CHAPTER 8

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The head is that portion of the body composed of the skull and all the structures on its inside and outside. It is essentially a highly specialized part of the body wall. The only representation of the body cavity is the space occupied by the auditory tube and middle ear. None of the other "cavities" in the head are related to the body cavity. The cranial cavity is only an upward extension of the vertebral canal, and the orbital cavity is simply a forward extension of the cranial cavity toward the surface. The nasal and oral cavities are invaginations from the body surface that rupture through into the pharynx.

The visceral structures of the head (i.e., those that contain smooth muscle or gland tissue) are, for the most part, akin to those found in the body wall elsewhere. Some of these are blood and lymphatic vessels; others are sweat glands. The salivary and lacrimal glands may be viewed as specialized sweat glands that open up onto the external surface of the body. Mucous glands of the oral and nasal cavity also open up onto the body surface, specifically onto the part that invaginated to form these cavities. There are some smooth muscles associated with the eye that have no clear counterpart elsewhere in the body.

THE SKULL

The skull consists of (1) the **cranium**, which houses the brain, and (2) the **face**, which surrounds the oral and nasal cavities and has a mobile component called the mandible (Fig. 8-1). The orbits lie at the boundary between face and cranium. Many authors use the word "cranium" as synonymous with "skull." They then refer to the braincase as the **neurocranium** and the face as the **viscerocranium**. There are major developmental differences between the neurocranium and face.

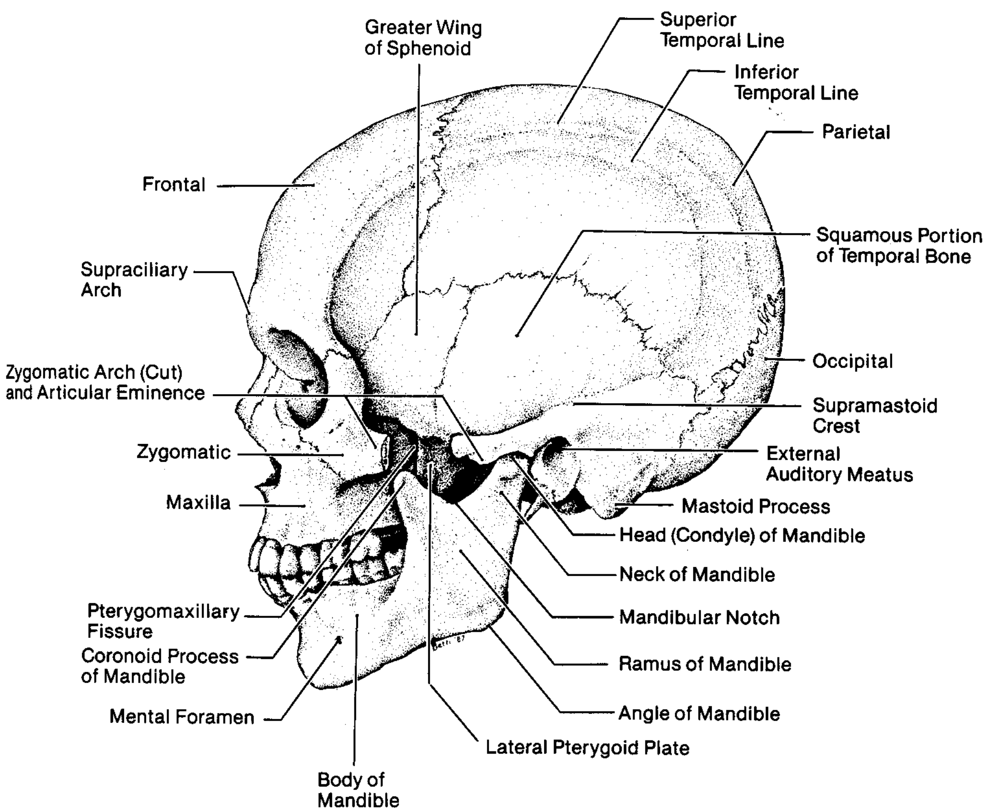


Figure 8-1. Lateral view of the skull.

Development of the Neurocranium

The neurocranium is of composite origin. The bones that form its inferior aspect (i.e., **base**) are laid down first in cartilage (Fig. 8-2). This is not true of the bones that form the sides and top of the braincase. The sides and top of the braincase are first formed as a connective sheet over the developing brain. This connective tissue is continuous with the perichondrium of the cranial base but does not itself chondrify.

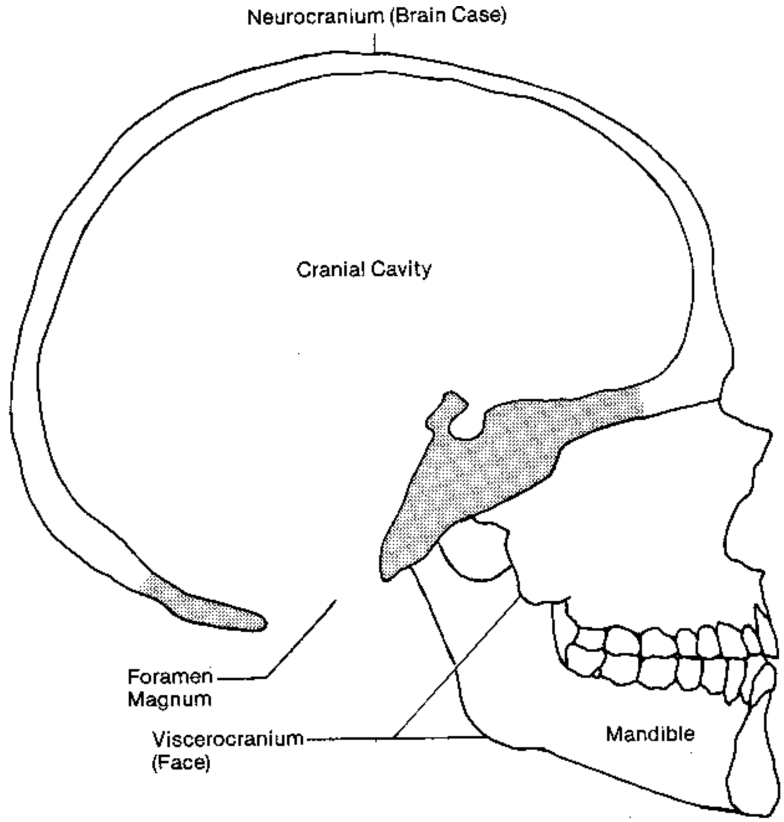


Figure 8-2. **Schematic sagittal section of the adult skull illustrating the area** ***(shaded)*** **preformed in cartilage during embryonic life.**

Cartilaginous Portion of the Neurocranium--The Cranial Base

The midline of the cranial base is like an upward extension of vertebral bodies. Added to its sides are cartilaginous otic capsules that form around the developing inner and middle ear structures; at its anterior extremity are appended the cartilaginous nasal capsules that develop around the invaginating nasal cavities (see Fig. 8-3). Numerous separate ossification centers soon form within the cartilaginous cranial base of the fetus (see Fig. 8-3). These endochondral ossification centers will ultimately give rise to most of the occipital bone (but not the part above the nuchal plane), most of the sphenoid bone (but not its pterygoid plates, nor the part of the greater wing along the side of the braincase), the petrous portion of the temporal bone (from which the mastoid process will later develop), the ethmoid bone, and the inferior nasal conchae. As the different ossification centers expand, their borders approach one another. Nonetheless, at birth some cartilage still persists between them (Fig. 8-4). Each such zone of cartilage is called a **synchondrosis** (meaning a cartilaginous joining of bone), and each represents a site of growth activity in the cranial base during early childhood. Eventually the bone of the ossification

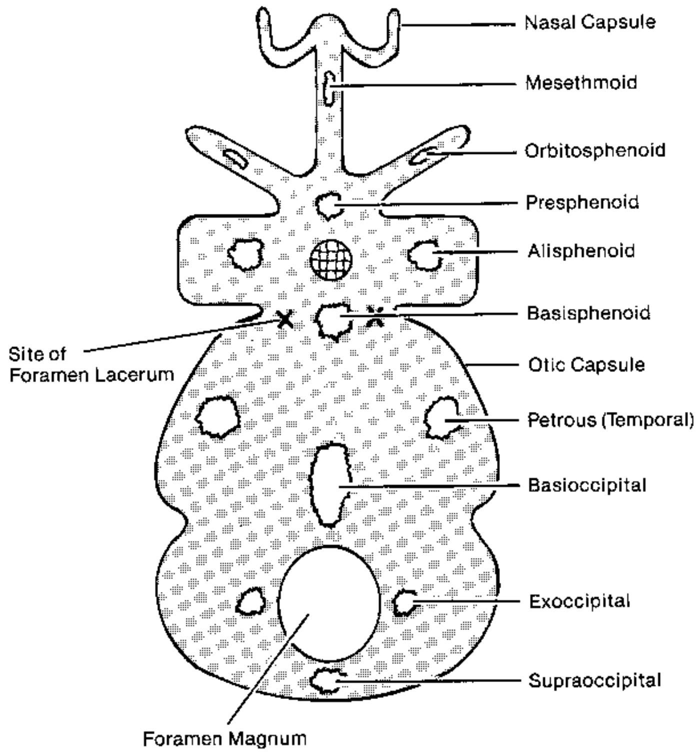


Figure 8–3. Schematic superior view of the embryonic cartilaginous base of the skull. Irregular areas in *white* indicate developing endochondral ossification centers. The *cross-hatched circle* represents the fossa in which the pituitary gland resides.

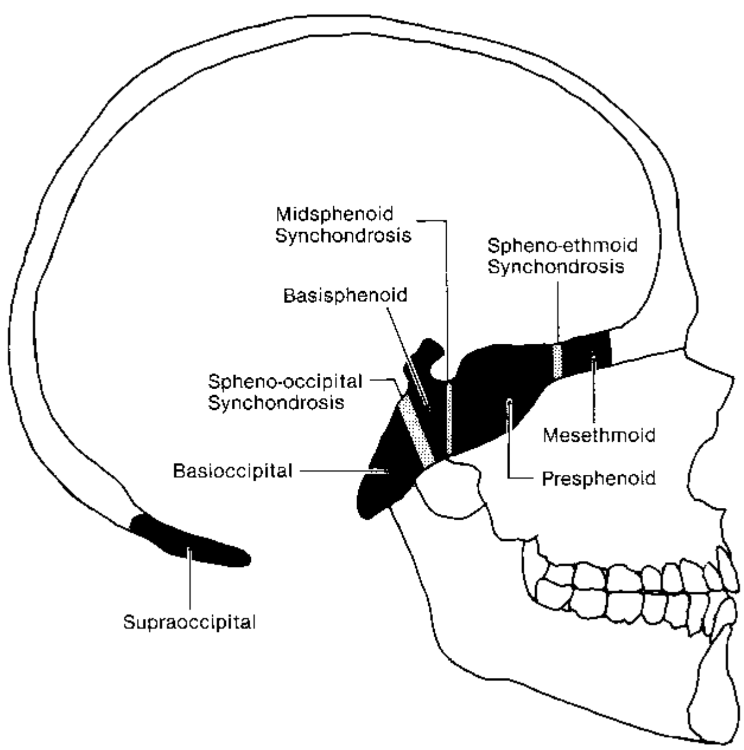


Figure 8–4. Schematic sagittal section of the adult skull illustrating the midline endochondral ossification centers of the base and the midline synchondroses that exist at birth.

centers encroaches upon and destroys most of these synchondroses, thereby leading to a unitized cranial base. Some synchondroses are overwhelmed quite early in childhood. However, the ossification center for that part of the occipital bone in front of the foramen magnum (i.e., the **basi-occipital center**) and that for back part of the body of the sphenoid (i.e., the **basisphenoid** center) remain separated by cartilage until puberty is completed. This **spheno-occipital synchondrosis** (see Fig. 8-4) is the major site of lengthwise growth of the base of the skull. In young children it is so thick that lateral radiographs of the skull show a gap between the basilar parts of the occipital and sphenoid bones. One may be tempted to interpret this gap as pathological, but recalling that cartilage does not show up on radiographs explains why this gap is to be expected.

Even in the adult there are regions of the cartilaginous cranial base that persist. The cartilaginous nasal septum, and the lateral nasal cartilages that branch from it, represent such regions. Another is the space on each side between the petrous portion of the temporal bone, on the one hand, and the lateral edges of the basilar parts of the occipital and sphenoid bones, on the other. The cranial end of this cartilage-filled space is expanded into a circular area several millimeters in diameter. Because cartilage is dissolved away during preparation of a skull for study, this circular area is left as the so-called **foramen lacerum**, from the posterior aspect of which extends the **petro-occipital fissure** (Fig. 8-5, see Fig. 8-3).

The base of the neurocranium, being preformed in cartilage, seems to follow a growth curve that is largely determined by genetic factors.

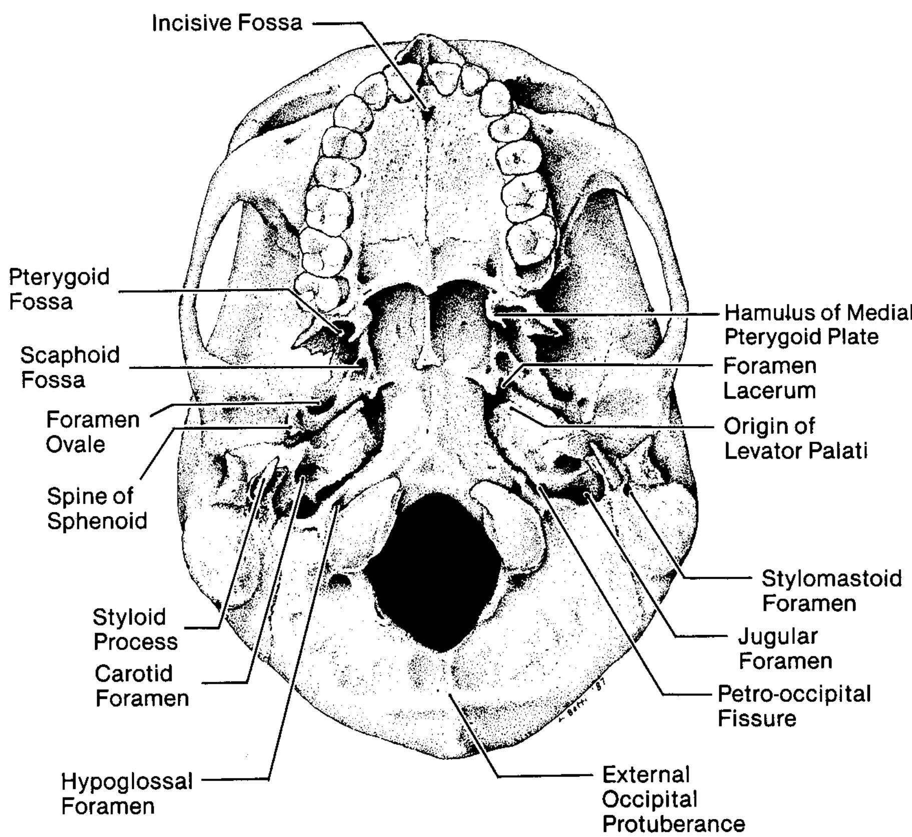


Figure 8–5. Inferior view of the skull (mandible excluded).

Membranous Portion of the Neurocranium--Sides and Top of the Braincase

Within the membrane overlying the fetal brain, several separate ossification centers form (Figs. 8-6*A*, 8-7*A*). On each side there is one center for (1) the supranuchal part of the occipital bone, (2) the parietal bone, (3) the squamous part of the temporal bone, (4) the part of the greater wing of the sphenoid that faces laterally, and (5) the frontal bone. Like the endochondral centers of the cranial base, the intramembranous ossification centers of the vault enlarge so that their borders approach one another (Figs. 8-6*B*, 8-7*B*). The centers for the right and left halves of the supranuchal part of the occipital bone fuse early in fetal life to form a single **interparietal** ossification center. On the other hand, even at birth the other intramembranous ossification centers are still separated by relatively wide strips of connective tissue. These are **neurocranial syndesmoses** (a syndesmosis being a joining of bone by connective tissue). They are given the special name of **sutures**. Between the two parietal ossification centers exists the **sagittal suture**. Between the two frontal centers exists the **metopic suture**. Separating the frontal centers from the parietal centers is the **coronal suture**. Separating the parietal centers from the interparietal center is the **lambdoidal suture**. Finally, a **squamous suture** intervenes between the center for the squamous part of each temporal bone and that for each parietal bone.

Where a fetal suture that courses in one direction runs into another that follows a different direction, the amount of connective tissue between the adjacent ossification centers is often considerable. These areas of extensive sutural connective tissue are called **fontanelles**; two of them are particularly noteworthy (see Fig. 8-6*B*). The **lambdoidal (posterior) fontanelle** is the connective tissue lying in the midline at the junction of the sagittal suture and the lambdoidal suture. A larger fontanelle lies more anteriorly, in the midline at the crossroads of the sagittal, coronal, and metopic sutures. This is the

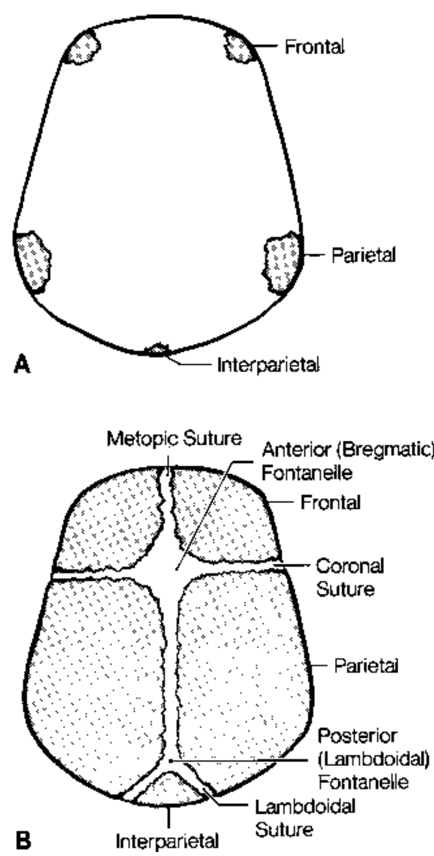
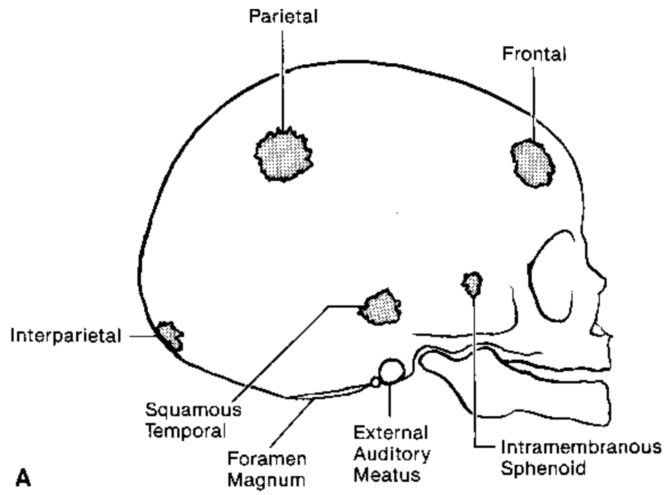


Figure 8–6. Schematic superior views of the fetal skull. *A*, A stage when the cranial vault is largely membranous but the intramembranous ossification centers *(shaded)* have already begun to form. *B*, At birth, when the intramembranous ossification centers have approached one another and now demarcate intervening sutures and fontanelles.



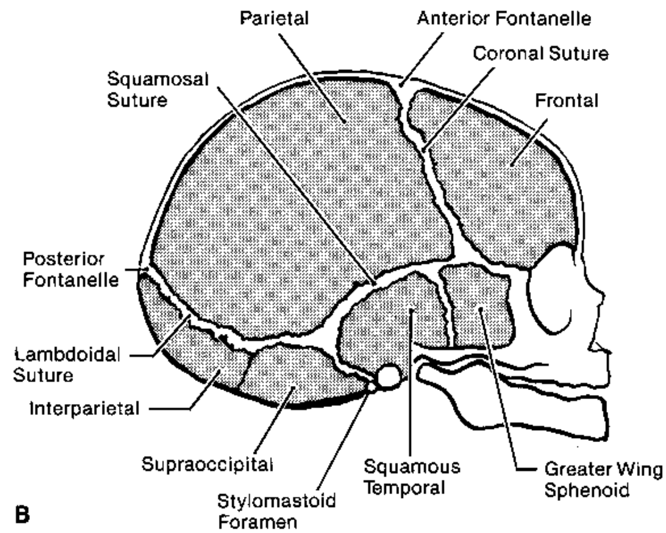


Figure 8–7. Schematic lateral views of the fetal skull depicting the same stages (*A*, *B*) as represented in Figure 8–6.

bregmatic (anterior) fontanelle. These two midline fontanelles represent soft regions that can be palpated through the skin overlying the skull of the newborn.

It is very useful to the fetus to have wide neurocranial sutures. They permit the bones of the vault to slide over one another by a small amount and, thus, allow the skull to yield to the pressures of childbirth without cracking. If you palpate the skull of a newborn you can usually feel the places where the edge of one bone overlaps its neighbor. Within a day or two after birth, the uniform pressure within the cranial cavity will cause such overlapping to disappear.

It would be quite disadvantageous for a postnatal human to have mobile bones of the cranial vault. After all, the function of these bones after birth is to provide a protective case for the brain. Thus, continued postnatal growth of the intramembranous ossification centers causes their edges to approach very close to one another and to interdigitate at their junction. The sutural connective tissue persists only as a very thin wavy band between the interdigitating bony spicules. Such a structure provides for the rigid joining of bones necessary to give strength to the cranial vault, while also maintaining just enough rapidly growing connective tissue to enable the braincase to accommodate the enlarging brain.

The fontanelles disappear as such when the child's sutural connective tissue becomes very thin. The site of a fontanelle merely becomes the point where sutures of different directions intersect. Where there was once a lambdoidal fontanelle, there is now only the **lambda**; the once large bregmatic fontanelle becomes the **bregma**.

It must be emphasized that sutures don't become thin overnight and that the disappearance of the fontanelles is gradual. The posterior fontanelle disappears during the first year of life and can no longer be palpated early during this period. The bregmatic fontanelle does not disappear completely until 18 months of age. It is often palpable during the entire first year of postnatal life. This fact endows the anterior fontanelle with particular clinical import. First, if the anterior fontanelle becomes so small that it cannot be felt as early as 4-5 months of age, the physician must anticipate premature sutural fusion (see further on). On the other hand, if the anterior fontanelle can be palpated well into the second year of postnatal life, the physician must consider causes of decelerated maturation (e.g., malnutrition).

The appearance of the scalp over the anterior fontanelle is another clue to the child's health. Increased intracranial pressure causes the connective tissue of the anterior fontanelle and its overlying scalp to bulge upward. Dehydration causes these tissues to be "sucked" downward, into the cranial cavity.

The importance of sutural connective tissue for growth of the cranial vault cannot be overestimated. The sutures grow in response to tension within them generated by intracranial pressure. Thus, the size of the cranial vault is not controlled genetically, but rather is a function of what is going on inside the braincase. If the newborn is microcephalic and the brain does not grow adequately, the cranial vault stays small. If the cranial contents become excessively voluminous, as in hydrocephalus, the cranial vault responds by excessive enlargement. Normally, the brain follows a growth curve that is very rapid in the first year and a half, and gradually trails off to puberty. It and the overlying cranial vault reach 90 per cent of adult size by the age of 6.

SUTURAL FUSION, BOTH NORMAL AND OTHERWISE

After adulthood, the sutural connective tissue is no longer essential for growth of the neurocranium. Nevertheless, this tissue usually persists well past puberty. In middle age the bones bordering any given suture may bridge across the connective tissue and fuse. The suture is then said to be obliterated. This happens a lot in some people and hardly at all in others. It is of no functional consequence.

The metopic suture is unusual in that its obliteration almost always occurs during early childhood. Typically, the metopic suture fuses completely by the age of 6, leaving the person with one frontal bone rather than the two he or she was born with. In rare instances the metopic suture does not become obliterated. It can then be visualized in anteroposterior radiographs as a wavy radiolucency in the midline of the frontal "bone." It is important to recognize this possibility so that such a wavy midline radiolucency is not mistaken for a fracture (which, by the way, is hardly ever in the midline and never appears wavy). More commonly a bit of the metopic suture just superior to the nasal bones persists well into adult life.

The other sutures are not supposed to fuse before adulthood because they are necessary for proper growth of the cranial vault. If any suture closes significantly before its period of growth normally ends, expansion of the cranial vault perpendicular to that suture is retarded. The remaining normal sutures will undergo excessive growth in order to keep the size of the vault in pace with intracranial contents. This leads to recognizable deformations of the skull. For example, if the metopic suture closes shortly after birth, the forehead ceases growth in width, but the back of the skull compensates. The result is as skull that, when viewed from the top, appears triangular, with the apex anteriorly. This is called **trigonocephaly**. If the sagittal suture closes prematurely, growth in width of most of the cranial vault will be retarded. Compensatory growth in the coronal suture will cause the braincase to become longer than normal, and compensatory growth in the lambdoidal and squamosal sutures will lead to excessive skull height. This condition is called **scaphocephaly**; it is the most common deformation due to premature sutural closure.

Premature sutural fusion is known as **craniosynostosis**. It comes in two varieties: simple (one suture fused) or compound (two or more fused sutures). Either may be primary (there are no other recognizable physical abnormalities) or secondary (associated with other obvious developmental defects). In simple primary craniosynostosis, the rate of mental retardation is 3-6% (somewhat higher when the coronal suture is fused than when the sagittal suture is fused). This value is 2 to 3 times greater than would otherwise be expected. In compound primary craniosynostosis, mental retardation occurs 35-50% of the time. Less severe learning disabilities appear in about half the children with simple primary craniosynostoses. It has not been determined whether the cognitive problems associated with craniosynostoses are caused by an underlying brain malformation, by increased intracranial pressure, or by a distortion of the brain due to the synostosis. Most people believe that the latter possibility is only reasonable when multiple sutures are fused.

Premature sutural fusion is treated surgically. In the simplest case, a strip of bone on either side of the fused suture is removed and some measure taken to prevent regrowth and closure. It has not been possible to demonstrate that surgery to correct the synostosis alters the cognitive development of the patient. One recent study on a small sample of children with simple synostosis, some of whom had surgery to correct it and others of whom did not, found no effect of surgical correction on rate of mental retardation or learning disability. The primary reason for performing such surgery is cosmetic.

Development of the Face

Like the cranial vault, the facial part of the skull is first laid down as a connective tissue sheet. This sheet is continuous with that of the cranial vault and with the perichondrium of the cranial base where it abuts the face. Numerous separate ossification centers form within the embryonic facial connective tissue. Each gives rise to a bone of the face, and sutures are created between these bones.

Also like the cranial vault, the growth of the face is highly dependent on the soft-tissue structures in the vicinity. Orbits are small if the eyes don't grow properly. Growth of the mandible and maxilla is influenced greatly by the tongue. Muscles attaching to the bones of the face play a role in determining the size of such bones.

Normally the eyes, and therefore the bony orbits, follow a growth curve similar to that of the brain. Other soft-tissue structures associated with the face develop at a different pace than do neural tissues. Nasal, oral, and muscular structures follow the so-called "general" body growth curve. General body structures undergo a slow-down in growth at about age 3, long before neural tissues begin their slow-down. From 3 years old to puberty, general body structures undergo steady but only moderate growth. At puberty they increase in size rapidly to reach their final adult size. Neural tissues have essentially stopped growing by puberty. Because the neurocranium and face follow such different patterns of growth, the braincase of a child is much larger in relation to its face than will occur later in life (see Fig. 8-7).

Growth of Two Special Skull Structures--the Mastoid Process and the Tympanic Bone

The mastoid process is a downward projection of the temporal bone behind the ear (see Fig. 8-1). The tympanic portion of the temporal bone is a tubular structure lying in front of the root of the mastoid process and forming the medial portion of the external auditory meatus (see Figs. 8-1, 8-5). If you look at the inferior surface of an adult skull, you will note a foramen located between the root of the mastoid process and the tympanic bone, posterior to the root of the styloid process (see Fig. 8-5). It is called the **stylomastoid foramen**, and it transmits the facial nerve into the retromandibular region of the neck. You should note that the stylomastoid foramen lies well away from the lateral surface of the skull. But such is not the case in newborns (see Fig. 8-7). This is because (1) the tympanic portion of the temporal bone of newborns is not tubular but is a simple ring with no significant mediolateral length, and (2) the mastoid process is undeveloped at birth, and subsequently grows as much outward as downward. Thus, in the newborn, the stylomastoid foramen is located behind the ear at the junction of the lateral and inferior surfaces of the skull (see Fig. 8-7), rather than 1 to 2 cm in from the lateral surface, as in adults.

You can imagine what might happen if you chose to assist delivery of the child by placing forceps behind the ear. The relatively superficial position of the stylomastoid foramen places the facial nerve in jeopardy of being crushed by the forceps, with catastrophic results for the future functioning of facial muscles. It is a cardinal rule of obstetrics that forceps never be placed behind the ears.

A second consequence of the short tympanic bone of newborns is that the eardrum is closer to the surface than in the adult. Like an adult, the child has a lateral cartilaginous part of the external auditory meatus, so the eardrum is not on the surface of the head, only relatively closer to it than will be the case later in life. One wants to be aware of this so that an otoscope is advanced more cautiously in the child than in the adult.

TEETH

Like most mammals, humans possess one set of small teeth that erupt early in life and are shed, and another set of larger teeth that erupt later and are meant to be permanent. The small teeth that will be shed are said to compose a **deciduous dentition**. At birth, the crowns of these teeth exist buried within the maxillae and mandible, below the gums, but they can be seen in radiographs of the skull. As the roots of the deciduous teeth develop, their crowns erupt through the gum surface into plain view. On each side of the upper and lower jaws, 5 deciduous teeth erupt. There are two incisors, one canine, and two premolars. Thus, a total of 20 deciduous teeth will exist. The deciduous incisors and canines look pretty much like the permanent incisors and canines that will come later. The deciduous premolars do not look like adult premolars. Rather, they have a crown structure resembling permanent molars. This makes sense, since the deciduous premolars are the grinding teeth of the child. Some authors simply refer to deciduous premolars as deciduous molars, but one must never lose sight of the fact that this is a functional, not developmental, nomenclature.

The first deciduous tooth to erupt is the medial incisor, at about 7 months. The last is the 2nd deciduous premolar, at about 2 years. The child has only deciduous teeth until about 6 years of age, at which time the 1st permanent molar erupts behind the 2nd deciduous premolar. From the age of 6 until the age of 12 the deciduous teeth are shed as growth of their permanent representatives causes resorption of their roots and pushes them out of the jaw. Following replacement of all deciduous teeth by their permanent representatives, the 2nd permanent molar erupts at about age 12. After a 6-year hiatus, the 3rd permanent molar erupts, although the development and eruption of this tooth is highly variable. It should be clear that the permanent molars have no deciduous precursors, but are simply added at the back of the jaw as its growth in length permits. The adult complement of teeth consist of two incisors, one canine, two premolars, and three molars in each half of each jaw (see Fig. 8-1). The total is, thus, 32.

CAVITIES OF THE HEAD

Cranial Cavity

The cranial cavity houses the brain. Persons interested in osteological details of the cranial cavity must consult a more comprehensive text. I wish to mention only a few salient facts. As you read further, it will help greatly if you can simultaneously look at a skull.

Posterior Cranial Fossa (Figs. 8-8, 8-9)

The floor of the cranial cavity is a three-tiered structure, with the lowest tier at the back and the highest at the front. The lowest tier of the cranial cavity is called the posterior fossa. It houses the cerebellum and much of the brainstem. In the floor of the posterior fossa is the large **foramen magnum**, through which the spinal cord and brainstem connect. We have already learned that the vertebral arteries enter the cranial cavity through this same hole, as do the apical dental ligament, upper band of the cruciate ligament of the atlas, and the tectorial membrane (upper end of the posterior longitudinal ligament of the spine). We shall now note that the spinal accessory nerves passes through the foramen magnum on their way up from the cervical spinal cord where they arise. Superior to the rim of the foramen magnum, anterolaterally, are the **hypoglossal foramina** that transmit the hypoglossal nerves forward out of the cranial cavity. These are separated by a bony ridge from the more laterally placed **condylar emissary foramina**, through which the condylar emissary veins pass backward out of the cranial cavity.

The middle part of the anterior wall of the posterior fossa is formed by the so-called **clivus** (which is the internal surface of the apposed basilar portions of the occipital and sphenoid bones) and its upward extension--the **dorsum sellae**. On either side of the clivus, the anterior wall of the posterior cranial fossa is formed by the petrous parts of the temporal bones and, below them, by the parts of the

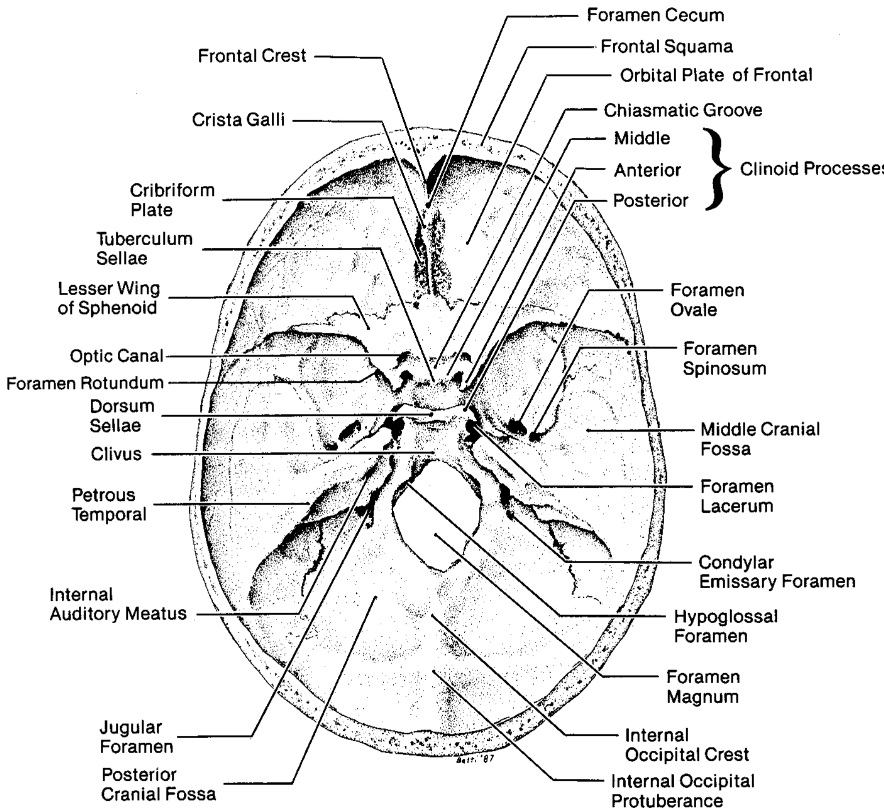


Figure 8–8. Superior view of the floor of the cranial cavity.

