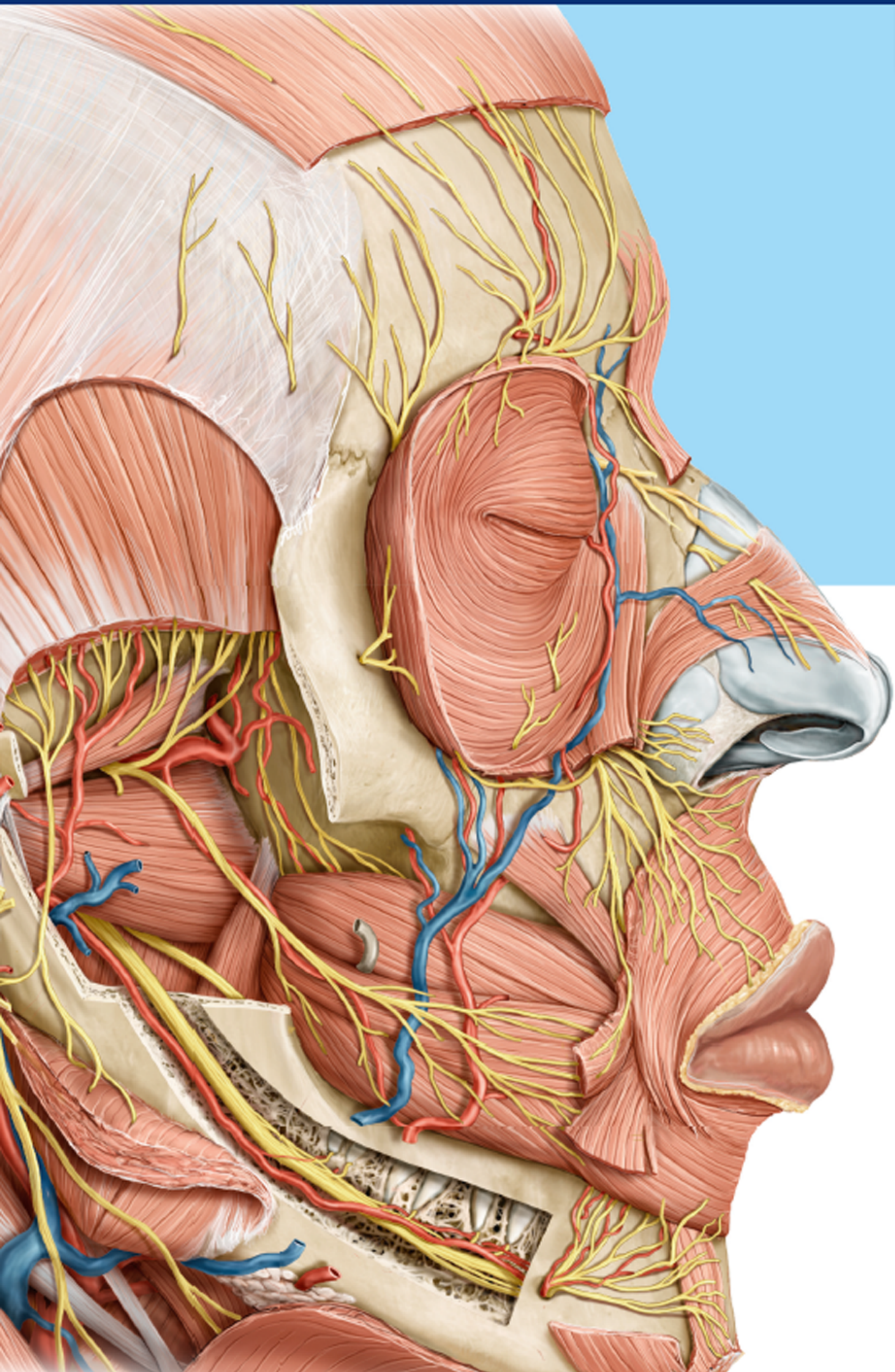
Anatomy for Dental Medicine

Third Edition



Edited by
Eric W. Baker
Associate Editor
Elisabeth K. N. Lopez

Based on the work of
Michael Schuenke
Erik Schulte
Udo Schumacher

Illustrations by
Markus Voll
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To my wonderful wife, Amy Curran Baker,
and my awe-inspiring daughters, Phoebe and Claire. — E.W.B.

To my loving and supportive family, Leonardo,
Penelope, and Ariadne, who never cease to inspire me. — E.K.N.L.

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Preface

The third edition of *Anatomy for Dental Medicine* keeps the key features of the first and second editions:

- A user-friendly format in which each two-page spread is a self-contained guide to a specific topic.
- An intuitive approach to each region, in which bones and joints are discussed first, followed by muscles, vasculature, and nerves, before showing an integrated neurovasculature topography.
- Detailed artwork supplemented with descriptive captions, simplified schematics, and tables of key information.
- Chapter dedicated to sectional anatomy, comparing such images to clinical imagery, to demonstrate how students will see anatomical structures in a clinical setting.
- Systemic anatomy at the start of the book, followed by a regional approach that allows this atlas to be used in conjunction with many lecture- and dissection-based courses.
- Information on embryology, histology, neuroanatomy, and anatomy of the body below the head, which allows students to integrate anatomy with different topics and makes this atlas a good companion for combined courses, as well as courses that only cover anatomy of the head and neck.
- An appendix that explains the anatomical basis of local anesthesia techniques used in dentistry.
- Two appendices with practice questions and explanations.

In preparing the third edition, we included additional radiology images to enhance the clinical relevance of the anatomy depicted in the artwork. We also added discussions of several structures that are commonly used as landmarks, both in learning the anatomy as a student and in the clinical setting. We reorganized the neuroanatomy sections to be in a more logical progression. And finally, we added additional practice questions, including some in the style of the Integrated National Board Dental Examination (INBDE).

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Head

1 Embryology of the Head & Neck

2 Cranial Bones

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4 Neuroanatomy & Innervation of the Head & Neck

Germ Layers & the Developing Embryo

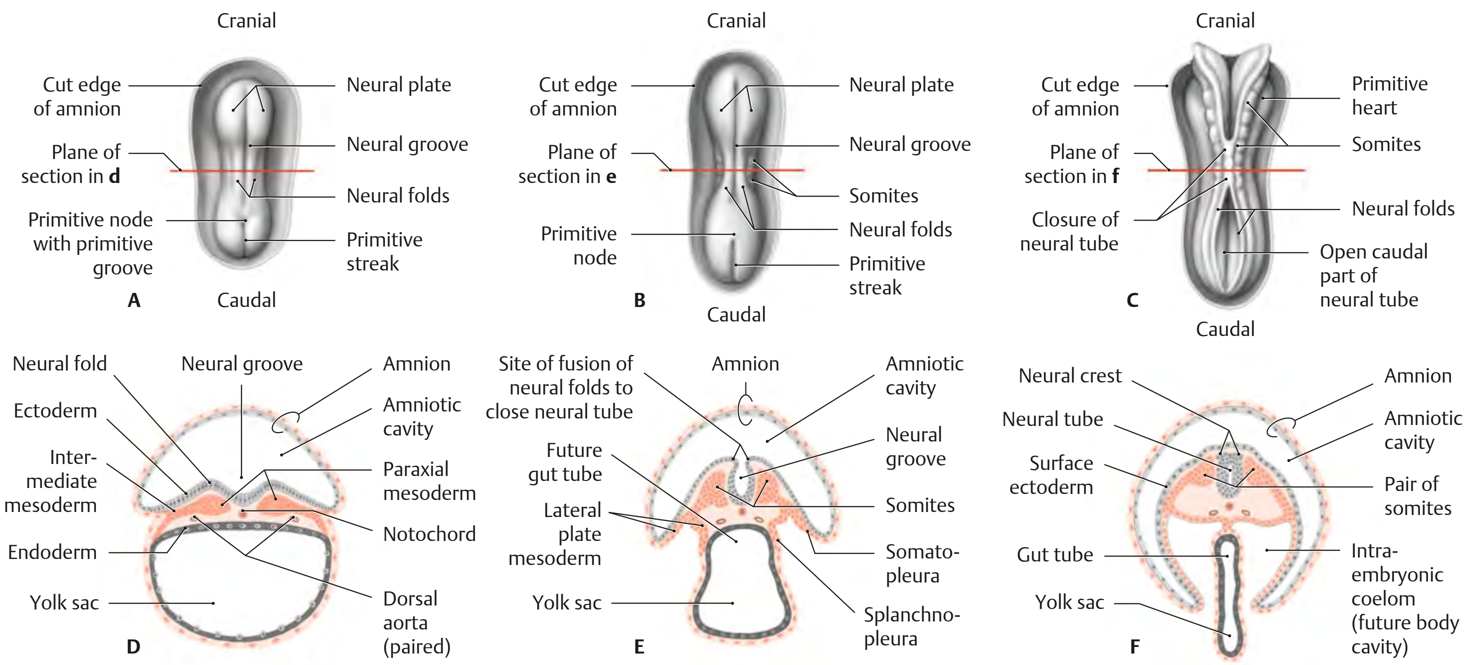


Fig. 1.1 **Embryonic development** (after Sadler)
Age in postovulatory days.
A-C Posterior (dorsal) view after removal of the amnion.
D-E Schematic cross sections of the corresponding stages at the horizontal planes of section marked in **A** to **C**. Gastrulation occurs in week 3 of human embryonic development. It produces three germ layers in the embryonic disk: ectoderm (light grey), mesoderm (red), and endoderm (dark grey).
A, D Day 19, the three layers are visible in the embryonic disk. The amnion forms the amniotic cavity dorsally, and the endoderm encloses the yolk sac. The neural tube is developing in the area of the neural plate.
B, E Day 20, the first somites have formed, and the neural groove is beginning to close to form the neural tube, with initial folding of the embryo.
C, F Day 22, eight pairs of somites flank the partially closed neural tube, which has sunk below the ectoderm. The yolk sac elongates ventrally to form the gut tube and yolk sac. At the sites where the neural folds fuse to close the neural tube, cells form a bilateral neural crest that detaches from the surface and migrates into the mesoderm.

Table 1.1 **Differentiation of germ layers**

Germ layer	Embryonic structure		Adult derivative
Ectoderm	Neural tube		Brain, retina, spinal cord
	Neural crest	Neural crest of the head	Sensory and parasympathetic ganglia; parafollicular cells; pigment cells; carotid body; cartilage, bone, dermis, subcutaneous tissue, and other connective tissues in the head; part of cardiac septum
		Neural crest of the trunk	Sensory, sympathetic, and parasympathetic ganglia; peripheral glia; pigment cells; adrenal medulla; intramural plexuses and enteric nervous system
	Surface ectoderm	Placodes	Anterior pituitary, cranial sensory ganglia, olfactory epithelium, inner ear, lens
			Epithelium of the oral cavity, salivary glands, nasal cavities, paranasal sinuses, lacrimal passages, external auditory canal, epidermis, hair, nails, cutaneous glands
Mesoderm	Paraxial	Somites	Dermis of skin (from dermatome), musculature (from myotome), vertebral column (from sclerotome)
	Axial	Notochord	Nucleus pulposus
		Prechordal mesoderm	Extraocular muscles
	Intermediate		Kidneys, gonads, renal and genital excretory ducts
	Lateral plates	Visceral (splanchnic)	Heart, blood vessels, smooth muscle, bowel wall, blood, adrenal cortex, visceral serosa
		Parietal (somatic)	Sternum, limbs without muscles (muscles develop from the myotomes), dermis and subcutaneous tissue of the anterolateral body wall, smooth muscle, connective tissue, parietal serosa
Endoderm	Intestinal tube		Epithelium of the bowel, respiratory tract, digestive glands, pharyngeal glands, pharyngotympanic (auditory) tube, tympanic cavity, urinary bladder, parathyroid glands, thyroid gland

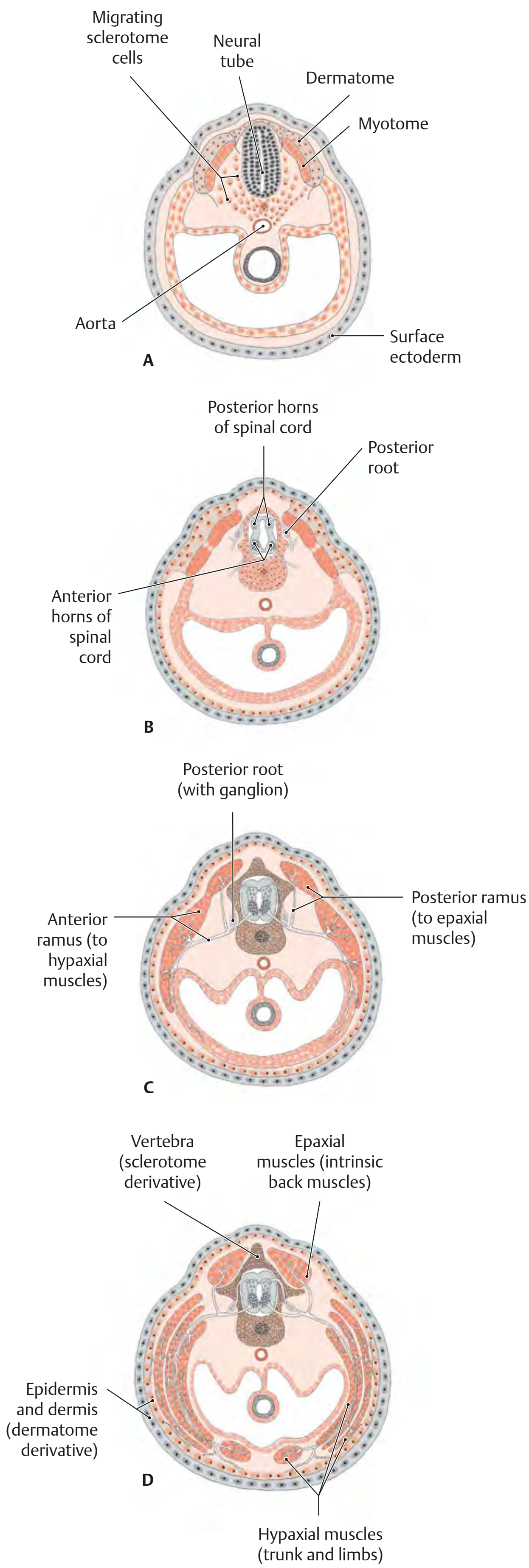


Fig. 1.2 **Somatic muscle development**
Age in postovulatory days. Each somite divides into a dermatome (cutaneous), myotome (muscular), and sclerotome (vertebral) at around day 22 (see **Fig. 1.1**).
A Day 28, sclerotomes migrate to form the vertebral column around the notochord (primitive spinal cord).
B Day 30, all 34 or 35 somite pairs have formed. The neural tube differentiates into a primitive spinal cord. Motor and sensory neurons differentiate in the anterior and posterior horns of the spinal cord, respectively.
C By day 40, the posterior and anterior roots form the mixed spinal nerve. The posterior branch supplies the epiaxial muscles (future intrinsic back muscles); the anterior branch supplies the hypaxial muscles (anterior muscles, including all muscles except the intrinsic back muscles).
D Week 8, the epiaxial and hypaxial muscles have differentiated into the skeletal muscles of the trunk. Cells from the sclerotomes also migrate into the limbs. During this migration, the spinal nerves form the plexuses (cervical, branchial, and lumbosacral), which innervate the muscles of the neck, upper limb, and lower limb, respectively.

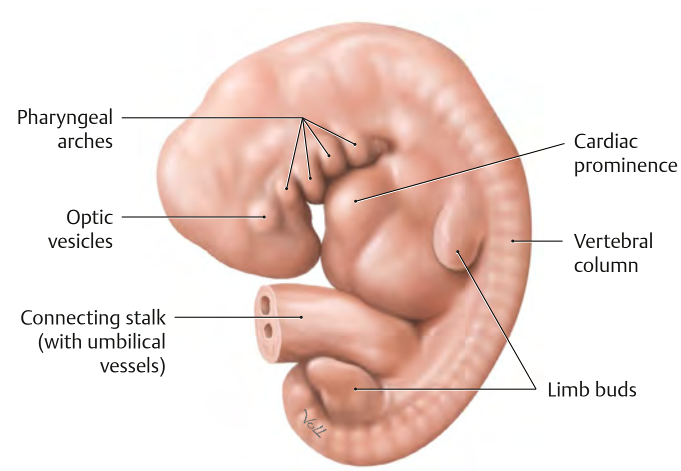


Fig. 1.3 **5-week-old embryo**
The human embryo at 5 weeks has a crown-rump length of approximately 5 to 7 mm. The umbilical cord, which attaches the embryo to the mother, is seen. The future cerebral hemispheres form along with the eye, ear, pharyngeal arches (which form a large portion of the structures of the head and neck), heart, neural tube, and limb buds.

Development of the Brain & Spinal Cord

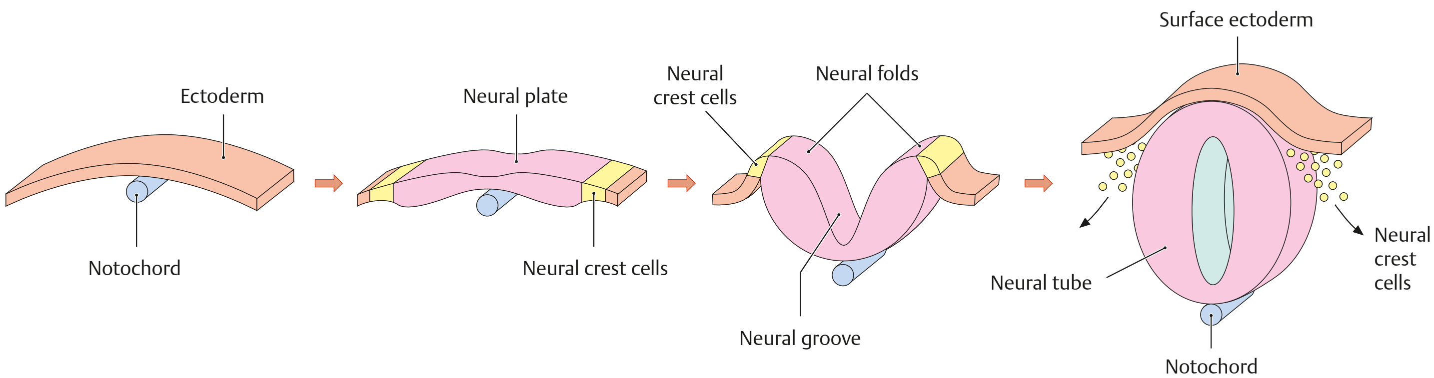


Fig. 1.4 **Development of the neural tube and neural crest** (after Wolpert)

The tissues of the nervous system orginate embryonically from the posterior surface ectoderm. The notochord in the midline of the body induces the formation of the neural plate, which lies dorsal to the notochord, and of the neural crests, which are lateral to the notochord. With further development, the neural plate deepens at the center to form the neural groove, which is flanked on each side by the neural folds. Later the groove deepens and closes to form the neural tube, which sinks below the ectoderm. The neural tube is the structure from which the central nervous system (CNS) – the brain and spinal cord – develops (further development of the spinal cord is shown in **Fig. 1.5**, further brain development in **Fig. 1.7**). Failure of the neural folds to fuse completely in the caudal region will leave an anomalous cleft in the vertebral column known as spina bifida. In the cranial region, this will lead to a defect known as anencephaly. The administration of folic acid to potential mothers around the time of conception can significantly reduce the incidence of spina bifida and other neural tube defects. Cells that migrate from the neural crest develop into various structures, including cells of the peripheral nervous system (PNS), such as Schwann cells, and the pseudounipolar cells of the spinal ganglion (see **Fig. 1.6**).

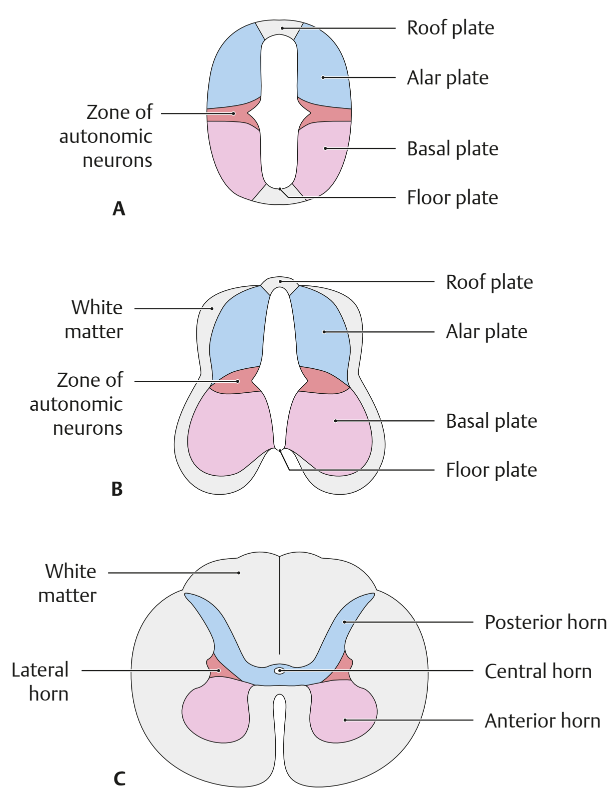


Fig. 1.5 **Differentiation of the neural tube in the spinal cord during development**

Cross-section, superior view.

A Early neural tube. **B** Intermediate Stage. **C** Adult spinal cord.

The neurons that form the basal plate are efferent (motor neurons), while the neurons that form the alar plate are afferent (sensory neurons). In the future thoracic, lumbar, and sacral spinal cord, there is another zone between them that gives rise to autonomic neurons. The roof plate and the floor plate do not form neurons.

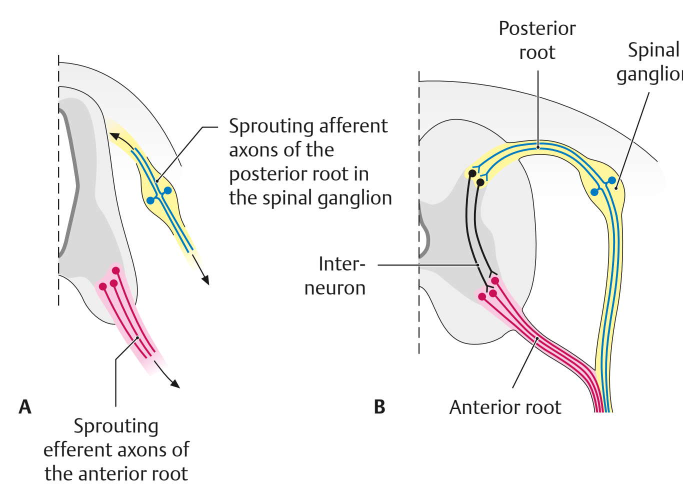


Fig. 1.6 **Development of a peripheral nerve**

Afferent (sensory) axons (blue) and efferent (motor) axons (red) sprout from the neuronal cell bodies during early embryonic development.

A Primary afferent neurons develop in the spinal ganglion, and alpha motor neurons develop from the basal plate of the spinal cord.

B The interneurons (black), which functionally interconnect the afferent and efferent neurons, develop at a later stage.

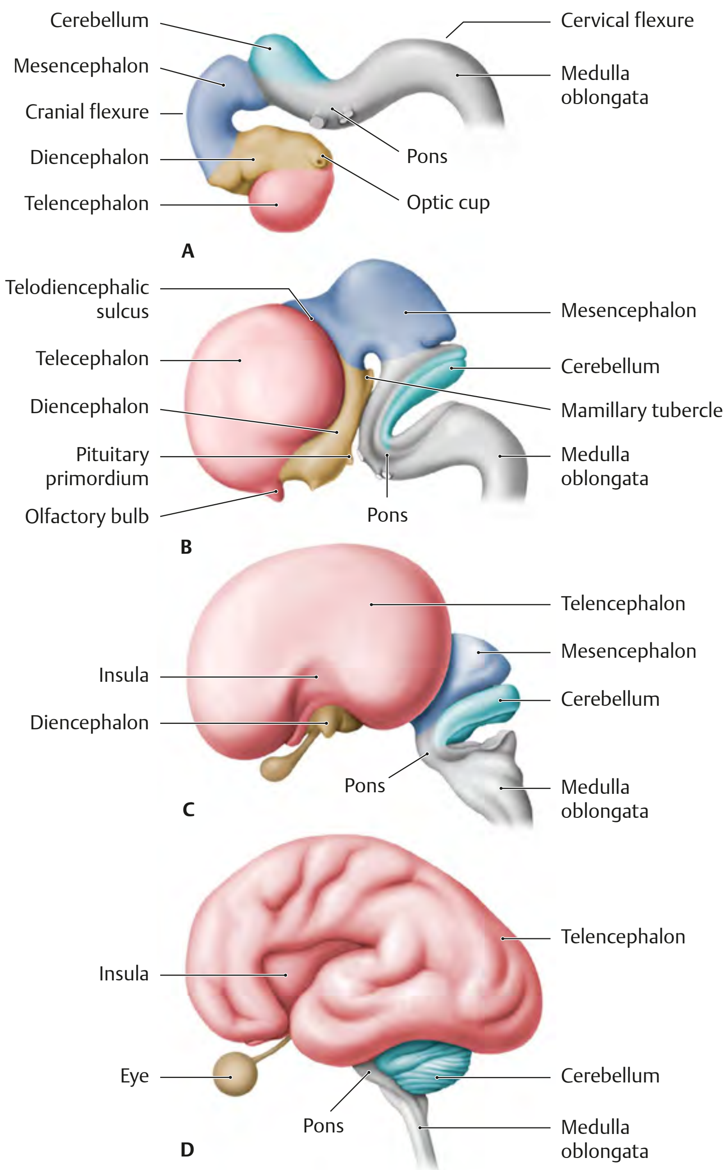


Fig. 1.7 **Development of the brain**

A Embryo with the greatest length (GL) of 10 mm at the beginning of the 2nd month of development. Even at this stage, we can see the differentiation of the neural tube into segments that will generate various brain regions.

- Red: telencephalon (cerebrum)
- Yellow: diencephalon
- Dark blue: mesencephalon (midbrain)
- Light blue: cerebellum
- Gray: pons and medulla oblongata

Note: The telencephalon outgrows all of the other brain structures as development proceeds.

B Embryo with a GL of 27 mm near the end of the 2nd month of development (end of the embryonic period). The telencephalon and the diencephalon have enlarged. The olfactory bulb is developing from the telencephalon, and the primordium of the pituitary gland is developing from the diencephalon.

C Fetus with a GL of 53 mm in approximately the 3rd month of development. By this stage the telencephalon has begun to cover the other brain areas. The insula is still on the brain surface but will subsequently be covered by the hemispheres (compare with **D**).

D Fetus with GL of 27 cm (270 mm) in approximately the 7th month of development. The cerebrum (telencephalon) has begun to develop well-defined gyri and sulci.

Table 1.2 **Development of the brain**

Primary vesicle		Region		Structure
Neural tube	Prosencephalon (forebrain)	Telencephalon		Cerebral cortex, white matter, basal ganglia
		Diencephalon		Epithalamus (pineal gland), thalamus, subthalamus, hypothalamus
	Mesencephalon (midbrain)*			Tectum, tegmentum, cerebral peduncles
	Rhombencephalon (hindbrain)	Metencephalon	Cerebellum	Cerebellar cortex, nuclei, peduncles
			Pons*	Nuclei, fiber tracts
		Myelencephalon	Medulla oblongata*	Nuclei, fiber tracts

*The mesencephalon, pons, and medulla oblongata are collectively known as the brainstem.

