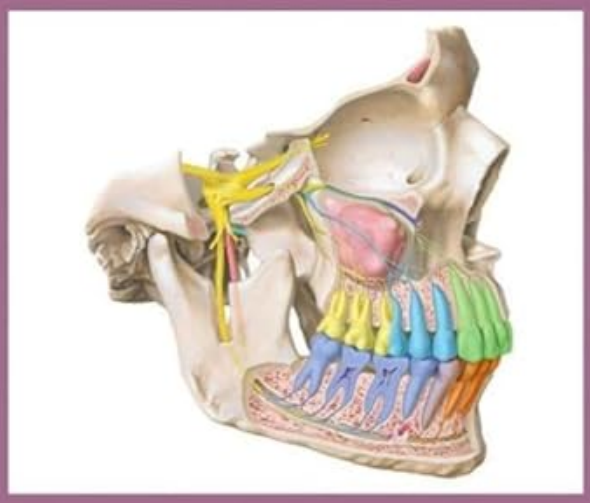

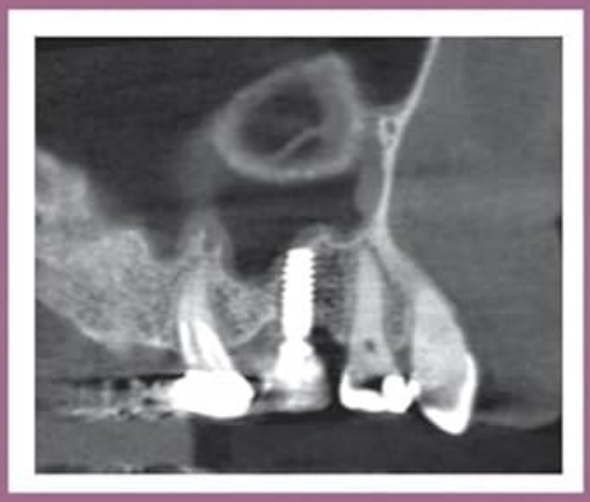

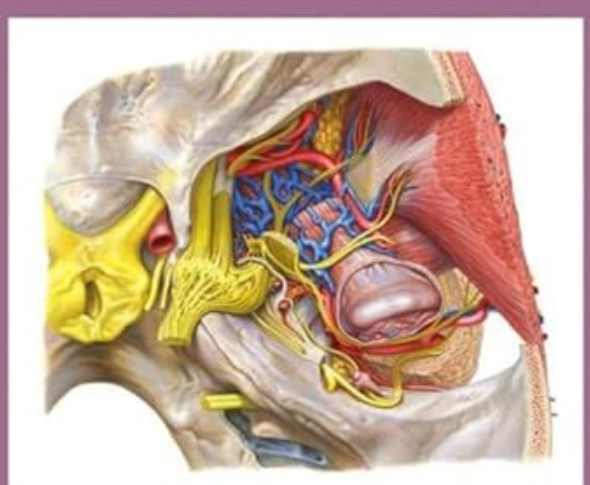

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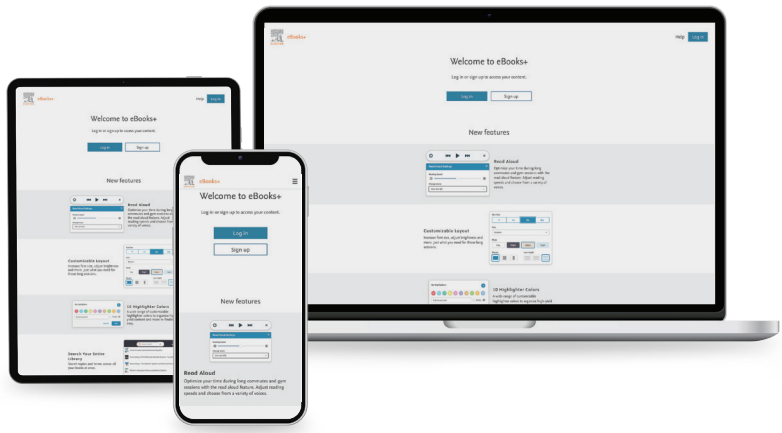

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NETTER'S
HEAD AND NECK ANATOMY FOR DENTISTRY

4TH EDITION

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In Memoriam

Neil and I became colleagues during our first year of graduate school. It was clear from the outset he thoughtfully chose the program we were in due to its emphasis on teaching. Neil's passion for teaching, for reaching others, and facilitating "aha!" moments was obvious in every interaction. In addition to teaching, Neil thoroughly enjoyed athletic events, in person or on screen, from intramural to professional levels. Neil's greatest joy, aside from interacting with students, was heckling referees and hammering the plexiglass behind the goalie. A dedicated Jay-backer, he was tireless in his support of Creighton athletic programs.

Proud of his Irish heritage, Neil became a dual citizen of the United States and Ireland. He traveled the world extensively (a "million-mile club" member) to teach, learn, and experience this world as richly as possible. He coveted cuisines unique to certain regions, especially New Mexico and New Orleans; he appreciated quality whiskey from Northern Ireland and never refused a well-made "screwdriver"! In line with his distinctive personal style, he pursued quirky interests: World Wrestling Entertainment (WWE) events all over the United States, over 30 Pink Floyd/Roger Waters concerts during his lifetime, and a favorite pet eel named Homer.

Opportunities to lead seemed to find him although he never appeared driven to pursue them. His leadership roles included President of the AACA, President of the Creighton University faculty council, and Associate Dean of Dental School Student Affairs and Admissions, among others. He had a knack for addressing challenging issues in a no-nonsense, straightforward manner and was viewed by most as tough but thoughtful and fair. In spite of his leadership accomplishments, Neil valued most his role as a teacher. He was the recipient of more teaching awards (locally and nationally) than any faculty member I have ever met over the past 30 years—clear evidence of his talents and drive to facilitate learning at the highest levels.

Neil will be remembered as a beloved colleague, mentor, teacher, and friend who put others first. He will be greatly missed. I know his spirit will live on through the pages of this text and in the joy of discovery that hopefully stems from those who choose to use and learn from it.

Gilbert M. Willett, PT, PhD, MS, OCS, CSCS

About the Authors

Neil S. Norton, PhD, joined Creighton University in 1996 and was the Associate Dean for Admissions and Professor of Oral Biology in the School of Dentistry. After graduating Phi Beta Kappa from Randolph-Macon College with a BA in Biology, he went on to receive his PhD training in anatomy from the University of Nebraska Medical Center. Dr. Norton was the recipient of over 25 teaching awards, including multiple Outstanding Instructor of the Year Awards from freshman classes and Dr. Theodore J. Urban Pre-Clinical Awards, presented by graduating senior classes for outstanding basic science instruction. Dr. Norton was the third professor in the history of the School of Dentistry to receive the prestigious Robert F. Kennedy Memorial Award for Teaching Achievement, the highest teaching recognition offered by the university. In 2007 Dr. Norton received the GlaxoSmithKline Sensodyne Teaching Award, the highest national teaching award given by the American Dental Education Association (ADEA). An active member of the School of Dentistry faculty, he was elected by colleagues to honorary membership in Omicron Kappa Upsilon, the National Dental Honor Society whose regular membership is reserved for dentists. His teaching responsibilities included head and neck anatomy, general anatomy, neuroscience, and pain control. Dr. Norton served 4 years as President of the University Faculty and chaired many committees, including the University Committee on Rank and Tenure and the University Committee on Academic Freedom and Responsibility. He also served as the Faculty Athletic Representative for Creighton to the Big East Conference and was an active member of the American Association of Clinical Anatomists (AACA), having served as the Treasurer for 7 years and as President from 2015–17. Neil died in 2022 after an extended battle with pancreatic cancer.

Gilbert M. Willett, PT, PhD, MS, OCS, CSCS, received a BS in physical therapy (1987), MS in anatomy and cell biology (1994), and a PhD in genetics, anatomy, and cell biology (2006) from the University of Nebraska Medical Center. Dr. Willett was a tenured Associate Professor in the College of Medicine at the University of Nebraska Medical Center, a tenured Professor in the Department of Oral Biology within the Creighton University School of Dentistry (2016–23), and is currently a Clinical Professor (Contributed Service) with the Creighton School of Dentistry as well as a Professor in the Department of Kinesiology, Physical Therapy Education Program, at Colorado Mesa University. Dr. Willett has practiced outpatient physical therapy for over 36 years and has taught basic science courses in human anatomy, physiology, histology, and neuroscience to dental, medical, physical therapy, physician assistant, and radiography students for over 32 years. In addition, he has extensive experience teaching anatomy and musculoskeletal-focused continuing education courses for practicing clinicians in these disciplines. He is a board-certified clinical specialist in orthopedic physical therapy (1994–present) and a certified strength and conditioning specialist (1996–present). He was elected by colleagues to honorary membership in Omicron Kappa Upsilon in 2022, a National Dental Honor Society whose regular membership is reserved for dentists. Dr. Willett has published research in the areas of applied clinical anatomy, scholarship of education, and clinical musculoskeletal physical therapy. He is also an active member of the American Association of Clinical Anatomists (AACA), having recently completed two consecutive terms of service on the Executive Council as an elected Allied Health Councilor.