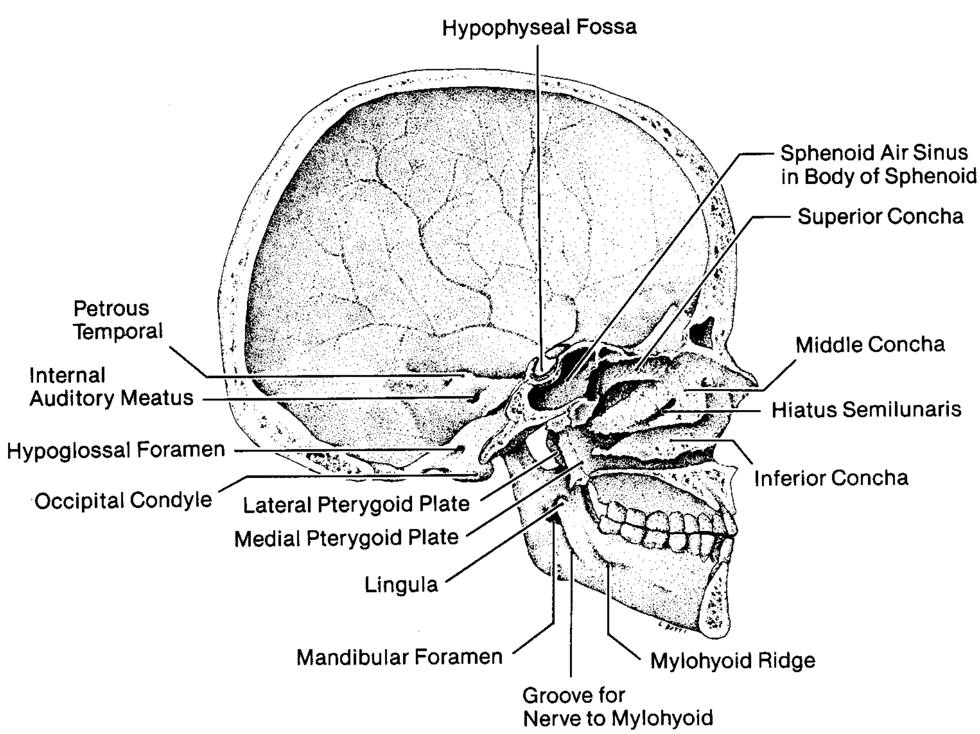


Figure 8–9. View of the skull in sagittal section. The middle concha has been made semitransparent to allow visualization of the hiatus semilunaris.

occipital bone from which the condyles are suspended. Between each petrous temporal and the occipital bone is a bipartite gap called the **jugular foramen**. The large posterolateral part of the jugular foramen contains the beginning (bulb) of the internal jugular vein. The small anteromedial part passes cranial nerves IX, X, and XI out of the cranial cavity. On the back wall of the petrous temporal, superior to the jugular foramen, is the **internal acoustic meatus** that leads the facial and stato-acoustic nerves through the bone toward the inner and middle ears.

Extending backward from the posterior rim of the foramen magnum, in the median sagittal plane, is a ridge of bone called the **internal occipital crest**. After a couple of inches it terminates in a bump called the **internal occipital protuberance**. Various grooves (sulci) are found in the posterior and lateral walls of the posterior fossa. They mark the sites of dural venous sinuses to be discussed subsequently.

Middle Cranial Fossa (see Figs. 8-8, 8-9)

The middle of three cranial tiers is the middle cranial fossa. Laterally this fossa houses the temporal lobes of the brain; in the center of the fossa lies the pituitary gland. Each lateral part of the fossa has a floor formed mainly by the superior surface of the petrous temporal and the base of the greater sphenoid wing. Near the petrosphenoid junction, the base of the greater wing has two holes. The smaller more posterolateral hole is the **foramen spinosum**, for passage of the middle meningeal vessels. The larger hole, anteromedial to the foramen spinosum, is the **foramen ovale**, for passage of the mandibular division of trigeminal nerve. Posteromedial to the foramen ovale, on the anterior surface of the petrous temporal near its tip, is a depression that marks the location of the semilunar ganglion of the trigeminal nerve. The bony floor of this depression separates the trigeminal nerve from the internal carotid artery, which is deep within the petrous temporal. The artery leaves its canal within the petrous temporal to enter the middle cranial fossa on the superior surface of the cartilage that occupies the **foramen lacerum**. Here, the internal carotid turns sharply upward, grooving the lateral surface of the body of the sphenoid.

Each lateral part of the middle cranial fossa has an anterior wall formed primarily by the greater wing of sphenoid. At the base of the greater wing, where the anterior wall of the fossa meets its floor, is the **foramen rotundum**, which passes the maxillary division of trigeminal. Superior to the foramen rotundum is a teardrop-shaped gap in the anterior wall of the middle cranial fossa. This is the **superior orbital fissure**, located between the greater and lesser wings of the sphenoid. It passes most of the nerves that enter the orbit and the veins that leave it. Each lesser wing of the sphenoid has a sharp posterior edge that terminates medially in an expansion known as the **anterior clinoid process**.

The middle portion of the middle cranial fossa is formed by the body of the sphenoid, which is excavated for reception of the pituitary gland. The excavation is called the **hypophyseal fossa** and is technically a part of a greater structural complex called the **sella turcica** (“turkish saddle”), which includes other structures on the upper surface of the sphenoid body. However, almost everybody uses the terms "sella turcica" and "hypophyseal fossa" synonymously.

Behind the hypophyseal fossa is the upward sheet of sphenoid bone called the **dorsum sellae**. Its upper lateral angles are expanded as the **posterior clinoid processes**. The broad bump in the middle of sphenoid just in front of the hypophyseal fossa is the **tuberculum sellae**. On either side of the tuberculum sellae are tiny bumps called **middle clinoid processes**. A ligament stretches between a middle clinoid process and the tip of the ipsilateral anterior clinoid process. This ligament is called the **interclinoid ligament**, and its very presence creates in life a foramen, bounded laterally by the anterior clinoid process. Through the foramen passes the internal carotid artery. Thus, the foramen is given the name **caroticoclinoid foramen**. Occasionally the interclinoid ligament is ossified, allowing the caroticoclinoid foramen to be seen in a prepared skull.

Anterior to the tuberculum sellae is the so-called **chiasmatic groove**, which is named for the optic chiasm, although the latter does not actually contact the bone here. At the lateral extremities of the chiasmatic groove are the **optic foramina**, one in each lesser wing of the sphenoid for transmission of the optic nerve and ophthalmic artery between the orbit and cranial cavity.

Anterior Cranial Fossa

The final, highest tier of the cranial cavity is the anterior fossa. At its extreme posterior limit its floor is formed primarily by the body and lesser wing of the sphenoid. The rest of the floor of the anterior cranial fossa is formed almost entirely by the horizontal **orbital plates of the frontal bone**. The anterior wall of the anterior fossa is formed by the vertical **squama of the frontal bone**. Projecting inward from the midline of the squama, just above the site where it joins the floor of the anterior fossa, is a crest of bone called the **frontal crest**.

In the middle of the floor of the anterior fossa is a rectangular area composed of an extensively perforated bony plate from the midline of which a triangular process projects upward, posterior to the frontal crest, and separated from it by a hole in the floor of the fossa. This perforated plate is the **cribriform plate** of the ethmoid bone (L. *cribrum*, meaning "sieve"). The median sagittal triangular process is the **crista galli** (crest of the cock); the hole between crista galli and frontal crest is the **foramen cecum**, which some people say passes an emissary vein.

Periosteum and Dura Within the Cranial Cavity (Fig. 8-10)

In a prepared skull (or radiograph of the skull of a living person), the cranial cavity appears as one large open space with a three-tiered floor. However, when the soft-tissues can be visualized, the situation is quite different, because the dura of the brain participates in some rather complex formations that partition the cranial cavity into smaller regions with narrow communications between them. To understand these formations, we must understand a bit about the periosteum of the skull.

All bones have **periosteum** on their outer surfaces. If the bone has a marrow cavity, this cavity is lined by a connective tissue called **endosteum**. The bones of the skull are no different. However, students are often confused when they think about the bones of the cranial cavity, because both the surface that faces into the cavity, and the surface that faces the scalp or neck are outer, periosteal surfaces. Most of the bones of the cranial vault have only a thin marrow cavity interposed between the inward facing compact bone (**inner table**) and the outward facing compact bone (**outer table**). This marrow cavity is the **diploe**; naturally, it is lined with endosteum.

Wanting to have a name for the periosteum on the outer table of bone (i.e., the periosteum beneath the scalp), anatomists chose to call it **pericranium**. The periosteum on the inner table (i.e., the periosteum lining the cranial cavity) is called **endocranium**. Endocranium is not the same as endosteum. Its only unique trait is that it is rather loosely attached to the actual osseous surface. Endocranium and pericranium are continuous at the sutures.

The endocranium is really the same sort of tissue as adheres to the inner surface of a vertebra, facing the vertebral canal. It will be recalled that intervening between the periosteum of the vertebral canal and the dura of the spinal cord is a fatty connective tissue with the internal vertebral plexus of veins running through it. This tissue and these veins are said to occupy an epidural space. In the cranial cavity,

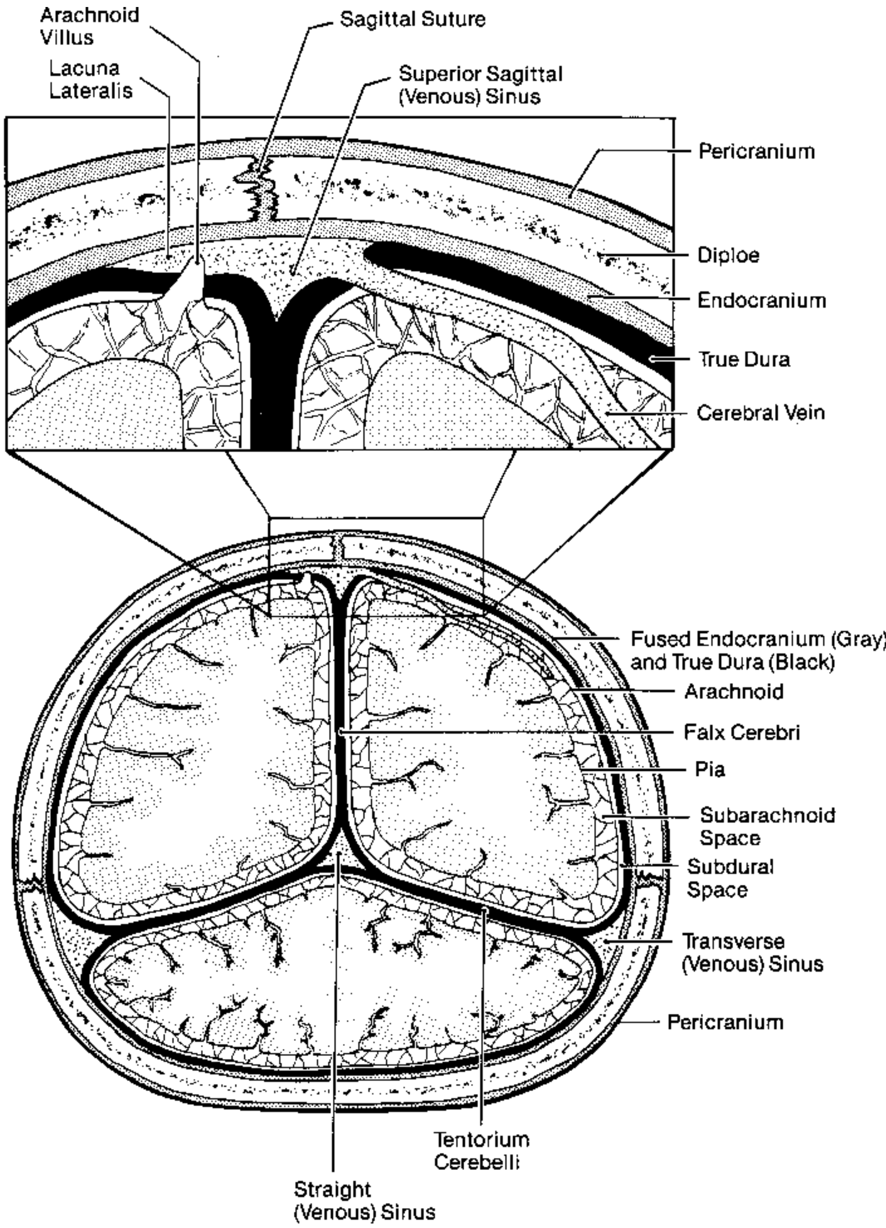


Figure 8-10. Schematic coronal section of the cranium taken posterior to the foramen magnum and illustrating the relationships between the periosteum, meninges, and dural venous sinuses.

the endocranium and dura are actually fused over vast areas. Thus the epidural space is obliterated. The fusion of cranial dura to endocranium has led to a confusion in terminology. Most clinicians choose to call the fused layers by the single term "dura." When they want to refer to endocranium, they speak of the **outer layer of the cranial dura**. When they want to refer to the layer equivalent to the spinal dura, they speak of the **inner layer of the cranial dura**. Using this nomenclature, the term "epidural space" comes to mean the potential space between the endocranium and the inner table of bone. It is this "epidural space" that epidural hematomas occupy (see further on).

I find it useful to be able to refer to the space between endocranium and the true cranial dura. However, I would not want to use the term "epidural" to name this space, for such usage would conflict with common clinical practice. Therefore, I shall coin the term "**subendocranial**" for that space in the cranial cavity homologous to the epidural space of the spine. As we know, the subendocranial space is largely obliterated, but we shall soon learn that it does persist at some locations.

Whereas the spinal dura is pretty much a simple tubular sleeve, the true cranial dura is far more complex. At specific sites it breaks away from the endocranium and invaginates into the cranial cavity as a double-layer fold. Two major dural folds--the tentorium cerebelli and the falx cerebri--are developed.

Tentorium Cerebelli (Fig. 8-11). On each side, from a line that starts at the internal occipital protuberance, runs laterally and then forward toward the upper margin of the petrous temporal, and finally passes anteromedially along this margin as far as the anterior end of the trigeminal impression, the true dura separates from the endocranium and passes inward to form a dural fold called the **tentorium cerebelli** (tent over the cerebellum). The tentorium cerebelli lies in a transverse plane. The root of the tentorium is continuous at its anterior end with a small dural fold that stretches from the upper margin of the petrous temporal across to the posterior clinoid process. This dural fold is called the **petroclinoid ligament**.

Fibers sweeping inward from the posterior half of the tentorial root on the right side actually meet their counterparts from the left side at the median sagittal plane. Fortunately, the tentorial fibers arising further anteriorly, from each petrous temporal, stop well short of the midline, so that an oval gap behind the dorsum sellae is created to allow passage of the brainstem from the posterior cranial fossa into the middle cranial fossa. The oval gap is called the **tentorial notch**. Its margins are strengthened by circumferential fibers that pass forward on either side into the middle cranial fossa to reach the anterior clinoid process. Thus, part of the margin of the tentorial notch lies lateral to the hypophyseal fossa and might be said to be "**parahypophyseal**." Dural fibers stretch from the petroclinoid ligament across to the

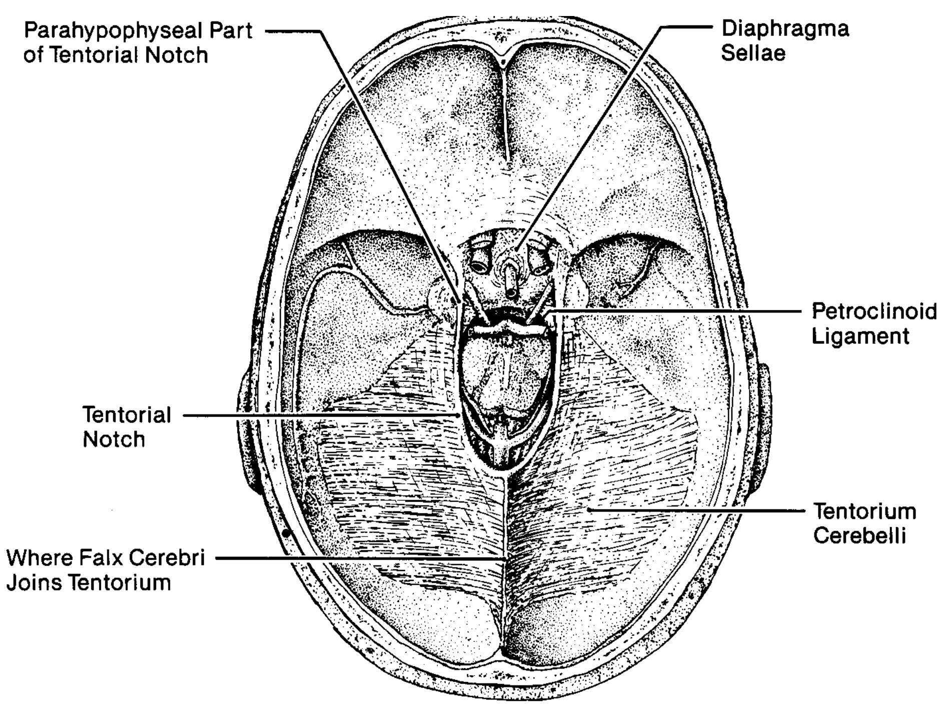


Figure 8-11. Superior view of the tentorium cerebelli.

parahypophyseal border of the notch anterior to the point of their crossing. This sheet of dura forms the roof of the cavernous sinus, which we will learn about shortly.

Falx Cerebri (Fig. 8-12). On the inner surface of the cranial vault, along a line that runs from the crista galli all the way back to the internal occipital protuberance, the true dura separates from the endocranium and dives downward into the cranial cavity. Posteriorly, the layers of this fold meet and merge with the superior layer of the tentorium, forming a triradiate junction (see Fig. 8-10). Elsewhere, this dural fold has a free lower edge that is more or less semicircular in profile (see Fig. 8-12). Looking like a sickle, this median sagittal fold of dura is called the **falx cerebri** ("falx" is the Latin word for "sickle"). It is placed between the right and left cerebral hemispheres, stopping just short of the upper surface of the corpus callosum, which must be able to pass from one side of the cranial cavity to the other. Being interposed between the cerebral hemispheres, the falx cerebri provides a useful mechanical barrier to undesirable side-to-side movement of the hemispheres that would otherwise occur during rapid displacement of the skull.

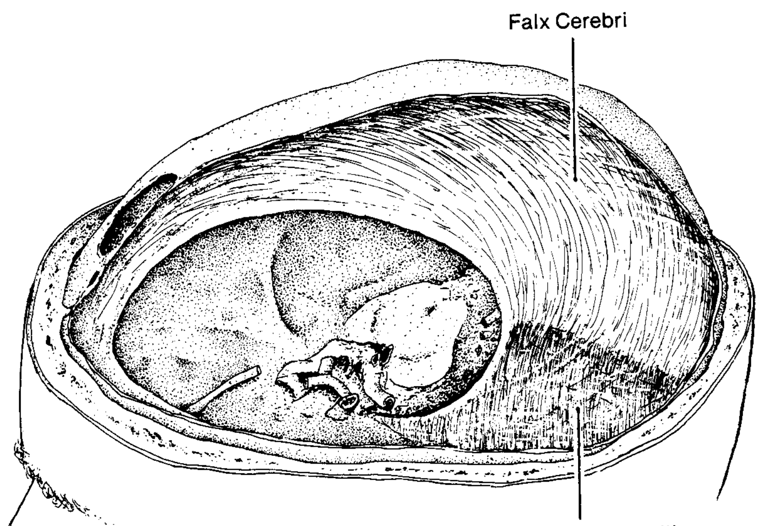


Figure 8–12. Oblique lateral view of the falx cerebri and tentorium cerebelli.

Lesser Dural Folds--Falx Cerebelli and Diaphragma Sellae. The falx cerebri and tentorium cerebelli are the most important folds of cranial dura, but they are not the only ones. Along the occipital crest the dura separates from endocranium to form a small median sagittal fold called the **falx cerebelli**. It passes but a short distance upward between the cerebellar hemispheres. Superiorly, the falx cerebelli merges with the lower surface of the tentorium near the internal occipital protuberance. Thus, just in front of this bump, there is a quadriradiate junction formed by the falx cerebri merging with the upper layer of tentorium and the falx cerebelli merging with its lower layer.

From the roofs of the two cavernous sinuses (see below), from a line connecting the two anterior clinoids, and from a line connecting the two posterior clinoids, the dura sweeps inward toward a point just superior to middle of the hypophyseal fossa (see Fig. 8-11). This fold--called the **diaphragma sellae**--stops short, leaving a circular gap through which the stalk of the pituitary gland descends. The diaphragma sellae forms a roof over the pituitary gland.

Dural Venous Sinuses

Dural Venous Sinuses in the Subendocranial Space at the Roots of Dural Folds (see Fig. 8-10). At the sites where true dura separates from endocranium to participate in formation of a dural fold, the opportunity arises for the creation of real subendocranial spaces. Such a space will exist until the two dural sheets that form any fold actually adhere to one another. Thus, each of these subendocranial spaces will be triangular in cross section, with the base being formed of endocranium and the side walls composed of true dura. An endothelium lines both the endocranium and dura bounding these spaces, and they are used as venous blood channels. They are called **dural venous sinuses**. Given their location between endocranium and true dura, the dural venous sinuses located in the roots of dural folds can be seen to be nothing more than modified versions of the internal vertebral veins.

The dural venous sinus formed at the root of the falx cerebri is the **superior sagittal sinus**. Narrow anteriorly, it becomes increasingly voluminous as the root of the falx approaches the internal occipital protuberance. At certain sites along the course of the superior sagittal sinus, endothelial outpocketings push laterally a short distance between the true dura and endocranium lining the cranial vault. These outpocketings form the so-called **lacunae laterales** of the superior sagittal sinus. They are particularly important because the subjacent arachnoid covering of the brain sends its own numerous outpocketings through the inferior (dural) wall of a lacuna to be bathed by blood contained therein. These are called **arachnoid villi** (or granulations). Through the wall of each villus cerebrospinal fluid passes into the venous system. With age, the arachnoid villi may become so large as to press on the superior (endocranial) wall of a lacuna and thereby cause resorption of inner-table bone. This is not pathological; it merely explains the depressions in the inner table seen near the groove for the superior sagittal sinus in prepared skulls or radiographs .

Along the root of the tentorium cerebelli, from the internal occipital protuberance all the way around to the petrous temporal, is formed the **transverse sinus**. It is said that there are two transverse sinuses, one on the left and one on the right, but they usually communicate across the posterior midline. Since the root of the tentorium meets that of the falx cerebri near the internal occipital protuberance, the opportunity arises for the superior sagittal sinus to join up with the transverse sinuses. If the communication between transverse sinuses is big, the superior sagittal will empty into this communication. Otherwise, the superior sagittal sinus will pass into one or the other of the transverse sinuses.

Along the root of the falx cerebelli is the rather small **occipital sinus**. Inferiorly, the occipital sinus communicates with the internal vertebral venous plexus through the foramen magnum. Superiorly, where the root of the falx cerebelli joins the root of the tentorium, the occipital sinus also opens into one of the transverse sinuses or into the communication between them. We often have a situation in which four sinuses (right and left transverse, superior sagittal, and occipital) all join at one site. This site is called the **confluence of sinuses**.

One more dural venous sinus is created at the root of a dural fold. This occurs along the petrous origin of the tentorium and is called the **superior petrosal sinus**. It is just a smaller anterior continuation of the transverse sinus.

Dural Venous Sinuses in the Subendocranial Space Independent of Dural Folds. Not all the venous sinuses with the subendocranial space are formed at the roots of dural folds. At some sites there simply occurs an endothelial-lined separation of true dura and endocranium not associated with any infolding of the dura. One of the most important of these sites extends from the junction of the transverse and superior petrosal sinuses downward and then medially to the jugular foramen. The sinuous course of this channel accounts for its name of **sigmoid sinus**. It terminates at the jugular foramen of the skull, where it is continuous with bulb of the internal jugular vein. The free part of the vein itself passes downward from its bulb.

Another very important dural sinus not associated with a dural fold is the **cavernous sinus** (Fig. 8-13). It is a simple separation of a square patch of dura from endocranium on the lateral surface of the sella turcica. It is called "cavernous" because strands of connective tissue bridge between dura and endocranium, creating a meshwork that seems to surround caverns within what is actually one blood-filled space.

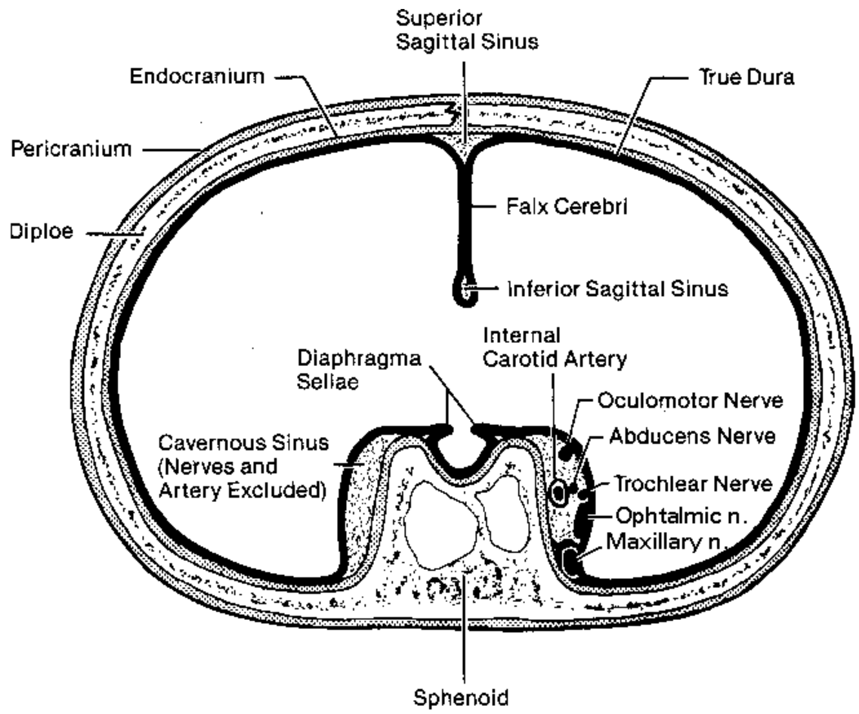


Figure 8–13. Schematic coronal section of the cranium taken through the sella turcica and illustrating the relationships of the periosteum, true dura, and cavernous sinuses.

The cavernous sinus is peculiar not only by possessing a transmural meshwork, but also by virtue of the fact that various nerves and the internal carotid artery run through its blood-filled space. This can be seen to be less remarkable by realizing that any nerve from the brain that wishes to leave the cranial cavity will have to pass through both dura and endocranium to get out. Some nerves first pierce the dura and then run for a while in the subendocranial space before finally going through periosteum. It is simply the case that a few nerves run in the blood-filled subendocranial space called the cavernous sinus. (A similar logic applies to the internal carotid arteries coming from outside the skull and going to the brain.)

Just how each nerve that travels through the cavernous sinus actually gets there will be described later. Suffice it to say now that the oculomotor, trochlear, and ophthalmic portion of the trigeminal run forward in the sinus with their epineuria adherent to the lateral (true dural wall), whereas the abducens runs forward more medially in the sinus, bathed by venous blood on all sides (see Fig. 8-13). The internal carotid artery is also completely bathed by blood but is still further medial than the abducens nerve. The maxillary nerve usually runs inferior to the cavernous sinus, but if the latter is especially large, this nerve too may be applied to the lateral wall of the sinus.

The upper posterior corner of the cavernous sinus is in communication with the superior petrosal sinus. The upper anterior corner communicates with a small sinus formed by separation of true dura from endocranium along the back edge of the lesser wing of the sphenoid. This is the **sphenoparietal sinus**.

A final subendocranial sinus not associated with a dural fold is the **inferior petrosal sinus**. it forms by separation of true dura from endocranium along the fissure between the clivus and petrous temporal. Anteriorly it communicates with the cavernous sinus; posteriorly it ends at the jugular foramen by joining the jugular bulb. Between the right and left inferior petrosal sinuses are communicating channels that altogether are said to form a **basilar plexus** sitting on the clivus. Inferiorly this basilar plexus communicates with the internal vertebral venous plexus through the foramen magnum. Often there are channels are on either side of the foramen magnum connecting the basilar plexus with the occipital sinus. Each such channel is called a **marginal sinus**.

Dural Venous Sinuses Not in the Subendocranial Space. I am sure everyone is tired of reading about dural venous sinuses, but there are still a few more to be mentioned. These are special in that they don't lie in the subendocranial space at all, but rather occupy a space created between the two layers of dura that make a dural fold. Thus, in the free edge of the falx cerebri, just where the left and right layers of dura join, is a longitudinal venous space called the **inferior sagittal sinus** (see Fig. 8-13). Traced posteriorly, this sinus arrives at the site where the free margin of the falx joins the tentorial notch (see Fig. 8-12). Here, the inferior sagittal sinus turns posteriorly, as the so-called **straight sinus** to travel in the intradural space at the triradiate junction of falx cerebri and tentorium (see Fig. 8-10). The straight sinus ends in the confluence of sinuses (or in one of the transverse sinuses).

Between the two layers of dura that form that part of diaphragm sellae in front of the pituitary stalk is a transverse venous channel connecting the right and left cavernous sinuses. This is the **anterior intercavernous sinus**. A similar **posterior intercavernous sinus** exists between the two layers of dura that form that part of the diaphragma sellae behind the pituitary stalk.

Cerebral Veins

The larger cerebral veins course within the subarachnoid space to reach one or another dural venous sinus. Naturally, such a vein must first pierce the arachnoid (actually the arachnoid merges with the vascular adventitia) before finally piercing true dura to empty into a sinus. Because of the pattern of flow within the dural sinuses, most blood from the brain eventually finds its way into the sigmoid sinus and internal jugular vein.

Particularly important is the fact that the veins on the lateral and superior surfaces of the cerebral hemispheres pass to the superior sagittal sinus (see Fig. 8-10). Cerebral veins that are destined for the sinus turn forward while still in the subarachnoid space to approach the dural wall of the sinus at an acute angle. These veins then travel obliquely forward through the dural wall before opening into the sinus.

To some degree the oblique course of cerebral veins into the superior sagittal sinus minimizes the likelihood that forward and backward motion of the cerebrum will cause the veins to shear off the sinus wall. However, apparently such a mechanism is imperfect, for occasionally a severe blow to the front or back of the skull causes such large anteroposterior displacements of the brain that some cerebral veins do shear off the sinus wall. Blood then spills into the subdural space producing a **subdural hematoma**. The blood is under low pressure and accumulation is usually gradual. Symptoms of cerebral compression may not occur until much later, when the blood breaks down and forms a fluid of high osmotic pressure that draws in further tissue fluid causing an increase in size.

Lastly, it should be mentioned that veins from the middle ear find their way to the superior petrosal sinus. This is of clinical significance as a route of spread of infection from the middle ear to the superior petrosal and transverse sinuses.

Emissary Veins

An emissary vein is a venous channel that runs from a dural sinus to a vein outside the cranial cavity. In addition to such channels, there is a giant emissary system formed by the **diploic veins**. The latter lie between the inner and outer tables of the cranial vault, communicate with one another, and empty into either the dural sinuses or veins of the scalp, face, and head. Individual emissary veins are a more direct route of communication. The more important emissary veins take the following paths:

1. Through the foramen ovale and/or foramen lacerum, establishing a communication between the cavernous sinus and veins around lateral pterygoid muscle (pterygoid venous plexus).

2. Through a hole at the back of each mastoid root, establishing a communication between the beginning of the sigmoid sinus and the veins of the scalp. These are the **mastoid emissary veins**.

3. Through a hole immediately behind each occipital condyle, establishing a communication between the termination of sigmoid sinus and the deep veins of the neck. These are the **condylar emissary veins**.

4. Through a hole in each parietal bone just lateral to the sagittal suture (at the junction of its anterior three quarters with its posterior one quarter), establishing a communication between the superior sagittal sinus and veins of the scalp. These are the **parietal emissary veins**.

The **superior and inferior ophthalmic veins** (to be discussed in more detail later) are kinds of emissary veins. The superior ophthalmic vein is in open communication both with superficial veins at the medial corner of the eye and with the cavernous sinus. The inferior ophthalmic vein, which also goes to the cavernous sinus, is connected to the pterygoid plexus via a communicating channel that passes through the inferior orbital fissure.

Although blood from the brain generally reaches the sigmoid sinus and internal jugular vein, it need not do so. Blood that has reached the dural venous sinuses may flow out to extracranial veins via emissary routes. The existence of such alternate routes is insurance that there will never be retardation of venous drainage from the brain.

CLINICAL SIGNIFICANCE OF EMISSARY VEINS

The routes of venous flow permitted by emissary veins are of considerable clinical significance. First, if a dural sinus becomes infected and thrombosed by virtue of some intracranial disease, the superficial veins with which that sinus communicates will become dilated, and the tissue drained by these superficial veins will become edematous. For example, thrombosis at the junction of the transverse and sigmoid sinuses secondary to a middle ear infection will lead to dilated veins and swollen tissue over the mastoid process. The thrombus and infection may even spread to this region.

More important than extracranial signs arising from an intracranial disease is the possibility, afforded by emissary veins, that infections in the face, nasal cavity, and scalp may be carried into the cranial cavity. Because emissary veins, diploic veins, and dural sinuses have no valves, any infectious material that penetrates a small vein of the face, scalp, or nasal cavity may flow through an emissary vein into one of the dural sinuses and produce a septic thrombosis within it. Such a state can progress to bacteremia, meningitis, or encephalitis.

CAVERNOUS SINUS THROMBOSIS

Infections of the face pose the very serious threat of passage to the cavernous sinus. One route is from the communication established between the facial vein and the cavernous sinus by the superior ophthalmic vein. Another, more complicated, route starts out by passing from the facial vein to the pterygoid plexus via the deep facial vein. Then, from the pterygoid plexus infectious material may spread to the cavernous sinus via the emissary vein through the foramen ovale, or via the emissary vein that runs through the inferior orbital fissure to the inferior ophthalmic vein. The cavernous sinus, having numerous transmural trabeculae, is a trap for infectious material.

The potential threats to life resulting from cavernous sinus thrombosis are the same as those of any other sinus thrombosis. However, before these occur, existence of cavernous sinus thrombosis is betrayed by a series of other symptoms. First there occurs a swelling of the eyelids and neighboring tissues, owing to retardation of venous flow through the superior ophthalmic vein (either hydrostatically or because the superior ophthalmic vein itself becomes thrombosed). Second, there is dilatation of retinal veins (which may be visualized ophthalmoscopically) and edema of orbital tissues (which causes the eyeball to move forward--a condition known as exophthalmos). The optic nerve may or may not become swollen.

Because important nerves run through the cavernous sinus, an inflammatory state within it will soon produce symptoms related to axonal malfunctioning. Thus, pain or tingling over the sensory distribution of the ophthalmic nerve will develop. This will be followed by anesthesia over the same area. Weakness (paresis) and then paralysis of the muscles supplied by the oculomotor, trochlear, and abducens nerves becomes apparent. Usually, the abducens nerve is the first to be affected because of its central location within the sinus. In the rare case that the maxillary nerve has a course through the lower part of the sinus, its areas of sensory distribution may be subject to the same disturbances as those of the ophthalmic nerve. Later in the text we will learn enough about the involved nerves to predict the actual symptoms of their malfunctioning.

As if septic thrombosis of one cavernous sinus were not bad enough, the existence of intercavernous sinuses permits spread from one side to the other. Hopefully, long before this happens, the patient will have been treated with antibiotics. Nerve symptoms will then disappear and collateral routes of venous drainage will expand, or the thrombus will resolve.

Cranial Arachnoid and Pia

The **pia** of the brain is actually thinner than the pia of the spinal cord, and also differs from the spinal pia in being only loosely attached to the external surface of the neural tissue. The spinal cord has a ventral median fissure into which the pia naturally follows. The brain has numerous grooves and sulci into the depths of which the cranial pia goes.

The **arachnoid** of the brain differs from that of the spinal cord in three rather important ways. First, the cranial arachnoid is thicker than the spinal arachnoid. Second, cranial arachnoid is connected to cranial pia by numerous fibrous bridges that cross the fluid-filled subarachnoid space. In a dissection, if you pull the cranial arachnoid away from brain, the pia comes with it. Finally, as mentioned above, the cranial arachnoid in the vicinity of the superior sagittal sinus is characterized by numerous villous outpocketings that project into the lacunae laterales and serve to pass cerebrospinal fluid into the blood (see Fig. 8-10).

Unlike the pia, the arachnoid does not dive into the grooves on the external surface of either the brain or spinal cord. Thus, the sulci of the cerebral hemispheres are filled with cerebrospinal fluid (CSF). There exist even larger accumulations of CSF at sites where the cranial arachnoid bridges across larger groves in the external surface of the brain. These accumulations are called **subarachnoid cisterns**.

