CHAPTER 7

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OVERVIEW

The head is the superior part of the body that is attached to the trunk by the neck. It is the control and communications center as well as the “loading dock” for the body. It houses the brain and, therefore, is the site of our consciousness: ideas, creativity, imagination, responses, decision making, and memory. It includes special sensory receivers (eyes, ears, mouth, and nose), broadcast devices for voice and expression, and portals for the intake of food, water, and oxygen and the exhaust of carbon dioxide.

The head consists of the brain and its protective coverings, the ears, and the face. The face includes openings and passageways, with lubricating glands and valves (seals) to close some of them, the masticatory (chewing) devices, and the orbits that house the visual apparatus. The face also provides our identity as individuals. Disease, malformation, or trauma of structures in the head form the bases of many specialties, including dentistry, maxillofacial surgery, neurology, neuro-radiology, neurosurgery, ophthalmology, oral surgery, otolaryngology, psychiatry.

CRANIUM

The cranium (skull) is the skeleton of the head (Fig. 7.1A). A series of bones form its two parts, the neurocranium and viscerocranium (Fig. 7.1B). The neurocranium is the bony case of the brain and its membranous coverings, the cranial meninges. It also contains proximal parts of the cranial nerves and the vasculature of the brain. The neurocranium in adults is formed by a series of eight bones: four singular bones centered on the midline (frontal, ethmoidal, sphenoidal, and occipital) and two sets of bones occurring as bilateral pairs (temporal and parietal) (Figs. 7.1A, 7.2A, and 7.3).

The neurocranium has a dome-like roof, the calvaria (skullcap), and a floor or cranial base (basocranium). The bones making the calvaria are primarily flat bones (frontal, parietal, and occipital; see Fig. 7.8A) formed by intramembranous ossification of head mesenchyme from the neural crest. The bones contributing to the cranial base are primarily irregular bones with substantial flat portions (sphenoidal and temporal) formed by endochondral ossification of cartilage (chondrocranium) or from more than one type of ossification. The ethmoid bone is an irregular bone that makes a relatively minor midline contribution to the neurocranium but is primarily part of the viscerocranium (see Fig. 7.7A). The so-called flat bones and flat portions of the bones forming the neurocranium are actually curved, with convex external and concave internal surfaces.

Most calvarial bones are united by fibrous (synchondroses). The spinal cord is continuous with the brain through the foramen magnum, a large opening in the cranial base (Fig. 7.1C).

The viscerocranium (facial skeleton) comprises the facial bones that mainly develop in the mesenchyme of the embryonic pharyngeal arches (Moore and Persaud, 2008). The viscerocranium forms the anterior part of the cranial and consists of the bones surrounding the mouth (upper and lower jaws), nose/nasal cavity, and most of the orbits (eye sockets or orbital cavities) (Figs. 7.2 and 7.3).

The viscerocranium consists of 15 irregular bones: 3 singular bones centered on or lying in the midline (mandible, ethmoid, and vomer) and 6 bones occurring as bilateral pairs (maxillae; inferior nasal conchae; and zygomatic, palatine, nasal, and lacrimal bones) (Figs. 7.1A and 7.4A). The maxillae and mandible house the teeth—that is, they provide the sockets and supporting bone for the maxillary and mandibular teeth. The maxillae contribute the greatest part of the upper facial skeleton, forming the skeleton of the upper jaw, which is fixed to the cranial base. The mandible forms the skeleton of the lower jaw, which is movable because it articulates with the cranial base at the temporomandibular joints (Figs. 7.1A and 7.2).

Several bones of the cranium (frontal, temporal, sphenoid, and ethmoid bones) are pneumatized bones, which contain air spaces (air cells or large sinuses), presumably to decrease their weight (Fig. 7.5). The total volume of the air spaces in these bones increases with age.

In the anatomical position, the cranium is oriented so that the inferior margin of the orbit and the superior margin of the external acoustic opening of the external acoustic meatus of both sides lie in the same horizontal plane (Fig. 7.1A). This standard cranio-metric reference is the orbitomeatal plane (Frankfort horizontal plane).

Facial Aspect of Cranium

Features of the anterior or facial (frontal) aspect of the cranium are the frontal and zygomatic bones, orbits, nasal region, maxillae, and mandible (Figs. 7.2 and 7.3).

The frontal bone, specifically its squamous (flat) part, forms the skeleton of the forehead, articulating inferiorly with the nasal and zygomatic bones. In some adults a metopic suture, a persistent frontal suture or remnant of it, is visible in the midline of the glabella, the smooth, slightly depressed area between the superciliary arches. The frontal suture divides the frontal bones of the fetal cranium (see the blue box “Development of Cranium,” p. 839).
FIGURE 7.1. Adult cranium I. A. In the anatomical position, the inferior margin of the orbit and the superior margin of the external acoustic meatus lie in the same horizontal orbitomeatal (Frankfort horizontal) plane. B. The neurocranium and viscerocranium are the two primary functional parts of the cranium. From the lateral aspect, it is apparent that the volume of the neurocranium, housing the brain, is approximately double that of the viscerocranium. C. The unpaired sphenoid and occipital bones make substantial contributions to the cranial base. The spinal cord is continuous with the brain through the foramen magnum, the large opening in the basal part of the occipital bone.
persistent part of frontal suture, a metopic suture

A. Facial (anterior) view of cranium

Glabella
Nasion
Internasal suture
Perpendicular plate of ethmoid
Vomer (part of nasal concha)
Anterior nasal spine
Intermaxillary suture
Mandibular symphysis
Supra-orbital margin of frontal bone
Temporal fossa
Nasion
Sphenoid bone
Internasal suture
Lacrimal bone
Perpendicular plate of ethmoid
Vomer (part of nasal concha)
Inferior nasal concha
Anterior nasal spine
Intermaxillary suture
Mandibular symphysis
Mental protuberance

B and C. The mandible is a major component of the viscerocranium, articulating with the remainder of the cranium via the temporomandibular joint. The broad ramus and coronoid process of the mandible provide attachment for powerful muscles capable of generating great force in relationship to biting and chewing (mastication).
The intersection of the frontal and the nasal bones is the nasion (L. nasus, nose), which in most people is related to a distinctly depressed area (bridge of nose) (Figs. 7.1A and 7.2A). The nasion is one of many craniometric points that are used radiographically in medicine (or on dry crania in physical anthropology) to make cranial measurements, compare and describe the topography of the cranium, and document abnormal variations (Fig. 7.6; Table 7.1). The frontal bone also articulates with the lacrimal, ethmoid, and sphenoids; a horizontal portion of bone (orbital part) forms both the roof of the orbit and part of the floor of the anterior part of the cranial cavity (Fig. 7.3).

