THE SURGICAL TREATMENT OF FACIAL INJURIES

by

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PREFACE

As in the first edition, our purpose in this book is to stress our viewpoint with respect to the surgical treatment of facial injuries and to cover this one subject thoroughly. We draw from vast experience in World Wars I and II and in civilian practice. As in the previous edition, we have limited the techniques described to those with which we have had actual personal experience. We do not wish to minimize the importance of other techniques not included in this volume. We owe much of our knowledge to those who have preceded us and we gratefully acknowledge our debt to them and to our contemporaries in this field.

This second edition contains six new chapters: Introduction to Fractures of the Facial Bones; Fractures of the Fronto-Ethmoidal Region and Traumatic Cerebrospinal Rhinorrhea; Facial Injuries in Children; Roentgen Examination of the Facial Bones; The Transplantation of Tissues; and Scars of the Face. Most of the other chapters have been considerably expanded.

Over 400 new illustrations have been added. Most of the new drawings are by Miss Daisy Stilwell, whose interest in plastic surgery and broad experience in the field make her high quality drawings invaluable for teaching. Miss Patricia Blake, Mr. Leonard D. Dank and Mr. Eric J. Derum also contributed some excellent drawings.

To supply a surgical background for the student and practitioner, the first three chapters deal with a brief survey of the evolution of the human face and some aspects of anatomy, the healing of wounds, and general principles of operating technique. These subjects are followed by chapters dealing with fractures of the bones of the face and jaws. Later chapters of the text are devoted to general principles of reconstructive surgery. Deformities of the upper portion of the face, eyelids, orbital and zygomatic regions, nose and soft tissues and bones of the lower portion of the face are discussed. Included also are chapters dealing with reconstructive techniques of the oral cavity and pharynx, temporomandibular ankylosis, facial paralysis, deformities of the external ear and burns of the face. No text dealing with reconstructive surgery of the maxillofacial area is complete without due consideration of the roles of the jaws and the dentition. We have attempted to evaluate the prosthetic and surgical aspects of facial reconstruction and to define their relative importance in a chapter on maxillofacial prosthetics.

There is no person more severely handicapped than the patient with severe facial disfigurement. Since the face is the center of attention wherever social interaction occurs, the region where the sense of self is generally located, the dominant part of the body image and the most revealing area of personality traits, those who have gross facial deformity undergo countless indignities and social deprivations.

In this new text an attempt has been made to integrate the basic biologic principles governing tissue transplantation with the principles of surgical treatment; a cursory review of tissue transplantation is included in the chapter so designated.

The authors have had an unusually close collaboration over the past twenty years. The junior author feels very privileged to have benefited from the affectionate intimacy of his teacher, one of the pioneers of plastic surgery in our time, whose sum of experience totals a half century.

ACKNOWLEDGMENTS

We have dedicated this book to the late Dr. Harry H. Shapiro, our friend, who edited the text and made many useful suggestions concerning the contents. His interest in the problems of the victims of facial injuries culminated in his devoting a major portion of his time to the Society for the Rehabilitation of the Facially Disfigured, of which he became executive director in 1951. His knowledge, innumerable talents and unfailing sense of humor will be missed.

Our deep gratitude goes to a number of our colleagues in associated fields who consented to collaborate with us on various sections of the book. Dr. Edgar A. Kahn, Professor of Neurosurgery and Dr. Richard C. Schneider of the Department of Surgery, Section of Neurosurgery, University of Michigan Medical School, helped prepare Chapter 10 dealing with fractures of the frontoethmoidal region. Dr. Judah Zizmor, Roentgenologist of the Manhattan Eye, Ear and Throat Hospital, contributed Chapter 13 on the roentgen examination of the facial bones. The assistance of Dr. Blair O. Rogers and of Dr. Felix T. Rapaport is gratefully acknowledged in the preparation of Chapter 15, a review of the principles of tissue transplantation. Dr. Byron Smith, Surgeon-Director in charge of ophthalmic plastic surgery at the Manhattan Eye, Ear and Throat Hospital, collaborated in the preparation of Chapter 21 dealing with deformities of the eyelids and orbital region. In Chapter 27 on facial paralysis, Dr Joseph Goodgold of the Institute of Rehabilitation and Physical Medicine, New York University-Bellevue Medical Center, contributed the section on electrodiagnosis. Dr. Richard J. Bellucci, Surgeon-Director in charge of the Hearing and Speech Clinic of the Manhattan Eye, Ear and Throat Hospital, contributed the section on the intratemporal repair of the facial nerve. Dr. James H. Maxwell, Department of Otolaryngology, University of Michigan Medical School, kindly allowed us to include one of his cases of repair of the branches of the facial nerve.

