Head and Neck 7

38

Face, Scalp, and Skull

Clinical Case 38.1

Patient Mark M. This 16-year old motorcyclist was brought to the emergency room following a collision with a car. Among other injuries, he has a skull fracture of his left parietal bone, a depressed fracture of the left zygoma ("cheek bone"), a broken nose, and severe lacerations on his scalp and face on the left. You accompany your clinical tutor, a plastic surgery specialist, who is treating this case. You assist in the repositioning of the zygoma and nose and suturing of the skin. Three days later when you visit him, he has bilateral blackened eyes and is unable to completely close his left eye. Sensation to the skin over the scalp and face is found to be normal 10 days after the accident, but the orbicularis oculi muscle encircling the left eye remains weak and the lower eyelid droops.

Skin of the Face

The skin of the face is an important feature to consider when initially examining a patient. Since the face of a patient is usually exposed to the clinician on initial presentation, the expression, color, texture, and temperature can give important clinical information about the patient. The skin of the face is highly mobile, particularly around the orifices of the head (mouth, nose, ears, and eyes). Through the sphincter and dilative action of muscles that underlie the skin, these orifices can be opened or closed to varying degrees by the skin that approximates them.

In man, these facial muscles have evolved to have an additional function in both nonverbal and verbal communication. As a group, they are called the **muscles of facial expression**. They were derived from a common embryological origin, the mesoderm of the **2nd pharyngeal arch (hyoid arch)**, and they are all innervated by branches of the seventh cranial nerve, the **facial nerve**. As this mesoderm migrates over the face, the branches of the facial nerve are drawn superficially from the trunk of the nerve in the posterior aspect of the **parotid gland** to the deep surface of the individual facial muscles. The muscles are unique in that (1) they arise from bone but insert into the skin, (2) they are located in the subcutaneous tissue of the face, (3) they lack a demonstrable deep fascial covering (except for the buccinator muscle) and (4) the ratio of muscle fibers to axons in the facial nerve is markedly low. These features allow these muscles to move small areas of facial skin in an adept fashion and produce a number of "expressions" that connote emotion.

Figure 38.1 illustrates the individual muscles of facial expression found on the superficial and deeper layers of the face. Additional facial muscles, the **platysma** muscle of the superficial neck, the **occipitalis** muscle of the scalp, and the **auricular** muscles associated with the ear, are not shown in this illustration.

Muscles of the Rima Oris (Aperture of the Mouth)

The **orbicularis oris** lies within the lips and encircles the oral aperture. A number of smaller muscles interlace with the fibers of the orbicularis oris to make up the muscles of the oral aperture.

Five muscles converge on the angles of the mouth on each side. The **levator anguli oris** arises from the **maxilla** just below the infraorbital foramen; the **zygomaticus major,** or smiling muscle, arises more laterally from the body

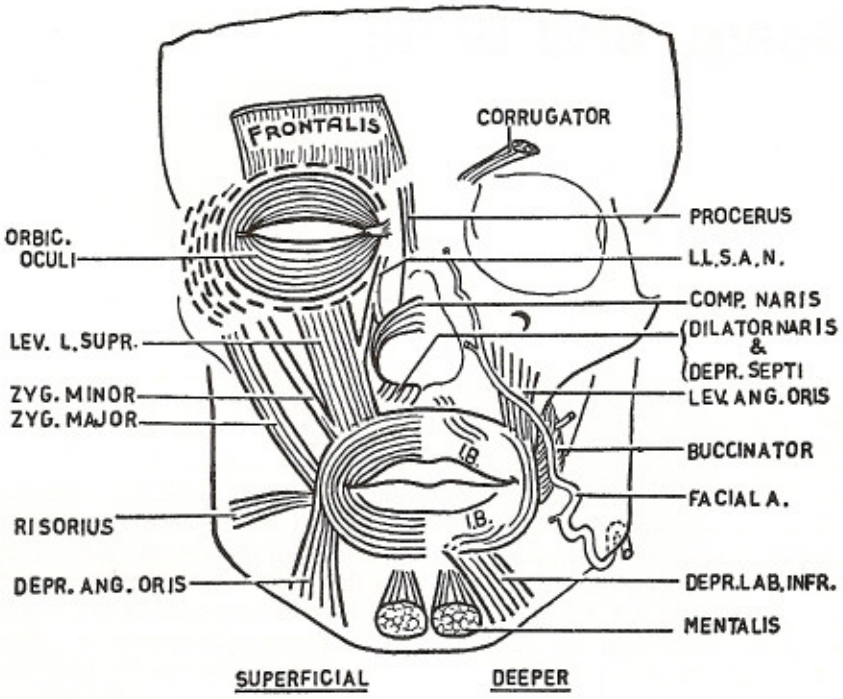

Figure 38.1. The muscles of the face. *LLSAN*, levator labii superioris alaeque nasi.

of the **zygoma** (the cheek bone); the **risorius**, or grinning muscle, arises from deep fascia of the face over the **mandible** and is joined by the fibers of the **platysma** that pass inferiorly over the mandible and into the skin of the neck and upper chest; the **depressor anguli oris** (triangularis) arises inferiorly from the oblique line of the mandible and inserts into the corner of the mouth.

Muscles of the Lips (L = *labium*, sing. *labia*, pl., *labii* = of the lip; *labiorum* = of the lips)

Inserting into the upper lip are three bands of muscles that arise from the medial and inferior borders of the orbital margin. They are the **levator labii superioris alaeque nasi, levator labii superioris**, and **zygomaticus minor** (L. *que* = and; *alae* = of the wing; *nasi* = of the nose).

Inserting into the lower lip is the **depressor labii inferioris** (quadratus), which arises from the oblique line of the mandible deep to the origin of the **depressor anguli oris.** The paired **mentales** originate from the mandible between the right and left depressor labii inferioris muscles. Each **mentalis** muscle inserts into the skin overlying the chin (L = *mentum*).

Muscles of the Cheek (L = *bucca*)

The **buccinator** is a flat muscle that exists between the mucous membrane lining of the oral cavity and the skin over the cheek. The buccinator possesses a definitive deep fascia that is continuous with the fascia of the **superior constrictor muscle** of the pharynx. Both the buccinator and the superior constrictor utilize the **pterygomandibular raphe**, the maxilla and the mandible for their sites of origin. While the superior constrictor passes posteriorly into the wall of the pharynx, the buccinator muscle passes anteriorly and laterally around the upper and lower molar teeth to fill the cheek and blend with the muscle fibers of the upper and lower lips. Its fibers contribute to the **orbicularis oris** musculature. The buccinator is pierced by the parotid duct and the long buccal branch of nerve V^3, which carries sensory innervation from the buccal mucosa.

ACTIONS

The buccinator aids in mastication by pressing the cheeks against the teeth and forcing food onto the **occlu-**

sal surfaces of the molar and premolar teeth. It prevents food from being forced into the **vestibule** of the mouth (*fig. 38.2*). The buccinator also aids in blowing and sucking actions.

NERVE SUPPLY

The **facial nerve** (cranial nerve VII) innervates *all* muscles of facial expression.

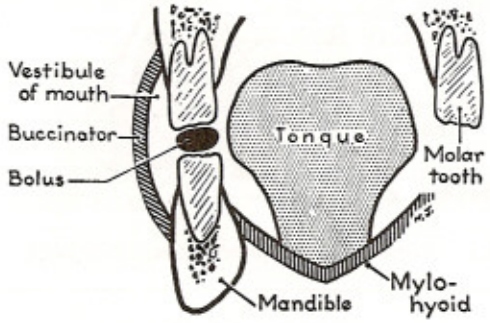

Figure 38.2. The buccinator and the tongue hold the food between the teeth.

Lips

If you run the tip of your tongue across the back of your lower or upper lip, you will feel the small nodular **labial glands**. Grasp the margin of either lip between your fingers and thumb to feel the pulsations of the **superior** and **inferior labial arteries** between the labial musculature and the glandular epithelium of the lip mucosa. Profuse bleeding of the lip can be controlled by compressing these labial arteries between the point of hemorrhage and the corner of the mouth.

The lip margins are red partly because the skin is translucent and partly because the vascular papillae or **thelia** are unusually long. Historically, the term "epithelium" was first used to describe the cells covering the thelia of the lip. The close approximation of blood vessels to epithelial surfaces allows one to qualitatively assess the oxygen content in the circulating blood. Bluish tones to the color of the lip or fingernail "beds" are a clinical sign of **cyanosis** (decreased O_2 content and increased CO_2 content in the hemoglobin).

External Nose (*figs. 38.3 and 38.4*)

The framework of the nose is made up of the paired nasal bones, hyaline cartilage, and fibroareolar tissue. The cartilages are **septal, lateral** and **alar.** The right and left **lateral cartilages** are not separate entities but are the wing-like expansions of the midline septal cartilage that projects posteriorly between the right and left nasal cavities. The septal cartilage is firmly attached to the maxilla and ethmoid bones as it assists in the partition of the two nasal cavities. The **alar** cartilages are loosely connected to the septal cartilage and underlie the skin of the anterior and medial aspect of the **nares** (nasal openings).

Auricle

The framework of the **auricle** is made of a single piece of elastic cartilage, except at its most dependent part, the **lobule,** which is fibrocartilage. The cartilage is continuous with the cartilage of the **external acoustic meatus** (L. *meatus* = canal). *Figures 38.5* and *38.6* provide the names of the elevations and depressions of the auricle.

Three extrinsic auricular muscles—**auricularis posterior, auricularis superior,** and **auricularis anterior**—act on the auricle to cause movement. These are all muscles of facial expression and they are innervated by branches of the facial nerve (Cranial Nerve VII).

Sensory supply to the skin of the auricle is important in neurological diagnosis. The upper half of the auricle is innervated by the **auriculotemporal branch** of the V^3. The lower half of the auricle is innervated by the **greater auricular nerve** and **lesser occipital nerve** (C2, 3) from the cervical plexus. The epithelium of the external auditory meatus and the opening onto the auricle, the **concha,** is innervated by the **vagus** nerve (Cranial Nerve X)

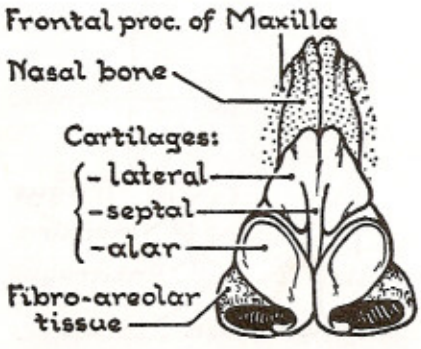

Figure 38.3. Framework of external nose.

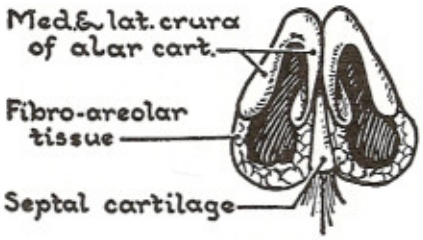

Figure 38.4. Framework of the external nose (from below).

for pain and perhaps the facial nerve (VII) for touch sensation.

Eyelids, Conjunctival Sac, and Tear Apparatus

DEFINITIONS

The upper and lower eyelids, or palpebrae, are united at the medial and lateral angles by the corresponding palpebral commissures. The eyeball is situated behind the palpebrae. The posterior five-sixths of the eyeball has an outermost coat of white, tough fibrous tissue called the **sclera.** The anterior one-sixth of the eyeball is transparent and called the **cornea.** Through the cornea you can see the varicolored **iris** with a central aperture, the **pupil.**

The potential space between the eyeball and the eyelids is the **conjunctival sac.** The membrane lining the sac is the **conjunctiva** (see *fig.* 41.3). At the upper and lower limits of the conjunctival sac, the conjunctiva reflects off of the eyeball onto the undersurface of the eyelid to form the **fornices.**

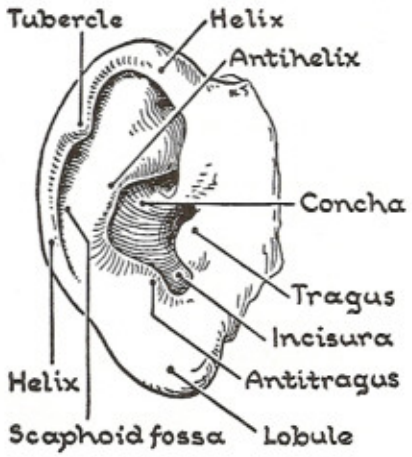

Figure 38.5. The auricle.

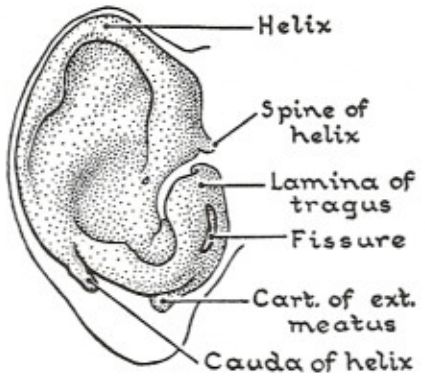

Figure 38.6. The cartilage of the auricle.

INSPECTION

Examine your eye in a mirror:

1. The margin of the lower eyelid crosses the lower limit of the cornea; the margin of the upper eyelid encroaches on the cornea (*fig. 38.7*).
2. The lateral five-sixths of the margins of the lids are flat and carry eyelashes or **cilia.** The medial one-sixth is devoid of hairs and rounded. This rounded area contains the **canaliculus** that drains away the tears.
3. At the medial angle, there is a triangular area, the **lacus lacrimalis,** bounded laterally by a free crescentic fold of conjunctiva, the **plica semilunaris.** In the lacus, there is a reddish area, the **caruncle.**

Gently pull down the lower lid to note:

4. A **papilla** on which the **punctum**, or entrance to the inferior lacrimal canaliculus, can easily be seen.

Evert the upper lid.

5. The hairs or cilia projecting from the lid margin are in 2 to 3 irregular rows.
6. Hairs imply the presence of sebaceous glands, and these open into each hair follicle. Sweat glands likewise open into or beside the hair follicles (*fig. 38.8*).
7. The **tarsal glands**, which waterproof the lids are embedded in the **tarsus**, a tough fibrous plate. The glands are visible as yellow streaks through the conjunctiva.

Figure 38.7. The margins of the eyelids.