Development & Derivatives of the Pharyngeal (Branchial) Arches

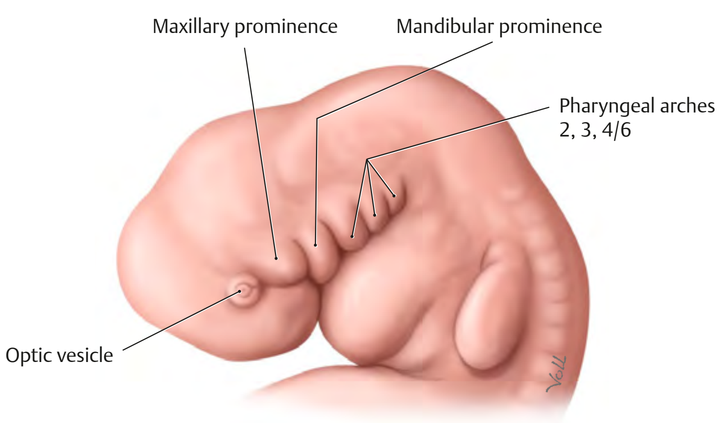


Fig. 1.8 **Head and neck region of a 5-week-old embryo, showing the pharyngeal (branchial) arches and clefts**
Left lateral view. The pharyngeal arches are instrumental in the development of the face, neck, larynx, and pharynx. Development of the pharyngeal arches begins in the 4th week of embryonic life as cells migrate from the neural crest to the future head and neck region. Within 1 week, a series of four oblique ridges (first through sixth pharyngeal arches, with the fifth arch only rudamentary in humans and the sixth arch not visible on the surface) form that are located at the level of the cranial segment of the foregut and are separated externally by four deep grooves (pharyngeal clefts). The pharyngeal arches and clefts are prominent features of the embryo at this stage.

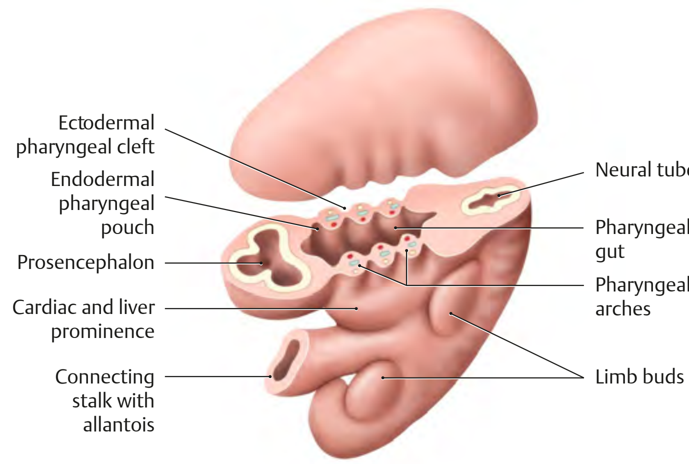
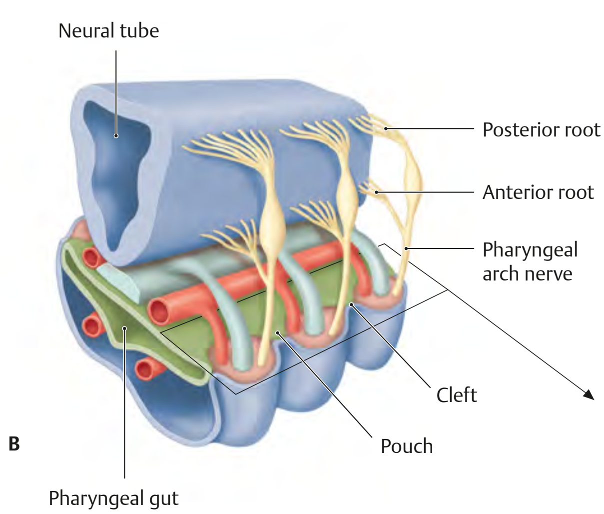


Fig. 1.9 **Cross section through an embryo at the level of the pharyngeal gut** (after Drews)
Left superior oblique view. Due to the craniocaudal curvature of the embryo, the cross section passes through the pharyngeal arches and pharyngeal gut as well as the prosencephalon and spinal cord. The pharyngeal gut is bounded on both sides by the pharyngeal arches, which contain the mesodermal core. They are covered externally by ectoderm and internally by endoderm. Ectodermal pharyngeal clefts and endodermal pharyngeal pouches lie directly opposite one another. Because the embryo is curved craniocaudally, the pharyngeal gut and pharyngeal arches overlie the prominence of the rudimentary heart and liver.



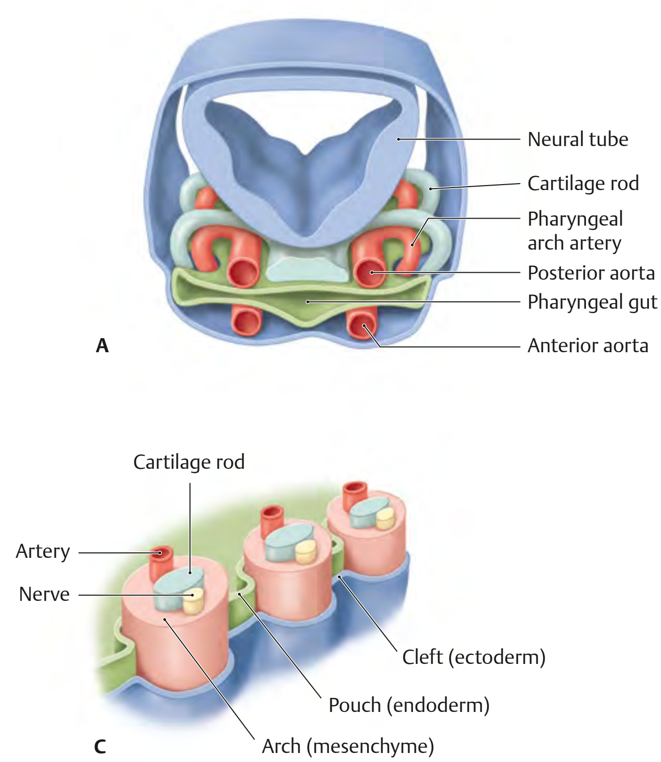
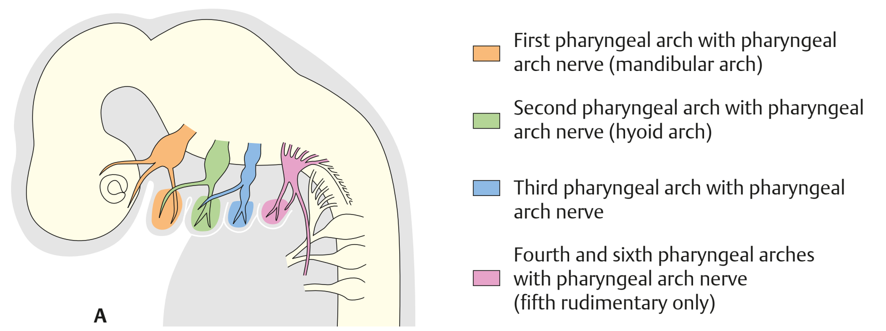


Fig. 1.10 **Structure of the pharyngeal arches** (after Sadler)
A Cross section through a pharyngeal arch and the neural tube, showing the pharyngeal arch cartilage and artery. **B** Oblique cross section through a pharyngeal arch and the neural tube, showing the pharyngeal arch nerves. **C** Blow up of section in **B**, showing the relationship of pharyngeal arch cartilage, artery, and nerve in the pharyngeal arches.
The pharyngeal arches are covered externally by ectoderm (blue) and internally by endoderm (green). Each pharyngeal arch contains an arch artery, an arch nerve, and a cartilaginous skeletal element, all of which are surrounded by mesenchyme and muscular tissue. The external grooves are called the pharyngeal clefts, and the internal grooves are called the pharyngeal pouches.

Fig. 1.11 **The arrangement and derivatives of the pharyngeal arches** (after Sadler and Drews)

A The pharyngeal arches with the associated pharyngeal arch nerves
B The mandibular nerve (CN V_3), facial nerve (CN VII), glossopharyngeal nerve (CN IX), and vagus nerve (CN X) derived from the pharyngeal arch nerves
C Muscles derived from the pharyngeal arches
D Skeletal and ligamentous elements derived from the pharyngeal arches



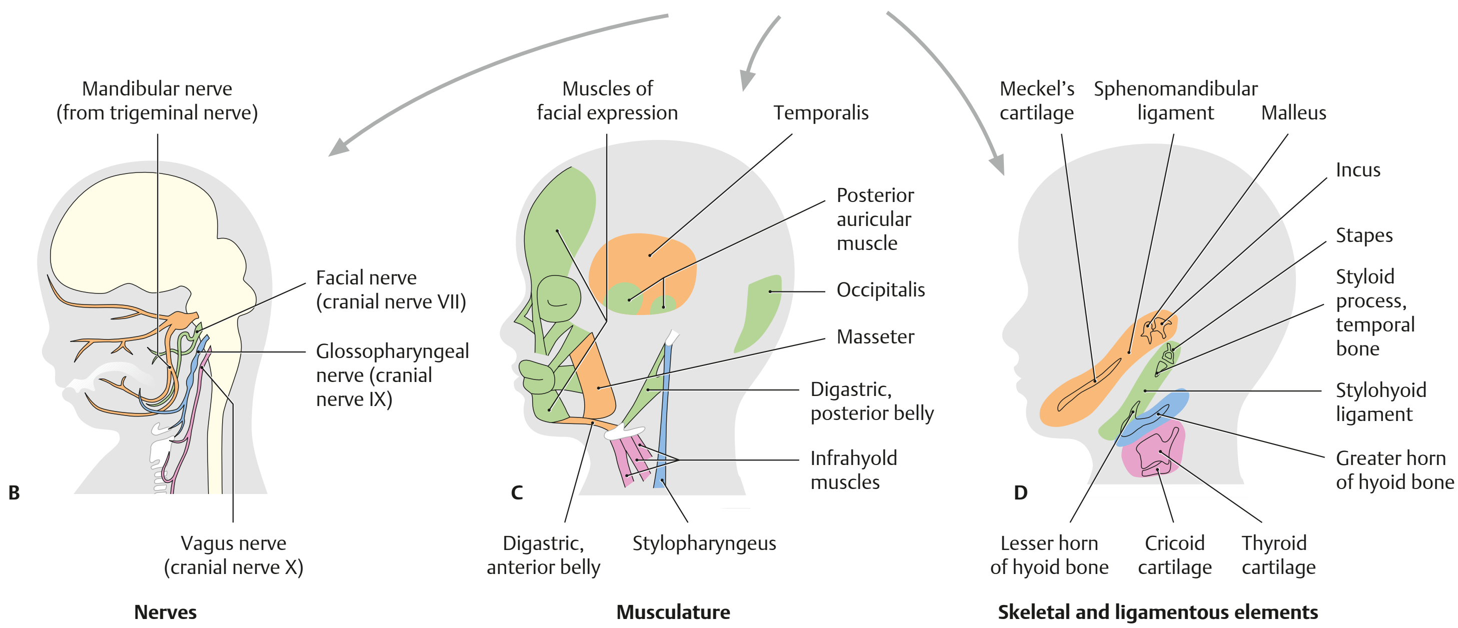


Table 1.3 **Derivatives of the pharyngeal arches**

Pharyngeal arch	Muscles*	Skeletal and ligamentous elements	Nerve accompanying arch
1	Muscles of mastication • Temporalis • Masseter • Lateral ptyergoid • Medial pterygoid Mylohyoid Digastric, anterior belly Tensor tympani Tensor veli palatini	Maxilla Mandible Malleus and incus Meckel's cartilage Sphenomandibular ligament Anterior ligament of malleus	Mandibular n. (CN V_3)
2	Muscles of facial expression Stylohyoid Digastric, posterior belly Stapedius	Stapes Styloid process, temporal bone Lesser horn, hyoid bone Upper part, hyoid bone Stylohyoid ligament	Facial n. (CN VII)
3	Stylopharyngeus	Greater horn, hyoid bone Lower part, hyoid bone	Glossopharyngeal n. (CN IX)
4 and 6	Pharyngeal muscles • Levator veli palatini • Uvular muscle • Palatoglossus • Salpingopharyngeus • Palatopharyngeus • Pharyngeal constrictors Laryngeal muscles • Thyroarytenoid • Vocalis • Lateral cricoarytenoid • Cricothyroid • Oblique arytenoids • Transverse arytenoids • Posterior arytenoids • Aryepiglottic folds • Thyroepiglottic	Laryngeal skeleton • Thyroid cartilage • Cricoid cartilage • Arytenoid cartilage • Corniculate cartilage • Cuneiform cartilage	Vagus n. (CN X)

Abbreviation: CN, cranial nerve.
*All branchial skeletal muscles

Development & Derivatives of the Pharyngeal Pouches, Membranes, & Clefts

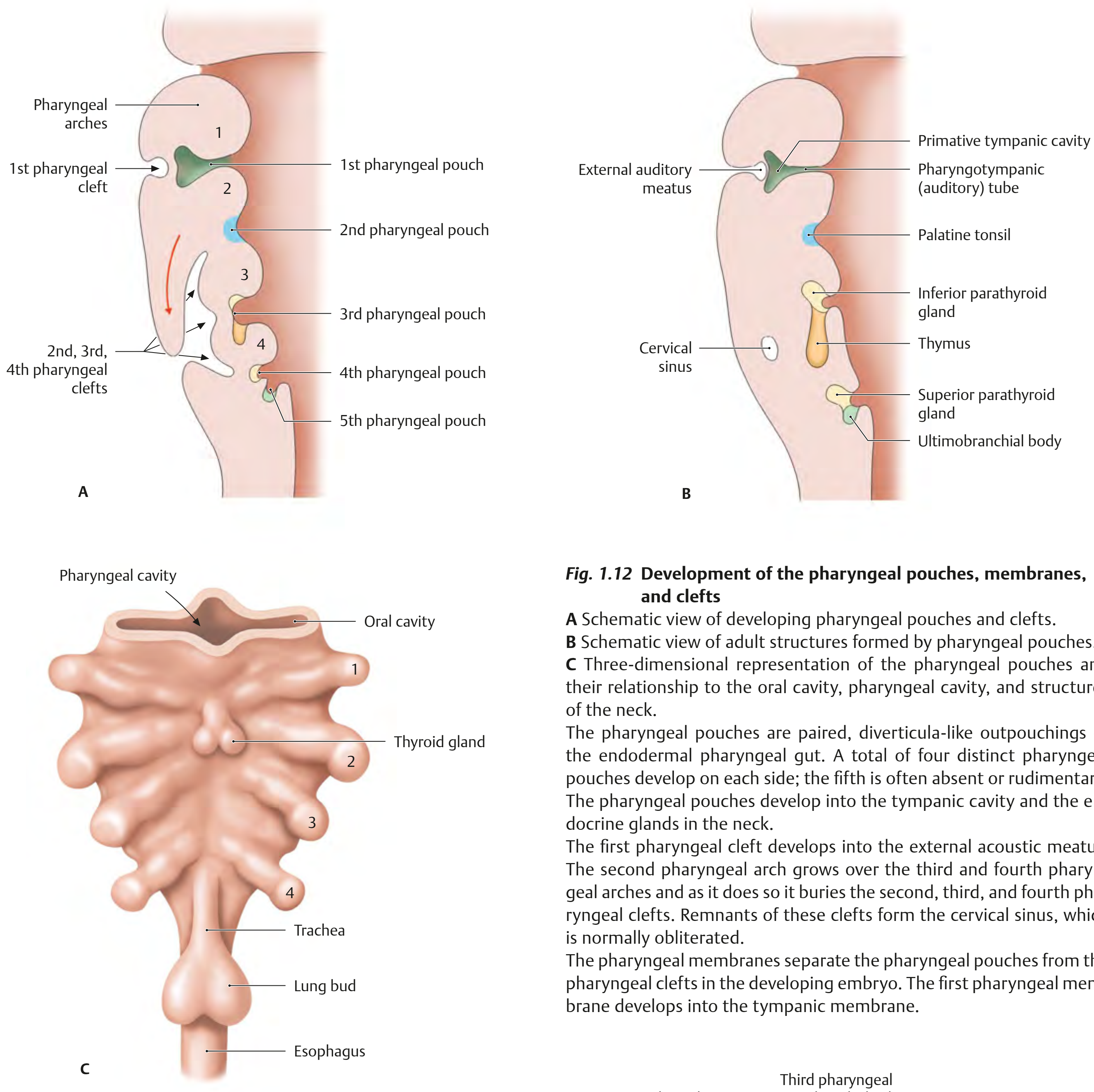


Fig. 1.12 **Development of the pharyngeal pouches, membranes, and clefts**

A Schematic view of developing pharyngeal pouches and clefts.

B Schematic view of adult structures formed by pharyngeal pouches.

C Three-dimensional representation of the pharyngeal pouches and their relationship to the oral cavity, pharyngeal cavity, and structures of the neck.

The pharyngeal pouches are paired, diverticula-like outpouchings of the endodermal pharyngeal gut. A total of four distinct pharyngeal pouches develop on each side; the fifth is often absent or rudimentary. The pharyngeal pouches develop into the tympanic cavity and the endocrine glands in the neck.

The first pharyngeal cleft develops into the external acoustic meatus. The second pharyngeal arch grows over the third and fourth pharyngeal arches and as it does so it buries the second, third, and fourth pharyngeal clefts. Remnants of these clefts form the cervical sinus, which is normally obliterated.

The pharyngeal membranes separate the pharyngeal pouches from the pharyngeal clefts in the developing embryo. The first pharyngeal membrane develops into the tympanic membrane.

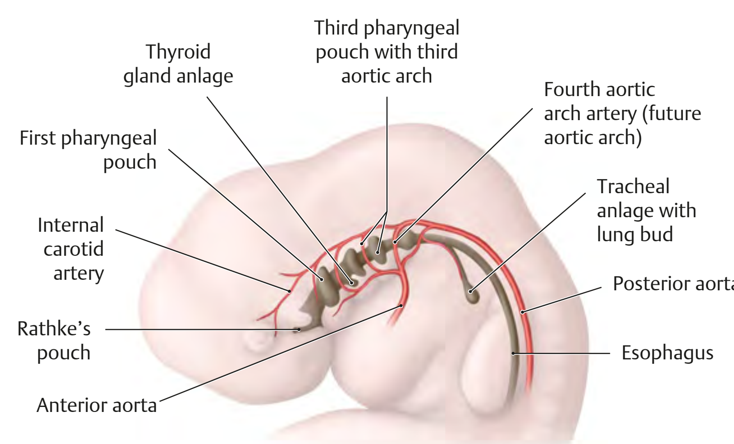


Fig. 1.13 **Pharyngeal pouches and the aortic arches** (after Sadler)
The aortic arches (pharyngeal arch arteries) arise from the paired embryonic anterior aorta and run between the pharyngeal pouches. They open posteriorly into the posterior aorta, which is also paired. The definitive aortic arch develops from the fourth aortic arch on the left side. Note: The pouch protruding from the roof of the oral cavity is called Rathke's pouch (precursor of the anterior pituitary). Note also the lung bud extending anteriorly from the pharyngeal gut, and the primordial (anlage) of the thyroid gland.

Table 1.4 **Derivatives of the pharyngeal pouches**

Pouch	Germ layer	Embryonic structure	Adult structure
1	Endoderm	Tubotympanic recess	Epithelium of the pharyngotympanic (auditory) tube Tympanic cavity
2		Primitive palatine tonsils	Tonsilar fossa Epithelium of the palatine tonsil
3		Divides into a posterior and an anterior part at its distal end	Inferior parathyroid gland (from posterior part) Thymus (from anterior part)
4		Divides into a posterior and an anterior part at its distal end	Superior parathyroid gland (from posterior part) Ultimobranchial body (from anterior part). This is later incorporated in thyroid gland and gives rise to the parafollicular or C cells, which secrete calcitonin.

Table 1.5 **Derviative of the pharyngeal membranes**

Membranes	Germ layers	Adult structure
1	Composed externally of ectoderm and internally of endoderm. The intervening core consists of mesoderm and neural crest cells.	Tympanic membrane
2 to 4		The 2nd to 4th membranes disappear when the 2nd arch grows over the cleft

Table 1.6 **Derivatives of the pharyngeal clefts**

Cleft	Germ layer	Adult structure
1	Ectoderm	External acoustic meatus
2 to 4		Cervical sinus, which is rapidly obliterated by the 2nd pharyngeal arch, which grows over clefts 2 to 4

Treacher Collins syndrome is a rare autosomal dominant craniofacial defect involving the structures derived from the first pharyngeal arch. It is characterized by malar hypoplasia (underdevelopment or incomplete development of the cheek), mandibular hypoplasia, downslanting eyes, eyelid coloboma (notching of the lower eyelids), and malformed external ears. It may also be associated with cleft palate, hearing loss (due to defects in the ossicles), vision loss, and difficulty breathing (dyspnea). Treatment will depend on the severity of the defects but will involve a multidisciplinary team of clinicians.

Pierre-Robin syndrome is characterized by an abnormally small mandible (micrognathia). As a result, the tongue musculature is unsupported by the mandible, allowing it to displace posteriorly, partially obstructing the airway, resulting in dyspnea (shortness of breath). This posterior displacement of the tongue (glossoptosis) is also responsible for cleft palate because it prevents the palatal shelves from fusing (see **Figs. 1.21** and **1.22**). Initial treatment involves surgery to repair the cleft palate to improve feeding and speech development.

Development of the Tongue & Thyroid Gland

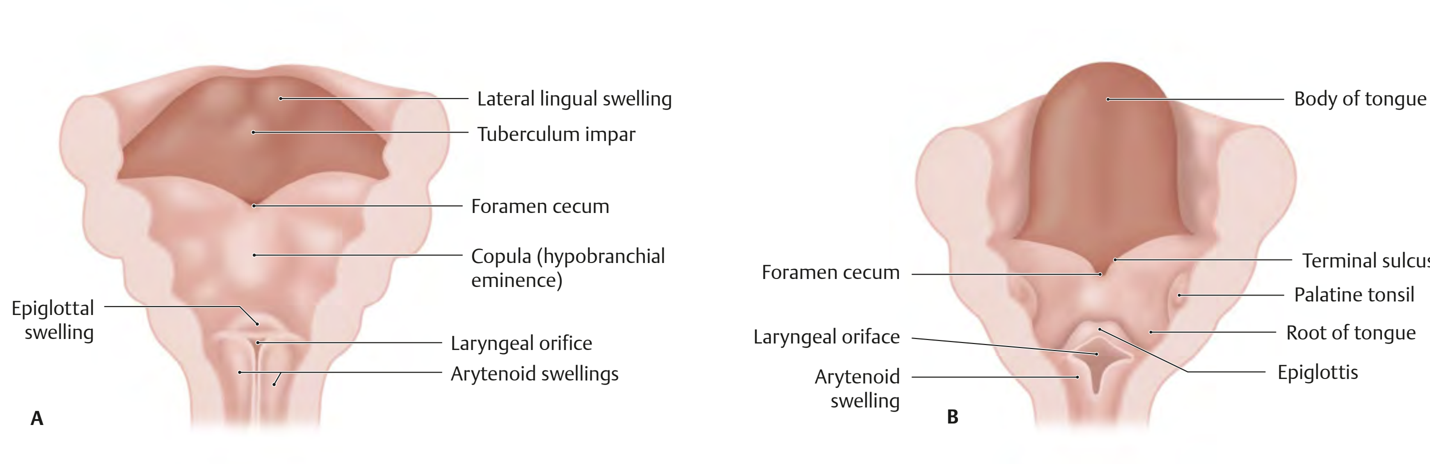


Fig. 1.14 **Development of the tongue**
A Early tongue development, around week 4. **B** Late tongue development, around week 8.

The tongue develops within the pharynx. While the musculature of the tongue is derived from somites, the tongue develops from the four pharyngeal (lingual) swellings. Three swellings are associated with the 1st arch and one, with the 3rd, 4th, and 6th arches. The two lateral and one midline swelling (the tuberculum impar) from the 1st pharyngeal arch contribute to the development of the anterior two thirds of the tongue. The single midline swelling (the hypobranchial eminence [copula]) from the 3rd, 4th, and 6th arches contributes to the development of the posterior one third of the tongue. A U-shaped sulcus develops around the tongue allowing it to move freely, except in one area, which is the lingual frenulum, which anchors the tongue to the floor of the oral cavity.

The lingual mucosa derived from the 1st arch swelling that covers the anterior two thirds of the tongue is innervated by the mandibular division of the trigeminal nerve (GSA) and the chorda tympani branch of the facial nerve (SVA); the lingual mucosa derived from the 3rd, 4th, and 6th arch swellings receives sensory innervation from both CN IX (glossopharyngeal nerve) and CN X (vagus nerve).

The V-shaped terminal sulcus (sulcus terminalis) separates the anterior two thirds of the tongue from the posterior one third. Located at the vertex of the terminal sulcus, between the tuberculum impar and the hypobranchial eminence, the foramen cecum marks the site of exit for the thyroid gland from the floor of the inside of the pharynx to an extrapharyngeal location.

Ankyloglossia (tongue-tie) is a congenital anomaly in which the lingual frenulum is unusually short or thick, thereby tethering the ventral surface of the tip of the tongue to the floor of the mouth. Clinical features include restricted elevation, protrusion, and side-to-side movement of the tongue, and demonstration of a heart-shaped tongue on protrusion. It may be noticed as difficulty feeding in infants. Treatment, when required, involves a frenectomy, where the frenulum is incised, releasing the tongue.

Table 1.7 **Derivation of the tongue**

Pharyngeal arch	Embryonic structure(s)	Adult structure	Innervation
1	Two lateral lingual swellings Tuberculum impar	Anterior two thirds of the tongue	GSA: lingual branch of the mandibular division of the trigeminal n. (CN V_3)
2	Is obliterated by the 3rd arch and therefore does not contribute to the adult tongue Hypobranchial eminence (minor involvement)	-	SVA: chorda tympani branch of the facial n. (CN VII) (it carries sensation from the anterior 2/3 of the tongue)
3	Hypobranchial eminence	Posterior one third of the tongue	GSA: glossopharyngeal n. (CN IX) SVA: glossopharyngeal n. (CN IX)
4	Hypobranchial eminence Epiglottic swelling Arytenoid swelling Laryngotracheal groove	Root of the tongue	GSA: internal laryngeal branch of the vagus n. (CN X) SVA: internal laryngeal branch of the vagus n. (CN X)

Abbreviations: GSA, general somatic afferent; SVA, special visceral afferent.

Table 1.8 **Dervivation of the skeletal muscles of the tongue**

Muscle origin	Muscles	Cranial nerves
Somites (from myotomes)	Intrinsic muscles of the tongue Extrinsic muscles of the tongue (genioglossus, styloglossus, and hyoglossus; ***not*** palatoglossus)	Hypoglossal n. (CN XII)

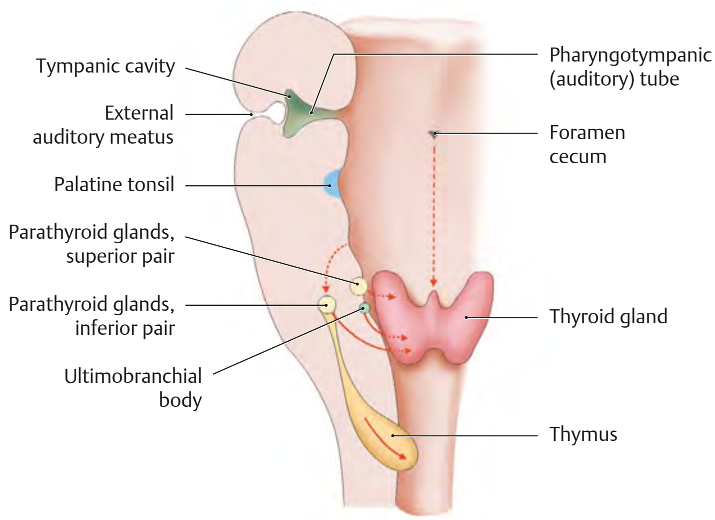


Fig. 1.15 **Migration of the pharyngeal arch tissues** (after Sadler)
Anterior view. During embryonic development, the epithelium from which the thyroid gland forms migrates from its site of origin on the basal midline of the tongue to the level of the first tracheal cartilage, where the thyroid gland is located in postnatal life. As the thyroid tissue buds off from the tongue base, it leaves a vestigial depression on the dorsum of the tongue, the foramen cecum. The parathyroid glands are derived from the 4th pharyngeal pouch (superior pair) or the 3rd pharyngeal pouch (inferior pair), which also gives rise to the thymus. The ultimobranchial body, whose cells migrate into the thyroid gland to form the calcitonin-producing C cells, or parafollicular cells, is derived from the 5th pharyngeal pouch. The external auditory meatus is derived from the 1st pharyngeal cleft, the tympanic cavity and pharyngotympanic tube from the 1st pharyngeal pouch, and the palatine tonsil from the 2nd pharyngeal pouch.
Ectopic thyroid is a rare condition in which the entire thyroid gland or thyroid tissues are not found in their normal position in the neck, i.e., inferolateral to the thyroid cartilage. Dentists may encounter this as a firm midline mass, which may appear as light pink to bright red, and may be regular or irregular on the dorsal tongue, just posterior to the foramen cecum (the embryonic origin of the thyroid gland). This is known as a lingual thyroid and represents approximately 90% of ectopic thyroid cases. Symptoms of lingual thyroid may include cough, pain, difficulty swallowing (dysphagia), difficulty speaking (dysphonia), and difficulty breathing (dyspnea).