The junior author wishes to express his deep appreciation to Dr. John H. Mulholland, George David Stewart Professor of Surgery, New York University College of Medicine, for his friendly advice and guidance over the years and to his long time associate, Dr. Ross M. Campbell; many of the patients shown have been treated in collaboration with him. To Mr. Thomas D'Arcy Brophy, President, and the Trustees of the Society for the Rehabilitation of the Facially Disfigured and to Mr. G. Lauder Greenway, Dr. Thomas Parran and the Trustees of the Avalon Foundation go our thanks for making possible much of the work necessary to complete this book.

The checking and listing of the bibliography, a seemingly unsurmountable task, were accomplished by Miss Pauline Porowski, R.N., in addition to her other duties and responsibilities. Miss Margaret L. Newton did much of the typing of the manuscript, assisted by Miss Margaret Gibbons and Miss Virginia Angelo.

The authors also wish to thank the Publisher for the patience and coöperation necessary to produce a technical book, particularly a succeeding edition.

V. H. K.
J. M. C.

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THE FACE

The face of man is formed of soft expressive tissues, draped upon an underlying framework of bony structures. Endowed with an inherent ability to convey emotions through the interplay of flexible facial structures and with such highly specialized organs as those of vision, audition and speech, humans possess the precious art of communication with their fellows.

In civilized man the face alone remains unclothed and exposed. An injury resulting in distortion of the features thus sets the unfortunate individual apart in a highly organized society where a premium is placed upon beauty and facial symmetry Because disfigurement of the face becomes a serious social handicap, the surgical treatment of facial injuries is of special significance, as it serves to restore the inner feelings of happiness and well-being in addition to the outer appearance and function.

EVOLUTIONARY CONSIDERATIONS

The structures of the human face owe their origin to primordia of the head and neck which begin to be outlined as early as the third and fourth weeks of embryonic life. A remarkable series of intra-uterine transformations then ensue which repeat in great part the evolutionary history of mammalian development.

Because an awareness of these processes is of assistance in understanding anomalous as well as normal development, the authors have chosen to begin this text with a brief consideration of these interesting and pertinent ancestral relationships.

The Jaws

Analysis of the component parts of the face of invertebrate or vertebrate forms suggests that the mouth is the central and most essential feature of the face. The mouth in its simplest form, as seen in the obelia, is merely a circular opening in a cylindrical bag. In the crustaceans, insects and other arthropods, accessory mouth parts are elaborated out of locomotor appendages. In the vertebrates the jaw parts consist of an entirely different set of organs, the gill arches. The transformation of gill arches into jaws is seen in various stages among the vertebrates. The primary jaws, the result of this transformation, become covered and replaced by secondary jaws in the higher forms. The gill pouches of fishes and embryos of higher vertebrates are supported by cartilaginous bars, the visceral arches. The mouth pouches of sharks and of embryo vertebrates are supported by similar cartilages. A modified first visceral cartilage forms the cartilages of the upper and lower jaws in the shark, (Fig. 1*A*); the cartilage of the lower jaw, Meckel's cartilage, articulates with that of the upper jaw. The sucking mouth of lower animals is thus replaced by the mouth with teeth. The upper jaw does not fuse with the cranium but remains an independent component of the skull. The hyomandibular cartilage, a portion of the second visceral arch, serves as a suspensory apparatus for the lower jaw, connecting the jaw to the brain trough. In amphibians and in reptiles the upper jaw is firmly attached