The supra-orbital margin of the frontal bone, the angular boundary between the squamous and the orbital parts, has a supra-orbital foramen or notch in some crania for passage of the supra-orbital nerve and vessels. Just superior to the supra-orbital margin is a ridge, the superciliary arch, that extends laterally on each side from the glabella. The prominence of this ridge, deep to the eyebrows, is generally greater in males.

The zygomatic bones (cheek bones, malar bones), forming the prominences of the cheeks, lie on the inferolateral sides of the orbits and rest on the maxillae. The anterolateral rims, walls, floor, and much of the infra-orbital margins of the orbits are formed by these quadrilateral bones. A small zygomaticofacial foramen pierces the lateral aspect of each bone (Fig. 7.3 and 7.4A). The zygomatic bones articulate with the frontal, sphenoid, and temporal bones and the maxillae.

Inferior to the nasal bones is the pear-shaped piriform aperture, the anterior nasal opening in the cranium (Figs. 7.1A and 7.2A). The bony nasal septum can be observed through this aperture, dividing the nasal cavity into right and left parts. On the lateral wall of each nasal cavity are curved bony plates, the nasal conchae (Figs. 7.2A and 7.3).

The maxillae form the upper jaw; their alveolar processes include the tooth sockets (alveoli) and constitute the supporting bone for the maxillary teeth. The two maxillae are united at the intermaxillary suture in the median plane (Fig. 7.2A). The maxillae surround most of the piriform aperture and form the infra-orbital margins medially. They have a broad
FIGURE 7.4. Adult cranium IV. A. The individual bones of the cranium are color coded. Within the temporal fossa, the pterion is a craniometric point at the junction of the greater wing of the sphenoid, the squamous temporal bone, the frontal, and the parietal bones. B and C. Sutural bones occurring along the temporoparietal (B) and lambdoid (C) sutures are shown.
connection with the zygomatic bones laterally and an infra-orbital foramen inferior to each orbit for passage of the infra-orbital nerve and vessels (Fig. 7.3).

The mandible is a U-shaped bone with an alveolar process that supports the mandibular teeth. It consists of a horizontal part, the body, and a vertical part, the ramus (Fig. 7.2B & C). Inferior to the second premolar teeth are the mental foramina for the mental nerves and vessels (Figs. 7.1A, 7.2B, and 7.3). The mental protuberance, forming the prominence of the chin, is a triangular bony elevation inferior to the mandibular symphysis (L. symphysis menti), the osseous union where the halves of the infantile mandible fuse (Fig. 7.2A & B).

**Lateral Aspect of Cranium**

The lateral aspect of the cranium is formed by both the neurocranial and the viscerocranium (Figs. 7.1A & B and 7.4A). The main features of the neurocranial part are the temporal fossa, the external acoustic opening, and the mastoid process of the temporal bone. The main features of the viscerocranial part are the infratemporal fossa, zygomatic arch, and lateral aspects of the maxilla and mandible.

The temporal fossa is bounded superiorly and posteriorly by the superior and inferior temporal lines, anteriorly by the frontal and zygomatic bones, and inferiorly by the zygomatic arch (Figs. 7.1A and 7.4A). The superior border of
the inferior limit of the cerebral hemisphere of the brain. The **zygomatic arch** is formed by the union of the **temporal process of the zygomatic bone** and the **zygomatic process of the temporal bone**.

In the anterior part of the temporal fossa, 3–4 cm superior to the midpoint of the zygomatic arch, is a clinically important area of bone junctions: the **pterion** (G. *pterion*, wing) (Figs. 7.4A and 7.6; Table 7.1). It is usually indicated by an H-shaped formation of sutures that unite the frontal, parietal, sphenoid (greater wing), and temporal bones. Less commonly, the frontal and temporal bones articulate; sometimes all four bones meet at a point.

The **external acoustic opening** (pore) is the entrance to the **external acoustic meatus** (canal), which leads to the tympanic membrane (eardrum) (Fig. 7.4A). The **mastoid process** of the temporal bone is posterosuperior to the external acoustic opening. Anteromedial to the mastoid process is the **styloid process** of the temporal bone, a slender needle-like, pointed projection. The **infratemporal fossa** is an irregular space inferior and deep to the zygomatic arch and the mandible.

**Occipital Aspect of Cranium**

The posterior or **occipital aspect of the cranium** is composed of the **occiput** (L. back of head, the convex posterior protuberance of the squamous part of the occipital bone), parts of the parietal bones, and mastoid parts of the temporal bones (Fig. 7.7A). The **external occipital protuberance** is usually easily palpable in the median plane; however, occasionally (especially in females) it may be inconspicuous. A craniometric point defined by the tip of the external protuberance is the **inion** (G. nape of neck) (Figs. 7.1A, 7.4A, and 7.6; Table 7.1).
The external occipital crest descends from the protuberance toward the foramen magnum, the large opening in the basal part of the occipital bone (Figs. 7.1C and 7.7A).

The superior nuchal line, marking the superior limit of the neck, extends laterally from each side of the protuberance; the inferior nuchal line is less distinct. In the center of the occiput, lambda indicates the junction of the sagittal and the lambdoid sutures (Figs. 7.1A, 7.6, and 7.7A; Table 7.1). Lambda can sometimes be felt as a depression. One or more sutural bones (accessory bones) may be located at lambda or near the mastoid process (Fig. 7.4B & C).

Superior Aspect of Cranium

The superior (vertical) aspect of the cranium, usually somewhat oval in form, broadens posterolaterally at the parietal eminences (Fig. 7.8A). In some people, frontal eminences are also visible, giving the calvaria an almost square appearance.