Probably the most well known subarachnoid cistern occurs where the arachnoid sweeps off the posterior surface of the cerebellum onto the dorsal surface of the medulla. This so-called **cisterna magna** is of particular clinical significance because it can be entered by a needle inserted through the posterior atlanto-occipital membrane and then upward and forward through the foramen magnum. Such a **cisternal puncture** is a more dangerous approach to obtaining cerebrospinal fluid than is the lumbar puncture. It is sometimes done if the physician has evidence of increased cerebrospinal fluid pressure. A lumbar puncture is generally contraindicated in cases of increased intracranial pressure because rapid withdrawal of spinal CSF may cause a pressure differential that results in portions of the cerebellum and brainstem being pushed downward through the foramen magnum. A properly performed cisternal puncture eliminates this risk.

The major vessels of the brain run within the subarachnoid space on the surface of the pia. Leakage from one of these vessels (more often an artery than vein) leads to blood mixing with the cerebrospinal fluid. One reason for performing a lumbar puncture is to enable detection of subarachnoid hemorrhage.

Orbital Cavity and Eye

Eyeball

Each eye begins as a laterally directed tubular outpocketing--the **optic diverticulum**--from the diencephalic region of the embryonic brain. Later during development the eyes rotate to their normal position facing toward the front. Any term of direction that I use assumes this normal position.

As the tip of the optic diverticulum approaches the body wall ectoderm, the diverticulum expands into a cup-shaped structure (**optic cup**) connected to the brain by a narrower **optic stalk**. The cells that form the cup will become the **retina**, with an inner **neural layer** that is photosensitive and an outer **pigmented layer** that is not (Fig. 8-14). Axons from cells of the neural layer of the retina grow back to the brain through the optic stalk, which then becomes the **optic nerve**. The site where the optic nerve joins the retina is called the **optic disc**. It is located a few millimeters medial to the posterior pole of the eyeball. The most discriminating part of the neural retina lies at the posterior pole of the eye. For reasons that histologist will explain to you, there is a depression here called the **fovea centralis**. When we want to see something clearly, we always position our eyes so that the image falls on the fovea.

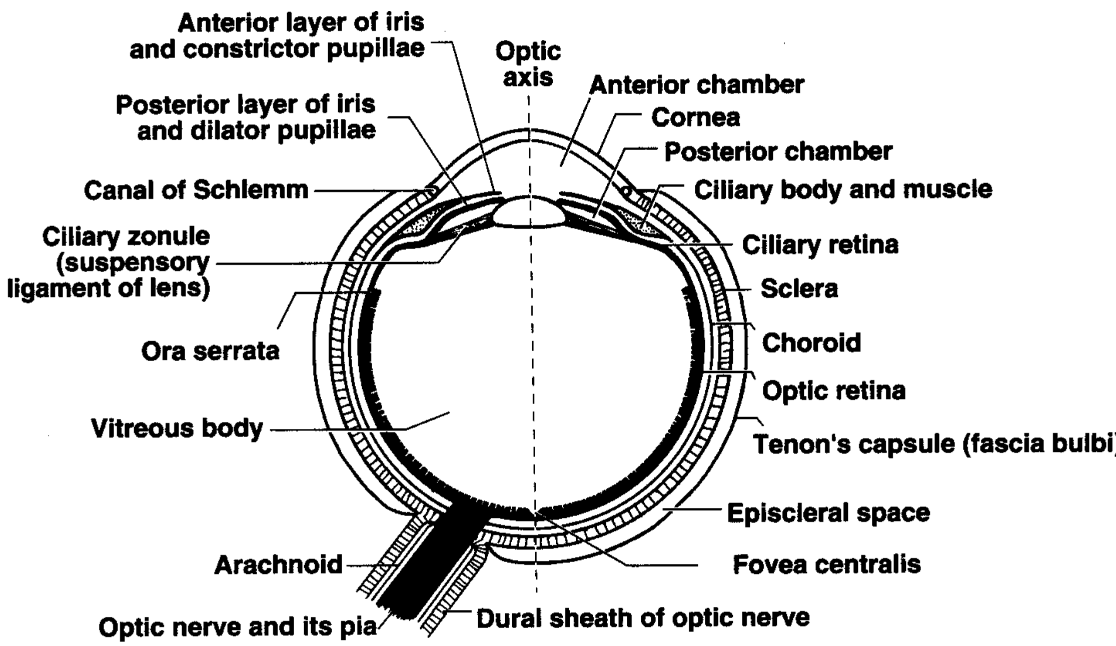


Figure 8–14. Schematic transverse section of the eyeball. The retina, uvea, and sclera have been drawn as if they do not adhere to one another, but in fact they do.

The retina forms almost a complete sphere, but has a circular defect - the **pupil -** anteriorly (see Fig. 8-14). That anterior one-quarter of the neural layer (i.e., the quarter near the pupil) does not participate in differentiation of photosensitive cells. Thus, encircling the pupil is the **nonoptical** part of the retina.

The presence of the optic cup near the embryonic ectoderm induces the development of the **lens**, which is an invagination of this ectoderm that pinches off, solidifies, and assumes a position deep to pupil. Once the lens vesicle pinches off, the surface ectoderm is reconstituted. It will eventually become the **bulbar conjunctiva**.

The mesoderm surrounding the optic cup organizes itself into two concentric layers. The outer layer forms a complete sphere (see Fig. 8-14). It is relatively thick and tough, and is called the **fibrous tunic**. It gives strength to the eyeball and serves as a structure into which muscles can insert. In front of the pupil the fibrous tunic bulges out a little and undergoes a specialization to make it transparent to light. This specialized region is the **cornea;** its circular margin is called the **corneal limbus**. The remainder of the fibrous tunic sphere is opaque white and is called the **sclera**. The cornea contacts the ectoderm that will become bulbar conjunctiva.

The inner layer of mesodermally derived connective tissue is called the **uvea**. This uveal layer is coextensive with and adherent to the retina (see Fig. 8-14). Thus, it also has a circular defect and contributes to the rim of the pupil. Almost all of the uveal layer will become thin connective tissue (**choroid**) through which run the blood vessels of the eye. However, two regions do become specialized. Deep to that part of the sclera nearest to the cornea, the uveal layer is thickened by the presence of smooth muscle to form the **ciliary body**. The adherent nonoptical retina forms a **ciliary part of the retina**, which gives rise to fibers (similar in composition to elastin) that run inward to the periphery of the lens. The mass of fibers is called the **ciliary zonule, or suspensory ligament of the lens**. Tension within the zonule fibers pulls on the periphery of the lens and keeps it from assuming a more rounded shape to which it is naturally inclined.

Anterior to the ciliary body the uveal layer thins down again to form a connective tissue that adheres to the outer surface of the nonoptical retina. Here these adherent layers form the **iris**, which surrounds the pupil. Just as the uveal layer of the ciliary body contains smooth muscle, so does that of the iris. The part of the nonoptical retina adherent to the uveal part of the iris is the highly pigmented **iridial retina**. If the uveal part of the iris contains no pigment itself, the individual will have blue eyes. However, most persons have additional pigment in melanocytes scattered within the uveal component of the iris, giving it a brown color overall.

Intraocular (Internal Ocular) Muscles. The smooth muscles within the ciliary body and uveal layer of the iris are said to be intraocular muscles. The fibers of the **ciliary muscle** are complex in arrangement, but their effect is to change the shape of the ciliary body so as to reduce tension within the suspensory ligament of the lens. As a consequence, the lens assumes a more rounded shape, light rays are more strongly bent, and the eye can focus on nearer objects. This process is called **accommodation**; thus, the ciliary muscle is the muscle of accommodation.

There are two separate smooth muscles within the iris. One causes the pupil to get smaller, thereby reducing the amount of light that enters the eye. This muscle is called the **constrictor pupillae**. The other causes the pupil to get larger, permitting more light to enter the eye. This muscle is called the **dilator pupillae**.

Being smooth muscles, the three internal ocular muscles are innervated by the autonomic nervous system. The dilator pupillae receives its motor axons from cells that lie in the superior cervical sympathetic ganglion. The constrictor pupillae and ciliary muscle are innervated by the parasympathetic component of the oculomotor nerve (see further on).

Cavity of the Eyeball (Fig. 8-14). The layers of the eyeball surround a cavity. This cavity is divided into a **retrolental portion**, behind the lens and ciliary zonule, and a **prelental portion**, in front of these same structures. The retrolental portion of the eyeball cavity is filled with a transparent gelatinous material said to form the **vitreous body**. The prelental part of the cavity is itself divided into two chambers because the deep surface of the iris near the pupil rests upon the front surface of the lens. The part of the prelental portion of the eyeball cavity that lies just deep to the iris and in front of the lens and its suspensory ligament is called the **posterior chamber** of the eye (though it is certainly not as far posterior as is the vitreal cavity). An anterior chamber lies in front of the iris and lens, just deep to the cornea. The retinal epithelium in the roof of the posterior chamber secretes a clear fluid into this region of the prelental cavity. The fluid is **aqueous humor**. It seeps through the suspensory ligament to permeate the vitreous body, and it also passes around the free margin of the iris into the anterior chamber of the eye.

It should be obvious that continuous secretion of aqueous humor without removal would tend to a continuous increase of intraocular pressure. Removal is accomplished by a specialization of the inner surface of the fibrous tunic (at the corneoscleral junction) facing the anterior chamber. The aqueous humor filters through trabecular meshwork here to reach a circular "vein" that encircles the cornea. This vein is called the **canal of Schlemm**, and it is peculiar in that it contains not blood, but aqueous humor. The canal of Schlemm is connected to the other veins of the eyeball, which carry away the aqueous humor.

The resistance to flow through the trabecular meshwork into the canal of Schlemm is sufficiently great to build a "head" of intraocular pressure that maintains eyeball shape. However, if resistance to flow should increase and pressure build within the eyeball cavity, the optical retina may be seriously damaged. Such a condition arises from causes unknown. It is called **glaucoma** and often must be treated by surgically creating a new path of egress of aqueous humor.

Meninges of the Optic Nerve. The optic nerve, being an outgrowth of the brain, is surrounded by sleeves of pia, arachnoid, and a dura all the way up to the point where it pierces the sclera. Naturally, the pia is adherent to the nerve. A thin but definite subarachnoid space lies between the pial sleeve and arachnoid sleeve. For this reason, any increase in cerebrospinal fluid pressure is transmitted around the optic nerve and may cause partial collapse of the veins within it.

Evidence of retardation of optic venous return is seen ophthalmoscopically in engorgement of the retinal veins. The optic disc itself becomes edematous (swollen), causing its margins to be blurred and its surface to be elevated from the surrounding retina. This condition is called **papilledema, or choked disc**.

Bony Orbit (Fig. 8-15)

The bones of the face form a socket around the optic nerve and eyeball. This socket is called the **orbit**. It is cone-shaped with the apex facing posteromedially. The roof of the orbit is formed by a backward shelf (i.e., orbital plate) of the frontal bone that separates the frontal lobes of the brain from the orbital contents. The lateral wall is formed by the greater wing of sphenoid and the zygomatic bone, which separate the temporalis muscle from the eye. The floor is formed almost entirely by the maxilla containing the maxillary air sinus. The medial wall is predominantly formed by the labyrinth of the ethmoid. Anteriorly the lacrimal bone makes its contribution, as does the frontal process of the maxilla. Just behind the inferomedial angle of the orbital rim there is a depression in the medial orbital wall for housing the lacrimal sac. Below this so-called **lacrimal fossa**, the orbital floor presents a large hole for passage of the nasolacrimal duct into the nasal cavity.

The eyeball itself occupies only the anterior half of the orbit. The optic nerve, which leaves the posterior surface of the eyeball medial to its posterior pole, runs through the back half of the orbit toward its apex. At the apex is a round hole in the lesser wing of the sphenoid called the **optic foramen**. The

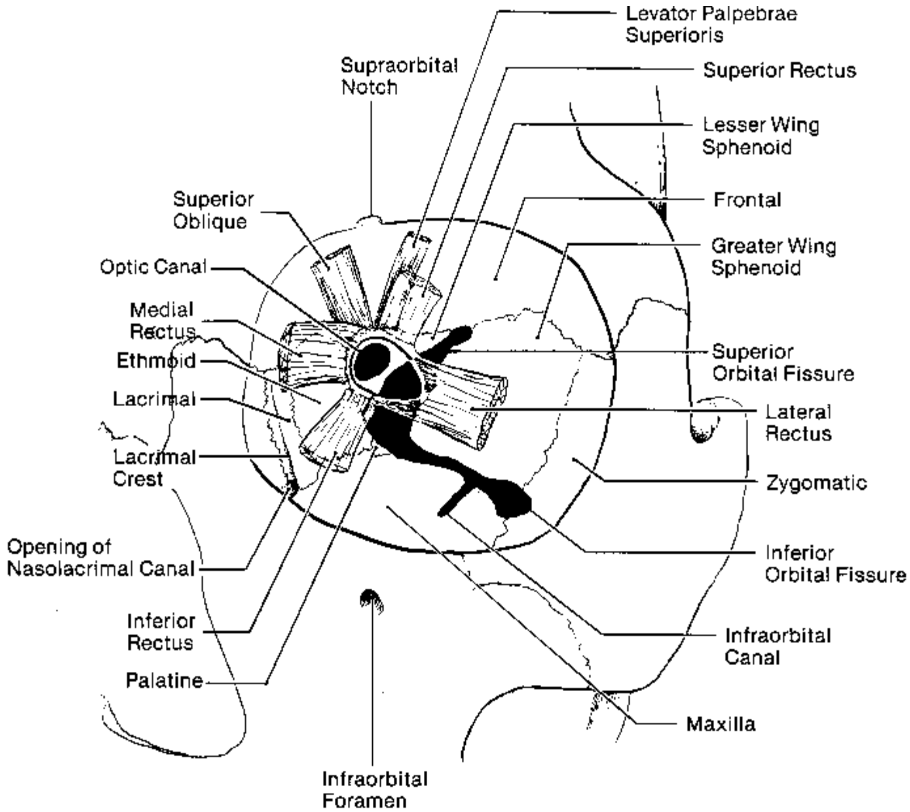


Figure 8–15. Anterior view of the left orbit and the origins of the extraocular muscles.

optic nerve leaves the orbit via the optic foramen, and the ophthalmic artery enters the orbit through the same hole.

Inferolateral to the optic foramen is a teardrop-shaped slit between the greater and lesser wings of the sphenoid. Through this so-called **superior orbital fissure** pass all the other nerves to the eyeball and to its muscles, and also the veins from these structures. Running most of the length of the orbit at its inferolateral angle is the **inferior orbital fissure**, which is a route of communication between the orbit and the infratemporal fossa (see further on). Various other small foramina exist in the bony walls of the orbit for other nerves and vessels.

Anulus Tendineus and Compartmentalization of Superior Orbital Fissure. If one peers into the orbit of a prepared skull from the front, a tiny spicule of bone can be seen projecting medially from the lateral border of the superior orbital fissure at a site directly across from the optic foramen (see Fig. 8-15). From this spine two ligamentous bands pass medially and backward toward the borders of the optic foramen. One band attaches to the superior border of the optic foramen; the other attaches to the foramen's inferior border. The two bands meet medial to the foramen. Because the ligaments have a common origin and once again meet medial to the optic foramen, they serve to form a tendinous ring (**anulus tendineus**), which is in fact more egg-shaped than round (see Fig. 8-15). The recti muscles of the eye arise from the anulus tendineus.

The two "transfissural" ligaments forming the anulus tendineus divide the superior orbital fissure into three compartments: superior (above the higher band), middle (between the bands), and inferior (below the lower band). The abducens nerve, the nasociliary nerve and the two divisions of the oculomotor nerve pass through the middle compartment of the superior orbital fissure. The frontal, lacrimal, and trochlear nerves enter the orbit through the superior compartment of the superior orbital fissure. The superior ophthalmic vein passes out of the orbit either through the middle or superior compartments of the fissure.

Periorbita. The periosteum on the bones of the orbit is continuous anteriorly with that covering the bones of the face, and it is continuous posteriorly (through the superior orbital fissure and optic foramen) with the endocranium lining the cranial cavity. This orbital periosteum is usually given the distinct name of **periorbita**. It is rather easily separated from the orbital bone. It also extends from the orbital rim into the eyelids as the orbital septum, which merges with the tarsi to provide a fibrous skeleton for the eyelids (see below).

Eyelids

Each eyelid consists of a fibrous "skeleton" overlain on the outside by subcutaneous tissue and skin, and on the inside by a thin epithelial-lined connective tissue called **palpebral conjunctiva**. At the free margin of each lid, the conjunctiva and skin merge at the so-called **cutaneoconjunctival junction**. The medial part of the upper eyelid joins the medial part of the lower eyelid, and the lateral part of the upper eyelid joins the lateral part of the lower eyelid. Each joining is said to be a palpebral commissure. Thus, there are **medial and lateral palpebral commissures**. At each commissure an angle is formed where the free edge of the upper lid meets that of the lower lid. These angles are known as canthi. Thus, there are **medial and lateral palpebral canthi**.

Conjunctival Sac. At the root of each eyelid the palpebral conjunctiva turns into the **bulbar conjunctiva** by reflecting onto the anterior aspect of the eyeball. The bulbar conjunctiva covers the whole front of the eyeball and fuses to the cornea. When the eyelids are closed, a **conjunctival sac** is created. When the eyelids are open, this "sac" opens forward into the environment. The part of the conjunctival sac located at the superior conjunctival reflection is called the **superior fornix**. The part of the sac located at the site of the inferior conjunctival reflection is called the **inferior fornix**. The ducts of the lacrimal gland open up into the lateral part of the superior conjunctival fornix.

Two structures of moderate interest bulge into the conjunctival sac near the medial canthus. One of these is a soft bump called the **lacrimal caruncle**. Posterolateral to this bump is a thin crescentic fold called the **plica semilunaris**. The portion of the conjunctival sac into which the caruncle and plica protrude is called the **lacrimal lake**, because it is toward this site that lacrimal fluid is swept during each blink of the upper eyelid.

Eyelashes. The hairs at the free margin of the eyelid form the eyelashes. Opening onto the surface of the skin just posterior to the eyelashes are modified sweat glands (of Moll). The eyelashes and nearby glands are lacking in the region of the lid adjacent to the medial canthus. Infection of the eyelash follicle produces a painful condition known as a **sty**.

The Fibrous "Skeleton" of an Eyelid--Composed of a Tarsus and an Orbital Septum (Fig. 8-16). As has been mentioned, sandwiched between subcutaneous tissue and the palpebral conjunctiva lies the fibrous "skeleton"of the eyelid. This consists primarily of a densely fibrous structure called the **tarsus**. Each tarsus is in the shape of a segment of a circle created by an eccentrically placed chord. The chord of the tarsus lies at the free edge of the lid and, in fact, makes a visible sharp ridge here. This ridge not only indicates the underlying tarsal chord, but also marks the site of the cutaneoconjunctival junction. The circumference of the tarsus faces the bony orbital rim. It lies about halfway between the free edge of the lid and its root.

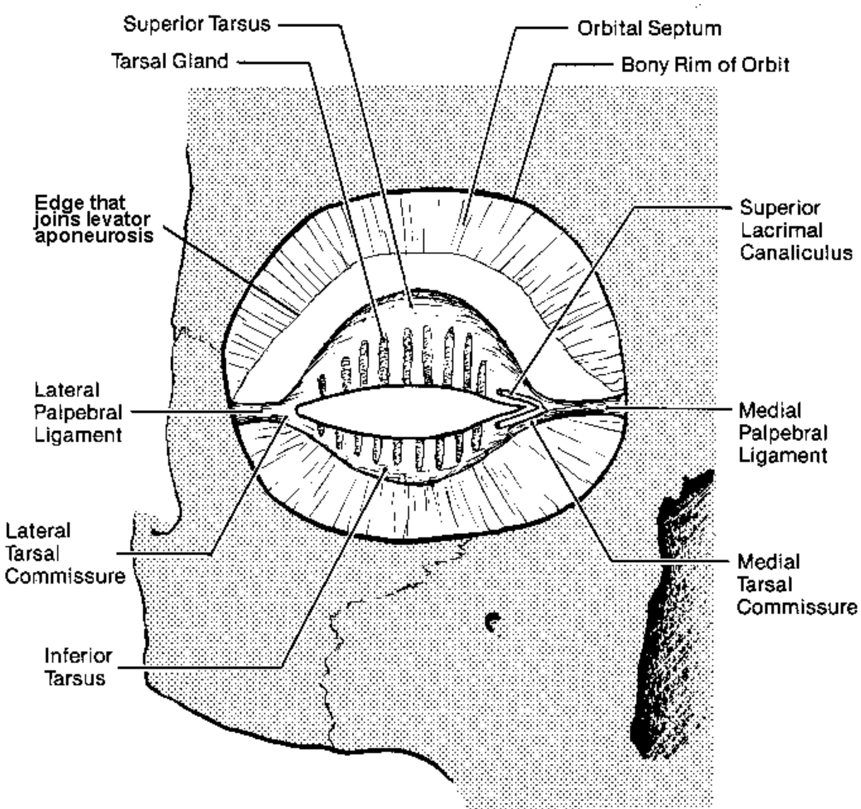


Figure 8–16. Anterior view of the fibrous "skeleton" of the eyelids.

The remainder of the fibrous "skeleton" of the lower eyelid consists of a connective tissue sheet that runs from the periosteum of the bony orbital rim up to the circumference of the tarsus. This sheet is called the inferior part of the **orbital septum**. The journey of the superior part of the orbital septum from periosteum of the orbital rim down to the upper edge of the superior tarsus is interrupted by passage of the aponeurosis of the levator palpebrae superioris muscle (see further on).

At their lateral extremities, the upper and lower tarsi join to form a short **lateral *tarsal* commissure**. From this commissure out to the lateral orbital rim runs a **lateral palpebral ligament** which, therefore, underlies the externally visible lateral palpebral commissure. A short **medial *tarsal* commissure** is formed where the medial extremities of the upper and lower tarsi meet. From this site to the medial orbital rim runs a **medial palpebral ligament** which, therefore, underlies the visible medial palpebral commissure. The medial palpebral ligament crosses in front of the lacrimal sac, located in the lacrimal fossa of the orbit.

Embedded within each tarsus is a series of glands (tarsal, or Meibomian glands) that open up onto the free margin of the lid at the cutaneoconjunctival junction (thus, on the ridge formed by the tarsal chord). The tarsal glands secrete a sebaceous substance onto the free margins of the lids so that a water-tight seal is created when the eyelids are closed. Obstruction of a tarsal gland produces a nonpainful swelling known as a **chalazion**.

Just as no eyelashes exist in the skin nearest the medial canthus, no tarsal glands exist in the tarsus nearest the medial canthus. What appears to be the particularly large opening of a most medial tarsal gland (a few millimeters from the canthus itself) is in fact the opening of a small tube called the **lacrimal canaliculus**. The opening is called the **lacrimal punctum**, and it raises a tiny bump in the free margin of each lid, which bump is called the **lacrimal papilla**. From the site of the punctum, each canaliculus runs toward the medial canthus following a path deep to the cutaneoconjunctival junction of the lid. Upon reaching the medial palpebral ligament, each canaliculus pierces this structure to empty into the lacrimal sac.

The lacrimal puncta are directed backward toward the lacrimal lake. Lacrimal fluid flows from the lake through the puncta and into the canaliculi, which carries the fluid to the lacrimal sac, and thence through the nasolacrimal duct into the inferior meatus of the nasal cavity.

Extraocular Structures

Fat and Fascia. The mesoderm interposed between the bony orbit and the developing eyeball differentiates into a fatty connective tissue. Immediately adjacent to the sclera this extraocular tissue is more densely fibrous, forming a **fascia bulbi** (**Tenon's capsule**) that attaches to the front of the eyeball near the corneoscleral junction and to the back of the eyeball where it is pierced by the optic nerve. The space between sclera and Tenon's capsule is called the **episcleral space**. It is bridged by only thin fibrous strands.

On the anterior surface of the eye Tenon's capsule intervenes between the bulbar conjunctiva and the sclera. Blood or infectious matter that accumulates in the episcleral space may elevate the bulbar conjunctiva away from the sclera at front of the eye. When the eye is removed at surgery, the plane of dissection is between the sclera and Tenon's capsule.

Muscles of the Oculomotor, Trochlear, and Abducens Somitomeres. The prechordal mesoderm and the oculomotor, trochlear, and abducens somitomeres send cells into the extraocular mesoderm surrounding the developing fascia bulbi. These immigrant cells differentiate into the striated muscles that will insert into the sclera and produce rotation of the eyeball within its bony socket. Such muscles are called the **extraocular (external ocular) muscles** to distinguish them from the ciliary and pupillary muscles, which are intraocular. The tendons of the extraocular muscles pierce Tenon's capsule to reach the sclera; the epimysium of the muscles is continuous with Tenon's capsule at these sites.

The trochlear somitomere gives rise to only the superior oblique muscle. The abducens somitomere gives rise to only the lateral rectus. The prechordal mesoderm and oculomotor somitomere gives rise to all other extraocular muscles--superior rectus, medial rectus, inferior rectus, inferior oblique--and to the levator palpebrae superioris, which does not actually attach to or move the eyeball.

The Lateral, Superior, Inferior, and Medial Recti of the Eye. The four recti muscles of the orbit take origin from the anulus tendineus (see Fig. 8-15). The lateral rectus muscle arises from the lateral, narrower end of anulus, the medial rectus arises from its more rounded medial end; the superior rectus arises from its superior band, the inferior rectus from its inferior band. The optic nerve passes through the optic foramen between the origins of superior and inferior rectus. The nerves that pass through the middle compartment of the superior orbital fissure (i.e., abducens nerve, nasociliary nerve, and the two divisions of the oculomotor nerve) run between the optic nerve and the origin of lateral rectus.

The fibers of each rectus muscle pass forward in the orbital fat related to the optic nerve in a manner suggested by the name of the muscle (i.e., lateral rectus is lateral to the nerve, superior rectus is superior to the nerve, and so on). Because of the location of the eyeball in the front half of the orbit, the recti muscles must travel half the length of the orbit before they even reach the vicinity of the eyeball. Upon reaching the eyeball, the recti pass onto its surface, again with a relationship suggested by the name of the muscle. Passing the equator of the eyeball, each rectus becomes tendinous, pierces Tenon's capsule, and inserts into the sclera not far behind the corneal limbus.

Superior Oblique. The superior oblique arises at the back of the orbit, but not from the anulus tendineus. The superior oblique arises from the lesser wing of the sphenoid bone just anterior to the superomedial region of the anulus (see Fig. 8-15). This cylindrical muscle passes forward in the superomedial "corner" of the orbit, above the medial rectus. As it nears the orbital rim, the superior oblique becomes tendinous. The round tendon passes through a fibrous pulley (trochlea) just behind the superomedial corner of the orbital rim. After passing through the trochlea, the tendon turns sharply backward and laterally, to run to the superior surface of the eyeball near its equator. Passing deep to the superior rectus, the tendon fans out before actually inserting into the sclera.

Levator Palpebrae Superioris. The levator palpebrae superioris is a second extraocular muscle that does not arise from the anulus tendineus. Instead, it arises from the lesser wing of the sphenoid bone just lateral to the origin of the superior oblique (see Fig. 8-15). The levator begins as a narrow muscle but broadens considerably as it passes forward on the upper surface of superior rectus. Consequently, at the back of the orbit only the medial part of superior rectus is under cover of the levator, whereas the whole superior rectus becomes covered more anteriorly. At the front or the orbit, the levator palpebrae superioris gives rise to a flat tendon that inserts both onto the anterior surface of the superior tarsus and into the subcutaneous tissue of the upper eyelid.

The levator palpebrae superioris is a striated voluntary muscle. On the deep surface of its aponeurosis are smooth muscle fibers that attach to the superior tarsus. These constitute the **tarsal muscle,** or **Müller's muscle.** They must receive an innervation appropriate to smooth muscle, and in fact are innervated by postganglionic sympathetic axons derived from cells of the superior cervical sympathetic ganglion. These axons travel with axons for the dilator pupillae. How such axons to get to eye muscles will be described later.

Inferior Oblique. This extraocular muscle does not even arise from the vicinity of optic foramen. Rather it arises just behind the orbital rim immediately lateral to the nasolacrimal foramen. The muscle sweeps backward and laterally, below the inferior rectus insertion, and then turns upward to insert into the sclera near the equator of the eye, deep to lateral rectus.

Actions and Functions of Extraocular Muscles

Levator Palpebrae Superioris. This muscle does what its name suggests--it elevates the upper lid. It is known from electromyographic studies that the striated muscle fibers are continuously active during waking hours. Voluntary lowering of the upper lid is accompanied by relaxation of the striated muscle fibers of levator palpebrae superioris and by slight activity in certain fibers of the palpebral portion of orbicularis oculi. Blinking involves rapid cessation of activity in the levator simultaneous with a burst of activity throughout the palpebral portion of the orbicularis oculi.

When damage to the oculomotor nerve causes paralysis of the striated fibers of the levator palpebrae superioris, the upper eyelid droops markedly. Yet it does not close entirely, and this must be due to continued activity of Müller's muscle.

Movements of the Eyeball (Fig. 8-17*A*). The eyeball is capable of rotating about three independent axes: superoinferior (vertical), mediolateral (transverse), and anteroposterior. These are defined when the eye is looking straight ahead. Thus, the anteroposterior axis coincides with the optic axis, which runs from the center of the cornea to the fovea centralis.

Rotation about the vertical axis causes the pupil to swing from side to side, i.e., to face either more toward the bridge of the nose or more toward the temple. Movement of the pupil toward the bridge of the nose is called medial deviation, or **adduction**; the opposite movement is called lateral deviation, or **abduction**. Rotation about the transverse axis cause the gaze to be directed either upward, **elevation**, or downward, **depression**. Rotation of the eyeball around the optic axis produces a spinning in the socket without the direction of gaze changing. If the rotation is such that the superior pole of the eye moves medially, this is called **incycloduction** (**intorsion**). If the rotation is such that the superior pole of the eye

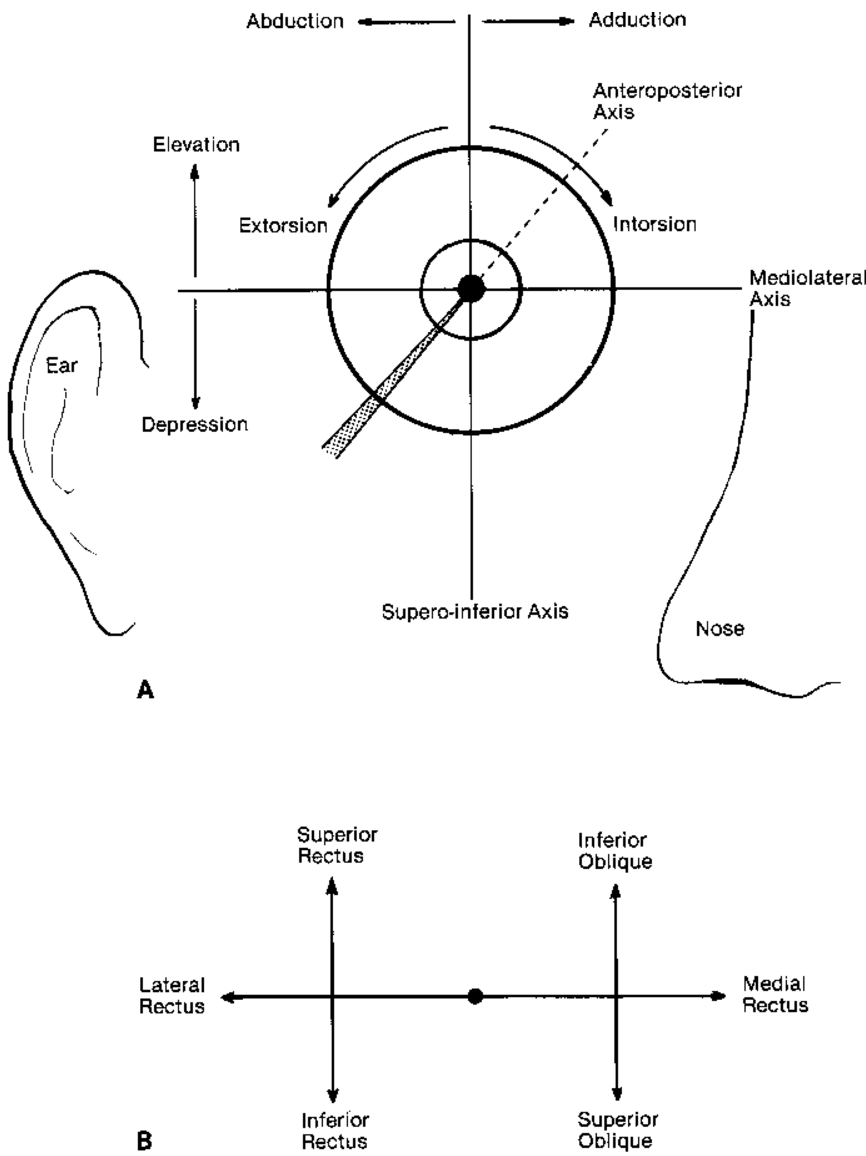


Figure 8-17. *A*, Schematic view of the axes and movements of the eyeball. *B*, Summary diagram of the functions of extraocular muscles (see text for explanation).

moves laterally, this is called **excycloduction** (**extorsion**). In most circumstances both kinds of cycloduction must be prevented, since they cause the individual to see the world as if it were rotating clockwise or counterclockwise, which clearly will be very disorienting. The key to understanding the functions of eye muscles in most situations is to realize that no muscle will be recruited in isolation if its action will produce cycloduction of the eyeball.

Functions of the Recti and Obliques. Regardless of eyeball position, two muscles--the lateral and medial recti--produce no torque about the optic axis and, therefore, have no tendency to produce cycloduction. The lateral rectus is a pure abductor of the eyeball; the medial rectus is a pure adductor (Fig. 8-18*B*). Each of the other four muscles attaching to the eyeball tend to cause cycloduction depending upon the position of the eyeball. This can be most readily appreciated by considering the case when the gaze is straight ahead. The superior rectus has a vector applied to superior surface of the eyeball (see Fig. 8-18*B*). This vector can be resolved into two components--one directed posteriorly, the other directed medially. The posteriorly directed component elevates the gaze by pulling the upper surface of the eyeball backward. The medially directed component pulls the upper surface inward, causing incycloduction. The superior rectus will not be called upon to elevate the eye unless its action as an incycloductor can somehow be negated.

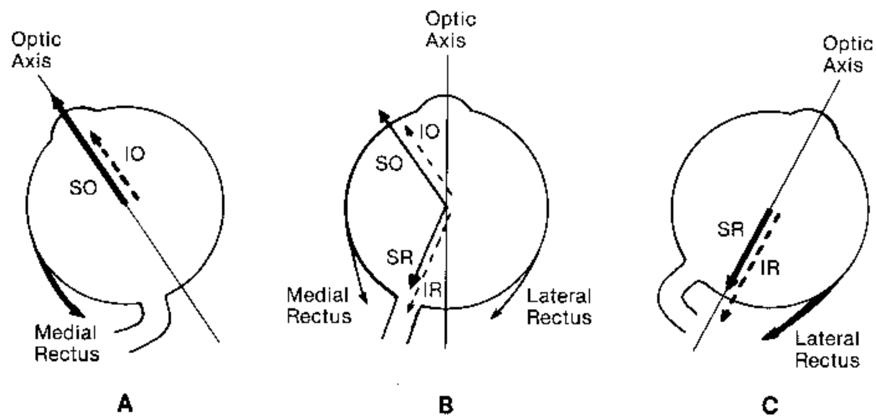


Figure 8-18. Schematic superior view of right eyeball illustrating the interactive functions of the extraocular muscles. *A*, When the medial rectus adducts the eyeball, the superior oblique (SO) can depress the gaze and the inferior oblique (IO) can elevate the gaze without torsion effects. *B*, The medial and lateral recti are the only two muscles that have no torsion effect on the eyeball when the gaze is directed straight ahead. *C*, When the lateral rectus abducts the eyeball, the superior rectus (SR) can elevate the gaze and the inferior rectus (IR) can depress the gaze without torsion effects.

