CHAPTER 10

Temporal, Infratemporal, and Prevertebral Regions
Pharynx, Nasal Cavities, Mouth, Larynx, and Middle Ear

MUSCLES OF THE TRIGEMINAL SOMITOMERE
Axis of Rotation of the Mandible for Opening and Closing the Jaw
Muscles of Mastication--Temporalis, Masseter, Lateral Pterygoid (Superior and Inferior Heads), Medial Pterygoid, and Anterior Belly of Digastric
Temporalis
Masseter The Infratemporal Fossa
Lateral Pterygoid
Superior Head
Inferior Head
Medial Pterygoid

TERMINAL BRANCHES OF THE EXTERNAL CAROTID ARTERY
Superficial Temporal Artery
Maxillary Artery

VEINS ACCOMPANYING THE MAXILLARY AND SUPERFICIAL TEMPORAL ARTERIES
Communications Between the Pterygoid Plexus and Other Venous Channels

MANDIBULAR DIVISION OF TRIGEMINAL NERVE - V_3

THE LESSER PETROSAL NERVE AND THE OTIC GANGLION

THE ATLAS, AXIS, AND ASSOCIATED JOINTS
Special Ligaments of the Atlanto-axial and Atlanto-occipital Joints
Rectus Capitis Anterior and Rectus Capitis Lateralis

PREVERTEBRAL REGION
Longus Colli and Longus Capitis -The Prevertebral Muscles, Representing a Group Unique to the Neck
Prevertebral Fascia

NERVES AT THE BASE OF THE SKULL
Vagus Nerve (C.N. X)
Branches Near the Base of the Skull
Pharyngeal Branch of the Vagus
Superior Laryngeal Nerve
Hypoglossal Nerve -C.N. XII
The (Spinal) Accessory Nerve - C.N. XI
Glossopharyngeal Nerve - C.N. IX
Branches

NASAL CAVITIES
Lateral Nasal Wall
Paranasal Sinuses

OLFACTORY NERVE - C.N. I
CLINICAL CONSIDERATIONS

LACRIMAL SAC AND NASOLACRIMAL DUCT

TENSOR VELI PALATINI

LEVATOR VELI PALATINI

DISTRIBUTION OF MAXILLARY ARTERY TO NASAL CAVITY AND PALATE

MAXILLARY DIVISION OF TRIGEMINAL - V_2
The Three Actual Branches of the Maxillary Nerve -- Posterior Superior Alveolar, Zygomatic, and Infraorbital
Branches of the Maxillary Nerve That Emanate From the Pterygopalatine Ganglion
CLINICAL CONSIDERATIONS FOR THE TRIGEMINAL NERVE

GREATER PETROSAL NERVE AND THE NERVE OF THE PTERYGOID CANAL

PHARYNX
Pharyngeal Muscles
Constrictors
Lesser Pharyngeal Muscles -- Stylopharyngeus, Palatopharyngeus, Salpingopharyngeus
Function of Pharyngeal Muscles
Innervation of the Pharynx

ORAL CAVITY
Muscular Floor of the Oral Cavity
Geniohyoid--the Deepest Suprahyoid Muscle
Tongue
Hyoglossus
Genioglossus
Styloglossus
Glossopharyngeal Nerve
CLINICAL CONSIDERATIONS FOR THE GLOSSOPHARYNGEAL NERVE

Submandibular Salivary Gland and Duct
Sublingual Salivary Gland
Lingual Nerve
Hypoglossal Nerve - C.N. XII
CLINICAL CONSIDERATIONS FOR THE HYPOGLOSSAL NERVE

LARYNX
Epiglottic Cartilage
Arytenoid and Corniculate Cartilages
Connective Tissue Membranes and Ligaments
Thyrohyoid Membrane and Ligaments
Hyo-epiglottic and Thyro-epiglottic Ligaments, Ary-epiglottic Membrane
The Conus Elasticus
Regions of the Larynx
Movements and Muscles of the Larynx
Epiglottis and Sphincter Vestibuli
Cricothyroid Joints and Cricothyroid Muscle
Crico-arytenoid Joint and the Muscles Acting Across It
Somatic Motor Innervation of the Larynx
Sensory and Parasympathetic Innervation of the Larynx
CLINICAL CONSIDERATIONS FOR THE VAGUS NERVE

TYMPANIC CAVITY AND AUDITORY (EUSTACHIAN) TUBE
Auditory Ossicles
Tympanic Cavity Proper and Its Relationships
Middle Ear Muscles
Tensor Tympani
Stapedius
Branches of the Facial Nerve Related to the Middle Ear
CLINICAL CONSIDERATIONS FOR THE FACIAL NERVE
Branches of the Glossopharyngeal Nerve Related to the Middle Ear
STATO-ACOUSTIC (VESTIBULO-COCHLEAR) NERVE - C.N. VIII
CLINICAL CONSIDERATIONS

LYMPHATICS OF THE HEAD
Lymph Nodes
Lymph Drainage From the Tongue and Lip

SURFACE ANATOMY
Bony Landmarks
Opening of the External Auditory (Acoustic) Meatus
Mastoid Process
Zygomatic Arch
Condyle of the Mandible
External Occipital Protuberance
Supraciliary Arches
Supraorbital Notch, Infraorbital Foramen, and Mental Foramen
Pterygoid Hamulus
Soft-Tissue Structures of the Head
Parotid Gland and Duct
Sublingual Gland and Opening of the Submandibular Duct
Readily Palpable Pulses

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 (see Chapter 9, p. 314). A sixth, the mylohyoid (see Chapter 9, p. 315), attaches to the mandible but plays only a minor role in chewing. Two others (tensor veli palatini, p.354, and tensor tympani, p. 383) 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. 10-1*B*)

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, 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

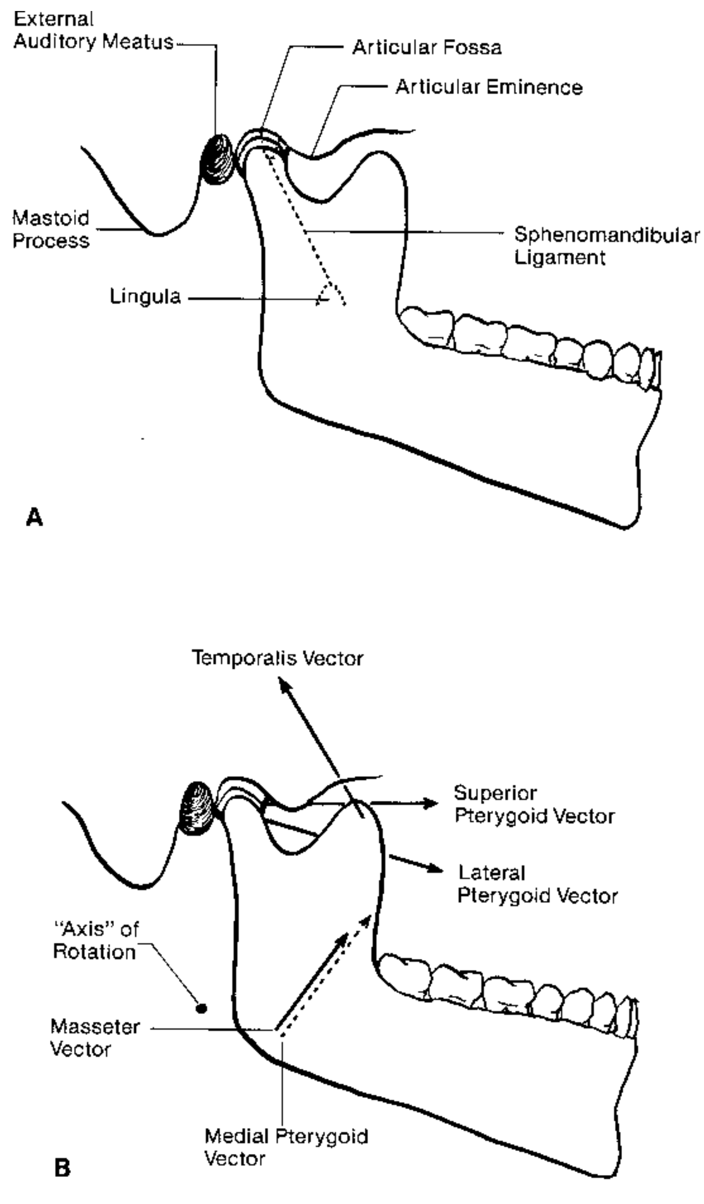

Figure 10-1. *A*, Lateral view of the mandible and the temporomandibular joint. *B*, Idealized vectors of the masticatory muscles in relation to the "axis" of rotation of the mandible. The vector drawn for the masseter is more representative of its superficial fibers than of its deep fibers.

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. 10-1*A*) 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.[36]

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. Projecting into the same space from below is the tip of the coronoid process of the mandible (see Fig. 8-

[36] 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. 8-4). 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. 8-4).

4). 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. 10-1B). 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. 9-19). 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. 10-1*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.

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.

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 [37] 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 front of the mandibular condyle and into the articular disc contained within the joint cavity (see Fig.10-1*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. 8-4). 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.10-1*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. 8-8). 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.)

---

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

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.10-1*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.

TERMINAL BRANCHES OF THE EXTERNAL CAROTID ARTERY

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.

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. The small **transverse facial artery** that courses anteriorly within the upper part of the gland below the zygomatic arch. It was discussed in Chapter 8 (p. 234).

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. 8-4).

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. 8-19). 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. 8-19). 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 division** of the maxillary artery, concerned with supply of the nasal cavity and palate, is described on p. 356.

VEINS ACCOMPANYING THE MAXILLARY AND SUPERFICIAL TEMPORAL 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 9 (p. 322).

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.

MANDIBULAR DIVISION OF TRIGEMINAL NERVE - 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. 10-2). (Frequently the buccal nerve gives off the anterior deep temporal.)

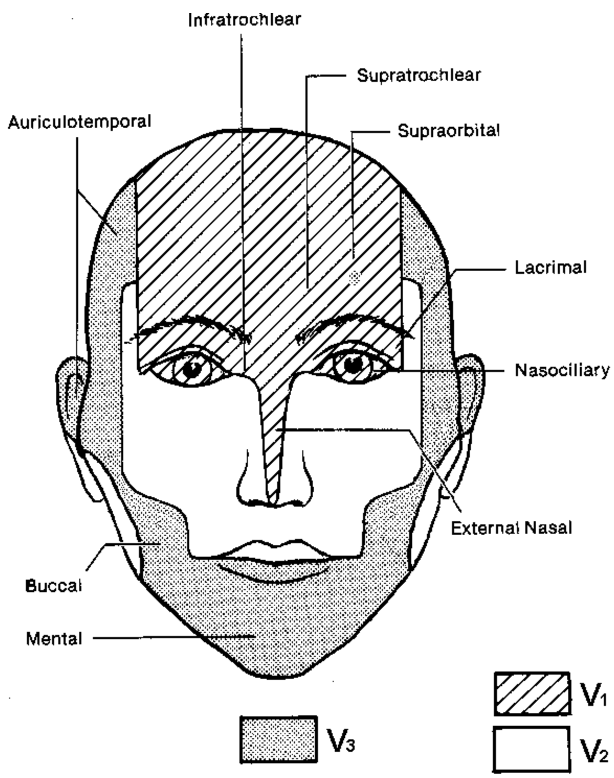

Figure 10-2. Sensory innervation of the face by V_3. The area served by V_1 is shown is shown for purpose of review. The area served by V_2 is indicated, but individual nerves will be named later.

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. 10-2). 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. 10-7). 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. 10-2).

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 in the oral cavity is described on p. 370.

Within the infratemporal fossa the posterior edge of the lingual nerve is joined by a small nerve that has run through the middle ear and then entered the fossa just behind the medial end of the jaw joint. This small nerve is the **chorda tympani**. It is a branch of the facial nerve (C.N. VII) that carries preganglionic para-sympathetic axons for the submandibular and sublingual salivary glands, and taste fibers from the anterior two-thirds of the tongue (see Fig. 10-11) .

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, the taste fibers leave its posterior surface to follow the chorda tympani through the middle ear to reach the facial nerve. 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. 10-11). 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.