The coronal suture separates the frontal and parietal bones (Fig. 7.8A & B), the sagittal suture separates the parietal bones, and the lambdoid suture separates the parietal and temporal bones from the occipital bone (Fig. 7.8A & C). Bregma is the cranio-ometric landmark formed by the intersection of the sagittal and coronal sutures (Figs. 7.6 and 7.8A; Table 7.1). Vertex, the most superior point of the calvaria, is near the midpoint of the sagittal suture (Figs. 7.6 and 7.7A).

The parietal foramen is a small, inconstant aperture located posteriorly in the parietal bone near the sagittal suture (Fig. 7.8A & C); paired parietal foramina may be present. Most irregular, highly variable foramina that occur in the neurocranium are emissary foramina that transmit emissary veins, veins connecting scalp veins to the venous sinuses of the dura mater (see “Scalp,” p. 843).

External Surface of Cranial Base

The cranial base (basicranium) is the inferior portion of the neurocranium (floor of the cranial cavity) and viscerocranium minus the mandible (Fig. 7.9). The external surface of the cranial base features the alveolar arch of the maxillae (the free border of the alveolar processes surrounding and supporting the maxillary teeth); the palatine processes of the maxillae; and the palatine, sphenoid, vomer, temporal, and occipital bones.

The hard palate (bony palate) is formed by the palatal processes of the maxillae anteriorly and the horizontal plates of the palatine bones posteriorly. The free posterior border of the hard palate projects posteriorly in the median plane as the posterior nasal spine. Posterior to the central incisor teeth is the incisive fossa, a depression in the midline of the bony palate into which the incisive canals open.

The right and left nasopalatine nerves pass from the nose through a variable number of incisive canals and foramina...
(they may be bilateral or merged into a single formation). Posterolaterally are the greater and lesser palatine foramina. Superior to the posterior edge of the palate are two large openings: the choanae (posterior nasal apertures), which are separated from each other by the vomer (L. plowshare), a flat unpaired bone of trapezoidal shape that forms a major part of the bony nasal septum (Fig. 7.9B).

Wedged between the frontal, temporal, and occipital bones is the sphenoid, an irregular unpaired bone that consists of a body and three pairs of processes: greater wings, lesser wings, and pterygoid processes (Fig. 7.10). The greater and lesser wings of the sphenoid spread laterally from the lateral aspects of the body of the bone. The greater wings have orbital, temporal, and infratemporal surfaces apparent in facial, lateral, and inferior views of the exterior of the cranial base (Figs. 7.3, 7.4A, and 7.9A) and cerebral surfaces seen in internal views of the cranial base (Fig. 7.11). The pterygoid processes, consisting of lateral and medial pterygoid plates, extend inferiorly on each side of the sphenoid from the junction of the body and greater wings (Figs. 7.9A and 7.10A & B).

The groove for the cartilaginous part of the pharyngo-otympanic (auditory) tube lies medial to the spine of the sphenoid, inferior to the junction of the greater wing of the sphenoid and the petrous (L. rock-like) part of the temporal bone (Fig. 7.9B). Depressions in the squamous (L. flat) part of the temporal bone, called the mandibular fossae, accommodate the mandibular condyles when the mouth is closed. The cranial base is formed posteriorly by the occipital bone, which articulates with the sphenoid anteriorly.

The four parts of the occipital bone are arranged around the foramen magnum, the most conspicuous feature of the cranial base. The major structures passing through this large foramen are the spinal cord (where it becomes continuous with the medulla oblongata of the brain), the meninges (coverings) of the brain and spinal cord, the vertebral arteries, the anterior and posterior spinal arteries, and the spinal accessory nerve (CN XI). On the lateral parts of the occipital bone are two large protuberances, the occipital condyles, by which the cranium articulates with the vertebral column.

The large opening between the occipital bone and the petrous part of the temporal bone is the jugular foramen, from which the internal jugular vein (IJV) and several cranial nerves (CN IX–CN XI) emerge from the cranium (Figs. 7.9 and 7.11; Table 7.2). The entrance to the carotid canal for the internal carotid artery is just anterior to the jugular foramen. The mastoid processes provide for muscle attachments. The stylomastoid foramen, transmitting the facial nerve (CN VII) and stylomastoid artery, lies posterior to the base of the styloid process.

**Internal Surface of Cranial Base**

The internal surface of the cranial base (L. basis cranii interna) has three large depressions that lie at different levels: the anterior, middle, and posterior cranial fossae, which form the bowl-shaped floor of the cranial cavity (Fig. 7.12).
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Palatine process
Posterior nasal spine
Choana (posterior nasal aperture)
Zygomatic process
Mandibular fossa
Styloid process
Basiocciput
Stylomastoid foramen
Mastoid process
Mastoid foramen
Foramen magnum
Inferior nuchal line
Superior nuchal line
External occipital protuberance
External occipital crest
Occipital bone
Squamous part
Jugular foramen
Occipital condyle
Spine of sphenoid
Medial and lateral plates of pterygoid process*
Greater and lesser palatine foramina
Infratemporal surface of greater wing of sphenoid
Groove for cartilaginous part of pharyngotympanic tube

(A) Inferior aspect

*Bones:
- Frontal
- Maxilla
- Occipital
- Palatine
- Parietal
- Sphenoid
- Temporal
- Vomer
- Zygomatic

*Collectively form pterygoid process of sphenoid
**The U-shaped (inverted here) ridge formed by the free border of the alveolar processes of the right and left maxillae makes up the alveolar arch

Inferior nuchal line
Groove for occipital artery
Horizontal plate
Alveolar process**
Incisive fossa
Palatine process

(B) Inferior aspect

FIGURE 7.9. Adult cranium VII. External cranial base. A. The contributing bones are color coded. B. The foramen magnum is located midway between and on a level with the mastoid processes. The hard palate forms both a part of the roof of the mouth and the floor of the nasal cavity. The large choanae on each side of the vomer make up the posterior entrance to the nasal cavities.
The anterior cranial fossa is at the highest level, and the posterior cranial fossa is at the lowest level.

**ANTERIOR CRANIAL FOSSA**

The inferior and anterior parts of the frontal lobes of the brain occupy the **anterior cranial fossa**, the shallowest of the three cranial fossae. The fossa is formed by the frontal bone anteriorly, the ethmoid bone in the middle, and the body and lesser wings of the sphenoid posteriorly. The greater part of the fossa is formed by the **orbital parts of the frontal bone**, which support the frontal lobes of the brain and form the roofs of the orbits. This surface shows sinuous impressions (brain markings) of the orbital gyri (ridges) of the frontal lobes (Fig. 7.11). The **frontal crest** is a median bony extension of the frontal bone (Fig. 7.12A). At its base is the **foramen cecum of the**
FIGURE 7.11. Cranial foramina.