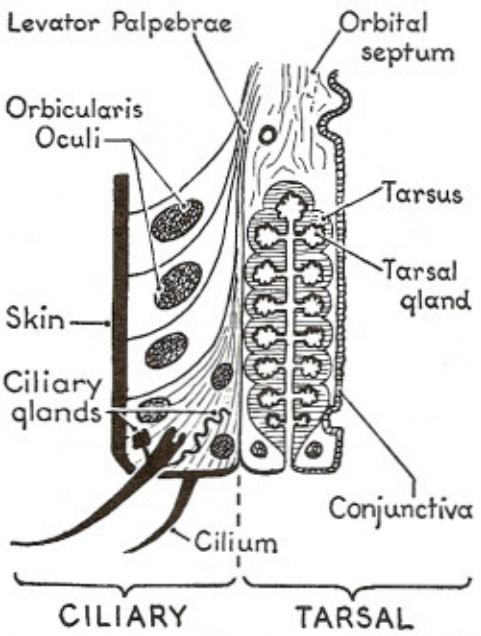

Figure 38.8. Section through the upper eyelid. (After Whitnall.)

An obstructed ciliary gland or inflamed hair follicle, a **stye** will project on the front of the eyelid while an obstructed tarsal gland projects internally onto the globe of the eye.

ORBITAL SEPTUM AND TARSI (*fig. 38.9*)

The eyelids develop as folds of skin that come together and adhere along their edges during the middle 3 months of intrauterine life. When they become free again the palpebral fissure is re-established.

While the eyelids are closed, the orbital septum, which runs from the orbital margin into the eyelids, forms a complete diaphragm for the orbital cavity. The medial aspect of the orbital septum passes behind the lacrimal sac to gain attachment to the lacrimal bone. This attachment creates a sharp bony crest, the **posterior lacrimal crest**. Operations on the lacrimal sac are therefore anterior to the orbital cavity proper.

Condensations and thickening of the septum takes place in the lids, forming the tarsal plates. These plates are anchored to the orbital margins by the **medial** and **lateral palpebral ligaments**. The medial palpebral ligament is a strong band of connective tissue that crosses in front of the lacrimal sac (*fig. 38.9*).

MUSCLES OF THE EYELIDS

The **orbicularis oculi** is the sphincter of the palpebral fissure. The fibers within the lids are the **palpebral portion**. The **orbital portion** makes a complete circle from the medial palpebral ligament, having no lateral attachment (*fig. 38.1*). It is responsible for the production of the "crow's feet" wrinkles around the eyes.

Closing the eyes against the resistance of an examiner's fingers is an excellent test for the functional status of the superior division of the **facial** nerve (VII).

The eye is opened by the **levator palpebrae superioris.** This is not a muscle of facial expression. It is a voluntary muscle of the orbit and is innervated principally by the **oculomotor** nerve (Cranial Nerve III). It also contains some smooth muscle fibers within its muscle mass that are innervated by sympathetic fibers. Damage to nerve III or the sympathetic fibers in the head and neck can produce a drooping of the eyelid. This clinical sign is called **ptosis**.

Muscles of the Forehead and Eyebrows (*fig. 38.1*)

The **frontalis** inserts into the eyelids as it descends over the frontal bone. It produces the transverse wrinkles on

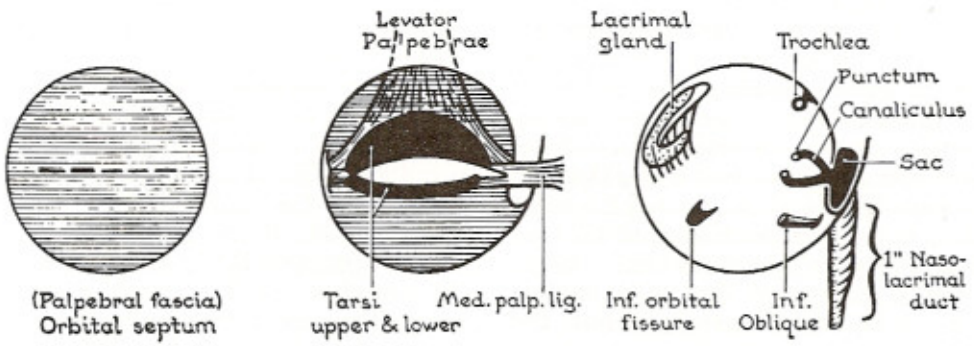

Figure 38.9. *A*, the orbital septum; *B*, the tarsi, ligaments, and levator palpebrae; *C*, features at the 4 corners of the orbital margin, and the tear apparatus (schematic).

the forehead that are produced when you raise your eyebrows.

The **corrugator supercilii** causes the short vertical wrinkles in front of the gabella above the root of the nose.

Lacrimal or Tear Apparatus (*fig. 38.9*)

The upper and lower **lacrimal canaliculi** are about 10 mm long and run near the free margin of the lid from the **lacrimal punctum** to the **lacrimal sac**. The lacrimal sac is the blind upper end of the **nasolacrimal duct** that lies just posterior to the medial palpebral ligament. The duct runs inferiorly in a bony canal of the lacrimal bone and empties into the nasal cavity in the inferior meatus. Thus, crying will produce tearing of the eyes as well as excessive nasal drainage.

Scalp

The scalp is a continuation of the skin above the face from the forehead to the posterior occipital area of the head. The scalp is regarded as a unit composed of (1) skin, (2) dense subcutaneous tissue, and (3) an epicranius muscle composed of **frontalis** and **occipitalis muscles** interconnected by an aponeurotic fascia. All three of these layers are firmly bound together and separated from the periosteum of the outer skull by a very loose areolar space. This space allows the upper three layers to move relatively freely over the underlying bone. It is, however, a "dangerous area" if it becomes infected. This space communicates with the meningeal venous sinuses around the brain via emissary veins that traverse the bone of the skull. Therefore, a scalp infection can spread through the bone via the veins and cause a **meningitis**. *Figure 38.10* shows how the **occipitalis** muscle is attached to the occipital bone posteriorly while the anteriorly placed **frontalis** inserts into the subcutaneous tissue and skin of the eyebrows. Blood in the loose areolar space of the scalp following a contusion can migrate anteriorly into the scant connective tissue area over the orbicularis oculi causing bilateral "black eyes." *Figure 38.10* shows how the five layers of the scalp can be easily remembered from the acronym SCALP (S = skin, C = subcutaneous tissue; A = aponeurosis; L = loose areolar tissue; and P = periosteum or pericranium).

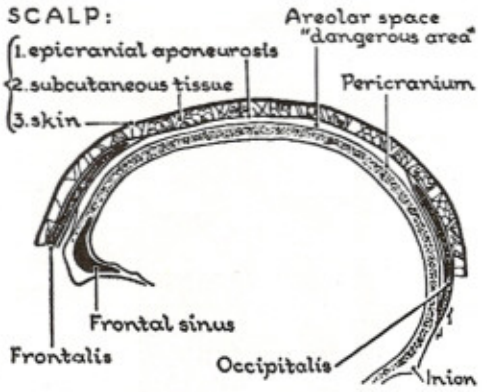

Figure 38.10. Sagittal section of skullcap and overlying tissues. Note the fibrous bands, fat, vessels, and nerves in the scalp.

Sensory Nerves of the Face and Scalp and Companion Arteries

The face develops from 3 rudiments, the **unpaired frontonasal process** and the bilateral **maxillary** and **mandibular** processes. Each process is supplied by one of the three divisions of the **trigeminal** nerve (Cranial Nerve V). The frontonasal process is innervated bilaterally by the ophthalmic divisions (V^1) while the maxillary divisions (V^2) and the mandibular divisions (V^3) are associated with the skin overlying their respective processes. Additional sensory innervation to the skin of the neck, parotid region, ear and angle of the mandible is provided by spinal nerves from the cervical plexus.

THE OPHTHALMIC DIVISION (V^1) (*fig. 38.11*)

Within the orbit the three major branches of V^1, (nasociliary, frontal and lacrimal nerves) give rise to the five cutaneous branches. Four of these cutaneous branches innervate the eyelid and one innervates the tip of the nose (*fig. 38.11*).

The **supra-orbital nerves** arise from the frontal nerve and exit the orbit through the supra-orbital foramen or notch. These branches innervate the scalp from the superciliary ridges to the vertex of the skull (occipitoparietal fissure). The supra-orbital nerve also innervates the central portion of the upper eyelid. The lateral aspect of the upper eyelid is innervated by the **lacrimal nerve** while the medial aspect of the eyelid is innervated by the **supratrochlear** and **infratrochlear** nerves. The supratrochlear nerve arises from the frontal nerve and passes above the superior oblique muscle to innervate the upper eyelid and forehead above the root of the nose. The infratro-

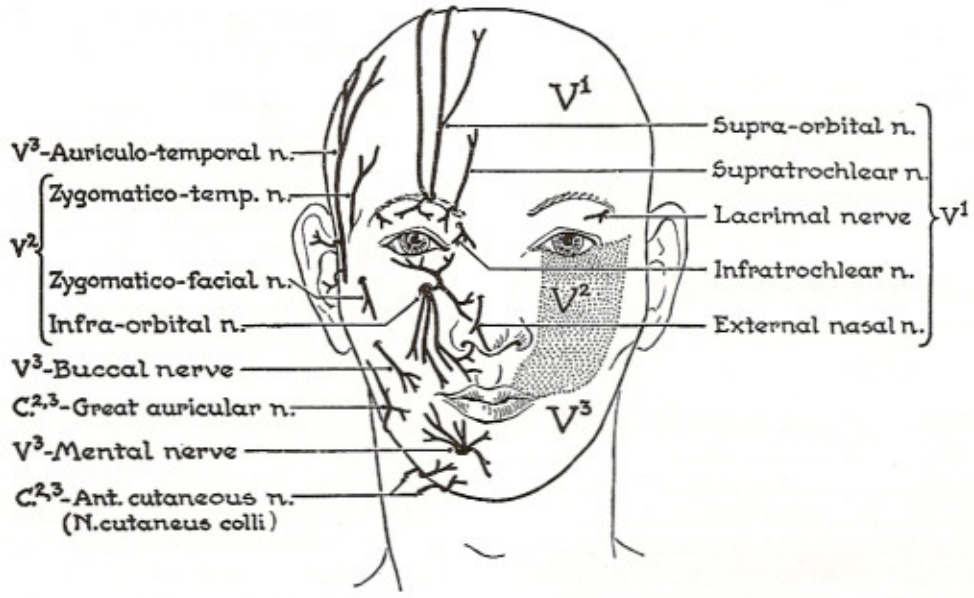

Figure 38.11. The sensory nerves of the face and front of the scalp.

chlear nerve is a branch of the nasociliary nerve within the orbit, and it emerges below the superior oblique muscle to innervate the skin of the upper eyelid and lateral aspect of the nose. The **external nasal branch** is also derived from the nasociliary nerve as the terminal component of the **anterior ethmoidal nerve**. It emerges at the lower border of the nasal bones and descends on the nasal cartilages to the tip of the nose.

Arteries

All of the cutaneous branches of V^1, are accompanied by a branch from the **ophthalmic artery** within the orbit. The arteries are named in accordance to the nerves they accompany.

Veins

The nerves and arteries are also accompanied by similarly named veins. These veins are important communications between the vascular system of the face and the dural sinuses of the brain. Since these veins lack valves, they may transmit infectious material from the face and scalp to intra-orbital and intracranial sites.

THE MAXILLARY NERVE V^2 (*fig. 38.11*)

Three branches of V^2 reach the cutaneous tissues of the face and scalp. The **infra-orbital branch** is the largest and emerges through the infra-orbital foramen. Its cutaneous branches innervate the lower eyelid and conjunctiva; the lateral aspect of the nose and the inside of the nostril; the upper lip, mucous membrane of the upper aspect of the cheek, the gingiva of the upper teeth and the anterior upper teeth as well.

Two smaller V^2 branches arise in the temporal region. They are the **zygomaticotemporal** and **zygomaticofacial nerves**. They innervate the skin over the **zygoma** (cheek bone).

All V^2 cutaneous nerves are accompanied by arteries and veins of the same name.

THE MANDIBULAR NERVE V^3 (*fig. 38.11*)

This nerve has several motor and sensory branches. Only 3 branches are cutaneous and discussed in this section.

The **mental nerve** emerges from the mental foramen of the mandible to innervate the skin of the chin, lower lips, and mucous membrane and gingiva adjacent to the lower lip.

The **buccal branch** of V^3 (the long buccal nerve) lies on the external aspect of the buccinator muscle. It runs from the depths of the cheek to the angle of the mouth. It supplies the skin overlying the buccinator and then pierces the muscle to supply the mucous membrane that lines the inner surface of the cheek and lower gums adjacent to the buccinator muscle.

The auriculotemporal branch emerges from the superior aspect of the parotid gland with the **superficial temporal** vessels and crosses the zygoma just in front of the ear. Its terminal distribution is to the auricle (superior 1/2) and the temporal region.

Arteries

While the superficial temporal artery accompanies the auriculotemporal nerve, the buccal and mental nerves are accompanied by buccal and mental arteries, respectively.

Motor Nerve to the Face (*fig. 38.12*)

The **facial** or **7th cranial nerve** (nerve VII) supplies the muscles of the face, scalp, and auricle. It also supplies the platysma, stylohyoid, posterior belly of the digastric, and the stapedius muscles in the head and neck.

Its terminal branches appear at the margins of the parotid gland and "fan out" to supply the facial muscles on their deep surfaces (*fig. 38.12*). Cervical branches cross the angle of the mandible into the neck to supply the platysma. These are vulnerable to damage during parotid, upper neck, and mandibular surgery. Paralysis of the platysma causes severe cosmetic effects when the facial tissue is allowed to "sag" under the jaw. Mandibular branches also extend over the jaw to supply the muscles of the lower lip.

Loops and communications are common, and the facial nerve is frequently described as having a superior (temporofacial) division and an inferior (cervicofacial) division. This relates to the clinical examination of the facial nerve when assessing the patient's ability to close the eyes and open the mouth. One is testing the integrity of the superior and inferior divisions of the nerve. It should also be noted that the terminal branches of VII are just deep to the muscles of facial expression in the subcutaneous tissues of the face. They are subject to trauma in facial lacerations, and denervation can have disastrous effects on appearance as well as protective reflex function for the eyes and mouth.