THE LESSER PETROSAL NERVE AND THE OTIC GANGLION

Emerging from the tympanic plexus within the middle ear (see p. 384) is the lesser petrosal nerve, a branch of the glossopharyngeal (C.N. IX). The lesser petrosal nerve is composed primarily of preganglionic parasympathetic axons that exited the brain with the glossopharyngeal and provide the preganglionic parasympathetic control of the parotid gland. The nerve leaves the cranial cavity ether through the foramen ovale with V_3, or, sometimes, passes next to it through a small unnamed foramen. Regardless., the lesser petrosal nerve is now in the infratemporal fossa just deep to V_3, and here it immediately encounters a tiny parasympathetic ganglion called the **otic ganglion** (see Fig.10-7). The preganglionic axons synapse on the cells of the otic ganglion. The postganglionic axons from the ganglion join the auriculotemporal nerve and travel with it as it enters the top of the parotid gland. However, whereas the sensory axons of the auriculotemporal nerve pass right through the gland and turn up toward the scalp, the postganglionic parasympathetic axons derived from the otic ganglion jump off the auriculotemporal nerve and distribute to the secretory cells of the gland. [38]

THE ATLAS, AXIS, AND ASSOCIATED JOINTS

The second cervical vertebra is highly modified from the others. Part of the tissue that should have become the centrum of C1 instead fuses to the upper surface of the centrum of C2, forming a process called the **dens** (Latin for "tooth") or **odontoid** (Greek for "tooth-like") **process** (Fig. 10-3). The first cervical vertebra obviously must be different than a typical cervical vertebra by virtue of the fact that most of its centrum has been given to C2. All that remains of the C1 centrum is an anterior arch with a prominent anterior tubercle (Fig. 10-4). On the inner surface of the anterior arch there will develop an articular facet for the dens of C2. The lever-like processes of the first cervical vertebra is sufficiently different from the others to deserve special mention. Because no powerful back muscles reach as high as C1, its spine is abortive and exists only as the so-called **posterior tubercle** of the atlas (not at all homologous to the posterior tubercles of cervical transverse processes). The anterior tubercles of the transverse processes of C2, and C1 are poorly developed because they receive few muscular attachments. In fact, that of C1 is so tiny a bump that the transverse process of the atlas is not considered to have two tubercles. The entire tip of the atlas transverse process is composed of an enlarged "posterior tubercle" that extends further laterally than do the posterior tubercles of the lower cervical vertebrae. The terms "anterior tubercle" and "posterior tubercle," when applied to the atlas, refer to bumps projecting from the middle of the anterior and posterior arches, respectively.

Because the globe of the skull sits on top of the first cervical vertebra, the latter reminds one of the mythological character Atlas supporting the earth. Hence, C1 is called the **atlas** vertebra. Because the dens of C2 acts as an axis around which C1 rotates, C2 is called the **axis** vertebra.

---

[38] 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.

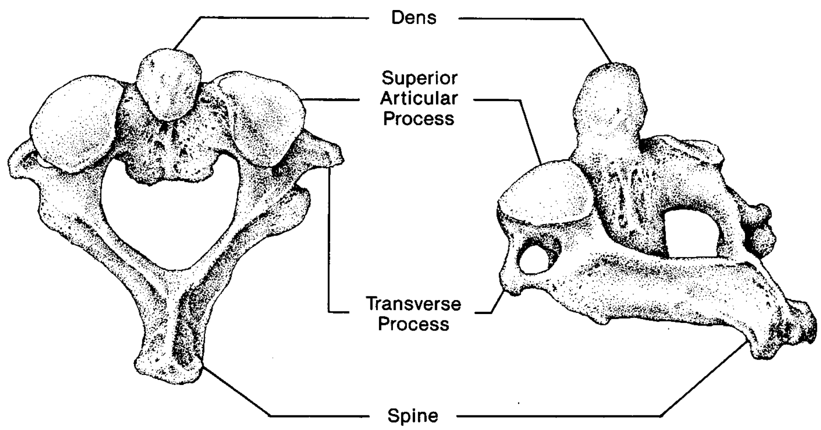

Figure 10-3. Superior view (*at left*) and oblique view (*at right*) of the axis (2nd cervical vertebra).

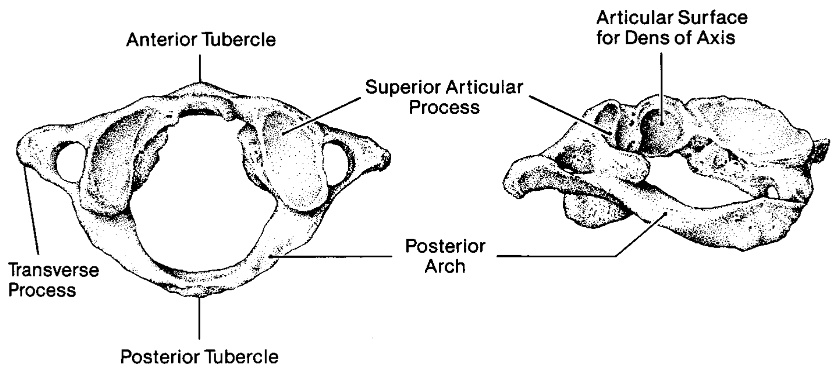

Figure 10-4. Superior view (*at left*) and oblique view (*at right*) of the atlas (1st cervical vertebra).

The superior zygapophysis of C2 and the inferior zygapophysis of C1 differ from those of all lower vertebrae in that they come from the site where the costal element meets the base of the neural arch (see Figs. 10-3 and 10-4), rather than from the vertebral arch further posteriorly. This change in location causes the second cervical spinal nerve to pass posterior to the zygapophyseal joint between C1 and C2, rather than anterior to it, as occurs for lower nerves. The planes of the zygapophyseal joints between C1 and C2 are also entirely different from the planes of lower cervical zygapophyseal joints. Each atlanto-axial joint lies almost in a transverse plane (but a little lower laterally than medially) and permits extensive rotation between the atlas and axis.

The superior articular processes of C1 are shallow cup-shaped structures (see Fig. 10-4) that receive the bulbous condyles of the occipital bone. They too are located at the junctions of the costal elements and the neural arch. Thus, the first cervical nerves pass posterior to the atlanto-occipital joints. The cup-shaped articulation of C1 with the skull allows a fair amount of flexion and extension, and some lateral flexion. Rotation between the skull and the atlas is effectively prohibited by the socket-like conformation of the paired atlanto-occipital joints. The atlanto-axial joints (between C1 and C2) are specialized to permit the rotation that is absent between C1 and the skull.

The superior zygapophysis, inferior zygapophysis and transverse process of the atlas are often said to form its **lateral mass**. Thus, the atlas has two lateral masses joined by **anterior** and **posterior arches**.

Special Ligaments of the Atlanto-axial and Atlanto-occipital Joints

The skull and atlas rotate as a unit around the dens of the axis. In order to prevent this rotation from proceeding to a point that threatens dislocation of the atlanto-axial interarticular joints, there exist powerful **alar** ligaments that run from the dens, near its tip, laterally to the inner surfaces of the occipital condyles. The left alar ligament becomes taut when a person turns the head too far to the right; the right ligament prevents excessive rotation of the head to the left. A tiny ligament of no particular functional significance runs from the apex of the dens to the inner surface of the occipital bone just above the anterior rim of the foramen magnum. This is the **apical dental ligament**.

In order to prevent dislocation of the dens from its articulation with the anterior arch of the atlas, a powerful **transverse ligament of the atlas** runs from the inner surface of its right lateral mass to the inner surface of its left lateral mass, passing behind the dens (see Fig. 10-5). Two smaller ligaments stabilize the vertical position of this transverse ligament. One runs from the middle of the transverse ligament to the inner surface of the occipital bone a bit above the anterior rim of the foramen magnum; the other runs from the middle of the transverse ligament down to the body of the axis. Because these two vertical bands and the transverse ligament make a cross-shaped structure, the three ligaments are often gathered together under the name **cruciate ligament of the atlas**, with transverse, upper, and lower bands. The cruciate ligament of the atlas lies just anterior to the tectorial membrane. Its upper band is sandwiched between the tectorial membrane and apical dental ligament.

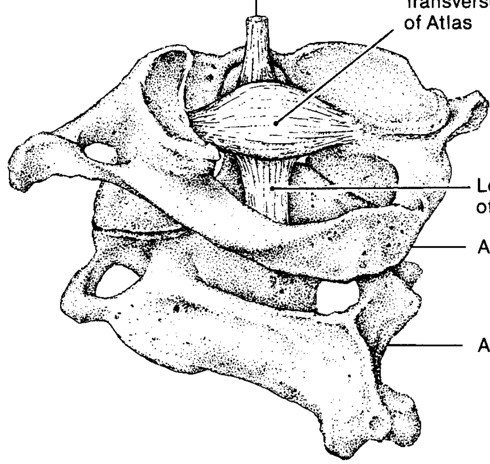

Figure 10-5. Oblique posterior view of articulated atlas and axis showing the powerful transverse ligament that holds the dens of the axis against the anterior arch of the atlas. Stabilizing upper and lower bands join the transverse ligament of the atlas to form the so-called cruciate ligament.

The arches of the atlas are connected by fibrous sheets to the inferior surface of the occipital bone. One such sheet forms the **anterior atlanto-occipital membrane**; the other is called the **posterior atlanto-occipital membrane**.

The uppermost fibers of the posterior longitudinal ligament (i.e., between C2 and the skull) are said to constitute the **tectorial membrane**.

Rectus Capitis Anterior and Rectus Capitis Lateralis

The trilaminar musculature represented in the thorax by the intercostal muscles has a variety of members in the neck. The purest versions of this muscle block are (1) the **anterior intertransverse muscles**, running between the anterior tubercles of adjacent cervical transverse processes, and (2) the **lateral intertransverse muscles**, running between the posterior tubercles of adjacent cervical transverse processes. It will be recalled that both sets of tubercles are part of the costal element of a cervical vertebra. In that the ventral ramus of a cervical spinal nerve passes laterally between the anterior and lateral intertransverse muscles (see Fig. 9-10), the former may be homologized to an innermost intercostal and the latter to an internal intercostal.[39]

The highest in the series of anterior intertransverse muscles is the **rectus capitis anterior**, between the atlas and the occipital bone immediately in front of the foramen magnum. The highest member of the lateral intertransverse series is the **rectus capitis lateralis**, again between the atlas and occipital bone. Its attachment to the occipital bone is in a region just lateral to the posterior part of the occipital condyle.

All these muscles laterally flex the neck. Obviously, the anterior and lateral rectus capitis muscles have an action on the head--the lateralis being a lateral flexor and the anterior being a flexor.

PREVERTEBRAL REGION

Longus Colli and Longus Capitis -The Prevertebral Muscles, Representing a Group Unique to the Neck (Fig. 10-6)

The hypaxial parts of the upper six cervical dermomyotomes send cells on a short course to a position just anterior to the developing vertebral column. These cells will form two **prevertebral muscles** that have no homologues lower in the body.

One of the prevertebral muscles is called the **longus colli**. It has a rather complicated pattern of origin and insertion. Some fibers arise from the front of the bodies of the upper three thoracic vertebrae and pass superolaterally to insert on the anterior tubercles of cervical vertebrae (see Fig. 10-6). Other fibers arise from such anterior tubercles and pass superomedially to insert on the named anterior tubercle of the atlas (not homologous to an anterior tubercle of a transverse process). Finally, some fibers arise from the bodies of the upper three thoracic and lower three cervical vertebrae and pass pretty much straight upward to insert on the bodies of the upper four cervical vertebrae.

In that the medial border of the scalenus anterior passes downward and outward from the anterior tubercle of C6, and the lower lateral border of the longus colli passes downward and inward from the same site, there is a triangular gap between these two muscles in the lower reaches of the neck (see Fig. 10-6). This has been called the "triangle of the vertebral artery,"[40] because this artery is one of the major structures passing through the gap.

---

[39] The possibility also exists that the lateral intertransverse muscles are serial homologues of the external intercostals, and that the internal layer is simply unrepresented in the neck.

[40] Sauerland, EK: Grant's Dissector, ed 9. Williams & Wilkins, Baltimore, 1984.

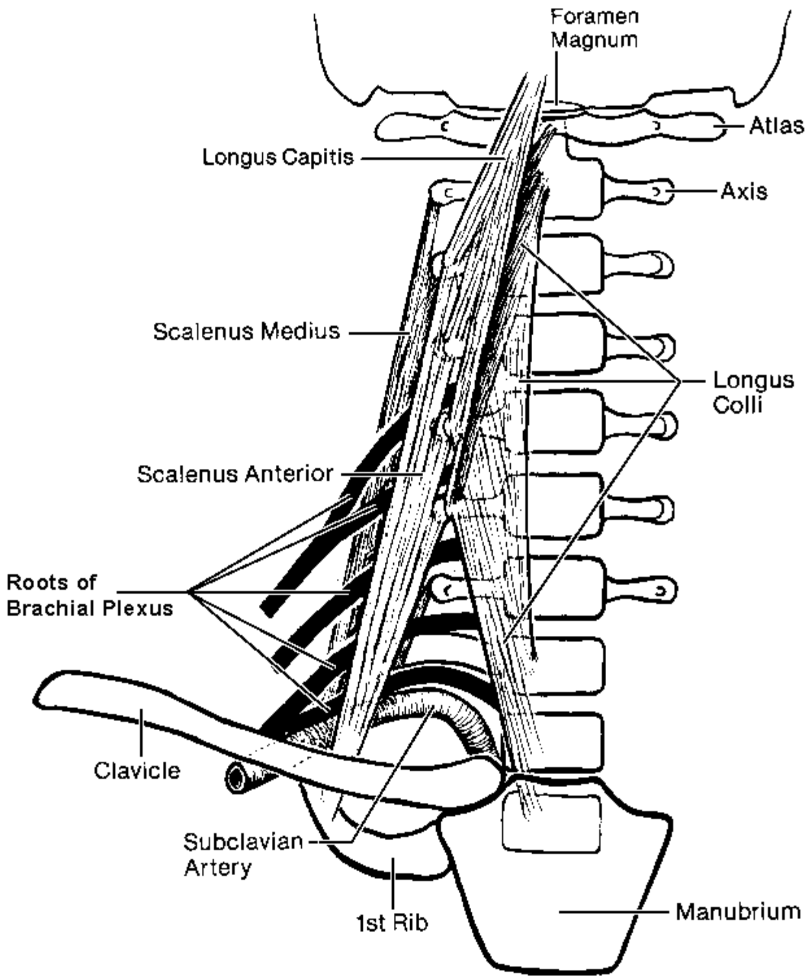

Figure 10-6. Anterior view of the prevertebral muscles, longus colli and longus capitis, in relation to the scalene muscles and lower cervical ventral rami.