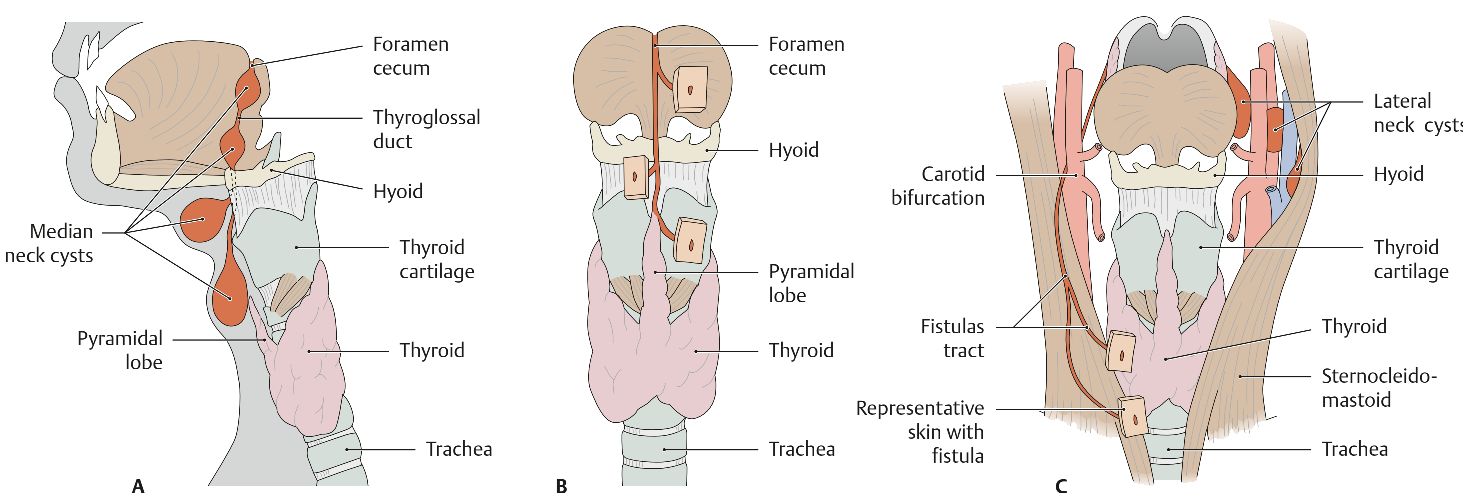


Fig. 1.16 **Location of cysts and fistulas in the neck**
A Median cysts. **B** Median fistulas. **C** Lateral fistulas and cysts.

A, B Median cysts and fistulas in the neck are remnants of the thyroglossal duct. Failure of this duct to regress completely may lead to the formation of a mucus-filled cavity (cyst), which presents clinically as a palpable, fluctuant, midline swelling in the neck at around the level of the hyoid bone. It is seen to move upward on swallowing or protrusion of the tongue due to the connection of the tongue with the duct. Symptoms may include dyspnea (difficulty breathing), dysphagia (difficulty swallowing), and pain (only if the cyst becomes infected).

C Lateral cysts and fistulas in the neck are anomalous remnants of the ductal portions of the cervical sinus, which forms as a result of tissue migrations during embryonic development.
If epithelium-lined remnants persist, neck cysts (right) or fistulas (an abnormal communication between structures; left) may appear in postnatal life. A complete fistula opens into the pharynx and onto the surface of the skin, whereas an incomplete (blind) fistula is open at one end only. The external orifice of a lateral cervical fistula is typically located at the anterior border of the sternocleidomastoid muscle.

Development of the Face

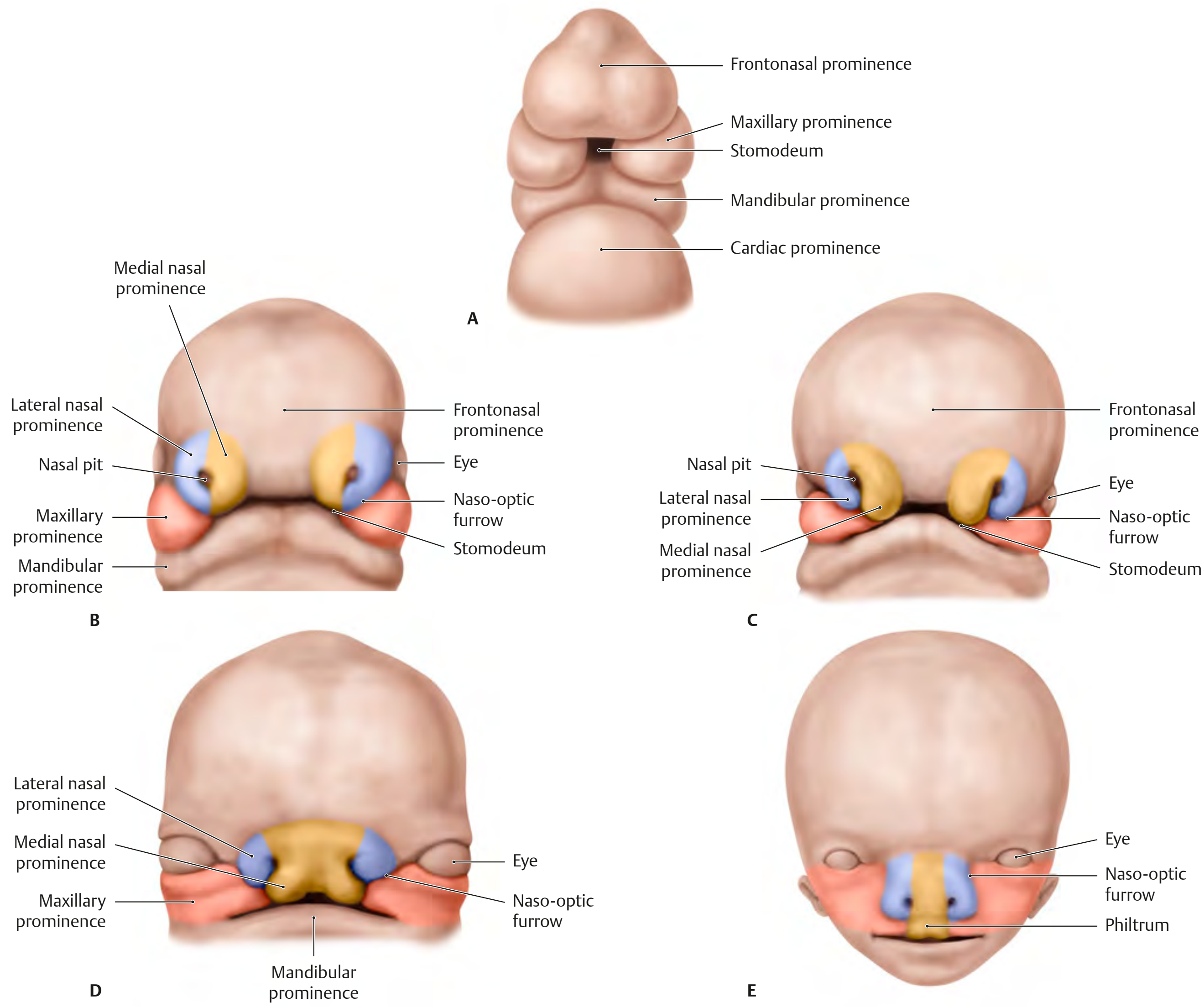


Fig. 1.17 **Development of the face** (after Sadler)

A Anterior view at 24 days. The surface ectoderm of the 1st pharyngeal arch invaginates to form the *stomodeum*, which is a depression between the forebrain and the pericardium in the embryo. It is the precursor of the mouth, oral cavity, and the anterior pituitary gland. At this stage, the stomodeum is separated from the primitive pharynx by the buccopharyngeal (oropharyngeal) membrane. This membrane later breaks down and the stomodeum become continuous with the pharynx.

The stomodeum is surrounded by five neural-crest-cell–derived mesenchymal swellings, known as *prominences*, which contribute to the development of the face.

B Anterior view at 5 weeks. Nasal placodes, ectodermal thickenings, form on each side of the frontonasal prominence. Invagination of the nasal placodes into the frontonasal prominence leads to the formation of the lateral and medial nasal prominences. The placodes now lie in the floor of a depression known as the *nasal pit*. The maxillary prominences continue to increase in size and merge laterally with the mandibular prominences to form the cheek. Medially, the maxillary prominences compress the medial nasal prominences toward the midline. A furrow (the naso-optic furrow) separates the nasal processes from the maxillary process. Ectoderm from the floor of the nasolacrimal groove (naso-optic furrow) will give rise to the nasolacrimal duct that connects the orbit with the nasal cavity; the two prominences will join to close the groove and create the nasolacrimal canal.

C Anterior view at 6 weeks. The medial nasal swellings enlarge, grow medially, and merge with each other to form the intermaxillary segment.

D Anterior view at 7 weeks. The medial nasal processes have fused with each other along the midline and with the maxillary processes and their lateral margins.

E Anterior view at 10 weeks. Cell migration is complete.

Table 1.9 **Prominences contributing to facial structures**

Prominence	Facial structure
Frontonasal prominence*	Forehead, nose, medial and lateral nasal prominences
Maxillary prominences	Cheeks, lateral parts of the upper lip
Medial nasal prominences	Philtrum of the upper lip, crest and tip of nose
Lateral nasal prominences	Alae of nose
Mandibular prominences	Lower lip

*The frontonasal prominence is a single unpaired structure; all other prominences listed are paired.

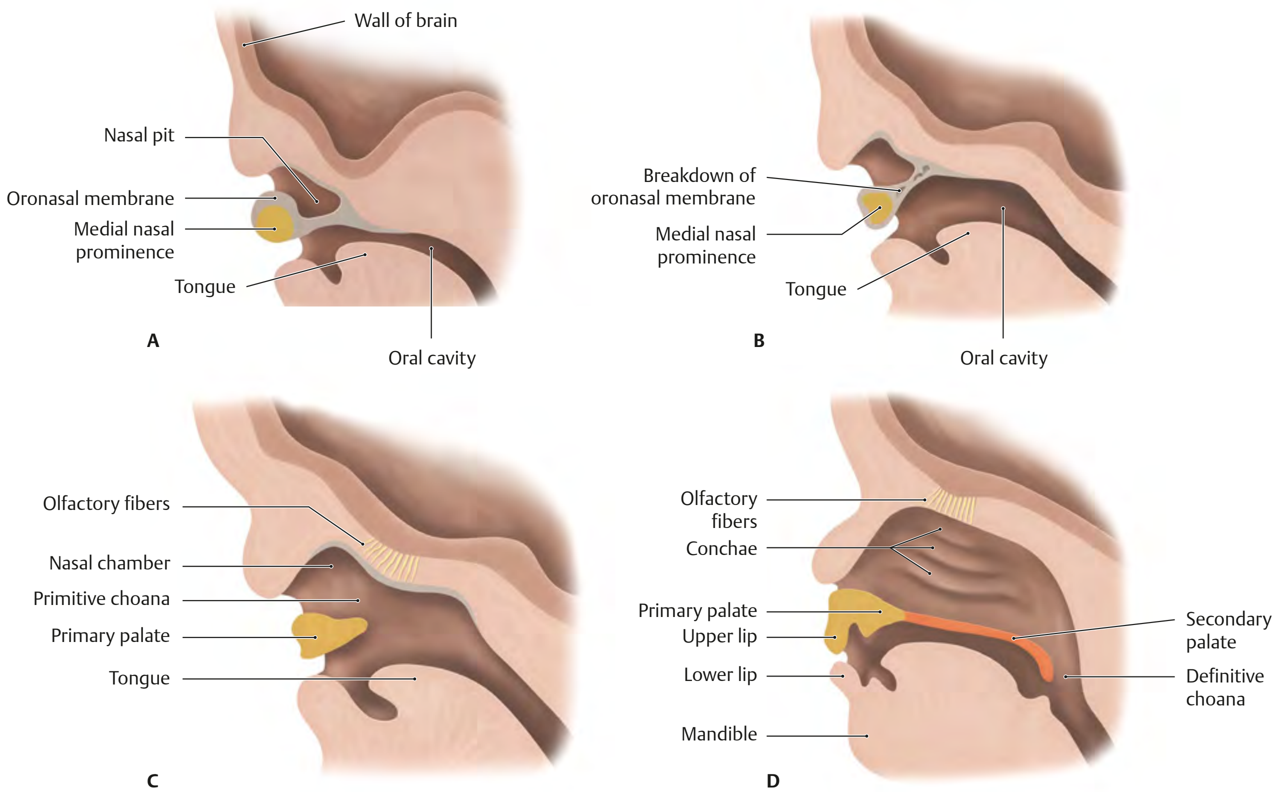


Fig. 1.18 **Development of the nasal cavity**
Sagittal section of embryo. At week 6, the primitive nasal cavity is separated from the oral cavity by the oronasal membrane **(A)**, which then breaks down **(B)**, leaving the nasal and oral cavities in open connection by week 7 **(C)**. In week 9, the nasal cavity and oral cavity are in their definitive arrangement **(D)**, separated by the primary and secondary palate with choanae at their junction in the pharynx. The lateral walls of the nasal cavity develop the superior, middle, and inferior conchae. The ectodermal epithelium in the roof of the nasal cavity becomes the specialized olfactory epithelium. The olfactory cells within the olfactory epithelium give rise to the olfactory nerve fibers (CN I) that grow into the olfactory bulb. The nasal septum (not shown) develops as a downgrowth of the merged medial nasal prominences. It fuses with the palatine process by weeks 9 to 12.

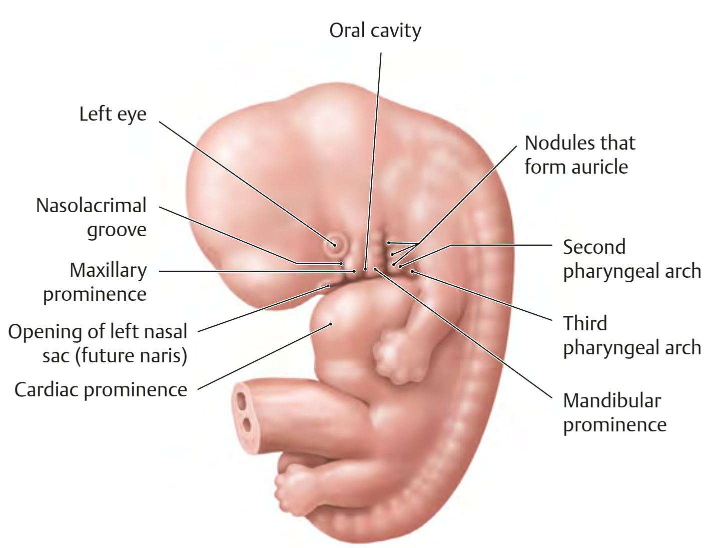


Fig. 1.19 **Development of the eyes and ears**
At about 22 days, the eyes and ears begin to develop. The eyes develop laterally in the embryo but during growth move medially to occupy their familiar position on the face. The auricle of the ear is formed from six swellings, known as *auricular hillcocks*, from the first and second pharyngeal pouches. The germ layers that contribute to the eyes and ears are listed in **Table 1.10**.

Table 1.10 **Derivation of the structures of the eye and ear**

Germ layer	Structure	
Eye		
Surface ectoderm	Corneal and conjunctival epithelium, lens, lacrimal glands, tarsal glands	
Neural crest cell ectoderm (neuroectoderm)	Retina, optic nerve (CN II), iris	
Mesenchyme	Corneal stroma, sclera, choroid, iris, parts of vitrous, ciliary muscle, muscles lining the anterior chamber	
Ear		
Ectoderm	Otic placode	Vestibulocochlear organ
	1st pharyngeal cleft	External acoustic meatus
Mesoderm	Cartilaginous otic capsule	Bony labyrinth
	Auricular hillocks	Auricle
Endoderm	1st pharyngeal pouch	Middle ear and auditory tube

Development of the Palate

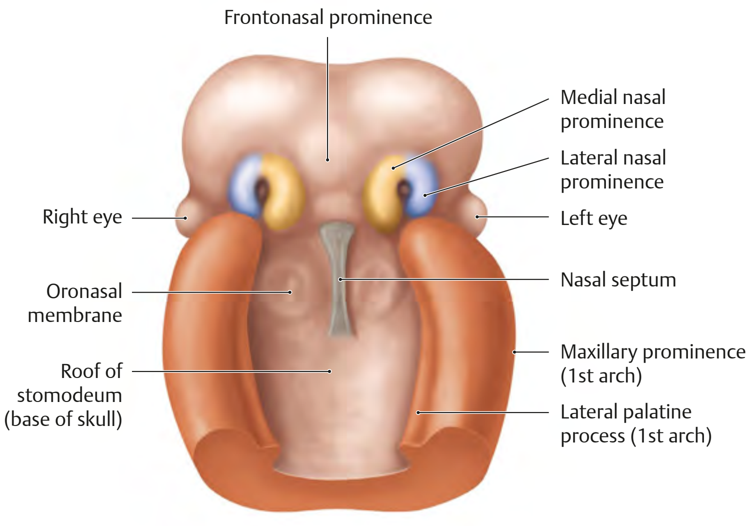


Fig. 1.20 **Palate formation, 7- to 8-week-old embryo**
Inferior view. Before the palate has formed, the oral cavity is open to the nasal cavity. The nasal septum can be seen as well as the oronasal membrane, which will ultimately form the choana. Development of the palate begins during week 5, but fusion of its parts is not complete until week 12. The most critical period for palate development is between the end of week 6 and the beginning of week 9. The palate forms from two major parts, the primary and secondary palates. The primary palate is derived from the wedge-shaped intermaxillary segment, which is formed by the merging of the two medial nasal prominences. The secondary palate is derived from two shelf-like outgrowths of the maxillary prominence, which, at this stage, are directed downward beside the tongue (removed).

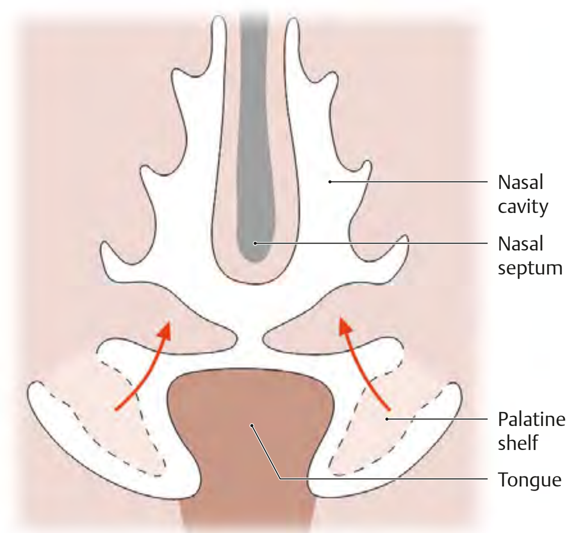


Fig. 1.21 **Elevation of the palatine shelves**
The palatine shelves, which form the secondary palate, are seen at around 6 weeks and are directed obliquely downward on each side of the tongue. At around 7 weeks, the palatine shelves ascend to a horizontal position above the tongue and fuse.

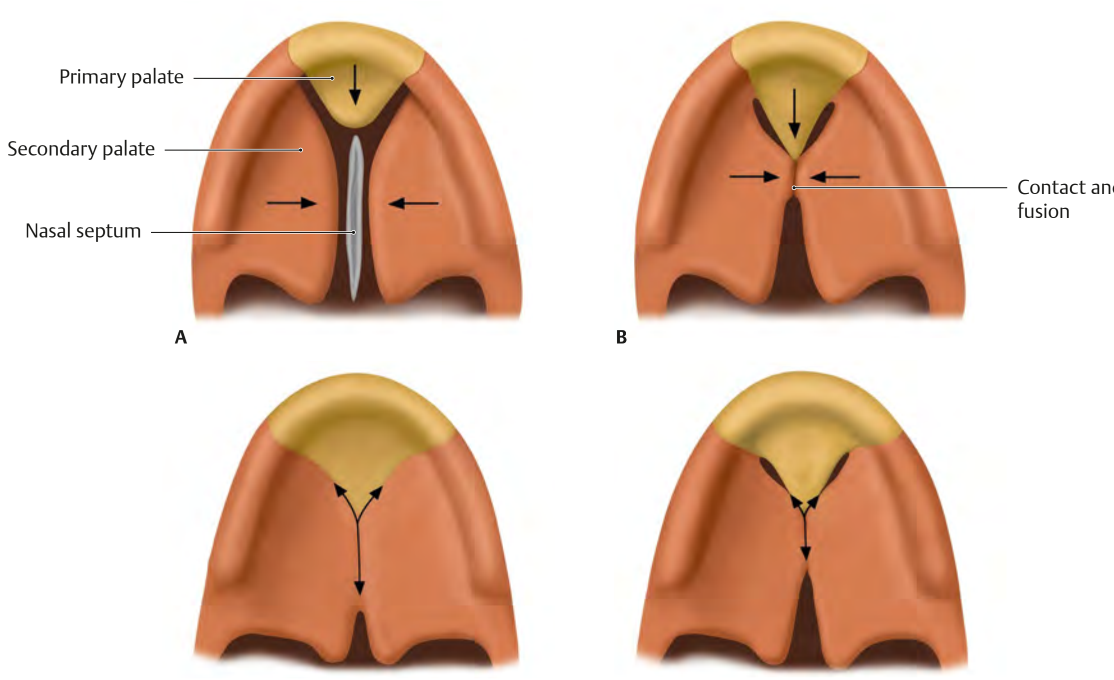


Fig. 1.22 **Fusion and merging of the palatine shelves**
Fusion of the palate begins at around 9 weeks and is completed posteriorly by week 12. **(A)** The primary palate and both halves of the secondary palate migrate toward each other as indicated by the arrows. **(B)** They contact and fuse at a point (marked by the incisive foramen) and merge anteriorly and posteriorly, as shown in **(C)** and **(D)**. The primary and secondary palates ossify, forming the hard palate. The posterior portions of the palatine shelves do not become ossified but extend beyond the nasal septum to form the soft palate and uvula.

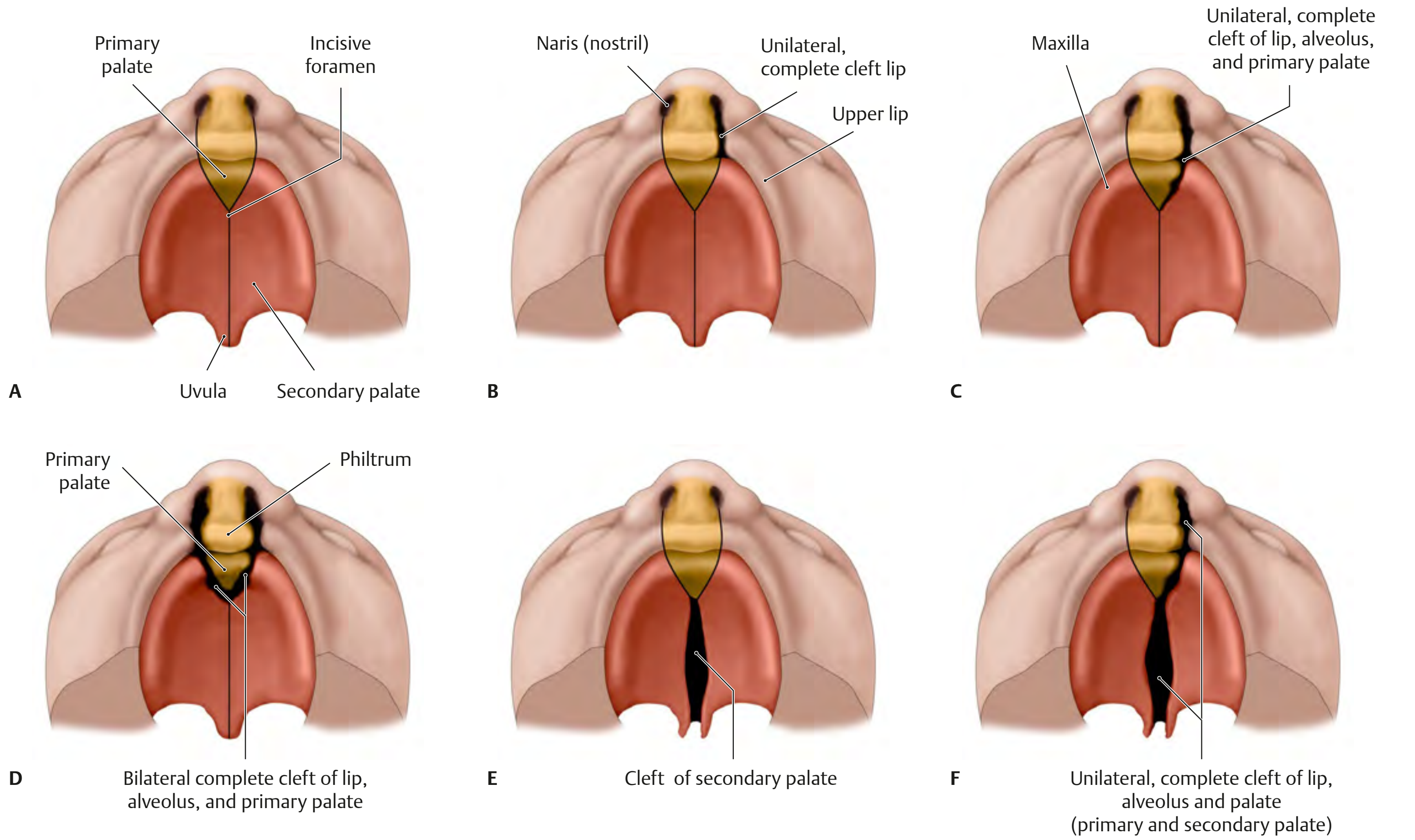


Fig. 1.23 **Formation of facial clefts** (after Sadler)
Inferior view.
Clefts (fissures or openings) can involve the lips and/or the palate. Clefts are classified as isolated (cleft lip or cleft palate), unilateral or bilateral, and as complete (when they extend to the nose) or incomplete (if they do not extend to the nose).
A Normal lips and palate, in which the maxillary prominences and medial nasal prominences have merged to form the upper lip and primary palate. The primary palate has also fused with the palatine processes of the maxillary prominences (secondary palate) to form the complete, unified, hard palate. The posterior portion of the secondary palate is unossified and forms the soft palate and uvula.
B Unilateral, complete cleft lip results from failure of fusion of the maxillary prominence with the medial nasal prominence on the affected side.
C Unilateral, complete cleft lip, alveolus, and primary palate (part of palate anterior to the incisive foramen) results from failure of fusion of the maxillary prominence with the medial nasal prominence on the affected side.
D Bilateral, complete cleft lip, alveolus, and primary palate result from failure of the maxillary prominences to fuse with the medial nasal prominences on both sides.
E Cleft of secondary palate (part of palate posterior to the incisive foramen) results from incomplete fusion of the two lateral palatine processes.
F Unilateral, complete cleft lip and complete cleft palate (involving both primary and secondary palate) result from failure of fusion of the maxillary prominence with the medial nasal prominence and failure of fusion of the two lateral palatine processes on the affected side.
Cleft lip and palate can cause difficulty in eating and speaking, and result in failure to thrive in infants. Treatment by a multidisciplinary team of healthcare professionals principally involves corrective surgery, which is usually performed between 6 and 12 months of age, often followed by surgical revisions, speech therapy, and orthodontic therapy.