The **temporal branches** cross the zygomatic arch and supply all the muscles above that level (tested when the patient wrinkles the forehead and elevates the eyebrows). The **zygomatic branches** pass forward above the parotid duct to supply the muscles of the infra-orbital region (tested with temporal branches by having the patient close the eyes while the physician tries to open them with his fingers). The **buccal branch** of VII supplies the buccinator and other muscles of the cheek (ask the patient to "purse"

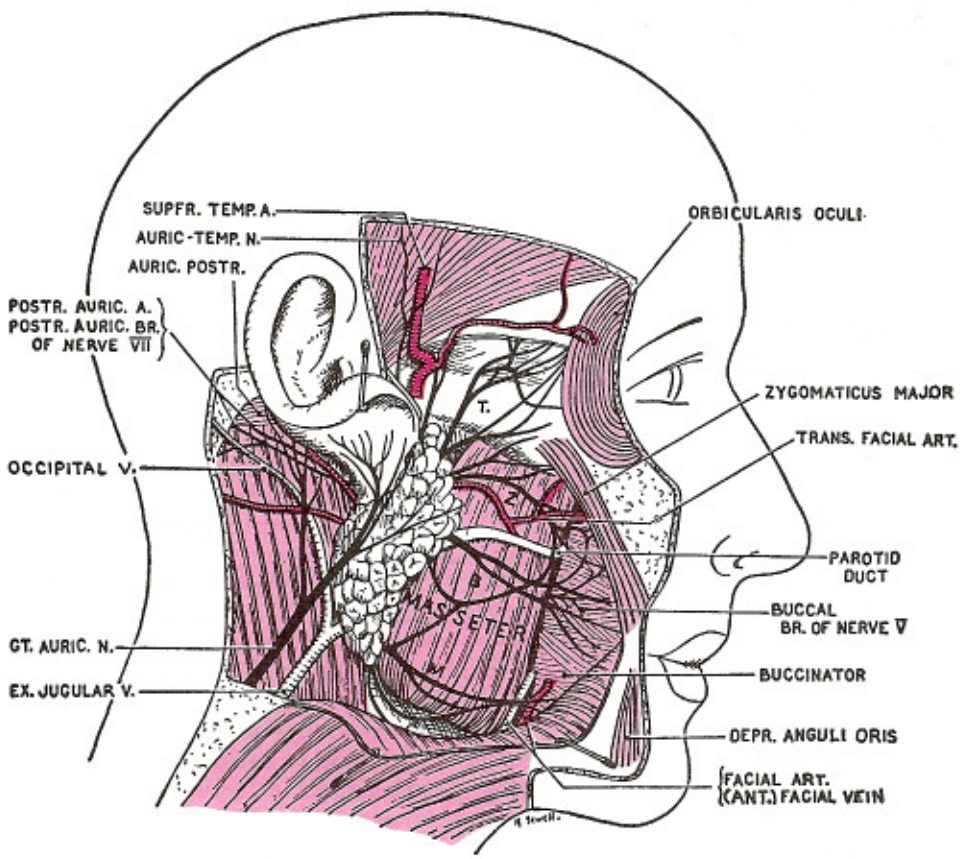

Figure 38.12. Dissection of the side of the face and facial nerve: *T*, temporal branches; *Z*, zygomatic branches; *B*, buccal branches; *M*, mandibular branch.

the lips and whistle to test these branches). The **mandibular branch** supplies the muscles of the lower lip and chin. The **auricular branches** arise behind the ear and innervate the muscles that move the auricle.

Blood Supply to the Face

The two principal arteries that supply the face are the **facial artery** and the **superficial temporal artery.** In addition, many branches of the ophthalmic and maxillary arteries that accompany cutaneous branches of the trigeminal nerve add to the rich vascular supply to the face.

FACIAL ARTERY (*figs. 38.1 and 38.12*)

The facial artery appears on the front of the face at the base of the jaw, immediately anterior to the insertion of the masseter muscle. The facial artery pulse can be taken as it courses over the mandible at this point. It rises on the face in a sinuous course to pass the corner of the mouth, the sides of the nose and terminates as the **angular artery** at the medial border of the eye. It lies deep to the muscles of facial expression and its sinuous nature allows for elongation when the central face is moved excessively. The **facial vein** is more posterior in its position and is not subjected to extensive elongation with movements of the mouth. The vein is therefore much straighter in its course from the medial aspect of the eye to the external jugular vein in the neck.

The important branches of the facial artery and vein are the **inferior** and **superior labial vessels**, a **lateral nasal vessel** that passes above the alar cartilage, and the **angular vessels** at the medial angle of the eye. The angular vessels allow for a communication between the facial artery of the face and the ophthalmic artery of the orbit. Venous connections of the facial vein with the cavernous sinus via the superior ophthalmic veins is an important clinical consideration for assessing routes of infection between the face and dural sinuses.

THE SUPERFICIAL TEMPORAL ARTERY (*fig. 38.12*)

The superficial temporal artery arises in the parotid gland as one of the two terminal branches of the **external carotid artery**. It emerges from the superior aspect of the parotid gland in front of the ear. It is accompanied in its course by the auriculotemporal branch of V^3. The artery divides into a frontal and parietal branch above the zygoma and is distributed to the scalp overlying the frontal and parietal bones, respectively. A **transverse facial artery** may arise from the superficial temporal artery within the parotid. The transverse facial artery courses between the parotid duct and the zygomatic arch to supply the facial tissue over the body of the zygoma. A **temporal pulse** is frequently taken by compressing the superficial temporal artery against the squamous part of the temporal bone above the ear.

A summary illustration of the cutaneous nerves and vessels of the scalp is shown in *Figure 38.13*.

Skull Related to Scalp and Face

SKULL VIEWED FROM ABOVE (*fig. 38.14*)

Three major skull bones are evident from a superior view. The **frontal bone** is usually a singular bone anteriorly. It was originally a right and left frontal bone separated by a suture (*fig. 38.15*). Fusion of the two frontal bones occurs in early childhood but a persisting **metopic** suture may occur in approximately 8% of adults. This retained frontal suture can be confused in radiology with a skull fracture. The frontal bone joins the **parietal** bones at the **coronal (frontoparietal) suture**. The two parietal bones are separated from each other in the midline by the **sagittal (interparietal) suture**. *Figure 38.14* depicts the sagittal suture in a newborn skull. It is shaped like an arrow (L. *sagitta*) with the arrow point (bregma) di-

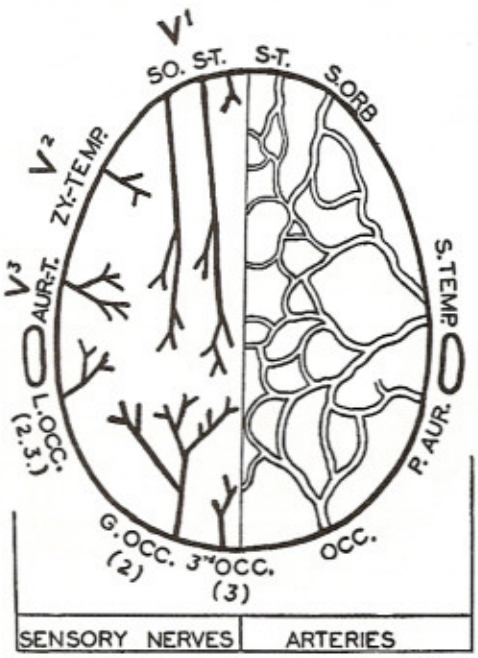

Figure 38.13. Sensory nerves and arteries of scalp.

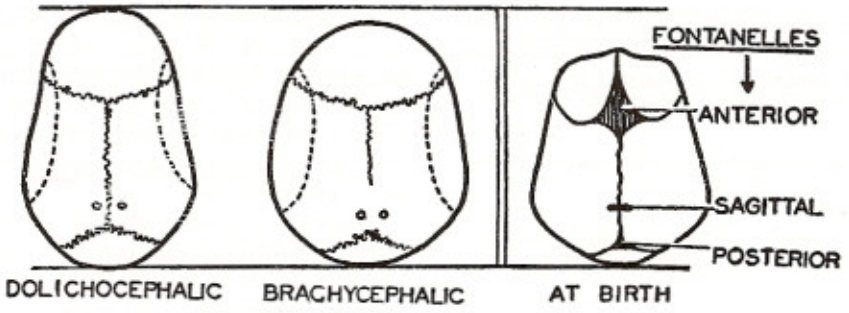

Figure 38.14. Skulls viewed from above. Fonticuli or fontanelles.

rected anteriorly. This can be palpated in the skull of the fetus during its descent in the birth canal. It is a valuable clinical sign to tell the physician the position of the head prior to delivery. A single **occipital** bone is seen posterior to the right and left parietal bones. The bones are separated by the **lambdoid (occipitoparietal) suture. Lambda** (the Greek letter λ) is the point where the lambdoid suture meets the sagittal suture. The parietal bones may show foramina for the parietal emissary veins just anterior to the lambdoid suture. These emissary veins traverse the parietal bones and communicate with the venous sinus within the dura of the cranium. They provide a means for blood (and infections) of the scalp to enter the meningeal venous sinuses.

The bones of the roof of the skull (calvaria) develop in membrane. Ossification of the frontal and parietal bones begins during the 2nd fetal month at their points of greatest fullness, the **frontal** and **parietal eminences**.

At birth, ossification has not reached the 4 corners of the parietal bones. These still membranous sites are called **fontanelles (fonticuli)**. The superior sagittal sinus is easily accessible by venapuncture through the scalp and dural membranes that lie above the brain at the junction of the coronal and sagittal sutures. This "soft spot" is the **anterior fontanelle** and may be used as a site for intravenous cannulas in hospitalized newborns. The anterior fontanelle is present as a soft membranous site on the child's head until 1–1½ years. It is 3–5 cm in length and shaped like a flat kite (*fig. 38.14*) at birth. It is normally obliterated before the end of the second year. The bregma marks its site in the completely ossified calvaria.

SKULL ON FRONTAL VIEW

The **zygomatic arches** lie at the widest parts of the face (*fig. 38.16*). Above them, the outline of the skull is rounded because it is formed by the **cranium** or brain case. The cranium bulges slightly to extend a few millimeters beyond the width of the zygomatic arches. Below the zygomatic arches, the skull is angular and is outlined by the prominent **mastoid processes** of the temporal bones and the posterior borders of the **ramus, angle,** and **base** or lower border of the mandible.

At birth (*fig. 38.15*), a median suture line bisects the skull vertically, separating the **parietal, frontal, nasal, maxillary** and **mandibular** bones of the opposite sides.

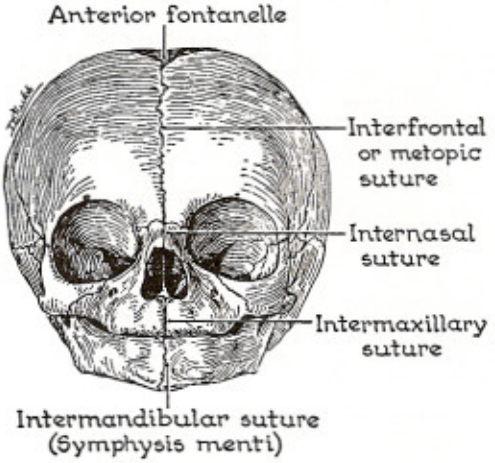

Figure 38.15. The skull at birth (front view).

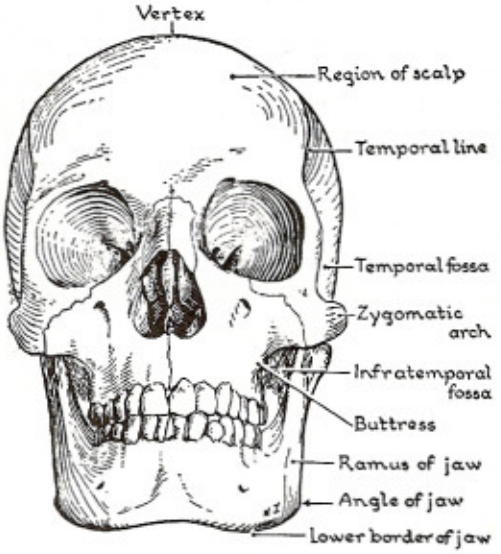

Figure 38.16. The skull (on front view).

During the 2nd year, the two halves of the mandible fuse at the **symphysis menti**.

The two halves of the frontal bone also fuse about the 2nd year. In some skulls, an interfrontal or **metopic** suture may persist into adulthood. The interparietal or sagittal suture usually persists but forms a **synostosis** (bony joint) between the two parietal bones. Connective tissue from the periosteum of the outer cranial bony table traverses the sagittal suture to join the connective tissue of the periosteum covering the inner cranial bony table.

The highest point of the skull is termed the **vertex** (*fig. 38.16*). This point marks the posterior extension of the V^1 dermatome on the scalp. In this vicinity, the branches of the supra-orbital nerve (V^1) overlap with the branches of the greater occipital nerve (C2) (*fig. 38.13*). The **nasion** is the point at the root of the nose where the frontal nasal suture crosses the median plane (*fig. 38.17*).

ENTRANCE TO THE ORBIT (ADITUS ORBITAE)

The frontal, maxillary, and zygomatic bones contribute to the formation of the orbital margin (*fig. 38.17*).

The fullness of the medial part of the supra-orbital margin of the frontal bone is the **superciliary arch**. This *is well marked in the male and is a feature used to sex-*type osteological remains in forensic pathology and anthropology. The elevation between the superciliary arches is the **glabella** because the overlying skin is glabrous or bald.

The **anterior nasal aperture (piriform aperture—L. = pear-shaped)** is formed by the nasal bones superiorly and the maxilla laterally and inferiorly. A median spine of bone, the **anterior nasal spine** projects forward from the maxilla and helps in supporting the septal cartilage of the nose.

Lateral to the orbit, the **zygomatic arch** (cheek bone) extends posteriorly toward the ear and fuses with the temporal bone above the **temporomandibular joint** where the mandible articulates with the base of the skull.

FORAMINA

Three osseous foramina are apparent from the frontal view of the skull. The **supra-orbital, infra-orbital** and **mental** foramina all open onto the face in a vertical line that passes sagitally between the premolar teeth. They penetrate the frontal bone, maxilla and mandible, and transmit sensory branches of V^1, V^2, and V^3, respectively. These foramina also transmit accompanying vascular elements with each nerve branch.