Each longus colli participates in flexion of the neck and lateral flexion to the same side. They also act during rotation of the head; the right longus colli acts when the head is turned to the right, and the left longus colli acts when the head is turned to the left. It may be that a longus colli functions during head rotation to counteract the tendency of the opposite sternocleidomastoid to laterally flex the neck (see further on).

The other prevertebral muscle is the **longus capitis**. It lies on the anterolateral surface of the upper half of the longus colli (Fig. 10-6). The muscle fibers arise from anterior tubercles of cervical vertebrae and pass superomedially to insert on the occipital bone in front of the foramen magnum (in fact, just anterior to the insertion of rectus capitis anterior). Acting across the atlanto-occipital joint, the longus capitis flexes the head. Acting across the atlanto-axial joint, the longus capitis rotates the head to the same side.

Because they are flexors, it falls upon the prevertebral muscles to protect the cervical part of anterior longitudinal ligament from further stretching after it has been damaged by a whiplash injury. To fulfill this function, the longus muscles undergo a sustained recruitment, to which they are unaccustomed. This leads to muscle fatigue and pain. One of the purposes of placing a collar around the neck of a person who has experienced whiplash is to provide for artificial flexion of the neck and head, thus relieving the prevertebral musculature from the need to contract continuously. Obviously, such a collar should be higher in the back than in the front.

The prevertebral muscles are innervated by small direct branches from the upper six cervical ventral rami very soon after these rami split from their spinal nerves.

Prevertebral Fascia

The deep fascia on the anterior surface of the prevertebral muscles is called the **prevertebral fascia** (see Fig. 9-10). It is continuous laterally with the fascia of the scalene muscles. Anterior to the prevertebral fascia is a layer of **alar fascia** that is not bound down to the prevertebral muscles(see Fig. 9-10). This alar fascia blends with the back of the esophagus in the superior mediastinum. Between the prevertebral fascia and alar fascia is the **danger space**, so called because infections that enter it can travel downward into chest and through the posterior mediastinum all the way to the diaphragm. Between the alar fascia and the buccopharyngeal fascia that covers the pharyngeal muscles is the retropharyngeal space - a part of the visceral space of Stiles. Infectious material that enters it may pass inferiorly into the superior mediastinum, but is stopped there by attachment of the alar fascia to the esophagus.

NERVES AT THE BASE OF THE SKULL

Vagus Nerve (C.N. X)

The vagus exits the jugular foramen of skull between the glossopharyngeal and accessory nerves. As you have learned, the vagus assumes a position within the carotid sheath between the posterior edges of the internal carotid artery and internal jugular vein, and holds such a position throughout the length of the neck (see Figs. 9-12, 9-17). Its course in the "jugulocarotid interval" takes the vagus down the neck on the anterior surface of the scalene musculature and, finally, between the first part of the subclavian artery and the brachiocephalic vein into the chest (see Fig. 9-17).

Branches Near the Base of the Skull

While in the jugular foramen, the vagus is slightly swollen owing to the presence of sensory cells said to form a **superior (jugular) ganglion** of the vagus. The **auricular branch** of the vagus leaves this jugular ganglion to run through the bone of the skull and eventually reach the external auditory meatus. This small nerve carries somatic sensation from the skin of the external auditory meatus. Within the auricular branch of the vagus are not only somatic sensory fibers with their cell bodies in the jugular ganglion of the vagus, but also some fibers from a communication with the glossopharyngeal nerve, and others from a communication with the facial. The glossopharyngeal fibers have their cell bodies in one of the sensory ganglia contained within the glossopharyngeal nerve; the facial fibers have their sensory cell bodies in the geniculate ganglion of the facial nerve. The importance of learning these seemingly trivial facts is that pain of the external auditory meatus can result from irritative lesions of the facial, glossopharyngeal, or vagus nerves.

Immediately below the skull, the vagus clearly appears swollen owing to the presence of sensory cell bodies said to form the **inferior (nodose) ganglion** of the vagus. From the swollen region come two important branches of the vagus--the pharyngeal and superior laryngeal. As discussed previously, lower in the neck the vagus gives off its direct contributions to cervical cardiac nerves. The role of the vagus in providing nerve supply to the infraglottic larynx and to the cervical parts of the trachea and esophagus is handled by its recurrent laryngeal branch.

Pharyngeal Branch of the Vagus. The pharyngeal branch of the vagus leaves the nodose ganglion and follows a path forward between the internal carotid artery and internal jugular vein. Having passed between the artery and vein, the pharyngeal branch of the vagus turns medially, running in front of the artery to reach the nearby pharynx and participate in formation of the pharyngeal nerve plexus.

The major role of vagal fibers in the pharynx is to innervate the three constrictors and the two small longitudinal muscles not supplied by the glossopharyngeal (i.e., palatopharyngeus and salpingopharyngeus) (see pp. 362-364). Somatic motor fibers also ascend to supply most of the palatal muscles. (In fact, with the exception of the tensor veli palatini, all muscles with the root "palat" in their names are innervated by the vagus nerve.) A less important role is to serve as the source of preganglionic parasympathetic innervation for the glandular cells of the pharynx.

Superior Laryngeal Nerve. The superior laryngeal branch of the vagus passes forward and downward on the *medial* surface of the internal carotid artery, sandwiched between this vessel and the superior cervical sympathetic ganglion. It is the only cranial nerve branch to run medial to the internal carotid artery. As it does so, the superior laryngeal nerve bifurcates into a slender branch called the external laryngeal nerve and a larger branch called the internal laryngeal nerve. These were found in the dissection of the anterior triangle of the neck (Chapter 9, p. 310)

Hypoglossal Nerve -C.N. XII

The hypoglossal emerges from the hypoglossal foramen of the skull, which lies posterior to that part of the jugular foramen transmitting cranial nerves IX, X, and XI (see Fig. 8-8). Very soon after it exits the skull, the hypoglossal nerve is joined by a branch from the 1st cervical ventral ramus carrying most of the latter's axons. The hypoglossal then becomes so firmly bound to the back of the vagus that they almost appear to be one. The two nerves pass a short distance so conjoined. Then the hypoglossal leaves the vagus and crosses the lateral side of the internal carotid artery (between the artery and the internal jugular vein) to emerge from between them at the lower border of the posterior belly of the digastric (see Fig. 9-16). At this point it is in the anterior triangle of the neck (Chapter 9, page 311). As it passes between the internal carotid artery and internal jugular vein, the majority of the C1 axons leave the hypoglossal nerve to comprise the small descendens hypoglossi (Chapter 9, p. 308).

The (Spinal) Accessory Nerve - C.N. XI

The accessory nerve exits the cranial cavity adjacent to the vagus nerve. It immediately embarks on an inferolateral course that takes it either behind or in front of the internal jugular vein. Upon passing the lateral edge of this vessel, the accessory nerve runs inferior to the posterior belly of the digastric and thereby reaches the upper part of the sternocleidomastoid muscle, which it penetrates. It subsequent course, the symptoms of damage to it, and the mechanism of testing for it, are described in Chapter 9 (p. 286).

Glossopharyngeal Nerve - C.N. IX (Fig. 10-7)

The glossopharyngeal nerve exits the skull through the most medial part of the jugular foramen, adjacent to the vagus nerve. The glossopharyngeal passes onto the back surface of the stylopharyngeus muscle, which it follows downward a short distance and then turns forward below the muscle's inferolateral edge to reach the lower edge of the styloglossus muscle. The glossopharyngeal nerve then follows the inferior edge of the styloglossus into the tongue.

Branches

While still in the jugular foramen, the glossopharyngeal nerve is slightly swollen at two sites by the presence of sensory cell bodies. These regions of swelling are said to constitute a **superior (jugular) ganglion** and an **inferior (petrosal) ganglion** of the glossopharyngeal. From the inferior ganglion comes a slender twig that connects to the vagus. This **communication with the vagus** contains somatic sensory fibers that travel with the auricular branch of the vagus to the external auditory meatus.

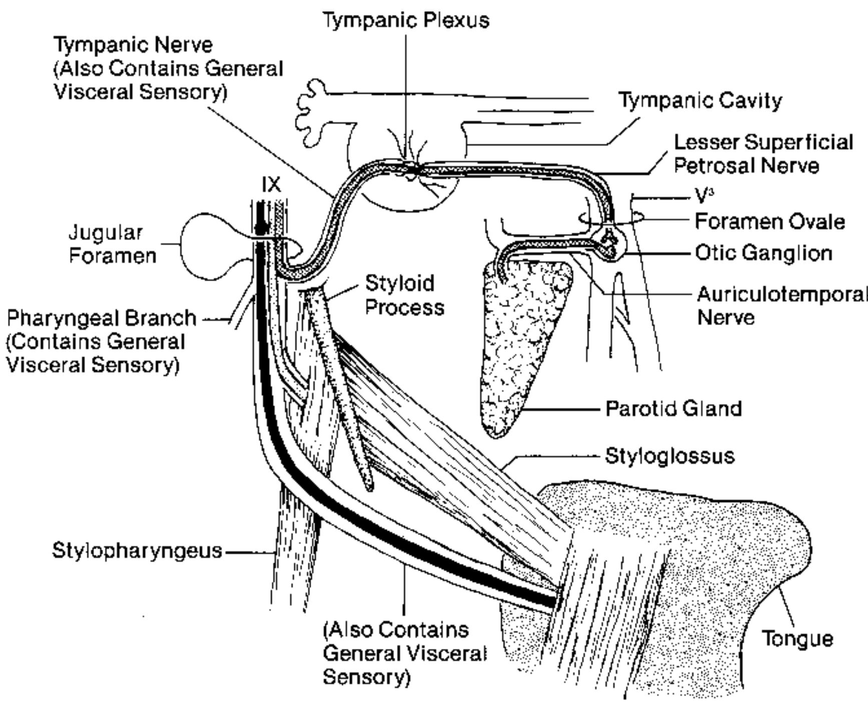

Figure 10-7. The distribution of the glossopharyngeal nerve. ***Lightly stippled bundles*** carry somatic motor axons; ***darkly stippled bundles*** carry parasympathetic axons; ***black bundles*** carry axons for taste. The cutaneous branch to the external auditory meatus is not shown.

Immediately after leaving the jugular foramen, the glossopharyngeal nerve gives off a **tympanic branch** that re-enters the skull through a small hole on the ridge of bone between the jugular and carotid foramina. This hole leads to a canal that carries the tympanic branch of the glossopharyngeal into the tympanic cavity, where the nerve joins in the **tympanic plexus** (p. 384) 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. In addition to carrying these sensory fibers, the tympanic branch of the glossopharyngeal contains parasympathetic preganglionic fibers for the parotid salivary gland. They leave the tympanic plexus as the lesser petrosal nerve for synapse on the otic ganglion and control of the parotid gland (p. 341).

As soon as it contacts the posterior surface of the stylopharyngeus the glossopharyngeal nerve gives off a variable number of small **branches to the pharynx**. In the wall of the pharynx, these branches participate with pharyngeal branches of the sympathetic trunk and vagus to form a **pharyngeal nerve plexus**. The role of the glossopharyngeal fibers is to provide sensation to the pharynx. Afferents from the carotid sinus and carotid body join one of the pharyngeal branches of the glossopharyngeal.

While hugging the posterior edge of the stylopharyngeus, the glossopharyngeal innervates this striated muscle.

In the tongue, the glossopharyngeal provides for general sensation and taste to the posterior third of the tongue.

NASAL CAVITIES (Fig. 10-8)

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 axons organize themselves into 20 or so separate nerve bundles (**fila olfactoria**, or **olfactory filaments**) that, collectively, constitute an **olfactory nerve** (p. 353).

Lateral Nasal Wall

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.