About the Artists

Frank H. Netter, MD

Frank H. Netter was born in 1906 in New York City. He studied art at the Art Student's League and the National Academy of Design before entering medical school at New York University, where he received his MD in 1931. During his student years, Dr. Netter's notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the U.S. Army during World War II, Dr. Netter began his long collaboration with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

In 2005, Elsevier Inc. purchased the Netter Collection and all publications from Icon Learning Systems. There are now over 50 publications featuring the art of Dr. Netter available through Elsevier (in the United States: www.us.elsevierhealth.com/Netter and outside the United States: www.elsevierhealth.com).

Dr. Netter's works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-book Netter Collection of Medical Illustrations, which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. The Netter Atlas of Human Anatomy, first published in 1989, presents the anatomical paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but, more importantly, for their intellectual content. As Dr. Netter wrote in 1949, "...clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a medical illustration if it does not serve to make clear some medical point." Dr. Netter's planning, conception, point of view, and approach are what inform his paintings and what make them so intellectually valuable.

Frank H. Netter, MD, physician and artist, died in 1991.

Learn more about the physician-artist whose work has inspired the Netter Reference collection at www.netterimages.com/artist/netter.htm.

Carlos Machado, MD

Carlos Machado was chosen by Novartis to be Dr. Netter's successor. He continues to be the main artist who contributes to the Netter collection of medical illustrations.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter's original plates and has created many paintings of his own in the style of Netter as an extension of the Netter collection. Dr. Machado's photorealistic expertise and his keen insight into the physician/patient relationship inform his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at www.netterimages.com/artist/machado.htm.

Acknowledgments

Dr. Neil Norton passed away on November 27, 2022, after a courageous battle with cancer. He had been in the process of working on the fourth edition of this text, and due to his illness, asked me to assist. I was honored to participate. I extend thanks to our colleagues, especially Drs. Laura Barritt, Cara Fischer, Matt Kling, Niranzena Panneer Selvam, and Abrar Alamoudi for their assistance with completing this edition. In addition, I would like to acknowledge the Creighton University School of Dentistry Administration and students; the Elsevier team, especially Kate Mannix; artist Tiffany DaVanzo; and my wife Sandy for their support throughout this endeavor. I hope this text is a clear reflection of Neil's vision to provide an invaluable educational resource for students and clinicians in dentistry as well as all pertinent health professions students and providers to whom head and neck anatomy knowledge is of value to their practice.

Gilbert M. Willett, PT, PhD, MS, OCS, CSCS

Preface

The initial intent of *Netter's Head and Neck Anatomy for Dentistry* was to provide a comprehensive anatomical resource designed for first-year dental students. As the text evolved, it became apparent that it would also be a valuable resource for dental hygiene, medical, and physician assistant students, as well as a useful reference for practicing clinicians (both dental and medical). Head and neck anatomy comprises the foundation for dental anatomical study. The many small, interrelated structures are not easily observable, which makes head and neck anatomy one of the most difficult disciplines for students to master.

This fourth edition has focused on revising and clarifying information in the previous edition with the intent of further improving the quality of this resource. Many enhancements were based on feedback from students and colleagues. Text and image improvements have been made in almost every chapter. Text inconsistencies have been addressed. Numerous images have been modified and new ones added. Additional imaging has been included to provide greater clinical context. A new chapter addressing anatomical considerations for dental implants has also been added as a result of colleague requests. Lastly, the question/answer section at the end of the text has been completely updated to reflect a more "board exam" style design. We hope you find this text to be a valuable, comprehensive head and neck anatomy resource, regardless of whether you are a student or clinician.

Gilbert M. Willett, PT, PhD, MS, OCS, CSCS

PREFACE TO THE THIRD EDITION

Netter's Head and Neck Anatomy for Dentistry is a text/atlas written to help dental students and professionals learn and review head and neck anatomy. Designed for first-year dental students, it also serves to teach anatomy to students of dental hygiene as well as a review for the practicing clinician. The head and neck comprise the foundation for dental anatomical study. The many small, interrelated structures are not easily observable, which makes head and neck anatomy one of the most difficult disciplines for students to master.

This third edition has received a bit of a facelift. Elsevier has redesigned the look of the book, and I hope you are as pleased with the outcome as I am. There are numerous additions and revisions to the book. First is the appendix on the lymphatics with emphasis on the head and neck. Second, more than 30 radiographic images have been added to the existing image catalog to complement the anatomy illustrations throughout the text. Radiology is an important part of the education of every dental student, and it is a natural addition to any anatomy text. Third, more clinical correlates have been added to provide real-world scenarios for the student. Fourth, many of the tables and artwork have been revised following the suggestions of many of our readers of the previous editions. There are also 50 new questions that cover the chapters in the text. However, to give our readers more, Elsevier has created a test bank of questions on eBooks+. Thus, students can access all of the questions from previous editions as well as other review questions on eBooks+ for a more robust review of the material. Another perk of eBooks+ includes the addition of short anatomical video clips using the imaging from the third edition.

To understand the clinical significance of an anatomical concept is to understand the anatomy. It is with that in mind that a series of clinical correlates that relate specifically to dentistry are provided at the end of the chapters. There are many anatomical topics covered in traditional head and neck courses that have been expanded especially for this text. A chapter has been dedicated to the temporomandibular joint. In the chapter on the oral cavity, more information has been provided for the reader on such topics as dentition. Chapters on the development of the head and neck and basic neuroscience are included to help connect with other related anatomical areas. A chapter on intraoral injections is included to help teach and reinforce an area often overlooked. The intent

of these chapters is to provide the reader with a brief overview of important concepts related to head and neck anatomy.

A superb team of medical illustrators created new art to complement the anatomical illustrations of Dr. Frank H. Netter, which resulted in a more complete learning tool. In particular, the new illustrations of Dr. Carlos Machado demonstrate why he continues to be the preeminent medical illustrator in his field. The Temporomandibular Joint chapter features six new figures by Dr. Machado, and I know you will find them as spectacular as I do. Essential information is presented in tables and brief text that are integrated with the Netter art to help bridge gaps and augment the readers' knowledge of head and neck anatomy.

Netter's Head and Neck Anatomy for Dentistry is for those in all stages of the dental profession. My hope is that this book will provide an essential resource to readers in helping them to learn and appreciate the complex anatomy of the head and neck.

Neil S. Norton, PhD

Contents

CHAPTER 1

DEVELOPMENT OF THE HEAD AND NECK

- 3 major germ layers form the initial developing embryo:
  - Ectoderm
  - Mesoderm
  - Endoderm
- Mesoderm differentiates into:
  - Paraxial mesoderm
  - Intermediate mesoderm
  - Lateral plate mesoderm
- Ectoderm gives rise to 3 layers:
  - Neuroectoderm
  - Neural crest
  - Epidermis
- The head and neck are formed by:
  - Paraxial mesoderm
  - Lateral plate mesoderm
  - Neural crest–derived mesoderm
  - Ectodermal placodes
- Most of the head and neck is formed from the pharyngeal region of the embryo