The vector of the superior oblique is also applied to the superior surface of the eyeball (see Fig. 8-18*B*). This vector is directed anteromedially, and may be resolved into an anterior component that causes the eye to gaze downward and a medial component that produces incycloduction. The superior oblique will not be called upon to depress the eye unless its tendency to produce incycloduction can be negated.

Similar vector analyses demonstrate that the inferior rectus, pulling posteromedially on the inferior surface of the eyeball (see Fig. 8-18*B*), is a depressor and excycloductor. Inferior oblique, for all intents and purposes pulling anteromedially on the undersurface of the eyeball, is an elevator and excycloductor (see Fig. 8-18*B*). Neither of these muscles will be used to produce up or down movements of the eye unless their cycloduction effects can be negated.

Now we must ask what clever means can be used to negate the cycloduction effects of the elevators and depressors of the eye so that these muscles can do their jobs? One method is to employ the lateral or medial rectus to move the eyeball into a position where one or more of the other muscles has no cycloduction effect. For example, let the lateral rectus abduct the eye (see Fig. 8-18*C*). The optic axis now is in line with the pull of the superior and inferior recti. The superior rectus may contract to elevate the abducted eye without producing any cycloduction about the optical axis. The inferior rectus may depress the abducted eye without producing cycloduction. The cycloduction effects of the obliques are accentuated and they become essentially useless as elevators or depressors.

What happens when the medial rectus adducts the eye (see Fig. 8-18*A*)? The cycloduction effects of the superior and inferior recti become accentuated, but the obliques now have a vector pull coinciding in direction with the optic axis. The superior oblique may depress the adducted eye without producing cycloduction; the inferior oblique may elevate the adducted eye without producing cycloduction.

These analyses are reflected in Figure 8-17*B*. The lateral rectus is a pure abductor. When it is acting, the superior rectus elevates and the inferior rectus depresses the abducted eye. The medial rectus is a pure adductor. When it is acting, the superior oblique depresses and the inferior oblique elevates the adducted eye.

This is all well and good. But what happens when a person wishes to look up or down without first abducting or adducting the eye? Then that person must use muscles that have counteracting cycloduction effects. Fortunately, the two elevators (superior rectus and inferior oblique) have opposite cycloduction actions that cancel. They can be used together to elevate the forward gazing eye. Similarly, owing to the opposite cycloduction effects of the superior oblique and inferior rectus, they can be used together to produce depression of the forward-gazing eye.

Many texts refer to the depressors and elevators of the eye as having torques about the superoinferior axis that endow these muscles with the ability to produce abduction or adduction. It is certainly true that such torques do exist in certain positions of the eye, but they are best viewed as nuisances to be overcome by the medial and lateral recti.

Nasal Cavities (Fig. 8-19)

In embryonic life, just cranial to the mouth are two invaginations of ectoderm that pass posteriorly through the head mesoderm to make contact with the cranial end of the foregut. These are right and left nasal pits. When the ectoderm in their floors contacts the endoderm of the foregut, the opposed epithelial surfaces break down and the nasal pits are turned into passageways from the external environment to the foregut lumen. These passageways are the **nasal cavities**. The part of the foregut into which they open becomes designated as the nasopharynx. The mesoderm trapped between the two nasal cavities (along with the epithelium that brackets it) is the embryonic **nasal septum**. Obviously, the nasal septum forms a common medial wall of each nasal cavity. Each cavity also has (1) a roof of epithelium backed by mesoderm, (2) a lateral wall of epithelium and mesoderm separating it from the developing eye, and (3) a floor (mesoderm with nasal epithelium on one side and oral epithelium on the other) separating it from the oral cavity. The floors--together known as the primary palate--will rupture through, only to be replaced by new floors constituting a secondary palate.

Some cells in the epithelium of the roof and adjacent parts of the medial and lateral walls of each nasal cavity differentiate into the chemoreceptive olfactory neurons. These send very short axons superiorly; these axons end by synapsing on the cells of the olfactory bulb. On each side the olfactory

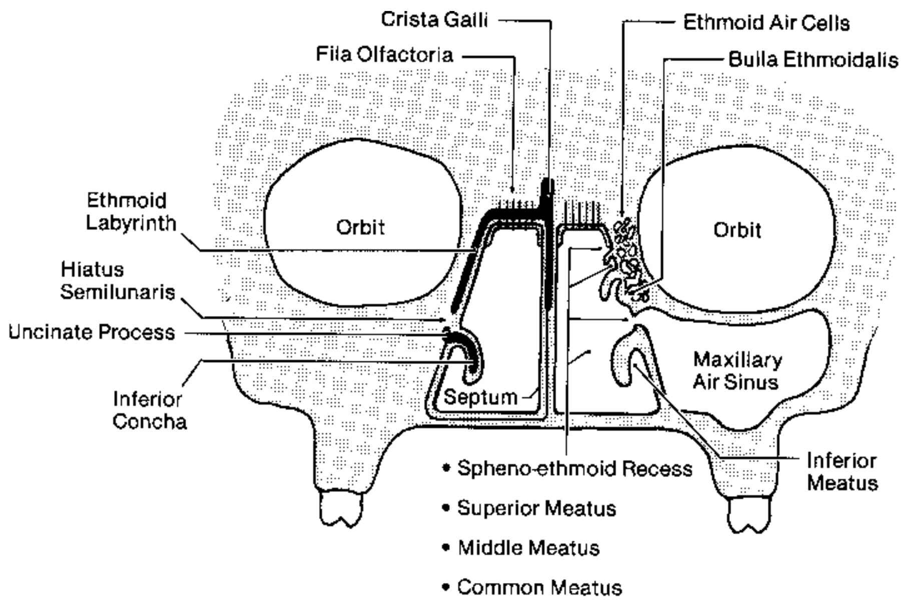


Figure 8–19. Schematic coronal section of the nasal cavities illustrating two developmental stages. On the *left side* of the figure is an early stage in which, subjacent to the nasal epithelium, the walls of the nasal cavity are cartilaginous (*thick black lines*) and membranous (*thin black lines*). The ethmoid labyrinth and uncinate process would be seen to join in a more anterior section. Surrounding the cartilage and membranes is undifferentiated mesenchyme. On the *right side* of the figure is a postjuvenile stage of development in which the walls of the nasal cavity are bony (*shaded*) and the air sinuses have evaginated into neighboring bones.

axons organize themselves into 20 or so separate nerve bundles (**fila olfactoria**, or **olfactory filaments**) that, collectively, constitute an **olfactory nerve**.

Cartilage forms in the roof mesoderm of each nasal cavity and extends down into the upper part of the septum and also into the upper parts of each lateral wall (see Fig. 8-19, *left*). This is the nasal capsule, spoken of previously. From the front of the lateral wall's cartilage (future ethmoid labyrinth) arises a process that hooks downward and then backward paralleling the lower edge of this plate, but separated from it by a small gap. The process is called the **uncinate process** and the gap between it and the future labyrinth is called the **hiatus semilunaris**. The inferior edge of the uncinate process grows medially to invaginate the mucous membrane on the lateral wall of the nasal cavity.

Within the inferior regions of the nasal septum and of each lateral wall, and within the palate, develops a connective tissue continuous with the perichondrium of the nasal capsule.

Various ossification centers appear in the cartilaginous nasal capsule and in the connective tissue parts of the nasal cavity walls. The mesethmoid center forms in the cartilaginous part of the septum and turns much of this into the **perpendicular plate of the ethmoid bone** and its superior extension--the **crista galli**. The more anterior part of the cartilaginous septum does not ossify. Furthermore, from its anterior edge are sent out two cartilaginous expansions (one on each side) that turn backward to form the lateral cartilages of the external nose. The connective tissue part of the embryonic nasal septum ossifies as the **vomer**.

The cartilage of the roof of the nasal cavity obviously has a series of scattered holes through which the olfactory filaments pass. When the cartilaginous roofs of the nasal cavities ossify as part of the ethmoid bone, the plate they form has lots of holes. This is the **cribriform plate of the ethmoid**, which we have already seen as contributing to the floor of the anterior cranial fossa.

The posterior part of the uncinate process, and all the part that invaginates the mucous membrane of the lateral wall of the nasal cavity, ossifies from a single center and becomes a separate bone--the **inferior nasal concha**. The remainder of the uncinate process, and all lateral wall cartilage above the hiatus semilunaris, ossifies as the **ethmoid labyrinth**.

The ethmoid labyrinth is originally a flat bone interposed between the nasal cavity and orbit, but in postnatal life it becomes highly complex by invasion of paranasal air sinuses (see further on) that separate the single bony plate into medial and lateral laminae. The lateral lamina (lamina papyracea) of the ethmoid labyrinth remains smooth and forms the medial wall of the orbit posterior to the lacrimal bone (see Fig. 8-15). From the medial lamina two bony sheets grow medially, invaginating the mucous membrane of the lateral nasal wall (see Fig. 8-19, *right*). The upper one is the **superior concha**; the lower one is the **middle concha**. The superior concha is rather short from front to back and lies toward the rear of the nasal cavity (see Fig. 8-9). The middle concha, like the inferior concha, is long from front to back, extending almost the whole length of the nasal cavity.

As a result of development of the three conchae, the lateral region of each nasal cavity is partitioned into four chambers. Below the inferior concha is the **inferior meatus**. Below the middle concha is the **middle meatus**. Below the superior concha is the **superior meatus**. The small space above the superior concha, between it and the roof of the nasal cavity, is the so-called **spheno-ethmoid recess**. The three meati open up backward into that part of each nasal cavity posterior to the conchae and inferior to the body of the sphenoid bone. It is called the **nasopharyngeal meatus** since it is the passageway to the nasopharynx. The site where each nasopharyngeal meatus actually communicates with the nasopharynx is called a **choana (posterior nasal aperture)**.

The spheno-ethmoid recess has a posterior wall formed by the front of the sphenoid body (see Fig. 8-9). Only the inferiormost part of this recess opens into the nasopharyngeal meatus via a slit-like space between the sphenoid and back edge of the superior concha.

On either side of the nasal septum is the narrow region of the nasal cavity medial to the conchae. This is sometimes called the **common meatus**. If the mucous membranes on the surfaces of the conchae are swollen, they may contact the septum and temporarily partition the common meatus.

Anterior to the conchae is that part of the nasal cavity bounded by the external part of the nose. Most of this is called the **atrium**, although the part surrounded by the alae of the external nose is called the **vestibule**.

Paranasal Sinuses

From the mucous membrane lining the lateral wall of the nasal cavity, and from that on the anterior wall of the body of sphenoid bone, arise evaginations that push into neighboring bones in a way that creates mucous membrane-lined air pockets surrounded by thin sheets of bony cortex. These air pockets are called paranasal sinuses and, obviously, are in communication with the air passing through the nasal cavities.

On each side, from the mucous membrane over the anterior wall of the sphenoid body, comes an outpocketing that pushes backward into the sphenoid bone. This is a **sphenoid air sinus**. The two sphenoid sinuses are variable in size, sometimes occupying only the space in front of the hypophyseal fossa, at other times occupying the whole body of the sphenoid and even infiltrating the base of the greater wing. They are separated by a vertical bony septum that will be eccentrically placed if either the right or left sphenoid air sinus is much smaller than its counterpart.

From the mucous membrane lining the lateral wall of the superior meatus comes an outpocketing that pushes laterally into the ethmoid labyrinth to form the so-called **posterior ethmoidal air cells**. From the mucous membrane of the lateral wall of the middle meatus comes an outpocketing that pushes laterally into the ethmoid labyrinth to form the **middle ethmoidal air cells**. The growth of these middle ethmoid cells will cause the medial lamina of the ethmoid labyrinth to bulge inward toward the nasal cavity at a site just inferior to the root of the middle concha and just above the hiatus semilunaris (see Fig. 8-19, *right*). The bulge is called the **bulla ethmoidalis** and it is onto its summit that the middle ethmoidal air cells open.

The mucous membrane that stretches across the hiatus semilunaris is depressed, forming a groove in the lateral wall of the middle meatus. From the mucous membrane at the anterior end of this groove arises an outpocketing that pushes upward into the frontal bone to become the **frontal air sinus**. Nearby, one or two outpockets push into the ethmoid labyrinth to become the **anterior ethmoidal air cells**. Finally, near the back end of the hiatus semilunaris, a mucosal outpocketing pushes laterally and then expands downward into the maxilla to become the **maxillary air sinus** (see Fig. 8-19, *right*). This downward growth is particularly important, because it means that the opening of the sinus is placed near its roof, preventing drainage by gravity when the head is upright. Furthermore, infectious material from the frontal sinus may flow in the groove of the hiatus semilunaris back to the opening of the maxillary sinus.

Having described the sites of origin of the paranasal sinuses from the nasal mucosa, we can recap the site of drainage of each one:

Sinus	**Drainage Site**
Sphenoid	Spheno-ethmoid recess
Posterior ethmoidal	Superior meatus
All others	Middle meatus

Although the mucous membrane outpocketings that will form the paranasal sinuses begin in fetal life, they are really quite poorly developed at birth, being little more than dimples in the walls of the nasal cavity. Parents can take some small comfort in the fact that infants are not susceptible to sinus headaches or sinusitis. The paranasal sinuses follow a complicated pattern of growth that is more similar to the general body growth curve than to any other. They develop into appreciably sized structures during the first few years of life but are still far from their adult state when puberty begins. During puberty, the paranasal sinuses undergo a rapid increase in size along with the whole facial skeleton.

Because the ostia (i.e., openings) of the paranasal sinuses into the nasal cavities are small and surrounded by easily swollen mucous membrane, the flow of air between the paranasal sinuses and nasal cavities is highly restricted. Mucous secreted by the epithelium lining each sinus normally flows into the nasal cavities unless the mucous membrane lining its ostium becomes swollen to the point of occlusion. Then the patient will want to take decongestants to reduce this swelling, open the ostium, and thereby "decompress" the sinus. Infectious organisms may pass from the nasal cavities into the sinuses, leading to the well-known condition of sinusitis.

At its full development, the maxillary sinus occupies virtually the whole body of the maxilla. Because of its relatively poor drainage, chronic infection of the of the maxillary sinus is not uncommon. The roots of the molar teeth lie just inferior to its floor and may actually come into contact with the mucous membrane of the sinus. This is important because abscesses of the molar teeth may spread to the sinus, or infection of the sinus may lead to pain in the teeth. In the adult, the maxillary sinus is separated from the orbit by only the thin bone of the orbital floor above which lies the infraorbital nerve. Infections of the maxillary sinus may lead to pain along the distribution of this nerve. Finally, the maxillary sinus is separated from the nasal cavity by only the thin bone of the inferior meatus. Surgical restoration of adequate drainage can be accomplished far more easily by producing a new opening through the inferior meatus than by attempting to dilate the natural, more superiorly placed, opening in the hiatus semilunaris.

The useful function of the paranasal sinuses is moot. Some persons believe they exist to reduce the weight of the facial skeleton and, thus, ease the task of the posterior neck muscles in preventing flexion of the head under its own weight. Other persons relate the paranasal sinuses to a role in modification of sound production. I prefer to believe that the paranasal sinuses function as "periorbital" sinuses. By this I wish to emphasize that they not only partly surround the nasal cavities, but also partly surround the orbits. The maxillary sinus lies below the orbital floor, the ethmoidal sinuses lie medial to the orbital cavity, and the frontal sinus lies above part of the orbital roof. Thus, the eye is surrounded on most sides by pockets of stagnant air kept at body temperature. These air pockets insulate the eye from temperature changes that might occur when cold air is breathed in through the nose, or cold fluids are brought into the mouth. Possibly the sphenoidal air sinus serves an insulating role for the pituitary gland.

Lacrimal Sac and Nasolacrimal Duct

The mucosal wall of the inferior nasal meatus does not give rise to any paranasal sinus, thus none drains into the inferior meatus. However, in a manner that is too complex to describe, an epithelial lined tube develops along a path from just behind the inferomedial corner of the orbital rim down to the anterior part of the inferior meatus. The upper end of this tube dilates a bit to become the **lacrimal sac**; the remainder is called the **nasolacrimal duct**. We saw previously (p. 29) how tears get into the lacrimal sac so they may be sent to the inferior meatus of the nose. This pathway accounts for the fact that people's noses run when they cry heavily.

Oral Cavity

Look into a friend's mouth and you will observe, on each side near the back, a vertical ridge of mucous membrane running from the soft palate down to the side of tongue at the junction of its anterior two-thirds with its posterior one-third. Each ridge constitutes a **palatoglossal fold**, and exists because the mucous membrane covers a **palatoglossus muscle** that runs between the connective tissue of the soft palate and that of the tongue. By definition, the **oral cavity** extends from the lips back to the palatoglossal folds; behind these folds is the oropharynx.

Posterior to each palatoglossal fold is a **palatine tonsil**. The tonsils are collections of lymphoid tissue beneath the mucous membrane of the oropharynx and separated from the more laterally lying superior constrictor muscle, styloglossus muscle and glossopharyngeal nerve by a connective tissue "hemicapsule." Each palatine tonsil is bounded superiorly by the soft palate, inferiorly by the tongue, and posteriorly by the **palatopharyngeal fold**, indicating the presence of the underlying **palatopharyngeus muscle** (see Chapter 7). The general site of communication between oral cavity and oropharynx is called the **fauces**. The palatoglossal and palatopharyngeal folds are often said to be **faucial pillars** (anterior and posterior, respectively). The palatine tonsil, which lies between the pillars, is often called the faucial tonsil.

The anterior two-thirds of the tongue lies in the oral cavity. Its dorsum faces superiorly. The posterior one-third of the tongue lies in the oropharynx; its dorsum faces posteriorly. As we mentioned earlier, the dorsum of the posterior one-third of the tongue may be viewed as representing a partial anterior wall of the oropharynx. The anterior two thirds and posterior one-third of the tongue are themselves demarcated by a V-shaped groove in its mucous membrane. The groove is called the **sulcus terminalis**; its apex points backward and is marked by a shallow pit called the **foramen cecum**. This pit is the original site of origin of the thyroid diverticulum. The sulcus terminalis is not as conspicuous as the row of large vallate papillae that lie immediately in front of it.

The mucous membrane on the inferior surface of the tongue is connected to the mucous membrane of the floor of the mouth by a thin crescentic fold lying in the median sagittal plane. This is called the **frenulum linguae**. The site where the tissue of the frenulum merges with the mucous membrane of the floor is called the root of the frenulum. Open your mouth and look into a mirror. On either side of the frenular root you can see raised ridges of mucous membrane that run more or less anteroposteriorly. These ridges actually converge toward the front of the mouth and end very close to midline just anterior to the frenular root. Each ridge is called a **plica sublingualis (sublingual fold)** and is caused by the underlying upper edge of the sublingual salivary gland. The numerous ducts of each gland empty on the summit of a plica. At the anterior extremity of each plica is a tiny hole marking the opening of the submandibular salivary duct, which has coursed forward between sublingual salivary gland and muscle of the tongue.

The part of the oral cavity sandwiched between the cheeks laterally and the gums and teeth medially is called the **oral vestibule**. Its lateral wall is smooth, lined by mucous membrane, and notable only for the fact that the parotid salivary duct opens onto it opposite the upper 2nd molar tooth.

The roof of the oral cavity is formed by the **palate**, which is mucous membrane-lined bone for most of its length. However, the posterior region of the palate has only a connective tissue "skeleton." The bony part is the hard palate, the back part is the soft palate. The connective "skeleton" of the soft palate is a posterior continuation of the periosteum at the back edge of the hard palate. It is into this connective tissue "**palatine aponeurosis**" that the palatal muscles attach. From the middle of the posterior edge of the soft palate there is a fleshy protuberance known as the **uvula**. Running the length of the uvula, on each side, is a **musculus uvulae**, the function of which is moot. The other muscles of the soft palate will be described later.

Just posterior to the interval between the roots of the upper medial incisors there occurs a small fleshy protuberance from the palate called the **incisive papilla**. Deep to it is the **incisive fossa** (see Fig. 8-5), the common opening of the two incisive canals that serve as passageways for some nerves and vessels from the nasal cavity to the oral cavity.

Tympanic Cavity and Auditory (Eustachian) Tube (Fig. 8-20)

In Chapter 6 I mentioned the presence in embryonic life of a series of outpocketings from the lateral pharyngeal epithelium. These are the pharyngeal pouches, which number four on each side. In Chapter 7 I drew attention to the fact that the cells of the caudal two pouches (III and IV) become separated from the pharyngeal epithelium to become parathyroid gland cells (III also contributes to the nonlymphoid part of the thymus). The fates of the cranial two pouches are remarkably different from those of the caudal two pouches, for the former maintain their original communication with the pharyngeal epithelium. The 2nd pharyngeal pouch persists on each side as the very shallow outpocketing that we identify as the epithelium on the surface of the palatine tonsil. The 1st pharyngeal pouches reach their full flower of development. On each side the first pouch develops into a long tubular structure that leads from the lateral wall of the nasopharynx (just behind the inferior meatus of the nasal cavity) backward, outward, and upward toward the medial end of the external auditory meatus (see Fig. 8-20*A*). The outer end of the pouch insinuates itself between the dorsal ends of the 1st and 2nd branchial arch cartilages and expands in diameter. The pharyngeal epithelium at its tip is separated from the cutaneous epithelium at the inner end of the external auditory meatus by only a thin connective tissue disc. This disc and its two epithelial coverings will grow into the **eardrum (tympanic membrane)**.

The lateral half of the 1st pharyngeal pouch (i.e., the expanded part nearest the future eardrum and a portion of the narrow tube leading to it) is soon surrounded by the cartilage of the otic capsule that is destined to ossify as the petrous portion of the temporal bone. Thus, the pouch comes to have an intrapetrous portion laterally and an extrapetrous portion medially. The extrapetrous portion is a narrow tube that opens into the nasopharynx posterior to the inferior meatus of the nasal cavity.

Obviously, the lateral half of the 1st pharyngeal pouch occupies a cavity in the ossifying petrous temporal (see Fig. 8-20*A*). The outer part of this cavity, in which the dilated end of the pouch resides, is the **tympanic (middle ear) cavity**. Extending medially from the tympanic cavity is the intrapetrous portion of the nonexpanded region of the 1st pharyngeal pouch. This epithelial-lined tubular channel represents the **intrapetrous, or osseous, part of the auditory tube**. It is continuous further medially with the extrapetrous portion of the pouch, which is surrounded by connective tissue of the head. Cartilage develops along the whole length of this connective tissue (see Fig. 8-20*B*). In this manner, the **cartilaginous, or extrapetrous, portion of the auditory tube** is created. The medial end of the auditory tube cartilage invaginates the mucous membrane of the nasopharynx posterior to the actual opening of the tube. The bump so produced is called the **torus tubarius**.

Although one might expect that a complete tubular sleeve of cartilage would form around the extrapetrous portion of the pharyngeal pouch, such is not the case, and for a very good reason. The process of chondrification does not extend very significantly into the connective tissue lying anterolateral to the pouch. Thus, a cross section of the cartilaginous part of the auditory tube shows cartilage that appears as an upside-down J (see Fig. 8-20*B*), with the long arm being posteromedial and the bend superior. **Because the "cartilaginous" part of the auditory tube is only partly made of cartilage, it is better spoken of as the extrapetrous part of the auditory tube**. Most of the anterolateral wall of the extrapetrous part of the auditory tube is in fact connective tissue continuous with the perichondrium of the cartilage. This connective tissue is normally held against the cartilaginous wall by surface tension, effectively closing off the passageway between nasopharynx and tympanic cavity unless the walls of the auditory tube are forced apart mechanically.

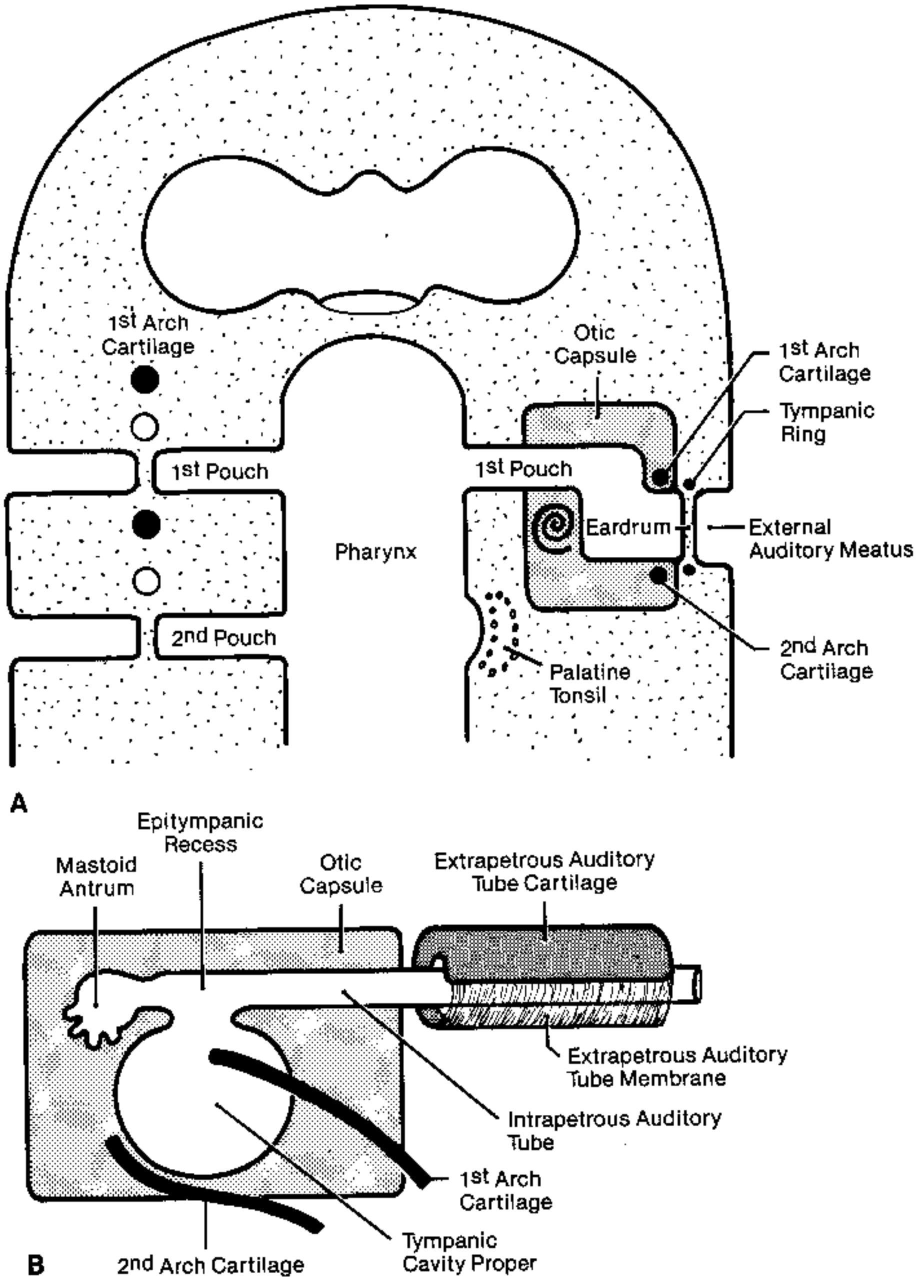


Figure 8–20. *A*, A schematic coronal section through the cranial end of an embryo at the level of the pharyngeal pouches and branchial arches. Two developmental stages are illustrated. On the *left* is an early stage corresponding to that shown in Figure 6–2. On the *right* is a later stage in which the lateral region of the 1st pharyngeal pouch has expanded to participate in development of the middle ear (see text for further discussion). The 2nd pharyngeal pouch regresses in size and will persist only as the epithelial lining of the palatine tonsil. *B*, A schematic anterolateral view of the tubes and chambers lined by the epithelium of the 1st pharyngeal pouch. The otic capsule will ossify as the petrous portion of the temporal bone that surrounds both the sensory organs of the inner ear (behind the plane of the paper) and the middle ear cavity. Pieces of the 1st and 2nd branchial arch cartilages become incorporated into the middle ear, where they ossify as the auditory ossicles.

The dilatation at the lateral end of the 1st pharyngeal pouch is larger from top to bottom than is needed to accommodate the eardrum on its outer wall (see Fig. 8-20*B*). The part of the tympanic cavity superior to the eardrum is called the **epitympanic recess**. The part of the cavity having the eardrum as its lateral wall is the **tympanic cavity proper**. The intrapetrous portion of the auditory tube connects to the cavity at the junction of the epitympanic recess and tympanic cavity proper. From the part of the pharyngeal pouch that lines the epitympanic recess emanates a diverticulum that pushes further backward into the otic capsule and itself undergoes a slight expansion (see Fig. 8-20*B*). This secondary expansion of the pouch lines a space in the petrous temporal bone called the **mastoid antrum**. The epithelial-lined passageway between the epitympanic recess and the mastoid antrum is called the **aditus ad antrum**.

After birth, the lining of the mastoid antrum will send out a series of highly branching evaginations into the newly developing mastoid process, creating the epithelial-lined **mastoid air cells** (see Fig. 8-20*B*). It should be obvious that if the lateral membranous wall of the extrapetrous auditory tube could be separated from its cartilaginous wall, air in the nasopharynx would be brought into continuity with that in the mastoid air cells.

Auditory Ossicles

In that the dorsal ends of the 1st and 2nd branchial arch cartilages bracket the expanded part of the 1st pharyngeal pouch, they too become surrounded by the otic capsule and cut off from the remaining portions of these cartilages.[33] The bones of the middle ear develop from the nearby dorsal ends of the 1st and 2nd branchial arch cartilages. These bones invaginate into the dilated end of the pouch to lie within the tympanic cavity covered by the pouch epithelium. From the encapsulated part of the 1st branchial arch cartilage arise the **malleus** and **incus**. The former has a bulbous head superiorly and a long narrow process (the manubrium, or handle) inferiorly. The head of the malleus and much of the incus will come to lie in the epitympanic recess. The handle of the malleus adheres to the connective tissue of the eardrum. The incus articulates with the malleus, and with the **stapes**, which derives from the encapsulated part of the 2nd branchial arch cartilage. Stapes is the Latin word for "stirrup," which is what this bone looks like. The apex of the stirrup articulates with the incus; the base sits in a tiny oval hole in the bony medial wall of the tympanic cavity. On the other side of this oval window resides the cochlea, also embedded in the petrous temporal.

Tympanic Cavity Proper and Its Relationships

Some authors speak of the tympanic cavity proper as if it has a lateral wall formed by the eardrum and a medial wall formed by the bone that houses the sensory organs of the inner ear. In truth, the tympanic cavity is obliquely placed within the petrous temporal, so that the eardrum faces almost as much anteriorly as laterally (and even a little bit downward). The bony "medial" wall faces almost as

[33] As we know, the remainder of the 2nd arch cartilage ossifies as the styloid process of the skull and part of the hyoid bone, with the stylohyoid ligament representing intervening perichondrium. The part of the 1st arch cartilage that escapes encapsulation by the otic capsule degenerates, except for a segment of its perichondrium that becomes the sphenomandibular ligament.

much posteriorly as medially. For this reason many anatomists prefer the terms **membranous** and **labyrinthine** to replace "lateral" and "medial" when referring to these two walls of the tympanic cavity. The oval window is in the labyrinthine wall; the facial nerve is embedded in the labyrinthine wall immediately superior to the oval window.

The tympanic cavity proper is actually rather flat from side to side. That is, the membranous and labyrinthine walls are close together. Additionally, the eardrum is cone-shaped, narrowing the depth of the middle of the cavity even further. Finally, a part of the cochlea causes the bony labyrinthine wall to bulge into the midregion of the cavity (this bulge is called the **promontory**). As Grant notes [34], the result is that the tympanic cavity proper takes on a shape pretty much like that of a red blood cell, narrowest in the middle and somewhat wider at the edges.

Because of the oblique disposition of the tympanic cavity, its "anterior" wall actually faces anteromedially. It is often called the **carotid wall** because it is immediately behind the internal carotid artery as that vessel enters the petrous temporal bone from the neck. The "posterior" wall (really posterolateral) is often called the **mastoid wall**. As we shall see later, the facial nerve runs embedded in the mastoid wall of the tympanic cavity. There is no particular need to rename the inferior wall, but it is often called the **jugular wall** to emphasize the fact that the bulb of the jugular vein is immediately below the tympanic cavity. The tympanic cavity proper has no superior wall because the epitympanic recess lies here, but the roof of the epitympanic recess is related to the temporal lobes of the brain within the cranial cavity.

> I have spent this little time mentioning important relationships of the middle ear cavity, because the structures around it are susceptible to being involved by disease within it. Middle ear infections are not at all uncommon as a result of the continuity with the nasopharynx. Prior to antibiotic therapy, such infections almost always spread into the mastoid air cells and frequently eroded the bony walls of the middle ear cavity to involve the brain, facial nerve, jugular bulb, internal carotid artery, or the inner ear.

MUSCLES OF THE FACIAL SOMITOMERE

The subcutaneous tissue of the head is most notable for containing deep within it striated muscles whose contraction causes the skin of the face to move and wrinkle in a wide variety of ways. Such muscles are called **muscles of facial expression**. They all are derived from the facial somitomere and, thus, are all innervated by the facial nerve. (It will be recalled that one muscle of facial expression--the platysma--lies mainly in the neck and was described in Chapter 7.) The deep layer of subcutaneous tissue in which facial muscles lie (analogous in position to Scarpa's fascia of the abdominal wall) is called the **superficial musculo-aponeurotic system**, or **SMAS** for short. Some persons refer to the overlying subcutaneous tissue (analogous to Camper's fascia in position) as the "fascial-fatty layer" of the face.

As could be anticipated, given the complexity of possible facial expressions, there are many facial muscles. The reader who wishes to learn all their names, attachments, and actions should refer to a larger text. I shall mention only those that are particularly important in clinical diagnosis (Fig. 8-21).

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[34] Grant, JCB, and Basmajian, JV: Grant's Method of Anatomy, ed 7. Williams & Wilkins, Baltimore, 1965.

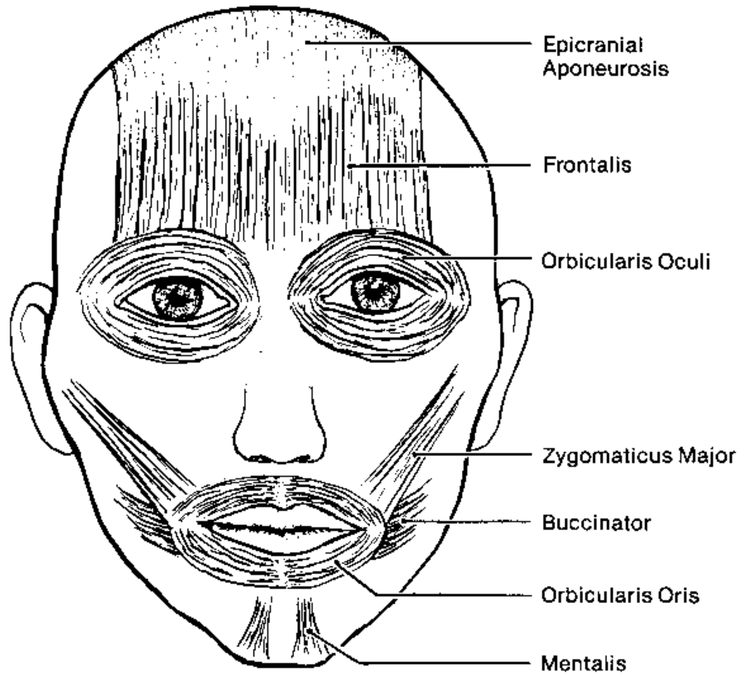

Figure 8-21. Anterior view of some important muscles of facial expression.

Occipitofrontalis

The occipitofrontalis begins in the vicinity of the eyebrows and skin above the root of the nose as a flat sheet of muscle fibers that course upward over the forehead onto the top of the skull. This sheet is actually formed by the apposed right and left **frontalis** muscles. At some point before the coronal suture is reached, the muscle fibers give rise to a flat tendon (i.e., aponeurosis) that continues backward over the top of the skull and down onto its posterior surface. This structure is called the **epicranial aponeurosis (or galea aponeurotica)**.