TABLE 7.2. FORAMINA AND OTHER APERTURES OF CRANIAL FOSSAE AND CONTENTS

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<td>Condylar canal</td>
<td>Emissary vein that passes from sigmoid sinus to vertebral veins in neck</td>
</tr>
<tr>
<td>Mastoid foramen</td>
<td>Mastoid emissary vein from sigmoid sinus and meningeal branch of occipital artery</td>
</tr>
</tbody>
</table>

*The internal carotid artery and its accompanying sympathetic and venous plexuses actually pass horizontally across (rather than vertically through) the area of the foramen lacerum, an artifact of dry crania, which is closed by cartilage in life.*
**frontal bone**, which gives passage to vessels during fetal development but is insignificant postnatally. The **crista galli** (L. cock’s comb) is a thick, median ridge of bone posterior to the foramen cecum, which projects superiorly from the ethmoid. On each side of this ridge is the sieve-like **cribriform plate** of the ethmoid. Its numerous tiny foramina transmit the olfactory nerves (CN I) from the olfactory areas of the nasal cavities to the olfactory bulbs of the brain, which lie on this plate (Fig. 7.12A; Table 7.2).

**MIDDLE CRANIAL FOSSA**

The butterfly-shaped **middle cranial fossa** has a central part composed of the **sella turcica** on the body of the sphenoid and large, depressed **lateral parts** on each side (Fig. 7.12). The middle cranial fossa is posteroinferior to the anterior cranial fossa, separated from it by the sharp **sphenoidal crests** laterally and the **sphenoidal limbus** centrally. The **sphenoidal crests** are formed mostly by the sharp posterior borders of the **lesser wings** of the sphenoid bones, which overhang the lateral parts.
of the fossae anteriorly. The sphenoidal crests end medially in two sharp bony projections, the anterior clinoid processes.

A variably prominent ridge, the limbus of the sphenoid forms the anterior boundary of the transversely oriented prechiasmatic sulcus extending between the right and the left optic canals. The bones forming the lateral parts of the fossa are the greater wings of the sphenoid and squamous parts of the temporal bones laterally and the petrous parts of the temporal bones posteriorly. The lateral parts of the middle cranial fossa support the temporal lobes of the brain. The boundary between the middle and the posterior cranial fossae is the superior border of the petrous part of the temporal bone laterally and a flat plate of bone, the dorsum sellae of the sphenoid, medially.

The sella turcica (L. Turkish saddle) is the saddle-like bony formation on the upper surface of the body of the sphenoid, which is surrounded by the anterior and posterior clinoid processes (Figs. 7.10C and 7.12A). Clinoid means “bedpost,” and the four processes (two anterior and two posterior) surround the hypophysial fossa, the “bed” of the pituitary gland, like the posts of a four-poster bed. The sella turcica is composed of three parts:

1. The tuberculum sellae (horn of saddle): a variable slight to prominent median elevation forming the posterior boundary of the prechiasmatic sulcus and the anterior boundary of the hypophysial fossa.
2. The hypophysial fossa (pituitary fossa): a median depression (seat of saddle) in the body of the sphenoid that accommodates the pituitary gland (L. hypophysis).
3. The dorsum sellae (back of saddle): a square plate of bone projecting superiority from the body of the sphenoid. It forms the posterior boundary of the sella turcica, and its prominent superolateral angles make up the posterior clinoid processes.

On each side of the body of the sphenoid, a crescent of four foramina perforate the roots of the cerebral surfaces of the greater wings of the sphenoids (Figs. 7.10C, 7.11, and 7.12A); structures transmitted by the foramina are listed in Table 7.2:

1. Superior orbital fissure: Located between the greater and the lesser wings, it opens anteriorly into the orbit (Fig. 7.2A).
2. Foramen rotundum (round foramen): Located posterior to the medial end of the superior orbital fissure, it runs a horizontal course to an opening on the anterior aspect of the root of the greater wing of the sphenoid (Fig. 7.10A) into a bony formation between the sphenoid, the maxilla, and the palatine bones, the pterygopalatine fossa.
3. Foramen ovale (oval foramen): A large foramen postero-lateral to the foramen rotundum, it opens inferiorly into the infratemporal fossa (Fig. 7.9B).
4. Foramen spinosum (spinous foramen): Located postero-lateral to the foramen ovale, it also opens into the infratemporal fossa in relationship to the spine of the sphenoid.

The foramen lacerum (lacerated or torn foramen) is not part of the crescent of foramina. This ragged foramen lies posterolateral to the hypophysial fossa and is an artifact of a dried cranium. In life, it is closed by a cartilage plate. Only some meningeal arterial branches and small veins are transmitted vertically through the cartilage, completely traversing this foramen. The internal carotid artery and its accompanying sympathetic and venous plexuses pass across the superior aspect of the cartilage (i.e., pass over the foramen), and some nerves traverse it horizontally, passing to a foramen in its anterior boundary.

Extending posteriorly and laterally from the foramen lacerum is a narrow groove for the greater petrosal nerve on the anterosuperior surface of the petrous part of the temporal bone. There is also a small groove for the lesser petrosal nerve.

**POSTERIOR CRANIAL FOSSA**

The posterior cranial fossa, the largest and deepest of the three cranial fossae, lodges the cerebellum, pons, and medulla oblongata (Fig. 7.12). The posterior cranial fossa is formed mostly by the occipital bone, but the dorsum sellae of the sphenoid marks its anterior boundary centrally and the petrous and mastoid parts of the temporal bones contribute its anterolateral “walls.”

From the dorsum sellae there is a marked incline, the clivus, in the center of the anterior part of the fossa leading to the foramen magnum. Posterior to this large opening, the posterior cranial fossa is partly divided by the internal occipital crest into bilateral large concave impressions, the cerebellar fossae. The internal occipital crest ends in the internal occipital protuberance formed in relationship to the confluence of the sinuses, a merging of dural venous sinuses (discussed later on page 867).