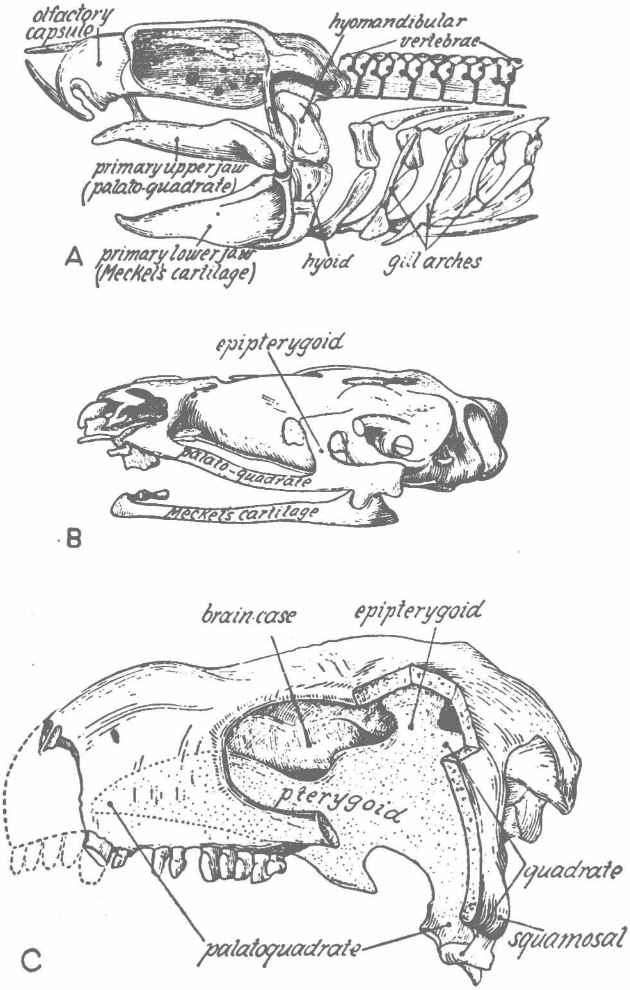

FIG. 1. Methods of attachment of the primary upper jaw to the under side of the skull

A. Hyostylic attachment (by means of the hyomandibular cartilage) characteristic of shark.

B. Autostylic attachment (by means of an epipterygoid process from the primary upper jaw). Cartilaginous braincase and primary upper jaw of fetal salamander.

C. Skull of primitive fossil reptile (Diadectes) from the Permo-Carboniferous of Texas. The bony mask covering the temporal region is cut through and a part of it removed to show the primary upper jaw (comprising the palatine, pterygoid, epipterygoid, and quadrate bones) and their relations to the braincase. From William K. Gregory, *Our Face from Fish to Man*, G. P. Putnam's Sons, 1929.

to the skull (Fig. 1*B*, *C*; Fig. 2). The hyomandibular cartilage slips into the tympanic cavity to form the stapes. The remaining visceral arches are reduced and associated with the larynx. The primary jaws are destined to be supplanted by secondary jaws.

Large bony plates and scales appeared in the skin of ancestral vertebrates. These dermal scales sank into the deep layers of the skin in later forms and became ensheathed and covered, largely supplanting the primary jaws.

In sharks, the secondary jaws are represented by the skin which covers the primary jaws. The primary jaws in the higher fishes and in early amphibians are ensheathed by bony tooth-bearing plates covered with ganoine, a porcelain-like substance; the skele-