Because the most medial fibers of each frontalis muscle become aponeurotic before the more lateral fibers do, the impression of two bellies apposed at their medial edges is reinforced. The aponeurotic fibers emanating from this midline region of apposition end at the back of the skull by attaching to the external occipital protuberance and to the highest (supreme) nuchal line on either side of this bump (see Fig. 8-5). The more lateral aponeurotic fibers do not gain a direct insertion onto bone. Instead, as they pass downward onto the back of the skull they give rise to another flat muscle belly--the **occipitalis**--the fibers of which continue inferiorly onto the posterolateral aspect of the skull to insert onto the lateral part of the highest nuchal line . Because aponeurotic fibers intervene between the right and left occipitalis, the two bellies are more readily identified than are the those of the frontalis.

When the occipitofrontalis muscles contract, the skin of the eyebrows is pulled upward.

More About the Epicranial Aponeurosis and the Subcutaneous Tissue of the Scalp

The epicranial aponeurosis is a very important structure, largely because of its relation to the more superficial subcutaneous tissue of the scalp. This subcutaneous tissue is unique in being densely fibrous and bound tightly both to the overlying skin and to the underlying epicranial aponeurosis. No movement between skin and aponeurosis is permitted. Elsewhere in the body, skin freely slides over deeper structures because the immediately subjacent subcutaneous tissue is only loosely fibrous. The sliding of the scalp over the cranium with which we all are familiar is possible because interposed between the epicranial aponeurosis and the pericranium is a very loose connective tissue called the **subaponeurotic fascia**. In fact, it is so sparsely populated with fibrous elements that it is often called the **subaponeurotic space**. Surgery on the cranium or brain first involves a peeling back of the scalp; the plane of this separation must be in the subaponeurotic space.

This specialization of the subcutaneous tissue of the scalp has three consequences important for the physician. First, the densely fibrous nature of subcutaneous tissue tends to hold the walls of superficial blood vessels open even when they are cut and the blood pressure within them drops. Thus, wounds to the scalp tend to bleed profusely and require suturing more frequently than do superficial wounds elsewhere. Second, if a wound to the scalp penetrates the epicranial aponeurosis, the consequences depend on the direction of the tear. A transverse tear in the aponeurosis will lead to a wound that gapes open because the occipitalis and frontalis muscles pull across the defect. A sagittal tear is more easily fixed by sutures. Finally, any wound that penetrates the epicranial aponeurosis is serious because infectious matter can enter the subaponeurotic space and spread over the entire surface of the cranial vault with little interference. The infectious material may even spread through emissary foramina to reach the cranial cavity.

The connective tissue of the SMAS of the scalp does not stop at the lateral edges of the occipitofrontalis muscles and epicranial aponeurosis. Rather, it passes down onto the sides of the head as **temporoparietal fascia** (**epicranial fascia**), which eventually attaches to bone (i.e., mastoid process and zygomatic arch). The temporoparietal fascia splits around the three little muscles that insert into the cartilage of the external ear: **auricularis anterior**, **auricularis superior**, and **auricularis posterior**.

Orbicularis Oculi

The orbicularis oculi is one of the most important of the facial muscles. It consists of three portions, each of which has a different function.

The **palpebral portion** of orbicularis oculi consists of fibers that arise from the outer surface of the medial palpebral ligament and sweep laterally in the subcutaneous tissue of both the upper and lower eyelids toward the lateral palpebral commissure. The muscle fibers of the upper lid meet those of the lower lid in a raphe that lies in the subcutaneous tissue external to the lateral palpebral ligament.

When the eyelids are open, the fibers of the palpebral portion of orbicularis oculi in the upper lid follow a markedly upward arching course. When they contract and straighten out, the upper eyelid is lowered. Electromyographic evidence[35] demonstrates that the fibers coursing near the margin of the upper lid are reserved for blinking. The slow lowering of the upper lid that accompanies downward gaze or voluntary closing of the eyes occurs partly under the influence of gravity (when the levator palpebrae superioris relaxes) and partly by contraction of those fibers of the palpebral portion of orbicularis oculi

[35] Gordon, G: Observations upon the movements of the eyelids. Br J Ophthalmol 35:339-351, 1951. Björk, A, and Kugelberg, E: The electrical activity of the muscles of the eye and eyelids in various positions and during movement. Electroencephalogr Clin Neurophysiol 5:595-602, 1953.

that lie furthest from the free margin of the lid. Patients with a paralyzed orbicularis oculi cannot completely close the eye.

The muscle fibers in the lower lid follow only a very slightly downward arching course. The lower lid does not move much during closure of the eyes. The clinical observation that older patients with a paralyzed orbicularis oculi often are characterized by a lower lid that droops under its own weight, suggests that passive tension in a normally innervated muscle helps the connective tissue of the lower lid to maintain this structure's resting position.

The orbicularis oculi also has a **lacrimal portion**. These muscle fibers arise from the crest of the lacrimal bone (behind the lacrimal sac) (see Fig. 8-15) and course anterolaterally to insert into the medial extremities of the upper and lower tarsi. The lacrimal portion of orbicularis oculi has the very important function of pulling the medial parts of the tarsi backward against the bulbar conjunctiva and, thus, keeping the lacrimal puncta in the lacrimal lake.

The third portion of the orbicularis oculi is its **orbital part**. It consists of muscle fibers that encircle the orbit peripheral to the roots of the eyelids. These fibers come into action only during forceful closure of the eyes, when it is desirable to interpose as much skin as possible between the external world and the eyeball.

Zygomaticus Major

The zygomaticus major arises from the outer surface of the zygomatic bone at the anterior end of the zygomatic arch. Its fibers pass forward and downward to the corner of the mouth. The muscle obviously pulls the corner of the mouth backward and upward, which is called smiling. It is occasionally assisted in this function by an inconstant muscle called the risorius, which arises from the fascia over the external surface of the parotid gland and goes more or less directly forward to the corner of the mouth. (Smiling also involves muscles such as the levator anguli oris, levator labii superioris, and levator labii superioris alaeque nasae, all of which help to elevate the upper lip.)

Orbicularis Oris

Orbicularis oris is the name given to the mass of muscle tissue that encircles the mouth within the subcutaneous tissue of the lips. A midline microscopic raphe joins the right and left orbicularis oris muscles.[36] When right and left, upper lip and lower lip fibers all contract, they act like a sphincter to close the mouth and seal off the oral cavity from the external world.

Mentalis

Each mentalis muscle arises from the outer surface of the mandible immediately below the lateral incisor tooth. The fibers pass *downward* and forward toward the skin of the chin. When the mentalis muscles contract they obviously pull the skin of the chin toward the incisor roots. It is less obvious, but just as true, that when this occurs the lower lip is caused to protrude forward, as in a pout.

Buccinator

[36] Some fibers of the grossly identifiable orbicularis oris are actually continuations of fibers that run with the levator anguli oris, depressor anguli oris, buccinator, and other tiny facial muscles that converge on the angle of the mouth.

The buccinator is one of the largest and most important facial muscles. It has an origin (1) from the outer surface of the mandible just lateral to the lower molar teeth, (2) from a very thin fibrous band (the pterygomandibular raphe) that runs from this site on the mandible upward to the hamulus of the medial pterygoid plate, and (3) from the outer surface of the maxilla lateral to the upper molar teeth. (It will be recalled that from the back edge of the pterygomandibular raphe arise fibers of the superior pharyngeal constrictor.) From this [-shaped origin of the buccinator, the fibers all course anteriorly to converge on the angle of the mouth and the orbicularis oris. Of course, if the buccinators contracted all by themselves, the angles of the mouth would be pulled backward. The buccinators apparently do participate a making a wide, forced smile.[37] However, this role is trivial. The buccinator has a far more important function under circumstances when the angle of the mouth is prevented from posterior displacement by the orbicularis oris and other facial muscles. Then, the contraction of each buccinator serves to increase the rigidity of the cheek. This is useful when blowing air out of the mouth (Dizzy Gillespie excepted). In fact, the term buccinator is derived from the Latin word *buccina*, which means "trumpet". Even more important in daily life is the role of the buccinator in making the cheek more rigid during chewing. Such an action keeps the inside of the cheek against the gums and, thus, prevents food from accumulating in the oral vestibule between the gums and the cheeks.

Other Muscles of the Facial Somitomere

In Chapter 7 we discussed two facial somitomere muscles that lie in the neck and have nothing whatsoever to do with facial expression. These are the posterior belly of digastric and the stylohyoid. The facial somitomere also gives rise to a muscle in the head unrelated to facial expression. This is the tiny muscle known as **stapedius**. It is enclosed within a space in the mastoid wall of the tympanic cavity. The tendon of the muscle emerges through a hole in this wall to reach the neck of the stapes. The stapedius is called reflexly into action (**acoustic reflex**, **AR**) whenever a loud sound is perceived. The contraction of the muscle dampens the vibration of the stapes and protects the cochlea from injury. Regardless, prolonged exposure to loud noise can lead either to temporary or permanent diminution of hearing due to cochlear damage, particularly for frequencies above 3000 Hz, where the AR is pretty much ineffective in damping ossicular vibrations.

MUSCLES OF THE TRIGEMINAL SOMITOMERE

The trigeminal somitomere gives rise to cells that form eight muscles of the head and neck. Five of these muscles act to move the lower jaw and, thus, are important in chewing. They are referred to as the **muscles of mastication** (temporalis, masseter, lateral pterygoid, medial pterygoid, and anterior belly of digastric). A sixth, the mylohyoid, attaches to the mandible but plays only a minor role in chewing. Two others (tensor tympani and tensor veli palatini) don't even attach to the jaw. However, one should keep in mind the rule, which is never violated, that **all muscles of the head with the word tensor in their name are derived from the trigeminal somitomere**.

Before one can understand the roles played by the different muscles of mastication in chewing, it is necessary to learn a bit about the movement of the lower jaw during opening and closing.

Axis of Rotation of the Mandible for Opening and Closing the Jaw (Fig. 8-22*A*)

An axis of rotation is a line around which some structure rotates. In man-made objects the axis is often a tangible structure, such as the pin through the center of a caster wheel on furniture. In the body,

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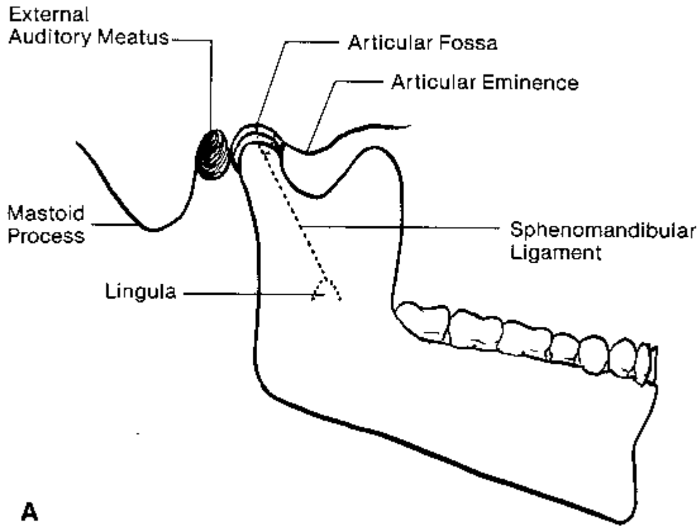
[37]Basmajian, JV: Muscles Alive, ed 5. Williams & Wilkins, Baltimore, 1985.



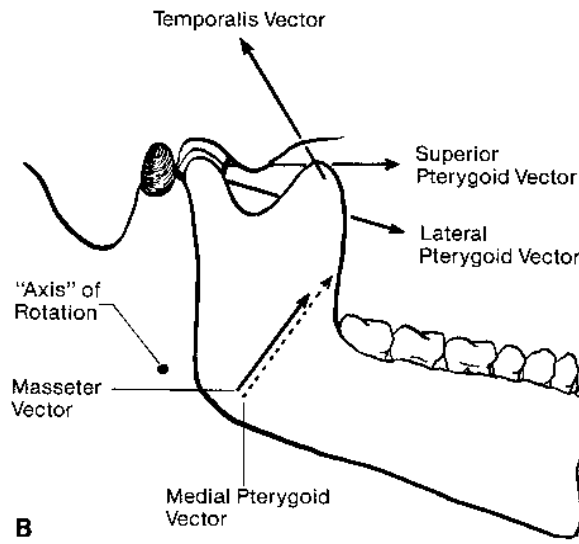


Figure 8-22. *A*, Lateral view of the mandible and the temporomandibular joint. *B*, Idealized vectors of the masticatory muscles in relation to the "axis" of rotation of the mandible. The vector drawn for the masseter is more representative of its superficial fibers than of its deep fibers.

no such tangible axes exist. Rather, a bodily axis of rotation is an imaginary line around which a body part rotates. In fact, motion of a body part often proceeds not around a single axis, but around a series of instantaneous axes that shift precise location from moment to moment as the movement progresses.

The opening/closing movement of the lower jaw does indeed take place around a series of shifting instantaneous transverse axes. Unfortunately, different authors have proposed different paths for these axes. I accept evidence suggesting their average location is just posterior to the angle of the mandible. One thing seems to be certain; because a **sphenomandibular ligament** runs from the tympanosquamosal fissure (on the base of the skull) downward and slightly forward to the lingula, the distance between the lingula and skull base must remain constant. Since important vessels and nerves enter the core of the mandible through a hole (the **mandibular foramen**) located just lateral to the lingula (see Fig. 8-9), it is a good idea to keep this hole a fixed distance from the skull base.

The **temporomandibular joint** (i.e., jaw joint) is characterized by the presence of a fibrocartilaginous intra-articular disc interposed between the upper surface of the mandibular condyle and the lower surface of the articular (mandibular) fossa of the temporal bone. When opening the mouth, the mandibular condyle is caused to rotate on the undersurface of the disc and, simultaneously, the condyle and disc form a unit that slides forward and downward on the undersurface of the temporal bone. If you place some fingers anterior to the external auditory meatus and then open your mouth, you will feel the lateral pole of the mandibular condyle undergo this forward and downward displacement. This movement carries the condyle (and articular disc) down the slope of the **articular eminence** (see Fig. 8-1) found on the undersurface of the zygomatic process of the temporal bone.

Normally, the downward and forward shift of the mandibular condyle that accompanies opening of the jaw presents no problem. However, if this shift is excessive, as may occur in an extreme yawn, the mandibular condyle may actually pass beneath the inferiormost point on the articular eminence and then ride up its anterior slope. The jaw of the patient will be fixed in an open position. Certain persons (maybe those with poorly developed articular eminences) are prone to this type of mandibular dislocation. Once the mandibular condyles have dislocated to a position in front of the articular eminences, an external force is required to push them back again. Someone must put their thumbs between the teeth and push the mandible downward and backward, so that the condyles and discs reenter the articular fossa. Since the jaw tends to snap closed after relocation, the person performing this maneuver should remove his or her thumbs quickly.

Muscles of Mastication--Temporalis, Masseter, Lateral Pterygoid (Superior and Inferior Heads), Medial Pterygoid, and Anterior Belly of Digastric

Temporalis

Each temporalis arises from the outer surface of the cranial vault. This surface of origin covers substantial portions of the laterally directed parts of the parietal and frontal bones, the squamous part of the temporal bone, the vertically directed part of the greater sphenoid wing, and the back of the frontal process of the zygomatic bone. The temporalis also arises from the epimysium on its own superficial surface. Thus, this epimysium is thickened to form a sheet called the **temporal fascia**, which lies just deep to the lateral continuation of the temporoparietal fascia.[38]

From their extensive surface of origin, the temporalis muscle fibers converge on the space immediately deep to the zygomatic arch. Many of the muscle fibers give way to tendon as they converge.

[38] The attachment of the temporal fascia to the frontal and parietal bones (at the periphery of the muscle's surface of origin) forms the **superior temporal line** of the skull (see Fig. 8-1). An even more prominent **inferior temporal line** is the result of the tendinous origin of certain temporalis muscle fibers. The inferior temporal line is continuous with supramastoid crest of temporal bone and the temporal crest of frontal bone (see Fig. 8-1).

Projecting into the same space from below is the tip of the **coronoid process** of the mandible (see Fig. 8-1). The temporalis tendon inserts along the entire edge of the coronoid process and continues down the front edge of the mandibular ramus all the way to where it joins the body. The deep surface of the coronoid process is occupied by the insertion of fleshy fibers of temporalis.

The "space" occupied by the temporalis muscle is called the **temporal fossa**. Now a fossa is supposed to be a depression in some structure, often a bone. The only sense in which there is a depression that houses the temporalis is if one considers that the lateral surface of the skull ought to be located in a sagittal plane through the zygomatic arch. Then, since much of the temporalis lies medial to this plane, it lies in a "depression" of the skull that can be called the temporal fossa.

The different fibers of the temporalis obviously exert different vectors of force on the mandible. The posterior fibers pull more or less directly backward; the anterior fibers pull straight upward. Nonetheless, all potential vectors pass in front of the axis of rotation, making the temporalis a closer of the jaw that plays a major role in biting and chewing (Fig. 8-22*B*). In many persons the temporalis, especially its posterior fibers, is more or less continuously active to oppose the tendency of the jaw to fall open under its own weight.

Masseter

The masseter arises by tendinous and fleshy fibers from the inferior edge and deep surface of the zygomatic arch (see Fig. 7-11). The insertion occupies virtually the whole outer surface of the mandibular ramus below the mandibular notch.

The masseter is a muscle of considerable thickness, with deeper fibers running a somewhat different course than more superficial ones. Although the origins of the deep and superficial fibers overlap, as a whole the deep ones come from a more posterior part of the zygomatic arch, while the superficial ones come from a more anterior part of the arch. As a result, deep masseter fibers follow a course straight downward to their insertion on the mandibular ramus, whereas the superficial fibers course backward and downward.

When the whole masseter contracts, the vector pull passes upward in front of the axis of rotation, causing the jaw to close. However, the vector of the superficial fibers also has a component pulling anteriorly (see Fig. 8-22*B*). Thus, the superficial fibers pull the jaw forward (i.e., protract) at the same time as they close it. If the superficial fibers on only one side contract, they shift only this side forward. This results in the chin being shoved laterally toward the opposite side.

Lateral Pterygoid

The lateral pterygoid has rather distinct superior and inferior heads. Not only to these heads have different origins and insertions, but they have entirely different functions. Juniper [39] has suggested that the morphological and functional separation of the two heads warrants their designation as separate muscles. The superior head would called superior pterygoid; the inferior head would retain the name of lateral pterygoid. For a while I adopted this terminology, but I have now reverted to the more classical usage for no particular reason.

Superior Head. The superior head of lateral pterygoid arises from the inferior surface of the base of the greater sphenoid wing. The muscle is flat from top to bottom; its fibers converge on an insertion into the

[39] Juniper, RP: The superior pterygoid muscle? Br J Oral Surg 19:121-128, 1981.

front of the mandibular condyle and into the articular disc contained within the joint cavity (see Fig. 8-22*B*).

The superior head of lateral pterygoid contracts simultaneously with the temporalis and masseter during all jaw-closing and biting movements. However, the superior head of lateral pterygoid does not actually have a leverage for closing the jaw. Rather, the muscle pulls the condyle forward against the back of the articular eminence on the zygomatic process of the temporal bone. In this way, stress on the thin roof of the articular fossa is reduced by redirection of temporomandibular joint force toward the thick articular eminence.

Inferior Head. The inferior head of lateral pterygoid muscle arises from the lateral surface of the lateral pterygoid plate (see Fig. 8-1). Unlike the superior head, it is broad from top to bottom. The muscle fibers converge on an insertion into the front of the neck of the mandible (see Fig. 8-22*B*).

The inferior head of lateral pterygoid differs dramatically from the temporalis, masseter, and superior head of lateral pterygoid in its function. The vector pull of the inferior head of lateral pterygoid is directed anteroinferiorly on the mandibular neck. Such a pull is positioned with respect to the axis of rotation so as to cause the jaw to open. It is the pull of the inferior head of lateral pterygoid that is responsible for the downward and forward movement of the condyle during jaw opening.

Since the vector of the inferior head of lateral pterygoid has such a major forward component, if some other muscle prevents the jaw-opening action of the muscle, the inferior head of lateral pterygoid simply pulls its side of the jaw forward (like the superficial masseter). As was mentioned earlier, pulling one side of the jaw forward causes the chin to deviate to the opposite side. If both the right and left inferior heads of the lateral pterygoids contract simultaneously with both superficial masseters, the chin is protruded straight forward.

Medial Pterygoid

The medial pterygoid does not arise from the medial pterygoid plate, despite one's predilection to believe so. The muscle arises primarily from the medial surface of the lateral pterygoid plate and from the floor of pterygoid fossa (see Fig. 8-5). The lateral pterygoid plate is a bony septum between the origins of the medial and lateral pterygoid muscles. (For the sake of completeness, it should be mentioned that the main bulk of the medial pterygoid is joined by a small bundle of fibers that arise from the back surface of the maxilla behind the root of the last upper molar. This bundle is called the superficial head of the medial pterygoid because it arises superficial to the lowermost fibers of the lateral pterygoid.)

From their origin, the fibers of the medial pterygoid pass downward, backward, and slightly outward, to reach the inner surface of the mandible adjacent to its angle. It should be noted that, whereas the medial pterygoid muscle starts out deep to the lateral pterygoid (hence their names), the outward course of the fibers toward their insertion brings the medial pterygoid to lie on the same sagittal plane as the lateral pterygoid.

In general direction, the fibers of the medial pterygoid are the internal counterpart of the superficial masseter (see Fig. 8-22*B*). (The medial pterygoid and superficial masseter do have opposite pulls in a transverse plane. The former muscle tends to pull the angle of the mandible medially, the latter pulls it laterally.) Like the superficial masseter, the medial pterygoid has a vector pull on the mandible that is mainly upward and forward in front of the axis of rotation. Thus, the medial pterygoid also closes the jaw and, to a certain extent, pulls it forward. Protrusion of the chin is actually caused by bilateral simultaneous contraction of the superficial masseter, medial pterygoid, and inferior head of lateral pterygoid.

Anterior Belly of Digastric

This muscle lies in the neck and was described in Chapter 7. It will be recalled that it functions along with the posterior belly of digastric (a facial somitomere muscle) in opening the mouth. However, the anterior belly also acts in positioning the hyoid bone.

Trigeminal Muscles Not Involved in Mastication--Mylohyoid, Tensor Veli Palatini, and Tensor Tympani

Mylohyoid

The mylohyoid lies at the junction of the head and neck, but, as it generally is classified as a suprahyoid hyoid muscle of the neck, it was described in Chapter 7. You will recall that its primary structure is that of a contractile hammock stretched between the right and left halves of the mandibular body. In this capacity, the mylohyoid contracts during swallowing so that the intrinsic muscles of the tongue will cause this organ to swell upward against the palate and not downward into the neck. Such a hammock is quite unable to move the jaw itself. It is conceivable that the most posterior fibers of the mylohyoid, i.e., those that run between mandible and the hyoid bone directly, could have some action on the mandible, but this is very unlikely to be important in moving the jaw. Any role the mylohyoid plays in chewing is probably limited to its ability to assist the tongue in positioning food between upper and lower teeth.

Tensor Veli Palatini

The tensor veli palatini is a small muscle derived from the trigeminal somitomere but having no functional relationship to the mandible. The major part of its origin is from a narrow linear surface that starts in the scaphoid fossa at the base of the medial pterygoid plate and extends posterolaterally along a strip of the greater wing of the sphenoid bone deep to the foramina ovale and spinosum (see Fig. 8-5). From this origin, which is about 2 cm long, the muscle fibers proceed inferiorly and forward, giving way to tendinous fibers that converge at a site just lateral to the root of the pterygoid hamulus (see Fig. 8-5). Here the tendon of the tensor veli palatini turns medially, using the root of the pterygoid hamulus as a pulley, and then fans out into the connective tissue of the soft palate.

The muscle fibers just described have an action that accounts for the muscle's name. As a result of the laterally directed pull of the tendon on the soft palate, simultaneous contraction of both right and left tensor veli palatini muscles tightens the soft palate in the same way that a person would tighten a strip of cloth by holding one end in each hand and pulling apart. The action of tensor veli palatini is important in swallowing. After the soft palate has been elevated to participate in closing off the oropharynx from the nasopharynx (see further on), tightness of the soft palate helps to prevent swallowed food from passing up into the nasopharynx and nasal cavity.

Not all the fibers of the tensor veli palatini arise from the undersurface of the skull. A deep lamina of the muscle arises from the membranous wall and adjacent cartilage of the extrapetrous auditory tube. The fibers of this deep lamina help to open the auditory tube by directly pulling the membranous wall of the auditory tube away from the cartilaginous wall, and also by deforming and rotating its cartilage. Opening the auditory tube allows air pressure within the middle ear to equalize with that in the nasopharynx. Some authors consider the deep lamina of the tensor veli palatini to be sufficiently distinct from the rest of the muscle to merit designation as a separate muscle called **dilator tubae**. Yet it does seem that these fibers are most often called into action during activities in which tensing the palate is a component. Thus, during the descent of an airplane passengers are advised to swallow or yawn in order to elicit contraction of dilator tubae by behaviors that include palatal tightening. These maneuvers often fail to work, indicating that it is possible to contract the bulk of the tensor veli palatini without simultaneous recruitment of dilator tubae. Eventually, however, a reflex swallow or yawn occurs in which the auditory tube is opened.

Tensor Tympani

The smallest muscle derived from the trigeminal somitomere is the tensor tympani. The "bulk" of the muscle lies within the petrous portion of the temporal bone in a tiny canal immediately superior to the osseous part of the auditory tube. In fact, because the intrapetrous canal for the auditory tube and the canal for the tensor tympani are separated by only the thinnest layer of bone, many authors speak of a single bony canal divided into a superior semicanal for the tensor tympani and an inferior semicanal for the auditory tube.

Many fibers (some authors say all) of the tensor tympani appear to be continuous with the posterior fibers of the tensor veli palatini, with only a thin fibrous septum intervening. The muscles are completely separate in rhesus monkeys, dogs, and early in human development. The tiny fusiform muscle gives rise to tendon that continues posterolaterally in its semicanal and, upon reaching the middle ear cavity, makes a right-angle turn (around a little bony edge) to pass anterolaterally toward an insertion on the handle of the malleus just below the bone's neck.

The tensor tympani acts precisely as its name implies. By pulling the malleus, which is attached by its handle to the eardrum, the muscle causes the eardrum to tighten. The effect of such tightening is to dampen oscillation. The function of the human tensor tympani is unknown, although its simultaneous contraction with stapedius during speech suggests to some authors that the two muscles allow us to better discriminate our own spoken words by reducing the masking effect of frequency components below 1000Hz.

The Infratemporal Fossa

The lateral pterygoid, origin of the medial pterygoid, and the tensor veli palatini all are located in a region of the head deep to the superior half of the mandibular ramus. This region is called the infratemporal fossa because it is below the temporal fossa. It would be more descriptive to call it the subramal fossa, but such is not the case. As we shall see later, the contents of the infratemporal fossa include not only the muscles just mentioned, but also many nerves and vessels running on the surfaces of these muscles.

MUSCLES OF THE VAGAL SOMITES

Most cells from the vagal somites migrate into the neck to differentiate into the striated muscles of the pharynx, larynx and cervical esophagus. Those cells that stay in the head becomes the striated muscles of the soft palate (with the exception of tensor veli palatini, which is derived from the trigeminal somitomere). Palatopharyngeus, palatoglossus, and musculus uvulae have already been described. However, the most important palatal muscle is the levator veli palatini.

Levator Veli Palatini

The levator veli palatini arises from the inferior surface of the petrous temporal just in front of the carotid foramen (see Fig. 8-5). Thus, the extrapetrous portion of the auditory tube separates the origin of levator palati from that of tensor veli palatini. The muscle fibers of the levator form a round bundle that passes along the inferior surface of the auditory tube and, with it, crosses over the free upper edge of the superior pharyngeal constrictor, to reach the nasopharynx. The auditory tube opens up into the nasopharynx behind the inferior nasal meatus; the levator veli palatini continues down to the palatine aponeurosis.

Levator veli palatini does exactly what its name suggests--it elevates the soft palate. Such elevation is particularly important when it occurs simultaneously with an anterior displacement of the back wall of the pharynx brought about by contraction of its superior constrictor. The two movements close off the cavity of the oropharynx from that of the nasopharynx, enabling production of certain sounds (eg., "Aaah") and preventing swallowed food or liquid from being regurgitated up into the nasal cavity (Fig. 8-23). A number of recent authors believe that the levator veli palatini also assists the tensor veli palatini in opening the auditory tube. The theory is that when the levator contracts it swells, and this swelling pushes up on the medial lamina of the auditory tube. That upward displacement, in conjunction with the inferolateral pull of the tensor on the lateral lamina of the cartilage and the lateral fibrous wall of the tube, cause it to open.

PAROTID GLAND IN THE HEAD

As we learned in Chapter 7, much of the parotid salivary gland lies in the retromandibular region of the neck. But it was also mentioned that glandular tissue extends forward a variable distance onto the lateral surface of the mandibular ramus and masseter below the zygomatic arch (see Fig. 7-11).

From the anterior edge of the parotid, at a site about 1 fingerbreadth (fb) below the zygomatic arch, emanates the **parotid duct**. This runs straight forward across the superficial surface of the masseter onto the buccinator, which it pierces to open into the oral vestibule opposite to upper 2nd molar tooth.

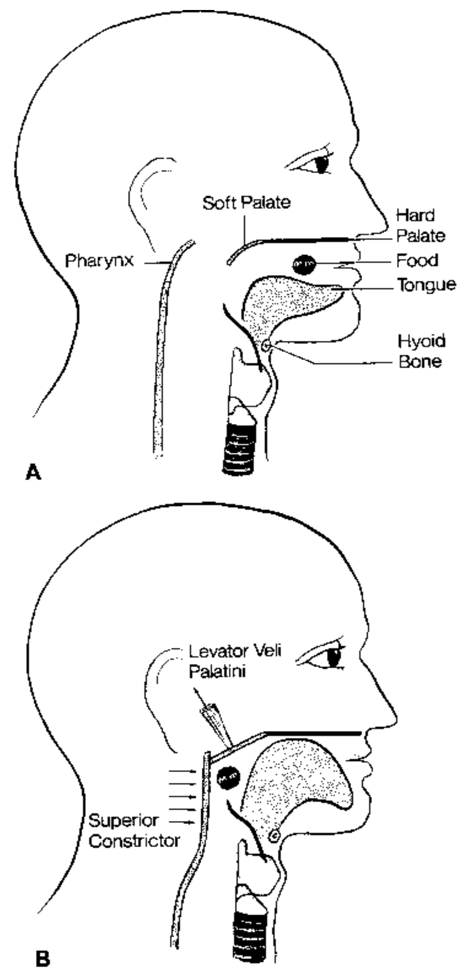


Figure 8-23. Schematic sagittal sections of the oral cavity illustrating the mechanism of swallowing. *A*, Food is in the mouth, but swallowing has not begun. *B*, Swallowing occurs by elevating the tongue and using it to push the food in the oropharynx, which has been sealed off from the nasopharynx by elevation of the soft palate and contraction of the superior pharyngeal constrictor.

Very often actual glandular tissue extends along the beginning of the duct.

Placed deeply within the parotid gland is the part of the facial nerve I have called ansa facialis (see Fig. 7-22), the branches of which exit from various borders of the parotid. The transverse facial vessels (see further on) run forward in the upper region of the parotid. When they leave its anterior edge, they course between the zygomatic arch and the parotid duct.

ARTERIES OF THE HEAD

The blood supply to the head is conveyed by the vertebral, internal carotid, and external carotid arteries. The vertebral artery is concerned primarily with supply of the posterior brain. The internal carotid provides blood to the remainder of the brain, the orbital structures, and certain bits of the face, scalp, and nasal cavities near the orbit. All the rest of the head receives its blood via the external carotid artery.

Distribution of the External Carotid Artery to the Head

The **occipital** and **posterior auricular** branches of the external carotid were described in Chapter 7. They end by distributing to the skin and subcutaneous tissue of the posterior scalp. The path of the **lingual artery** to the tongue and sublingual gland was also discussed in Chapter 7. Nor should we forget that the **ascending pharyngeal** and **facial** arteries give off branches to the soft palate.

In this section, I shall be concerned with the course of the facial artery in the head and the courses of the two terminal branches of the external carotid. It will be recalled that the external carotid artery passes posterolaterally above the stylohyoid muscle to enter the parotid gland behind the ramus of the mandible. Here the vessel turns superiorly and ascends within the gland to a position behind the neck of the mandible, where it bifurcates into its two terminal branches--the superficial temporal and maxillary arteries.

Facial Artery in the Head

When last we left the facial artery it was entering the subcutaneous tissue of the face at the lower border of the mandible adjacent to the anterior edge of the masseter. The vessel follows a sinuous course in the subcutaneous tissue toward the angle of the mouth, where it turns more superiorly to run along the side of the nose up to the medial palpebral commissure. In its course through the face, the facial artery runs deep to some facial muscles and superficial to others. The artery terminates at the medial palpebral commissure by giving small branches to nearby structures. This very last bit of the vessel, in the medial "angle" of the eye, is often called the **angular artery**.

Naturally, the facial artery gives off many small unnamed branches to superficial structures near its path. It also has two named branches: the **inferior labial** and **superior labial** arteries. Both pass medially into the substance of their respective lips, close to the mucous membrane lining. The superior labial artery sends a small twig to the lower front part of the nasal septum. The pulse of a labial artery can be felt deep to the mucous membrane by gently compressing a lip between thumb and forefinger.

Superficial Temporal Artery

Arising within the parotid gland behind the neck of the mandible, the superficial temporal artery jogs outward and then upward, exiting the parotid gland to reach a position between the external auditory meatus and mandibular condyle. Here the vessel enters the subcutaneous tissue and continues upward across the root of the zygomatic arch into the scalp in front of the ear. Its pulse should be palpable as it crosses the zygomatic arch immediately in front of the ear.

The superficial temporal artery has numerous branches, only four of which are of any consequence:

1. While still in the parotid, the superficial temporal gives off a small **transverse facial artery** that courses anteriorly within the upper part of the gland below the zygomatic arch. The transverse facial artery then passes out the anterior border of the parotid onto the surface of the masseter, where it runs between the zygomatic arch and parotid duct, supplying nearby structures.

2. After crossing the posterior root of the zygomatic arch in front of the ear, the superficial temporal gives off a **middle deep temporal artery** that dives deeply into the temporalis muscle, contributing to that muscle's blood supply.

3 and 4. Near the upper edge of the ear, the superficial temporal artery bifurcates into a **posterior (parietal) branch** that passes upward toward the vertex of the skull, and an **anterior (frontal) branch** that goes to the forehead. These are tortuous superficial vessels that can often be seen pulsating beneath the skin in thin bald persons.

Maxillary Artery

The other product of the external carotid's bifurcation behind the mandibular neck is the maxillary artery. This vessel passes deeply for a few millimeters and then turns forward to cross the medial surface of the mandibular neck (between it and the sphenomandibular ligament). The maxillary artery soon encounters the lower border of the inferior head of lateral pterygoid near that muscle's insertion, and then makes a partial turn upward, either passing deep or superficial to the muscle. Its new oblique (anterosuperior) course takes the maxillary artery toward the top of the pterygomaxillary fissure (see Fig. 8-1).

Immediately after it arises, the maxillary artery gives off two tiny arteries--the **anterior tympanic** and **deep auricular**--that pass backward for supply of the external auditory meatus, eardrum, and tympanic cavity.

At the lower edge of the lateral pterygoid the maxillary artery gives off three very important branches. The first of these is the **inferior alveolar artery**, which descends through the mandibular foramen into the mandibular canal. This artery supplies the mandible and lower teeth. It ends by leaving the front of the mandible through the mental foramen in order to supply the soft-tissue structures of the chin. This terminal part of the inferior alveolar artery is called the **mental artery**.