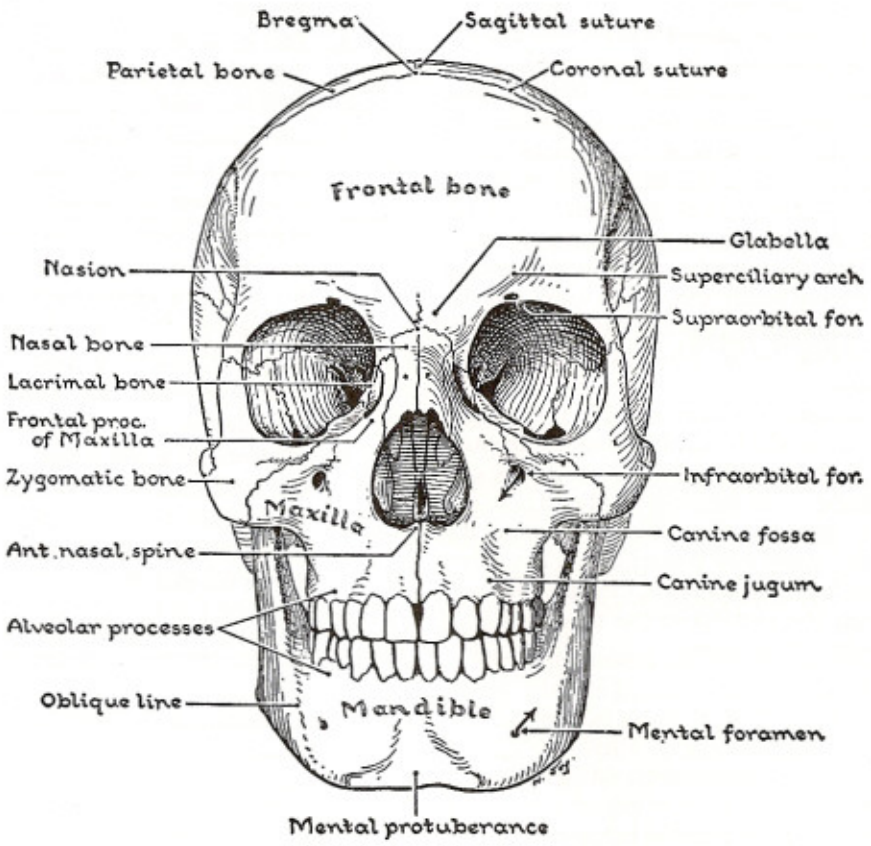

Figure 38.17. The skull on front view (norma frontalis of anthropologists).

Teeth

There are 32 teeth in the fully dentulous adult. Sixteen teeth are embedded in the bone of the maxilla, and 16 are embedded in the mandible. The teeth are further grouped into upper and lower quadrants of 8 teeth. Each quadrant from the midline to posterior aspect of the dental arch contains 2 **incisors,** 1 **cuspid,** 2 **premolars** and 3 **molars**. The incisors and cuspids are for cutting and tearing while the premolars and molars are for crushing food upon the **occlusal surfaces** of the premolar and molar teeth in the opposing arches.

Children under six years of age have a **deciduous** (L., to fall off) dentition of 20 teeth. Each quadrant contains 2 incisors, 1 cuspid and 2 **primary molars**. This first dentition erupts from the bone of the maxillary and mandibular arches between 6 months and 2 years of age with the incisors preceding the cuspids and primary molars in appearance. These teeth are then "shed" or exfoliated between 6 and 12 years of age to be replaced by the permanent adult dentition. The incisors and first permanent molars erupt around 6 years of age, the permanent cuspids, premolars and 2nd molars erupt by 12 years of age and the 3rd molars **(wisdom teeth)** usually erupt between 17 and 21 years of life to complete the adult dentition of 32 teeth.

The bony ridges supporting the teeth in the maxilla and mandible are termed the **alveolar processes**. They are produced by the eruption of the teeth and consist of mainly spongy bone with a thin cortical component superficially and around the roots of each tooth. When a permanent tooth is lost, the alveolar ridge in that area is also lost, causing a severe reduction in the height of the alveolar process. Persons who are edentulous (toothless) have a marked reduction in the bony content of their maxilla and mandible.

The mandible articulates with the skull at the **temporomandibular joint**. When the teeth of the mandible close on the upper teeth in the maxilla, a force of 100 kg can be exerted. The bone above the upper molar teeth is therefore strengthened to transmit these forces through the zygoma and the lateral margin of the orbit into the dome of the cranium. Stress from the action of the incisive teeth are dispersed through the maxilla to the medial orbital margin and into the frontal process.

The "point of the jaw" is formed by a triangular area of raised bone, the **mental protuberance**. From its lateral angle, an **oblique line** passes posteriorly and superiorly over the **body of the mandible** to reach the **ramus of the mandible**. The body and the ramus are oriented to form an obtuse **angle of the mandible**. The body is oriented in the horizontal plane, while the ramus is oriented in a vertical plane.

Clinical Mini-Problems

1. **The buccinator has two nerves entering its external surface. They are the buccal branch of the facial (VII) and the long buccal nerve of V^3. Only one of these is motor. (a) Damage to which nerve (VII or V^3) causes paralysis of the buccinator? (b) Which branchial arch mesoderm gives rise to the buccinator muscle?**
2. **Examination of the external ear (auricle) can reveal the integrity of the brainstem and spinal cord from the level of the C2 vertebra to the midpons region of the brainstem within the posterior cranial fossa. Which 3 major nerves innervate the skin covering the auricle?**
3. **The muscles of the upper and lower eyelid have different nerve supplies. Which eyelid would be affected most in a facial nerve (VII) palsy?**
4. **On a Sunday afternoon, a young boy had a severe fall from his bicycle that resulted in a scalp laceration over the parietal bone. When he went to school on Tuesday morning, he had two severely blackened eyes. Suspecting that he had been abused, his teacher sent him to the school nurse who called his doctor. Having seen the child earlier, he explained that a scalp injury could produce the blackened eye signs. How would you explain this accumulation of blood in the orbital region?**
5. **Why would a physician put a local anesthetic into the subcutaneous tissue above the right supra-orbital notch if he wishes to suture a scalp laceration over the right parietal bone just anterior to the vertex of the skull?**

(Answers to these questions can be found on p. 587.)

39

Interior of Cranium

Clinical Case 39.1

Patient Andrew W. This young driver suffered a closed head injury following a collision with another car. He arrives in the emergency room in a semicomatose state. An x-ray reveals a skull fracture in the temporal area and an underlying epidural hematoma. The neurosurgeon, whom you assist, removes a core of cortical bone from the calvaria overlying the hematoma and flushes the extravasated blood from the epidural site. He also ligates a lacerated middle meningeal artery to prevent further bleeding. The next day, the patient is recovering normal consciousness and is expected to be discharged in a few days.

Skull Cap or Calvaria

The **calvaria** is made up of superior portions of the frontal, parietal, and occipital bones. It forms the vault or "skullcap" of the cranium.

Structure. The bones of the roof of the cranial vault consist of an **outer** and **inner plate** or **lamina** of compact bone with an intervening layer of spongy bone called the **diploë**. The cortical bony plates give strength to the cranial vault, while the diploë serves to lighten the weight of the cranium and provide a site for blood marrow production. Blows to the head may cause fractures of either or both cortical plates. When the inner is fractured, it has a tendency to shatter and can lacerate the underlying vascular elements within the dura.

The bone in the cranial vault of a newborn consists of a single compact layer. This bone is eventually invaded by veins, which branch and rebranch, and unite with adjacent veins.

Bone marrow cells are "seeded" into the spaces around the venous channels to form the diploë. The four principal diploic veins are illustrated in *Figure 39.1*. These venous channels drain mostly into the dural venous channels within the cranial cavity. They lack valves and may communicate with veins that drain the scalp overlying the cranial vault. Scalp infections may spread via these veins to the diploë or the meninges of the brain that contain the intracranial venous sinuses.

The spongy bone of the diploic layer may also be "invaded" by mucous membranes from the nasal cavity and mastoid antrum to form **air sinuses**. The air sinuses are lined by respiratory epithelium and drain their secretions into the nasal cavity. They should not be confused with the venous sinuses of the cranium.

Diploë does not form in the cranial bones that are covered with thick, fleshy muscle, i.e., the squamous portion of the temporal bone and the nuchal part (base) of the occipital bone. The bone in these areas remains thin, translucent and cortical.

Meninges

Beneath the calvaria, three meningeal or membranous coverings envelop the brain and give it further protection within the cranial cavity. The three meninges—**the dura mater, arachnoid mater** and **pia mater**—are illustrated with their relationship to the calvaria and the brain in *Figure 39.2*.

The **dura mater (or dura)** consists of two closely adherent fibrous layers. The **outer layer of dura** is the periosteum for the inner plate of the calvaria and the cortical bone of the entire cranial cavity. This endosteal layer is also called the **endocranium**, and like other periostea, has a rich vascular supply. **Anterior, middle,** and **posterior meningeal arteries** supply the endocranium in the cranial cavity.

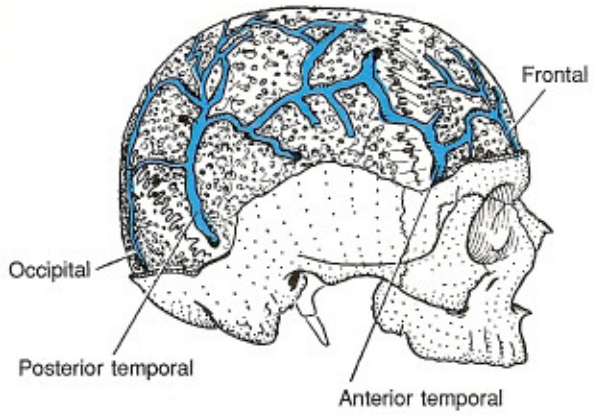

Figure 39.1. The 4 diploic veins.

The **inner layer of the dura** is a smooth serous membrane that opposes the arachnoid mater. It is also termed the **meningeal layer of dura**. While the periosteal dura is consistently attached to the bone of the cranial cavity, the meningeal dura maintains a close association to the underlying brain. When it approaches the **longitudinal fissure** of the brain, which separates the right and left cerebral hemispheres in the sagittal plane, the meningeal layer of the dura separates from the periosteal dura and approximates the meningeal dura from the opposite side to form the **falx cerebri** (*fig. 39.2*). The meningeal dura also forms partitions between the occipital lobes of the brain and the cerebellum to produce the **tentorium cerebelli** (*figs. 39.3 and 39.4*). These two major dural partitions subdivide the cranial cavity into compartments that support the brain and prevent gross shifting of the brain within the cranium.

When the periosteal dura and the meningeal dura become separated during the formation of these dural partitions, they create a cavity within the dura (*fig. 39.2*). These cavities become lined by endothelium and form the **venous sinuses** of the cranial cavity (*fig. 39.3*). Venous blood draining the brain, the meninges, the diploë and even some of the scalp will collect within these meningeal venous sinuses and eventually drain into the **internal jugular vein** at the base of the posterior cranial fossa (*fig. 39.3*).

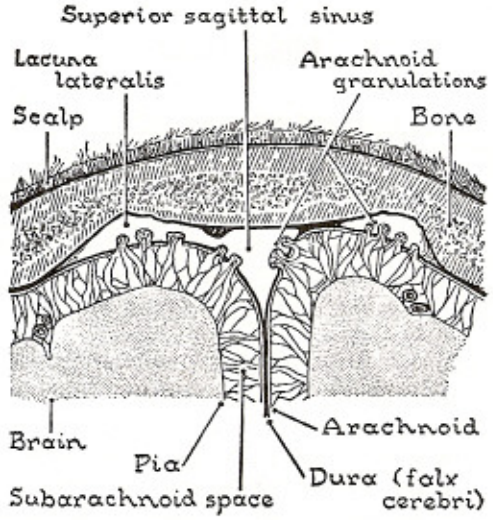

Figure 39.2. The arachnoid granulations return the cerebrospinal fluid.

Two **potential spaces** are related to the dural lining of the cranium. The **epidural space** is between the periosteal dura and the bone of the cranial cavity. If the meningeal arteries are damaged and bleed into this space, an **epidural hematoma** will occur between the bone and dura. Since this is arterial and a high pressure system, a considerable amount of blood may accumulate in this space following a head injury. The **subdural space** exists between the meningeal dura and arachnoid. Bleeding by the cerebral veins that traverse this space as they enter the **superior sagittal sinus** may expand this potential space. This is a low-pressure system on the venous side and much smaller amounts of blood would be present in this type of intracranial "bleed." Both situations, however, pose major problems for the patient and require different treatments.

The **arachnoid mater (or arachnoid)** is a delicate membrane that exists between the dura and the pia mater on the surface of the brain. The arachnoid is actually a split layer with intervening trabeculae of arachnoid tissue connecting the layers associated with the overlying dura and the underlying pia. This "cobwebbed-like" membrane is the basis for naming this layer arachnoid **(L. = spider)**.

Two essential features of the arachnoid are depicted in *Figure 39.2*. First, the **subarachnoid space** is between the arachnoid and pia. This space contains the **cerebrospinal fluid** that surrounds the entire brain and virtually "floats" the brain in the cranial cavity. The cerebrospinal fluid serves to protect as well as nourish the brain. Also within the subarachnoid space are the major cerebral arteries and veins that supply and drain the blood supply to the brain. Bleeding into the subarachnoid space is a common sign following a **cerebrovascular hemorrhage** or **"stroke."**

The second essential feature is that the subarachnoid space is extended into the **superior sagittal sinus** by the **arachnoid granulations** (*fig. 39.2*). These arachnoid granulations allow the cerebrospinal fluid to be drained into the venous system. Cerebrospinal fluid is continually produced within the brain by the arterial **choroid plexuses** and must therefore be removed by the venous system to maintain a balance in the volume of cerebrospinal fluid that exists in the subarachnoid space. The arachnoid granulations may be extensive and cause the periosteal dura to cavitate the inner surface of the parietal bones. They may be calcified to some degree in older adults and become visible in radiographs of the head.

The **pia mater (or pia)** is closely adherent to the outer surface of the brain. It follows all of the contours of the brain and actually adheres to the cerebral vessels as they

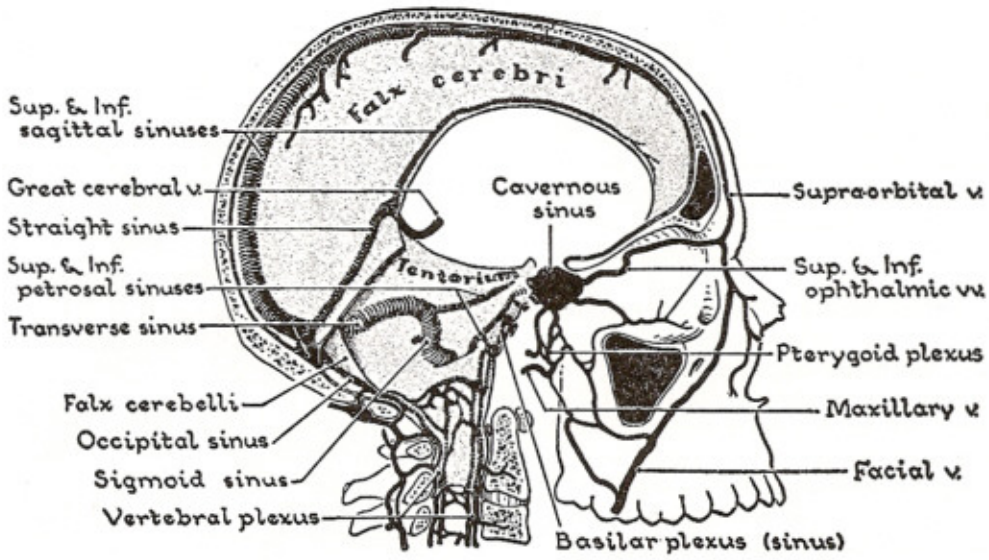

Figure 39.3. The folds of the dura mater. Venous sinuses. Vertebral venous plexus.

penetrate the brain tissue. One cannot separate the pia from the brain in a gross manner. It can be readily seen on the surface of the brain, but it is best appreciated in histologic preparations as a single cell layer external to the brain tissue.