Development of the Cranial Bones

Fig. 2.1 **Bones of the skull**
Left lateral view. The skull forms a bony capsule that encloses the brain and viscera of the head. The bones of the skull are divided into two parts. The viscerocranium (orange), the facial skeleton, is formed primarily from the pharyngeal (branchial) arches (see pp. 6 and 7). The neurocranium (gray), the cranial vault, is the bony capsule enclosing the brain. It is divided into two parts based on ossification (see **Fig. 2.2**). The *cartilaginous* neurocranium undergoes endochondral ossification to form the base of the skull. The *membranous* neurocranium undergoes intramembranous ossification.

Fig. 2.2 **Ossification of the cranial bones**
Left lateral view. The bones of the skull develop either directly or indirectly from mesenchymal connective tissue. The bones of the desmocranium (gray) develop directly via intramembranous ossification of mesenchymal connective tissue. The bones of the chondrocranium (blue) develop indirectly via endochondral ossification of hyaline cartilage. *Note:* The skull base is formed exclusively by the chondrocranium. Elements formed via intramembranous and endochondral ossification may fuse to form a single bone (e.g., the elements of the occipital, temporal, and sphenoid bones contributing to the skull base are cartilaginous, while the rest of the bone is membranous).

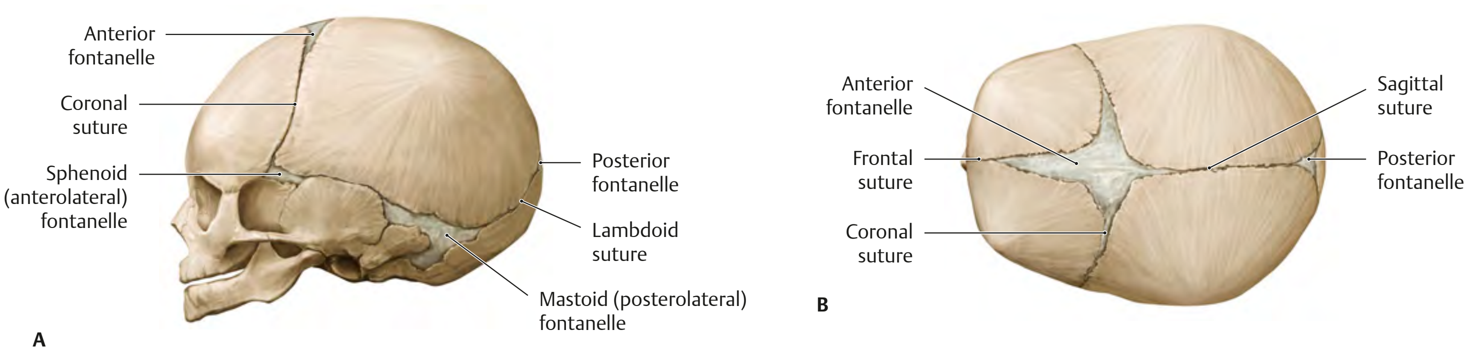


Fig. 2.3 **Cranial sutures (craniosynostoses) and fontanelles**
A Left lateral view of neonatal skull.
B Superior view of neonatal skull.
The flat cranial bones grow as the brain expands; thus the sutures between them remain open after birth. In the neonate, there are six areas (fontanelles) between the still-growing cranial bones that are occupied by unossified fibrous membrane. The posterior fontanelle provides a reference point for describing the position of the fetal head during childbirth. The anterior fontanelle provides access for drawing cerebrospinal fluid (CSF) samples in infants (e.g., in suspected meningitis).

Table 2.1 **Closure of sutures and fontanelles**

Fontanelle	Age at closure	Suture	Age at ossification
1 Posterior fontanelle	2–3 months (lambda)	Frontal suture	Childhood
2 Sphenoid (anterolateral) fontanelles	6 months (pterion)	Sagittal suture	20–30 years old
2 Mastoid (posterolateral) fontanelles	18 months (asterion)	Coronal suture	30–40 years old
1 Anterior fontanelle	36 months (bregma)	Lambdoid suture	40–50 years old

Table 2.2 Development of the skull			
Bone	**Ossification**	**Arch**	**Embryological tissue**
Viscerocranium			
Maxilla (premaxilla)	I	Frontonasal process	Neural crest
Nasal bone	I	Frontonasal process	Neural crest
Lacrimal bone	I	Frontonasal process	Neural crest
Vomer	I	Frontonasal process	Neural crest
Ethmoid (part)	E	Frontonasal process	Neural crest
Inferior nasal concha	E	Frontonasal process	Neural crest
Maxilla	I	1st arch	Neural crest
Zygomatic bone	I	1st arch	Neural crest
Mandible	I	1st arch	Neural crest
Palatine bone	I	1st arch	Neural crest
Temporal bone (tympanic ring)	I	1st arch	Neural crest
Sphenoid (pterygoid)	I	1st arch	Neural crest
Malleus	E	1st arch	Neural crest
Incus	E	1st arch	Neural crest
Hyoid (superior body, lesser horn)	E	2nd arch	Neural crest
Temporal (styloid)	E	2nd arch	Neural crest
Stapes	E	2nd arch	Neural crest
Hyoid (inferior body, greater horn)	E	3rd arch	Neural crest
Membranous neurocranium			
Greater wings of sphenoid (lateral)	I		Neural crest
Frontal	I		Neural crest
Squamous temporal	I		Neural crest
Parietal	I		Paraxial mesoderm
Supranuchal squamous occipital	I		Paraxial mesoderm
Cartilaginous neurocranium			
Ethmoid (part)	E		Neural crest
Sphenoid (lesser wing)	E		Neural crest
Sphenoid (body)	E		Paraxial mesoderm
Occipital (base)	E		Paraxial mesoderm
Temporal	E		Paraxial mesoderm
Sphenoid (greater wing, medial)	E		Neural crest
Infranuchal squamous occipital	E		Paraxial mesoderm

Abbreviations: I, intramembranous; E, endochondral.
Note: Tubular (long) bones undergo endochondral ossification. The clavicle is the only exception. Congenital defects of intramembranous ossification therefore affect both the skull and clavicle (cleidocranial dysostosis).

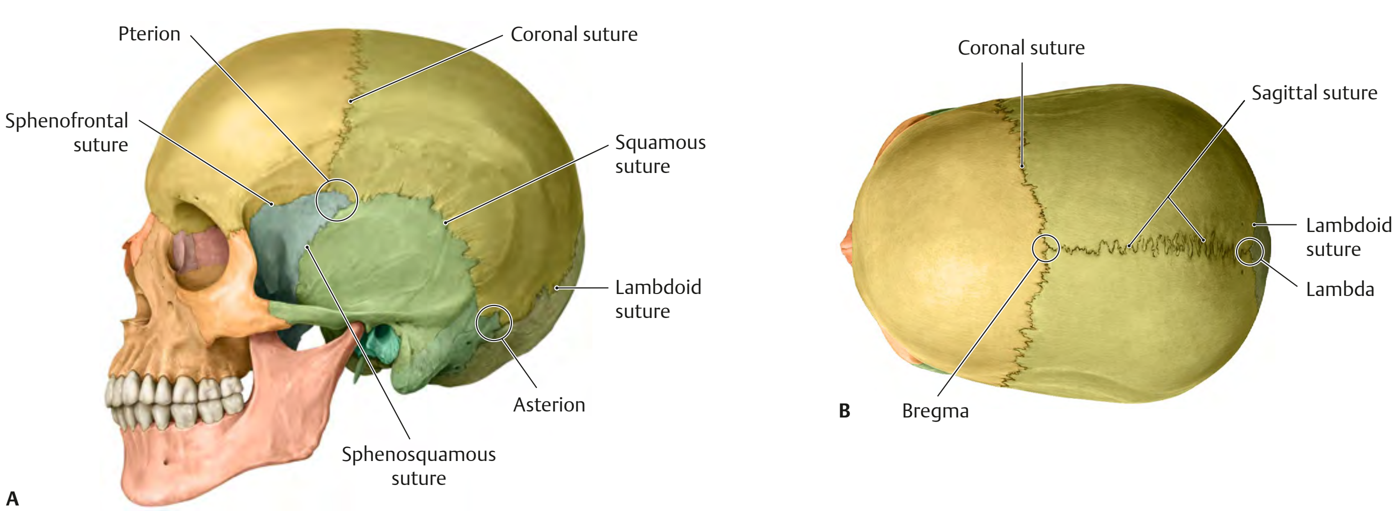


***Fig. 2.4* Sutures in the adult skull**
A Left lateral view.
B Superior view.

Synostosis (the fusion of the cranial bones along the sutures) occurs during adulthood. Although the exact times of closure vary, the order (sagittal, coronal, lambdoid) does not. Closure of each fontanelle yields a particular junction (see **Table 2.1**). Premature closure of the cranial sutures produces characteristic deformities (see **Fig. 2.11**, p. 22).

Skull: Lateral View

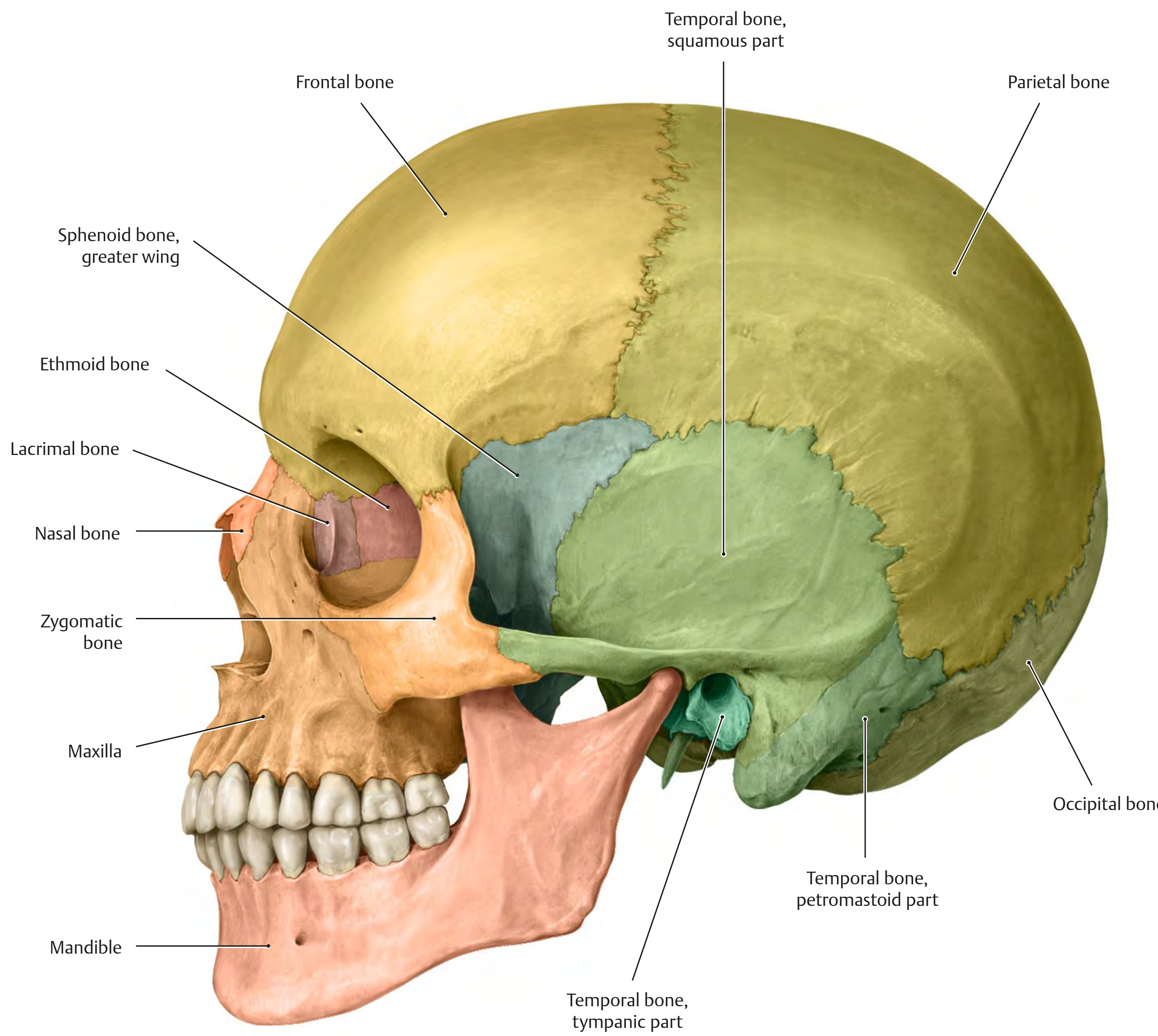


Fig. 2.5 **Cranial bones**
Left lateral view.

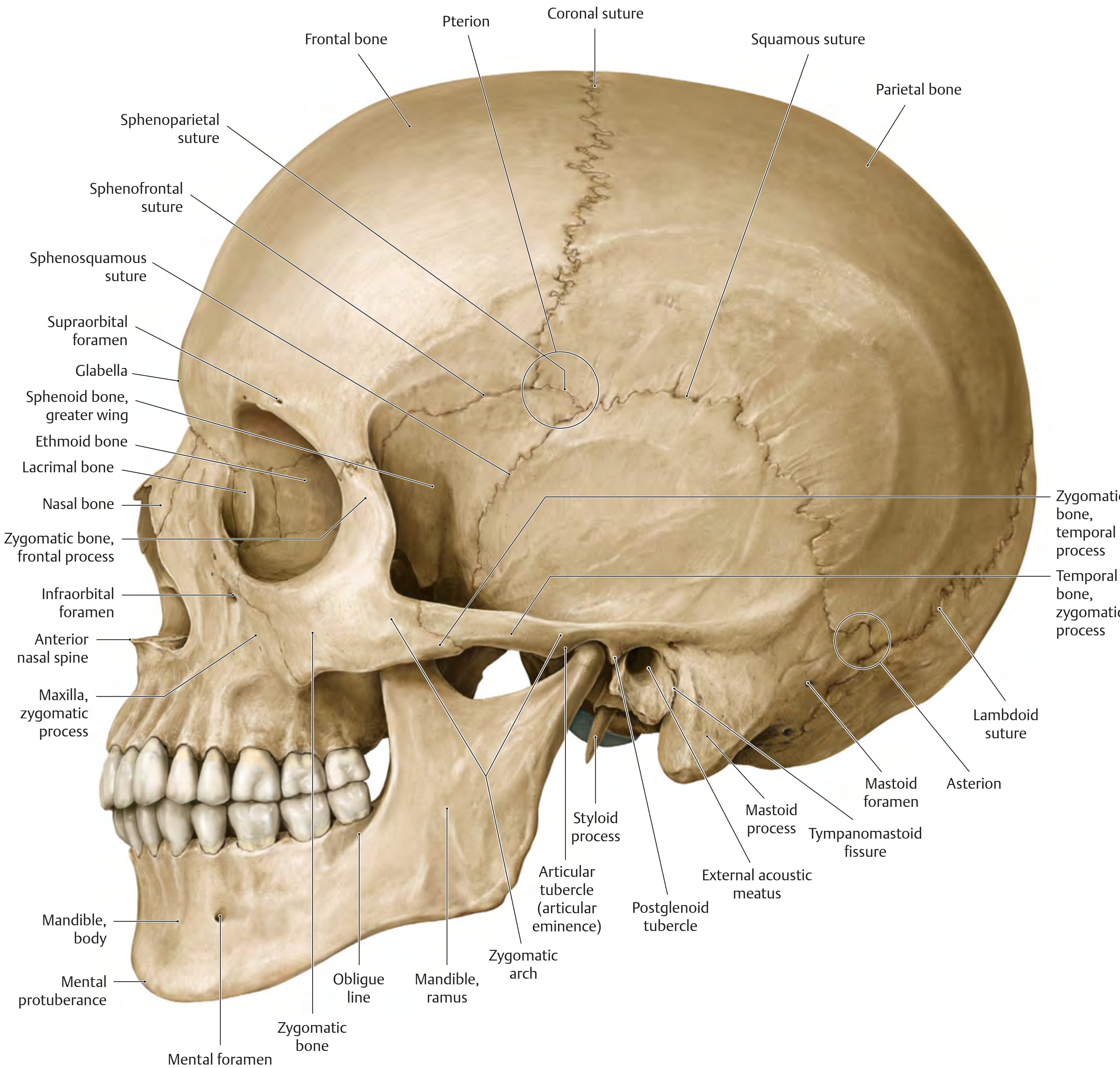


Fig. 2.6 **Skull (cranium)**
Left lateral view. This view displays the greatest number of cranial bones (indicated by different colors in **Fig. 2.5**). The zygomatic arch is formed by the zygomatic process of the temporal bone and the temporal process of the zygomatic bone, which are united by an oblique suture.

Skull: Anterior View

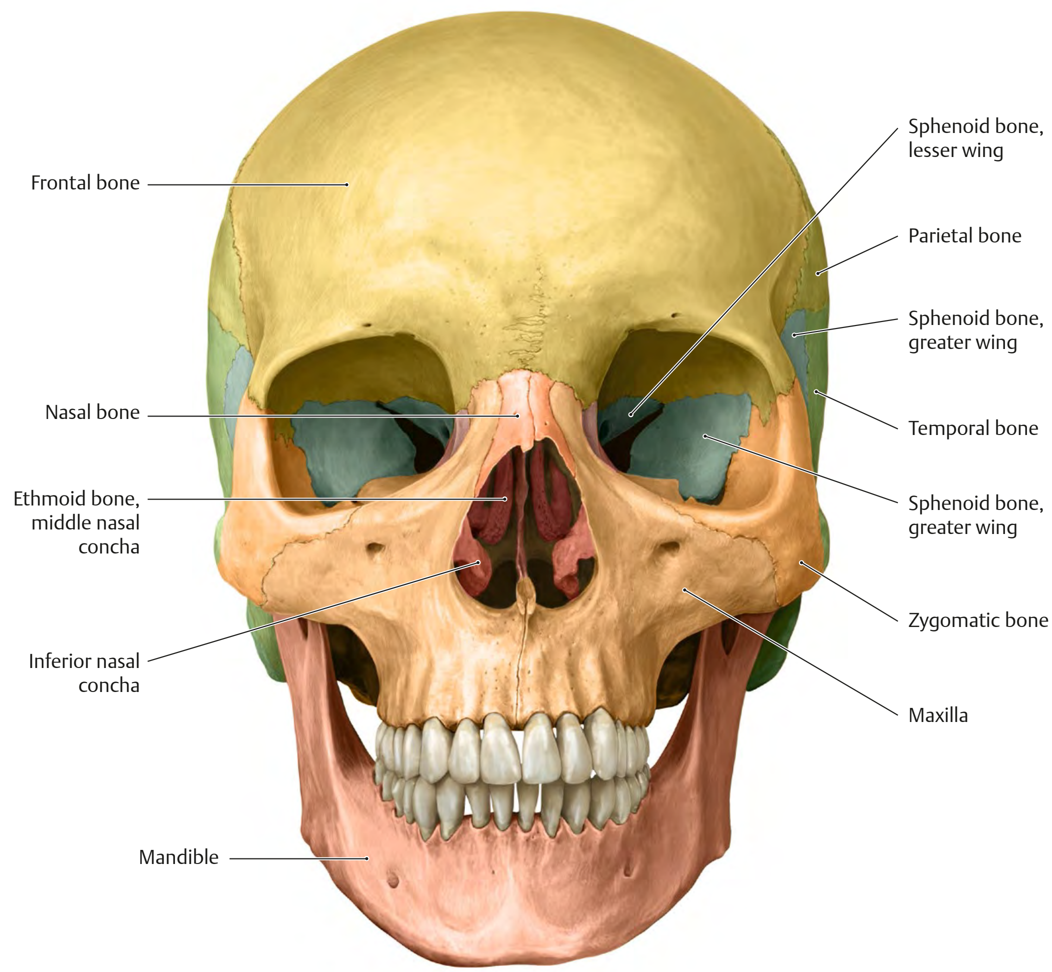


Fig. 2.7 **Cranial bones.**
Anterior view.

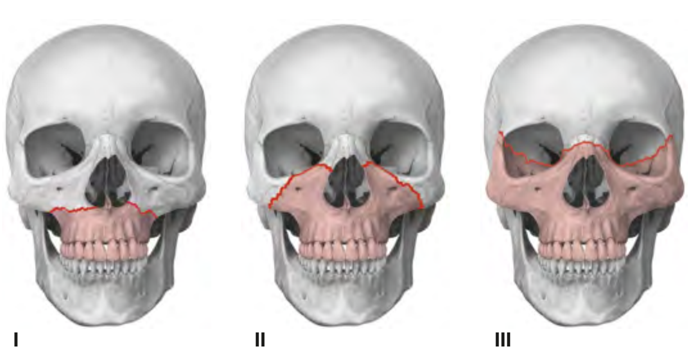


Fig. 2.8 **Le Fort classification of midfacial fractures**
The framelike construction of the facial skeleton leads to characteristic patterns of fracture lines in the midfacial region (Le Fort I, II, and III).
Le Fort I: This fracture line runs across the maxilla and above the hard palate. The maxilla is separated from the upper facial skeleton, disrupting the integrity of the maxillary sinus (*low transverse fracture*).
Le Fort II: The fracture line passes across the nasal root, ethmoid bone, maxilla, and zygomatic bone, creating a *pyramid fracture* that disrupts the integrity of the orbit.
Le Fort III: The facial skeleton is separated from the base of the skull. The main fracture line passes through the orbits, and the fracture may additionally involve the ethmoid bones, frontal sinuses, sphenoid sinuses, and zygomatic bones.

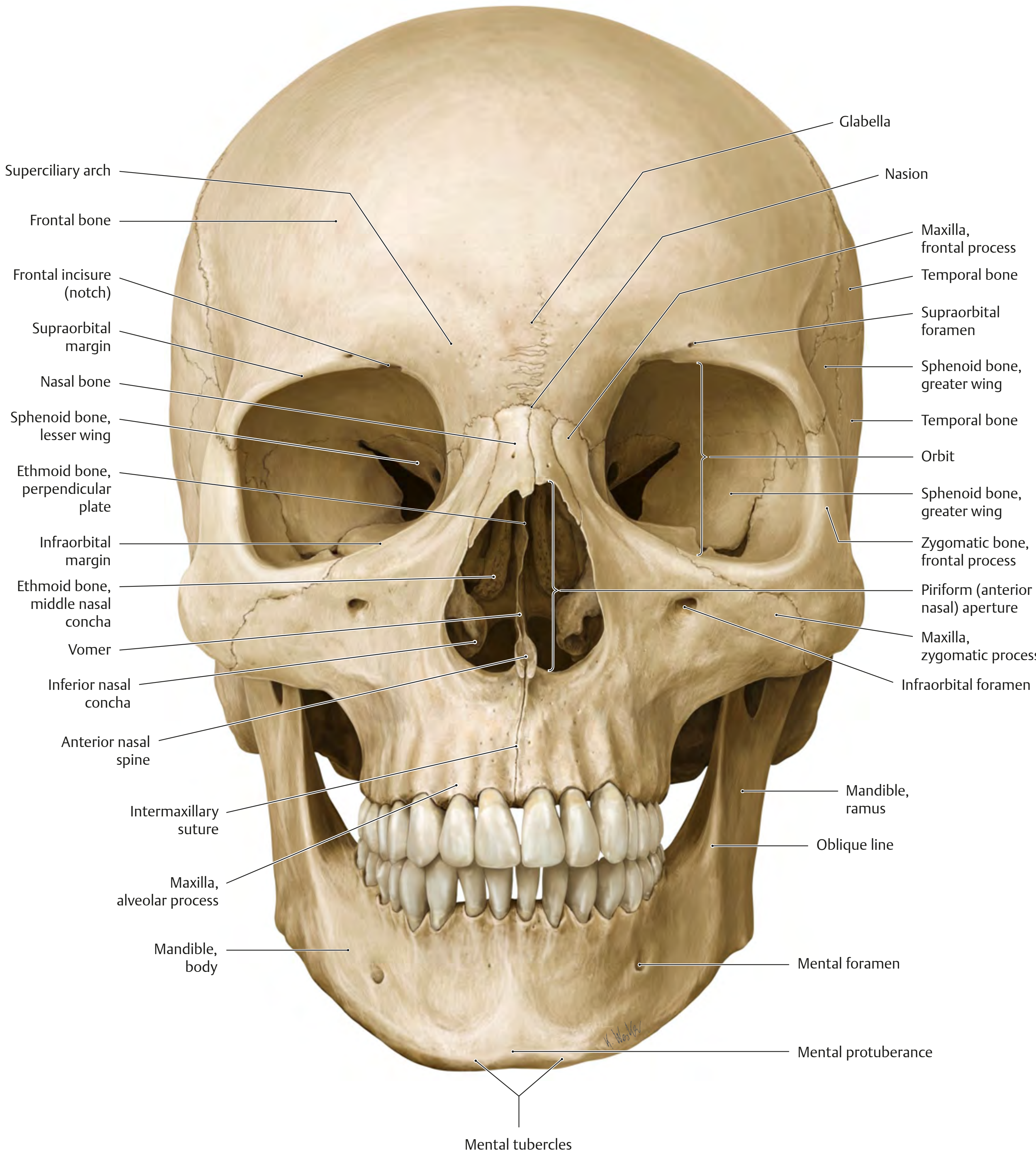


Fig. 2.9 **Skull**

Anterior view. The boundaries of the facial skeleton (viscerocranium) can be clearly appreciated in this view. The bony margins of the anterior nasal aperture mark the start of the respiratory tract in the skull. The nasal cavity, like the orbits, contains a sensory organ (the olfactory mucosa). The *paranasal sinuses* are shown schematically in **Fig. 7.8,** p. 187. The anterior view of the skull also displays the three clinically important openings through which sensory nerves pass to supply the face: the supraorbital foramen, infraorbital foramen, and mental foramen.

Skull: Posterior View

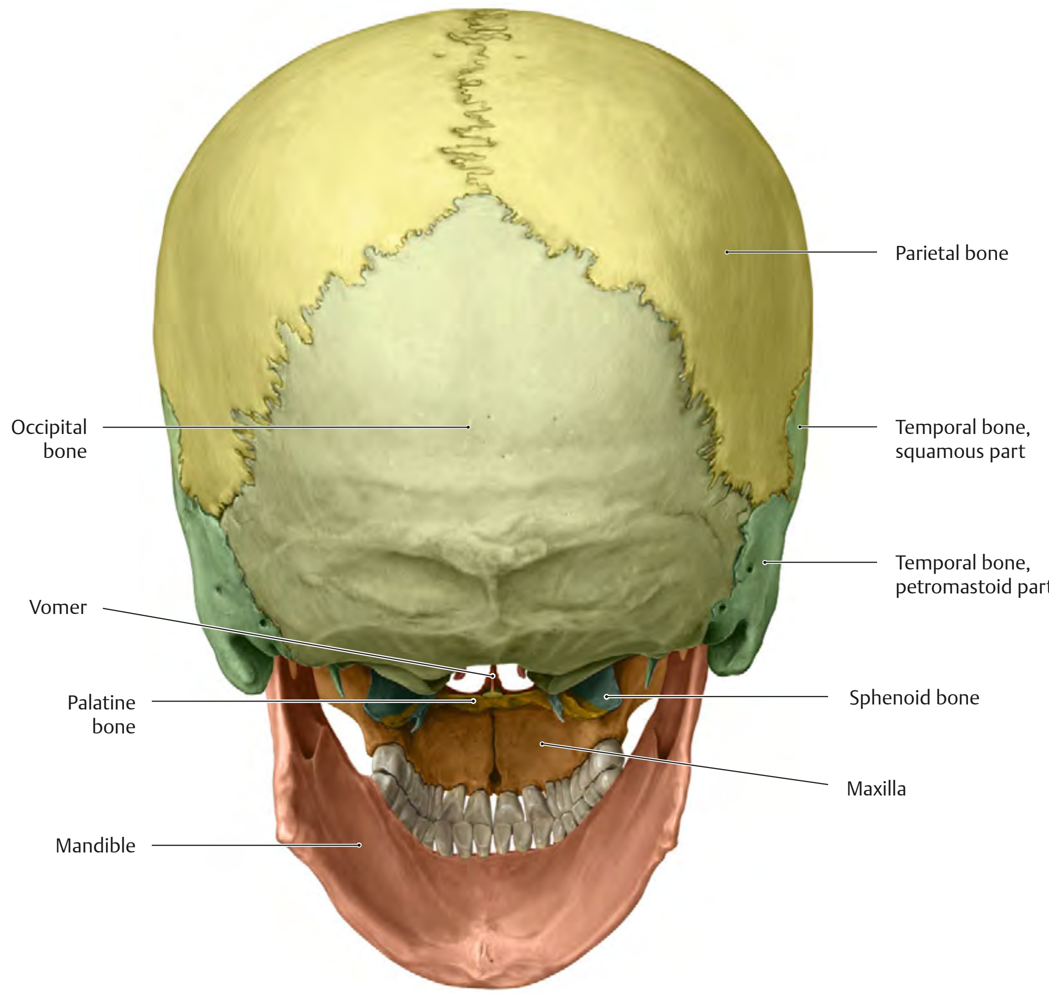
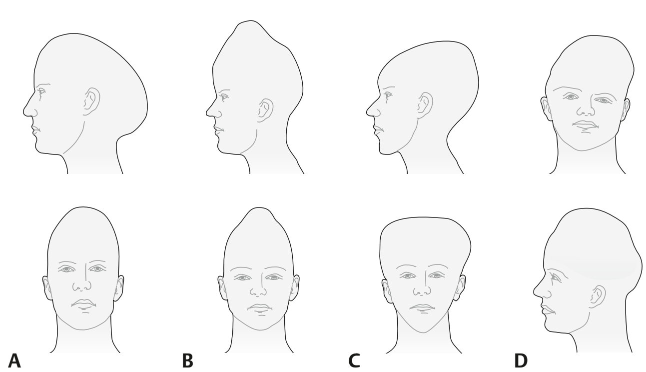


Fig. 2.10 **Cranial bones.**
Posterior view.