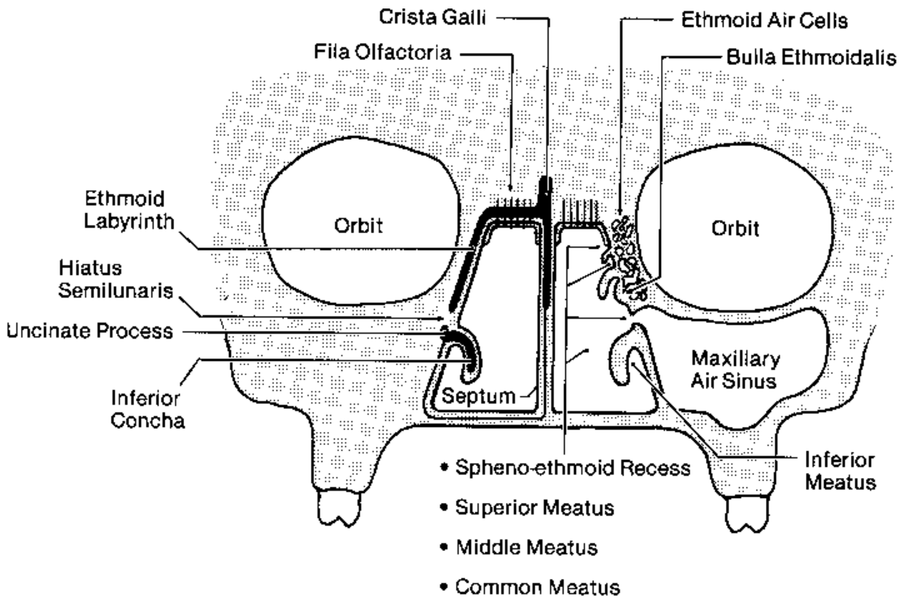

Figure 10-8. Schematic coronal section of the nasal cavities illustrating two developmental stages. On the *left side* of the figure is an early stage in which, subjacent to the nasal epithelium, the walls of the nasal cavity are cartilaginous (*thick black lines*) and membranous (*thin black lines*). 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.

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. 8-19). From the medial lamina two bony sheets grow medially, invaginating the mucous membrane of the lateral nasal wall (see Fig. 10-8, *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. 8-12). 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. 8-12). 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. 10-8, *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. 10-8, *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.

OLFACTORY NERVE - C.N. 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.

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 (Chapter 8, p. 237) 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.

TENSOR VELI PALATINI

This muscle is usually seen following a dissection of the lateral nasal wall. The medial pterygoid plate is the most posterior bony structure of the lateral nasal wall (see Fig. 8-12) Lying against the lateral surface of the medially pterygoid plate, and extending posteriorly beyond its back edge, is the muscle tissue of the tensor veli palatini. Despite the fact that this small muscle has no functional relationship to the mandible, it is derived from the trigeminal somitomere and, therefore, innervated by V_3. 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. 8-8). 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. 8-8). 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 (see p. 381). 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.

LEVATOR VELI PALATINI

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). To be described later are palatopharyngeus (p. 364), palatoglossus (p. 365), and musculus uvulae (p. 366). However, the most important palatal muscle is the levator veli palatini.

This is another muscle usually seen in dissection of the nasal cavity because it passes inferior to the medial portion of the auditory tube, which opens into the nasopharynx posterior to the inferior meatus. The levator veli palatini arises from the inferior surface of the petrous temporal just in front of the carotid foramen (see Fig. 8-8). Thus, the extrapetrous portion of the auditory tube (see p. 381) 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. 10-9). 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.

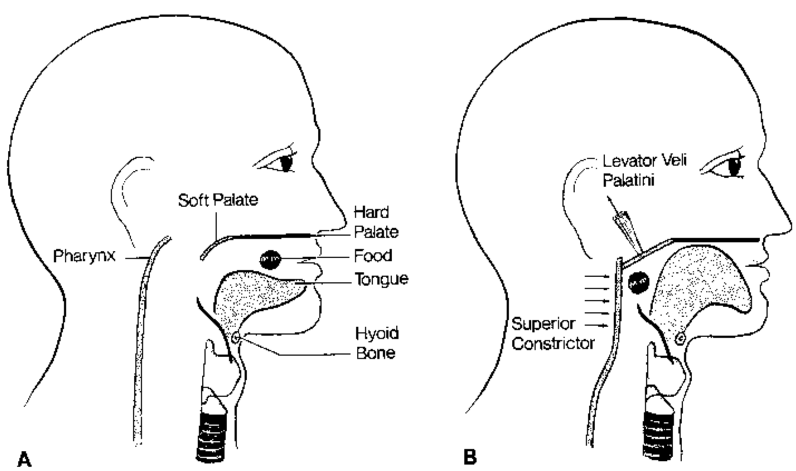

Figure 10-9. Schematic sagittal sections of the oral cavity illustrating the mechanism of swallowing. *A*, Food is in the mouth, but swallowing has not begun. *B*, Swallowing occurs by elevating the tongue and using it to push the food in the oropharynx, which has been sealed off from the nasopharynx by elevation of the soft palate and contraction of the superior pharyngeal constrictor.

DISTRIBUTION OF MAXILLARY ARTERY TO NASAL CAVITY AND PALATE

At the anterior end of the infratemporal fossa, the maxillary artery terminates by dividing into inner and outer divisions (p. 337). 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. 8-8). 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.

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 (pp. 360-361 and Fig. 10-11). 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. 8-19), 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. 10-10).

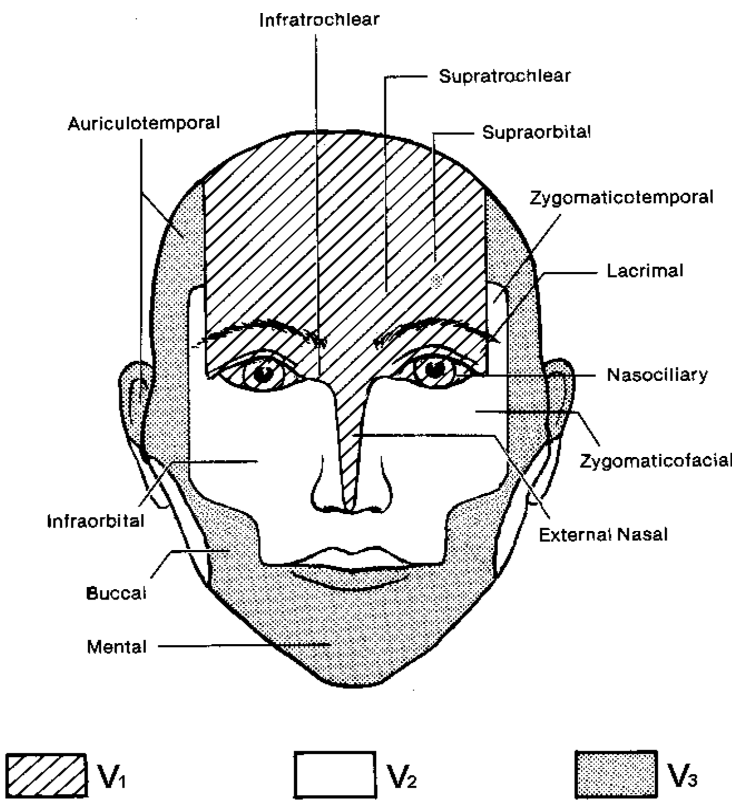

Figure 10-10. Sensory innervation of the face by V_2. The areas served by V_1 and V_3 are shown for purpose of review.

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 (see Chapter 8, p. 269) gives off a tiny twig(s) that accompany the zygomatic nerve (or its branches) out of the orbit.

After the maxillary nerve has given off its posterior superior alveolar and zygomatic branches, it continues into the infraorbital groove (see Fig. 8-19) 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 (Fig. 10-10).

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 (p. 361).

CLINICAL CONSIDERATIONS FOR THE TRIGEMINAL NERVE

Now that all the branches of the trigeminal nerve have been described, we can proceed to a consideration of symptoms arising from its damage, and how to test it during a physical examination.

Damage to the ophthalmic nerve is revealed by disturbances of sensation from the skin supplied by this nerve and from the eye (see Fig. 10-10. 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. 10-10). 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. 10-10). 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.

GREATER PETROSAL NERVE AND THE NERVE OF THE PTERYGOID CANAL

The facial nerve arises by two roots from the brainstem in the posterior cranial fossa. Like the trigeminal nerve, **one root is somatic motor** (Fig. 10-11). The second root of the facial nerve (unlike that of the trigeminal) contains not only somatic sensory axons but also preganglionic parasympathetic 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 CN VIII. 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 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 a narrow channel in the petrous temporal called the **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 (fig. 10-10). The larger fork heads posterolaterally and the smaller heads anteromedially, both essentially paralleling the long axis of petrous temporal. 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

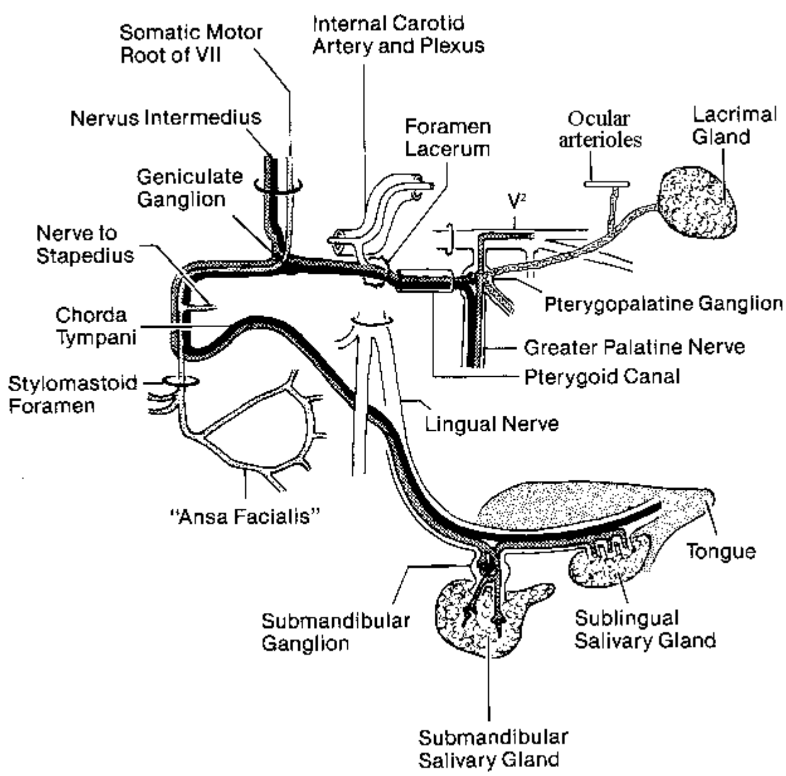

Figure 10-11. The distribution of the facial nerve. *Lightly stippled bundles* carry somatic motor axons; *darkly stippled bundles* carry parasympathetic axons; *black bundles* carry axons for taste. The cutaneous branch to the external auditory meatus is not shown.

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** (see Fig. 10-11, p. 360). The continuation of the facial nerve posterolaterally from the geniculate ganglion carries all the somatic motor axons for innervation of those skeletal muscles supplied by the facial nerve - mainly the muscles of facial expression, but also posterior belly of digastric, stylohyoid, and stapedius (see Chapter 9, p. 314, and Chapter 10, p. 383). It also carries the axons that travel in the chorda tympani and later join the lingual nerve (p. 340).

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 (Fig. 10-10). 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 (sphenopalatine) ganglion**, on whose cells the parasympathetic preganglionic axons synapse. Almost all of the postganglionic parasympathetic axons from the ganglion are distributed with branches of the maxillary nerve in a manner that was described above. However, 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. 10-11).

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. Of less importance is the fact 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.

PHARYNX

The pharynx is the most cranial end of the foregut. It extends from the base of the skull down to the lower border of the cricoid cartilage, where it turns into the esophagus. The internal structure of the pharynx is pretty much like that of the rest of the gut. It is lined by a mucous membrane, has an intermediate muscle layer, and has an external fibrous layer called tunica fibrosa. The tunica fibrosa of the pharynx is more often referred to as **buccopharyngeal fascia**.

Some differences between the pharynx and the rest of the gut do exist. Notable among them is the absence of a well-defined submucosal layer except in the region immediately inferior to the skull base. A submucosal layer is developed at this site because both side walls of pharynx are devoid of muscle here (Fig. 10-12). The limited submucosal layer of the pharynx is called **pharyngobasilar fascia**. A second noteworthy characteristic of the pharynx is that its muscle is striated (not smooth) and derived from *somites* associated with the vagus nerve. Finally, at the sites where the embryonic nasal and oral cavities ruptured into the pharynx, this gut tube is missing an anterior wall.

Anatomists divide the pharynx into three regions. The uppermost region lies between the base of the skull and the palate. Because it opens up into the nasal cavities, it is called the **nasopharynx**. The nasopharynx has no anterior wall (unless one wishes to consider the back edge of the nasal septum as all that is left of an anterior wall after the nasal cavities rupture into the pharynx during development).