The other two branches of the maxillary at the lower border of the lateral pterygoid are the posterior deep temporal artery and the middle meningeal artery. The middle meningeal comes off prior to the posterior deep temporal if the maxillary artery is going to pass superficial to the lateral pterygoid. The order of branching is reversed if the maxillary artery moves deep to the muscle.

This **middle meningeal artery** ascends deep to the inferior head of lateral pterygoid heading toward the foramen spinosum. The vessel then passes through this foramen into the cranial cavity, where it embeds itself in the endocranium. Here the middle meningeal artery ramifies for supply of the bulk of the cranial dura and the bones of the vault. (Just before the middle meningeal passes through foramen spinosum, it often gives off a tiny accessory meningeal branch that enters the cranial cavity via the foramen ovale. The accessory meningeal artery may arise directly from maxillary.)

Soon after its origin, the **posterior deep temporal artery** gives off a **masseteric branch** that heads laterally through mandibular notch and directly into the deep surface of the masseter muscle. The posterior deep temporal artery then runs upward on the superficial surface of the lateral pterygoid to enter a plane between pericranium and the temporalis muscle, supplying both muscle and bone.

After giving off middle meningeal and posterior deep temporal branches, the maxillary artery continues a course toward the pterygomaxillary fissure, supplying small muscular branches to all three pterygoid muscles, and, shortly before reaching the fissure, giving off anterior deep temporal and buccal branches. The **anterior deep temporal artery** ascends between pericranium and the anterior part of temporalis, supplying both muscle and bone. The **buccal artery** passes downward and forward to emerge from under cover of the anterior edge of the masseter onto the superficial surface of buccinator. It supplies soft tissues of the cheek along with the facial artery.

Upon reaching a site immediately lateral to the pterygomaxillary fissure, the maxillary artery bifurcates into its two terminal divisions. The **outer division** is the common stem of the infraorbital and posterior superior alveolar arteries. Neither of these vessels pass through the fissure. Rather, the **posterior superior alveolar artery** descends for a centimeter or so, hugging the back surface of the maxilla, and then passes through a hole in that bone to supply the molar teeth and gums of the upper jaw. (It may branch once or twice before piercing the bone.) The **infraorbital artery** passes upward and forward into the infraorbital groove beneath the periorbita of the orbital floor (see Fig. 8-15). The anterior part of the groove is bridged over by bone to form the infraorbital canal, which opens as the infraorbital foramen onto the front of the maxilla several millimeters beneath the inferior orbital rim (at the junction of its lateral two thirds with its medial third) (see Fig. 8-15). The infraorbital artery supplies the lower eyelid and soft-tissue structures below the orbit. While in the infraorbital groove and canal, the infraorbital artery gives off (1) a **middle superior alveolar artery** that travels in the bony anterolateral wall of the maxillary sinus to reach the premolar teeth, and (2) an **anterior superior alveolar artery** that travels in the bony anterior wall of the maxillary sinus to reach the canine and incisor teeth.

The **inner terminal division** of the maxillary artery passes through the pterygomaxillary fissure into the pterygopalatine fossa. Once inside the fossa, the vessel divides into two main branches: the greater (descending) palatine artery and the sphenopalatine artery. The **greater (descending) palatine artery** immediately heads downward to leave the pterygopalatine fossa through a long hole called the **greater palatine canal**, which opens up as the **greater palatine foramen** onto the undersurface of the hard palate medial to the 3rd (sometimes the 2nd) molar tooth (see Fig. 8-5). In its path through the greater palatine canal, the artery gives off one to three tiny **lesser palatine arteries** that leave the back of the canal to travel in tiny **lesser palatine canals** (parallel to but behind the greater canal) that open up as **lesser palatine foramina** behind the greater palatine foramen. The lesser palatine arteries supply the soft palate (along with the ascending palatine and tonsillar branches of the facial artery, and the ascending pharyngeal artery). After the origin of the last lesser palatine artery, the greater palatine artery exits through the greater palatine foramen, and then turns anteriorly to run in the mucoperiosteum at the lateral border of the hard palate, supplying nearby structures.

The other large branch of the inner terminal division of the maxillary artery is the **sphenopalatine artery**. It exits the pterygopalatine fossa through the sphenopalatine foramen. This takes the artery into the nasal cavity, where it immediately gives off a vessel that ramifies in the mucoperiosteum over the conchae as the so-called **posterior lateral nasal arteries**. The continuation of the sphenopalatine artery crosses the roof of the nasal cavity to encounter the back of the nasal septum and then ramifies in the mucoperiosteum of the septum as **posterior septal arteries**. The lowest of these continues forward to the incisive canal, passes through it onto the undersurface of the palate, where it anastomoses with the greater palatine artery.

Vertebral Artery in the Head

When last we left the vertebral arteries, they had entered the cranial cavity through the foramen magnum. Each had given off a small **posterior meningeal branch**, **anterior and posterior spinal**

arteries, unnamed branches to the medulla, and a **posterior inferior cerebellar artery**. Then, on the ventral surface of the brainstem at the posterior edge of the pons, the two vertebral arteries merge to form the single **basilar artery** that travels within the subarachnoid space in the midline groove on the ventral surface of the pons. The basilar artery has unnamed branches to the brainstem, and it also gives off the **anterior inferior cerebellar** and the **superior cerebellar** arteries (Fig.8-24).

At the anterior end of the pons, the basilar artery bifurcates into the **posterior cerebral arteries** (see Fig. 8-24) that go to the occipital lobes of the cerebrum. About a centimeter after they arise, each posterior cerebral artery is connected to the internal carotid of the same side by a communicating vessel of variable size. This vessel is called the **posterior communicating artery** (see Fig. 8-24). Not infrequently the first centimeter of a posterior cerebral artery is extraordinarily tiny, in which case the posterior communicating artery on that side will be larger than usual so as to carry arterial blood from the internal carotid into the posterior cerebral beyond its constricted portion (see Fig. 8-24, *right side*).

The first centimeter or so of each posterior cerebral artery and the posterior communicating vessels are part of the famous circle of Willis, the description of which will be completed shortly.

Internal Carotid Artery

The internal carotid artery enters the carotid foramen in the petrous temporal at the base of the skull (see Fig. 8-5). Immediately the vessel makes a 90-degree turn to travel anteromedially within this bone toward its apex, at which point the internal carotid artery emerges from the petrous temporal at a site superior to the cartilage filling the foramen lacerum, and immediately below the posterior part of the cavernous sinus. The artery then makes another turn of almost 90 degrees upward into the sinus, whereupon it turns forward and runs in the sinus alongside the body of the sphenoid bone, which it grooves. Once past the middle clinoid process, the internal carotid artery turns up again, pierces the dural roof of the cavernous sinus and the arachnoid to pass through the caroticoclinoid foramen into contact with the undersurface of the optic nerve. The internal carotid, now lying within the subarachnoid space, turns backward to run lateral to the optic chiasm and medial to the parahypophyseal margin of the tentorial notch. Upon reaching the lateral edge of the posterior clinoid process, the artery turns laterally toward the brain.

The first turn of the internal carotid that occurs immediately after it enters the petrous temporal is located in front of the anterior wall of the tympanic cavity. It is here that the artery gives off its first branch--the tiny **caroticotympanic artery**, which passes through the anterior wall of the tympanic cavity to contribute to the blood supply of the middle ear.

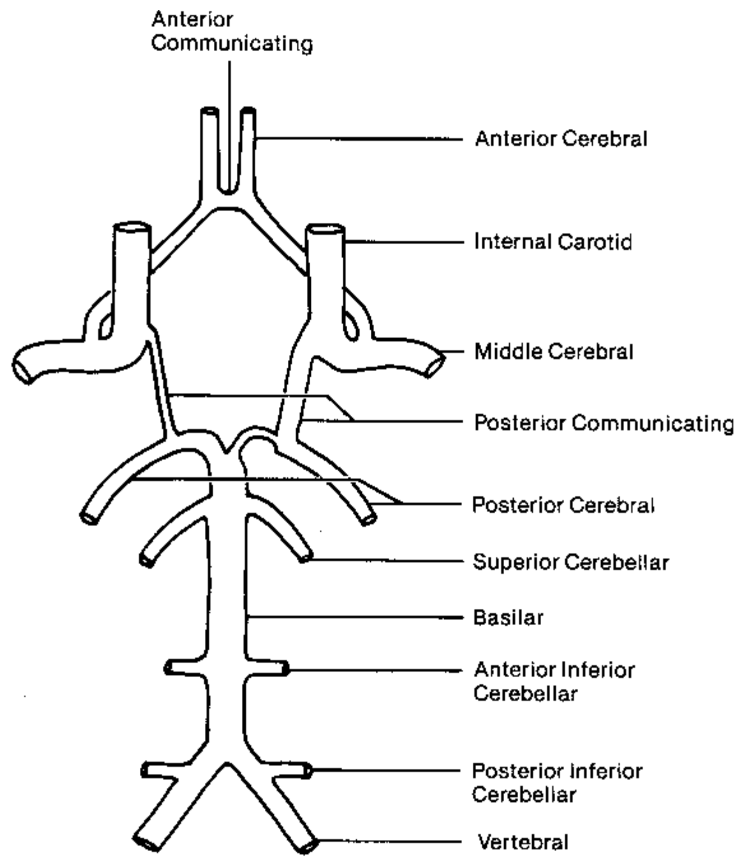


Figure 8–24. Schematic inferior view of the circle of Willis. On the *left side* of the figure is the common condition in which the posterior cerebral artery is large and the posterior communicating artery is small. On the *right side* of the figure is a variation in which a large posterior communicating artery takes over supply of blood to the distal portion of the posterior cerebral artery.

From the site where it exits the petrous canal until the site where it leaves the cavernous sinus, the internal carotid artery gives off minuscule branches to the trigeminal ganglion, nerves within the cavernous sinus, and the pituitary gland.

When the internal carotid artery leaves the cavernous sinus to achieve a position beneath the optic nerve, the **ophthalmic artery** is given off. The ophthalmic artery enters the optic canal on the inferior surface of the optic nerve.

As the internal carotid approaches the posterior clinoid process, it is joined by the posterior communicating artery that connects it to the posterior cerebral branch of the basilar artery.

Alongside the posterior clinoid process, as the internal carotid artery is executing its final turn laterally, the **anterior cerebral artery** is given off (see Fig. 8-24). The continuation of the internal carotid into the sylvian fissure of the brain is then called the **middle cerebral artery**. The anterior cerebrals from each side pass forward and medially toward the longitudinal fissure between the cerebral hemispheres. As they enter it, they are connected by a short communicating channel called the **anterior communicating artery** (see Fig. 8-24). Now the **circle of Willis** is completed (see Fig. 8-24), allowing blood from the vessels on one side of the body to reach those on other side, or for blood from the vertebral distribution to reach the carotid distribution, if exigencies so demand.

Ophthalmic Artery

Entering the optic canal on the inferior surface of the optic nerve, the ophthalmic artery soon pierces the arachnoid and dural sheaths of the nerve to emerge into the orbit still inferior to the nerve but now in the extraocular space. Once in the orbit, the ophthalmic artery usually passes upward around the lateral side of the optic nerve and then turns anteromedially across its top surface, beneath the superior rectus muscle. However, in about 25 percent of cases, the artery simply heads anteromedially below the nerve. Regardless, its anteromedial course takes the ophthalmic artery toward the upper border of the medial rectus muscle, where the vessel turns anteriorly to run all the way to the front of the orbit. Just before reaching the orbital septum, the ophthalmic artery bifurcates into its two terminal branches--the supratrochlear and dorsal nasal arteries.

Although the ophthalmic artery is small, it has quite a few named branches. Additionally, it gives off unnamed muscular branches to the extraocular muscles.

Immediately after entering the orbit, while still beneath the optic nerve, the ophthalmic artery gives off the tiny but very important **central artery of the retina**. This vessel pierces the dural sheath of the optic nerve and travels forward embedded in this sheath until about 1 cm from the back of the eyeball. Here, the central artery of the retina pierces the arachnoid and pia to reach the middle of the optic nerve, where it runs forward into the eyeball for distribution to the optical retina.

While traveling upward on the lateral surface of the optic nerve, the ophthalmic artery gives off the **lacrimal artery**. This vessel travels forward along the upper edge of the lateral rectus muscle. It eventually reaches the lacrimal gland, which the artery supplies, and then terminates in branches to the eyelids. Before reaching the lacrimal gland, the lacrimal artery gives off a tiny **zygomatic branch** that runs through the zygomatic bone with the zygomatic nerve (see further on). More importantly, the lacrimal artery gives off a **recurrent meningeal** branch that turns posteriorly and passes through a foramen between the greater wing of the sphenoid bone and the frontal bone (see Fig. 8-15) to anastomose with the anterior branch of the middle meningeal artery. In this manner, an anastomosis between the internal and external carotid arteries is established.

From the same stretch of the ophthalmic artery that gives off the central retinal and lacrimal branches come two (sometimes more) **posterior ciliary arteries**. They may even come off common trunks with the central retinal and lacrimal arteries. The posterior ciliary arteries run toward the eyeball parallel to the optic nerve, but close to the eyeball they branch several times. Thus, numerous tiny posterior ciliary arteries actually pierce the sclera all around the entrance site of the optic nerve. Most of these ramify in the choroid for supply of the nonretinal tissues. The two largest posterior ciliary branches (one entering the eyeball lateral to the optic nerve and one entering medial to the nerve) pass all the way round to the front for supply of the ciliary body and iris. These two vessels are called **long posterior ciliary arteries**, thereby causing the others to be called **short posterior ciliary arteries**.[40]

[40] There would be no ciliary arteries specified as posterior if there were not some that are called anterior. The anterior ciliary arteries are not direct branches of the ophthalmic. Rather, the muscular branches of the ophthalmic send tiny vessels that ramify on the surface of the sclera beneath the bulbar conjunctiva. These communicate with the long posterior ciliary arteries through vessels that pass through the sclera.

As the ophthalmic artery runs anteromedially across the top surface of the optic nerve beneath the superior rectus, it gives off a **supraorbital artery**. This vessel passes onto the superior surface of the levator palpebrae superioris by crossing its medial edge. Traveling forward on the levator palpebrae superioris, the supraorbital artery encounters the orbital septum just below the supra-orbital notch. The vessel pierces the septum and turns superiorly deep to the frontalis muscle. After a variable distance, the artery pierces frontalis and continues backward in the subcutaneous tissue of the scalp.

While running forward in the interval between the superior oblique and medial rectus muscles, the ophthalmic artery sometimes gives off a tiny **posterior ethmoidal artery** and always gives off a slightly larger **anterior ethmoidal artery**. Both course medially (the posterior ethmoidal superior to the superior oblique muscle, the anterior ethmoidal between the superior oblique and medial rectus) to pass through separate foramina in the medial orbital wall and thereby reach the ethmoid air cells, which they supply. However, both also continue beyond the ethmoidal air cells into the cranial cavity at the lateral border of the cribriform plate. The posterior ethmoidal artery terminates in the anterior cranial fossa by giving rise to meningeal branches and to nasal branches, which pass through the cribriform plate for supply of the upper nasal septum and lateral nasal wall. The anterior ethmoidal artery gives off similar branches, but it also continues forward on the superior surface of the cribriform plate to pass through a slit at its anterior end and enter the nasal cavity far anteriorly. Here it gives rise to further branches for the septum and lateral nasal wall, but then continues on the deep surface of the nasal bone to its inferior edge, where the vessel emerges between nasal bone and lateral nasal cartilage as a cutaneous artery.

After the ophthalmic artery gives off its anterior ethmoidal branch, it continues forward along the upper edge of medial rectus until very near the orbital septum, where the artery bifurcates into its terminal branches--the **supratrochlear and dorsal nasal arteries**. Both pierce the orbital septum above the medial palpebral ligament, but then the supratrochlear turns upward into the subcutaneous tissue of the scalp, whereas the dorsal nasal turns medially into the subcutaneous tissue over the bridge of the nose. From the supratrochlear, the dorsal nasal, or both, come branches to the eyelids.

VEINS OF THE HEAD

Veins Accompanying the Maxillary, Superficial Temporal, and Facial Arteries

There are a few noteworthy facts concerning the veins that accompany the major branches of the external carotid artery to the head. First, the veins that run with the branches of the maxillary artery do *not* empty directly into a maxillary vein that runs alongside this vessel. Rather, there is a plexus of veins all around the lateral pterygoid muscle. This **pterygoid plexus of veins** receives tributaries from vessels that accompany branches of the maxillary artery. From the back of the pterygoid plexus emerges a short **maxillary vein** that passes medial to the neck of the mandible and then turns laterally to enter the parotid gland. Here the maxillary vein encounters the **superficial temporal vein**, which it joins to form the retromandibular vein superficial to the external carotid artery. The course and drainage of retromandibular vein has been described in Chapter 7.

The course and communications of the **facial vein** that accompanies the facial artery are also deserving of special attention. The facial vein begins at the medial palpebral commissure by the junction of two veins that descend in the anterior scalp. These are the **supratrochlear vein**, very near the midline, and the **supraorbital vein**, about an inch lateral to the midline. (Interestingly, the supratrochlear and supraorbital arteries are branches of the ophthalmic artery off the internal carotid, not branches of the facial artery.) The very beginning of the facial vein is often called the **angular vein**, just as the termination of the facial artery is called the angular artery. Below the orbit, the facial vein follows a more or less straight course toward the lower border of the mandible adjacent to the anterior edge of masseter. Thus, the facial vein and artery are separated by some distance at the level of the mouth before they come together again lower down.

Superiorly, the angular vein and/or its two tributaries are in free communication with the superior ophthalmic vein of the orbit, which in turn drains to the cavernous sinus. There being no valves in any of the involved vessels, blood may flow from the cavernous sinus and orbit into the facial vein, or vice versa.

The communication between the angular vein and the cavernous sinus predisposes the latter to septic thrombosis, owing to passage of infectious material entering the upper part of the facial vein.

Communications Between the Pterygoid Plexus and Other Venous Channels

At the level of the cheek the facial vein is connected to the pterygoid plexus of veins by a communicating vessel called the **deep facial vein**. The latter reaches the pterygoid plexus by passing deep to the anterior border of the masseter. Again, in that the participating veins have no valves, blood may pass from the pterygoid plexus out to the facial vein, or *vice versa*. Additionally, the pterygoid plexus communicates with (1) the cavernous sinus via small venous channels that pass through the foramen lacerum and/or foramen ovale, and (2) the inferior ophthalmic vein (which drains to the cavernous sinus) via a small venous channel that passes through the inferior orbital fissure.

The communications between the cavernous sinus and the pterygoid plexus provide a route for infectious material that arrives at the plexus to pass up into the sinus. Since the upper and lower jaws are drained by veins that end in the pterygoid plexus, osteomyelitis of either jaw subsequent to tooth extractions may be followed by septic thrombosis of the cavernous sinus. The communicating channels between the pterygoid plexus and the cavernous sinus make the deep facial vein part of a second route for passage of infectious material from the face to the cavernous sinus.

The Absence of Veins Accompanying the Intracranial Parts of the Vertebral and Internal Carotid Arteries

No veins run alongside the intracranial parts of the either the vertebral or internal carotid arteries. Instead, veins from the brain follow independent courses to the dural sinuses. The only branch of the internal carotid to be accompanied by a vein is the ophthalmic artery. Even then, the ophthalmic artery and ophthalmic veins do not really lie alongside one another, although both are in the orbit.

Ophthalmic Veins

The major vein of the orbit is the **superior ophthalmic vein**. It begins as a confluence of small, posteriorly directed channels from the backs of the supraorbital, supratrochlear, and/or angular veins.

These pass through the orbital septum, join one another, and the resultant superior ophthalmic vein passes backward deep to the superior rectus muscle. As it does so, it picks up tributaries that accompany all the named branches of the ophthalmic artery. The superior ophthalmic vein eventually passes out of the orbit through either the middle or upper compartment of superior orbital fissure, whereupon it empties immediately into the cavernous sinus.

An **inferior ophthalmic vein** begins as tributaries draining the inferior rectus and inferior oblique muscles near the front of the orbit. It passes backward below the eyeball, picks up a few ciliary veins, and then either joins the superior ophthalmic vein or passes separately through the lower compartment of the superior orbital fissure to reach the cavernous sinus. I have already mentioned the important communicating channel that passes through the inferior orbital fissure between the inferior ophthalmic vein and the pterygoid plexus.

NERVES OF THE HEAD

Some cervical nerves have a cutaneous role in the head. These are the greater, third, and lesser occipital nerves to the back of the scalp, and the great auricular nerve to the lower half of the ear and skin over the parotid gland. Otherwise all the innervation of the head derives either from cranial nerves or from postganglionic sympathetic plexuses that travel around the internal and external carotid arteries.

Cranial Nerves

Olfactory Nerve--Cranial Nerve I

The olfactory is a purely sensory nerve. It is not a single bundle of axons, as are most other named nerves, but, rather, the olfactory "nerve" on each side consists of 20 or so separate bundles that contain axons arising from olfactory cells scattered among the supporting epithelial cells in the roof of the nasal cavity (and the immediately adjacent parts of the nasal septum and lateral nasal wall). On each side these 20 or so "**fila olfactoria**" pass through holes in the cribriform plate of the ethmoid and then pierce the dura and arachnoid to enter the **olfactory bulb**, where the olfactory axons synapse.

CLINICAL CONSIDERATIONS

Damage to the olfactory nerve can occur in fractures of the skull that involve the cribriform plate. Also, tumors of the frontal lobes of the cerebral cortex, or of the meninges of the anterior cranial fossa, can compress the olfactory bulb and lead to loss of smell.

The sense of smell is rarely tested unless one suspects conditions such as those just described. If one wishes to test for smell, each olfactory nerve must be tested separately in order to detect asymmetry in the response. Bilateral loss of smell is usually of no significance because many common nasal infections greatly impair the sense of smell bilaterally, and some persons are simply born with a very poor sense of smell. On the other hand, tumors or fractures often involve damage to only one side.

To test the sense of smell on each side, a nonirritating odoriferous substance is placed beneath one nostril while the other nostril is compressed. Oil of peppermint, wintergreen, cloves, or camphor are commonly used. Obviously, the patient must keep the eyes closed during the test.

Optic Nerve--Cranial Nerve II

The optic nerve is a purely sensory nerve. (By this I mean that it carries no motor fibers to glands or muscles; it does contain efferent axons that influence retinal function.) The sensory axons within the optic nerve originate in cells of the optical retina and pass backward to the lateral geniculate body located inferior to the back end of the thalamus. Gross anatomists tend to be most concerned with the optic pathway from the eye to the brain, leaving the rest for neuro-anatomists.

The part of the world seen by the eyes is known as the **visual field**. The entire visual field is divided into regions *defined when the eyes are looking straight ahead*. Objects that are toward the sky lie in the upper part of the visual field; objects toward the ground lie in the lower part. Objects to our left are in the left visual field; objects to our right are in the right visual field.

Each eye has its own visual field (i.e., the part of the world seen by that eye alone) (Fig. 8-25). The left visual field of the left eye is often called its temporal field, whereas the right visual field of the left eye is often called its nasal field. Similarly the right visual field of the right eye is its temporal field, whereas the left visual field of the right eye is its nasal field. Because of the interference presented by the bridge of the nose, the temporal field of vision of an eye is wider than that same eye's nasal field. Thus, although the fields of vision of the two eyes overlap greatly, the left eye sees things far to the left that the right eye cannot see. Similarly, the right eye sees things far to the right that the left eye cannot see.

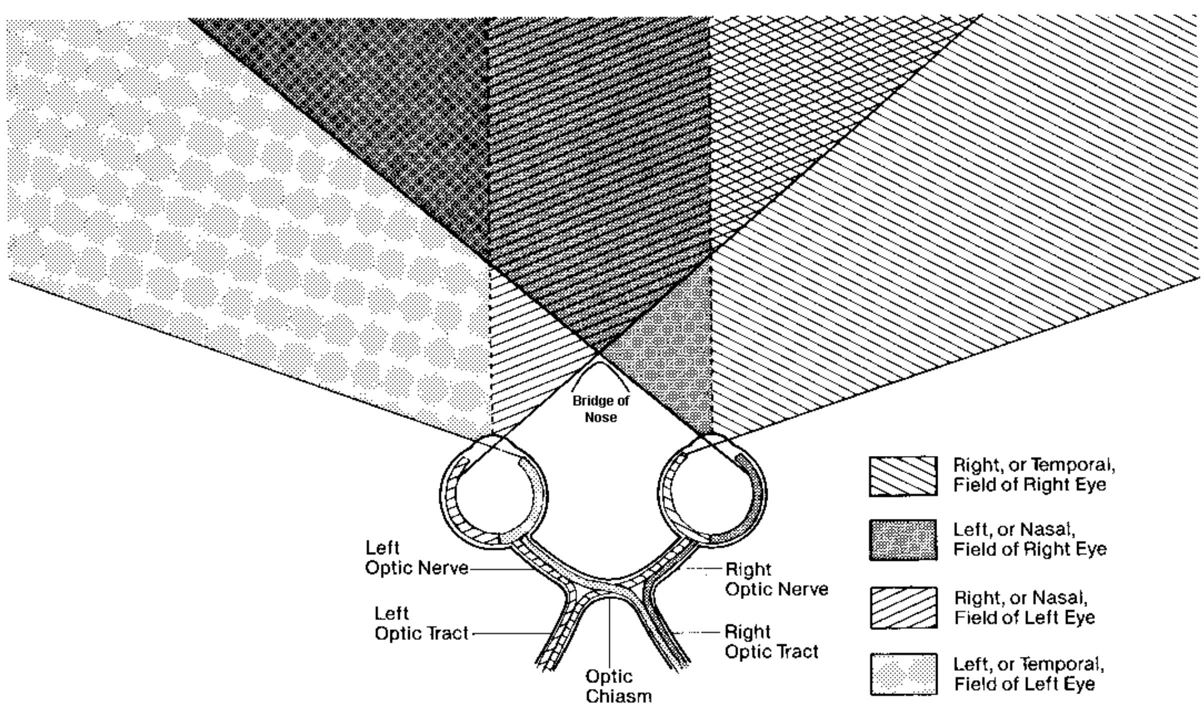


Figure 8-25. Fields of vision and the optic chiasm (superior view).

The image of the visual field created on the retina is inverted. Thus, the higher an object is out there in the real world, the lower on the retina is its projected image. The further to the right is an object, the further to the left on the retina is its image. As a result, the left visual field of each eye is seen by the right half of its retina, and the right visual field of each eye is seen by the left half of its retina (see Fig. 8-25). Expressed in terms of "nasal" and "temporal," the nasal half of a retina sees the temporal field of vision, and the temporal half of a retina sees the nasal field of vision.

Each optic nerve carries axons from the entire retina of its corresponding eye (see Fig. 8-25). However, after passing backward through the optic foramina, the right and left optic nerves engage in a redistribution of axons at the so-called **optic chiasm**, located just anterior to the pituitary stalk. The optic chiasm is formed of fibers from the nasal half of each retina crossing over to the opposite side (see Fig. 8-25). Emerging from the optic chiasm are the two **optic tracts**. The right optic tract contains axons from the temporal half of the right retina and the nasal half of the left retina, thus carrying information about the entire left visual field. The left optic tract contains axons from the temporal half of the left retina and the nasal half of the right retina, thus carrying information about the entire right visual field. The optic tracts are named according to the side of the body on which they lie. These names belie the fact that each is concerned with the contralateral visual field.

CLINICAL CONSIDERATIONS

If one optic nerve is put out of commission (e.g., by tumor or inflammation) the eye served by that nerve cannot see. This is simply called **unilateral blindness**. Quite a different result occurs if one optic tract is inoperative. Loss of function in the right optic tract causes loss of sight in the left visual field. This is called left **homonymous hemianopia** (where hemianopia means that half the visual field of *each* eye is lost, whereas homonymous means the lost half-field of one eye is the same side as the lost half-field of the other eye). Interruption of function in the left optic tract causes right homonymous hemianopia (loss of vision in the right visual fields of both eyes). Finally, pituitary tumors may press forward onto the optic chiasm. Each eye undergoes loss of the field served by the nasal half of its retina. Thus, each eye has a hemianopia (loss of half its visual field) that involves its temporal field. In other words, lesions of the optic chiasm are said to produce a **bitemporal hemianopia**. Since the temporal field of the right eye is its right field, but the temporal field of the left eye is its left field, a bitemporal hemianopia is **heteronymous**.

Neuro-ophthalmologists have ways of accurately assessing visual field defects. In the more typical physical exam, the exploration of visual fields is usually done simply by bringing a wiggling finger into view of the patient from the sides, from above, and from below. The patient looks straight ahead and is requested to state when the finger can first be seen.

Oculomotor Nerve--Cranial Nerve III

The oculomotor nerve is a purely motor nerve. It supplies somatic motor input to levator palpebrae superioris, superior rectus, medial rectus, inferior rectus, and inferior oblique muscles. It also carries parasympathetic preganglionic axons for the ciliary muscle and constrictor pupillae. (There are proprioceptive fibers that run back from extraocular muscles, but by some route or another these end up in the ophthalmic division of trigeminal heading toward cell bodies in the brain.)

After the oculomotor nerve exits the midbrain, it passes forward between the superior cerebellar and posterior cerebral arteries to reach the roof of the cavernous sinus slightly anterior to the posterior clinoid process. The nerve pierces the cavernous sinus roof and runs forward in the sinus applied to the inner surface of its dural wall (see Fig. 8-13). Emerging from the front of the sinus, the oculomotor nerve divides into superior and inferior divisions that pass into the orbit through the middle compartment of the superior orbital fissure. The superior division supplies the levator palpebrae superioris and the superior rectus. The inferior division supplies the two inferior extraocular muscles and sends a branch below the optic nerve to reach the medial rectus.

There is a clump of parasympathetic ganglion cells sandwiched between the lateral surface of the optic nerve and the lateral rectus muscle, just anterior to the site where the ophthalmic artery crosses the optic nerve. This clump is called the **ciliary ganglion**. The inferior division of the oculomotor nerve passes forward just below the ciliary ganglion, and, as it does so, sends a bundle carrying preganglionic parasympathetic axons upward to synapse in the ganglion. The postganglionic axons leave the front of the ganglion through two or three **short ciliary nerves** that, after branching a few times, pierce the sclera in a circle around the optic nerve (along with the posterior ciliary arteries). The short ciliary nerves then run forward deep to the sclera to reach the ciliary muscle and constrictor pupillae, which they supply.

CLINICAL CONSIDERATIONS

Damage to the oculomotor nerve has effects which are due both to interruption of its somatic motor and its visceral motor fibers.

Since the oculomotor nerve supplies the levator palpebrae superioris, which is largely responsible for maintaining the eyes open while awake, damage to the nerve causes the upper lid to droop dramatically, almost to the point of closure. No conscious effort can produce elevation of the lid. In compensation, the patient will try to elevate the upper lid indirectly by pulling up on the eyebrow with the frontalis. The elevation of the eyebrow and resultant creasing of the forehead are usually obvious.

Damage to the oculomotor nerve also leads to a paralysis of most of the extraocular muscles that actually insert on the eyeball, leaving only the lateral rectus and superior oblique intact. Thus, the eyeball is essentially immobile. Because of the unopposed pull of the lateral rectus, the eye assumes an abducted position, which is also known as a **lateral strabismus** (or **lateral squint**, or **exotropia**). Because the two eyes do not point in the same direction, double vision (**diplopia**) is present.

Interruption of the parasympathetic input to the constrictor pupillae leads to an unusually wide pupil that does not narrow either when light is shown into the eye or when the eye focuses on a close object (see further on). The ciliary muscle is also paralyzed, with resulting inability to accommodate.

One tests for integrity of the oculomotor nerve by (1) requiring the patient to perform movements of the upper lid or eyeball that employ muscles supplied by the nerve and (2) eliciting contraction of the constrictor pupillae via certain reflexes.

Function of the levator palpebrae superioris is assessed by asking the patient to gaze upward. Normally, such a gaze is always accompanied by elevation of the upper lid. Testing muscles that insert on the eyeball is performed by asking the patient to gaze at the examiner's finger as it is moved in various directions. Eliciting adduction is a clear test of the medial rectus. Which muscles are tested by other movements can be gleaned from the discussion of eyeball movement presented earlier (and summarized in Fig. 8-17*B*). If the medial rectus can adduct, then eliciting elevation of the adducted eye is a test for the inferior oblique. If the lateral rectus (supplied by the abducens nerve) is operative, eliciting elevation of the abducted eye tests for the superior rectus, whereas depression of the abducted eye tests for the inferior rectus.

The pupil normally constricts under two different circumstances. One is when a light is shone in the eye. This is called the **pupillary light reflex**. It is consensual, which means that shining a light into only one eye causes both pupils to constrict. The pupil also constricts when one attempts to focus on objects very close to the eye. Apparently, recruitment of the ciliary muscle and the constrictor pupillae are linked. Because looking at close objects also induces one or both eyes to rotate so that their optical axes converge on the nearby point, the accompanying pupillary constriction is said to be an **accommodation/convergence reflex**. Usually it is elicited by bringing the examiner's finger toward the bridge of the patient's nose, in which case both eyes actually adduct. However, even if the finger is brought close in toward the front of one eye, so that it need not move, the pupillary accommodation reflex still occurs.

Damage to the oculomotor nerve affects both the pupillary light and pupillary accommodation reflexes. Some central nervous system diseases (e.g., neurosyphilis) produce a pupil that constricts on accommodation but not in response to light. This is called an Argyll-Robertson pupil (mnemonic: the initials AR correspond to Accommodation Reactive).

Trochlear Nerve--Cranial Nerve IV

The trochlear nerve is purely somatic motor to the superior oblique muscle (i.e., the muscle whose tendon passes through a trochlea). The nerve exits the dorsal surface of the midbrain and sweeps around its side to pierce the dural roof of the cavernous sinus just anterior to the site where the margin of the tentorial notch crosses the petroclinoid ligament. The nerve runs forward in the cavernous sinus, with its epineurium adherent to the dural wall (see Fig. 8-13). About halfway through the sinus, the trochlear nerve encounters the upper border of the ophthalmic nerve and then runs along with it out of the sinus toward the superior orbital fissure. The trochlear nerve enters the orbit through the upper compartment of the superior orbital fissure. The nerve then turns medially and crosses above the origins of superior rectus and levator palpebrae superioris onto the upper surface of the superior oblique muscle, which it penetrates.

CLINICAL CONSIDERATIONS

Isolated lesions of the trochlear nerve are uncommon. Obviously, the effect will be limited to paralysis of the superior oblique. As explained previously, the superior oblique is chiefly active during depression of the eye when it either looks straight ahead or is adducted (see Fig. 8-17*B*). When the muscle is paralyzed on one side, such depression cannot occur, resulting in double vision when the patient attempts to look downward. The two most common daily activities that involve looking down are reading and walking downstairs. A complaint of double vision during these activities is a sign of trochlear nerve damage. A test of trochlear nerve function is depression of the adducted eye. This assumes normal medial rectus function.

Abducens Nerve--Cranial Nerve VI

It seems best to discuss this nerve now, so as to complete a consideration of the motor nerves to extraocular muscles. The sole function of the abducens is to innervate the lateral rectus--the abductor of the eyeball.

The abducens nerve pierces the dura on the back of the clivus a centimeter or so below the root of the dorsum sellae. The nerve then travels upward and laterally (sandwiched between dura and endocranium) toward the side of the dorsum sellae, around which it passes to enter the cavernous sinus. Here the abducens takes up a position on the lateral surface of the internal carotid artery (see Fig. 8-13). The nerve continues forward in the cavernous sinus, bathed on all sides by venous blood, and eventually leaves it to pass through the middle compartment of the superior orbital fissure onto the deep surface of the lateral rectus muscle. The abducens nerve runs forward on the deep surface of the lateral rectus for a centimeter or so before penetrating the muscle to supply it.

CLINICAL CONSIDERATIONS

The abducens is the most frequently damaged of all nerves feeding extraocular muscles. It is the first nerve to be affected by septic thrombosis of the cavernous sinus. Aneurysm of the internal carotid artery within the cavernous sinus may put pressure on the abducens. A variety of tumors at the base of the brain will tend to compress the nerve against the clivus.