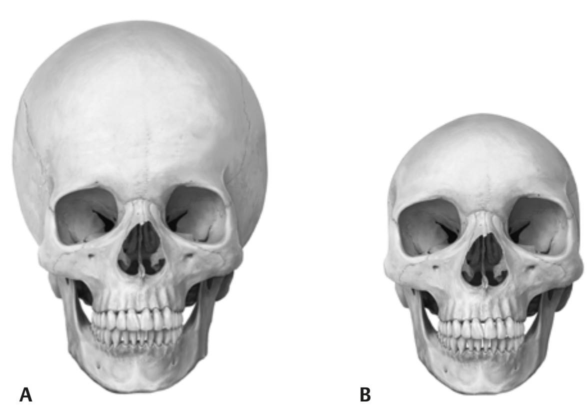


Fig. 2.11 **Premature closure of cranial sutures**
The premature closure of a cranial suture (craniosynostosis) may lead to characteristic cranial deformities:

A Sagittal suture: scaphocephaly (long, narrow skull).
B Coronal suture: oxycephaly (pointed skull).
C Frontal suture: trigonocephaly (triangular skull).
D Asymmetrical suture closure, usually involving the coronal suture: plagiocephaly (asymmetric skull).

Fig. 2.12 **Hydrocephalus and microcephaly**
A Hydrocephalus: When the ventricles become dilated due to cerebrospinal fluid (CSF) accumulation *before* the cranial sutures ossify, the neurocranium will expand, whereas the facial skeleton remains unchanged.
B Microcephaly: Premature closure of the cranial sutures or decreased growth of brain results in a small neurocranium with relatively large orbits.

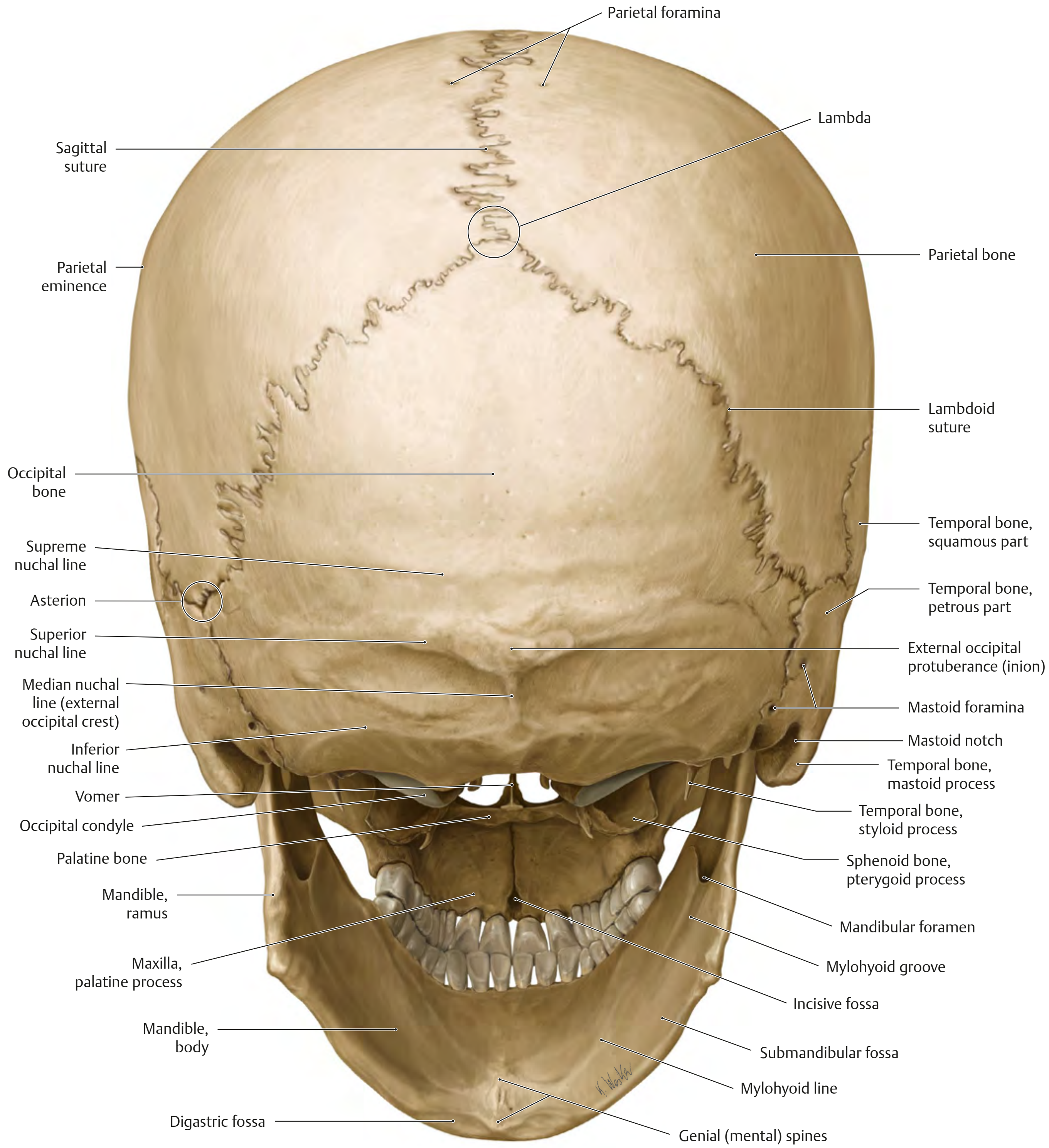


Fig. 2.13 **Skull**
Posterior view. The occipital bone, which is dominant in this view, articulates with the parietal bones, to which it is connected by the lambdoid suture. Wormian (sutural) bones are isolated bone plates often found in the lambdoid suture. The cranial sutures are a special type of syndesmosis (i.e., ligamentous attachments that ossify with age). The outer surface of the occipital bone is contoured by muscular origins and insertions: the inferior, superior, median, and supreme nuchal lines.

Calvaria

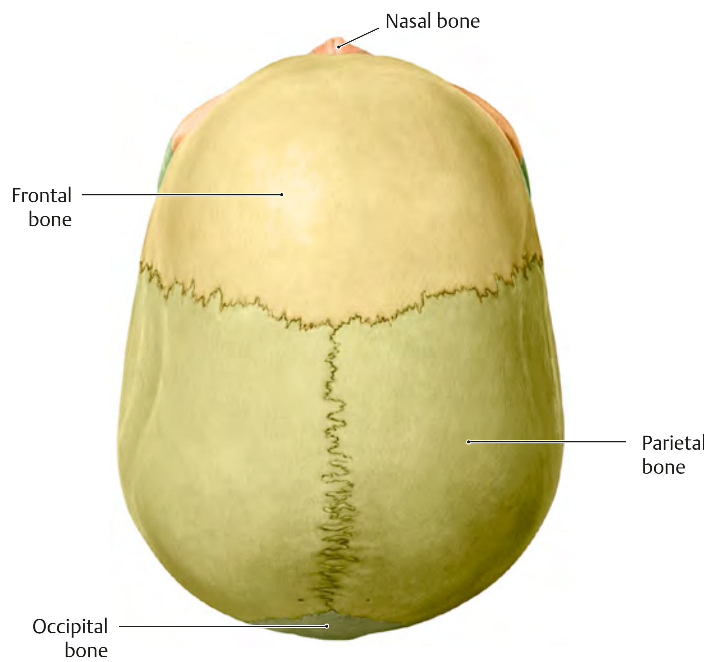


Fig. 2.14 **Bones of the calvaria**
External surface, superior view.

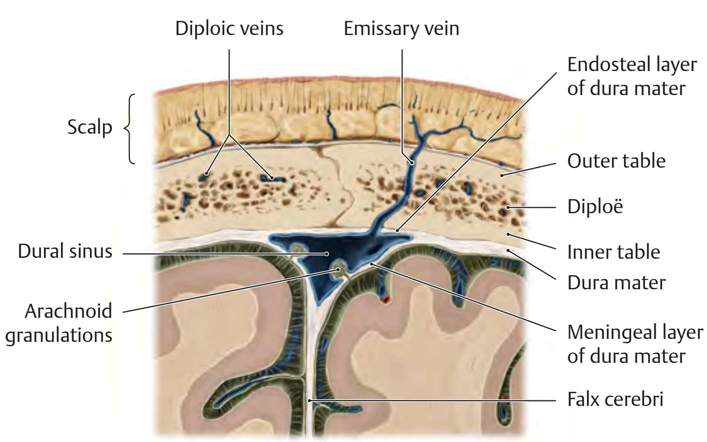


Fig. 2.15 **The scalp and calvaria**
The three-layered calvaria consists of the outer table, the diploë, and the inner table. The diploë has a spongy structure and contains red (blood-forming) bone marrow. With a plasmacytoma (malignant transformation of certain white blood cells), many small nests of tumor cells may destroy the surrounding bony trabeculae, and radiographs will demonstrate multiple lucent areas ("punched-out lesions") in the skull.

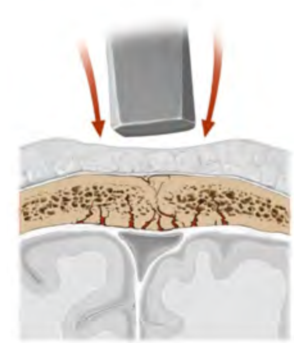


Fig. 2.16 **Sensitivity of the inner table to trauma**
The inner table of the calvaria is very sensitive to external trauma and may fracture even when the outer table remains intact.

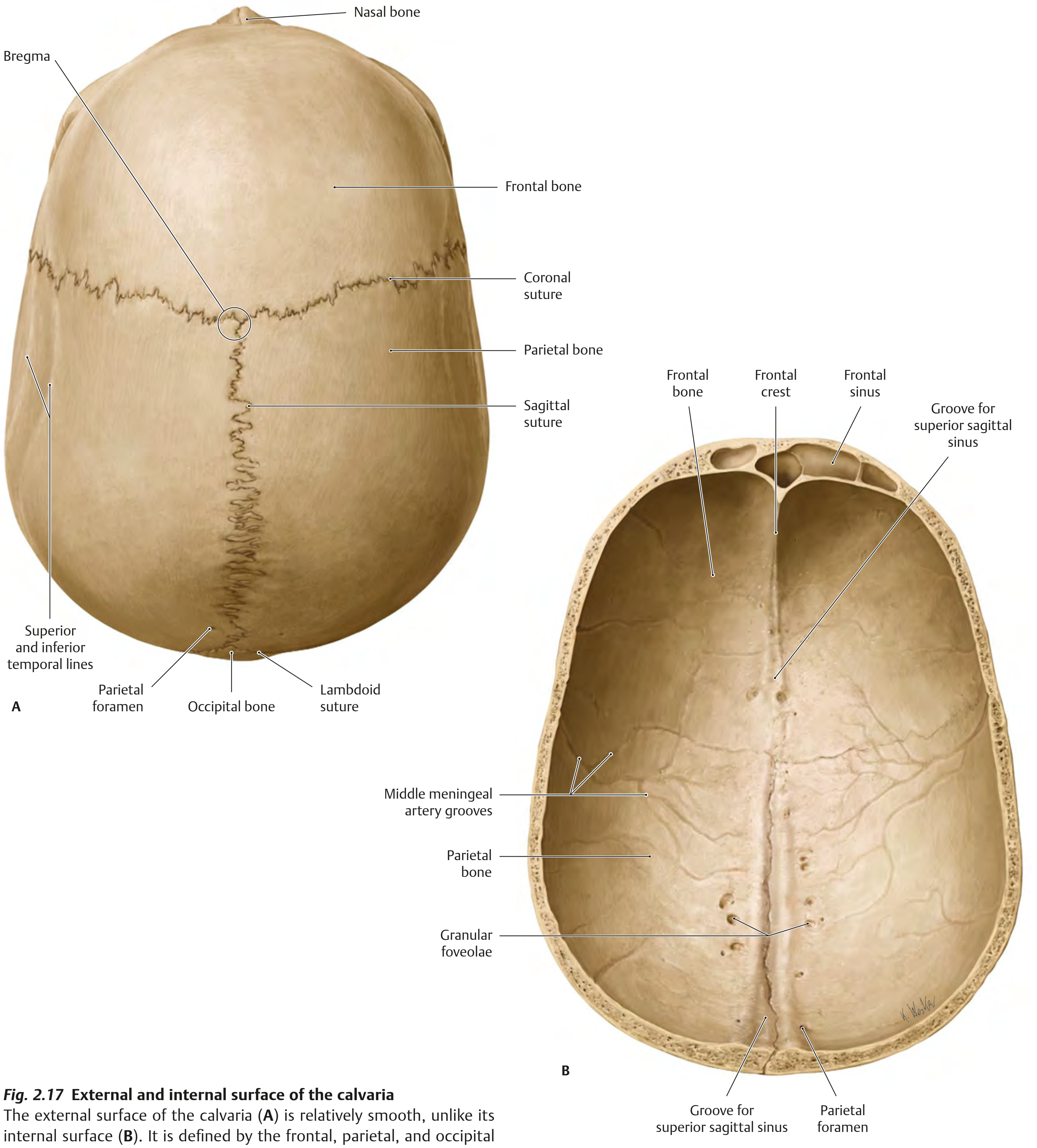


Fig. 2.17 **External and internal surface of the calvaria**
The external surface of the calvaria (**A**) is relatively smooth, unlike its internal surface (**B**). It is defined by the frontal, parietal, and occipital bones, which are interconnected by the coronal, sagittal, and lambdoid sutures. The smooth external surface is interrupted by the parietal foramina, which gives passage to the parietal emissary veins (see **Fig. 3.24**, p. 71). The internal surface of the calvaria bears a number of pits and grooves:

- Granular foveolae (small pits in the inner surface of the skull caused by saccular protrusions of the arachnoid membrane [arachnoid granulations] covering the brain)
- Groove for the superior sagittal sinus (a dural venous sinus of the brain, see **Fig. 3.22**, p. 70)
- Arterial grooves (which mark the positions of the arterial vessels of the dura mater, such as the middle meningeal artery, which supplies most of the dura mater and overlying bone)
- Frontal crest (which gives attachment to the falx cerebri, a sickle-shaped fold of dura mater between the cerebral hemispheres).

Skull Base: Exterior

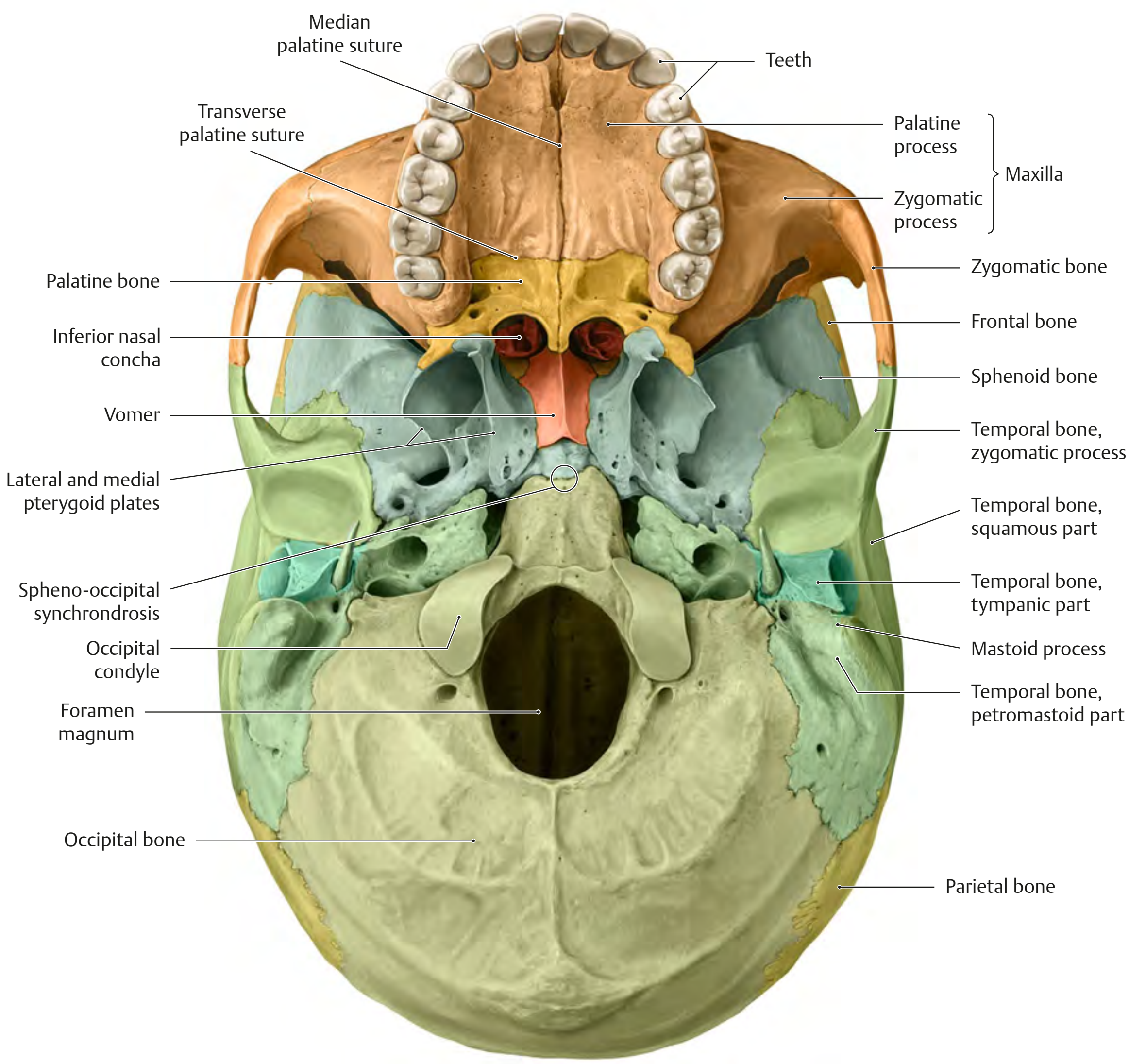


Fig. 2.18 **Bones of the skull base**
External surface, inferior view. The base of the skull is composed of a mosaic-like assembly of various bones.

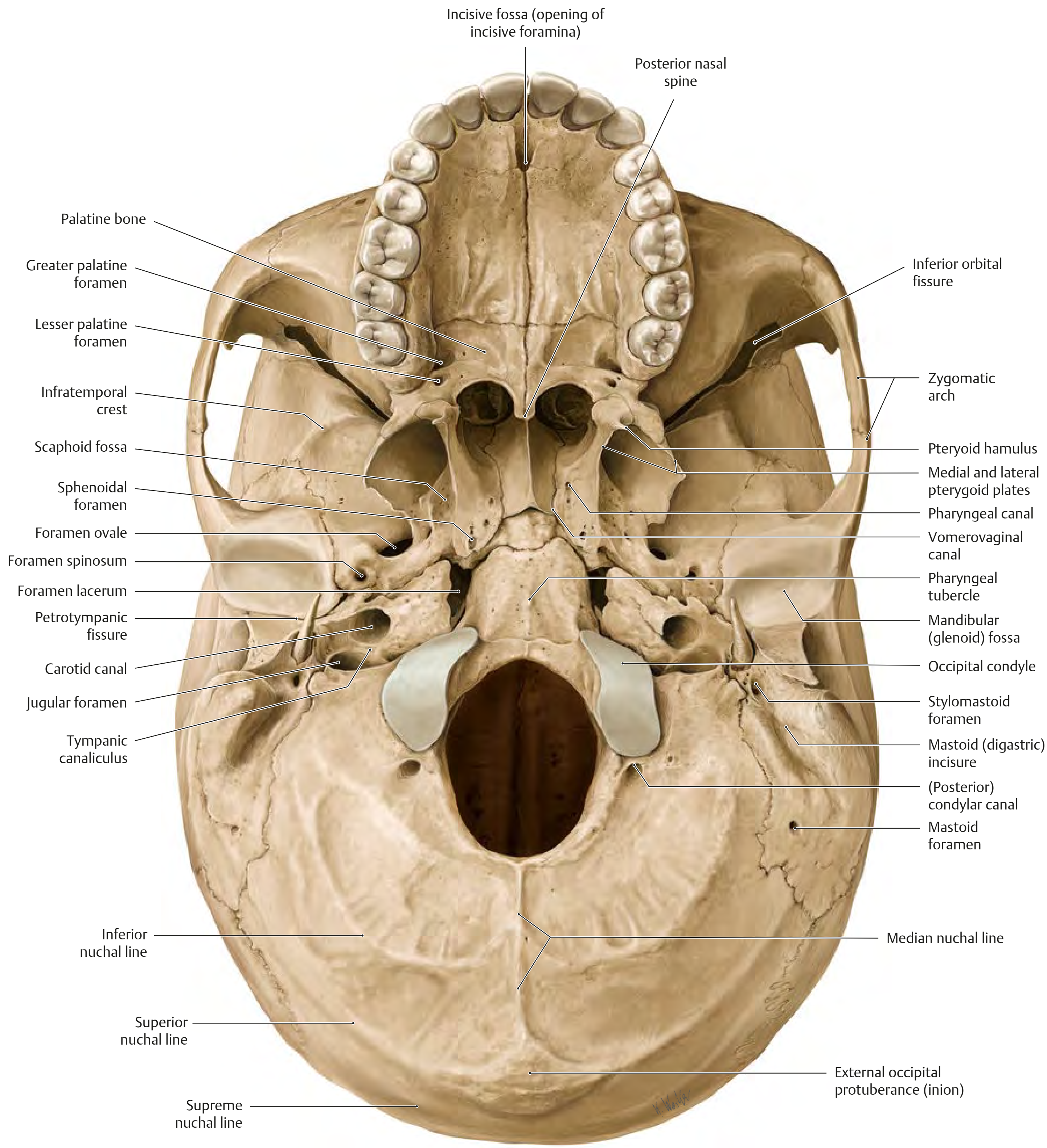


Fig. 2.19 **Skull base**
External surface, inferior view. Note the openings that transmit nerves and vessels. With abnormalities of bone growth, these openings may remain too small or may become narrowed, compressing the neurovascular structures that pass through them. The symptoms associated with these lesions depend on the affected opening. All of the structures depicted here will be considered in more detail in subsequent pages.

Skull Base: Interior

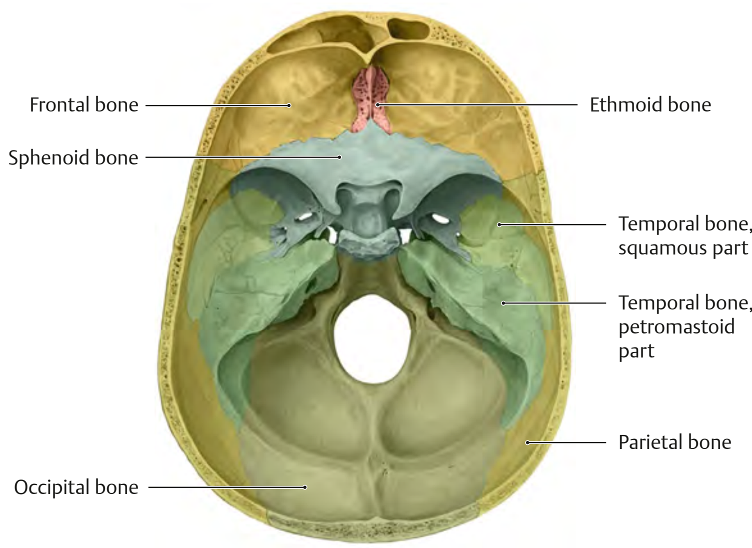


Fig. 2.20 **Bones of the skull base**
Internal surface, superior view.

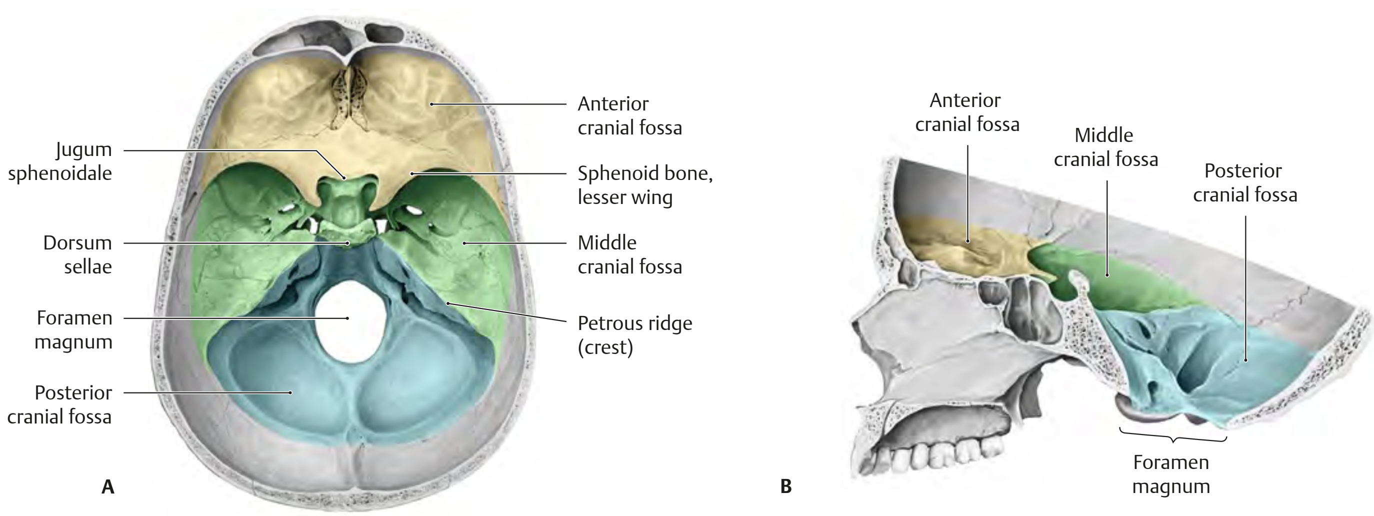


Fig. 2.21 **The cranial fossae**
A Skull base, internal surface, superior view. **B** Skull base, midsagittal section. The interior of the skull base is deepened to form three successive fossae: the anterior, middle, and posterior cranial fossae. These depressions become progressively deeper in the frontal-to-occipital direction, forming a terraced arrangement that is displayed most clearly in **B**.