Broad grooves show the horizontal course of the transverse sinus and the S-shaped sigmoid sinus. At the base of the petrous ridge of the temporal bone is the jugular foramen, which transmits several cranial nerves in addition to the sigmoid sinus that exits the cranium as the internal jugular vein (IJV) (Fig. 7.11; Table 7.2). Anterosuperior to the jugular foramen is the internal acoustic meatus for the facial and vestibulocochlear nerves (CN VIII) and the labyrinthine artery. The hypoglossal canal for the hypoglossal nerve (CN XII) is superior to the anterolateral margin of the foramen magnum.

**Walls of Cranial Cavity**

The walls of the cranial cavity vary in thickness in different regions. They are usually thinner in females than in males and are thinner in children and elderly people. The bones tend to be thinnest in areas that are well covered with muscles, such as the squamous part of the temporal bone (Fig. 7.11). Thin areas of bone can be seen radiographically (Fig. 7.5) or by holding a dried cranium up to a bright light.

Most bones of the calvaria consist of internal and external tables of compact bone, separated by diploë (Figs. 7.5
and 7.11). The diploë is cancellous bone containing red bone marrow during life, through which run canals formed by diploic veins. The diploë in a dried calvaria is not red because the protein was removed during preparation of the cranium. The internal table of bone is thinner than the external table, and in some areas there is only a thin plate of compact bone with no diploë.

The bony substance of the cranium is unequally distributed. Relatively thin (but mostly curved) flat bones provide the necessary strength to maintain cavities and protect their contents. However, in addition to housing the brain, the bones of the neurocranium (and processes from them) provide proximal attachment for the strong muscles of mastication that attach distally to the mandible; consequently, high traction forces occur across the nasal cavity and orbits that are sandwiched between. Thus thickened portions of the cranial bones form stronger pillars or buttresses that transmit forces, bypassing the orbits and nasal cavity (Fig. 7.13). The main buttresses are the **frontonasal buttress**, extending from the region of the canine teeth between the nasal and the orbital cavities to the central frontal bone, and the **zygomatic arch–lateral orbital margin buttress** from the region of the molars to the lateral frontal and temporal bones. Similarly, **occipital buttresses** transmit forces received lateral to the foramen magnum from the vertebral column. Perhaps to compensate for the denser bone required for these buttresses, some areas of the cranium not as mechanically stressed become pneumatized (air-filled).

**Regions of Head**

To allow clear communications regarding the location of structures, injuries, or pathologies, the head is divided into regions (Fig. 7.14). The large number of regions into which the relatively small area of the face is divided (eight) is a reflection of both its functional complexity and personal importance, as are annual expenditures for elective aesthetic surgery. With the exception of the **auricular region**, which includes the external ear, the names of the regions of the neurocranial portion of the head correspond to the underlying bones or bony features: **frontal, parietal, occipital, temporal, and mastoid regions**.

The viscerocranial portion of the head includes the **facial region**, which is divided into five bilateral and three median regions related to superficial features (oral and buccal regions), to deeper soft tissue formations (parotid region), and to skeletal features (orbital, infra-orbital, nasal, zygomatic, and mental regions). The remainder of this chapter discusses several of these regions in detail as well as some deep regions not represented on the surface (for example, the infratemporal region and the pterygopalatine fossa). The surface anatomy of these regions will be discussed with the description of each region.

<table>
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<tr>
<th>Regions of the Head</th>
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<tr>
<td>1  Frontal region</td>
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<td>2  Parietal region</td>
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<td>3  Occipital region</td>
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<td>4  Temporal region</td>
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<td>5  Auricular region</td>
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<td>6  Mastoid region</td>
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<td>Facial region:</td>
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<td>7  Orbital region</td>
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<td>8  Infraorbital region</td>
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<td>9  Buccal region</td>
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<td>10 Parotid region</td>
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<td>11 Zygomatic region</td>
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<td>12 Nasal region</td>
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<tr>
<td>13 Oral region</td>
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<td>14 Mental region</td>
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**FIGURE 7.13.** Buttresses of cranium. The buttresses are thicker portions of cranial bone that transmit forces around weaker regions of the cranium.

**FIGURE 7.14.** Regions of head.
CRANIUM

Head Injuries

Head injuries are a major cause of death and disability. The complications of head injuries include hemorrhage, infection, and injury to the brain and cranial nerves. Disturbance in the level of consciousness is the most common symptom of head injury. Almost 10% of all deaths in the United States are caused by head injuries, and approximately half of traumatic deaths involve the brain (Rowland, 2005). Head injuries occur mostly in young persons between the ages of 15 and 24 years. The major cause of brain injury varies but motor vehicle and motorcycle accidents are prominent.

Headaches and Facial Pain

Few complaints are more common than headaches and facial pain. Although usually benign and frequently associated with tension, fatigue, or mild fever, headaches may indicate a serious intracranial problem such as a brain tumor, subarachnoid hemorrhage, or meningitis. Neuralgias (G. algos, pain) are characterized by severe throbbing or stabbing pain in the course of a nerve caused by a demyelinating lesion. They are a common cause of facial pain. Terms such as facial neuralgia describe diffuse painful sensations. Localized aches have specific names, such as earache (otalgia) and toothache (odontalgia). A sound knowledge of the anatomy of the head helps in understanding the causes of headaches and facial pain.

Injury to Superciliary Arches

The superciliary arches are relatively sharp bony ridges; consequently, a blow to them (e.g., during boxing) may lacerate the skin and cause bleeding. Bruising of the skin surrounding the orbit causes tissue fluid and blood to accumulate in the surrounding connective tissue, which gravitates into the superior (upper) eyelid and around the eye (“black eye”).

Malar Flush

The zygomatic bone was once called the malar bone; consequently, you will hear the clinical term malar flush. This redness of the skin covering the zygomatic prominence (malar eminence) is associated with a rise in temperature in various fevers occurring with certain diseases, such as tuberculosis and systemic lupus erythematosus disease.