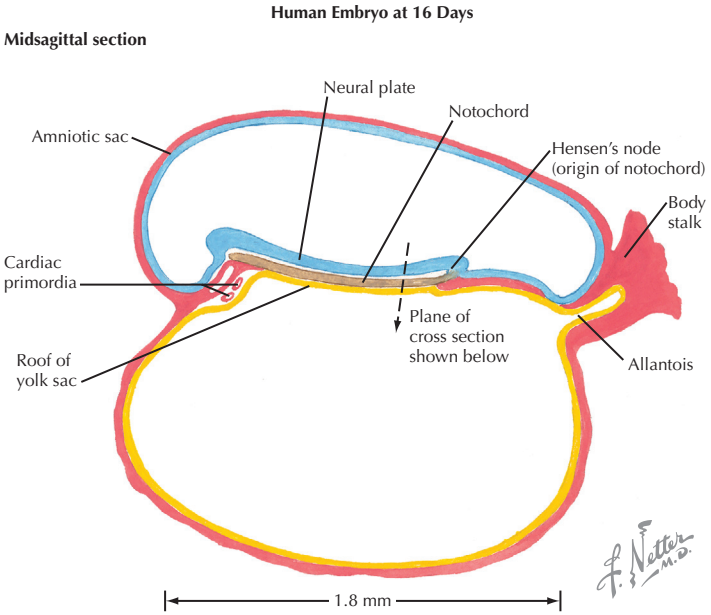


Figure 1-1

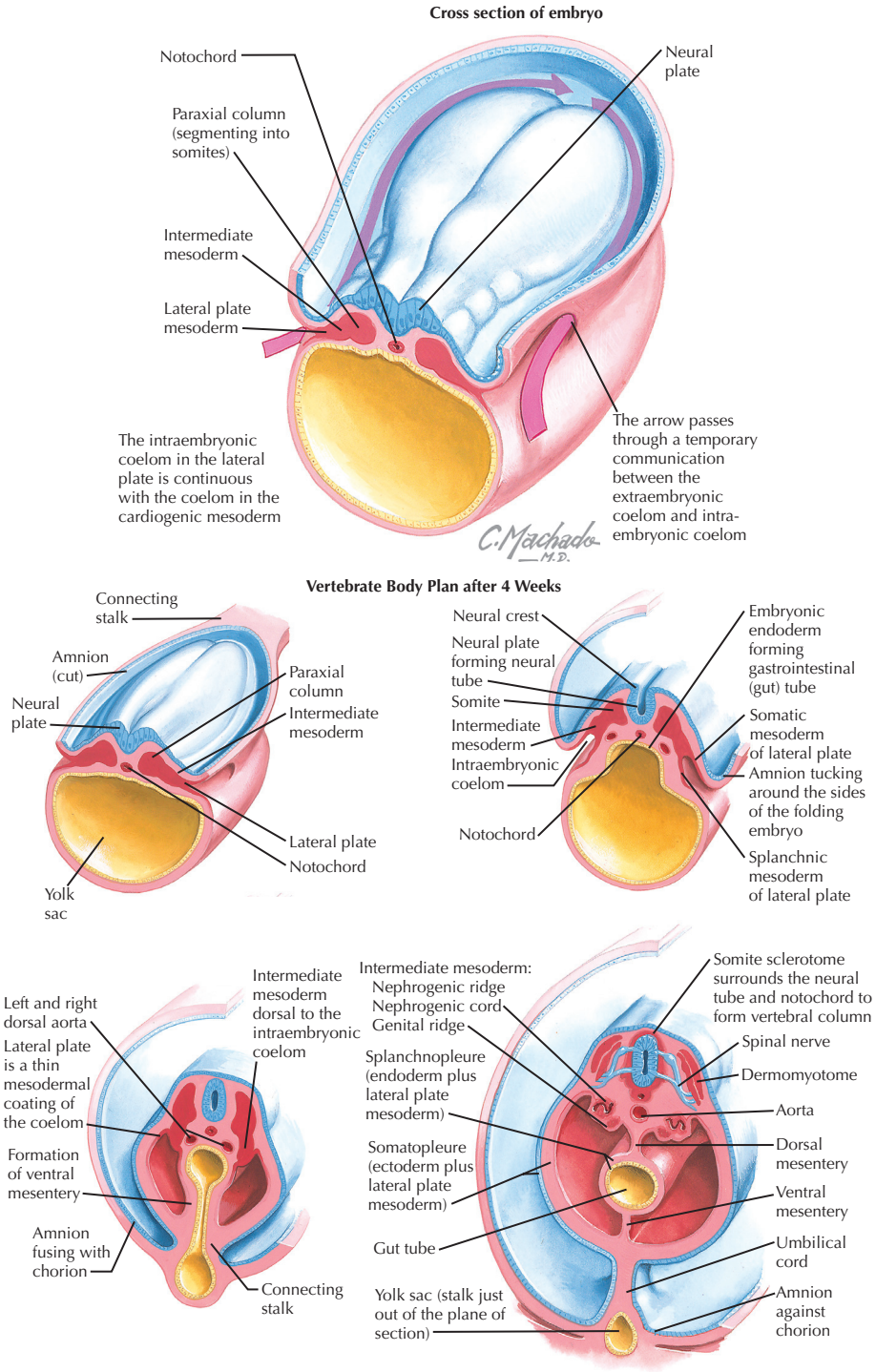

Cross section of embryo
Notochord
Neural plate
Paraxial column (segmenting into somites)
Intermediate mesoderm
Lateral plate mesoderm
The intraembryonic coelom in the lateral plate is continuous with the coelom in the cardiogenic mesoderm
The arrow passes through a temporary communication between the extraembryonic coelom and intra-embryonic coelom
C. Machado M.D.
Vertebrate Body Plan after 4 Weeks
Connecting stalk
Amnion (cut)
Neural plate
Paraxial column
Intermediate mesoderm
Lateral plate
Notochord
Yolk sac
Neural crest
Neural plate forming neural tube
Somite
Intermediate mesoderm
Intraembryonic coelom
Notochord
Embryonic endoderm forming gastrointestinal (gut) tube
Somatic mesoderm of lateral plate
Amnion tucking around the sides of the folding embryo
Splanchnic mesoderm of lateral plate
Left and right dorsal aorta
Lateral plate is a thin mesodermal coating of the coelom
Formation of ventral mesentery
Amnion fusing with chorion
Intermediate mesoderm dorsal to the intraembryonic coelom
Connecting stalk
Intermediate mesoderm:
Nephrogenic ridge
Nephrogenic cord
Genital ridge
Splanchnopleure (endoderm plus lateral plate mesoderm)
Somatopleure (ectoderm plus lateral plate mesoderm)
Gut tube
Yolk sac (stalk just out of the plane of section)
Somite sclerotome surrounds the neural tube and notochord to form vertebral column
Spinal nerve
Dermomyotome
Aorta
Dorsal mesentery
Ventral mesentery
Umbilical cord
Amnion against chorion

Figure 1-2

- Start forming in the 4th week of development
- Develop as blocks separated by pharyngeal clefts (formed by ectoderm)
- Initially, 6 pharyngeal arches develop, but the 5th regresses
- Arising from the endoderm are compartments called pharyngeal pouches that extend toward the pharyngeal clefts; where pharyngeal pouch endoderm meets pharyngeal cleft ectoderm is known as the *pharyngeal membrane*
- Help form 4 of the 5 swellings (embryonic primordia) of the face:
  - 2 mandibular processes (pharyngeal arch)
  - 2 maxillary processes (pharyngeal arch)
  - 1 frontonasal prominence
- Composed of
  - External surface—ectoderm
  - Internal surface—endoderm
  - Central part—lateral plate mesoderm, paraxial mesoderm, and neural crest–derived mesoderm
- Skeletal components and associated connective tissue develop from neural crest–derived mesoderm cells
- Muscular structures develop collectively from mesoderm
- Each arch is innervated by a cranial nerve that migrates with the muscles