The cranial fossae are bounded by the following structures:

- Anterior to middle: lesser wings of the sphenoid bone and the jugum sphenoidale
- Middle to posterior: superior border (ridge) of the petrous part of the temporal bone and the dorsum sellae

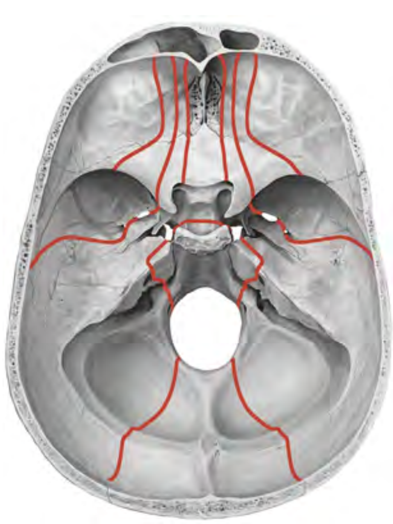


Fig. 2.22 **Common fracture lines of skull base**
Internal surface, superior view. In response to masticatory pressures and other mechanical stresses, the bones of the skull base are thickened to form "pillars" along the principal lines of force. The intervening areas that are not thickened are sites of predilection for bone fractures, resulting in the typical patterns of skull base fracture lines shown here in red. An analogous phenomenon of typical fracture lines is found in the midfacial region (see the anterior views of Le Fort fractures on p. 20).

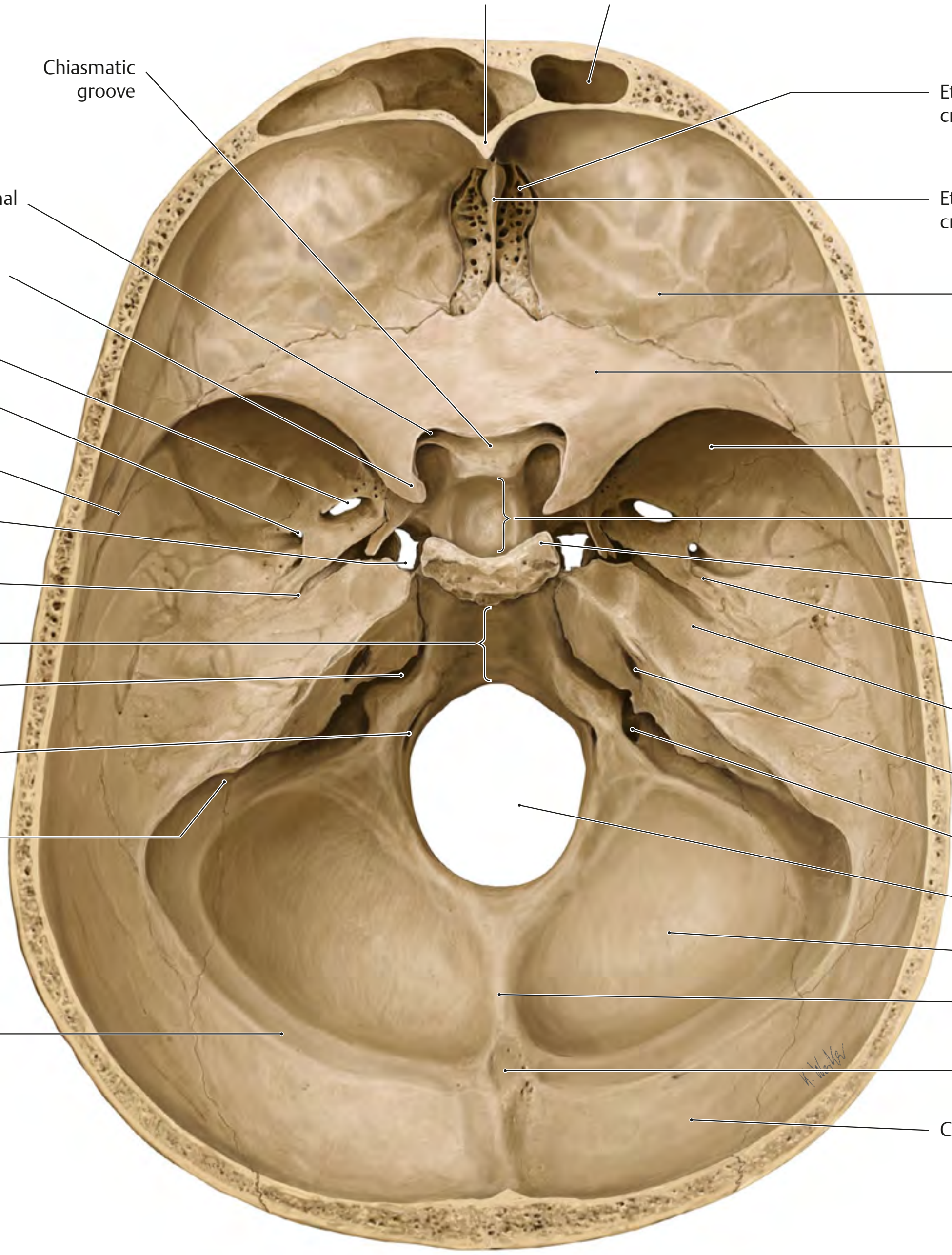
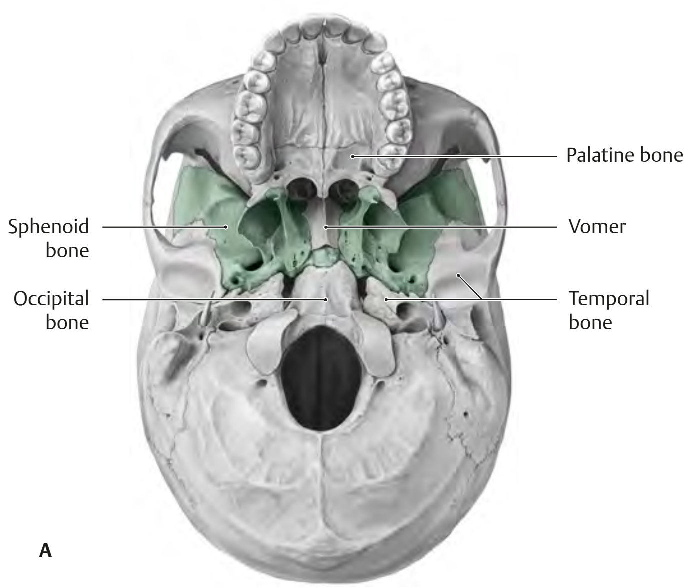
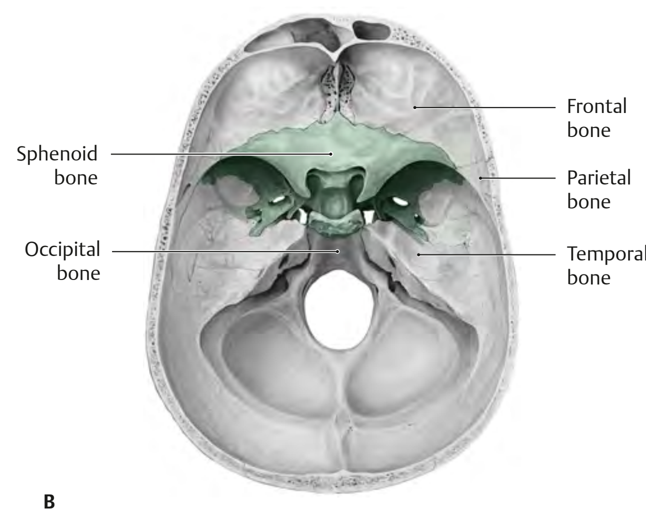


Fig. 2.23 **Skull base**
Internal surface, superior view. The openings in the interior of the base of the skull do not always coincide with the openings visible on the exterior because some neurovascular structures change direction when passing through the bone or pursue a relatively long intraosseous course. An example of this is the internal acoustic meatus, through which the facial nerve, among other structures, passes from the interior of the skull into the petrous part of the temporal bone. Most of its fibers then leave the petrous bone through the stylomastoid foramen, which is visible from the external aspect (see **Fig. 4.87**, p. 137, and **Fig. 2.45**, p. 44, for further details).

In learning the sites where neurovascular structures pass through the base of the skull, it is helpful initially to note whether these sites are located in the anterior, middle, or posterior cranial fossa. The arrangement of the cranial fossae is shown in **Fig. 2.21** (page 28).
The cribriform plate of the ethmoid bone connects the nasal cavity with the anterior cranial fossa and is perforated by numerous foramina for the passage of the olfactory fibers (see **Fig. 7.22**, p. 192). *Note:* Because the bone is so thin in this area, a frontal head injury may easily fracture the cribriform plate and lacerate the dura mater, allowing cerebrospinal fluid (CSF) to enter the nose. This poses a risk of meningitis, as bacteria from the nonsterile nasal cavity may enter the sterile CSF.

Sphenoid Bone





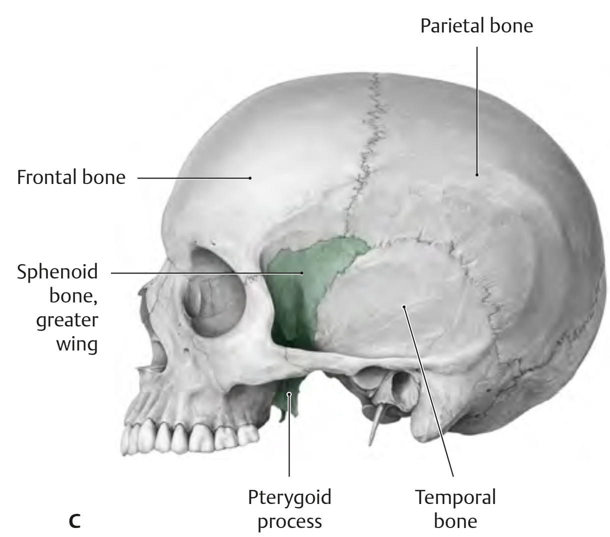
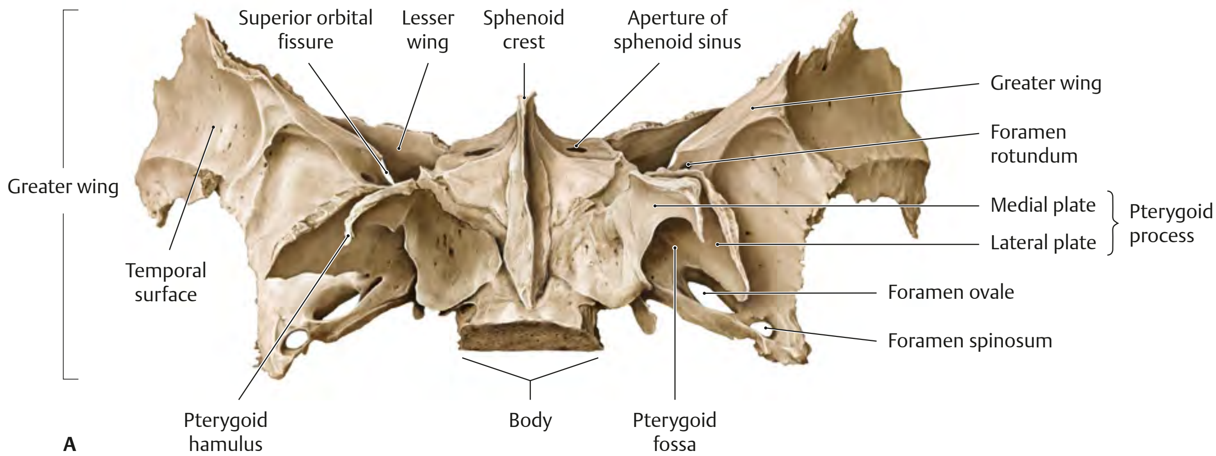


Fig. 2.24 **Position of the sphenoid bone in the skull**
The sphenoid bone is the most structurally complex bone in the human body. It must be viewed from various aspects in order to appreciate all its features (see also **Fig. 2.25**):

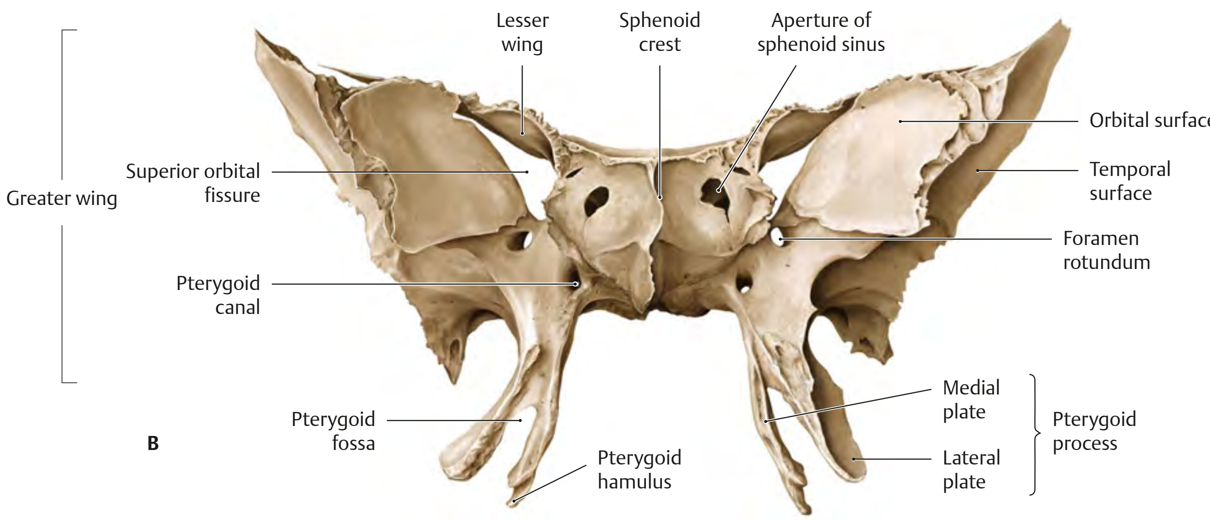
A **Skull base, exterior.** The sphenoid bone combines with the occipital bone to form the load-bearing midline structure of the skull base.
B **Skull base, interior.** The lesser wing of the sphenoid bone forms the boundary between the anterior and middle cranial fossae. The openings for the passage of nerves and vessels are clearly displayed (see details in **Fig. 2.45**).
C **Left lateral view.** Portions of the greater wing of the sphenoid bone can be seen above the zygomatic arch, and portions of the pterygoid process can be seen below the zygomatic arch.

Fig. 2.25 **Isolated sphenoid bone**
A **Inferior view** (its position in situ is shown in **Fig. 2.24**). This view demonstrates the medial and lateral plates of the pterygoid process. Between them is the pterygoid fossa, which is occupied by the medial pterygoid muscle. The foramen spinosum and foramen ovale provide pathways through the base of the skull (see also in **C**).
B **Anterior view.** This view illustrates why the sphenoid bone was originally called the sphecoid bone ("wasp bone") before a transcription error turned it into the sphenoid ("wedge-shaped") bone. The apertures of the sphenoid sinus on each side resemble the eyes of the wasp, and the pterygoid processes of the sphenoid bone form its dangling legs, between which are the pterygoid fossae. This view also displays the superior orbital fissure, which connects the middle cranial fossa with the orbit on each side. The two sphenoid sinuses are separated by an internal septum (see **Fig. 7.11**, p. 187).
C **Superior view.** The superior view displays the sella turcica, whose central depression, the hypophyseal fossa, contains the pituitary gland. The foramen spinosum, foramen ovale, and foramen rotundum can be identified.
D **Posterior view.** The superior orbital fissure is seen clearly in this view, whereas the optic canal is almost completely obscured by the anterior clinoid process. The foramen rotundum is open from the middle cranial fossa to the pterygopalatine fossa of the skull (the foramen spinosum is not visible in this view; compare with **A**). Because the sphenoid and occipital bones fuse together during puberty ("tribasilar bone"), a suture is no longer present between the two bones. The cancellous trabeculae are exposed and have a porous appearance.



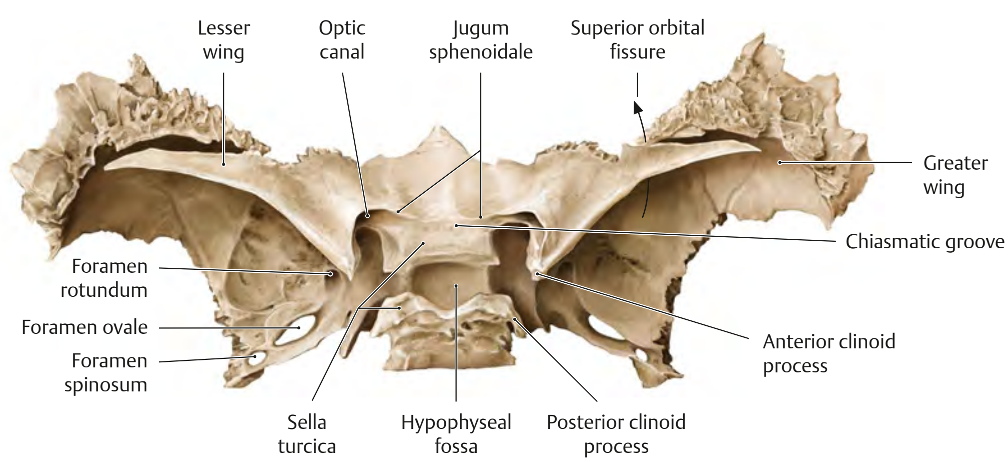
Superior orbital fissure
Lesser wing
Sphenoid crest
Aperture of sphenoid sinus
Greater wing
Foramen rotundum
Medial plate
Lateral plate
Pterygoid process
Foramen ovale
Foramen spinosum
Greater wing
Temporal surface
Pterygoid hamulus
Body
Pterygoid fossa

A



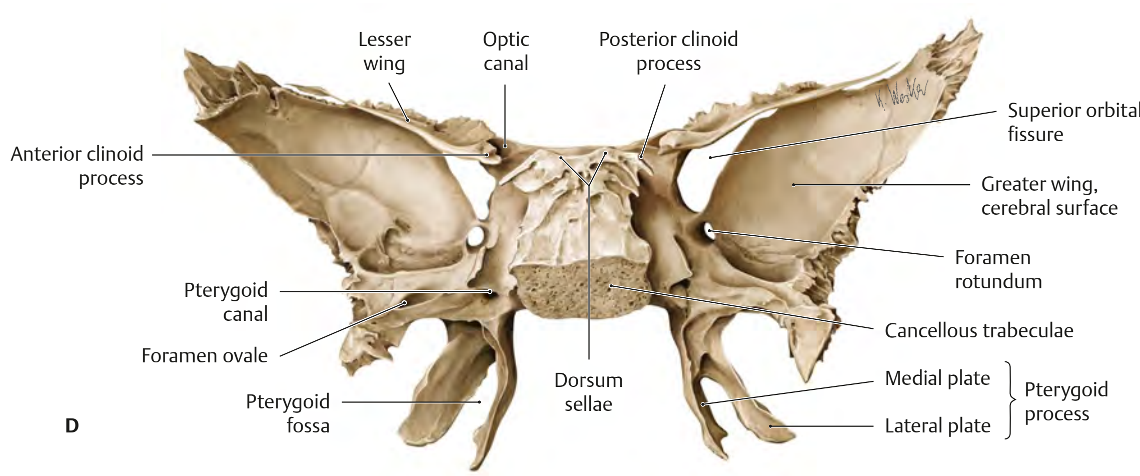
Lesser wing
Sphenoid crest
Aperture of sphenoid sinus
Orbital surface
Temporal surface
Foramen rotundum
Greater wing
Superior orbital fissure
Pterygoid canal
Pterygoid fossa
Pterygoid hamulus
Medial plate
Lateral plate
Pterygoid process

B



Lesser wing
Optic canal
Jugum sphenoidale
Superior orbital fissure
Greater wing
Chiasmatic groove
Foramen rotundum
Foramen ovale
Foramen spinosum
Anterior clinoid process
Sella turcica
Hypophyseal fossa
Posterior clinoid process

C



Lesser wing
Optic canal
Posterior clinoid process
Superior orbital fissure
Anterior clinoid process
Greater wing, cerebral surface
Foramen rotundum
Pterygoid canal
Cancellous trabeculae
Foramen ovale
Pterygoid fossa
Dorsum sellae
Medial plate
Lateral plate
Pterygoid process

D

Temporal Bone

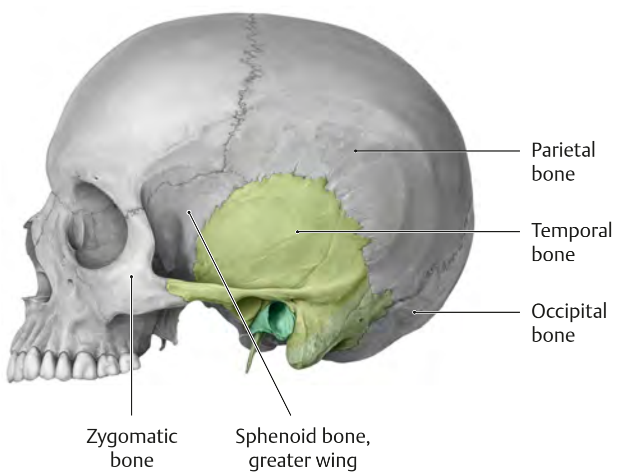
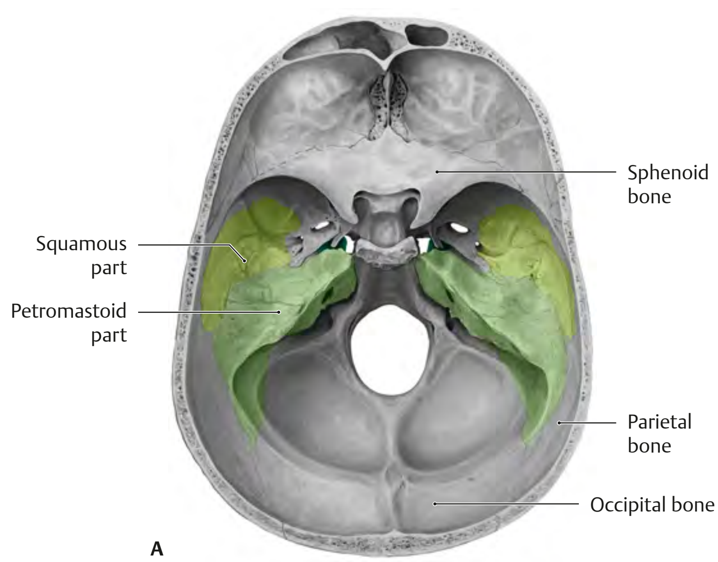


Fig. 2.26 **Position of the temporal bone in the skull**
Left lateral view. The temporal bone is a major component of the base of the skull. It forms the capsule for the auditory and vestibular apparatus and bears the articular fossa of the temporomandibular joint (TMJ).



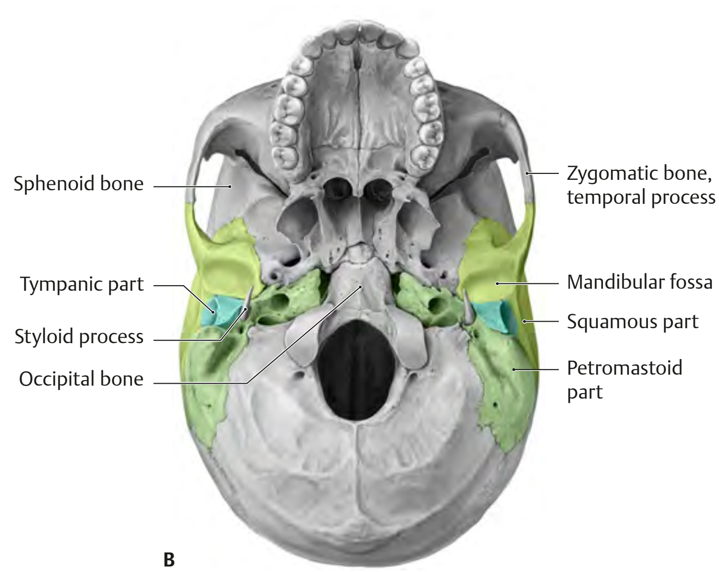


Fig. 2.27 **Temporal bone in the skull**
A Internal view. **B** Inferior view.
The temporal bone, develops from four centers that fuse to form a single bone:

- The *squamous part* (light green) includes the articular fossa (mandibular [glenoid] fossa) of the temporomandibular joint (TMJ).
- The *petromastoid part* (pale green) contains the auditory and vestibular apparatus.
- The *tympanic part* (darker green) forms large portions of the external auditory canal.
- The *styloid process* develops from cartilage derived from the second pharyngeal arch and is a site of muscle attachment.

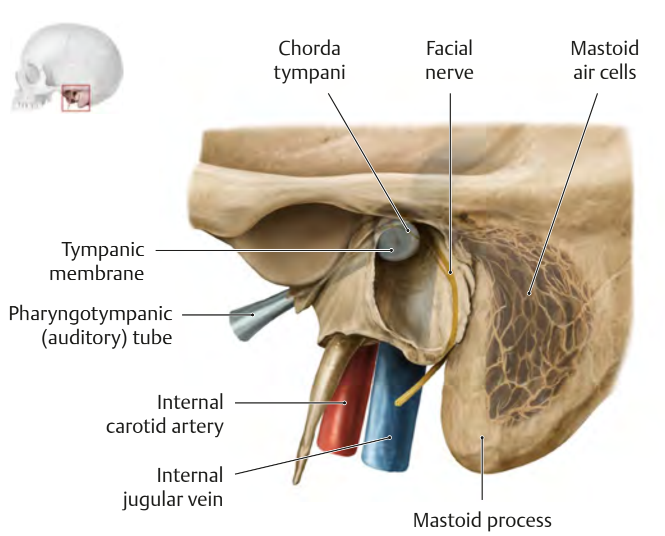


Fig. 2.28 **Projection of clinically important structures onto the left temporal bone**
The tympanic membrane is shown translucent in this lateral view. Because the petrous bone contains the middle and inner ear and the tympanic membrane, a knowledge of its anatomy is of key importance in otological surgery. The internal surface of the petrous bone has openings (see **Fig. 2.29**) for the passage of the facial nerve, internal carotid artery, and internal jugular vein. A fine nerve, the chorda tympani, passes through the tympanic cavity and lies medial to the tympanic membrane. The chorda tympani arises from the facial nerve, which is susceptible to injury during surgical procedures. The mastoid process of the petrous bone forms air-filled chambers, the mastoid cells, that vary greatly in size. Because these chambers communicate with the middle ear, which in turn communicates with the nasopharynx via the pharyngotympanic (auditory or Eustachian) tube, bacteria in the nasopharynx may pass up the pharyngotympanic tube and gain access to the middle ear. From there they may pass to the mastoid air cells and finally enter the cranial cavity, causing meningitis.