DURAL FOLDS

There are 4 major double-layered meningeal dural folds in the cranial cavity. They are the "sickled-shaped" **falx cerebri** and the **falx cerebelli** in the midline sagittal plane and the horizontally oriented **tentorium cerebelli** and the **diaphragma sellae**, which forms a roof above the cerebellum and the pituitary gland, respectively. The margins of these dural folds contain some of the major venous sinuses of the cranial cavity.

The **falx cerebri** is suspended from the inner surface of the skull and projects inferiorly between the two cerebral hemispheres (*figs. 39.2 and 39.3*). It is attached anteriorly within the anterior cranial fossa to the **crista**

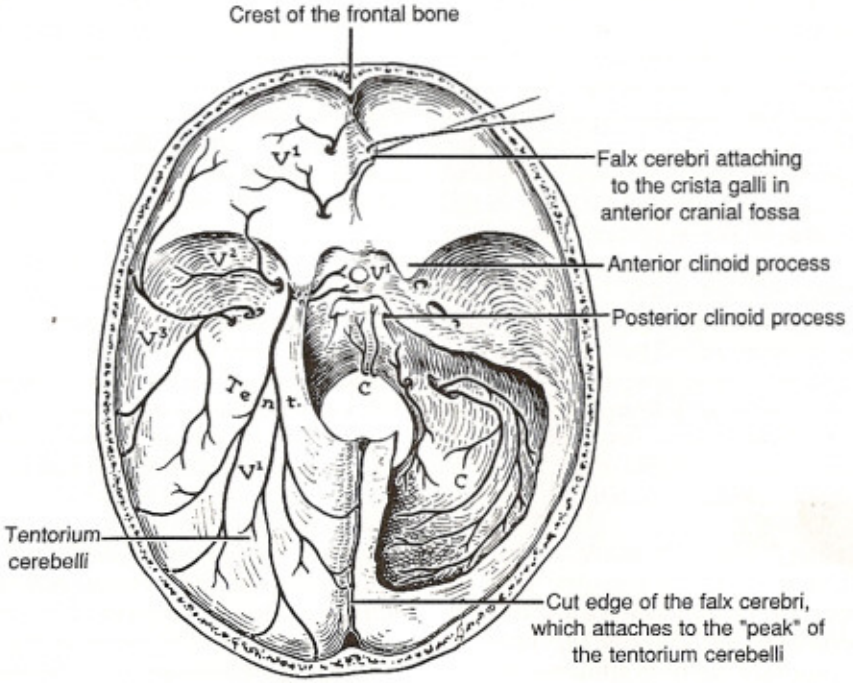

Figure 39.4. Nerves of cranial dura mater (Kimmel).

galli of the ethmoid bone and **crest of the frontal bone** (*fig. 39.4; see also fig. 39.15*). Its convexed upper border attaches to the lips of the sagittal sulcus on the frontal, parietal, and occipital bones as it passes posteriorly in the cranium. The attached superior border contains the **superior sagittal sinus** while the "free" inferior border contains the smaller **inferior sagittal sinus**. This inferior margin overlies the corpus callosum of the brain, which is a large transverse bundle of axons connecting the two cerebral hemispheres.

The broad posterior attachment of the falx cerebri is mainly into the midline "peak" of the tentorium cerebelli (*fig. 39.4*). Anteriorly, this basal attachment is associated with the terminal aspect of the inferior sagittal sinus. The **straight sinus** is contained within the union of the falx cerebri and the tentorium cerebelli. This straight sinus drains the inferior sagittal sinus and venous blood from the underlying brain tissue into the **confluens of the sinuses** on the inner aspect of the occipital bone at the **internal occipital protuberance**.

The **falx cerebelli** is a slight fold attached inferior to the tentorium cerebelli on the **crest** of the occipital bone. An **occipital sinus** is found in its posterior border as it attaches to the occipital bone.

The **tentorium cerebelli** attaches medially to the base of the falx cerebri and the falx cerebelli and forms a roof over the posterior one-half of the posterior cranial fossa. The anterior one-half of the posterior cranial fossa is opened by a "notch" in the tentorium cerebelli, which allows the brainstem to connect to the forebrain in the middle cranial fossa (*figs. 39.4 and 39.5*). The peripheral attachments of the tentorium cerebelli are well shown in *Figure 39.4*. From the internal occipital protuberance, the tentorium cerebelli attaches to the occipital bone and the temporal bone and encloses the **transverse sinus**. At the junction of the posterior and middle cranial fossae, the tentorial attachment continues in an anteromedial direction on the **crest** of the **petrous temporal bone** to reach the **posterior clinoid processes of the sphenoid bone** (*fig. 39.4*). The "free" border of the tentorial notch passes anteriorly over the peripheral attachment of the tentorium cerebelli and attaches to the **anterior clinoid processes of the sphenoid bone**. This "overlap" of tentorial attachments is illustrated in *Figure 39.5* and has an important relationship to the III, IV, and V cranial nerves and the **cavernous sinus**. The tentorial notch is also a site for "herniation" of the brain in intracranial disorders. Since the tentorium separates the cerebral cortices and forebrain superiorly from the brainstem and cerebellum in the posterior cranial fossa, pressure in the "supratentorial space" can force parts of the temporal lobes of the brain through the tentorial notch into the posterior cranial fossa.

The **diaphragma sellae** forms a "tentorium" for the hypophysis cerebri (pituitary). It has a central aperture to allow the pituitary stalk to connect with the hypothalamus of the forebrain superiorly and the pituitary gland inferiorly. The pituitary gland is situated in bony depression within the body of the sphenoid bone, the **sella turcica** (Turkish Saddle). Because the diaphragma

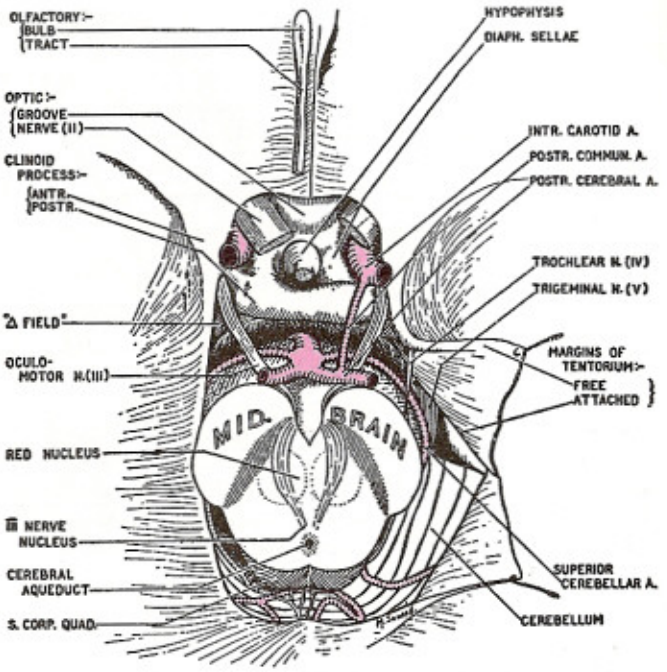

Figure 39.5. A stage in the removal of the brain.

sellae separates the pituitary from the base of the forebrain, care must be taken in elevating the brain from the middle cranial fossa. Disconnecting the pituitary gland from the hypothalamus constitutes a **hypophysectomy**. Surgical procedures on the pituitary gland are usually done from the nasal cavity by removal of the body of the sphenoid bone due to this unique separation of the gland from the brain by the diaphragma sellae (*fig. 39.5*).

Meningeal arteries, being periosteal arteries, lie embedded in the outer layer of the dura mater. They supply the dura, the inner table of the skull, and bone marrow of the diploë. The **middle meningeal artery** is most important for the supply of the supratentorial dura. A branch of the **external carotid system**, it gains access to the inner cranial cavity via the foramen spinosum in the sphenoid bone (*fig. 39.6*). Laceration of the middle meningeal artery is a common cause for **epidural hematoma** formation. The artery can be ligated to control bleeding by drilling a hole in the skull at the **pterion** (junction of parietal, frontal, sphenoid and temporal bones) to expose the anterior branch of the artery (*fig. 39.6*).

The anterior and posterior cranial fossae are supplied by the smaller **anterior** and **posterior meningeal arteries**, respectively. The anterior meningeal artery is derived from the anterior ethmoid branch of the ophthalmic artery and the posterior meningeal arteries are branches from the ascending pharyngeal, occipital and vertebral arteries. **Meningeal veins** accompany the arteries and communicate with the venous sinus and the diploic veins.

Meningeal nerves supply the cranial dura by branches from the trigeminal nerve (V^1, V^2, V^3) and cervical nerve(s) C2(3) in a pattern comparable to the overlying skin area

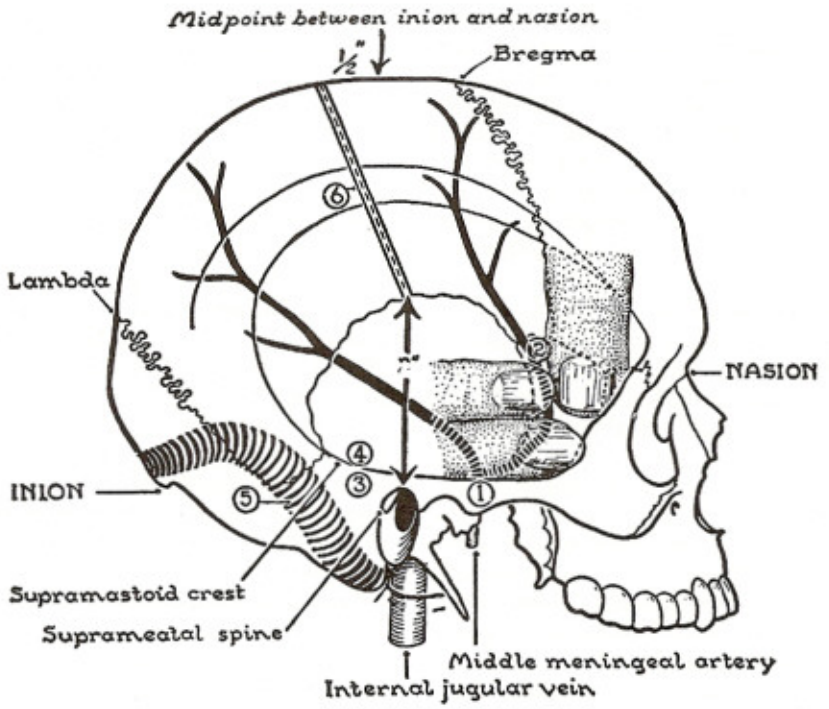

Figure 39.6. Surface anatomy of the skull. *1*, the stem of the *middle meningeal artery*, passing through the foramen spinosum, deep to the head of the mandible, which is readily located by palpation on opening and closing the mouth; *2*, the *anterior branch* of the middle meningeal artery crossing the pterion. The **pterion** is the point where 4 bones meet (parietal, frontal, greater wing of sphenoid and temporal squama). To locate it on the skin, place the thumb behind the frontal process of the zygomatic bone and 2 fingers above the zygomatic arch, and mark the angle so formed (Stiles). This great landmark overlies anterior branch of the middle meningeal art, and the lateral cerebral sulcus. *3*, the *Suprameatal Triangle* lies below the supramastoid crest and behind the suprameatal spine; a hole drilled here enters the *mastoid antrum*; *4*, a hole drilled above the supramastoid crest enters the *middle cranial fossa*. *5*, the "*lateral sinus*," i.e., transverse and sigmoid sinuses, passing from the inion to a point 2 cm or less behind the external acoustic meatus to become the internal jugular vein deep to the anterior border of the mastoid process. *6*, the *central sulcus* of the cerebrum running from a point 1 cm (½") behind the mid inion-nasion point to a point 5 cm above the external acoustic meatus. *Application* of key in *Figure 39.16*. The *crescent of foramina* on surface projection runs from the head of the mandible to the pterion.

(*figs. 39.4 and 38.13*). The dura is sensitive to pain and may be the source for "headache" when tensed by vasodilatation of the meningeal vessels, intracranial inflammation and swelling, or extensive shifts in brain tissue. The arachnoid, pia and brain tissue are insensitive to pain. Neurosurgery is frequently done under local anesthesia to relieve pain in the scalp, skull and dura only. The patient can be awake and feel no discomfort from the surgical procedures within the brain tissues that underlie the dura.

Clinical Case 39.2

Patient John R. This 20-year-old farmer's son, home from college for the summer, began feeling severely dizzy and developed headaches during the day while working on a tractor. He told his father he thought he was going blind. The headaches became so severe that he was admitted to the neurology clinic of the University Medical Center. Radiology quickly revealed the presence of an abnormal mass in the hypophyseal (pituitary) fossa. The neurosurgeon called in on the case plans to explore and remove a pituitary tumor believed by all to be the diagnosis. As your clinical tutor, he quizzes you on the anatomy of the middle cranial fossa, relationship of all the nerves and venous sinuses surrounding the hypophysis (pituitary gland), and the possible surgical approaches to the area through the nasal cavity, orbit, forehead, or temporal region.

VENOUS SINUSES OF THE DURA MATER (*figs. 39.3 and 39.7*).

The **superior sagittal sinus** within the superior aspect of the falx cerebri usually joins the right **transverse sinus**

within the right peripheral margin of the tentorium cerebelli. Blood from these sinuses will drain via the right **sigmoid sinus** into the right internal jugular veins. The **inferior sagittal sinus** unites with the **great cerebral vein** (of **Galen**) to form the **straight sinus** within the base of the falx cerebri and the crest of the tentorium cerebelli. The straight sinus tends to flow to the left side of the **confluens of sinuses** and drain through the left **transverse sinus** and **left sigmoid** sinus into the left **internal jugular vein**.

The **sigmoid sinuses** are formed by the joining of the **transverse sinuses** with the **superior petrosal sinuses** on each side of the posterior cranial fossa. The sigmoid sinuses have an "S-shaped" course on the lateral wall and floor of the posterior cranial fossa and they join the **inferior petrosal sinuses** to form the superior "bulb" of the internal jugular vein within the **jugular foramen**.

The inferior and superior petrosal sinuses drain the important **cavernous sinuses** (*fig. 39.3*), which flank the lateral borders of the body of the sphenoid bone in the middle cranial fossa. The cavernous sinuses drain the orbits via the superior and inferior ophthalmic veins, the anterior cranial fossa via the sphenoparietal sinuses and the brain via the middle cerebral vein (most other cerebral veins drain into the superior sagittal sinus in the roof of the cranial cavity). The right and left cavernous sinuses are also joined by an **intercavernous sinus** that extends posteriorly and inferiorly around the pituitary and body of the sphenoid bone.