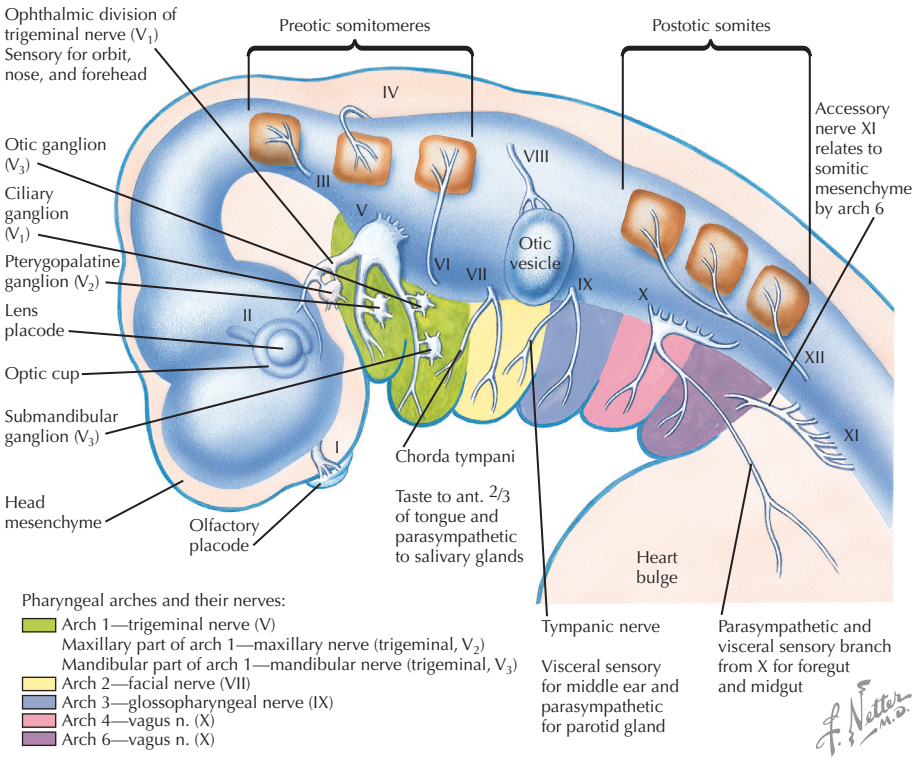
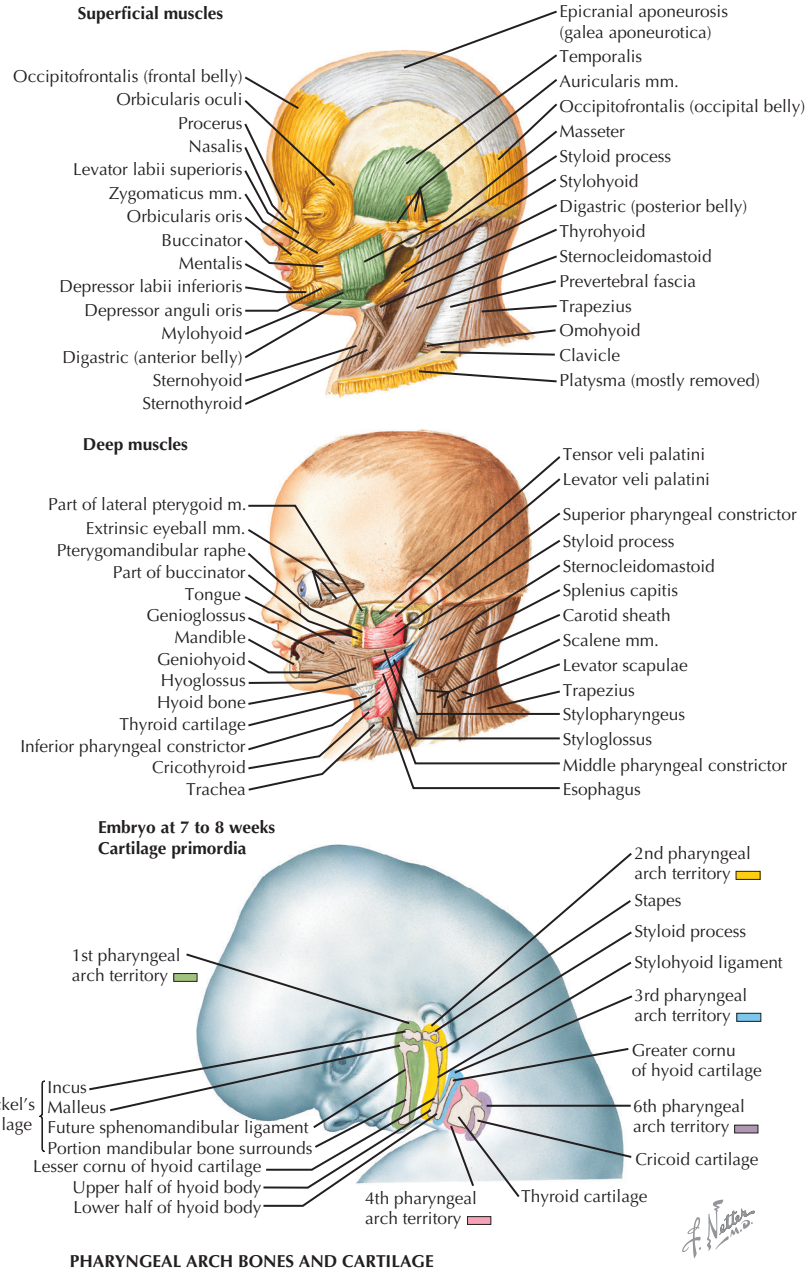


Figure 1-3

Arch	Muscle(s) from Mesoderm	Cartilage Structure(s) from Neural Crest–Derived Mesoderm	Cartilage Structure(s) from Mesoderm	Connective Tissue Structure(s) from Neural Crest–Derived Mesoderm	Nerve
1 (also called the mandibular arch) Develops into: ▪ Maxillary process ▪ Mandibular process	Masseter Temporalis Lateral pterygoid Medial pterygoid Mylohyoid Anterior digastric Tensor tympani Tensor veli palatini	Malleus Incus (both from Meckel's cartilage, which degenerates in adulthood)		Sphenomandibular ligament Anterior ligament of the malleus (both from Meckel's cartilage, which degenerates in adulthood)	Trigeminal
2 (also called the hyoid arch)	Muscles of facial expression Posterior digastric Stylohyoid Stapedius	Lesser cornu of the hyoid Superior part of the hyoid body Styloid process Stapes (all from Reichert's cartilage)		Stylohyoid ligament Connective tissue of the tonsil	Facial
3	Stylopharyngeus	Greater cornu of the hyoid Inferior part of the hyoid body		Connective tissue of the thymus and inferior parathyroid	Glossopharyngeal
4	Musculus uvulae Levator veli palatini Palatopharyngeus Palatoglossus Superior constrictor Middle constrictor Inferior constrictor Salpingopharyngeus Cricothyroid		Epiglottis Thyroid (both from lateral plate mesoderm)	Connective tissue of the superior parathyroid and the thyroid	Vagus
6	Thyroarytenoid Vocalis Lateral cricoarytenoid Oblique arytenoids Transverse arytenoids Posterior cricoarytenoid Aryepiglotticus Thyroepiglotticus		Arytenoid Cricoid Cuneiform Corniculate (all from lateral plate mesoderm)		Vagus



PHARYNGEAL ARCH BONES AND CARTILAGE

Arch #	Derivatives of Arch Cartilages
1	Malleus, incus, sphenomandibular ligament, anterior ligament of malleus
2	Stapes, styloid process, stylohyoid ligament, upper half and lesser horn of hyoid
3	Lower half and greater horns of hyoid
4	Thyroid and epiglottic cartilages of larynx
6	Cricoid, arytenoid, and corniculate cartilages of larynx

Figure 1-4

- Pharyngeal pouches—4 develop from endoderm
- Pharyngeal clefts—each is a groove formed from ectoderm
- Pharyngeal membranes—each is composed of tissue located between a pharyngeal pouch and a pharyngeal cleft; composed of external ectoderm, mesoderm, and neural crest–derived mesoderm in the core and an internal endoderm lining

Pharyngeal Pouches

Pouch	Location	Embryonic Structure	Adult Structure
1	Opposite the 1st pharyngeal cleft, separated by the 1st pharyngeal membrane	Tubotympanic recess	Epithelium of the (pharyngotympanic auditory) tube Tympanic cavity
2	Opposite the 2nd pharyngeal cleft, separated by the 2nd pharyngeal membrane	Primordial palatine tonsils	Tonsillar (sinus fossa) Epithelium of the palatine tonsil
3	Opposite the 3rd pharyngeal cleft, separated by the 3rd pharyngeal membrane	Divides into a dorsal and a ventral part Dorsal part—migrates inferiorly toward the thorax	Inferior parathyroid gland (from the dorsal part) Thymus (from the ventral part)
4	Opposite the 4th pharyngeal cleft, separated by the 4th pharyngeal membrane	Divides into a dorsal and a ventral part Ventral part is invaded by neural crest to form the parafollicular or C cells	Superior parathyroid gland (from the dorsal part) Ultimobranchial body (from the ventral part)