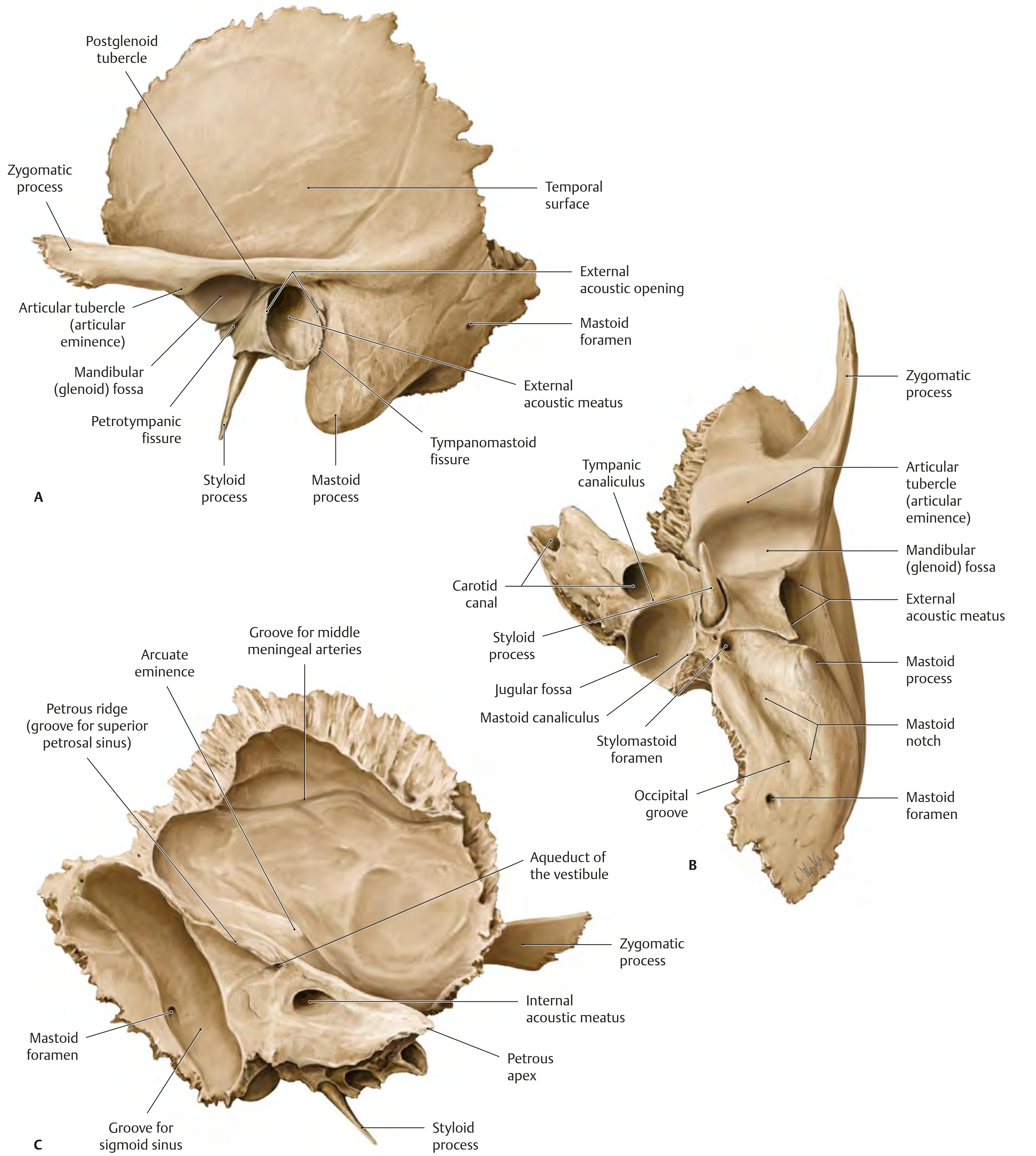


Fig. 2.29 **Left temporal bone**

A **Lateral view.** An emissary vein passes through the mastoid foramen (external orifice shown in **A**, internal orifice in **C**), and the chorda tympani passes through the medial part of the petrotympanic fissure. The mastoid process develops gradually in life due to traction from the sternocleidomastoid muscle and is pneumatized from the inside (see **Fig. 2.28**).

B **Inferior view.** The shallow articular fossa of the temporomandibular joint, the mandibular (glenoid) fossa, is clearly seen from the inferior view. The facial nerve emerges from the base of the skull through the stylomastoid foramen. The initial part of the superior jugular bulb is adherent to the jugular fossa, and the internal carotid artery passes through the carotid canal to enter the skull.

C **Medial view.** This view displays the internal orifice of the mastoid foramen and the internal acoustic meatus. The facial nerve and vestibulocochlear nerve are among the structures that pass through the internal meatus to enter the petrous bone. The part of the petrous bone shown here is also called the *petrous pyramid*, whose apex (often called the "petrous apex") lies on the interior of the base of the skull.

Occipital Bone & Ethmoid Bone

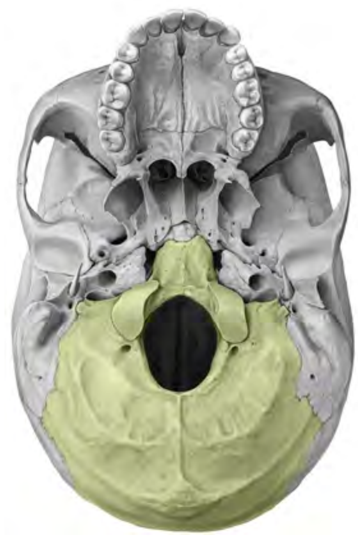
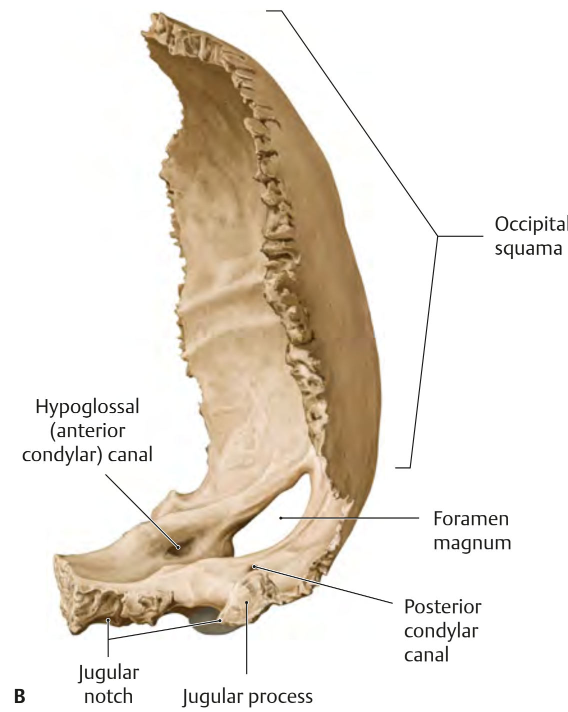


Fig. 2.30 **Position of the occipital bone in the exterior skull base**
Inferior view.



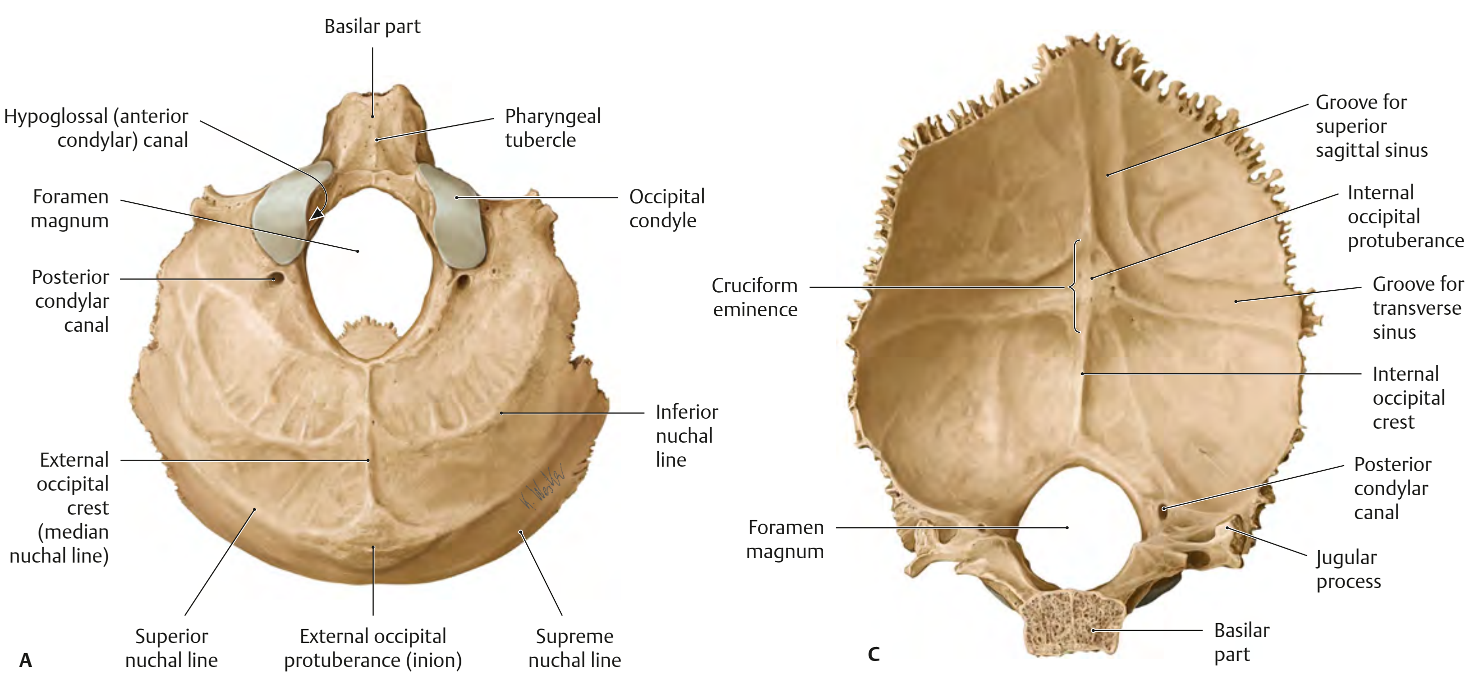


Fig. 2.31 **Isolated occipital bone**

A **Inferior view.** This view shows the basilar part of the occipital bone, whose anterior portion is fused to the sphenoid bone. The condylar canal terminates posterior to the occipital condyles, and the hypoglossal canal passes superior and opens anterior to the occipital condyles. The condylar canal is a venous channel that begins in the sigmoid sinus and ends in the occipital vein. The hypoglossal canal contains a venous plexus in addition to the hypoglossal nerve (CN XII). The pharyngeal tubercle gives attachment to the pharyngeal raphe, and the external occipital protuberance provides a palpable bony landmark on the occiput.

B **Left lateral view.** The extent of the occipital squama, which lies above the foramen magnum, is clearly appreciated in this view. The internal openings of the condylar canal and hypoglossal canal are visible along with the jugular process, which forms part of the wall of the jugular foramen (see p. 27).

C **Internal surface.** The grooves for the dural venous sinuses of the brain can be identified in this view. The cruciform eminence overlies the confluence of the superior sagittal sinus and transverse sinuses. The configuration of the eminence shows that in some cases the sagittal sinus drains predominantly into the left transverse sinus.

Fig. 2.32 **Position of the ethmoid bone in the interior skull base**
Superior view. The superior part of the ethmoid bone forms part of the anterior cranial fossa, and its inferior portions contribute structurally to the nasal cavities and orbit. The ethmoid bone is bordered by the frontal and sphenoid bones.

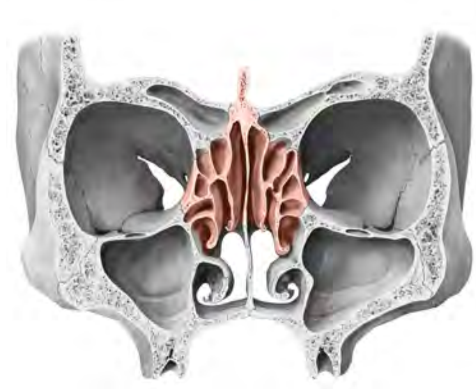


Fig. 2.33 **Position of the ethmoid bone in the facial skeleton**
Anterior view. The ethmoid bone is the central bone of the nose and paranasal sinuses. It also forms the medial wall of each orbit.

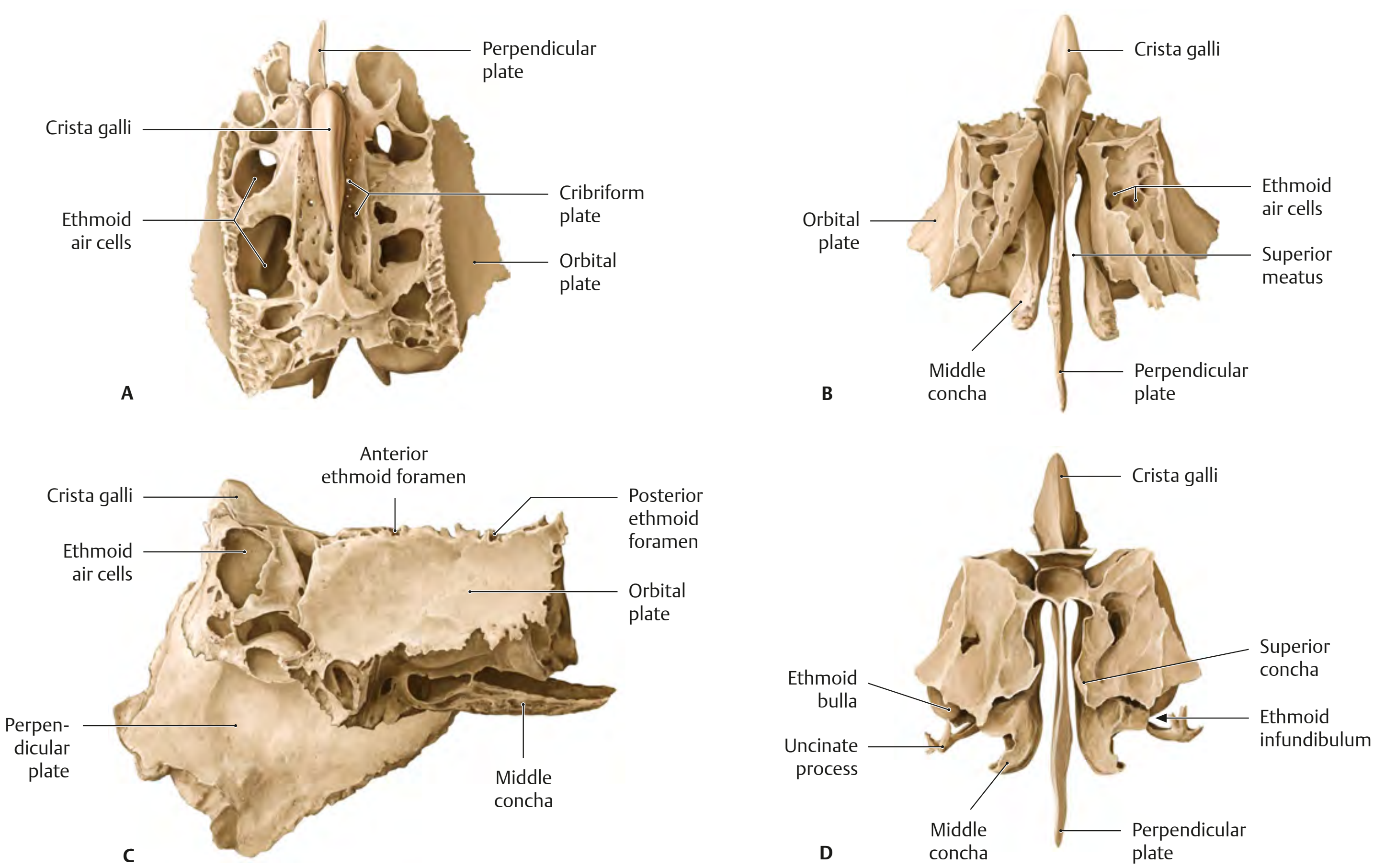


Fig. 2.34 **Isolated ethmoid bone**

A Superior view. This view demonstrates the crista galli, which gives attachment to the falx cerebri and the horizontally directed cribriform plate. The cribriform plate is perforated by foramina through which the olfactory fibers pass from the nasal cavity into the anterior cranial fossa (see **Fig. 7.22**, p. 192). With its numerous foramina, the cribriform plate is a mechanically weak structure that fractures easily in response to trauma. This type of fracture is manifested clinically by CSF leakage from the nose ("runny nose" in a patient with head injury).

B Anterior view. The anterior view displays the midline structure that separates the two nasal cavities: the perpendicular plate. Note also the middle nasal concha, which is part of the ethmoid bone (of the conchae, only the inferior nasal concha is a separate bone), and the ethmoid cells, which are clustered on both sides of the middle conchae.

C Left lateral view. Viewing the bone from the left side, we observe the perpendicular plate and the opened anterior ethmoid cells. The orbit is separated from the ethmoid cells by a thin sheet of bone called the orbital plate.

D Posterior view. This is the only view that displays the uncinate process, which is almost completely covered by the middle concha when in situ. It partially occludes the entrance to the maxillary sinus, the semilunar hiatus, and it is an important landmark during endoscopic surgery of the maxillary sinus. The narrow depression between the middle concha and uncinate process is called the ethmoid infundibulum. The frontal sinus, maxillary sinus, and anterior ethmoid air cells open into this "funnel." The superior concha is located at the posterior end of the ethmoid bone.

Zygomatic (Malar) Bone & Nasal Bone

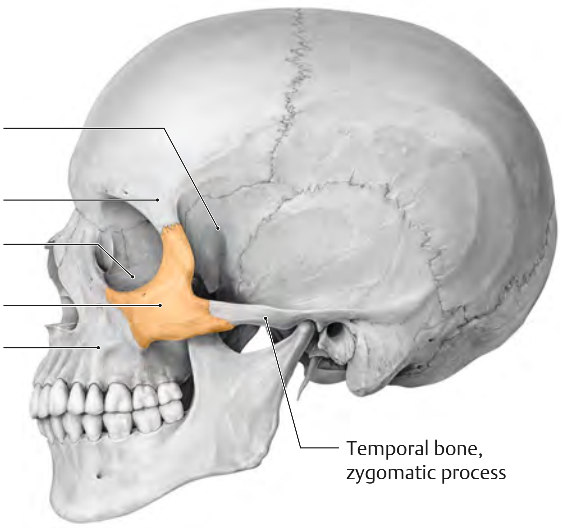
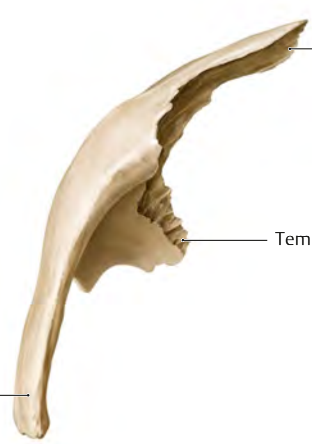


Fig. 2.35 **Zygomatic bone in the skull**
A Left lateral view. **B** Inferior view.

The zygomatic (malar) bone, or zygoma, is important in determining the width and morphology of the face and is a major buttress between the maxilla and the skull. In addition, it forms a significant portion of the floor and lateral walls of the orbit. The zygoma contains foramina that transmit the zygomaticofacial and zygomaticotemporal arteries and the corresponding nerves (from the maxillary nerve [CN V_2]) . Muscles that attach along the zygomatic arch include the masseter, zygomaticus major, and some fibers of the temporalis fascia. The Whitnall tubercle, which is the attachment site for the lateral canthal tendon, is located on the zygoma. This tendon is crucial in maintaining the contour of the eye.



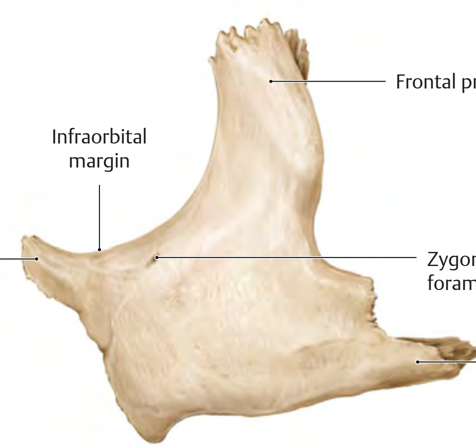


Fig. 2.36 **Isolated zygomatic bone**
A Inferior view. **B** Left lateral view.

The zygoma is a substantial bone but its prominent position on the face leaves it vulnerable to fracture following trauma. Trauma that transmits minimal force to the zygoma may cause a non-displaced fracture at the suture lines. Greater force, for example, following a motor vehicle accident, will result in displacement of the bone and involvement of the orbital rim and floor, the zygomaticofrontal suture, the zygomaticomaxillary buttress, and the zygomatic arch. Symptoms of zygoma fracture include pain, facial bruising and swelling, a flattened malar eminence, diplopia (double vision), trismus (lock jaw), and altered mastication (due to masseteric spasm or interference of the normal mechanism of the coronoid process by bony fragments), loss of sensation below the orbit (due to infraorbital nerve involvement), and ipsilateral epistaxis (nosebleed) (due to laceration of the mucosa of the maxillary sinus). Nondisplaced fractures do not require treatment. Displaced fractures commonly require open reduction and fixation, with reconstruction of the orbit. Displacement of the zygomatic arch may be reduced by the Gillies technique, in which an incision is made over the temporalis muscle and an instrument is slid under the arch and hooked and the arch is elevated into its normal position.

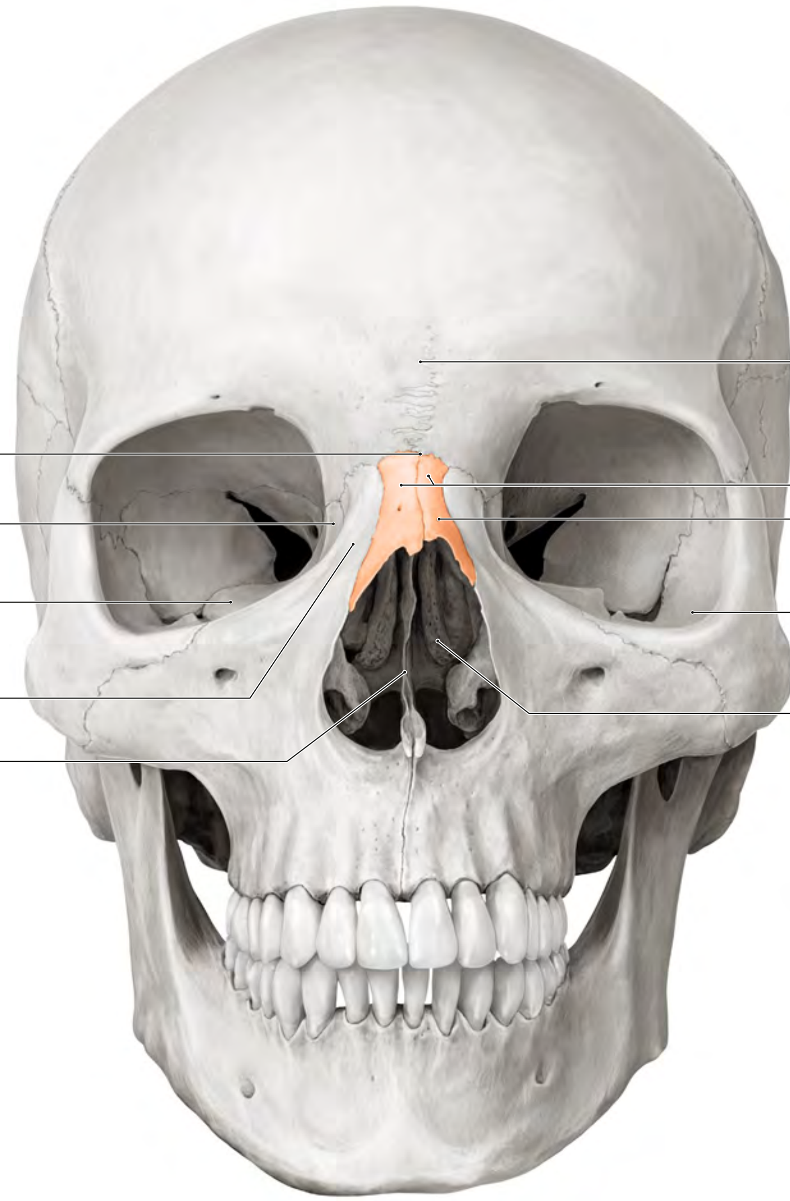


Fig. 2.37 **Nasal bone in the skull**
Anterior view.
Fractures of the nasal bones are common following facial trauma, for example, motor vehicle accidents, sports injuries, or fights. This is due both to the prominence of the nose and the fragility of the nasal bones. Symptoms of nasal fractures include pain, bruising, swelling, epistaxis (nosebleeds), and deformity of the nose. The patient may also experience difficulty breathing. Minor nasal fractures require no treatment while those that cause deformity will require manual realignment. More severe nasal fractures, for example, those involving the nasal septum or other facial bones will require surgery.

Maxilla & Hard Palate

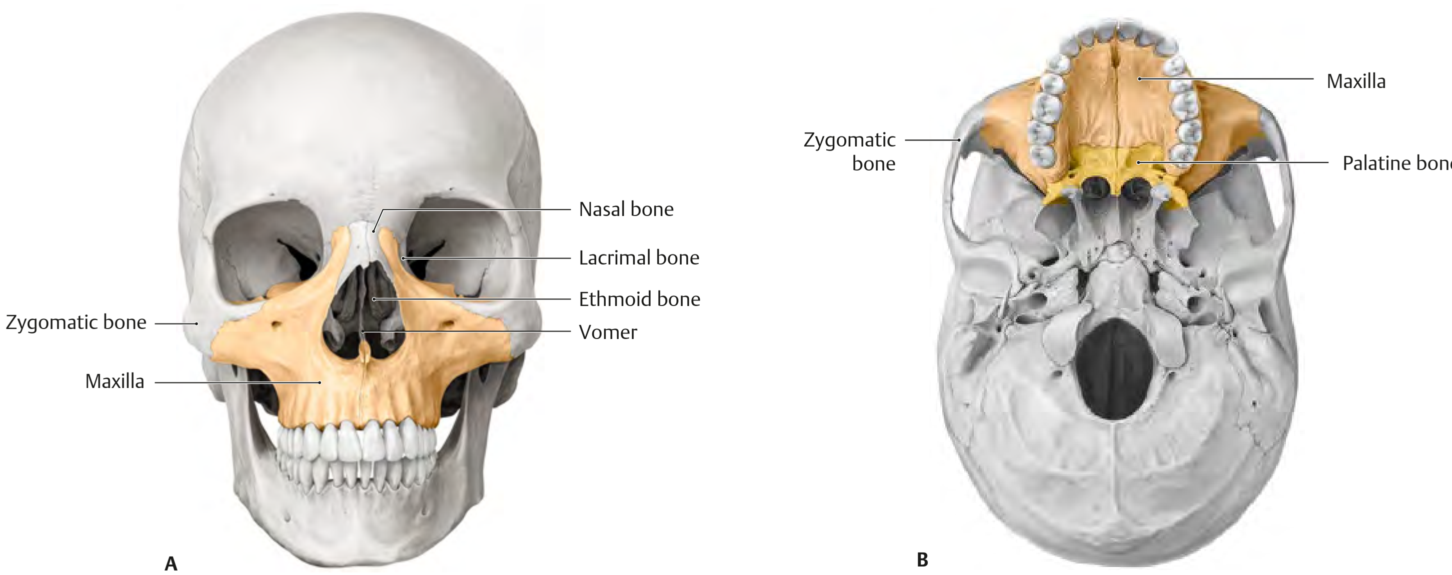
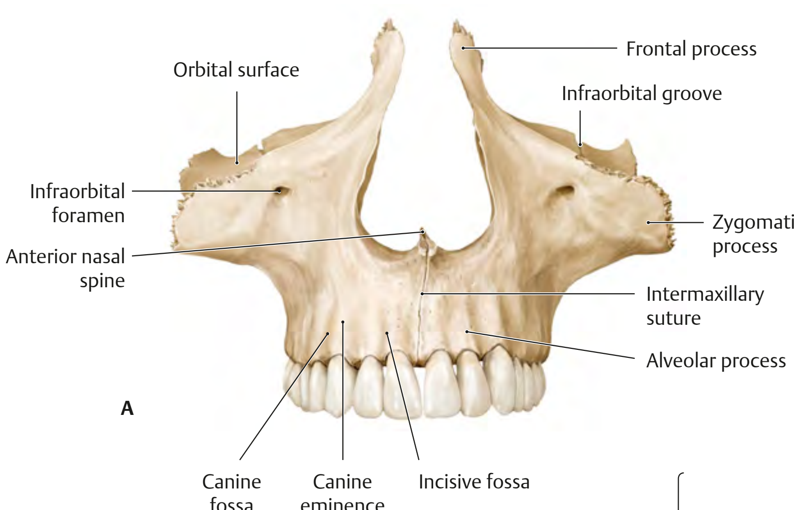


Fig. 2.38 **Maxilla and hard palate in skull**
A Anterior view. **B** Exterior of skull base, inferior view.



