Nerves
 - Arteries
- Pharyngeal pouches:
 - 4 indentations of endoderm located on the internal surface of the structure
 - Become:
 - Internal epithelium
 - Glands

Development of the Pharyngeal Arches:

The pharyngeal arches develop into key components of the head and neck.

- Each arch contains a core of dense mesenchyme that develops into:
 - Cartilage rod → bone via endochondral ossification
 - Muscles
 - Connective tissue
- Somitomeres:
 - Segmented muscular tissue from paraxial mesoderm located on either side of the neural tube
 - Migrate into the developing arches

- Associate with developing cartilage there
- Branchial nerves:
 - Derived from neural crest cells, which are originally located dorsal to the neural tube
 - Migrate with the somitomeres down into the developing mesenchymal tissue of the pharyngeal arches
 - Develop into the cranial nerves innervating the muscles simultaneously developing within each arch
- Blood supply is via the associated branchial aortic arches.

Derivations and associations of each pharyngeal arches:

Derivates of pharyngeal folds	Arch number	Aortic arch	Cranial nerve	Examples of branchiomic muscles	Skeletal derivatives	Derivates of pharyngeal pouch
	I mandibular	maxillary artery	V trigeminal	muscles of mastication etc.	malleus, incus spheno-mandibular lig. Meckel cart.	I middle ear auditory tube
	II hyoid	hyoid, stapedial artery	VII facial	muscles of facial expression etc.	stapes, styl. proc., stylohyoid lig., part of hyoid cart.	II supra-tonsillar fossa
	III	internal carotid artery	IX glossopharyngeal	m. stylopharyngeus	parts of hyoid cart.	III thymus, parathyroid gland
	IV	right subclavian artery, aorta	X vagus	pharyngeal and laryngeal musculature	laryngeal cart.	IV thymus parathyroid gland ultimobranchial body

Development of the Pharyngeal Clefts and Pouches

Pharyngeal clefts (pharyngeal grooves)

The pharyngeal clefts are created by the invaginations of ectoderm on the external between the pharyngeal arches.

- Only 1 of the 4 ectodermal pharyngeal clefts develops into a definite organ system.
- 1st pharyngeal cleft becomes:
 - External auditory canal
 - External surface of the tympanic membrane
- 2nd pharyngeal cleft:
 - Proliferates and grows caudally
 - Grows “over” the 3rd and 4th pharyngeal clefts
- - Merges with the epicardial ridge → forms the cervical sinus (lined by ectoderm):
 - Later degenerates
 - If degeneration fails, lateral branchial cleft cysts may develop.
- 3rd and 4th pharyngeal clefts:
 - Form the medial lining of the cervical sinus
 - Ultimately degenerate