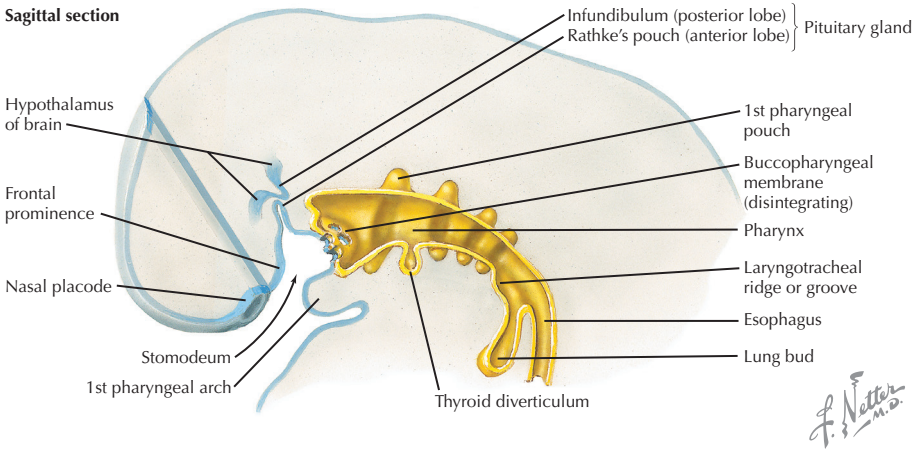


Figure 1-5

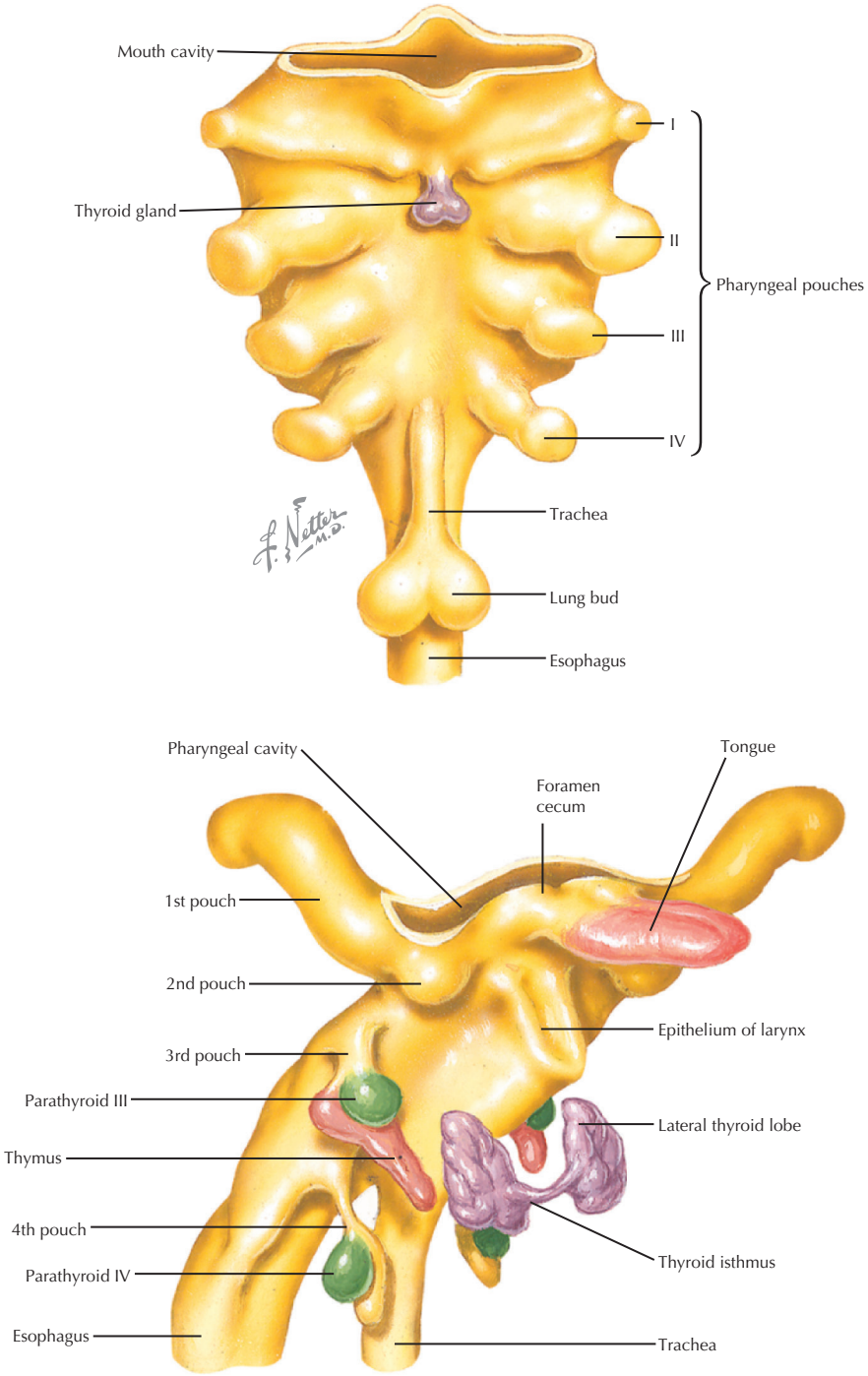

Mouth cavity
Thyroid gland
I
II
III
IV
Pharyngeal pouches
Trachea
Lung bud
Esophagus
F. Netter M.D.
Pharyngeal cavity
Foramen cecum
Tongue
1st pouch
2nd pouch
3rd pouch
Epithelium of larynx
Parathyroid III
Lateral thyroid lobe
Thymus
4th pouch
Thyroid isthmus
Parathyroid IV
Esophagus
Trachea

Figure 1-6

Membrane	Location	Adult Structure
1	Between the 1st pharyngeal cleft and the 1st pharyngeal pouch	Tympanic membrane
2	Between the 2nd pharyngeal cleft and the 2nd pharyngeal pouch	
3	Between the 3rd pharyngeal cleft and the 3rd pharyngeal pouch	
4	Between the 4th pharyngeal cleft and the 4th pharyngeal pouch	

Pharyngeal Clefts

Cleft	Location	Adult Structure
1	A groove between the 1st and 2nd pharyngeal arches	External acoustic meatus
2	A groove between the 2nd and 3rd pharyngeal arches	Obliterated cervical sinus by the 2nd pharyngeal arch, which grows over the clefts
3	A groove between the 3rd and 4th pharyngeal arches	
4	A groove between the 4th and 6th pharyngeal arches	

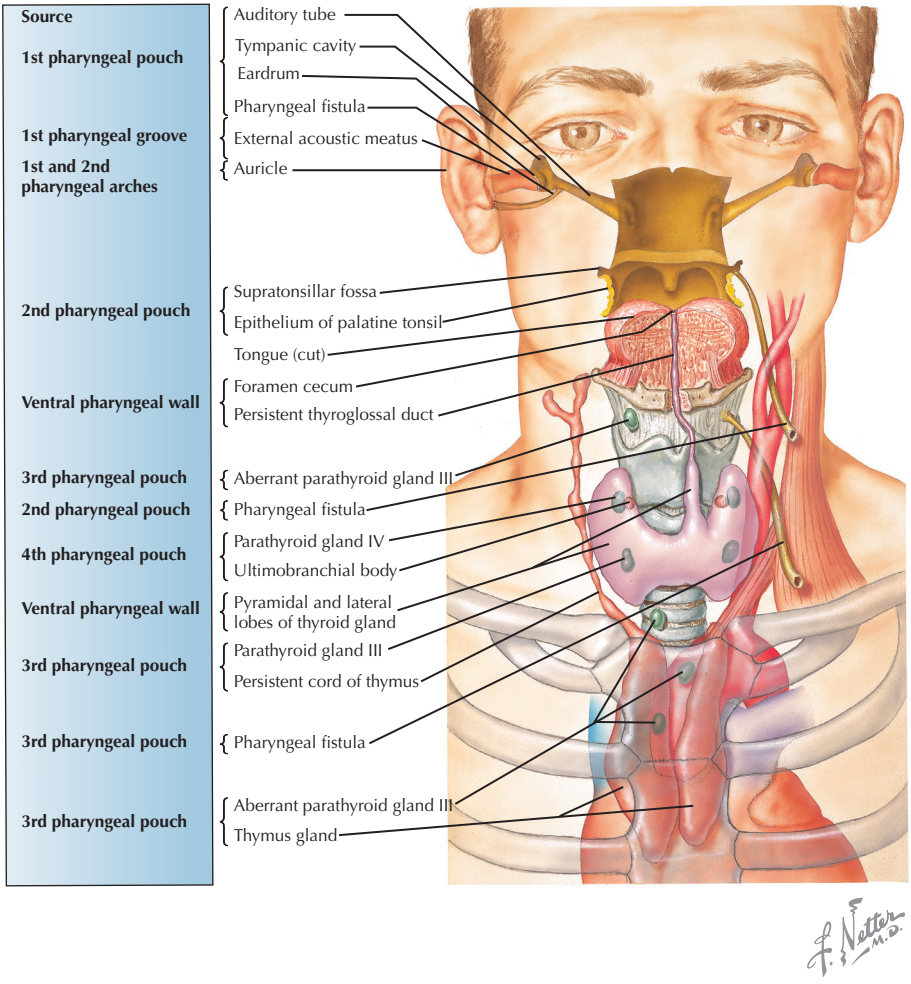


Figure 1-7

- Cranium (skull) is formed from
  - Lateral plate mesoderm (neck region)
  - Paraxial mesoderm
  - Neural crest
- Cranium development is divided into 2 parts:
  - Viscerocranium—forms the bones of the face (from the pharyngeal arches)
    - Forms completely from neural crest
  - Neurocranium—forms the bones of the cranial base and cranial vault, and the function is to protect and surround the brain and organs of special sense (olfaction, vision, auditory, and equilibrium). It can be divided into
    - Membranous neurocranium (forms from neural crest and paraxial mesoderm)
    - Cartilaginous neurocranium (forms from neural crest and paraxial mesoderm)
- Bony skull is formed by either of 2 mechanisms:
  - Intramembranous ossification
  - Endochondral ossification

Viscerocranium

Germ Layers	Origins	Adult Structure(s)	Ossification
Neural crest	1st pharyngeal arch *Maxillary process*	Maxilla	Intramembranous
		Temporal bone	
		Zygoma	
		Palatine	
		Lacrimal	
		Vomer	
		Nasal	
		Inferior nasal concha	Endochondral
	1st pharyngeal arch *Mandibular process*	Mandible	Intramembranous (body) Endochondral (coronoid and condylar process)
		Malleus	Endochondral
		Incus	
	2nd pharyngeal arch	Styloid process	Endochondral
		Stapes	
		Hyoid	