Figure 39.7 shows how the meningeal dura forms the lateral wall of the cavernous sinus as it is drawn laterally in the middle cranial fossa. The periosteal dura layer adheres faithfully to the bone on the lateral side of the body of the sphenoid. The intervening space is endothelially lined and forms the trabeculated (honeycomb-like) cavernous sinus. Within the sinus are two important **nonvenous** structures; the **internal carotid artery** and the **Abducens** or **sixth cranial (VI) nerve**. They are separated from the venous blood by the internal endothelium of the cavernous sinus. The lateral wall of the cavernous sinus contain 3 additional cranial nerves: **Occulomotor (III), Trochlear (IV)**, and the **Ophthalmic Division of Trigeminal (V^1)**. The Maxillary Division of the Trigeminal (V^2) may also be in the inferior border of the wall of the cavernous sinus (*fig. 39.7*). These structures within the cavernous sinus have a long dural course before they leave the cranial cavity to enter the orbit. Inflammation and thrombosis of the cavernous sinus can cause a **meningitis** that involves these cranial nerves and produces signs and symptoms that are related to the function of the eye and skin over the orbit.

The **basilar sinus** is a wide trabeculated space behind the dorsum sellae and the basioccipital bone. It unites the cavernous and inferior petrosal sinuses of the opposite sides and communicates with the vertebral plexus of veins through the foramen magnum.

The dural sinuses, like most venous channels above the heart (including the vertebral plexus of veins), are drained by gravity and contain **no valves**. Therefore, infections in the face, scalp, skull, vertebral column, meninges or brain can spread to the cranial cavity and cause meningitis. Since the cavernous, inferior petrosal and

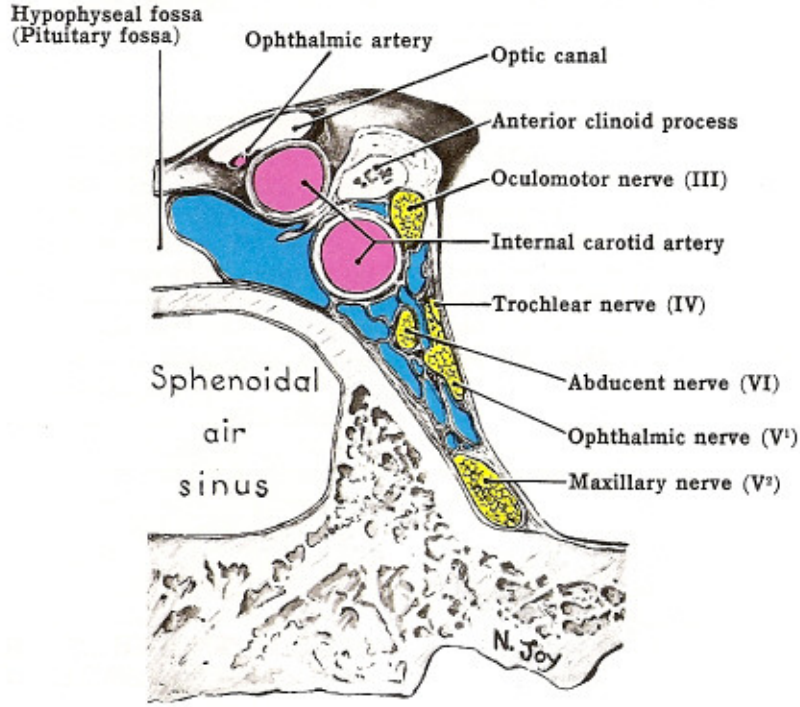

Figure 39.7. Cavernous sinus, coronal section.

transverse sinus intercommunicate, these infections can readily become bilateral and affect both the right and left side of the intracranial cavity and associated cranial nerves.

Cranial Nerves

There are 12 cranial nerves in man. They arise and are "numbered" sequentially from I–XII (1–12) in the anterior, middle, and posterior cranial fossa (*figs. 39.8 and 39.9*).

The **olfactory nerve** (I) arises in the nasal cavities and enters the anterior cranial fossae through the cribriform plate of the ethmoid bone (*see fig. 39.14*). The **olfactory bulb** and **olfactory tract** convey the sensory pathways for smell through the floor of the anterior cranial fossa to the brain (*figs. 39.5 and 39.8*).

The **optic nerve** (II) leaves the orbit and enters the middle cranial fossa through the **optic canal** within the lesser wings of the sphenoid bone (*figs. 39.5 and 39.8*). The portions of the optic nerves from the nasal one-half of the retina cross the midline in the **optic (chiasmic) groove** on the sphenoid bone to form the **optic chiasm**. Posterior to the optic chiasm, the visual fibers project to the brain as the **optic tracts**. Due to the optic chiasm, the **right optic tract** will contain fibers from the nasal retina of the left eye and the temporal retina of the right eye. The right side of the brain (the right occipital lobe) will therefore receive visual stimuli from the left visual field of the patient.

The **occulomotor nerve** (III) is the highest cranial nerve to arise from the brainstem at the midbrain level. It passes anteriorly in the subarachnoid space of the posterior cranial fossa between the posterior cerebral and superior cerebellar arteries to enter the dura between the attachments of the tentorium cerebelli to the posterior and anterior clinoid processes (*fig. 39.5*). It has an extensive course through the superior aspect of the lateral wall of the cavernous sinus to enter the orbit via the **superior orbital fissure** of the sphenoid bone (*figs. 39.7, 39.10, and 39.11*). The cranial nerve III provides voluntary motor fibers to four extrinsic skeletal muscles of the eye: medial rectus, superior rectus, inferior rectus, and inferior oblique muscles; and a skeletal muscle of the eyelid, **the levator palpebrae superioris** muscle. It also supplies the preganglionic **parasympathetic** neurons to the pupillary constrictor muscle and ciliary body muscle within the eye. The latter two muscles are smooth muscles and require an innervation by autonomic neurons.

The **trochlear nerve** (IV) is also motor to an extrinsic eye muscle; the **superior oblique muscle**. The trochlear nerve leaves the posterior aspect of the midbrain to traverse the subarachnoid space of the posterior cranial fossa and enter the free edge of the tentorial dura in the same triangle as the occulomotor nerve (III) (*figs. 39.5 and 39.9*). Cranial nerve IV lies in the lateral wall of the cavernous sinus as it passes forward to enter the superior orbital fissure (*figs. 39.7 and 39.10*).

The **trigeminal nerve** (V) is the great sensory nerve to the skin of the face as well as a motor nerve to the muscles that move the mandible (**muscles of mastication**). It arises from the pons region of the brainstem and crosses the subarachnoid space to enter the dura at the most medial aspect of the superior border of the petrous bone (*figs. 39.8 and 39.9*). The trigeminal ganglion lies within the dura of the middle cranial fossa lateral to the cavernous sinus (*fig. 39.11*). The ganglion is a swelling on V formed by the presence of the sensory pseudo-unipolar neuron cell bodies. No synapses occur in this or any other peripheral sensory ganglion. It is simply a site for the cell bodies of the peripheral sensory nerves of V. The 3 branches from the ganglion are the **ophthalmic (V^1), maxillary (V^2)** and **mandibular (V^3)** divisions. V^1 exits the middle cranial fossa via the **superior orbital fissure** with cranial nerves III, IV, and VI. The maxillary division (V^2) exits the middle cranial fossa through the **foramen rotundum** of the sphenoid bone, while V^3 exits through the **foramen ovale** of the sphenoid bone (*fig. 39.11*).

The **abducens nerve (VI)** innervates the lateral rectus (abductor) muscle of the eye. It has the longest intracranial course and is frequently a sensitive monitor to changes in intracranial pressure and disease. **VI** arises from the pons-medullary junction of the brainstem and passes forward in the subarachnoid space to enter the dura of the posterior cranial fossa that covers the posterior wall of the cavernous sinus (*figs. 39.8 and 39.9*). The 6th cranial nerve then enters the cavernous sinus to lie lateral to the internal carotid artery (*figs. 39.7 and 39.10*) as it proceeds anteriorly to the superior orbital fissure. The unique positioning of VI *within* the cavernous sinus forms the basis for observing difficulties in eye abduction as an initial sign in cavernous sinus thrombosis.

The **facial nerve (VII)** and its accompanying component, the **nervus intermedius,** leave the brainstem at the pons-medullary junction and pass through the subarachnoid space to enter the dura at the **internal acoustic (auditory) meatus** (*figs. 39.8 and 39.9*). Cranial nerve VII passes through the internal auditory meatus of the petrous temporal bone to reach the middle ear. An enlarged **geniculate ganglion** for taste is found on the facial nerve as this point and marks the bifurcation point for the peripheral distribution of the nerve (*fig. 39.11*). The **greater (superficial) petrosal branch** passes anteromedially to enter the floor of the middle cranial fossa, courses though the pterygoid canal, and eventually reaches the pterygopalatine fossa behind the nasal cavity. The greater (superficial) petrosal nerve is part of the nervus intermedius that will carry taste sensations from the palate and secretomotor (parasympathetic) innervation to the glands of the palate, nose, and orbit.

The remaining taste and secretomotor fibers of the

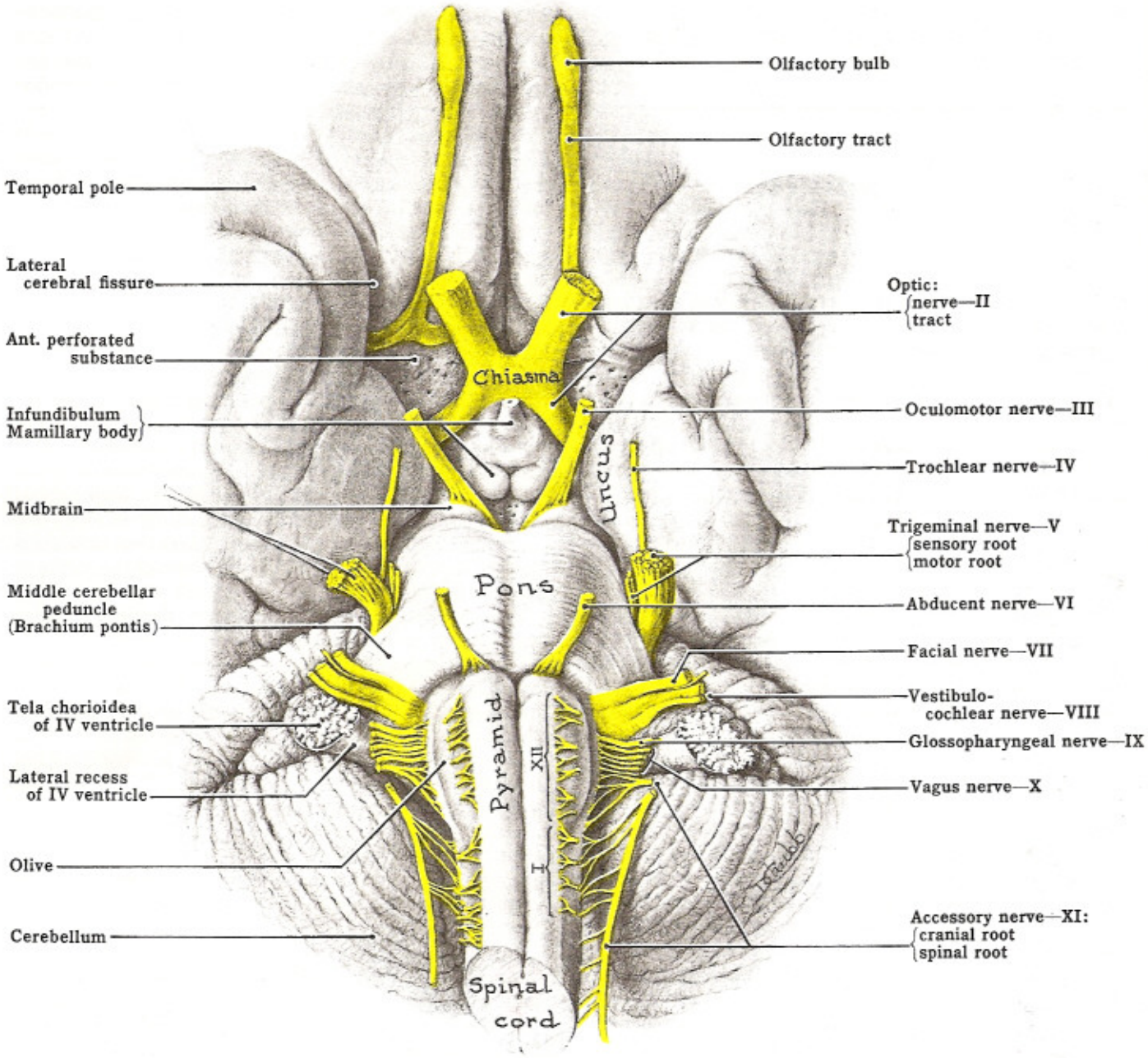

Figure 39.8. Base of the brain: The superficial origins of the cranial nerves.

Note:

1. The olfactory bulb, in which the olfactory (cranial I) nerves (not shown) end.
2. The superficial origin of the trochlear (cranial IV) nerve is from the dorsal aspect of the brainstem and cannot be seen in this figure.
3. The slender nervus intermedius, or so-called sensory root of the facial nerve (not labeled) between the facial (VII) and vestibulocochlear (VIII) nerves.
4. The fila of the hypoglossal (XII) nerve, arising between the pyramid and the olive, and in line with the ventral root of the 1st cervical nerve.

(From Anderson, J.E.: *Grant's Atlas*, 8th edition, Williams & Wilkins, Baltimore, 1983.)

nervus intermedius form the **chorda tympani** branch of VII. They leave the middle ear through the **petrotympanic fissure** and go to the floor of the mouth. Cranial nerve VII then exits the middle ear cavity via the stylomastoid foramen in the base of the skull just posterior to the **external acoustic (auditory) meatus** (external ear canal). The facial nerve is motor to the facial muscles that surround the cranial orifices (ears, mouth, nose, and eyes) as well as the stapedius, posterior digastric, and stylohyoid muscles. The trunk of VII continues anteriorly to

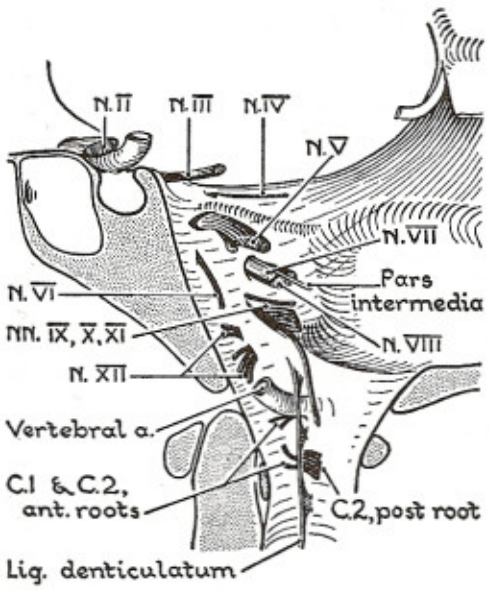

Figure 39.9. Cranial nerves, piercing dura mater.