Below the palate and above the epiglottis is a region of pharynx that opens forward into the oral cavity. The palatoglossal arches (see p. 365) mark the boundary between this **oropharynx** and the oral cavity *per se*. Owing to the oblique disposition of the epiglottis, the oropharynx is taller in front than in back. Like the nasopharynx, the oropharynx has not much of an anterior wall. However, it must be remembered that the dorsum of tongue is a curved structure. Its anterior two thirds faces superiorly, but its posterior third faces backward. Thus, just above the hyoid bone, the oropharynx has an anterior wall composed of the posterior third of the tongue.

Below the oropharynx is the **laryngopharynx**. In embryonic life the laryngotracheal diverticulum formed as an outpocketing of the anterior wall of the foregut at the lower end of the pharynx. The opening into this laryngotracheal diverticulum was the primitive laryngeal aperture. The diverticulum grew downward into the chest, hugging the anterior wall of the esophagus along the way. The cranial part of the laryngotracheal diverticulum becomes the larynx. During its development, the larynx pushes backward and upward into the lower part of the pharynx, raising the laryngeal aperture so that it lies behind and partly above the hyoid bone, and causing the anterior wall of the lower pharynx to curve around the sides of the larynx (hence the piriform recesses).

It is interesting that the larynx actually sits higher in the newborn than in the adult.[41]] At birth, the superior tip of the epiglottis lies just behind the palate. The oropharynx exists only as a small region anterior to the epiglottis. An oropharynx of significant dimensions develops concomitantly with descent of the larynx in early childhood. As a result of the high position of the larynx in the newborn, the food and air passageways are separate, enabling liquid food to be swallowed at the same time as breathing occurs. Newborns tend to breathe solely through their noses, although they outgrow this habit before the larynx descends.

Pharyngeal Muscles

Constrictors (Fig.10-12)

The lateral and posterior walls of the pharynx are composed primarily of the three pharyngeal constrictor muscles: superior, middle, and inferior. The **superior constrictor** arises from (1) the lower part of the posterior edge of the medial pterygoid plate (see Fig. 8-8), (2) the hamulus at the inferior extremity of this plate (see Fig. 8-8), (3) the pterygomandibular raphe (which is a narrow connective tissue band that runs from the pterygoid hamulus to the mandible posterior to the 3rd molar), and (4) the mandible a short distance behind the attachment of the pterygomandibular raphe. From this rather extensive linear origin, the fibers of each superior constrictor pass backward and then turn medially to meet their opposite members in the midline, with only a thin band of connective tissue interposed. This

[41] Crelin, ES: Functional Anatomy of the Newborn. Yale University Press, New Haven, CT, 1973.

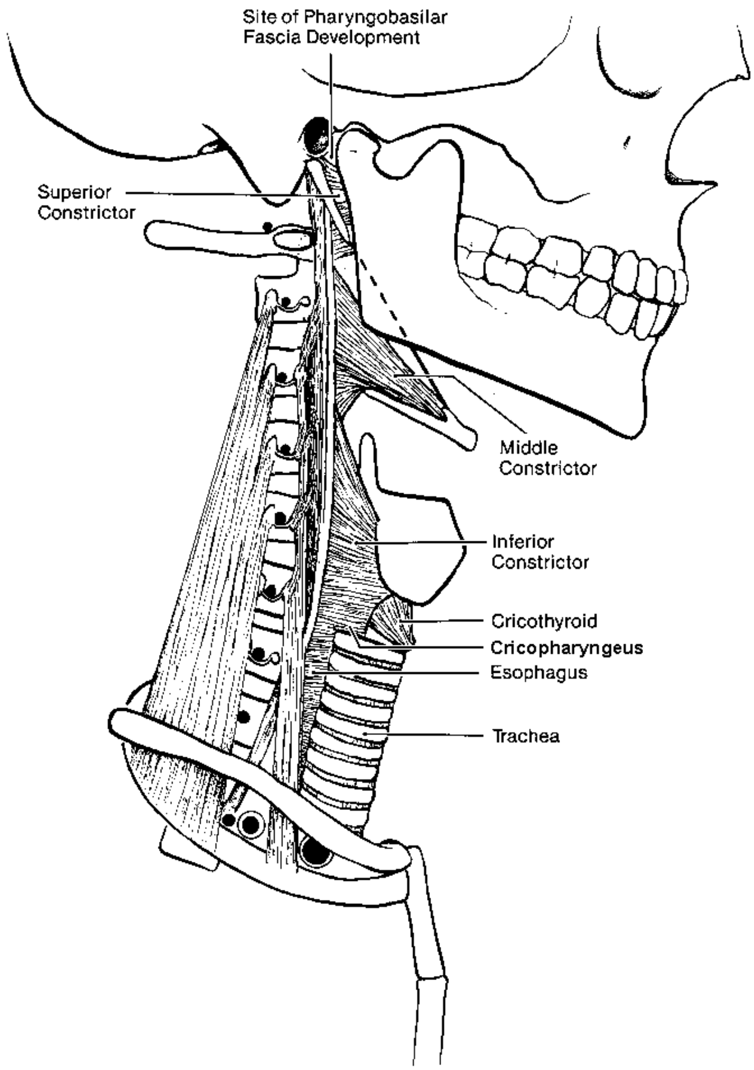

Figure 10-12. Lateral view of the three pharyngeal constrictors, the trachea, the esophagus, and the one external laryngeal muscle—the cricothyroideus.

band, which thus receives the insertion of both the right and left superior pharyngeal constrictors, is the **median raphe** of the superior constrictor.

The fibers of the superior constrictor fan out slightly as they follow their backward and then medial course. Thus the raphe into which they insert is longer than the origin of the muscle. The most superior muscle fibers arch upward and actually terminate in a bump--the **pharyngeal tubercle**--on the inferior surface of the occipital bone about a centimeter in front of the foramen magnum. The upper end of the median raphe is also attached here. Between these arching muscle fibers and the base of the skull, the pharyngeal wall lacks muscle but gains a well-developed submucous connective tissue (**pharyngobasilar fascia**) that provides strength. Piercing this tissue, above the muscle fibers themselves, are the auditory tube (p. 381) and levator veli palatini muscle (p. 355).

The **middle constrictor** of the pharynx arises deep to the hyoglossus from the superior surface of the greater cornu of the hyoid all the way from its tip to its junction with the lesser cornu. The origin then passes upward and backward along the postero-inferior edge of the lesser horn and up onto the lower part of the stylohyoid ligament. Although this origin is long from front to back, it is short from top to bottom. The fibers of the middle constrictor pass backward and, like the other constrictors, turn medially to meet their opposite members at a midline raphe.

The middle constrictor fibers fan out dramatically as they pass from origin to raphe. The uppermost fibers pass superficial to the lower fibers of the superior constrictor. Thus, the upper part of the middle constrictor raphe overlaps the superior constrictor raphe and the two raphe are fused. On either side there is a small muscle free area between the upward arching fibers of the middle constrictor and the downward arching fibers of the superior constrictor (see Fig. 10-12). Through this gap pass the styloglossus muscle and the glossopharyngeal nerve on their way to the tongue.

The origin of each **inferior constrictor** starts at the top of the oblique line of thyroid cartilage and passes downward along this line (just posterior to the insertion of the sternothyroid) and then onto the fascia on the superficial surface of the cricothyroid muscle, and finally onto the arch of the cricoid itself. The muscle fibers pass backward from this origin and then turn medially to meet their opposite members in a midline raphe.

The lowermost fibers of the inferior constrictor are essentially horizontal and intertwine with the circular muscle of the esophagus. They are said to constitute a **cricopharyngeus** muscle. The higher fibers of the inferior constrictor fan upward to a marked degree and cover the inferior part of the middle constrictor. The raphe of the inferior constrictor overlies most of the middle constrictor raphe, and the two are fused.

Lesser Pharyngeal Muscles -- Stylopharyngeus, Palatopharyngeus, Salpingopharyngeus

There are three small pharyngeal muscles (with common insertions) whose fibers run more or less longitudinally. The biggest of these is the **stylopharyngeus**. It arises from the medial surface of the styloid process (i.e., that surface closest to the pharynx). The fibers pass medially and downward to contact the external surface of the lower fibers of the superior constrictor. The stylopharyngeus then slips deep to the upper border of the middle constrictor and continues deep to it and then the inferior constrictor all the way to an insertion on the posterior border of the thyroid lamina and (possibly) the actual connective tissue of the pharyngeal wall.

The **palatopharyngeus** arises from the connective tissue of the soft palate and descends almost straight vertically deep to the superior constrictor (thus, separated by it from the stylopharyngeus). At the lower border of the superior constrictor, the palatopharyngeus and stylopharyngeus meet and pass together to a common insertion.

The **salpingopharyngeus** arises from the medial end of the cartilaginous auditory tube and descends almost straight vertically deep to the superior constrictor to contact the back edge of the palatopharyngeus and pass with it to join the stylopharyngeus.

Function of Pharyngeal Muscles

The pharyngeal muscles play a role in swallowing. The constrictors are activated in sequence, from top to bottom, to propel food toward the esophagus. The longitudinal muscles elevate the larynx and pharynx at the initiation of the swallow.

Innervation of the Pharynx

The pharyngeal muscles are somatic motor structures derived from vagal somites. They receive motor innervation from the pharyngeal branch of the vagus nerve. The inferior constrictor receives some additional nerve fibers traveling in the external laryngeal and recurrent laryngeal branches of the vagus. The same nerves as innervate the striated muscle also bring parasympathetic preganglionic fibers for pharyngeal glands. Most authors believe that sensation to the pharynx is provided by branches of the glossopharyngeal nerve (p. 348 and p. 368).

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**. 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 extrinsic muscles of the soft palate were described previously (pp. 354-355).

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. 8-8), 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.

Muscular Floor of the Oral Cavity

The muscular floor of the oral cavity is provided by the **mylohyoid** muscle. 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 9 (p. 315). 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.

Geniohyoid--the Deepest Suprahyoid Muscle (see Fig.10-13)

Deep to the mylohyoid, on either side of its midline raphe, are the geniohyoid muscles. In most mammals the geniohyoid is innervated by the hypoglossal nerve and, thus, must be derived from caudal occipital somites. Although the same muscle in humans is usually described as being innervated by fibers from the ventral ramus of C1 that join the hypoglossal nerve (see further on), I am aware of no indisputable evidence to substantiate such a claim.

Each geniohyoid arises via a short tendon from the inferior aspect of a little bump on the inner surface of the mandible just lateral to the symphysis. This bump is called the **mental spine**. (Each mental spine sometimes appears divided into two smaller bumps called genial tubercles.) The geniohyoid muscle fibers pass backward and downward to insert mainly on the body of the hyoid deep to the mylohyoid insertion (some superficial fibers of the geniohyoid extend onto the greater horn). The geniohyoids are elevators of the hyoid, important in swallowing and phonation.

Tongue

The tongue is composed of skeletal muscles covered by a mucous membrane that has taste buds placed in strategic locations. Some of the muscles (**intrinsic lingual muscles**) are wholly confined to the substance of the tongue and change its shape. Others (**extrinsic lingual muscles**) attach to bones outside the tongue and can cause change in its position. Two of these--hyoglossus and genioglossus--lie deeply in the suprahyoid region; one--styloglossus--arises from the styloid process of the skull. All the tongue muscles, both intrinsic and extrinsic, are derived from caudal occipital somites and, thus, are innervated by the hypoglossal nerve.

Hyoglossus

The hyoglossus (Fig. 10-13) is a flat muscle with an origin from the superior border of the hyoid bone all the way from the tip of its greater horn forward onto the bit of the body deep to the superficial fibers of geniohyoid. The hyoglossus fibers pass upward and slightly forward, out of the neck, to insert into the fibrous tissue of the tongue near its dorsum. Upon contraction, the hyoglossus flattens the tongue and pulls it backward slightly.

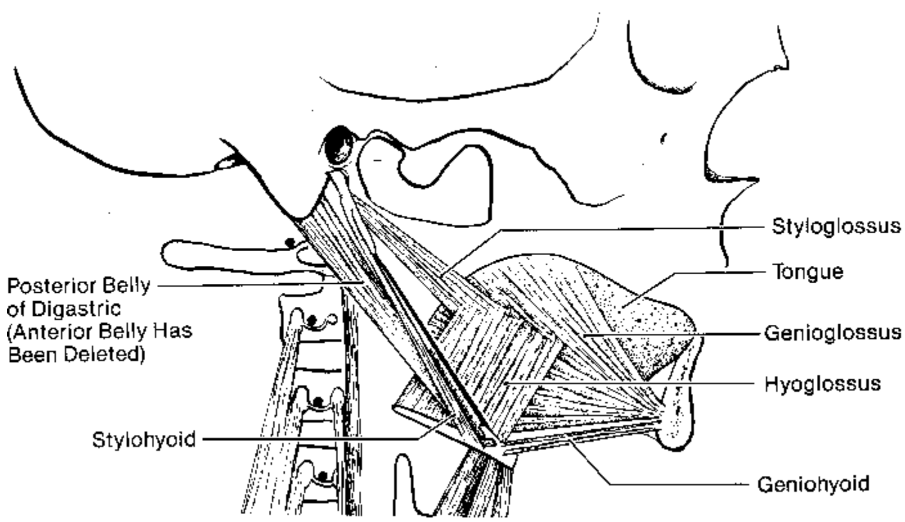

Figure 10-13. Lateral view of the stylohyoid, geniohyoid, and the three extrinsic muscles of the tongue—hyoglossus, styloglossus, and genioglossus (revealed by removal of the mylohyoid, anterior belly of the digastric, and most of the mandible).