The only effect of abducens injury is paralysis of the lateral rectus. This causes the eyeball to assume an adducted position at rest (due to the unopposed pull of the medial rectus). The name for this is a **medial strabismus** (or **medial squint**, or **esotropia**). Obviously there will be double vision because the two eyes do not face in the same direction. However, patients with ocular abductor palsy have a clever way of avoiding this double vision. For example, consider a person whose right lateral rectus is paralyzed and whose right eye is turned inward, i.e., toward the left. This person will have double vision looking at any object not far to his or her left side. On the other hand, when looking at an object far to the left, the person can use the good lateral rectus of the left eye to aim it in the same direction as the abnormally adducted right eye. Thus, a person with a paralyzed right lateral rectus may avoid double vision by turning his or her head so that whatever is to be viewed is made to occur in the left visual field. If a patient holds the head askance while looking at you, you should suspect that he or she is attempting to avoid the double vision that would occur if the patient were to face you directly.

Testing for the abducens is no more complicated than asking the patient to look at your finger as you move it to the side.

Trigeminal Nerve--Cranial Nerve V

The trigeminal nerve is both somatic sensory and somatic motor. It leaves the brainstem in two separate bundles, one of which contains all the sensory axons--the **sensory root**-- and the other of which contains all the motor axons--the **motor root**. After leaving the brain, the two roots travel alongside each other (with the motor root deep to the sensory root) toward the superior edge of the petrous temporal near its apex. They encounter the arachnoid lying on the dura just below the superior petrosal sinus and push both meningeal layers out to form a two-layered pocket that insinuates itself between the endocranium and dura on the anterior surface of the petrous temporal (at the site known as the trigeminal impression) (Fig. 8-26). This pocket is called **Meckel's cave (or cavum trigeminale)**. While the nerve is within Meckel's cave, it is still in subarachnoid space.

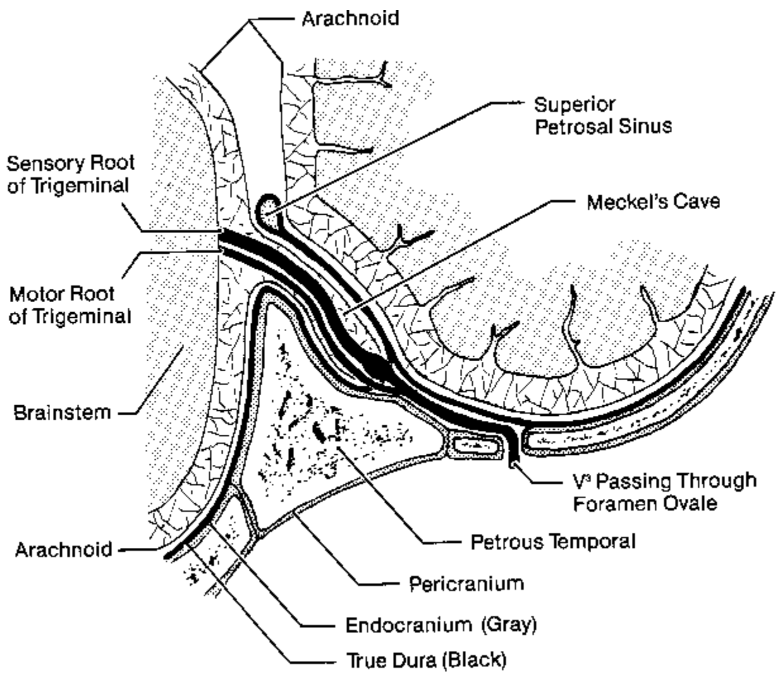


Figure 8–26. Schematic coronal section through the base of the skull at the site of the trigeminal impression on the petrous temporal. This figure illustrates the manner by which the arachnoid and true dura participate in formation of the cavum trigeminale (Meckel's cave), through which pass the sensory and motor roots of the trigeminal nerve.

The sensory cell bodies of the trigeminal nerve are located in a clump along the sensory root at the site where this root actually pierces the arachnoid/dural floor of Meckel's cave to take up a position between true dura and endocranium (see Fig. 8-26). This clump is crescentic in shape and is often called the **semilunar (Gasserian) ganglion**. The peripheral processes of the sensory axons emerge from the distal edge of the ganglion in three separate bundles. These three bundles are the ophthalmic, maxillary, and mandibular divisions of the trigeminal. Also piercing the floor of Meckel's cave is the motor root, which then joins the mandibular division.

Ophthalmic Division of Trigeminal--V_1. The ophthalmic nerve passes straight forward into the cavernous sinus. Like the oculomotor and trochlear nerves, V_1 runs anteriorly in the sinus with its epineurium adherent to the medial face of the dural wall (see Fig. 8-13). V_1 is the largest and most inferior of the three nerves adherent to the dural wall of the cavernous sinus. While traveling within the sinus, V_1 picks up postganglionic sympathetic fibers from the internal carotid plexus (these probably pass through the abducens n. to reach V_1). The sympathetic axons will distribute with branches of the ophthalmic nerve to supply vasculature of the orbit and forehead, sweat glands of the forehead, and the dilator pupillae.

After V_1 exits the front of the cavernous sinus, it divides into its three main branches--frontal, lacrimal, and nasociliary. These pass through the superior orbital fissure separately--frontal and lacrimal in the upper compartment, nasociliary in the middle compartment.

The **frontal nerve** continues forward in the orbit onto the upper surface of levator palpebrae superioris, and follows it toward the front of the eye. Not far from the nerve is the supraorbital artery. Before reaching the orbital septum, the frontal nerves bifurcates into a **supratrochlear and a supraorbital branch**. The supratrochlear is the smaller and more medial of the two. They both pierce the orbital septum and turn upward into the subcutaneous tissue of the scalp deep to the frontalis muscle. The supraorbital nerve passes through the supraorbital notch, where it is separated from the more inferiorly placed supraorbital artery by a ligament (sometimes ossified) that bridges across the notch. The supratrochlear nerve crosses the orbital rim at its upper inner angle. Both the supraorbital and supratrochlear nerves are cutaneous for supply of the skin of the forehead all the way up to the vertex of the skull (Fig. 8-27). Not surprisingly, they give twigs to the upper eyelid as they leave the orbit.

The small **lacrimal nerve** passes along the upper edge of the lateral rectus along with the artery of the same name. The nerve passes inferior to the lacrimal gland, to which it sends branches, and then pierces the orbital septum above the lateral palpebral ligament for cutaneous innervation of the upper eyelid (see Fig. 8-27).

The **nasociliary nerve** passes through the middle compartment of the superior orbital fissure (thus, inferolateral to the optic nerve). The nasociliary then follows a path identical to the most common course of the ophthalmic artery (i.e., upward on the lateral side of the optic nerve, anteromedially across its top surface, and then forward along the upper border of medial rectus). It gives off branches corresponding to branches of the ophthalmic artery (other than the supraorbital, supratrochlear, and lacrimal arteries, which are accompanied by branches of the frontal and lacrimal nerves). Early in its course, the nasociliary nerve gives off two **long ciliary nerves** that run with the long posterior ciliary arteries parallel to the optic nerve and pierce the sclera adjacent to it. These carry sensation from the eyeball and, notably, the cornea. They may also carry postganglionic sympathetic axons to the dilator pupillae and vasculature of the eye. After giving off the long ciliary nerves, the nasociliary sometimes gives off a **posterior ethmoidal nerve** but always gives off an **anterior ethmoidal nerve**. These accompany the arteries of the same name and carry sensation from the areas to which the arteries send blood. The terminal branch of the anterior ethmoidal nerve accompanies the cutaneous branch of the anterior ethmoidal artery onto the surface of the nose (see Fig. 8-27). The cutaneous branch of the artery has no separate name, but the accompanying nerve is called the **external nasal nerve**. (Of course, when we do this, we must then refer to the branches of the anterior ethmoidal within the nasal cavity as internal nasal nerves.)

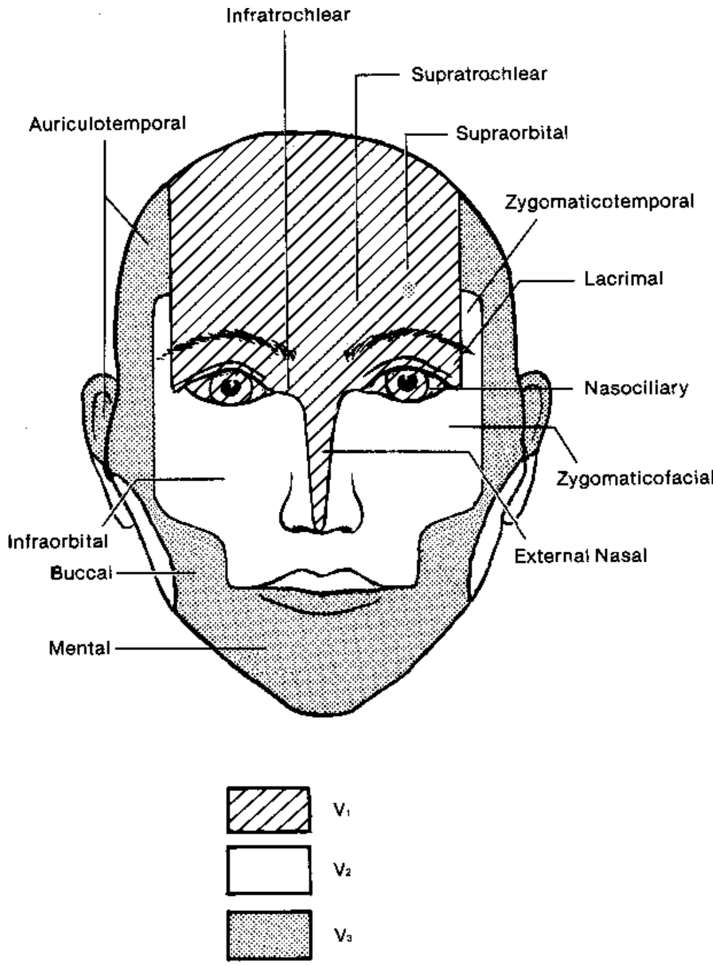


Figure 8-27. Sensory innervation of the face by the trigeminal nerve.

Once the anterior ethmoidal nerve is given off by the nasociliary, the latter has no function other than to innervate the skin on the bridge of the nose supplied by the dorsal nasal branch of the ophthalmic artery (see Fig. 8-27). This part of the nasociliary nerve is called the **infratrochlear nerve**.

The nasociliary nerve, immediately after it enters the orbit, is connected to the ciliary ganglion by a small twig. It has been suggested that some sensory fibers from the eyeball travel with the short ciliary nerves to the ganglion and then pass through it into this twig to reach the nasociliary nerve, which carries them back to V_1. It has also been said that postganglionic sympathetic axons in the nasociliary nerve leave it and run in the twig to the ganglion, which they pass right through to enter the short ciliary nerves and thence reach the eye either for supply of vascular smooth muscle or the dilator pupillae. The validity of these statements remains unknown, as does the pathway of sympathetic fibers that reach the smooth muscle portion of levator palpebrae superioris.

Maxillary Division of Trigeminal--V_2. The maxillary nerve, arising from the middle of the semilunar ganglion, passes forward between the dura and endocranium below the lower border of the cavernous sinus. (Although if the sinus is large, the blood-filled space may extend inferiorly between V_2 and endocranium.) After a centimeter or so, the maxillary nerve encounters the foramen rotundum, through which it passes into the pterygopalatine fossa. Within the fossa, V_2 is located superolateral to a parasympathetic ganglion called the **pterygopalatine (sphenopalatine) ganglion**. This ganglion gets its preganglionic supply from the facial nerve in a manner described subsequently (Fig. 8-28). However, a thick short nerve bundle passes between the maxillary nerve and pterygopalatine ganglion. This bundle carries postganglionic parasympathetic axons from the ganglion to V_2 for distribution with its branches, and it also carries sensory axons from V_2 down to the ganglion to distribute with nerves that emanate directly from it. Since the nerves that emanate directly from the pterygopalatine ganglion actually carry sensory axons that run back to the trigeminal ganglion, they are always spoken of as branches of the maxillary nerve even though they are not dissectible as such. It must be emphasized that the pterygopalatine ganglion is visceral motor and contains no sensory cell bodies.

The Three Actual Branches of the Maxillary Nerve--Posterior Superior Alveolar, Zygomatic, and Infraorbital. After its connection to the pterygopalatine ganglion, the maxillary nerve heads toward the infraorbital groove in the floor of the orbit. Just before reaching the groove, it gives off the posterior superior alveolar and zygomatic nerves. The **posterior superior alveolar nerve** joins the artery of the same name to pass downward applied to the back surface of the maxilla. Both structures may branch once or twice before perforating the back wall of the maxilla to reach the molar teeth.

The **zygomatic nerve** courses toward the lateral part of the inferior orbital fissure (see Fig. 8-15), through which it passes into the orbit to run between the periorbita and bone anterior to the fissure. The nerve may then (1) pass through a single foramen in the orbital surface of the zygomatic bone and within that bone bifurcate into **zygomaticofacial and zygomaticotemporal nerves**, or (2) bifurcate into the two aforementioned nerves, each of which passes through its own foramen in the zygomatic bone. Regardless, the zygomaticofacial nerve emerges from the zygomatic bone on the outer surface of its ascending (frontal) process, whereas the zygomaticotemporal nerve emerges from the posterior surface of this process. The zygomaticofacial nerve is cutaneous to a small region of the face over the side of the cheek bone; the zygomaticotemporal nerve is cutaneous to a small region of the temple behind the orbit (see Fig. 8-27).

The reader may recall that no mention was made of a zygomatic branch of the maxillary artery. In fact there is none. Rather, the lacrimal artery gives off a tiny twig(s) that accompany the zygomatic nerve (or its branches) out of the orbit.

Among the parasympathetic ganglion cells that form the pterygopalatine ganglion are some whose axons are destined for the lacrimal gland. These travel through the inferior orbital fissure and go directly to the lacrimal gland (see Fig. 8-28).

After the maxillary nerve has given off its posterior superior alveolar and zygomatic branches, it continues into the infraorbital groove (see Fig. 8-15) as the **infraorbital nerve**. Like the infraorbital artery, the nerve gives off a **middle superior alveolar branch** for the premolar teeth, an **anterior superior alveolar branch** for the canines and incisors (which branch also sends a twig to the anterior part of inferior nasal meatus). The infraorbital nerve then exits onto the face below the orbit. Here it is cutaneous to the lower eyelid, upper lip, side of the nose, front of the cheek, and skin lining the nasal vestibule (see Fig. 8-27).

The maxillary sinus is supplied by branches from all three superior alveolar nerves. Although these nerves are primarily sensory, they do carry postganglionic parasympathetic fibers to mucous glands of the maxillary sinus. It should be no trick to deduce that these originated in the pterygopalatine ganglion.

Branches of the Maxillary Nerve That Emanate From the Pterygopalatine Ganglion. The pterygopalatine ganglion gives off branches that distribute to the same structures supplied by branches of the inner terminal division of the maxillary artery. A **greater palatine nerve** and a few **lesser palatine**

nerves pass with the greater palatine artery out the bottom of the pterygopalatine fossa into the greater palatine canal. The lesser palatine nerves go to the soft palate after passing through lesser palatine canals and foramina. The greater palatine nerve passes through the greater palatine foramen onto the roof of the mouth, where it turns forward with the artery.

Other branches from the pterygopalatine ganglion pass medially through the sphenopalatine foramen (along with the sphenopalatine artery) to supply the posterior part of the lateral nasal wall and posterior part of the nasal septum. One of the nerves to the septum is larger than the others and accompanies the largest posterior septal artery to the incisive canals. This is the **nasopalatine nerve**, and it too passes through the incisive foramen out the roof of the mouth behind the incisor teeth.

Again, although the nerves that supply the nasal cavity and palate are largely sensory, they must also carry the postganglionic parasympathetic axons for mucous glands. These derive from cells in the pterygopalatine ganglion. (It also seems that taste fibers from the palate run in palatal branches of the maxillary nerve back to the pterygopalatine ganglion, which they pass through to enter the greater petrosal branch of the facial nerve; see further on.)

Mandibular Division of Trigeminal--V_3. The sensory root of the mandibular nerve emanates from the posterior region of the semilunar ganglion. It is joined by the motor root of the trigeminal nerve and the composite mandibular nerve passes straight downward out the foramen ovale into the infratemporal fossa, where it finds itself sandwiched between the superior head of lateral pterygoid and tensor veli palatini, anterior to the middle meningeal artery.

Almost immediately upon emerging from the foramen ovale, the mandibular nerve sprays out its numerous branches. **Muscular twigs go to the nearby pterygoid muscles and tensor muscles**. A **masseteric** and two **deep temporal nerves (anterior and posterior)** pass laterally above the superior head of lateral pterygoid. The nerve to the masseter continues outward through the mandibular notch; the deep temporal nerves turn upward deep to temporalis for its supply. A **buccal nerve** passes between the heads of the lateral pterygoid heading downward and forward to emerge from under cover of the masseter with the buccal artery. The buccal nerve continues forward to supply the skin and mucous membrane of the cheek (see Fig. 8-27). (Frequently the buccal nerve gives off the anterior deep temporal.)

From the posterior surface of V_3 splits off the **auriculotemporal nerve**. As it starts backward it very soon encounters the middle meningeal artery about to pass through the foramen spinosum. The auriculotemporal nerve usually bifurcates, sending one division medial and the other lateral to the vessel (occasionally it fails to bifurcate and the single bundle may pass either lateral or medial to the vessel). Once past the middle meningeal artery, the two divisions re-unite and continue posteriorly deep to the neck of the mandible. At the back of the mandibular neck, the auriculotemporal turns sharply laterally to run behind it (passing through or skirting the top of the parotid gland, to which it gives branches) and then turns sharply upward between mandibular condyle and external auditory meatus to join the superficial temporal vessels and travel with them across the root of the zygomatic arch into the subcutaneous tissue of the scalp. The auriculotemporal nerve is cutaneous to the top half of the ear and most of the temple (see Fig. 8-27). It also participates in the innervation of the external auditory meatus and eardrum.

Interestingly, just like the maxillary nerve passes near a parasympathetic ganglion after it leaves the cranial cavity, so does the mandibular nerve. Immediately below foramen ovale, deep to V_3, is a tiny clump of parasympathetic ganglion cells called the **otic ganglion** (see Fig. 8-30). The otic ganglion receives its preganglionic input from a branch of the glossopharyngeal nerve (described below). A small twig connects the otic ganglion to the auriculotemporal branch of V_3. This twig carries the postganglionic axons into the auriculotemporal nerve, which then carries them behind the neck of the mandible into proximity with the parotid gland. Here the postganglionic parasympathetic axons leave to innervate the parotid gland.

The two largest branches of the mandibular nerve--inferior alveolar and lingual--also arise immediately after V3 leaves the cranial cavity. They continue the downward course of their parent nerve and, thus, are carried deep to the inferior head of the lateral pterygoid muscle. The **inferior alveolar nerve** follows an almost vertical course and, when it reaches the lower border of lateral pterygoid, is able to move laterally to enter the mandibular foramen along with the inferior alveolar artery. The inferior alveolar nerve is sensory to all the lower teeth, but after giving off its last dental branch it continues out the mandibular canal through the mental foramen as the **mental nerve**. The mental nerve is cutaneous to the skin over the front half of the mandible (see Fig. 8-27).

Just prior to entering the mandibular foramen, the inferior alveolar nerve gives off from its back surface a slender twig--the **nerve to the mylohyoid**--that pierces the sphenomandibular ligament and then turns forward in the space between the medial pterygoid muscle and the mandibular ramus. At the anterior border of medial pterygoid, the nerve to the mylohyoid encounters the back edge of the mylohyoid muscle, onto whose superficial surface it passes. In addition to supplying the mylohyoid, the nerve innervates the anterior belly of digastric.

The **lingual nerve**, after its origin from V_3, descends along a course in front of the inferior alveolar nerve, also deep to the lateral pterygoid. It gradually moves forward during its descent, so that the two nerves are about a centimeter apart as they appear beneath the lower edge of the muscle. Below the lateral pterygoid, the lingual nerve turns more noticeably forward, interposed between the medial pterygoid and mandible, but superior to the nerve to the mylohyoid. At the anterior edge of the medial pterygoid, the lingual nerve also encounters the back edge of the mylohyoid, to which it passes *deep*. Its course deep to the mylohyoid has been discussed in Chapter 7.

The axons that run in the lingual nerve back to V_3, and thence to the semilunar ganglion, carry somatic sensation from the anterior two thirds of the tongue (and nearby parts of the oral cavity). Axons carrying taste from the anterior two thirds of the tongue also travel in the lingual nerve toward V_3, but, where the lingual nerve lies deep to the lateral pterygoid, the taste fibers leave its posterior surface in a bundle that follows an upward and backward course (deep to the inferior alveolar nerve) toward a tiny foramen behind the medial end of the jaw joint (see Fig. 8-28). This foramen leads to the middle ear cavity, and the nerve bundle carrying taste axons courses through the tympanic cavity to join the facial nerve in its mastoid wall. The nerve bundle is called the **chorda tympani**, and it is considered to be a branch of the facial nerve that joins up with the lingual.

Not only does the chorda tympani carry taste fibers away from the lingual nerve back to the facial, but it is also the conduit for parasympathetic preganglionic fibers that exit the brainstem with the facial nerve and want to get to the lingual nerve (see Fig. 8-28). These visceral motor fibers reach the lingual nerve via the chorda tympani, run with the lingual nerve for a while, then leave it to synapse in the submandibular ganglion. Some postganglionic axons take a very short course to the submandibular salivary gland; others rejoin the lingual nerve and are carried by it to the sublingual salivary gland.

CLINICAL CONSIDERATIONS FOR THE TRIGEMINAL NERVE

Damage to the ophthalmic nerve is revealed by disturbances of sensation from the skin supplied by this nerve and from the eye (see Fig. 8-27). It is tested by determining the responsiveness of the skin of the forehead (frontal nerve) to touch and pin prick. A second test involves the **corneal reflex**. When the cornea is touched, the sensation travels via V_1 back to the trigeminal nerve and thence to the brain. Here fibers synapse with facial neurons innervating the palpebral portion of orbicularis oculi, which is caused to contract, producing a blink. Like the pupillary light reflex, the corneal reflex is consensual, i.e., both eyelids blink when either cornea is touched. Obviously, disturbances of the corneal reflex will occur if either the sensory or motor limb is damaged. If the sensory limb is damaged, neither eyelid will blink when the affected cornea is touched. On the other hand, if touching the cornea of one eye produces a blink in the opposite eye, the examiner knows that V_1 is working and that the defect is in the contralateral facial nerve.

Damage to the maxillary nerve leads to disturbance of sensation over its region of distribution (see Fig. 8-27). Usually this is only tested by assessing the responsiveness of the skin over the front of the cheek (infraorbital nerve) to touch and pain. Nasal, palatal, and upper dental sensation are affected by damage to maxillary nerve, but these are not routinely tested.

Damage to the sensory fibers that run in V_3 leads to disturbances in sensation in its region of supply (see Fig. 8-27). This is very broad, but during a routine exam the test is usually confined to the skin over the chin (mental nerve) and side of the cheek (buccal nerve). General sensation to the front of the tongue (lingual nerve) may also be tested. Obviously, a thorough neurological exam can involve tests over other regions (e.g., temple, ear).

Damage to the motor fibers within V_3 leads to severe disturbances in chewing. Wasting of the temporalis and masseter can be seen. There is also an obvious symptom due to paralysis of the inferior head of lateral pterygoid. As we know, this muscle is the main depressor of the mandible. When both lateral pterygoids work properly, the jaw moves straight down during voluntary opening. If only the right lateral pterygoid is working the right side of the jaw will be pulled forward during opening and the chin will deviate to the left. If only the left lateral pterygoid is working, the chin deviates to the right upon jaw opening.

Extirpation of the tensor veli palatini in experimental animals leads to severe middle ear pressure dysfunction. Children born with cleft plate have increased incidence of middle ear problems, presumably because the function of tensor veli palatini is deleteriously affected by disruption of the muscle’s insertion. Yet I have not encountered a description of similar problems arising from trigeminal nerve damage in humans. Neither have I discovered any reports of symptoms attributable to paralysis of either tensor tympani or mylohyoid.

Patients with unilateral weakness of the masticatory muscles will complain that their teth don’t seem to come together properly. You can easily test to determine the side of the weakness. The examiner places one hand over the left temporalis and the other hand over the right temporalis and then asks the patient to clench his or her teeth. As assessment is made about the degree to which one side may be contracting less strongly than the other. The test is repeated with the examiner's fingers placed over each masseter.

The inferior head of lateral pterygoid, medial pterygoid, and superficial masseter, when acting together on one side, protract that side and cause the jaw to deviate toward the opposite side. The left protractors push the chin toward the right; the right protractors push the chin to the left. If the examiner places a hand on the right side of the chin and attempts to push the jaw to the left, the patient must use the left protractors to resist this. If the examiner places a hand on the left side of the chin and attempts to push the jaw to the right, the right muscles must be used to resist this. By asking the patient to resist such pushes on the jaw, an assessment of strength of the jaw protractors on one side compared with those on the other may be made.

Facial Nerve--Cranial Nerve VII (see Fig. 8-28)

The facial nerve arises by two roots from the brainstem in the posterior cranial fossa. Like the trigeminal nerve, **one root is somatic motor**. Unlike the trigeminal nerve, the other contains preganglionic parasympathetic axons as well as sensory axons. Although some texts refer to this as the sensory root of the facial nerve, its other name--**nervus intermedius**--is better because it contains no implication about fiber type (it refers to its position between the somatic motor root and cranial nerve VIII). The somatic motor root and nervus intermedius enter the internal acoustic meatus of the petrous temporal along with the 8th cranial nerve. All three are enveloped by an arachnoid/dura sheath that extends the length of the meatus. The internal acoustic meatus is several millimeters long, being capped

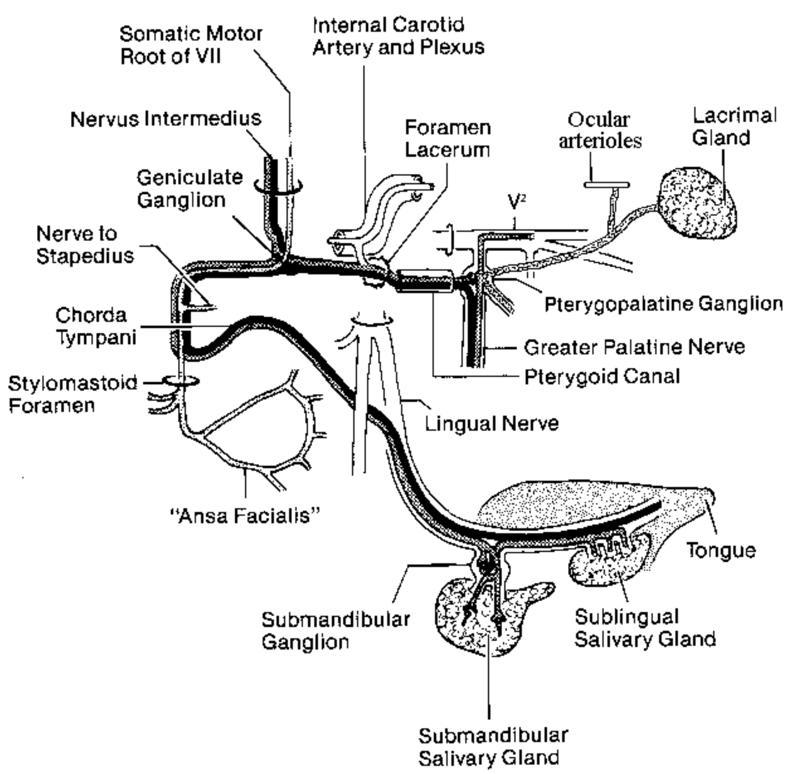


Figure 8–28. The distribution of the facial nerve. *Lightly stippled bundles* carry somatic motor axons; *darkly stippled bundles* carry parasympathetic axons; *black bundles* carry axons for taste. The cutaneous branch to the external auditory meatus is not shown.

by a bony plate with foramina for passing the nerves that have traveled in it. The nervus intermedius and motor root of the facial join to form the complete facial nerve just before the end of the meatus, and this complete nerve pierces the arachnoid and dura to enter the so-called **facial canal**. The facial canal runs anterolaterally in the petrous bone for a millimeter or two and then encounters the labyrinthine wall of the tympanic cavity, where the facial nerve bifurcates in two forks that move off in opposite directions perpendicular to the path of their parent nerve. The larger fork heads posterolaterally and the smaller heads anteromedially, both essentially paralleling the long axis of petrous temporal. At the site of the bifurcation are located the cells forming the sensory ganglion of the facial nerve.

The larger fork retains the name facial nerve and the channel within the petrous bone through which it travels retains the name facial canal. Thus, most texts say that when the facial nerve encounters the labyrinthine wall of the tympanic cavity it undergoes a >90-degree bend in course that takes it posterolaterally. This bend is called the **genu** of the facial nerve (from the Latin word for "knee"). The sensory ganglion located at the facial bifurcation is called the **geniculate ganglion**.

Greater Petrosal Nerve and the Nerve of the Pterygoid Canal. The smaller, anteromedially coursing fork of the facial nerve is called the **greater petrosal nerve**. It soon emerges into the middle cranial fossa on the anterior surface of the petrous temporal (between bone and endocranium) through a hole called the **hiatus of the facial canal**. Its continued course takes it deep to the trigeminal ganglion and onto the cartilage that fills the foramen lacerum, where it is located just lateral to the internal carotid artery (see Fig. 8-28). Here, postganglionic sympathetic fibers from the internal carotid plexus join the greater petrosal nerve. The sympathetic axons are said to form a **deep petrosal nerve**. The product of this joining will leave the cranial cavity by passing obliquely through the cartilage of the foramen lacerum to enter a canal in the sphenoid bone at the root of the medial pterygoid plate. This is the **pterygoid canal**, and the bundle formed by the conjoined deep petrosal and greater petrosal nerves is called the **nerve of the pterygoid canal**.

The pterygoid canal ends by opening into the pterygopalatine fossa inferomedial to the foramen rotundum. As soon as the nerve of the pterygoid canal enters this fossa, it encounters the **pterygopalatine ganglion**, on whose cells the parasympathetic preganglionic axons synapse. The postganglionic parasympathetic axons from the ganglion are distributed with branches of the maxillary nerve in a manner that has already been described.

The postganglionic sympathetic axons within the nerve of the pterygoid canal pass right through the pterygopalatine ganglion, without synapse, to distribute with branches of the maxillary nerve. I have also mentioned that taste fibers from the palate travel through palatine nerves up to the ganglion, and then pass through it into the nerve of pterygoid canal and greater petrosal nerve, which carries them to their cells of origin in the geniculate ganglion.

The Facial Nerve Beyond the Geniculate Ganglion. The continuation of the facial nerve past the geniculate ganglion runs posterolaterally in the labyrinthine wall of the tympanic cavity. This course takes it above the oval window but inferior to the lateral semicircular canal. Upon reaching the mastoid wall of the tympanic cavity, the facial nerve passes below the aditus ad antrum into this wall. The nerve then continues downward in the mastoid wall of the tympanic cavity to emerge from the stylomastoid foramen (see Fig. 8-28).

Somewhere near the vicinity of the geniculate ganglion, the facial nerve gives off a tiny twig that participates in a nerve plexus that lies beneath the mucous membrane that covers the promontory of the tympanic cavity. The plexus is called the **tympanic plexus**, and it receives its main input from the tympanic branch of the glossopharyngeal nerve (discussed later). From the sympathetic nerves surrounding the internal carotid artery comes a caroticotympanic nerve that travels backwards to join in the tympanic plexus.

During its descent in the mastoid wall of the middle ear cavity, the facial nerves gives off two branches. First is the minuscule **nerve to the stapedius** muscle. A little further along, the facial nerve gives off the **chorda tympani**. This nerve passes forward out of the mastoid wall into the tympanic cavity (but outside its mucous membrane), where it continues anteriorly, crossing lateral to the long process of the incus and then medial to the neck of the malleus. The chorda tympani then passes out the carotid wall of the tympanic cavity through a slit that leads to the infratemporal fossa just behind the medial end of the jaw joint. Its course beyond this point is linked to the lingual branch of V_3, and was discussed with that nerve. It was mentioned that the chorda tympani carries preganglionic para-sympathetic axons for the submandibular and sublingual salivary glands, and taste fibers from the anterior two-thirds of the tongue.

While traveling in the mastoid wall of the tympanic cavity, the facial nerve sends a small twig to communicate with the auricular branch of the vagus. This twig carries somatic sensory axons from the external auditory meatus.

Upon exiting the skull through the stylomastoid foramen, the facial nerve enters the retromandibular region of the neck. Here it sends branches to auricularis posterior, stylohyoid, and the posterior belly of digastric. After these are given off, the nerve enters the parotid gland and divides into upper and lower divisions, which turn forward, pass lateral to the retromandibular vein, and thereby reach the part of the parotid lying in the face (see Fig. 7-22). Here, within the gland, the two divisions join again to form the "ansa facialis." From this loop spray out the branches of the facial nerve to the remaining facial muscles. These branches are given names according to the general area of the face to which they run (temporal, zygomatic, buccal, marginal mandibular, cervical). The significance of the fact that the marginal mandibular branch, which feeds the muscles of the lower lip and chin, often loops into the neck before reaching its destination was discussed in Chapter 7 (see Fig. 7-22).[41]

CLINICAL CONSIDERATIONS

The symptoms of damage to the facial nerve depend on where along its course the damage has occurred. One of the most common sites is in that region of the facial canal just above the stylomastoid foramen. Here, an inflammatory disease of unknown etiology (though more frequent in patients with Lyme disease) causes a condition known as **Bell's palsy**. All the facial muscles on one side are paralyzed, but the glandular and taste functions of the facial nerve remain intact.

Bell's palsy is characterized by a host of symptoms that can be predicted from paralysis of facial muscles. In older persons, in whom elasticity of skin is diminished, paralysis of facial muscles causes the normal creases in facial skin to be diminished or absent on the affected side. In all persons, both young and old, the eye cannot be completely closed. Because blinking is impossible, the normal cleansing of the surface of

[41] Although I have described all the major functions of the facial nerve, it should be mentioned that some unnamed intracranial and extracranial branches carry vasodilatory fibers. It has also been suggested, but not proven, that proprioceptive sensation from facial muscles travels in axons of cells located in the geniculate ganglion.

the eye is impossible. In an attempt to compensate, the lacrimal gland increases its secretion. However, without blinking, the tears are not distributed toward the lacrimal puncta. Furthermore, paralysis of the lacrimal portion of orbicularis oculi causes the lacrimal puncta to lift off the surface of the eyeball, and paralysis (or loss of passive elasticity) of the palpebral orbicularis oculi of the lower lid causes it to fall forward away from the eye. The effect of all these changes is for the excess tears to pool beneath the lower lid and then spill over onto the cheek. The potential for irritation to the cornea is great, and persons with a Bell's palsy must wear an eyepatch to keep the lids closed.

As if these problems with the eyes are not sufficiently annoying, the corner mouth and lower lip droop on the side of the paralysis, allowing saliva to run out of the mouth. Paralysis of the buccinator allows food to accumulate between the cheek and lower gum. The patient prefers to chew on the unparalyzed side, but often must manually push on the cheek of the affected side in order to express food out of the oral vestibule.

Occasionally, a facial paralysis may be psychosomatic in nature. It has been suggested that this can be diagnosed by availing oneself of the **oculo-auricular phenomenon**.. Normally, when a person looks very strongly to one side, the opposite ear is pulled back by the auricularis posterior muscle. This phenomenon is absent in Bell's palsy, but it is intact if the facial paralysis is psychosomatic.