Fractures of the Maxillae and Associated Bones

Dr. Léon-Clement Le Fort (Paris surgeon and gynecologist, 1829–1893) classified three common variants of fractures of the maxillae (Fig. B7.1):

- **Le Fort I fracture**: wide variety of horizontal fractures of the maxillae, passing superior to the maxillary alveolar process (i.e., to the roots of the teeth), crossing the bony nasal septum and possibly the pterygoid plates of the sphenoid.
- **Le Fort II fracture**: passes from the posterolateral parts of the maxillary sinuses (cavities in the maxillae) superiorly through the infra-orbital foramina, lacrimals, or ethmoids to the bridge of the nose. As a result, the entire central part of the face, including the hard palate and alveolar processes, is separated from the rest of the cranium.
- **Le Fort III fracture**: horizontal fracture that passes through the superior orbital fissures and the ethmoid and nasal bones and extends laterally through the greater wings of the sphenoid and the frontozygomatic sutures. Concurrent fracturing of the zygomatic arches causes the maxillae and zygomatic bones to separate from the rest of the cranium.

Fractures of Mandible

A fracture of the mandible usually involves two fractures, which frequently occur on opposite sides of the mandible; thus if one fracture is observed, a search should be made for another. For example, a hard blow to the jaw often fractures the neck of the mandible and its body in the region of the opposite canine tooth. Fractures of the coronoid process are uncommon and usually single (Fig. B7.2). Fractures of the neck of the mandible are often transverse and may be associated with dislocation.
Fractures of Calvaria

The convexity of the calvaria distributes and thereby usually minimizes the effects of a blow to the head. However, hard blows in thin areas of the calvaria are likely to produce depressed fractures, in which a bone fragment is depressed inward, compressing and/or injuring the brain (Fig. B7.4). Linear calvarial fractures, the most frequent type, usually occur at the point of impact, but fracture lines often radiate away from it in two or more directions. In comminuted fractures, the bone is broken into several pieces. If the area of the calvaria is thick at the site of impact, the bone may bend inward without fracturing; however, a fracture may occur some distance from the site of direct trauma where the calvaria is thinner. In a contrecoup (counterblow) fracture, no fracture occurs at the point of impact, but one occurs on the opposite side of the cranium.

Resorption of Alveolar Bone

Extraction of teeth causes the alveolar bone to resorb in the affected region(s) (Fig. B7.3). Following complete loss or extraction of maxillary teeth, the sockets begin to fill in with bone and the alveolar process begins to resorb. Similarly, extraction of mandibular teeth causes the bone to resorb. Gradually, the mental foramen lies near the superior border of the body of the mandible. In some cases, the mental foramina disappear, exposing the mental nerves to injury. Pressure from a dental prosthesis (e.g., a denture resting on an exposed mental nerve) may produce pain during eating. Loss of all the teeth results in a decrease in the vertical facial dimension and mandibular prognathism (overclosure). Deep creases in the facial skin also appear that pass posteriorly from the corners of the mouth.

Surgical Access to Cranial Cavity: Bone Flaps

Surgeons access the cranial cavity and brain by performing a craniotomy, in which a section of the neurocranium, called a bone flap, is elevated or removed.
Because the adult pericranium has poor osteogenic (bone-forming) properties, little regeneration occurs after bone loss (e.g., when pieces of bone are removed during repair of a comminuted cranial fracture). Surgically produced bone flaps are put back into place and wired to other parts of the calvaria or held in place temporarily with metal plates. Reintegration is most successful when the bone is reflected with its overlying muscle and skin, so that it retains its own blood supply during the procedure and after repositioning. If the bone flap is not replaced (i.e., a permanent plastic or metal plate replaces the flap), the procedure is called a craniectomy.

Development of Cranium

The bones of the calvaria and some parts of the cranial base develop by intramembranous ossification; most parts of the cranial base develop by endochondral ossification. At birth, the bones of the calvaria are smooth and unilaminar; no diploë is present. The frontal and parietal eminences are especially prominent (Fig. B7.6). The cranium of a newborn infant is disproportionately large compared to other parts of the skeleton; however, the facial aspect is small compared to the calvaria, which forms approximately one eighth of the cranium. In the adult, the facial skeleton forms one third of the cranium. The large size of the calvaria in infants results from precocious growth and development of the brain and eyes.

The rudimentary development of the face makes the orbits appear relatively large (Fig. B7.6A). The smallness of the face results from the rudimentary development of the
maxillae, mandible, and paranasal sinuses (air-filled bone cavities), the absence of erupted teeth, and the small size of the nasal cavities.

The halves of the frontal bone in the newborn are separated by the frontal suture, the frontal and parietal bones are separated by the coronal suture, and the maxillae and mandibles are separated by the internasal suture and mandibular symphysis (secondary cartilaginous joint), respectively. There are no mastoid and styloid processes (Fig. B7.6B). Because there are no mastoid processes at birth, the facial nerves are close to the surface when they emerge from the stylomastoid foramina. As a result, the facial nerves may be injured by forces during a difficult delivery or later by an incision posterior to the auricle of the external ear (as for the surgical treatment of mastoiditis or middle ear problems). The mastoid processes form gradually during the 1st year as the sternocleidomastoid muscles complete their development and pull on the petromastoid parts of the temporal bones.

The bones of the calvaria of a newborn infant are separated by membranous intervals; the largest occur between the angles (corners) of the flat bones (Fig. B7.6A & B). They include the anterior and posterior fontanelles and the paired sphenoidal and mastoid fontanelles. Palpation of the fontanelles during infancy, especially the anterior and posterior ones, enables physicians to determine the:

- Progress of growth of the frontal and parietal bones.
- Degree of hydration of an infant (a depressed fontanelle indicates dehydration).
- Level of intracranial pressure (a bulging fontanelle indicates increased pressure on the brain).

The anterior fontanelle, the largest one, is diamond or star shaped; it is bounded by the halves of the frontal bone anteriorly and the parietal bones posteriorly. Thus it is located at the junction of the sagittal, coronal, and frontal sutures, the future site of bregma (Fig. 7.5; Table 7.1). By 18 months of age, the surrounding bones have fused and the anterior fontanelle is no longer clinically palpable.

At birth the frontal bone consists of two halves. Union of the halves begins in the 2nd year. In most cases, the frontal suture is obliterated by the 8th year. However, in approximately 8% of people, a remnant of it, the metopic suture, persists (Figs. 7.2A and 7.3). Much less frequently, the entire frontal suture remains (Fig. B7.6C). A persistent suture must not be interpreted as a fracture in a radiograph or other medical image.