Because the fibers of the hyoglossus are essentially parallel, the muscle is trapezoidal in shape. A line from its posterosuperior angle to its antero-inferior angle divides it into two regions. In front and above this line the hyoglossus is under cover of the mylohyoid (see Fig. 9-18).

Genioglossus

Another tongue muscle partly in the suprahyoid region of the neck is the genioglossus (see Fig. 10-13). It is a large muscle forming much of the body of the tongue. The genioglossus arises from the mental spine (remember, this is a small bump on the inner surface of the mandible near the symphysis). From this small area of origin the fibers pass more or less posteriorly, but also fanning out a great deal, to insert into the submucosal connective tissue of the tongue from the middle of its dorsum all the way back to the site where this submucosal tissue meets the epiglottis. The most inferior fibers of the genioglossus either skim right past the upper edge of the hyoid body or insert on it. Most of the genioglossus, lying as it does above the lower border of the mandible, is, technically, not in the neck.

The genioglossus is the protractor of the tongue. It is active in swallowing, speech, and, interestingly, during the inspiratory effort of breathing. This last activity serves to prevent the tongue from being sucked into the pharynx and thereby closing off the air passageway. For the same reason, the genioglossus is more or less continuously active when a person lies in the supine position. It has been suggested that some persons subject to respiratory distress during sleep may have periods of inactivity of the genioglossus. Certainly during general anesthesia, one must guard against the tongue falling backward and obstructing the air passageway.

Styloglossus

The last of the extrinsic tongue muscles is the styloglossus (see Fig. 10-13). It arises from the anterior surface of the styloid process and passes antero-inferiorly toward the upper edge of the hyoglossus. Styloglossus fibers interweave with hyoglossus fibers and insert into the connective tissue of the tongue. The styloglossus pulls the tongue backward and upward. This is a particularly important movement in propelling food from the oral cavity into the pharynx during swallowing.

Glossopharyngeal Nerve

The glossopharyngeal nerve enters the posterior one-third of the tongue by traveling adjacent to the postero-inferior edge of the styloglossus muscle (see Fig. 10-7) The nerve supplies general sensation and taste to the posterior one-third of the tongue.

CLINICAL CONSIDERATIONS FOR THE GLOSSOPHARYNGEAL NERVE

Now that all the functions and relations of the glossopharyngeal nerve have been described, we can consider symptoms of damage to it. 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 glossopharyngeal 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.

Submandibular Salivary Gland and Duct

From the posterior part of the submandibular salivary gland emanates its duct, which travels forward **deep to** the mylohyoid muscle (Fig. 10-14), at first on the superficial surface of the hyoglossus and then on the superficial surface of genioglossus. The duct eventually opens into the floor of the mouth on either side of the frenulum of the tongue. There is always some actual glandular tissue that extends along the beginning of the duct and continues with it deep to the mylohyoid.

Sublingual Salivary Gland

Lying immediately deep to the mandible, on either side of its symphysis, are the **sublingual salivary glands** (fig. 10-14). Each gland raises a ridge in the mucous membrane of the floor of the mouth on either side of the frenulum of the tongue. The ridge is called the **plica sublingualis (or sublingual fold)**.

Clearly the sublingual salivary gland is not in the neck, yet I mention it here because it has an important relationship to the submandibular duct. The latter passes forward, trapped between the sublingual gland and the genioglossus. The submandibular duct opens up at the anterior extremity of the sublingual fold. The sublingual salivary gland itself does not have a single duct. Rather it has numerous small ducts that travel the short distance straight upward to open on the sublingual fold.

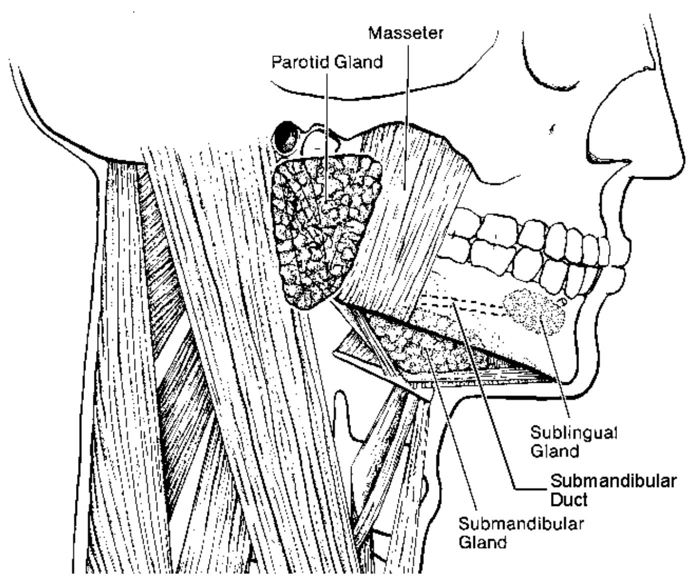

Figure 10-14. Position of submandibular duct deep to mylohyoid and of sublingual gland deep to mandible.

Lingual Nerve

After its origin from V_3 within the infratemporal fossa, the lingual nerve passes onto the external surface of the hyoglossus and deep to the posterior edge of the mylohyoid very near that muscle's origin from the mandible. At this site the lingual nerve is superior to the submandibular duct. The nerve then runs forward between hyoglossus and mylohyoid, but also moves inferiorly, causing it to cross the external surface of the duct. Thus when the lingual nerve and submandibular duct pass together onto the genioglossus, the nerve is below the duct. While on the genioglossus, the lingual nerve turns superiorly again, but this time passes deep to the submandibular duct and then dives into the tongue.

The lingual nerve carries fibers for somatic sensation from the anterior two thirds of the tongue back to the trigeminal ganglion, where the sensory cell bodies lie. Also running within the distal part of the lingual nerve are sensory fibers carrying taste from the anterior two thirds of the tongue. But these fibers will eventually leave the lingual nerve in the chorda tympani to run back to the geniculate ganglion of the facial nerve. They are not trigeminal fibers, even though they run for part of their course with a branch of the trigeminal nerve. Their route was described on p. 340 and p. 384.

The lingual nerve carries yet another set of axons that are not originally part of the trigeminal nerve. It picks up preganglionic parasympathetic axons that left the brain with the facial nerve and entered its chorda tympani branch (see p. 340 and p.384). These axons travel with the lingual nerve onto the external surface of the hyoglossus and then leave the inferior edge of the lingual nerve to travel a millimeter or so to a clump of postganglionic parasympathetic cell bodies located on the surface of the hyoglossus above the submandibular duct. This clump is called the **submandibular ganglion**. Some of its cells send postganglionic axons to the submandibular salivary gland; other of its cells send axons back up to the lingual nerve, where they turn forward and are carried by it to the sublingual salivary gland.

Hypoglossal Nerve - C.N. XII

The hypoglossal nerve moves from the digastric triangle of the neck into the tongue by passing deep to the posterior edge of the mylohyoid., thereby becoming sandwiched between hyoglossus and mylohyoid. Continuing forward in this plane, the hypoglossal nerve eventually passes beyond the hyoglossus onto the lateral surface of the genioglossus, into which it dives. While on the surface of the hyoglossus, branches are given to it, to the styloglossus, and to the geniohyoid. The intrinsic muscles of the tongue and the genioglossus are supplied by the hypoglossal nerve after it dives into the latter muscle. It might be noted that, with the exception of the *palat*oglossus (which we can deduce is innervated by the vagus), all muscles with the root "glossus" in their names are innervated by the hypoglossal nerve.

The hypoglossal nerve is the third structure to lie on the external surface of the hyoglossus deep to the mylohyoid. In this same interval, above the hypoglossal nerve, is the deep part of the submandibular gland with its duct. Above the gland and duct is the lingual nerve, with the submandibular ganglion hanging down from it. The lingual nerve will eventually cross the duct to lie between it and the hypoglossal nerve, and then cross back again to regain a position superior to both structures.

CLINICAL CONSIDERATIONS FOR THE HYPOGLOSSAL NERVE

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.

LARYNX

The larynx is a passageway for air. It lies below the hyoid bone and above the trachea. Its most important structures are the vocal cords.

The larynx is composed of:

Four major cartilages--thyroid, cricoid, arytenoid (bilateral), and epiglottis
Two minor cartilages--corniculate and cuneiform (both bilateral)
Connective sheets between some of the cartilages
Muscles running between cartilages
A mucous membrane lining

The thyroid and cricoid cartilages were described in Chapter 9 (pp. 294-296).

Epiglottic Cartilage (Fig. 10-15)

The epiglottis is an elongate leaf-shaped cartilage lying posterior to the body of the hyoid bone. The stem of the "leaf" is directed inferiorly and passes deep to the superior thyroid notch. The rounded (or notched) tip of the leaf rises a centimeter or so above the upper edge of the hyoid body, to a position behind the back of the tongue. The epiglottis is curved from side to side so that the surface facing the hyoid bone is convex, whereas that facing the interior of the larynx is concave.

Arytenoid and Corniculate Cartilages

There are two arytenoid cartilages--a right and a left. Their shape is difficult to describe. Roughly speaking, each arytenoid resembles a three-sided pyramid with the base inferiorly and the apex superiorly (Fig. 10-16). One side of the pyramid faces medially, another faces posteriorly, and the last faces anterolaterally. Thus, the base has medial, posterior, and anterolateral edges; it also has anteromedial, posteromedial, and posterolateral angles. The anteromedial angle is elongated to form the **vocal process**,

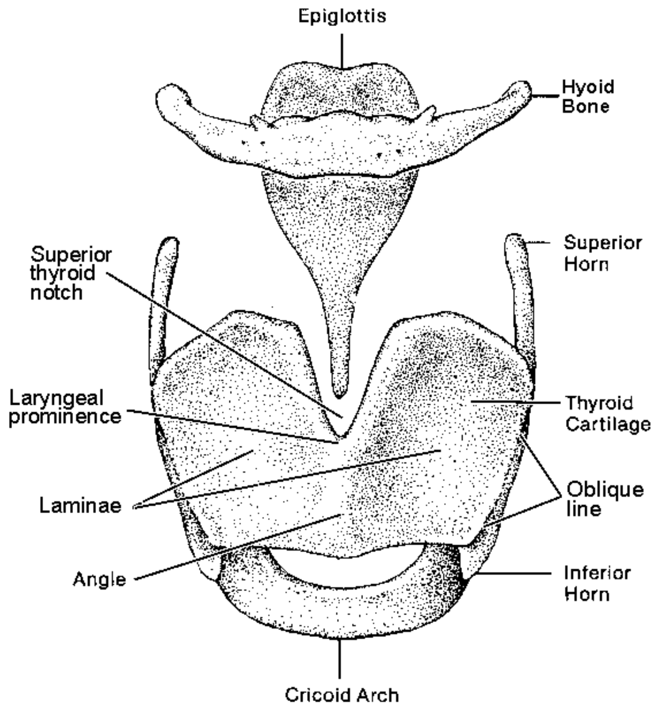

Figure 10-15. Anterior view of the skeletal framework of the larynx.

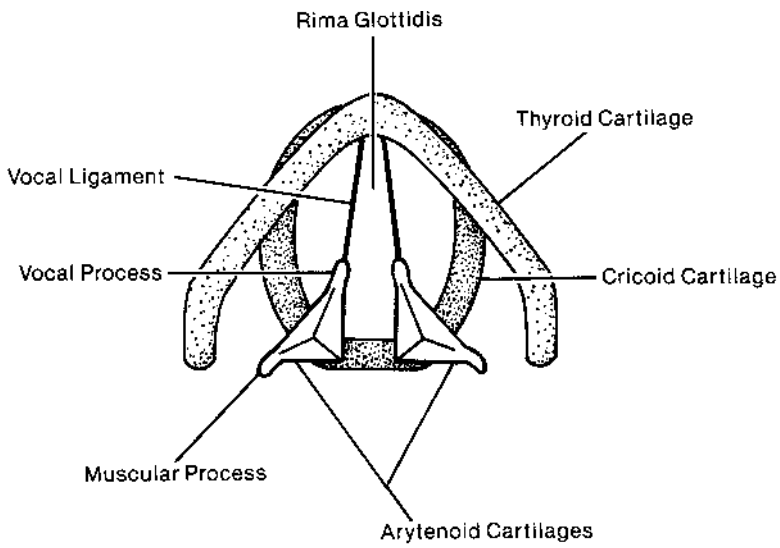

Figure 10-16. Schematic superior view of the arytenoid cartilages, vocal ligaments, and the space they bound—the rima glottidis. Anterior is at the *top* of the figure, posterior at the *bottom*.

to which the vocal ligament attaches. The posterolateral angle is expanded to receive the insertions of muscles, thus is called the **muscular process**. The undersurface of the arytenoid base has a concave elliptical facet for the convex elliptical facet on the superior rim of the cricoid. Surmounting the apex of the arytenoid pyramid, and fixed to it by perichondrium, is the small corniculate cartilage.