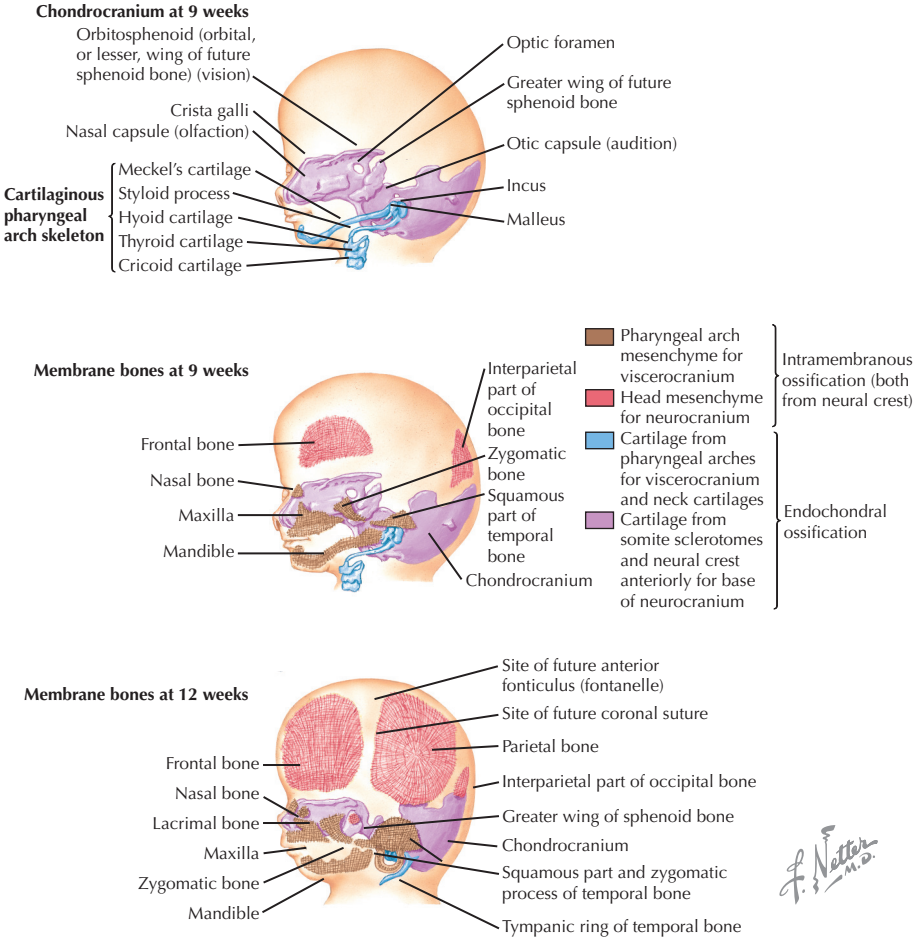


Figure 1-8

Cranial Fontanelles

Fontanelle	Time of Closure
Anterior fontanelle (bregma)	4–26 months
Posterior fontanelle (lambda)	1–2 months
Sphenoidal fontanelle (pterion)	2–3 months
Mastoid fontanelle (asterion)	12–18 months

Germ Layer	Portions of Neurocranium	Adult Structure	Ossification
Neural crest	Main portion of the roof and lateral sides of the cranial vault	Frontal bone Squamous portion of the temporal bone	Intramembranous
Paraxial mesoderm		Parietal bone Occipital bone (intraparietal portion)	

Cartilaginous Neurocranium

Germ Layer	Portions of Neurocranium	Adult Structure	Ossification
Neural crest	Prechordal Anterior to the sella turcica	Ethmoid Sphenoid	Endochondral
Paraxial mesoderm	Chordal Posterior to the sella turcica	Petrous portion of the temporal bone Mastoid process of the temporal bone Occipital bone	

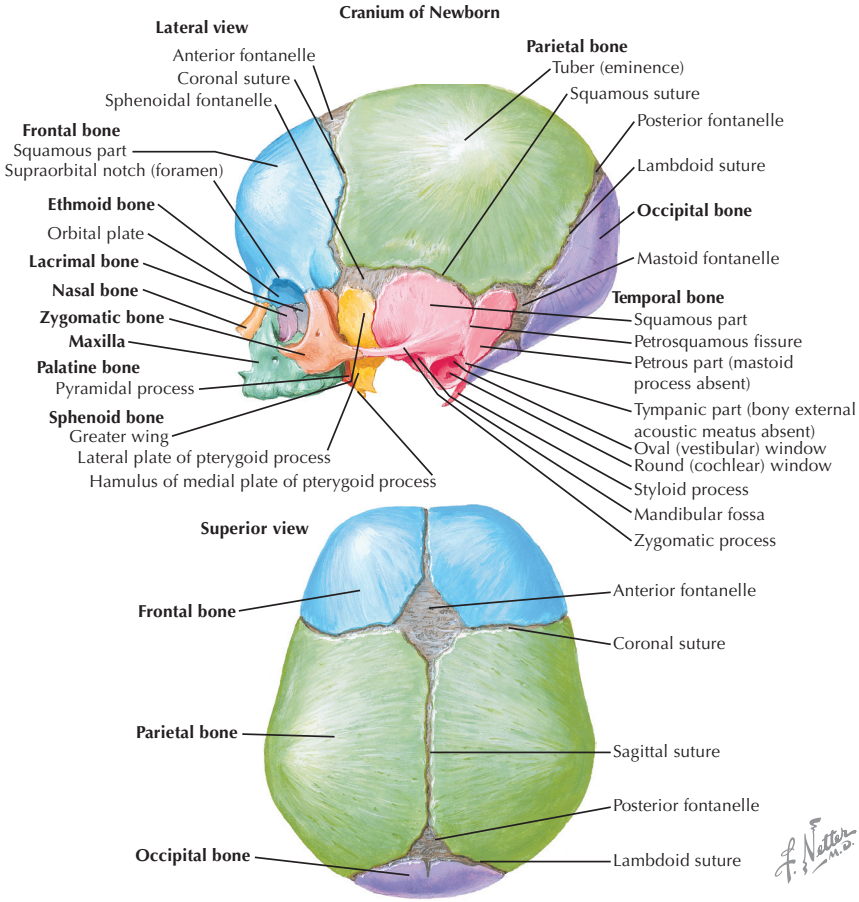


Figure 1-9

- The face is formed mainly from neural crest, which makes 3 swellings (prominences) that surround the stomodeum:
  - Frontonasal prominence
  - Maxillary prominence (from the 1st pharyngeal arch)
  - Mandibular prominence (from the 1st pharyngeal arch)
- Lateral to the frontonasal prominence, 2 additional areas of ectoderm form the 2 nasal placodes that invaginate in the center to form nasal pits, creating ridges of tissue on either side of the pits:
  - Lateral nasal prominence
  - Medial nasal prominence
- Fusion of the medial nasal prominences at the midline results in formation of the intermaxillary segment

ADULT STRUCTURES OF THE FACE	
Structure	**Develop(s) from**
Forehead	Frontonasal prominence
Upper lip	Maxillary prominence (lateral part of upper lip) Medial nasal prominence (middle part of upper lip)
Lower lip	Mandibular prominence
Lacrimal sac Nasolacrimal duct	A nasolacrimal groove that separates the lateral nasal prominence and the maxillary prominence
Nose	Frontonasal prominence (bridge of nose) Medial nasal prominence (nose attaching at philtrum) Lateral nasal prominence (alae of nose)
Cheeks	Maxillary prominence
Philtrum	Medial nasal prominence
Primary palate Upper jaw containing the central and lateral incisors	Intermaxillary segment (fusion of medial nasal prominences)