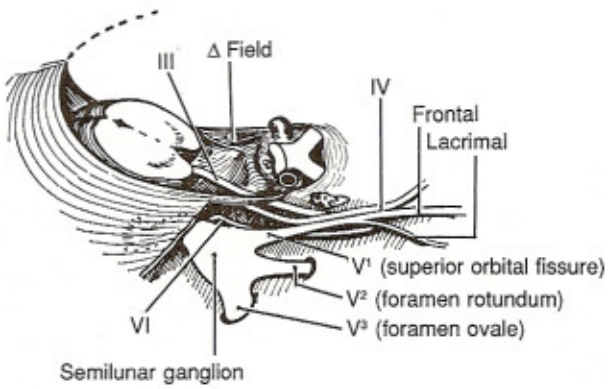

Figure 39.11. The 3 divisions of the trigeminal nerve (N. V.). (*Ganglion: semilunar = trigeminal.*)

enter the substance of the parotid gland. A plexus of nerves emerges from the parotid as the terminal branches of VII to the **muscles of facial expression**. Facial paralysis is the most common feature of disorders in VII, but additional signs and symptoms related to the nervus (pars) intermedius components can be seen in lesions of VII that occur within the temporal bone or the posterior cranial fossa.

The 8th cranial nerve (VIII) can be named the **auditory** or **vestibulocochlear nerve**. It has the same origin and pathway as the VII from the brainstem, through the subarachnoid space, and into the internal acoustic meatus (*fig. 39.9*). Cranial nerve VIII innervates the organs for hearing (the **cochlea**) and balance (the **semicircular canals, utricle** and **saccule**) within the petrous portion of the temporal bone.

The **glossopharyngeal nerve** (IX) is a mixed motor and sensory nerve to the tongue and pharynx. It arises with the Vagus (X) and cranial component of XI from the medulla of the brainstem and exits the skull via the jugular foramen (*fig. 39.9*). As IX passes inferiorly through the jugular foramen, it also sends sensory and secretomotor fibers through the lateral wall of the jugular foramen to enter the middle ear. The secretomotor (parasympathetic) fibers exit from the middle ear cavity as the *lesser petrosal* to pass through the middle cranial fossa and leave the

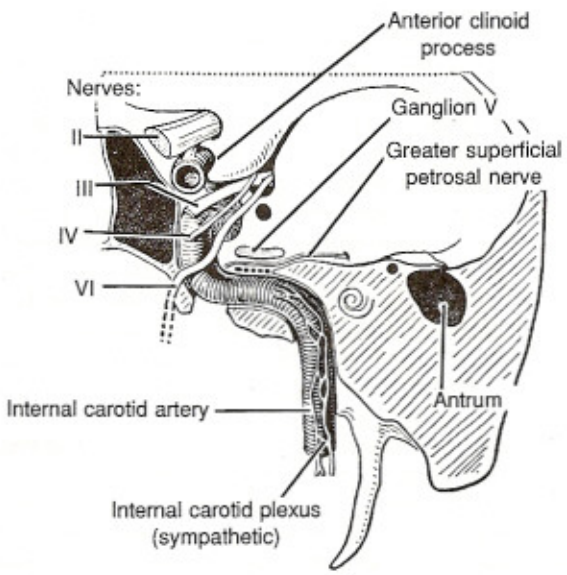

Figure 39.10. The course and relations of the intrapetrous and intracranial parts of the internal carotid artery.

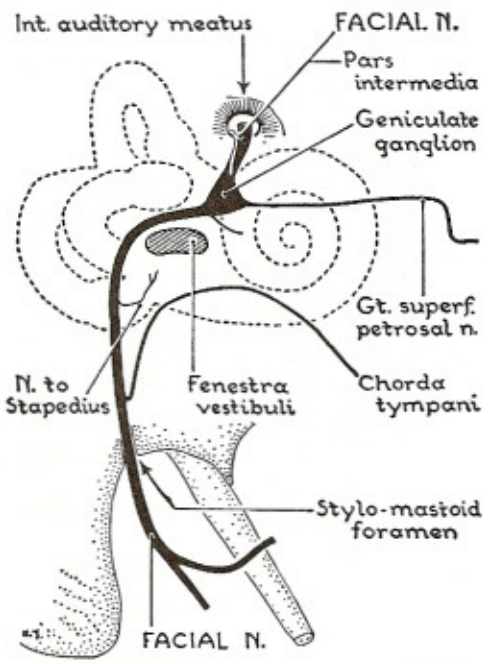

Figure 39.12. Intrapetrous course of facial nerve.

cranium via the **foramen ovale** (with V^3) to innervate the parotid gland. The sensory fibers innervate the mucosa of the middle ear.

The principle branch of IX passes inferiorly from the jugular foramen to spiral around the **stylopharyngeus muscle** and enters the pharynx and the base of the tongue. IX is motor *only* to the stylopharyngeus muscle and sensory to the mucosa of the pharynx and posterior one-third of the tongue. It is also sensory for taste in the mucosa of the posterior aspect of the tongue. **IX** can be tested clinically by eliciting a "gag reflex" upon touching the mucosa around the palatine tonsils, lateral to the tongue.

The **vagus (X) nerve** is a clinically important cranial nerve that supplies the head, neck, thorax, and abdomen. It contains a large portion of the parasympathetic fibers within the body. X is also motor to skeletal muscles in the head and neck and contain sensory neurons to skin in the external ear and mucous membranes of the gastrointestinal and respiratory systems. **X** arises from the medulla and exits the skull through the jugular foramen (*figs. 39.8 and 39.9*). Like IX, it sends fibers into the ear via the canals in the lateral wall of the jugular foramen. These fibers are sensory to the epithelium lining the external auditory meatus and the tympanic membrane. Below the jugular foramen, the vagus descends within the carotid sheath through the neck. It gives motor and sensory branches to the palate, pharynx, and larynx as it descends. It can be readily assessed in the head and neck by testing for pain in the ear, movement of the palate, and production of normal voice in the larynx.

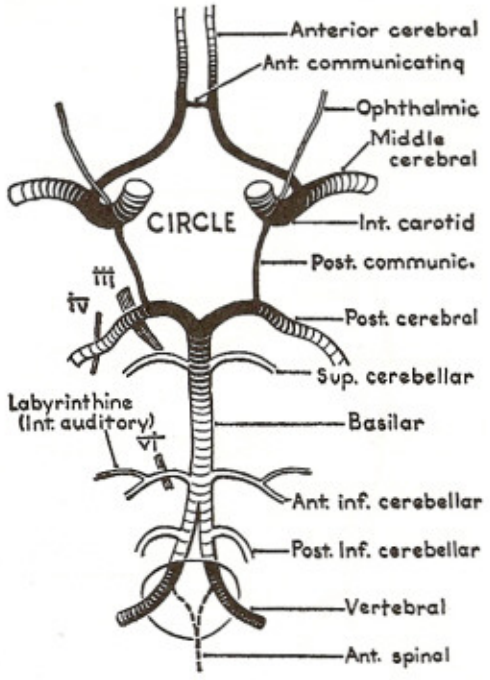

Figure 39.13. Two vertebral and 2 internal carotid arteries supply the brain and form an arterial circle.

The **accessory (XI) nerve** arises with IX and X as well as from a spinal root that enters the foramen magnum from C2–4 spinal segments (*fig. 39.8*). It contains the motor fibers to **sternomastoid** and **trapezius muscles**. These fibers exit the posterior cranial fossa via the internal jugular foramen and then pass posteriorly onto the inferior surface of the **sternomastoid muscle**. The fibers to trapezius emerge from the posterior border of sternomastoid, cross the posterior triangle of the neck, and descend on the deep surface of trapezius through the neck and superficial back.

The **hypoglossal (XII) nerve** arises from the medulla of the brainstem between the olive and the pyramids (*fig. 39.8*). It leaves the subarachnoid space by entering the hypoglossal canal (*fig. 39.9*) and passing into the neck and floor of the mouth to innervate the muscles of the tongue.

Cerebral Arteries in Relation to Cranial Nerves

The **internal carotid** and **vertebral** arteries arise bilaterally in the neck and ascend to the cranial cavity to supply the brain.

The **internal carotid artery** (*fig. 39.10*) enters the skull through the **carotid canal** and lies within the cavernous sinus. It forms a "hairpin loop" within the cavernous sinus (the "carotid siphon") (*figs. 39.7 and 39.13*) and then pierces the dura mater medial to the anterior clinoid process, which it grooves. The **ophthalmic artery** arises from the internal carotid artery (*figs. 39.7 and 39.13*) as it enters the subarachnoid space and passes anteriorly into the optic canal to lie below the optic nerve. A **posterior communicating branch** also arises from the internal carotid (*figs. 39.5 and 39.13*) and courses posteriorly, medial to the oculomotor (III) nerve, to unite with the posterior cerebral artery. The internal carotid then terminates in the subarachnoid space by dividing into the **anterior** and **middle cerebral arteries**. The two anterior cerebral arteries are interconnected by an **anterior communicating** artery, as they enter the horizontal fissure alongside the falx cerebri. The middle cerebral artery passes laterally through the stem of the lateral fissure to supply the lateral aspects of the frontal, temporal, and parietal lobes of the brain.

The **vertebral artery** (*figs. 39.9 and 39.13*) pierces the dura behind the occipital condyles and grooves the margins of the foramen magnum. It passes forward on the lower border of the pons, where it unites with its companion artery from the opposite side to form the basilar artery (*fig. 39.13*). In its intracranial course, the vertebral artery supplies the medulla, cerebellum, and spinal cord.

The **posterior inferior cerebellar arteries** arise from each vertebral artery in the posterior cranial fossa and are important clinical branches that loop over the rootlets of the IX, X and XI cranial nerves.

The **basilar artery** ascends on the bony slope of the basioccipital bone beneath the pons and midbrain (*fig. 39.5*). It bifurcates at the midbrain to **right** and **left posterior cerebral arteries** that pass through the tentorial notch and supply the medial aspects of the occipital and temporal lobes of the brain. The posterior cerebral arteries are closely related to the III and IV cranial nerves (*fig. 39.13*) in the posterior cranial fossa. **Superior** and **anterior inferior cerebellar arteries** are major branches of the basilar artery as it courses over the undersurface of the pons.

The resultant anastomosis of the internal carotid and the posterior cerebral branches of the basilar artery is termed the "Circle of Willis" (*fig. 39.13*). It provides the brain with the potential for alternate blood flow should a major carotid or vertebral vessel(s) become occluded or constricted by disease.

Floor or Base of the Skull

THREE CRANIAL FOSSAE

Boundaries (*fig. 39.14*)

The interior of the skull has three terraces, or levels, called fossae—an **anterior**, a **middle** and a **posterior**.

The anterior cranial fossa is sharply marked off from the middle cranial fossa by three free concave crests: one median and two lateral. The median concaved crest connects the **anterior clinoid processes** to which the free border of the tentorium cerebelli attach. The processes are components of the sphenoid bone and their interconnecting median crest overlies the **optic canals** and their openings, the **optic foramina** (singular: **optic foramen**). Each lateral crest is formed by the **lesser wing of the sphenoid**. It passes laterally from the anterior clinoid process over the superior orbital fissure to the **pterion** and projects posteriorly above the tips of the temporal lobes into the lateral sulcus of the brain.

The middle cranial fossa is demarcated from the posterior cranial fossa by a median rectangular plate, the **dorsum sellae**. The superior free angles of the dorsum sellae form the **posterior clinoid processes**, to which attach the most anterior peripheral components of the tentorium cerebelli. The lateral boundaries that separate the middle and posterior cranial fossae are the crests or superior borders of the **petrous part of the temporal bone**. This bony crest also serves to attach peripheral components of the tentorium cerebelli and mark the sites of the intradural **superior petrosal sinuses** (*fig. 39.14*).

CONTENTS

Anterior Cranial Fossa (*figs. 39.14 and 39.15*)

The floor of the anterior cranial fossa is mainly formed by the **orbital plates of the frontal bone** and the **jugum** (yoke) and lesser wings of the sphenoid bone. A central rectangular defect between these bones is filled by the ethmoid bone that separates the anterior cranial fossa from the nasal cavities inferiorly. The ethmoid component of the anterior cranial fossa contains the midline **crista galli** (L. cock's comb) which is an anterior attachment point for the falx cerebri.

Flanking the crista galli on each side is a sieve-like bony plate, the **cribriform plate** of the ethmoid bone. These bony perforations allow the **Olfactory Nerve (I)** to transmit its peripheral nerves from the mucosa of the nasal cavity to the **Olfactory bulb** that lies on the superior aspect of the cribriform plate. The olfactory bulb is connected to the brain tissue overlying the lesser wings of the sphenoid bone via the **olfactory tract**, which lies on the superior aspect of the cribiform plate and the **jugum** of the sphenoid bone.

Anteriorly, between the crista galli and the **crest of the frontal bone** is the **foramen cecum**. This bony channel may transmit an emissary vein from the nasal cavity to the superior sagittal sinus and serve as a potential route for nasal infections to spread to the meninges of the intracranial cavity.

Middle Cranial Fossa (*fig. 39.16*)

The middle cranial fossa is associated with six cranial nerves (II–VII), the internal carotid and middle meningeal arteries, the cavernous sinus, the hypothalamus, the pituitary gland, and the temporal lobes of the cerebral cortex. It is a very important area within the cranial cavity and highly relevant to clinical diagnosis of intracranial disease. A more detailed discussion of its contents will be given at the end of this chapter. The middle cranial fossa is shaped like a butterfly (*fig. 39.14*), with a median component and two expanded lateral components. Its bony floor is formed by parts of the sphenoid and temporal bones.