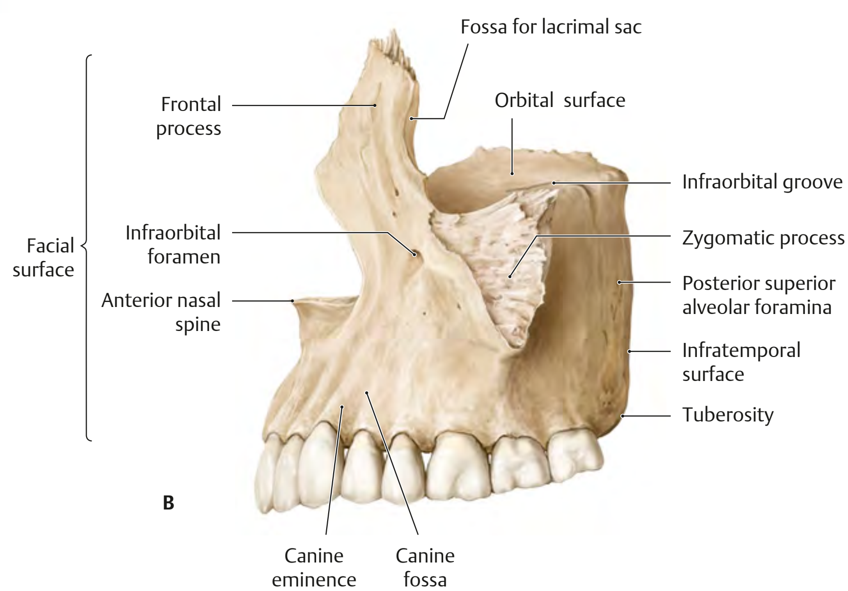


Fig. 2.39 **Isolated maxilla**
A Anterior view. **B** Left lateral view.

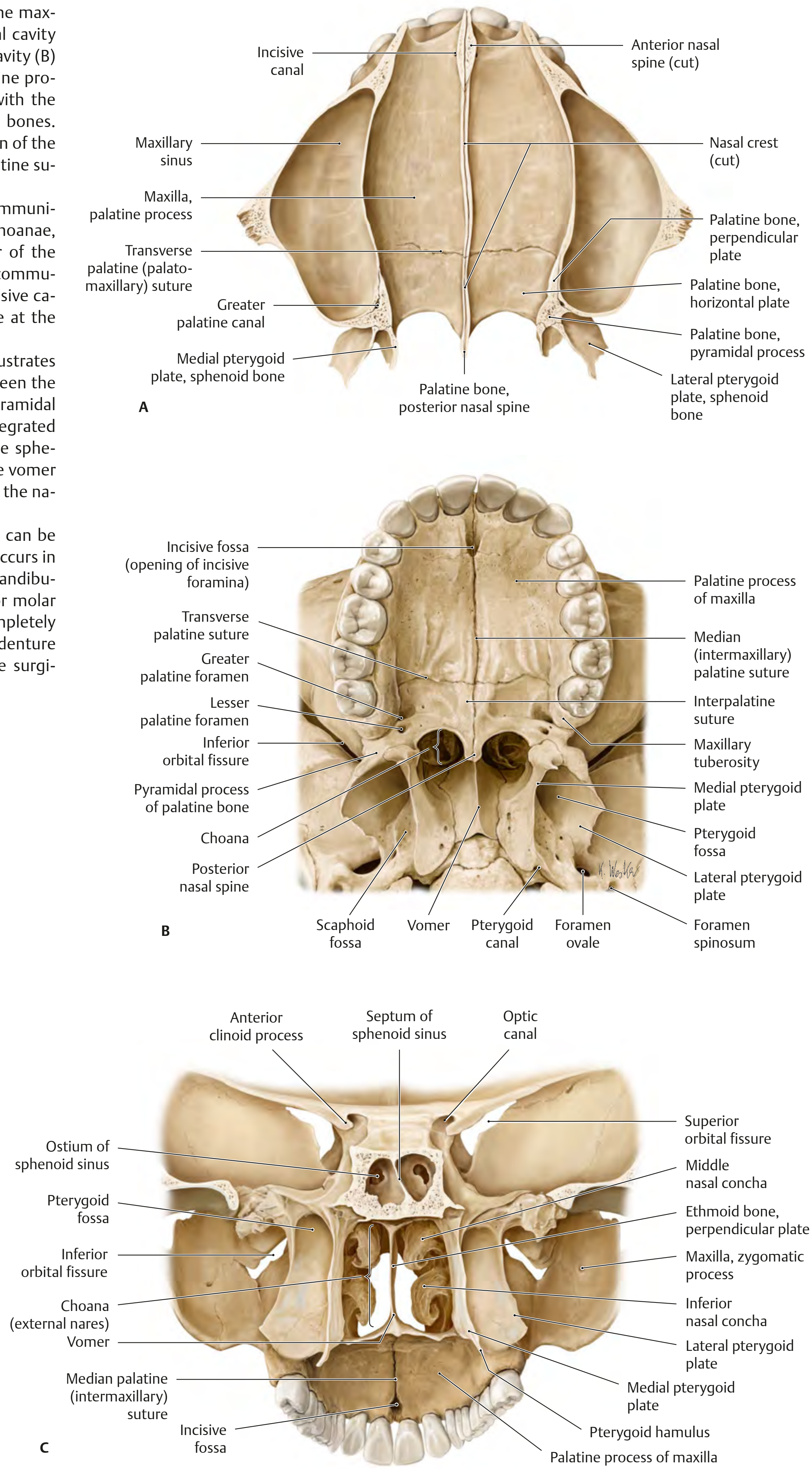
Fig. 2.40 **Bones of the hard palate**

A Superior view. The upper part of the maxilla is removed. The floor of the nasal cavity shown here and the roof of the oral cavity (B) are formed by the union of the palatine processes of the two maxillary bones with the horizontal plates of the two palatine bones. Cleft palate results from a failed fusion of the palatine processes at the median palatine suture (see p. 15).

B Inferior view. The nasal cavity communicates with the nasopharynx via the choanae, which begin at the posterior border of the hard palate. The two nasal cavities communicate with the oral cavity via the incisive canals (A), which combine and emerge at the incisive foramen.

C Oblique posterior view. This view illustrates the close anatomic relationship between the oral and nasal cavities. Note: The pyramidal process of the palatine bone is integrated into the lateral pterygoid plate of the sphenoid bone. The palatine margin of the vomer articulates with the hard palate along the nasal crest.

Tori are bony exostoses (lumps) that can be found on both jaws. Torus palatinus occurs in the center of the hard palate; torus mandibularis occurs in the lingual premolar or molar region of the mandible. Tori are completely benign but may cause problems for denture retention, in which case they can be surgically excised.



Mandible & Hyoid Bone

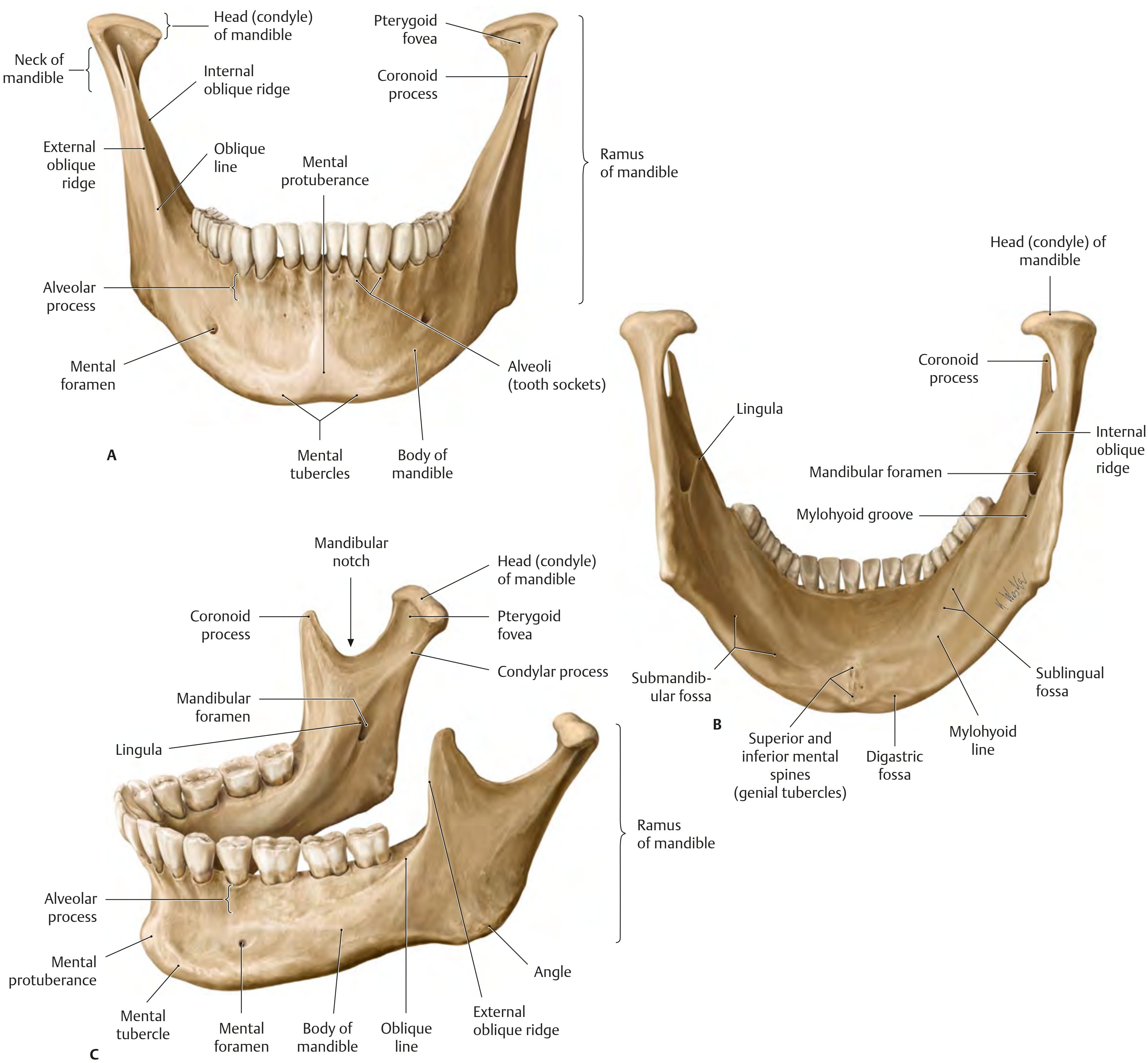


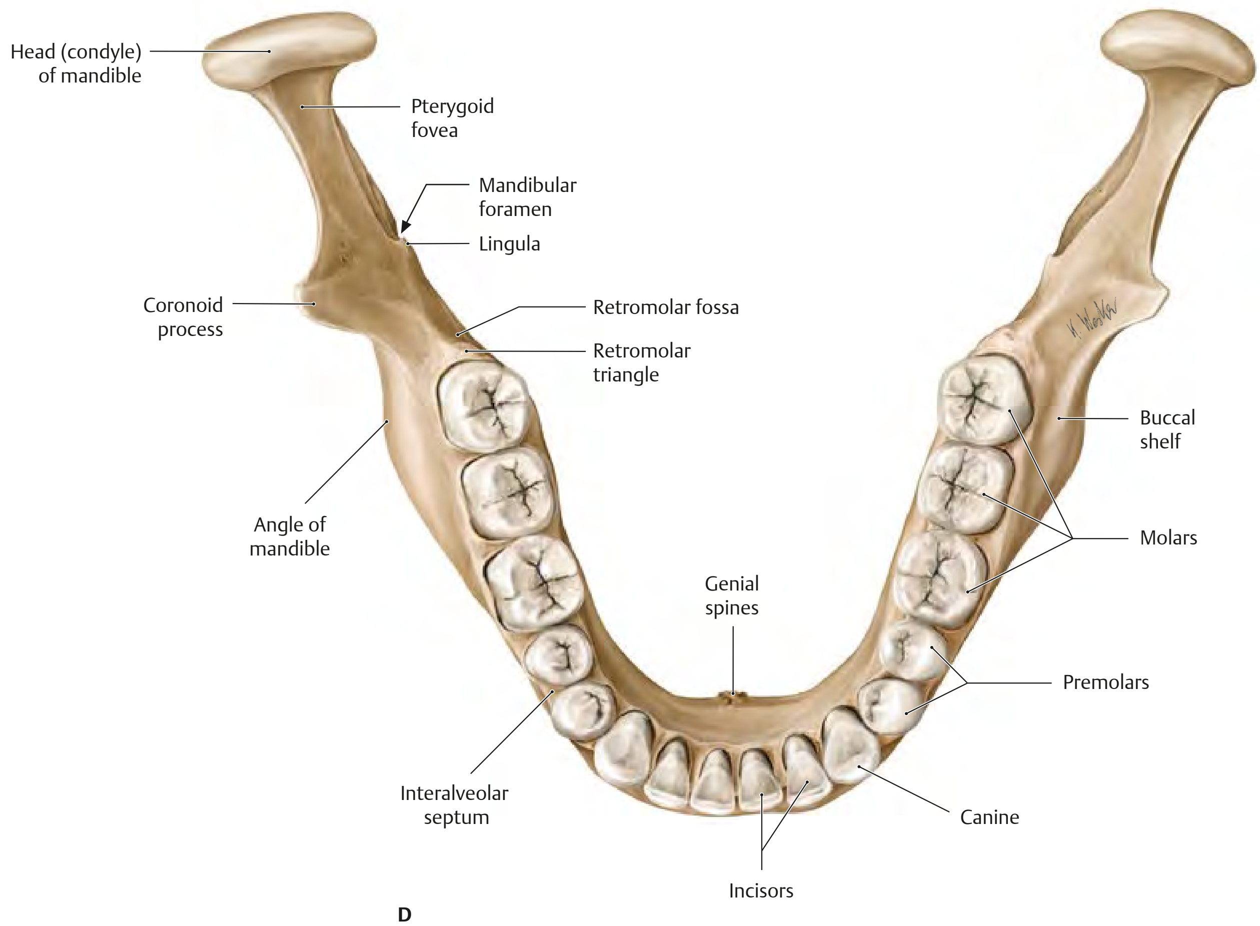
Fig. 2.41 **Mandible**

A **Anterior view.** The mandible is connected to the viscerocranium at the temporomandibular joint, whose convex surface is the head of the mandibular condyle. This "head of the mandible" is situated atop the vertical (ascending) ramus of the mandible, which joins with the body of the mandible at the mandibular angle. The teeth are set in the alveolar processes (alveolar part) along the upper border of the mandibular body. This part of the mandible is subject to typical age-related changes as a result of dental development (see **Fig. 2.43**). The mental branch of the trigeminal nerve exits through the mental foramen. The location of this foramen is important in clinical examinations, as the tenderness of the nerve to pressure can be tested at that location.

B **Posterior view.** The mandibular foramen is particularly well displayed in this view. It transmits the inferior alveolar nerve, which supplies sensory innervation to the mandibular teeth. Its terminal branch emerges from the mental foramen. The mandibular foramen and the mental foramen are interconnected by the mandibular canal.

C **Oblique left lateral view.** This view displays the coronoid process, the condylar process, and the mandibular notch between them. The coronoid process is a site for muscular attachments, and the condylar process bears the head of the mandible, which articulates with the articular disk in the mandibular (glenoid) fossa of the temporal bone. A depression on the medial side of the condylar process, the pterygoid fovea, gives attachment to portions of the lateral pterygoid muscle.

D **Superior view.** This view displays the retromolar fossa, retromolar triangle, and buccal shelf. The retromolar fossa is the insertion point for some fibers of the temporalis muscle. Lower dentures should be designed to avoid this area so that they are not dislodged during mastication. The buccal shelf (as a primary bearer of stress) and the retromolar triangle are areas that are utilized to support for lower dentures.



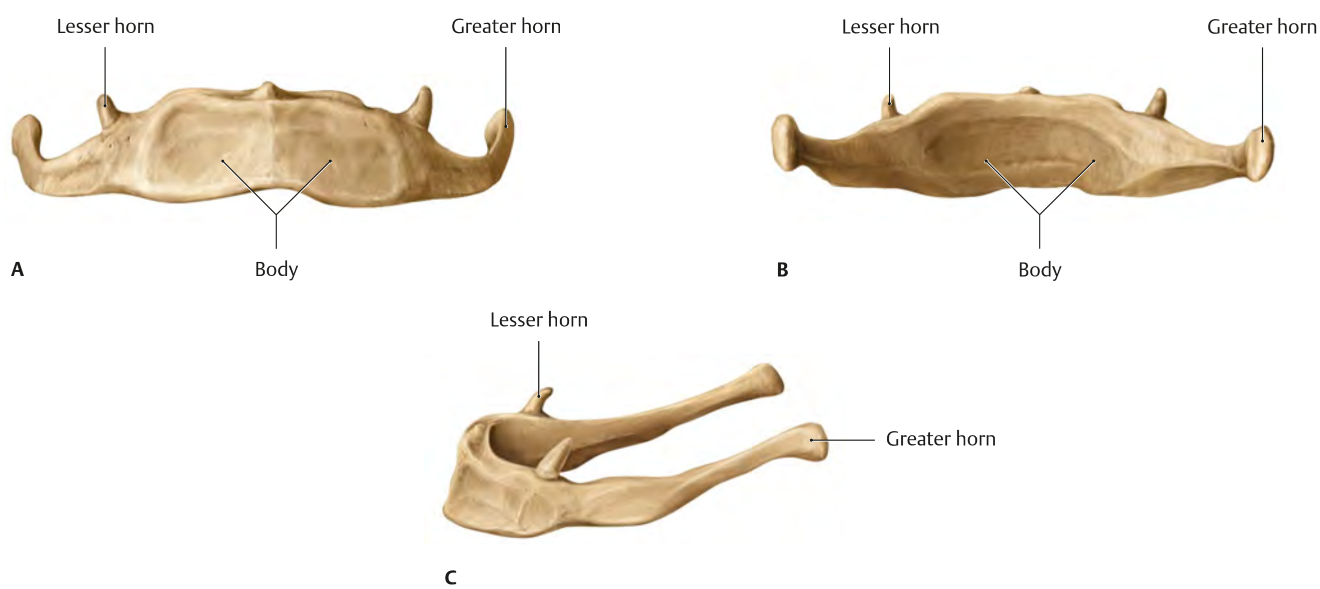


Fig. 2.42 **Hyoid bone**
A Anterior view. **B** Posterior view. **C** Oblique left lateral view. The hyoid bone is suspended by muscles and ligaments between the oral floor and the larynx. The greater horn and body of the hyoid bone are palpable in the neck. The physiological movement of the hyoid bone can be palpated during swallowing.

Mandible: Age-related Changes & Mandibular Fractures

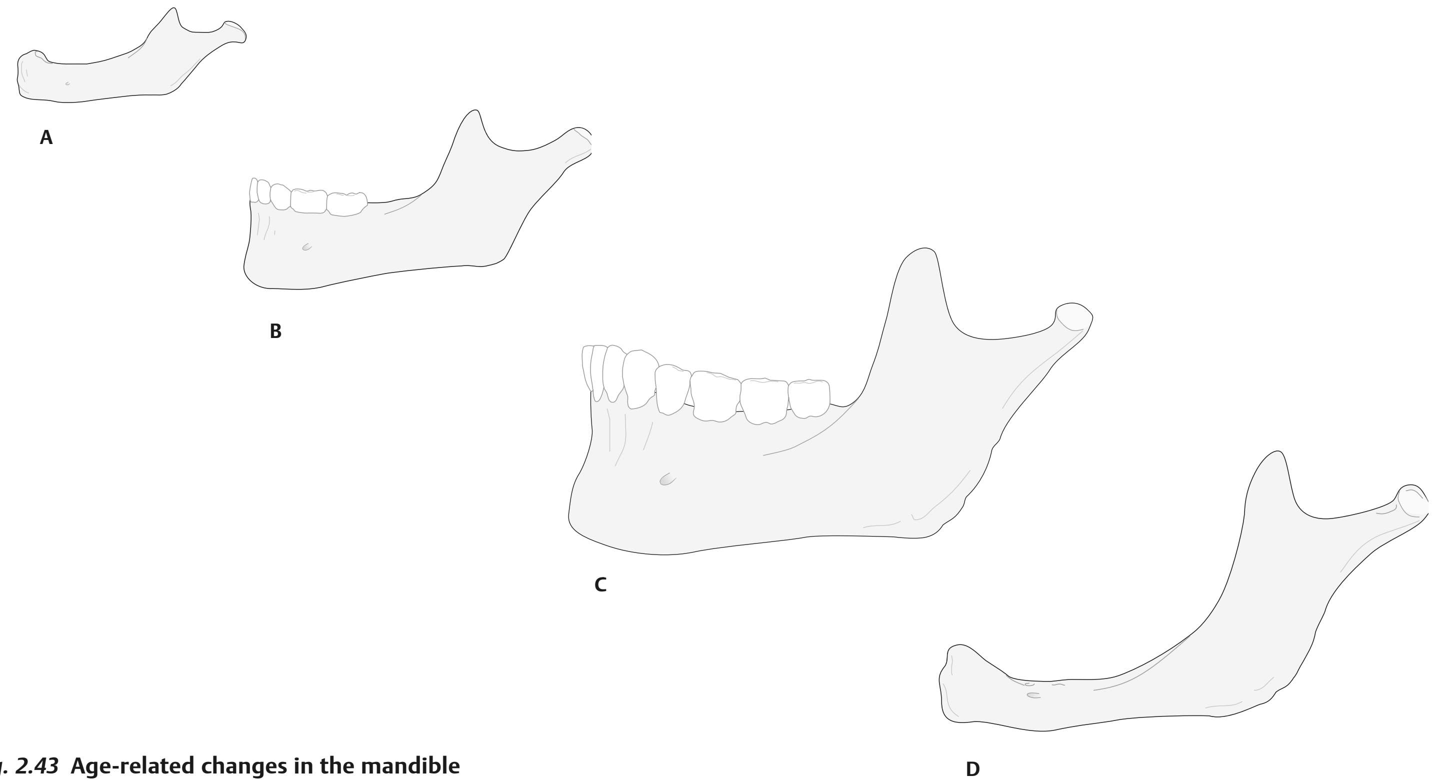
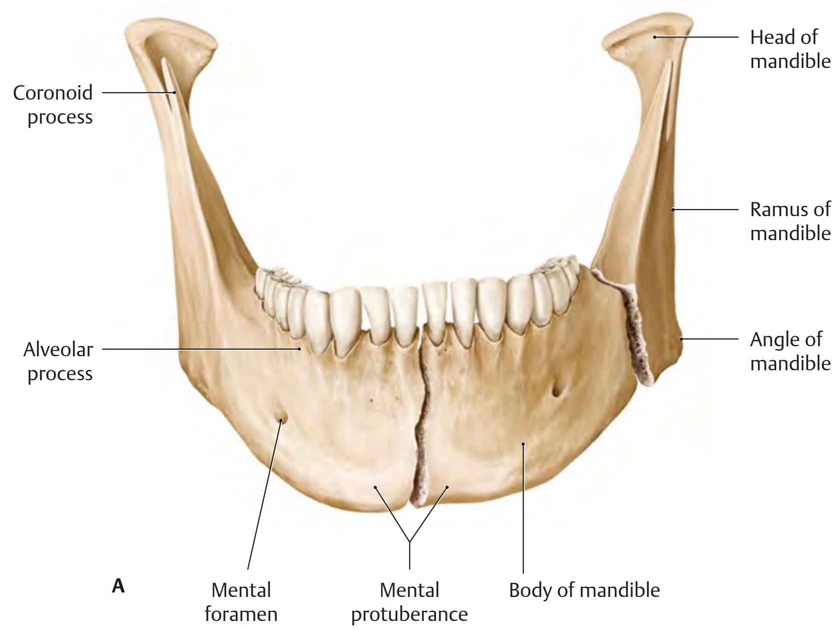


Fig. 2.43 **Age-related changes in the mandible**
The structure of the mandible is greatly influenced by the alveolar process the teeth. Because the angle of the mandible adapts to changes in the alveolar process, the angle between the body and ramus also varies with age-related changes in the dentition. The angle measures approximately 150 degrees at birth and approximately 120 to 130 degrees in adults, decreasing to 140 degrees in the edentulous mandible of old age.

A **At birth** the mandible is without teeth, and the alveolar process has not yet formed.
B **In children** the mandible bears the deciduous teeth. The alveolar process is still relatively poorly developed because the deciduous teeth are considerably smaller than the permanent teeth.
C **In adults** the mandible bears the permanent teeth, and the alveolar process is fully developed.
D **In old age**, the mandible can be edentulous (toothless), with accompanying resorption of the alveolar process.

Note: The resorption of the alveolar process with age leads to a change in the position of the mental foramen (which is normally located below the second premolar tooth, as in **C**). This change must be taken into account in surgery or dissections involving the mental nerve. The alveolar process is the portion of the maxilla and mandible that supports the roots of the teeth. It is composed of two parts, the alveolar bone proper and the supporting bone. The alveolar bone proper lines the tooth sockets (alveoli). Supporting bone consists of cortical plates of compact bone on the inner and outer surfaces of the maxilla and mandible and the intervening spongy bone between the cortical plates and alveolar bone proper. Alveolar bone is subject to resorption following tooth loss (a normal physiological process) and in certain disease states (e.g., abscess formation, cysts, osteoporosis). Basal bone is that portion of the maxilla and mandible deep to the alveolar bone. It is not subject to resorption.



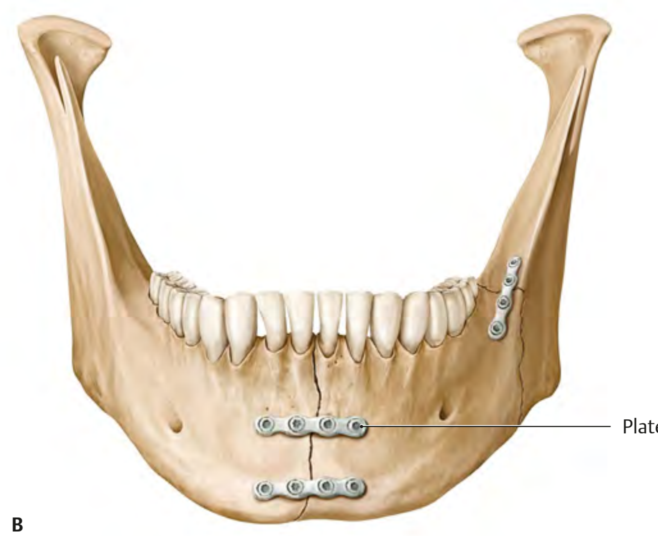


Fig. 2.44 **Mandibular fracture**

Anterior view. **A** Mandibular fracture. **B** Reduction and fixation of mandibular fracture. Mandibular fracture is a common injury, for example, following motor vehicle accidents, fights, or sporting accidents, due to the prominence of the mandible and its relative lack of support. Most fractures occur in the body (~30%), condyle (~25%), angle (~25%), and symphysis (~17%). To avoid misdiagnosis of the injury, the history should include not just information about the current injury but information about previous mandibular trauma or temporomandibular joint (TMJ) dysfunction. Determine the patency of the airway and the presence of other injuries (facial lacerations, swellings, or hematomas). Inspect intraoral tissuesa for bruising, which, if present, is suggestive of a fracture of the body or symphysis. Palpate the mandible from the symphysis to the angle, noting any swelling, tenderness, or step deformities. Next palpate the condyle through the external acoustic meatus; tenderness may indicate a fracture at this site. Note any deviation on opening the mouth. With condylar fractures, the mandible deviates toward the side of the fracture. Note also any obstruction to mouth opening, e.g., trismus (lock jaw due to spasm of the muscles of mastication) or impaction of the coronoid process. Now evaluate the occlusion. If the teeth do not occlude as normal, this is highly suggestive of mandibular fracture, although this can also occur following tooth subluxation (loosening) or TMJ injury. Note any areas of altered sensation (paresthesia, dysesthesia, or anesthesia). The latter is suggestive of a fracture distal to the mandibular foramen. Following this, the mandible should be grasped at either side of the suspected fracture and gently manipulated to assess mobility. Confirm the diagnosis via either radiography or CT scans. Treat with antibiotics to prevent infection, followed by reduction (to the patient's normal occlusion) and surgical fixation of the fracture. The fixation method depends on many factors including the type and site of fracture and may involve the use of bars, wires, or plates for intermaxillary fixation.

The double mandibular fracture shown here is treated in a two-step process. First, the fracture at the midline is fixated with metal plates followed by the angle fracture. Note that two plates provide much more stability than a single plate.