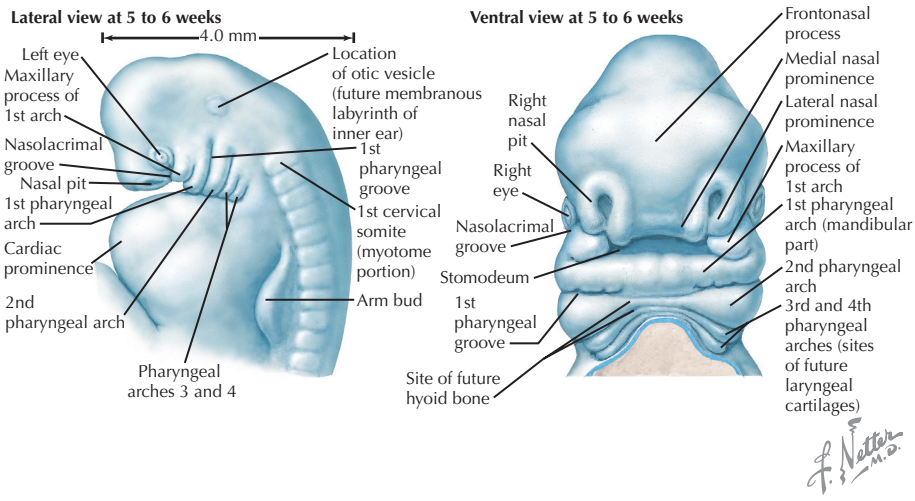


Figure 1-10

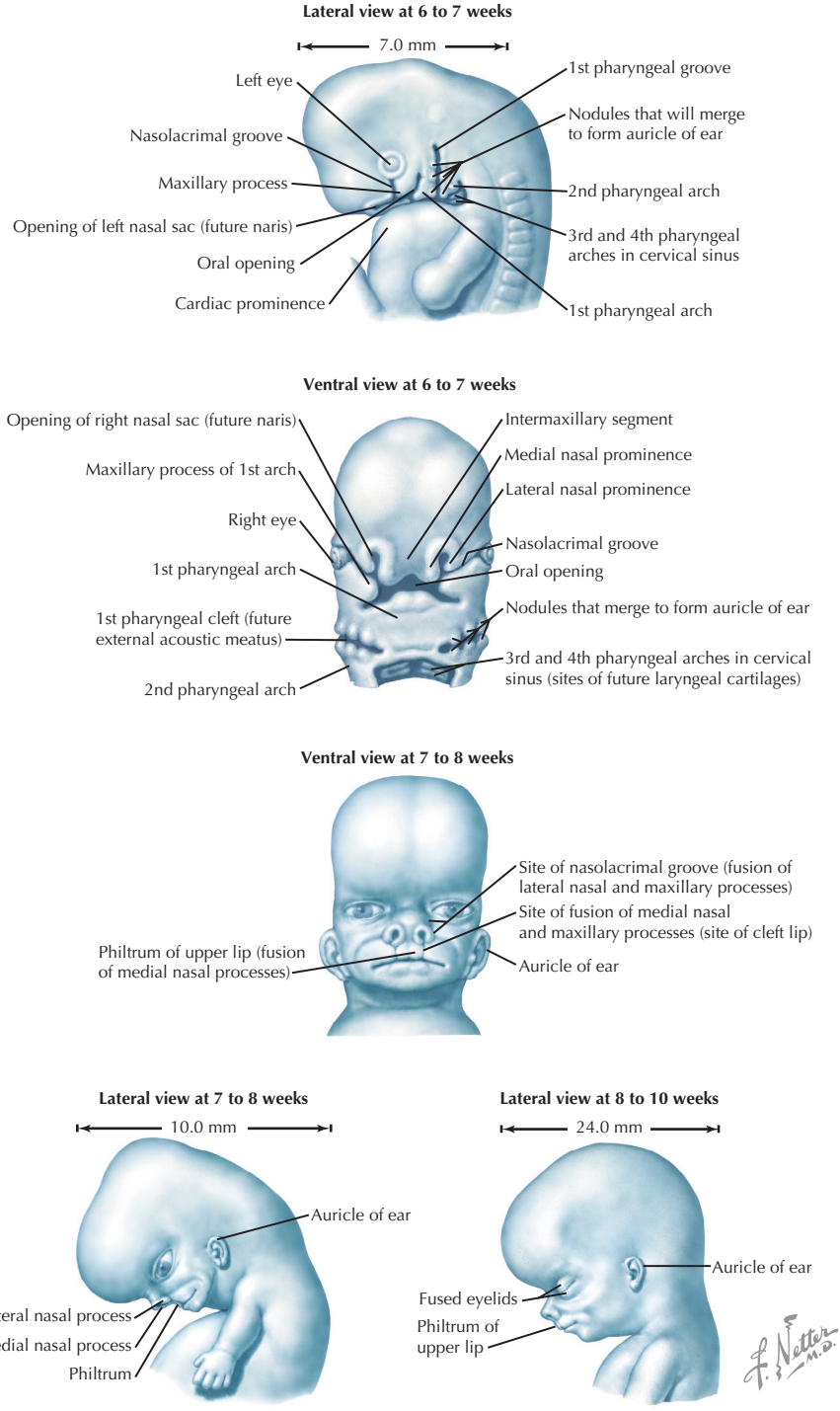

Lateral view at 6 to 7 weeks
7.0 mm
Left eye
Nasolacrimal groove
Maxillary process
Opening of left nasal sac (future naris)
Oral opening
Cardiac prominence
1st pharyngeal groove
Nodules that will merge to form auricle of ear
2nd pharyngeal arch
3rd and 4th pharyngeal arches in cervical sinus
1st pharyngeal arch
Ventral view at 6 to 7 weeks
Opening of right nasal sac (future naris)
Maxillary process of 1st arch
Right eye
1st pharyngeal arch
1st pharyngeal cleft (future external acoustic meatus)
2nd pharyngeal arch
Intermaxillary segment
Medial nasal prominence
Lateral nasal prominence
Nasolacrimal groove
Oral opening
Nodules that merge to form auricle of ear
3rd and 4th pharyngeal arches in cervical sinus (sites of future laryngeal cartilages)
Ventral view at 7 to 8 weeks
Philtrum of upper lip (fusion of medial nasal processes)
Site of nasolacrimal groove (fusion of lateral nasal and maxillary processes)
Site of fusion of medial nasal and maxillary processes (site of cleft lip)
Auricle of ear
Lateral view at 7 to 8 weeks
10.0 mm
Auricle of ear
Lateral nasal process
Medial nasal process
Philtrum
Lateral view at 8 to 10 weeks
24.0 mm
Auricle of ear
Fused eyelids
Philtrum of upper lip
F. Netter M.D.

Figure 1-11

- Formed by the
  - Primary palate (intermaxillary segment)
  - Secondary palate (protrusions from the maxillary prominences)
- Intermaxillary segment—the initial portion of the palate in development; contains the central and lateral incisors
- Swellings of the maxillary prominence form shelves (lateral palatine processes) that project medially and are separated by the tongue
- When the tongue no longer occupies the space between the palatal shelves, these lateral palatine processes fuse together to form the secondary palate
- The primary and secondary palatal tissues all meet at the *incisive foramen*
- Primary and secondary palates and the nasal septum fuse to form the definitive palate

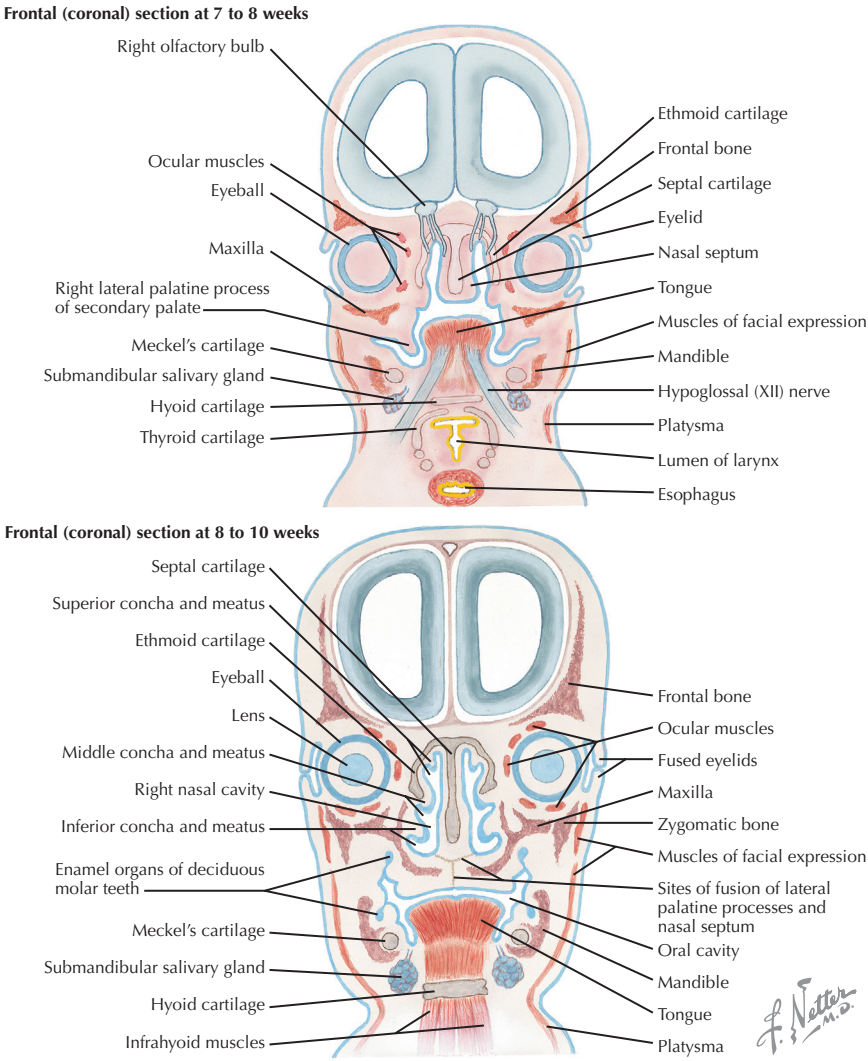
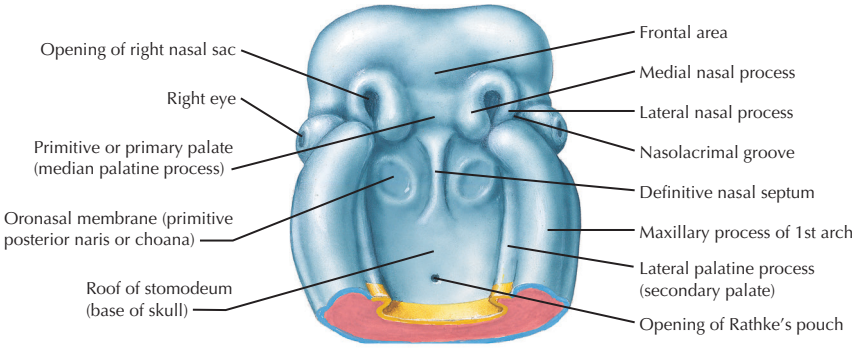
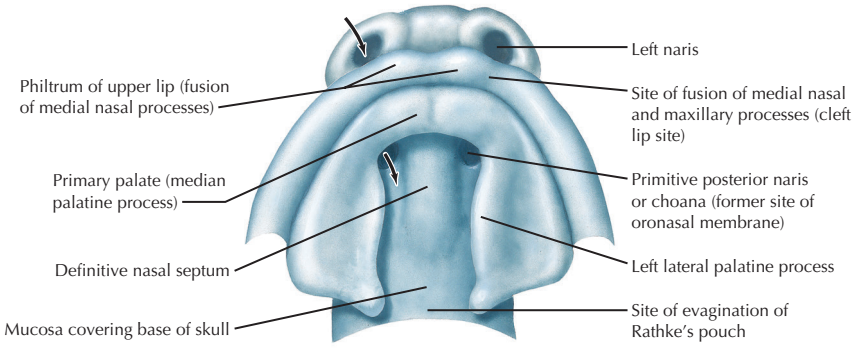