Development of the Pharyngeal Pouches

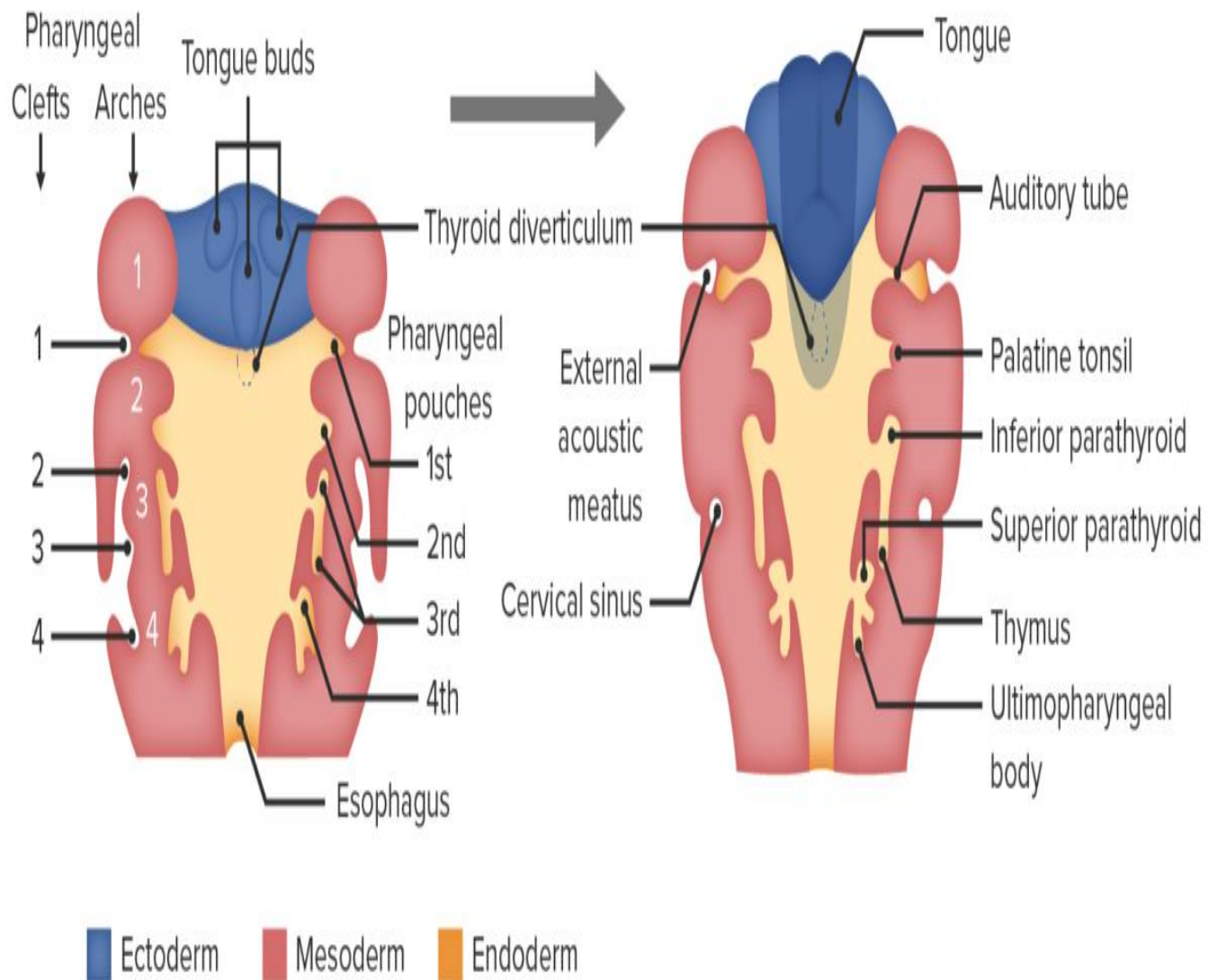
The pharyngeal pouches are created by the internal invaginations of endoderm between the pharyngeal arches.

- 1st pharyngeal pouch:
 - Tympanic cavity (i.e., middle ear cavity)

- Auditory or eustachian tube (draining the middle ear into the nasal cavity)
- 2nd pharyngeal pouch: tonsils
- 3rd pharyngeal pouch: splits into dorsal and ventral components:
 - Dorsal sprout → inferior parathyroid glands (start higher and move down)
 - Ventral sprout → thymus (starts in the neck and moves down into the chest)
- 4th pharyngeal pouch: splits into dorsal and ventral components:
 - Dorsal sprout → superior parathyroid glands (start lower and move up)
 - Ventral sprout → ultimobranchial body (sometimes attributed to a 5th pharyngeal pouch) → calcitonin-producing parafollicular or C cells of the thyroid gland