Connective Tissue Membranes and Ligaments

Thyrohyoid Membrane and Ligaments

The whole length of the inferior edge of edge of hyoid bone is connected to the whole length of the superior edge of the thyroid cartilage by a connective tissue sheet called the **thyrohyoid membrane**. It is a bit thicker in the anterior midline, where it is said to form a **median thyrohyoid ligament**, and also between the tips of the cornua of the two elements, where it is said to form **lateral thyrohyoid ligaments**.

Hyo-epiglottic and Thyro-epiglottic Ligaments, Ary-epiglottic Membrane

The epiglottic cartilage is bound to the neighboring skeletal structures by two ligaments and a connective tissue sheet (i.e., membrane).

The stem of the epiglottis is connected to the inner surface of the thyroid angle (immediately below the superior thyroid notch) by a strong elastic **thyro-epiglottic ligament** (Fig. 10-17). A broader condensation of fibrous tissue connects the anterior surface of the epiglottis to the upper edge of the hyoid bone. This is called the **hyo-epiglottic ligament**. Between hyo-epiglottic and thyro-epiglottic ligaments, the anterior surface of the epiglottis is separated from the body of the hyoid bone and the thyrohyoid membrane by fat.

Above the hyo-epiglottic ligament lies the free part of the epiglottis, covered by mucous membrane and related to the back of the tongue. As the mucous membrane reflects from the anterior surface of the epiglottis onto the back of the tongue it is thrown into three longitudinal ridges, each running anteroposteriorly. The one in the middle is called the **median glosso-epiglottic fold**. The two lateral ones are called **lateral glosso-epiglottic folds**. The depressions on either side of the median fold are called **valleculae**.

Inferior to each lateral glosso-epiglottic fold, the mucous membrane on the anterior surface of the epiglottis reflects onto the inner surface of the thyrohyoid membrane. The grooves marking this reflection are called the **piriform recesses**.

On each side, attached to the lateral edge of the epiglottis and, below this, to the thyro-epiglottic ligament, is a flat connective tissue sheet that sweeps downward and backward to reach the corniculate cartilage and the anteromedial edge of the arytenoid almost down to its vocal process (see Fig. 10-17). These sheets are called **quadrangular, or ary-epiglottic, membranes**. Each has a free upper edge called the ary- epiglottic ligament and a free lower edge called the **ventricular ligament**. Embedded in each ary-epiglottic ligament just in front of the corniculate cartilage is the **cuneiform cartilage**. An ary-epiglottic ligament, together with its adherent mucous membrane is called an **ary-epiglottic fold**. Each ventricular ligament together with its adherent mucous membrane forms a **ventricular (or vestibular) fold**, which is also called the **false vocal cord**.

The Conus Elasticus (see Fig. 10-17)

This highly elastic membrane is the most important of the laryngeal connective tissues. It has an origin from the perichondrium along the superior rim of the cricoid arch. At the back of the arch, this origin passes upward in front of the crico-arytenoid joints onto the anterolateral edges of the arytenoid bases and then forward out along their vocal processes. From this broad origin, the fibers converge anteriorly on a much shorter vertical insertion into the inner surface of the thyroid angle below the

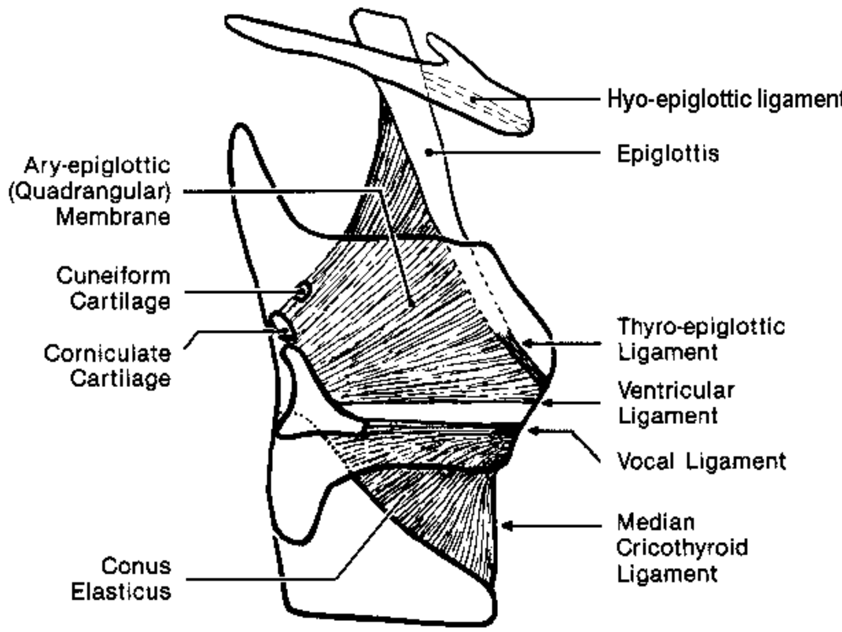

Figure 10-17. Lateral view of the skeletal framework of the larynx and of certain connective tissue sheets binding it together. The thyrohyoid membrane has been excluded.

attachment of the hyo-epiglottic ligament. Thus, fibers arising from the arytenoid pass straight forward, while fibers arising progressively further toward the front of the cricoid arch pass more directly superiorly. Those fibers arising from each arytenoid form free upper edges to the conus elasticus. The two upper edges are called **vocal ligaments**. Together with their overlying squamous epithelium, they form the **vocal folds** (**cords**). The most anterior fibers of the conus elasticus run in the midline between the cricoid arch and inferior border of the thyroid angle. These fibers are thickened to form a **median cricothyroid ligament**.

On each side, between an upper edge of the conus elasticus (i.e., vocal ligament) and a lower edge of a quadrangular membrane (i.e., ventricular ligament) there is a gap. The mucous membrane lining the inside of the quadrangular membrane does not simply bridge across this gap to reach the conus elasticus. Instead, it evaginates into the gap to form the so-called **ventricle of the larynx**. Of course there are right and left laryngeal ventricles.

Regions of the Larynx

The superior edges of the epiglottis and the ary-epiglottic folds encircle a space called the **laryngeal aperture**. From this aperture down to the ventricular folds, the cavity of the larynx is called the **vestibule**. The space between the right and left ventricular folds is called the **rima vestibuli**, below which is the part of the laryngeal cavity that opens up into the ventricles. Immediately inferior to the ventricles the laryngeal cavity narrows dramatically as the space between the vocal folds, vocal processes of the arytenoids, and medial arytenoid surfaces (covered by mucous membrane). This space is the **rima glottidis** (see Fig. 10-16). The vocal folds and the part of the rima between them form the **glottis** *per se*.

Movements and Muscles of the Larynx

Epiglottis and Sphincter Vestibuli

The epiglottis is a mobile structure. During swallowing, the bolus of food contacts the upper, exposed part of the anterior epiglottic surface and pushes the cartilage down over the laryngeal aperture. There is also a sheet of muscle on the external surface of the quadrangular membrane that acts as a **sphincter vestibuli**. Because different fibers of the sphincter vestibuli have different attachments, bundles of muscle are customarily given specific names, but these names are not important.

Cricothyroid Joints and Cricothyroid Muscle

The thyroid cartilage can rotate forward around a horizontal axis that passes between the right and left cricothyroid joints. The muscles that produce such rotation are the **cricothyroid muscles** (see Fig. 10-12). The fibers of each cricothyroid arise from the external surface of the cricoid arch lateral to the anterior midline. They pass posterosuperiorly to insert on the lower rim of a thyroid lamina and into its inferior horn. By pulling the thyroid cartilage downward and forward, the cricothyroid muscles cause the vocal cords to become tighter and to move slightly closer together (i.e., to adduct).

Upon surgical entrance to the visceral compartment of the neck, the cricothyroid muscle is the only laryngeal muscle that can be visualized without further dissection. Thus it is called an **external laryngeal muscle**. It also has a nerve supply different from all the other, so-called internal, laryngeal muscles (see further on).

Crico-arytenoid Joint and the Muscles Acting Across It

Each crico-arytenoid joint is elliptical and condyloid. The articular surface on the cricoid cartilage is convex; that on the arytenoid is concave. The long axis of each joint follows the superior rim of cricoid at its lamina-arch junction. That is, the long axis passes from posterior, superior, and medial to anterior, inferior, and lateral. The movements that are permitted at a crico-arytenoid joint consist of rotation around this long axis and sliding to and fro parallel to it.[42] Virtually no rotation around a vertical axis can occur since such would dislocate the joint (remember the atlanto-occipital joint!).

Rotation of an arytenoid cartilage around the long axis of the crico-arytenoid joint either carries the vocal process inward and downward so that the vocal cords are adducted and the rima glottidis closed, or outward and upward so that the vocal cords are abducted and the rima opened. Sliding of the arytenoid backward parallel to the long axis of the joint adducts and tightens the vocal cords.

Almost all the muscles acting across a crico-arytenoid joint cause the vocal cords to adduct. The adductors are:

1. **Lateral crico-arytenoideus**, which arises from the upper rim of the cricoid arch and passes backward and upward to insert onto the muscular process of the arytenoid. This muscle runs under cover of the cricothyroid, on the external surface of the lower end of the conus elasticus.

2. **Thyro-arytenoideus (proper)**, which arises from the inner surface of the thyroid cartilage near its angle and passes back to the arytenoid. This muscle runs along external surface of the upper end

---

[42] Landman, GHM: Laryngography and Cinelaryngography. Excerpta Medica, Amsterdam, 1970.

of conus elasticus and its vocal ligament. The most medial of the superiormost fibers of the thyro-arytenoideus are called **vocalis**.

3. **Arytenoideus** is an unpaired muscle on the posterior surfaces of the arytenoid cartilages that has two parts: a **transverse** bundle passing horizontally from the back surface of one arytenoid to the back surface of the other, and **oblique** bundles passing from the back surface of one arytenoid near its apex to the back surface of the other arytenoid near its base.

Not much purpose is served by detailing the individual actions of these adductor muscles, since they don't ever act alone. However, it should be noted that although they act together to adduct the vocal cords, they do not have equal effects on tension within the cord. The thyroarytenoideus (particularly its vocalis part) causes the cord to slacken; the arytenoideus causes it to tighten.

When both arytenoid cartilages rotate so that their vocal processes move upward and outward, the vocal cords are abducted (brought away from another) and the rima glottidis thus opened. The only muscles that produce this motion are the paired **posterior crico-arytenoidei**. On each side the fibers of the posterior crico-arytenoideus arise from the back of the cricoid lamina and pass upward and laterally to the muscular process of the ipsilateral arytenoid. Being the only abductors of the vocal cords, the posterior crico-arytenoids play a vital role in holding the glottis open during breathing.

Somatic Motor Innervation of the Larynx

All laryngeal muscles are derived from the more caudal of the two vagal somites. Consequently, all these muscles are innervated by branches of the vagus. The cricothyroid muscle is uniquely different from the internal laryngeal muscles. **Each cricothyroid gets its nerve supply from the external laryngeal nerve, which is a branch of the superior laryngeal branch of the vagus. The internal laryngeal muscles of one side are all supplied by the recurrent laryngeal branch of the ipsilateral vagus**. As each recurrent laryngeal nerve enters the larynx from below, it changes its name to inferior laryngeal nerve, thus giving us symmetry of nomenclature.

Vagal fibers innervating the striated muscles of the larynx are considered by most authors to be the homologue of the cranial accessory nerve found in lower vertebrates. No such thing as a cranial accessory nerve is dissectible in humans. It is for this reason that most anatomists do not feel it is necessary to use the word "spinal" as a preface when referring to the only part of the accessory nerve identifiable in humans.

Sensory and Parasympathetic Innervation of the Larynx

Two separate branches of the vagus are responsible for the sensory and preganglionic parasympathetic innervation of the larynx. The internal laryngeal nerve, which is the other branch of the superior laryngeal branch of the vagus, pierces the thyrohyoid membrane to serve these functions above the glottis. The inferior laryngeal nerve (mentioned above) is sensory and parasympathetic to the infraglottic larynx. The two nerves overlap in supply of the glottis itself.