The posterior fontanelle is triangular and bounded by the parietal bones anteriorly and the occipital bone posteriorly. It is located at the junction of the lambdoid and sagittal sutures, the future site of lambda (Fig. 7.7A and 7.8C). The posterior fontanelle begins to close during the first few months after birth; and by the end of the 1st year, it is small and no longer clinically palpable. The sphenoidal and mastoid fontanelles, overlain by the temporal (L. temporalis) muscle, fuse during infancy and are less important clinically than the midline fontanelles. The halves of the mandible fuse early in the 2nd year. The two maxillae and nasal bones usually do not fuse.

The softness of the cranial bones in infants and their loose connections at the sutures and fontanelles enable the shape of the calvaria to change molding during birth (Fig. B7.7). During passage of the fetus through the birth canal, the halves of the frontal bone become flat, the occipital bone is drawn out, and one parietal bone slightly overrides the other. Within a few days after birth, the shape of the calvaria returns to normal. The resilience of the cranial bones of infants allows them to resist forces that would produce fractures in adults. The fibrous sutures of the calvaria also permit the cranium to enlarge during infancy and childhood. The increase in the size of the calvaria is greatest during the first 2 years, the period of most rapid brain development. The calvaria normally increases in capacity for 15–16 years. After this, the calvaria usually increases slightly in size for 3–4 years as a result of bone thickening.

**FIGURE B7.7. Molding of calvaria.**

### Age Changes in Face

The mandible is the most dynamic of our bones; its size and shape and the number of teeth it normally bears undergo considerable change with age. In the newborn, the mandible consists of two halves united in the median plane by a cartilaginous joint, the mandibular symphysis. Union between the halves of the mandible is effected by means of fibrocartilage; this union begins during the 1st year and the halves are fused by the end of the 2nd year. The body of the mandible in newborn infants is a mere shell lacking an alveolar process, each half enclosing five deciduous teeth. These teeth usually begin to erupt in infants at approximately 6 months of age. The body of the mandible elongates, particularly posterior to the mental foramen, to accommodate this
development and later eight permanent teeth, which begin to erupt during the 6th year of life (Fig. B7.8). Eruption of the permanent teeth is not complete until early adulthood.

Rapid growth of the face during infancy and early childhood coincides with the eruption of deciduous teeth. Vertical growth of the upper face results mainly from dentoalveolar development. These changes are more marked after the permanent teeth erupt. Concurrent enlargement of the frontal and facial regions is associated with the increase in the size of the paranasal sinuses, the air-filled extensions of the nasal cavities in certain cranial bones (Fig. B7.9). Most paranasal sinuses are rudimentary or absent at birth. Growth of the paranasal sinuses is important in altering the shape of the face and in adding resonance to the voice.

**Obliteration of Cranial Sutures**

The obliteration of sutures between the bones of the calvaria usually begins between the ages of 30 and 40 years on the internal surface and approximately 10 years later on the external surface (Fig. B7.10; cf. Fig. 7.8B). Obliteration of sutures usually begins at bregma and continues sequentially in the sagittal, coronal, and lambdoid sutures.

**Age Changes in Cranium**

As people age, the cranial bones normally become progressively thinner and lighter, and the diploë gradually become filled with a gray gelatinous material. In these individuals, the bone marrow has lost its blood cells and fat, giving it a gelatinous appearance.

**Craniosynostosis and Cranial Malformations**

Premature closure of the cranial sutures (primary craniosynostosis) results in several cranial malformations (Fig. B7.11). The incidence of primary craniosynostosis is approximately 1 per 2000 births (Kliegman et al., 2007). The cause of craniosynostosis is unknown, but genetic factors appear to be important. The prevailing hypothesis is that abnormal development of the cranial base creates exaggerated forces on the dura mater (outer covering membrane of the brain) that disrupt normal cranial sutureal development. These malformations are more common in males than
The cranium is the skeleton of the head, an amalgamation of functional components united to form a single skeletal formation. ♦ The basic functional components include the neurocranium, the container of the brain and internal ears, and viscerocranium, providing paired orbits, nasal cavities and teeth-bearing plates (alveolar processes) of the oral cavity.

♦ Although some mobility between cranial bones is advantageous during birth, they become fixed together by essentially immovable joints (sutures), allowing independent movement of only the mandible.

♦ Abundant fissures and foramina facilitate communication and passage of neurovascular structures between functional components.

♦ The bony substance of the cranium is unequally distributed. Relatively thin (but mostly curved) flat bones provide the necessary strength to maintain cavities and protect contents.

♦ However, the bones and processes of the neurocranium also provide proximal attachment for the strong muscles of mastication (chewing) that attach distally to the mandible.

♦ The high traction forces generated across the nasal cavity and orbits, sandwiched between the muscle attachments, are resisted by thickened portions of the bones forming stronger pillars or buttresses.

♦ The mostly superficial surface of the cranium provides both visible and palpable landmarks.

Internal features of the cranial base reflect the major formations of the brain that rest on it.

♦ Bony ridges radiating from the centrally located sella turcica or hypophysial fossa divide it into three cranial fossae.

♦ The frontal lobes of the brain lie in the anterior cranial fossa.

♦ The temporal lobes lie in the middle cranial fossa.

♦ The hindbrain, consisting of the pons, cerebellum, and medulla, occupies the posterior cranial fossa, with the medulla continuing through the foramen magnum where it is continuous with the spinal cord.

The face is the anterior aspect of the head from the forehead to the chin and from one ear to the other. The face provides our identity as an individual human. Thus defects (malformations, scarring, or other alterations resulting from pathology or trauma) have marked consequences beyond their physical effects.

The basic shape of the face is determined by the underlying bones. The individuality of the face results primarily from anatomical variation: variations in the shape and relative prominence of the features of the underlying cranium; in the
Axes about which movements of the eyeball occur. Colors in (A) are NOT coordinated with B-D or Table 7.8.

(A) Axes about which movements of the eyeball occur. Colors in (A) are NOT coordinated with B-D or Table 7.8.