Figure 1-12

Roof of stomodeum (inferior view; 6 to 7 weeks)



Palate formation (inferior view; 7 to 8 weeks)



Roof of oral cavity (inferior view; 8 to 10 weeks)

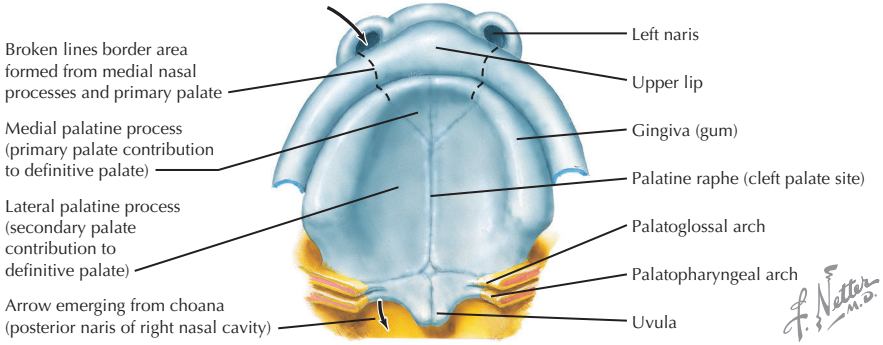


Figure 1-13

- The general somatic afferent (GSA) fibers that supply the epithelium of the tongue mirror the development of the tongue by the pharyngeal arches (arches 1, 3, and 4)
- Although the 2nd pharyngeal arch does not contribute to the tongue, the special visceral afferent (SVA) fibers (taste) that travel to the anterior two-thirds of the tongue come from the chorda tympani (a branch of the facial n.), which joins the lingual n. in the infratemporal fossa, allowing the SVA fibers to be distributed to the anterior two-thirds of the tongue

Pharyngeal Arch	Embryonic Structure(s)	Adult Structure	Innervation
1	2 lateral lingual swellings Tuberculum impar	Anterior 2/3 of the tongue	*GSA:* Lingual branch of the mandibular division of the trigeminal n.
2	Is overgrown by the 3rd arch; does not contribute to the adult tongue Slight contribution to the hypopharyngeal eminence	Does not contribute to the adult tongue	
3	Hypopharyngeal eminence	Posterior 1/3 of the tongue	*GSA:* Glossopharyngeal n. *SVA:* Glossopharyngeal n.
4	Hypopharyngeal eminence Epiglottic swelling Arytenoid swelling Laryngotracheal groove	Root of the tongue	*GSA:* Internal laryngeal branch of the vagus n. *SVA:* Internal laryngeal branch of the vagus n.

Muscles

- Mesoderm from the occipital somites migrates anteriorly with the hypoglossal nerve to give rise to the extrinsic and intrinsic muscles of the tongue, except the palatoglossus, which is from mesoderm from the 4th pharyngeal arch (and thus is innervated by the vagus nerve)

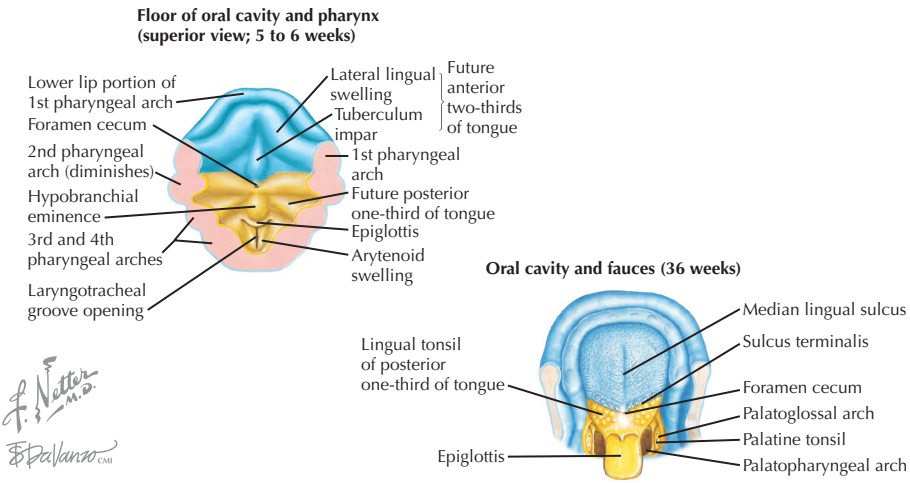


Figure 1-14

STAGES OF TOOTH DEVELOPMENT

- Primary and permanent teeth develop from interactions between oral ectoderm and neural crest–derived dental mesoderm
- Tooth development is a continuous process that is broken into stages for descriptive purposes, and all teeth pass through each stage
- The morphologic stage describes the histologic appearance of the developing tooth and corresponds to a functional stage related to physiologic changes occurring over time
- The physiologic processes that begin in one stage may continue as the tooth progresses developmentally

Morphologic Stage	Key Functional Stage	Description of Physiologic Process
Dental placode	Induction	▪ Thickening of ectoderm to form dental placode ▪ Induction of ectoderm to form tooth in specific positions in arch—requires oral ectoderm signaling and the neural crest–derived mesoderm being receptive
Bud	Proliferation	▪ Proliferation of ectoderm and proliferation and condensation of neural crest–derived mesoderm ▪ Specification of folding of enamel organ (EO) to form specific type of tooth by neural crest–derived mesenchyme
Cap	Morphogenesis Proliferation continues	▪ Tooth germ comprised of EO, dental papilla (DP), and dental follicle (DF) first recognized ▪ EO gives rise to ameloblasts, which deposit enamel ▪ DP differentiates into odontoblasts, which deposit dentin ▪ DF forms the periodontium (alveolar bone, cementum, and periodontal ligament) ▪ Proliferation and folding of epithelium under the direction of neural crest–derived mesoderm cause tooth to change shape ▪ Signaling by the epithelium of enamel knot directs DP and EO to differentiate and progress to bell stage
Early bell	Cytodifferentiation/ histodifferentiation (cell differentiation) Proliferation continues	▪ In cytodifferentiation/histodifferentiation ▪ Cells of EO differentiate into 4 layers—inner enamel epithelium (IEE), stratum intermedium (SI), stellate reticulum (SR), and outer enamel epithelium (OEE) ▪ Cells differentiate from DP into odontoblasts (outer) and pulp fibroblasts (inner) ▪ Multiple cusp positions are specified by signals from secondary enamel knot
Late bell	Morpho-differentiation Dentin deposition in cusps Proliferation continues	▪ Folding and differential growth of IEE and adjacent odontoblasts at points of future cusps change the shape of the tooth into final type and cusp number ▪ Deposition of predentin by odontoblasts signals overlying IEE cells to differentiate into ameloblasts and begin secreting the enamel matrix
Crown stage	Apposition Incremental deposition of enamel and dentin Differentiation and maturation occurs cusp to cervix	▪ Dentin and enamel are secreted simultaneously and establish the enamel–dentin junction ▪ Hard tissue deposition begins at the cusps and proceeds toward the cervical loop/intercuspal region; cusp region 1st to mineralize and mature ▪ EO becomes progressively smaller as hard tissue fills the space ▪ Crown size is determined by the amount of hard tissue deposited by active secretory ameloblast cells ▪ Final maturation of enamel begins when enamel deposition is finished by maturational ameloblasts
Root formation	Root elongation from cervix to apex Dentin and cementum deposited in root	▪ Cervical loop fuses to form Hertwig's epithelial root sheath (HERS) ▪ Beginning at the tooth cervix, HERS induces dentin deposition by odontoblasts ▪ Cementoblasts deposit cementum and establish the cementum–enamel junction and cementum–dentin junction