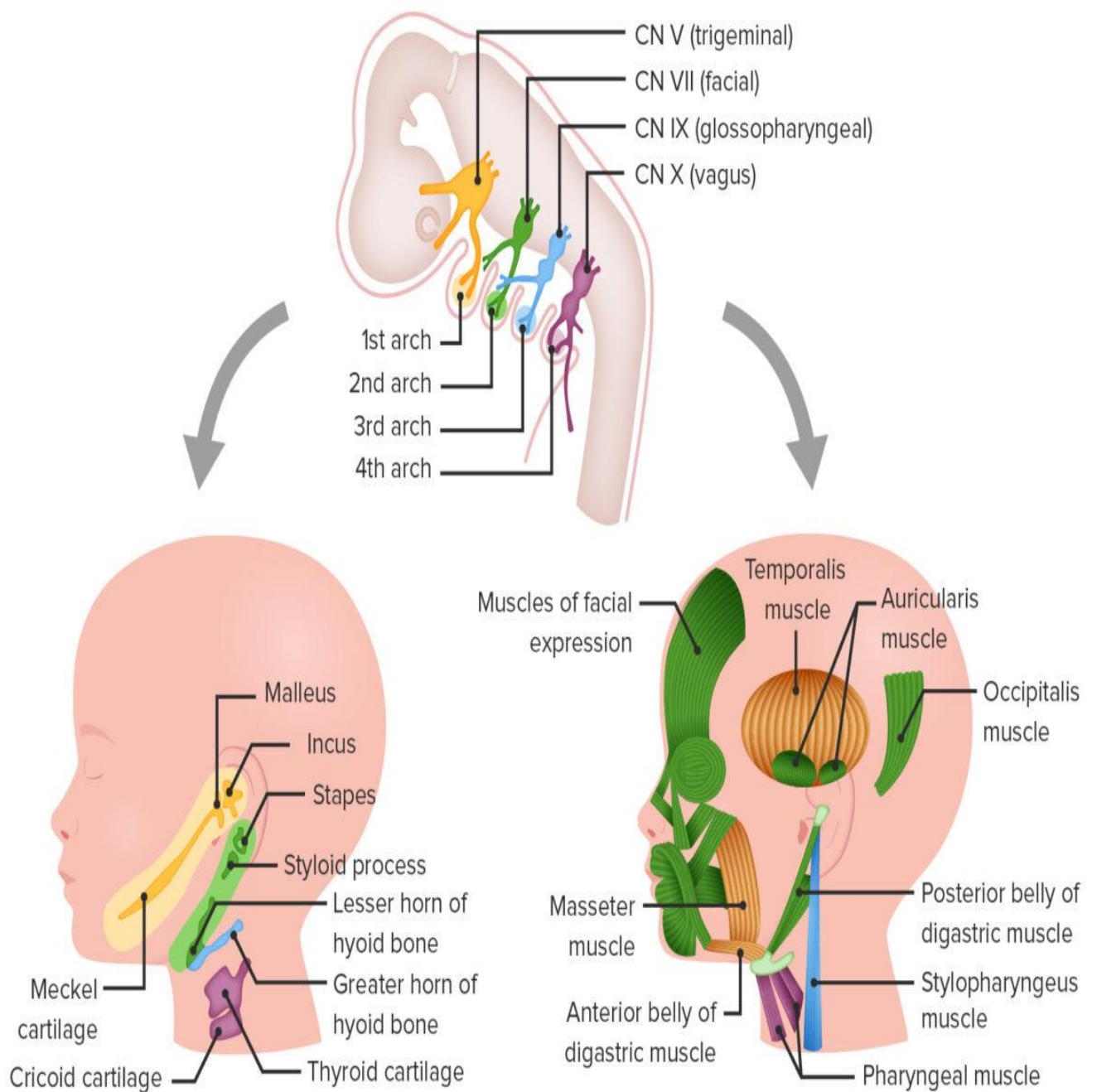
TABLE 17.2 Derivatives of the Pharyngeal Pouches

Pharyngeal Pouch	Derivatives
1	Tympanic (middle ear) cavity Auditory (eustachian) tube
2	Palatine tonsils Tonsillar fossa
3	Inferior parathyroid gland Thymus
4	Superior parathyroid gland ultimobranchial body (parafollicular [C] cells of the thyroid gland)



Development of the pharyngeal pouches

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Derivatives of branchial apparatus