Median Part

The median part is likened to a bed with four clinoid processes representing the bedposts (Gr. kline = a bed). It lies above the body of the sphenoid, which is "inflated" by the sphenoid air sinuses contained within it. The space between the superior aspect of the body of the sphenoid

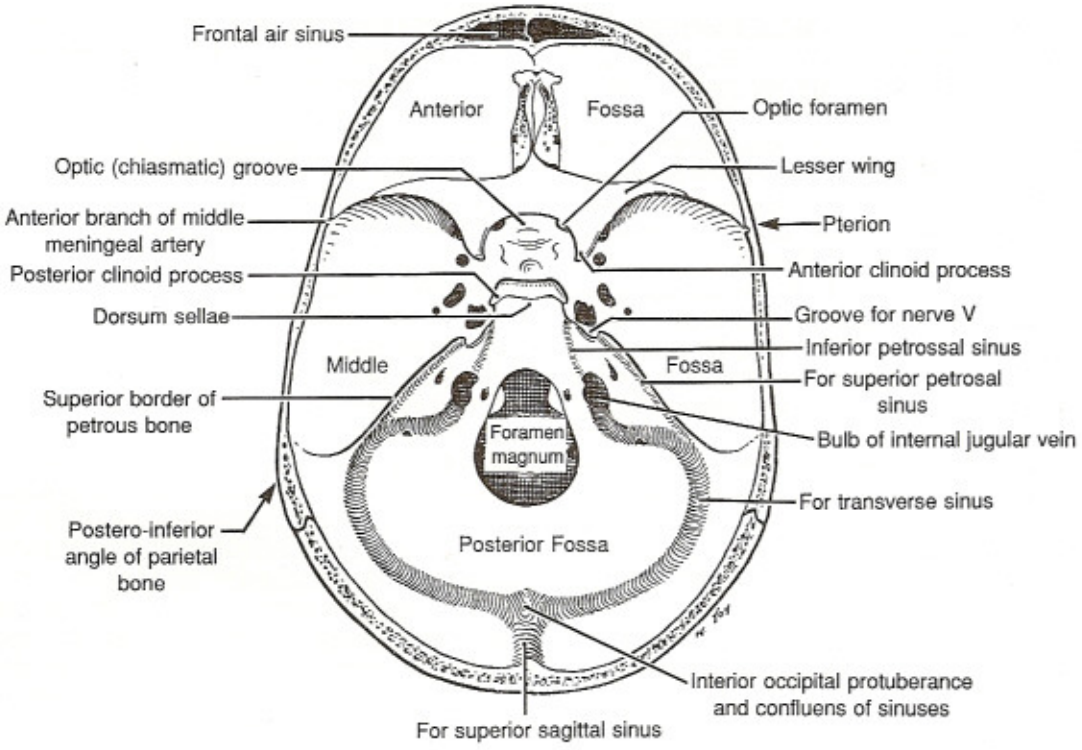

Figure 39.14. The interior of the base of the skull—the 3 cranial fossae.

and the clinoid processes is the **sellae turcica** (Turkish Saddle). It has a horizontal dural partition, the diaphragma sellae, that separates the **hypothalamus cerebri**, or pituitary gland, from the base of the brain (hypothalamus). The "seat" of the saddle is also called the **pituitary (hypophyseal) fossa** (*fig. 39.16*).

The **optic canals** arise in the anterior aspect of the medial part of the middle cranial fossa and run anterolaterally through the lesser wing of the sphenoid bone to open into the orbits. Each optic canal contains an **optic nerve** (II) and an **ophthalmic artery** inferior to the optic nerve. The **optic (chiasmatic) groove** is located between the optic foramina and above the **tuberculum sellae**. This groove is a bony landmark only and **does not** actually contain the optic chiasm, where the nerves from the two nasal parts of the retina cross the midline to enter the optic tracts on the opposite side of the head.

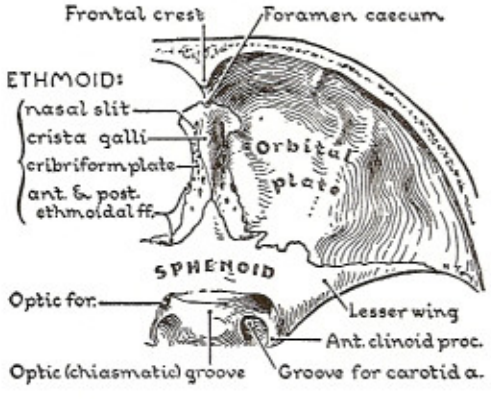

Figure 39.15. The anterior cranial fossa. (*Optic foramen and optic groove = optic canal and chiasmatic sulcus.*)

The sellae turcica lies behind the optic groove and has three parts—the **tuberculum sellae**, the **hypophyseal fossa**, and the **dorsum sellae** (back of saddle).

A ragged-edged foramen, the **foramen lacerum** (*fig. 39.14*), is readily observable in the middle cranial fossa of dried skull preparations or basal view radiographs of the skull. In life, it is filled by fibrocartilage and forms part of the floor of the middle cranial fossa between the median part of the fossa and **apex of the petrous temporal bone**. The carotid artery passes above the cartilage-filled foramen lacerum, as it leaves the carotid canal and enters the cavernous sinus on the lateral aspects of the body of the sphenoid bone.

Lateral Part

Each lateral part is limited anteriorly by the lesser wing of the sphenoid and posteriorly by the superior border of the petrous bone. The floor and lateral walls include the greater wing of the sphenoid and the petrous and squamous parts of the temporal bone.

Clinically significant features associated with the greater

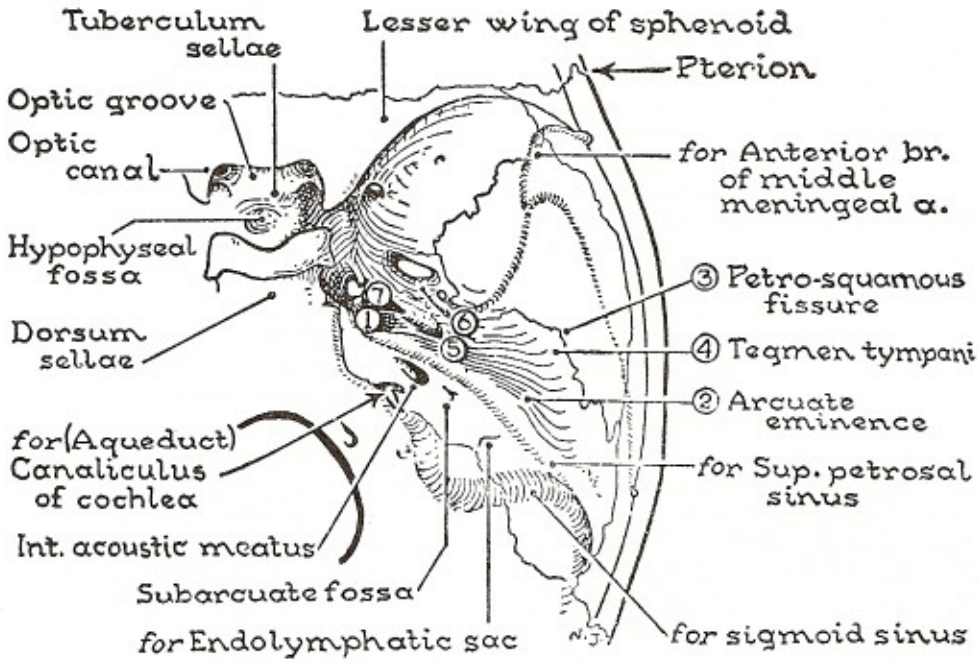

Figure 39.16. Middle cranial fossa. Seven details of petrous bone: (*1*) depression for trigeminal ganglion; (*2*) elevation for anterior semicircular canal; (*3*) remains of petrosquamous fissure; (*4*) tegmen tympani; (*5*) hiatus for greater petrosal nerve; (*6*) hiatus for lesser petrosal nerve; (*7*) roof of carotid canal, commonly membranous.

wing of the sphenoid, include four foramina: the **superior orbital fissure, foramen rotundum, foramen ovale** and **foramen spinosum**. These bony apertures are illustrated from a superior view in *Figures 39.14 and 39.16* and in schematic form in *Figure 39.17*.

The **superior orbital fissure** is formed between the lesser and greater wings of the sphenoid near their points of origin. It is readily visible radiographically as a crescent-shaped radiolucency in an anterior-posterior view of the orbit. It transmits the III, IV, V^1, VI cranial nerves and the superior ophthalmic veins, as they pass between the orbit and the middle cranial fossa.

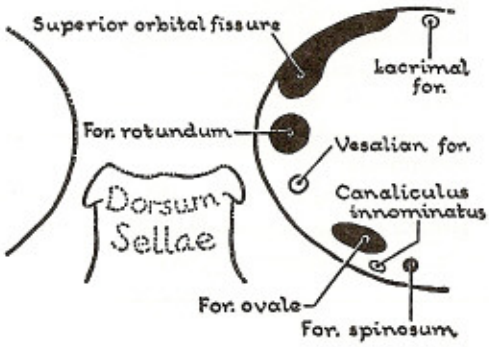

Figure 39.17. The crescent of foramina within the greater wing. Of these foramina, 4 are constant and 3 (lacrimal; Vesalian, for an emissary v.; and innominatus, for a small nerve) are not.

The **foramen rotundum** connects the middle cranial fossa to the pterygopalatine fossa that lies deep within the face lateral to the nasal cavities. V^2 enters the middle cranial fossa via the foramen rotundum with sensory fibers from the face, over the maxilla, the nasal cavity, and the palatal aspect of the oral cavity. The foramen rotundum is visible in the anteroposterior radiograph of the head as a round radiolucency inferior to the superior orbital fissure. It is commonly confused with the infraorbital foramen in radiographs. However, the two foramina are oriented in different planes and need different x-ray projections to reveal their bony location in skull films.

The **foramen ovale** is a horizontally oriented aperture on the floor of the medial cranial fossa. It transmits V^3 and the lesser petrosal branch of the IX from the cranial cavity to the infratemporal fossa inferiorly. It may also contain an **accessory meningeal artery**, which can arise from the maxillary artery below the base of the skull.

The **foramen spinosum** lies posterior to the foramen ovale and transmits the **middle meningeal artery** from the maxillary artery in the infratemporal fossa to the dura of the middle cranial fossa. The course of the middle meningeal artery in the middle cranial fossa is readily visible in dissection, skeletal preparations, and skull x-rays. The foramen ovale and foramen spinosum are also easily visualized as radiolucencies in the basal view of the skull.

The **squamous portion** of the temporal bone forms the lateral wall of the middle cranial fossa and overlies the dura covering aspects of the temporal lobe of the brain. The inner surface of the squama is grooved by the **middle**

meningeal artery and its terminal **anterior** and **posterior branches** (*fig. 39.16*). The anterior branch traverses the **pterion** where the greater wing of the sphenoid and squamous part of the temporal bone fuse with the frontal and parietal bones. The medial aspect of **petrosquamous fissure** overlies the auditory (Eustachian) tube that will connect the middle ear cavity within the petrous bone to the nasal cavities inferior to the body of the sphenoid bone. Posterior to the lateral aspect of the petrosquamous fissure is the **tegmen tympani**. This is on the anterior surface of the petrous bone and forms the roof for the bony part of the auditory tube, the middle ear, and the mastoid air cells that are contained within the temporal bone (petrous and mastoid processes, respectively). The anteromedial aspect of the tegmen tympani have a hiatus (opening) for each of the **greater (superficial) petrosal (VII)** and **lesser petrosal nerves (IX)** that exit the middle ear cavity and run over the floor of the middle cranial fossa. These nerves carry the parasympathetic secretomotor fibers to glands associated with the oral cavity, nasal cavities, and orbits. The greater petrosal nerve also carries taste fibers from the palatal region of the oral cavity.

Posterior Cranial Fossa (*figs. 39.14 and 39.4*)

This fossa lodges the hindbrain, which is comprised of the medulla (oblongata), pons, midbrain, and overlying cerebellum. The fossa is roofed by the tentorium cerebelli except at the tentorial notch, where the midbrain passes to connect with the forebrain in the middle cranial fossa.

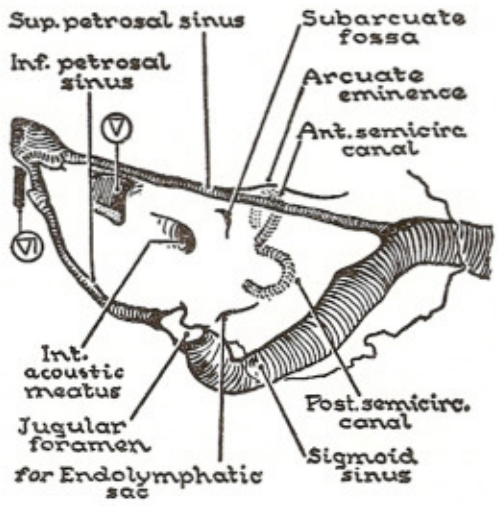

Figure 39.18. The posterior surface of the petrous bone is bounded by venous sinuses.

The posterior, lateral, and inferior aspects of the posterior cranial fossa are formed by the occipital bone. Within the floor is the **foramen magnum**, a large opening that transmits the spinal cord, vertebral arteries, vertebral plexus of veins, and the spinal roots of XI. The foramen magnum lies medial to the atlanto-occipital articulations between the condyles on the base of the occipital bone and the superior articulating facets of the **atlas** (1st cervical vertebra, C1). The occipital condyles form the lateral walls of the foramen magnum (*fig. 39.14*). They contain the hypoglossal canal for nerve XII, as it exits the posterior cranial fossa to reach the base of the skull and carotid sheath on its way to the tongue.

Anteriorly and superiorly above the hypoglossal canal, is the **jugular foramen** that lies in the suture between the occipital and petrous bones. The jugular foramen transmits the cranial nerves IX, X and XI and the **sigmoid** and **inferior petrosal sinuses** to the **bulb** of the **internal jugular vein** (*figs. 39.14 and 39.18*). Superior to the jugular foramen, one finds the **internal acoustic (auditory) meatus**. This opening and canal transmits the **VII** and **VIII** cranial nerves from the posterior cranial fossa to the internal aspect of the petrous bone. The **inner, middle,** and bony parts of the **external ear cavities** are contained in the petrous bone and are closely related to cranial nerves VII and VIII.

A number of emissary veins are also associated with the posterior cranial fossa. Most consistently, one can find major emissary veins in the posterior aspects of the occipital condyles and mastoid processes of the temporal bone. These emissary veins lack valves and can transmit venous blood from the scalp to the venous sinuses within the dural reflections of the posterior cranial fossa. The emissary veins are therefore potential routes by which infections of the scalp "spread" to the meninges.

Clinical Mini-Problems

1. **How could a scalp infection over the parietal bones lead to a subsequent meningitis?**
2. **Would you expect to find blood in the cerebrospinal fluid following the intracranial laceration of the middle meningeal artery?**
3. **Why would the 6th cranial nerve (abducens) be more susceptible to dysfunction in a cavernous sinus thrombosis?**
4. **Which cranial nerve(s) could be affected by tumor growth into the superior orbital fissure?**

(Answers to these questions can be found on p. 587.)