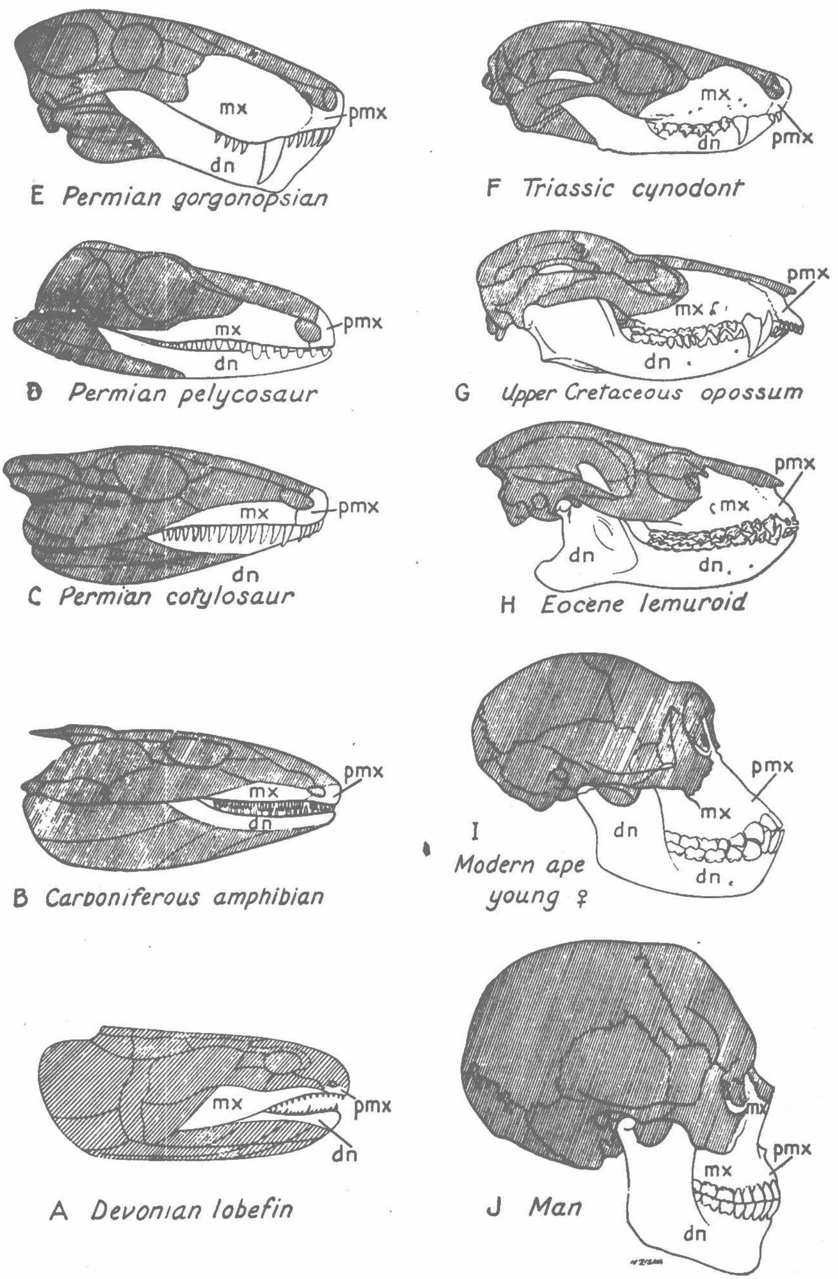

FIG. 2. Evolution of the human jaw-bones (Gregory). Abbreviations: pmx, *premaxilla*; mx, *maxilla*; dn, *dentary*.

The maxillary bone, in its earlier form, is a slender, vertically shallow element. By the time of the early mammal-like reptiles it has extended dorsally and gained contact with the nasals (D, E). In the mammals it extends still further, reaching the frontal bone and separating the lacrimal from the zygoma (G, H, I, J). In anthropoids and man the premaxillae unite with the maxillae (I, J). The dentary is at first confined to the anterior half of the mandible (A). In the higher mammal-like reptiles it becomes dominant (E), and in the earliest mammals the ascending ramus of the dentary gains a new contact with the squamosal, the temporomandibular joint (G, H).

ton of the human face has been traced back to these origins. In higher mammal-like reptiles and in mammals, three of these tooth-bearing plates are found throughout the scale of the vertebrates. These are the premaxilla and maxilla, paired bones of the upper jaw, and the dentary, paired bone of the lower jaw (Fig. 2).

Thus it appears that the jaws are formed by a number of distinct bony plates, some of which disappear in the higher vertebrates. The premaxilla and dentary persist in man, while the pterygoids and quadrates of the upper jaw, and the elements behind the dentary of the lower jaw are progressively diminished.

The dentary bone in the higher vertebrates leading to the mammals increases in size until it crowds out the other elements of the lower jaw. This increase of the dentary bone causes it to press against the jaw muscles in which its upper end is embedded. The pressure gives rise to a bursa, formed by a slip of the external pterygoid muscle, which passes between the lower jaw and its socket in the squamosal bone. The socket formed by the pressure of the dentary bone of the lower jaw against the squamosal, characterizes the mammalian temporomandibular joint (Fig. 2*G*, *J*), as contrasted with the reptilian joint between the quadrate bone of the upper jaw and the articular bone of the lower jaw.