(B) Lateral view

Levator palpebrae superioris (Origin: Lesser wing of spheroid bone, superior and anterior to optic canal; Insertion: Superior tarsus and skin of superior eyelid; Innervation: Oculomotor nerve (CN III); Main Action: Elevates superior eyelid)

Superior oblique (SO) (Origin: Body of spheroid bone; Insertion: Its tendon passes through a fibrous ring or trochlea, changes its direction, and inserts into sclera deep to superior rectus muscle; Innervation: Trochlear nerve (CN IV); Main Action: Abducts, depressing, and medially rotates eyeball)

Inferior oblique (IO) (Origin: Anterior part of floor of orbit; Insertion: Sclera deep to lateral rectus muscle; Innervation: Oculomotor nerve (CN III); Main Action: Abducts, elevates, and laterally rotates eyeball)

Superior rectus (SR) (Origin: Common tendinous ring; Insertion: Sclera just posterior to corneoscleral junction; Innervation: Oculomotor nerve (CN III); Main Action: Elevates, adducts, and rotates eyeball medially)

Inferior rectus (IR) (Origin: Common tendinous ring; Insertion: Sclera just posterior to corneoscleral junction; Innervation: Oculomotor nerve (CN III); Main Action: Depresses, adducts, and rotates eyeball laterally)

Medial rectus (MR) (Origin: Adducts eyeball)

Lateral rectus (LR) (Origin: Abducts eyeball)

*The actions described are for muscles acting alone, starting from the primary position (gaze directed anteriorly). In fact, muscles rarely act independently and almost always work together in synergistic and antagonistic groups. Clinical testing requires maneuvers to isolate muscle actions. Only the actions of the medial and lateral rectus are tested, starting from the primary position (Fig. 7.56E).
FIGURE 7.54. (Continued) C. Position of muscles in right and left orbits. Arrows at left, movements of the eyeball around the AP axis; arrows at right, movements of the eyeball around the vertical axis. To understand the actions produced by muscles starting from the primary position, it is necessary to observe the placement and line of pull of the muscle relative to the axes about which the movements occur. D. Unilateral and bilateral demonstration of extraocular muscle actions, starting from the primary position. For movements in any of the six cardinal directions (large arrows) the indicated muscle is the prime mover. Movements in directions between large arrows requires synergistic actions by the adjacent muscles. For example, direct elevation requires the synergistic actions of IO and SR; direct depression requires synergistic action of SO and IR. Small arrows, muscles producing rotational movements around the AP axis. Coordinated action of the contralateral yoke muscles is required to direct the gaze. For example, in directing the gaze to the right, the right LR and left MR are yoke muscles.
**FIGURE 7.55.** Relationship at apex of orbit. A. The common tendinous ring is formed by the origin of the four recti muscles and encircles the optic sheath of CN II, the superior and inferior divisions of CN III, the nasociliary nerve (CN V1), and CN VI. The nerves supplying the extraocular muscles enter the orbit through the superior orbital fissure: oculomotor (CN III), trochlear (CN IV), and abducent (CN VI). B. Structures (minus membranous fascia and fat) after enucleation (excision) of the eyeball.

**FIGURE 7.56.** Clinical testing of extraocular muscles. A and B. When the eye is abducted by MR, only the rectus muscles can produce elevation and depression. C and D. When the eye is adducted by LR, only the oblique muscles can produce elevation and depression. E. Following movements of the examiner’s finger, the pupil is moved in an extended H-pattern to isolate and test individual extraocular muscles and the integrity of their nerves.
superior rectos muscles are fused; thus, when the gaze is directed superiorly, the superior eyelid is further elevated out of the line of vision.

Triangular expansions from the sheaths of the medial and lateral rectos muscles, called the medial and lateral check ligaments, are attached to the lacrimal and zygomatic bones, respectively. These ligaments limit abduction and adduction. A blending of the check ligaments with the fascia of the inferior rectos and inferior oblique muscles forms a hammock-like sling, the suspensory ligament of the eyeball. A similar check ligament from the fascial sheath of the inferior rectos retracts the inferior eyelid when the gaze is directed downward. Collectively, the check ligaments act with the oblique muscles and the retrobulbar fat to resist the posterior pull on the eyeball produced by the rectus muscles. In diseases or starvation that reduce the retrobulbar fat, the eyeball is retracted into the orbit (inophthalmos).

**Nerves of Orbit**

The large optic nerves convey purely sensory nerves that transmit impulses generated by optical stimuli (Figs. 7.45A and 7.57). They are cranial nerves (CN II) by convention, but develop as paired anterior extensions of the forebrain and are actually central nervous system (CNS) fiber tracts formed of second-order neurons. The optic nerves begin at the lamina cribrosa of the sclera, where the unmyelinated nerve fibers pierce the sclera and become myelinated, posterior to the optic disc. They exit the orbits via the optic canals. Throughout their course in the orbit, the optic nerves are surrounded by extensions of the cranial meninges and subarachnoid space, the latter occupied by a thin layer of CSF (Fig. 7.45A, inset). The intra-orbital extensions of the cranial dura and arachnoid mater constitute the optic sheath, which becomes continuous anteriorly with the fascial sheath of the eyeball and the sclera. A layer of pia mater covers the surface of the optic nerve within the sheath.

In addition to the optic nerve (CN II), the nerves of the orbit include those that enter through the superior orbital fissure and supply the ocular muscles: oculomotor (CN III), trochlear (CN IV), and abducent (CN VI) nerves (Figs. 7.55B and 7.57). A memory device for the innervation of the extraocular muscles moving the eyeball is similar to a chemical formula: LR₆SO₄AO₃ (lateral rectus, CN VI; superior oblique, CN IV; all others, CN III). The trochlear and abducent nerves pass directly to the single muscle supplied by each nerve. The oculomotor nerve divides into a superior and an inferior division. The superior division supplies the superior rectus and levator palpebrae superioris. The inferior division supplies the medial and inferior rectus and inferior oblique and carries presynaptic parasympathetic fibers to the ciliary ganglion (Fig. 7.58). The movements are stimulated by the oculomotor, trochlear, and abducent nerves, starting from the primary position in the right and left orbits, and produce binocular vision, demonstrated in Fig. 7.59.

**FIGURE 7.57.** Nerves of orbit. Three cranial nerves (CN III, IV, and VI) supply the seven voluntary extraocular muscles. CN IV supplies the superior oblique, CN VI supplies the lateral rectus, and CN III supplies the remaining five muscles. The CN III also brings presynaptic parasympathetic fibers to the ciliary ganglion. The trigeminal nerve (CN V) supplies sensory fibers to the orbit, orbital region, and eyeball.