CLINICAL CONSIDERATIONS FOR THE VAGUS NERVE

Now that all functions and relations of the vagus nerve have been described [43], we can consider symptoms associated with damage to it. Despite the enormous contribution of the vagus to autonomic innervation of internal organs of the chest and abdomen, 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 also 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. 10-19). When the tensor veli palatini (innervated by V_3) 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. 10-18). The cadaveric vocal cord is a bit closer to midline than is the normal position of the cord in quiet respiration (see Fig. 10-18), 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,

[43] Except that it shares in the sensory innervation of the external auditory meatus through its auricular branch, and that it also provides a small sensory branch to the dura of the posterior fossa.

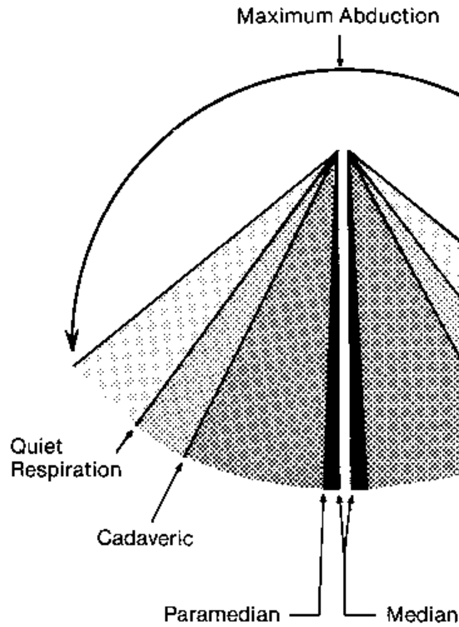

Figure 10-18. Schematic view of various standard vocal cord positions. See text for further discussion.

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.[44] 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 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 during 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. 10-18). The voice will start out hoarse, but recovery of normal voice is likely to be complete (with deficiencies in

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

singing and shouting only)[45]. 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.

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.

TYMPANIC CAVITY AND AUDITORY (EUSTACHIAN) TUBE (FIG. 10-19)

In Chapter 7 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 9 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.10-19*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.

---

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

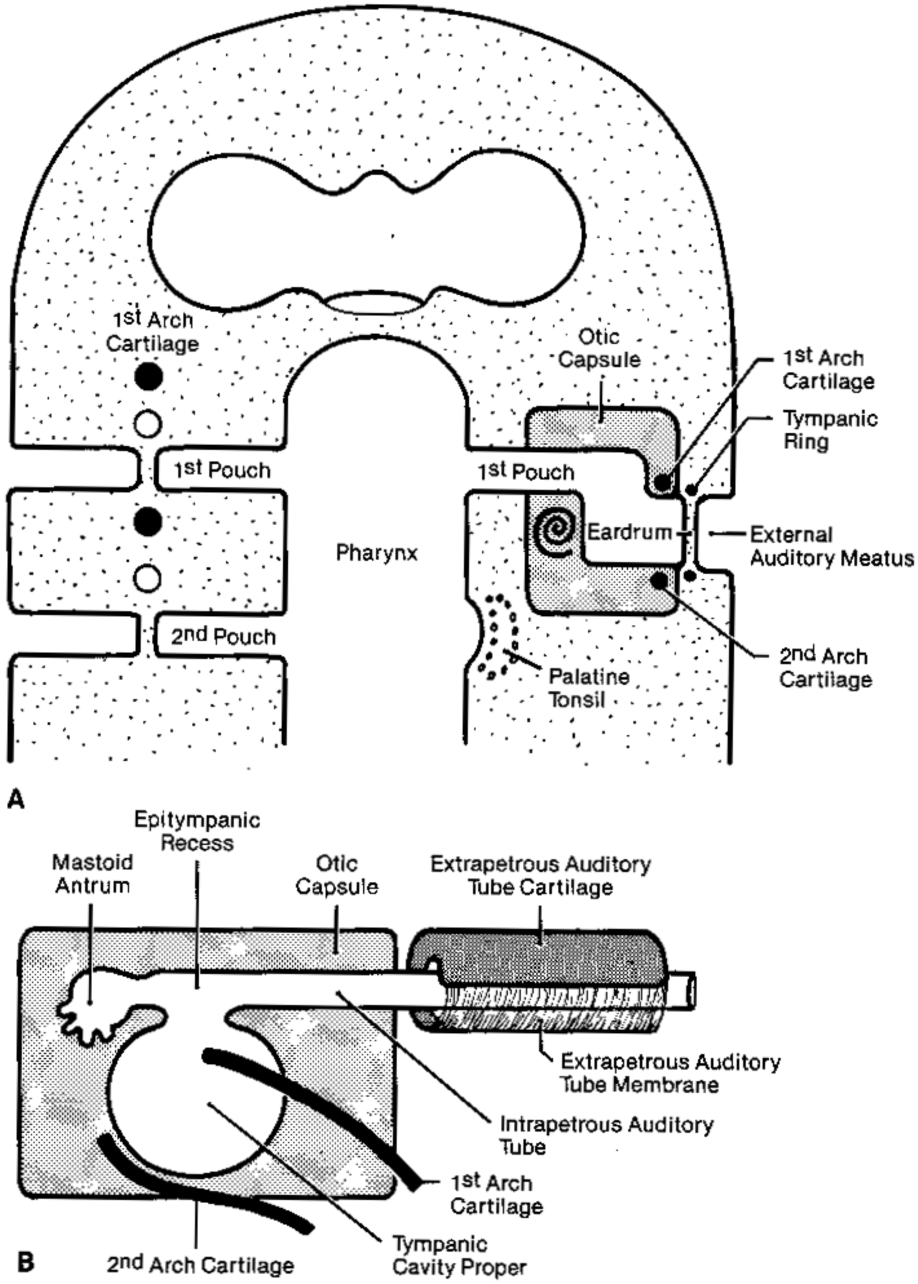

Figure 10-19. *A*, A schematic coronal section through the cranial end of an embryo at the level of the pharyngeal pouches and branchial arches. Two developmental stages are illustrated. On the *left* is an early stage corresponding to that shown in Figure 6–2. On the *right* is a later stage in which 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.

Obviously, the lateral half of the 1st pharyngeal pouch occupies a cavity in the ossifying petrous temporal (see Fig. 10-19*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. 10-19*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. 10-19*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.

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. 10-19*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. 10-19*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. 10-19*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.[46] The bones of the middle ear develop from the nearby dorsal ends of the 1st

---

[46] 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.

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 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 [47], 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.

---

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

Middle Ear Muscles

Tensor Tympani

The smallest muscle derived from the trigeminal somitomere, and therefore innervated by V_3, 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.

Stapedius

Enclosed within a space in the mastoid wall of the tympanic cavity is a tiny muscle called the stapedius. Being derived from the facial somitomere, it is innervated by the facial nerve. 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.

Branches of the Facial Nerve Related to the Middle Ear

As we know, the somatic motor root of the facial nerve and the nervus intermedius enter the internal acoustic meatus of the petrous temporal. Just before the end of the meatus, the two nerve bundles join and this completed facial nerve enters a narrow channel in the petrous temporal called the facial canal. The facial canal runs in the petrous temporal for a millimeter or two and then encounters the labyrinthine wall of the tympanic cavity, where the facial nerve bifurcates in two forks at the site of the geniculate ganglion (see Fig. 10-11). The larger posterior fork retains the name facial nerve, and its channel in the labyrinthine wall of the tympanic cavity retains the name facial canal. This part of the nerve carries all the somatic motor axons for innervation of those skeletal muscles supplied by the facial - mainly the muscles of facial expression, but also posterior belly of digastric, stylohyoid, and stapedius. It also carries the axons that travel in the chorda tympani and later join the lingual nerve.

The course of the facial nerve in the labyrinthine wall of the tympanic cavity 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. 10-11).

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 (p. 348). 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 (p. 340). It was mentioned that the chorda tympani carries preganglionic parasympathetic 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.[48]

CLINICAL CONSIDERATIONS FOR THE FACIAL NERVE

Now that all the functions and relations of the facial nerve have been described, we can consider symptoms resulting from its damage. These symptoms 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 the eye is impossible. In an attempt to compensate, the lacrimal gland increases its

---

[48] 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.

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 of the mouth droops on the side of the paralysis. This, and paralysis of the ipsilateral orbicularis oris, allows saliva to run out of the mouth during chewing. 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. 8-1). 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.

Branches of the Glossopharyngeal Nerve Related to the Middle Ear (see Fig. 10-7)

As discussed on page 348, the tympanic branch of the glossopharyngeal 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 that carry (among other things) glossopharyngeal sensory axons for the middle ear cavity, Eustachian tube, and mastoid air cells. Also emanating from the tympanic plexus is the **lesser petrosal nerve** composed of glossopharyngeal preganglionic parasympathetic axons that synapse on the otic ganglion for control of the parotid gland.

STATO-ACOUSTIC (VESTIBULOCOCHLEAR) NERVE - C.N. 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 C.N. 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. 10-20*A*). 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.

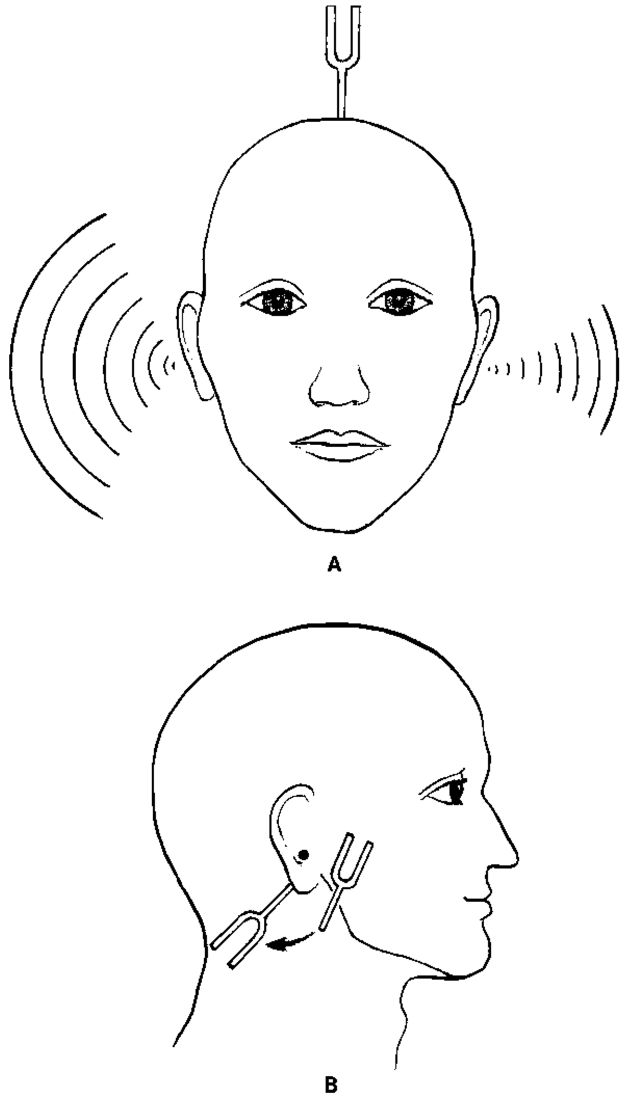

Figure 10-20. *A*, The Weber test, illustrating that sound seems louder in the right ear (1) if the left cochlea or the left 8th cranial nerve is damaged, or (2) if the right ossicular chain is operating inadequately. *B*, The Rinne test performed on the right ear. See text for further discussion.

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. 10-20*B*): 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.

LYMPHATICS OF THE HEAD

Lymph Nodes

In Chapter 9 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 9 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 9 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 jugulo-omohyoid node), but there is also a second route of drainage 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

Bony Landmarks

Opening of the External Auditory (Acoustic) Meatus

This landmark id both visible and palpable. It lies superficial to the root of the styloid process and to the even more deeply placed jugular foramen (which marks the beginning of the internal jugular vein). A bit more deeply is the opening of the hypoglossal canal, marking the site where the hypoglossal nerve exits the skull. Posterior to the external auditory meatus is the root of the mastoid process. The facial nerve exits the stylomastoid foramen between the roots of the styloid and mastoid processes.

Mastoid Process (see Fig. 8-4)

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. 8-4)

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.

Condyle of the Mandible (see Fig. 8-4)

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. The lateral tip of the condyle can be palpated if a finger is placed in front of the external auditory meatus and the patient is asked to open and close the jaw. The condyle is felt as it passes forward and downward during opening.

When the jaw is closed, a point between the mandibular condyle and external auditory meatus is the surface projection of the carotid foramen of the skull, where the internal carotid artery enters its canal in the petrous portion of the temporal bone. At the base of the skull the internal carotid artery is anterior to the internal jugular vein (deep to external auditory meatus). Medial to the interval between them exit the 9th, 10th, and 11th nerves.

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. 8-8). 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. 8-8)

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. 8-4)

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. 8-19). 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. 8-19), 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. 8-4). 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. 8-8) 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. 10-14). 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.