Pathology of the facial nerve within the facial canal may extend upward to involve the communicating twig to the vagus and the origin of the chorda tympani. Since so many other nerves provide sensation to the external auditory meatus, loss of function in the facial axons that do so is undetectable. However, irritative lesions of the facial nerve may lead to pain in the external auditory meatus. If the chorda tympani is damaged, taste from the anterior two thirds of the tongue will be lost (or greatly diminished). Some patients with damage to the chorda tympani also complain of partial numbness of the tongue on the ipsilateral side. It is not known whether this is simply the way persons perceive disruption of sensory input from the tongue, or if some of the sensory axons within the chorda tympani of humans are connected to mechanoreceptors, as occurs in cats. Progress of the disease even more superiorly in the facial canal leads to paralysis of the stapedius and a resultant increased sensitivity to loud sounds, known as **hyperacusis**.

Tumors within the petrous temporal may affect the facial nerve at the site of the geniculate ganglion. This leads to all the symptoms just described, plus loss of tearing on the affected side. (Diminished mucous secretion on one side of the nasal cavity and palate is not symptomatic.)

Lesions of the facial nerve between the brain and the facial canal may affect one root and not the other because the two roots are actually separate during this part of their courses.

There is a peculiarity about the cortical input to the facial nuclei of the brainstem that is useful in diagnostics. The facial motoneurons projecting to the upper third of the face receive cortical control from both the right and left cerebral hemispheres, whereas the facial motoneurons to the lower two thirds of the face receive cortical control only from the opposite cerebral hemisphere. Thus, if a facial paralysis is due to interruption in the corticobulbar pathway on one side, the symptoms due to paralysis of the mouth and cheek on the opposite side are full-blown, but the orbicularis oculi and frontalis of this same side are not nearly as weakened as in Bell's palsy.

Testing of the facial nerve during a routine physical examination is confined to assessing the major facial muscles (see Fig. 8-21). The patient is asked to raise the eyebrows or wrinkle the forehead (occipitofrontalis) and the examiner looks to see if this is done symmetrically. The patient is asked to close the eyes very tightly (orbicularis oculi--orbital and palpebral portions) and the examiner tries to pry them open by pushing up on the eyebrows. A broad smile is requested (mainly zygomaticus major) and assessed for symmetry. The patient is asked to puff out the cheeks. Puffing out one's cheeks is made possible by the action of orbicularis oris to prevent escape of air between the lips. If one side is very weak, air escapes on that side. If air does not escape, the examiner can apply a test of strength by pushing in on both cheeks to see if the orbicularis oris on one side can be overwhelmed.

Only if these tests of facial muscles reveal deficit does the examination progress to a test of taste or lacrimation. Taste on the anterior two thirds of the tongue can be evaluated by applying a strong tasting solution (e.g., salt, sugar, citric acid, quinine) to its right and left edges, where most of the taste buds are concentrated. There exist special absorbent paper strips that can be applied to the surface of the eye for assessing tear production.

Stato-acoustic (Vestibulocochlear) Nerve--Cranial Nerve VIII

The stato-acoustic nerve, vestibular apparatus, and cochlea are structures of greater concern to neuro-anatomists than to gross anatomists. The nerve enters the internal auditory meatus alongside the roots of the facial nerve. At the end of this meatus, branches of CN VIII pass through foramina to distribute to the ampullae of the **semicircular canals**, to the **utricle**, **saccule, and cochlea**.

There are three semicircular canals on each side. A lateral canal lies in the transverse plane, a superior canal lies above this, in plane perpendicular to the petrous axis; a posterior canal lies behind both others, parallel to the posterior surface of the petrous temporal a few millimeters behind the internal acoustic meatus. The superior surface of the petrous temporal is bulged out by the underlying superior semicircular canal to form the so-called arcuate eminence. The vestibular apparatus is connected to the **cochlea**, which lies more anteromedially along the petrous axis. The beginning of the facial canal passes between the cochlea and vestibular apparatus.

CLINICAL CONSIDERATIONS

The assessment of sense of equilibrium, or of frequency of auditory sensitivity, is left to specialists. However, a routine physical examination may attempt to judge general hearing acuity, particularly as it depends on adequate operation of both the middle ear mechanism and cochlea.

Normal hearing relies on sound transmission from the eardrum through the ossicular chain (i.e., malleus, incus, and stapes) and thence to the cochlea. However, sound impinging directly on the bones of the skull is also detected by the cochlea without the intervention of ossicular bones. This is a less sensitive mechanism known as **bone**

conduction. The interaction between air conduction and bone conduction is vital to interpreting simple tests of hearing.

A first test - the Weber test - can be done to determine if there is unilateral hearing diminution due either to sensorineural (cochlea or nerve) or conductive (eardrum and ossicular chain) problems. Although the Weber test is described in most physical diagnosis and neurology texts, there is evidence that it has a high risk both of giving false positive and false negative results (Miltenburg, DM, J. Otolaryngology, 23:254-259, 1994). Nonetheless, I shall describe how it is performed. The stem of a vibrating tuning fork (256 or 512 Hz) is placed in contact with the vertex of the skull so that sound is sent directly through the bone to reach both the right and left cochleae (Fig. 8-29A). If hearing is normal, the sound will be reported as being equally loud in both ears. As you might expect, if a cochlea or its nerve is damaged on one side, the sound of the tuning fork will be heard as louder on the opposite, normal side. On the other hand, you might be surprised to learn that if there is a problem with the conductive mechanism on one side, the tuning fork will actually be heard as louder on this abnormal side. This is because the sound of the tuning fork transmitted through the bone of the skull competes with room noise transmitted through the eardrum and ossicular chain. Such room noise becomes a poorer competitor if the conductive mechanism that brings it to the cochlea is defective, with the consequence that the tuning fork sounds louder in that ear. To summarize, in a Weber test, lateralization of the tuning fork's sound to a particular side occurs if there is a problem either with that side's conductive mechanism or the opposite side's sensorineural mechanism. The inherent ambiguity of this result should be resolved by the application of the Rinne test, described next.

The Rinne test is considered a pretty good (though not perfect) method for determining if a suspected hearing loss is due to a conductive or sensorineural problem. The Rinne test is applied to each side separately. Various neurology and physical diagnosis texts describe it as consisting of three steps: (1) apply the stem of a vibrating tuning fork to the patient's mastoid process so that the vibrations reach the cochlea via bone conduction, (2) ask the patient to report when the sound is no longer heard, (3) then place the tines of the tuning fork near the external auditory meatus and inquire if the sound can once again be heard. If the patient's middle ear on the tested side is operating normally, the sound will once again be heard, usually for an additional period of time that equals the duration of the audible bone conduction through the mastoid process.

Otolaryngologists seem to agree that the accuracy of the Rinne test can be improved by performing it somewhat differently than just described. They recommend the following method (Fig. 8-29B): 1) strike a 256 or 512 Hz tuning fork and hold its tines about one inch from the external auditory meatus for a few seconds; 2) move the stem of the tuning fork onto the patients mastoid process for a few seconds; 3) ask the patient whether the sound was louder in the front or the back. If the patient reports that the front (i.e., air conduction) sounded louder than the back (i.e., bone conduction), the test indicates that nothing is wrong with the conductive mechanism - any hearing loss probably being sensorineural in origin. If the bone conduction sounded louder than the air conduction, there is a significant likelihood of a problem with the conductive mechanism.

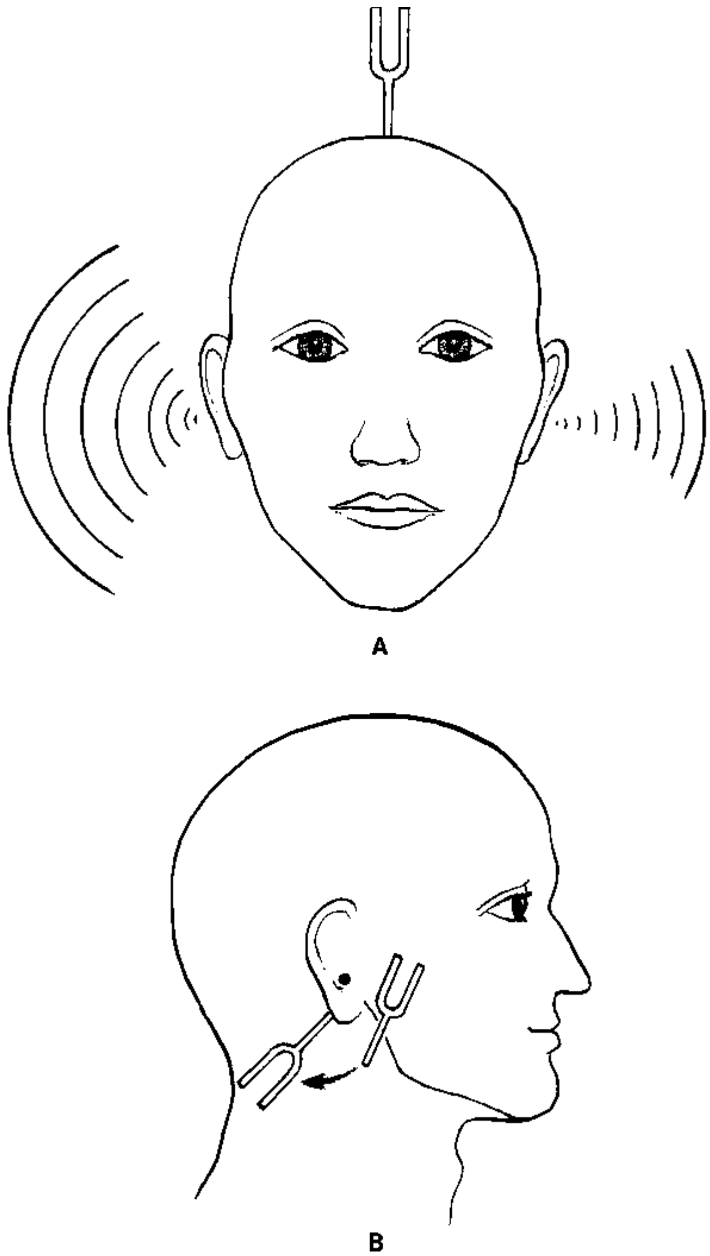


Figure 8–29. *A*, The Weber test, illustrating that sound seems louder in the right ear (1) if the left cochlea or the left 8th cranial nerve is damaged, or (2) if the right ossicular chain is operating inadequately. *B*, The Rinne test performed on the right ear. See text for further discussion.

Glossopharyngeal Nerve--Cranial Nerve IX (Fig. 8-30)

The path of this nerve in the neck and to the tongue has been described in Chapter 7. It will be recalled that the glossopharyngeal nerve is somatic motor to the stylopharyngeus muscle and also carries sensory axons back from the pharynx and posterior third of the tongue. The nerve's tympanic branch was mentioned in Chapter 7, but a thorough discussion of its course was left for now. Additionally, within the

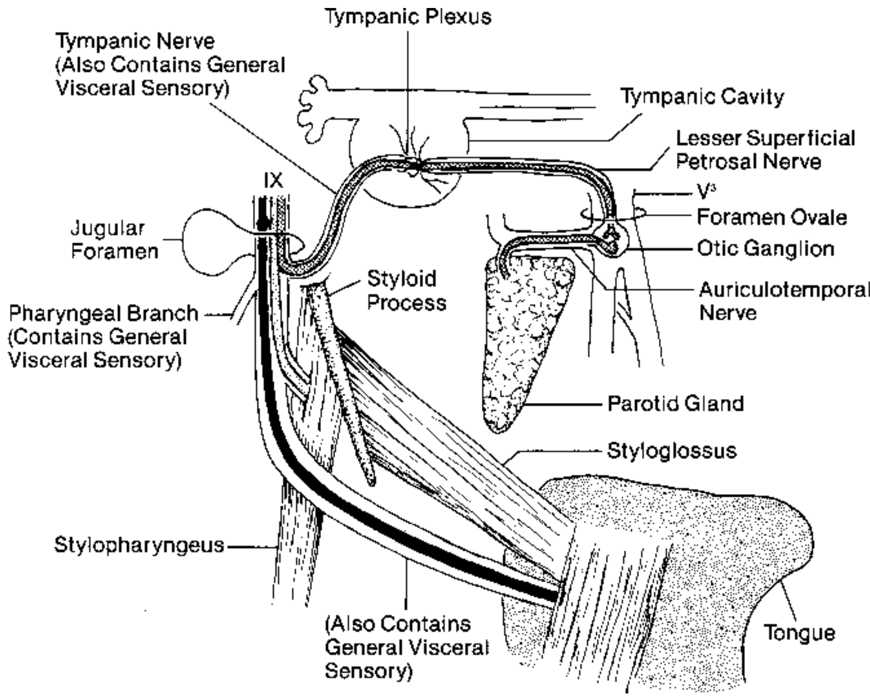


Figure 8–30. The distribution of the glossopharyngeal nerve. *Lightly stippled bundles* carry somatic motor axons; *darkly stippled bundles* carry parasympathetic axons; *black bundles* carry axons for taste. The cutaneous branch to the external auditory meatus is not shown.

jugular foramen the glossopharyngeal nerve sometimes sends a small communicating twig to the vagus that carries somatic sensory axons from the external auditory meatus.

The **tympanic nerve** arises from the glossopharyngeal in the lower part of the jugular foramen. It re-enters the skull through a tiny foramen in the shelf of bone between the jugular bulb and internal carotid artery. This foramen opens up into the middle ear, where the nerve joins in the **tympanic plexus** beneath the mucous membrane on the promontory. Emanating from the tympanic plexus are twigs to the middle ear cavity, the Eustachian tube in front of the cavity, and the mastoid air cells behind it. It is believed that these twigs are predominantly composed of sensory axons feeding back to the glossopharyngeal. Also emanating from the tympanic plexus is a nerve that leaves the tympanic cavity through its anterior wall to enter in the middle cranial fossa (between endocranium and bone) anterolateral to the greater petrosal nerve. This is the **lesser petrosal nerve**. It travels anteromedially to aposition deep to V3 and then either turns down through the foramen ovale with V3, or, sometimes, passes next to it through a small unnamed foramen. Regardless, the lesser petrosal nerve enters the infratemporal fossa just deep to V3 and immediately encounters the **otic ganglion**. The lesser petrosal nerve is composed primarily of preganglionic parasympathetic axons that exited the brain with the glossopharyngeal and will synapse on the cells of the otic ganglion. The path of the postganglionic axons to the auriculotemporal nerve and thence to the parotid gland has been described above.[42]

[42] While the chorda tympani courses through the infratemporal fossa it is connected to the otic ganglion by a tiny twig. I mention this fact because my only successful attempts to locate the otic ganglion have occurred by first locating the chorda tympani and then following the connecting twig up to the ganglion. Several suggestions have been made about what kinds of axons might be carried in this twig, but no-one knows for sure.

CLINICAL CONSIDERATIONS

Isolated lesions of the glossopharyngeal nerve are very rare. The closeness of this nerve to the vagus (both in the brainstem and throughout their intracranial courses) leads to their joint damage by many diseases. In years past, one treatment for glossopharyngeal neuralgia (i.e., bouts of excruciating pain emanating from the tonsils, pharynx, back of tongue, middle ear, and, sometimes, external auditory meatus) was surgical transection of the nerve. This gives us an opportunity to discover the effects of isolated injury to the glossopharyngeal nerve. Some authors reported that following successful surgical treatment of glossopharyngeal neuralgia, the patient did indeed experiences loss of all sensation classically described as being mediated by the glossopharyngeal nerve. However, neither this loss nor the presumed paralysis of the stylopharyngeus muscle interferes with swallowing. Other authors reported no loss of pharyngeal sensation (as tested by the gag reflex - see below), general sensation from the posterior one-third of the tongue, or taste from the posterior one-third of the tongue. It would seem that more remains to be learned about the complete pathway of such modalities

The routine test of glossopharyngeal function is the gag reflex. This reflex consists of pharyngeal constriction when the back wall of oropharynx is touched. The glosso-pharyngeal nerve is supposed to be the sensory limb of the gag reflex; the vagus is the motor limb. However, if the gag reflex is not lost after glossopharyngeal section, the vagus may participate in conducting pharyngeal sensation. If this is true, then the standard test for glossopharyngeal function is not informative.

Taste on the posterior third of the tongue can be assessed by applying a small electrical current between copper electrodes placed on the back of the tongue. An acid or metallic taste is elicited. This is not a common procedure. Applying solutions of strong taste to the back of the tongue is not a good method because of the rapid spread to the other side.

Vagus Nerve--Cranial Nerve X

The distribution of the vagus nerve to structures of the neck, chest, and abdomen has been described in previous chapters. Its only roles in the head are (1) to supply all palatal muscles except tensor veli palatini, (2) to share in the sensory innervation of the external auditory meatus, and (3) to provide a small branch to the dura of the posterior fossa.

CLINICAL CONSIDERATIONS

Despite the enormous contribution of the vagus to autonomic innervation of internal organs, no consistent symptoms associated with heart, lungs, or bowel result from complete unilateral vagal interruption. The symptoms that do arise are related to vagal innervation of levator veli palatini, pharyngeal constrictors, and laryngeal muscles. Bilateral destruction of the vagus that includes the output to the cardiac nerves is sooner or later incompatible with life. Difficulty emptying the stomach aslo occurs.

The levator veli palatini and pharyngeal constrictors play their major role in swallowing. As the tongue pushes the food into the throat, the superior pharyngeal constrictor contracts so as to bring the back wall of the oropharynx forward, where contact can be made with the soft palate after it has been elevated by the levator veli palatini (see Fig. 8-23). When the tensor veli palatini (innervated by V3) stretches the soft palate taut, the passageway between oropharynx and nasopharynx is closed and the ingested material must pass downward. I have mentioned that paralysis of the tensor veli palatini on one side does not lead to problems in swallowing. However, unilateral damage to the vagus may lead to slight **dysphagia** (difficulty swallowing) characterized by regurgitation of softer food items into the nasal cavity on the affected side. Inability to completely close off the nasopharynx may give rise to a **nasal quality of speech**. These symptoms are far more severe in certain lesions of the brainstem that produce bilateral paralysis of the palate and pharynx but are still compatible with life because they do not involve the visceral motor output of the vagus nerves.

The vagus innervates the laryngeal muscles via its superior laryngeal and recurrent laryngeal branches. **The most consistent symptom of unilateral damage to the vagus is caused by paralysis of the vocal cord.** The vocal cords play a role in breathing, speech, and coughing. In order to breathe, you must be able to separate your vocal cords. In order to speak intelligibly, you must be able to bring them fairly close together and to tighten one of them. If only one cord can be tightened, the speech will be hoarse and breathy; normal speech requires that both cords can be tightened. In order to cough effectively, you must be able to bring your vocal cords into contact and tighten both of them. When the motor supply to the laryngeal muscles is completely interrupted on one side, the vocal cord on that side assumes the so-called **cadaveric, or intermediate, position**. The cord is relaxed, immobile, and lies about halfway between maximum abduction (which occurs on deep inspiratory efforts) and the median position (which occurs during glottic closure and phonation) (Fig. 8-31). The cadaveric vocal cord is a bit closer to midline than is the normal position of the cord in quiet respiration (see Fig. 8-31), however, the narrowing of the glottis is insufficient to cause **dyspnea** (difficulty breathing), especially since the intact cord can compensate by wider abduction. On forced inspiration there may be some slight **stridor** (a whistling noise). Because the intact cord can be brought across the midline to a position very near the cadaveric cord, phonation is still possible, but the voice is hoarse and breathy. The ability to cough is greatly impaired. In brainstem lesions that produce a bilateral cadaveric position of the vocal cords, stridor, while more prominent, still occurs only on deep breathing, but phonation is virtually impossible, and coughing is definitely impossible.

Isolated destruction of the superior laryngeal nerve (due to surgery or tumor on the neck) has been reported.[43] Aside from anesthesia of the upper larynx, which is asymptomatic, the only effect is paralysis of the cricothyroid muscle. A change in position of the vocal cords can be detected by laryngoscopy, but the only effect that can

[43] Faaborg-Andersen, K, and Munk Jensen, Aa: Unilateral paralysis of the superior laryngeal nerve. Acta Otolaryngol 57:155-159, 1964.

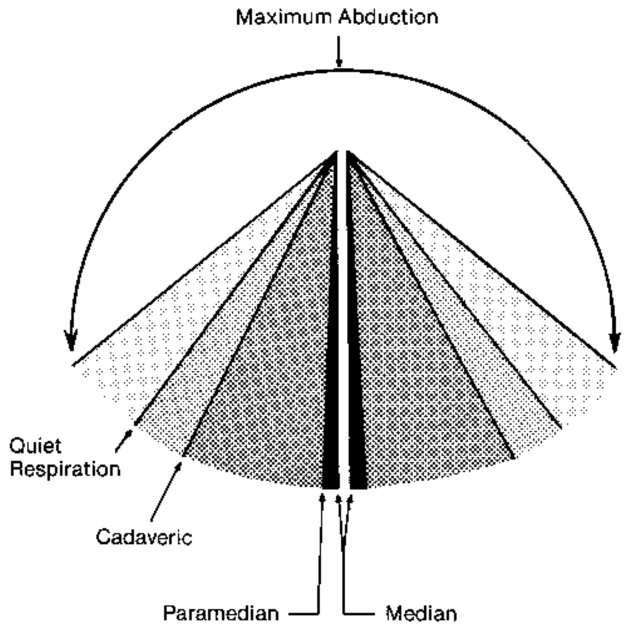


Figure 8-31. Schematic view of various standard vocal cord positions. See text for further discussion.

be determined by casual observation is a slightly lower and more monotone voice. Singing is deleteriously affected.

Damage to the recurrent laryngeal nerve alone is one of the more common afflictions related to the vagus nerve. The left nerve is susceptible to compression by an aortic aneurysm, a dilated pulmonary trunk, or enlarged superior mediastinal lymph nodes. It may also be injured durimg surgery on the aortic arch.Disease of the apex of the right lung may involve the right recurrent laryngeal nerve as it passes beneath the subclavian artery. Both nerves are susceptible to injury by thyroid masses, trauma to neck, or thyroid surgery.

If the recurrent laryngeal nerve is damaged on one side, the position assumed by a vocal cord is not the same as in complete unilateral vagal interruption. This is because the cricothyroid muscle is spared. The result is a tight **paramedian** cord, i.e., one positioned only 1 to 2 mm from the midline (see Fig. 8-31). The voice will start out hoarse, but recovery of normal voice is likely to be complete (with deficiencies in singing and shouting only)[44]. Coughing is also good and dyspnea occurs only on strenuous exertion.

Bilateral damage to the recurrent laryngeal nerves produces a situation in which both vocal cords are tight and in the paramedian position. The speaking voice is reasonably good, though a little weak. However, breathing is very difficulty. Inspiration is accompanied by stridor; no exertion can be tolerated. Subsequent inflammatory disease may cause complete glottal closure. Rarely one or both vocal cords tend to move apart with time (as muscles atrophy or fibrosis occurs), but bilateral recurrent laryngeal damage must generally be treated by surgery.

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[44] Greene, MCL: The Voice and Its Disorders, ed 4. JB Lippincott, Philadelphia, 1980.

If there are no symptoms attributable to vagal damage, routine testing of the vagus nerve consists of (1) observation of the soft palate at rest and while the patient says "Ah," and (2) elicitation of the gag reflex. If the soft palate droops on one side or does not rise on that side when the patient says "Ah," damage to the ipsilateral vagus must be suspected. Failure of the paralyzed half of the palate to rise when the patient says "Ah" may cause the uvula to deviate to the intact side. If the contraction of the pharynx that is elicited by touching its back wall is absent on the same side as the drooping soft palate, this is further indication of vagal malfunction.

(Spinal) Accessory Nerve--Cranial Nerve XI

The accessory nerve arises from a special column of cells in the upper cervical spinal cord. These are believed to have migrated from an origin in the brain. The cells send bundles of axons laterally out the spinal cord dorsal to the ligamentum denticulatum. On each side, lower bundles turn upward to join higher ones and form a single spinal accessory nerve that passes from the spinal subarachnoid space into the cranial subarachnoid space through the foramen magnum. Each nerve then turns toward the jugular foramen, where it exits the cranial cavity adjacent to the vagus nerve. The extracranial course of the accessory nerve has been described, as have the symptoms of damage to it and the mechanism of testing for it (Chapter 7, p. 20).

It is worth mentioning here that cerebral control of the sternocleidomastoids is unusual. Whereas the general rule is that one side of the cerebral cortex controls muscles on the opposite side of the body (but see discussion of superior facial muscles above), the sternocleidomastoids get cortical input from both cerebral hemispheres. As would be predicted from the general rule, the contralateral hemisphere stimulates the sternocleidomastoid when you use it to flex or laterally flex your neck. For example, a right hemisphere lesion causes weakness in the left sternocleidomastoid when you try to touch your left ear to your left shoulder. Unexpectedly, the ipsilateral hemisphere stimulates the sternocleidomastoid when you turn your head. For example, when you want to turn your head to the right, use of your left sternocleidomastoid is initiated by the ipsilateral left cerebral cortex. Since the left cortex also causes your eyes to turn to the right, deviation from the normal pattern for sternocleidomastoid during head turning behaviors is functionally sound.

Hypoglossal Nerve--Cranial Nerve XII

This nerve has a very short intracranial course from the brainstem to the hypoglossal foramen. Its extracranial course to supply the tongue muscles and geniohyoid has been described in Chapter 7.

CLINICAL CONSIDERATIONS

Lesions of the hypoglossal nerve produce paralysis of all glossal muscles (the palatoglossus is a palatal muscle and, thus, innervated by the vagus). The affected side of the tongue is atrophic. When the patient attempts to protrude the tongue forward out of the mouth, the intact genioglossus pulls its side forward but the paralyzed genioglossus cannot. As a result, the tongue deviates to the side of the disease (just as a mandible will deviate to the injured side if its protractors are paralyzed unilaterally). Surprisingly, speech, chewing, and swallowing are affected only slightly in cases of unilateral hypoglossal damage. On the other hand, in bilateral injury to the hypoglossal nerve complete paralysis of the tongue markedly affects all these behaviors. Pronunciation of most words is defective. Chewing is difficult, because the tongue cannot keep food between the teeth. The patient has difficulty swallowing because the tongue cannot push food into the pharynx.

Routine examination of the hypoglossal nerve consists of a request that the patient stick out the tongue and wiggle it from side to side. The patient may also be asked to push first one and then the other cheek out with the tongue while the examiner resists the movement. In theory the left genioglossus is primarily responsible for pushing out the right cheek while the right genioglossus is chiefly responsible for pushing out the left cheek. This test is entirely analogous to resisting sideways deviations of the chin in order to assess mandibular protractors.

Sympathetic Innervation of the Head

The preganglionic sympathetic neurons concerned with the head and neck lie in the upper three or four thoracic segments of the spinal cord, with T1 being particularly important. As we know, at each relevant level, the preganglionic axons leave via the ventral root, enter the spinal nerve, pass into its ventral ramus, and proceed to the nearest paravertebral ganglion via a white ramus communicans. Upon reaching the nearest ganglion, the axons turn cranially and travel upward in the sympathetic trunk, passing through any ganglia along the way, until they reach the superior cervical ganglion, where they synapse. From this ganglion, postganglionic axons accompany both the internal and external carotid arteries.

The postganglionic sympathetic axons running with the external carotid artery and its branches form an **external carotid nerve plexus** that innervates the vascular smooth muscle and nearby sweat glands.

Accompanying the internal carotid artery are one to three nerve bundles that are called **internal carotid nerves**. They exchange some fibers forming a minimal **internal carotid plexus**, not tightly bound to the vessel. Along the way, fibers to the smooth muscle of the internal carotid artery are given off, as are the **caroticotympanic** and **deep petrosal nerves**. Within the cavernous sinus, all grossly visible fibers of the plexus join the abducens nerve, but almost immediately leave it to join V_1. They are distributed with the branches of V_1. Among their functions are innervation of the vasculature of the orbit, the dilator pupillae, Müller’s muscle, and the vasculature and sweat glands of the forehead supplied by the frontal nerve. However, it is certainly possible that some of these tasks are controlled by internal carotid plexus sympathetic axons that join other orbital nerves passing through the cavernous sinus.

CLINICAL CONSIDERATIONS

Interruption of the sympathetic pathway to the head leads to a set of four symptoms known as Horner's syndrome: (1) constriction of the pupil (**miosis**), (2) slight drooping (**ptosis**) of the upper eyelid, (3) loss of cutaneous vasodilatation in response to thermal or emotionl stimuli, and (4) anhydrosis (loss of sweating) in response to a thermal stimulus. These symptoms occur on the same side as the sympathetic pathway damage. All four components of Horner's syndrome occur if the sympathetic trunk or superior cervical ganglion is damaged. If only the sympathetic input from the T1 spinal segment is interupted, the two ocular symptoms occur but vascular responses and sweating, both controlled by T2, are normal. The ptosis of a Horner's syndrome can be easily distinguished from that due to oculomotor nerve injury simply by asking the patient to direct the gaze upward. This movement will elicit elevation of the upper lid by the striated fibers of levator palpebrae superioris no matter what the state of the innervation to its smooth muscle.

No disease states have been described that involve only the external carotid plexus, but there are some pathological conditions affecting the internal carotid artery within the petrous canal that either compress the internal carotid plexus or interfere with the blood supply to these nerves. Specific injury to the internal carotid plexus leads to a miosis and ptosis, but any loss of sweating is confined to the part of the forehead supplied by the frontal nerve.

LYMPHATICS OF THE HEAD

Lymph Nodes

In Chapter 7 it was mentioned that lymph from all structures above the clavicle reaches the **deep cervical chain of nodes**, in some instances directly and in others after passing through intermediary nodes. Three groups of intermediary nodes receiving lymph from the head were noted in Chapter 7 because they lie either wholly in the neck (**submandibular and submental nodes**) or partly in the neck (**parotid nodes**). However, there are some intermediary lymph nodes actually located in the head itself:

1. A few **occipital nodes** at the site where the occipital artery enters the scalp, an inch or so lateral to the external occipital protuberance

2. A few **posterior auricular (retroauricular, mastoid) nodes** along the posterior auricular artery behind the ear

3. A few **facial (buccal) nodes** along the lower half of the facial vein

Lymph Drainage From the Tongue and Lip

The interested reader should consult a major text for detailed descriptions of lymphatic drainage from specific structures of the head. However, I would like to discuss briefly lymphatic drainage of the tongue and lip, because these are frequent sites of cancer.

I mentioned in Chapter 7 how the jugulodigastric node receives lymph from the tonsil, and the jugulo-omohyoid node from the tip of the tongue. The region of the tongue between tonsil and tip drains to nodes between the jugulodigastric and jugulo-omohyoid. Most lymph from the tongue goes directly to the deep cervical chain. Not surprisingly, the far right side of the tongue drains to nodes of the right deep cervical chain and the far left side drains to left deep cervical nodes. However, the region of the tongue near its midline will also send some lymph to the contralateral side. Some lymph from the tip of the tongue proceeds directly to deep cervical nodes (specifically the juguloomohyoid node), but there is also a second route of drainge through submental nodes and then submandibular nodes before reaching the deep cervical chain. Being near the midline, the tip of the tongue drains to both right and left submental nodes, as well as directly to both right and left jugulo-omohyoid nodes.

Lymphatic drainage from the upper lip passes to ipsilateral submandibular nodes. So does the lymph from the lateral regions of the lower lip. However, regions of the lower lip near the midline send lymph to both ipsilateral and contralateral submental nodes.

Paramedian cancer of the tongue or lower lip is far more serious than cancer of their lateral portions, because of the potential for metastases to both right and left deep cervical chains.

SURFACE ANATOMY

Soft-Tissue Landmarks

The major soft-tissue landmark on the exterior of the head is the opening of the external acoustic meatus. As was mentioned in Chapter 7, the external acoustic meatus lies superficial to the root of the styloid process and to the even more deeply placed jugular foramen of the skull. Posterior to the meatus is the root of the mastoid process. The facial nerve exits the stylomastoid foramen between the roots of the styloid and mastoid processes. In front of the external acoustic meatus lies the condyle of the mandible. The interval between it and the external acoustic meatus corresponds to the site where, more deeply, the internal carotid artery enters its canal within the petrous temporal. Inferior to the meatus, wedged between the mastoid process and neck of the mandible is the upper region of the retromandibular part of the parotid gland.

Bony Landmarks

Mastoid Process (see Fig. 8-1)

The tip of the mastoid process can be palpated posterior to the earlobe--a little behind and below the external acoustic meatus.

Zygomatic Arch (see Fig. 8-1)

The posterior root of the zygomatic arch can be felt anterosuperior to the external acoustic meatus. The arch is palpable as it passes forward to join the body of the zygomatic bone, which forms the bony cheek.

Head of the Mandible (see Fig. 8-1)

In front of the external acoustic meatus, below the posterior root of the zygomatic arch, lies the head of the mandible sitting in the mandibular fossa of the temporal bone. However, the mandibular head is usually not palpable except as it moves when the mouth is opened and closed (see earlier).

When the head of the mandible sits in its fossa it is directly lateral to the spine of the sphenoid and foramen spinosum (passing the middle meningeal artery) (see Fig. 8-5). A few millimeters in front of the foramen spinosum (thus, in front of the mandibular head) is the foramen ovale, for the mandibular nerve.

External Occipital Protuberance (see Fig. 8-5)

The external occipital protuberance is a bump of variable size located on the external surface of the occipital bone in the midline, at the superior limit of the posterior neck musculature. Its greatest significance lies in the realization that it is normal rather than indicative of some underlying disease. The external occipital protuberance corresponds in position to the confluens of sinuses within the cranial cavity. The occipital artery and greater occipital nerve enter the scalp 2-3 cm lateral to the external occipital protuberance.

Supraciliary Arches (see Fig. 8-1)

Superior to the medial half of each eyebrow one can feel a variably developed transverse ridge on the external surface of the frontal bone. Each ridge is called a supraciliary arch.

Supraorbital Notch, Infraorbital Foramen, and Mental Foramen

In the superior rim of the orbit, at the junction of its medial one-third with its lateral two-thirds, one can palpate the **supraorbital notch** (see Fig. 8-15). Through it passes the supraorbital branch of the frontal nerve. Occasionally the ligament that bridges across the notch becomes ossified, converting the easily palpable supraorbital notch into a less easily palpable supraorbital foramen.

A vertical line dropped straight down from the site of the supraorbital notch will cross the **infraorbital foramen** (located a few mm below the inferior rim of the orbit) (see Fig. 8-15), and then the **mental foramen** (located below the interval between the premolar teeth about halfway between the superior and inferior edges of the body of the mandible in a person with teeth, or about 1.5 cm up from the lower border of the mandible in an edentulous adult) (see Fig. 8-1). Each of these two foramina pass a nerve, artery, and vein with the same name as the foramen.

Pterygoid Hamulus

If you like to gag, you can feel the hamulus of your medial pterygoid plate (see Fig. 8-5) in the roof of the mouth just behind and medial to the 3rd upper molar.

Soft-Tissue Structures of the Head

Parotid Gland and Duct

The parotid gland is located behind the ramus of the mandible (in the retromandibular region of the neck) and extends forward onto the surface of the mandibular ramus and masseter muscle below the posterior half of the zygomatic arch (see Fig. 7-11). The parotid duct follows a course 1 fb below the anterior half of the zygomatic arch. The duct opens into the vestibule of the oral cavity opposite the upper 2nd molar tooth, which corresponds to a vertical line dropped from the lateral canthus of the eye.

Sublingual Gland and Opening of the Submandibular Duct

In the floor of the oral cavity, on either side of the root of the frenulum linguae, are the sublingual ridges (plicae sublinguales). Each ridge is formed by the upper edge of a sublingual salivary gland. The numerous ducts of the gland open up onto the summit of the ridge but are not usually visible. At the anterior extremity of each sublingual ridge is the visible opening of the submandibular salivary duct.

Readily Palpable Pulses

The pulse of the facial artery can be felt by gently compressing it against the lower border of the mandible at the anterior edge of the masseter muscle.

The pulse of the superficial temporal artery can be felt by compressing it against the root of the zygomatic arch at the anterior edge of the auricle. In thin, bald persons, the anterior and posterior branches of the superficial temporal artery may be visualized pulsing beneath the skin of the temple.

The pulses of the inferior and superior labial arteries can be felt close to the deep (mucous-lined) surface of the lip by gently compressing the lip between a thumb and finger.