The maxilla increases in height, joining with the nasal bones in the early mammal-like reptiles (Fig. 2*E*). The frontal process of the maxilla usually meets the frontal bone in most mammals without disrupting the primitive contact between the lacrimal and zygomatic bones; the maxillary process merely overlaps the facial extension of the lacrimal. The separation of the zygoma from the lacrimal bone is probably associated with outward displacement of the zygoma, widening and shortening of the jaws, pull of the masseter muscle, and widening of the brain. The upper jaw becomes shortened antero-posteriorly and increased vertically, thus greatly modifying the shape of the face in anthropoids and in man (Fig. 2*I*, *J*). In primates, the shape of the face is further influenced by the subsequent evolution of the mandible, involving chiefly the shortening of the body of the jaw and a reduction in the dental formula (Fig. 3). In anthropoids and in man the dentaries of each side finally fuse to form the mandible, sole survivor of eighteen bones in the ancestral lobe-finned fish. The outgrowth of a chin and the re-

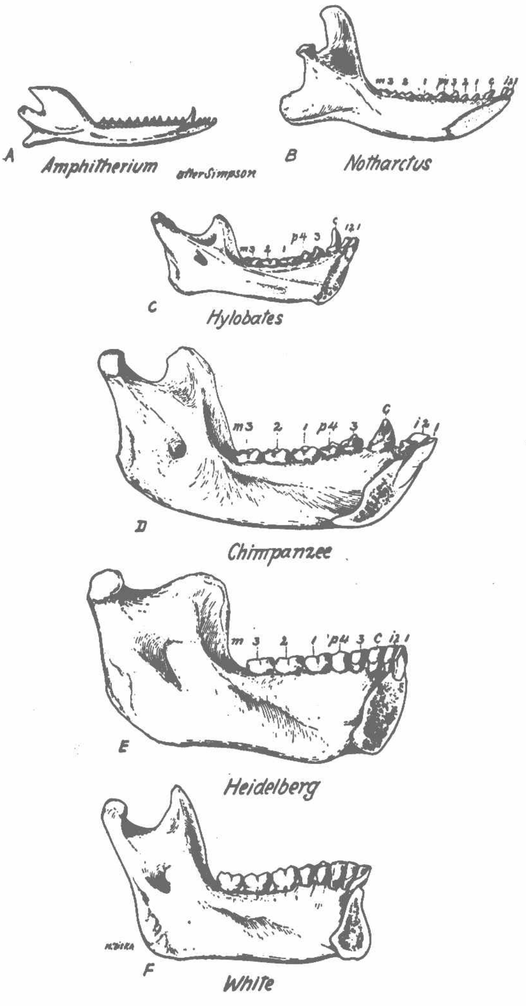

FIG. 3. Evolution of the mandible in primates (Gregory). The evolution of the mandible in primates (B to E) involves the shortening of the horizontal portion or body of the mandible with a reduction in the dental formula. Later human stages were characterized by the refinement of the jaw and the outgrowth of the chin (F).

finement of the jaw are characteristic of man (Fig. 3*E*, *F*).

The Mouth

Cheeks and Lips

The mouth in lower forms is large, somewhat funnel-shaped and lacks lateral walls. The oral cavity of the herbivora is bounded by cheeks which prevent the escape of food during mastication. Cheeks are well-developed in monkeys, higher apes and man. Mobile lips, variously formed, are seen in all mammals, perhaps due to the need for obtaining nourishment by suckling during infancy (Negus, 1938).

The Tongue

The size and shape of the tongue varies considerably in animals. The chameleon, anteater and giraffe use it for grasping food. The crocodilia bolt their food with the aid of a flat, mobile tongue. The tongue of a carnivorous animal is well-formed and mobile and is exceptionally well-developed in the herbivora. The relatively large size of the tongue in modern man may be traced to the large oral cavity of earlier man; its dimensions and mobility are of assistance in speech.

The Nose

The early development of the face is linked to that of the mouth and jaws. The growth of an independent olfactory and air-breathing apparatus is a later development.

In the olfactory apparatus of the shark the nose communicates with the mouth cavity through an external oronasal groove. This groove is closed anteriorly in lung fishes. A tube, thus formed, extends from the nose to the mouth cavity, and the nasopharyngeal duct and the functional association of the olfactory sense with the inspired air is thus established. The development of an independent air-breathing apparatus led to further progressive evolutionary changes: the air, inspired into the olfactory chamber of amphibians, is enabled to pass through a pair of tubes opening into the anterior portion of the roof of the mouth.

The choanae open into a chamber lying above the level of the tooth-bearing bones of the upper jaw in early mammal-like reptiles. A secondary palate is formed in higher mammal-like reptiles by horizontal outgrowths of bony plates from the palatine and maxillary bones that form a shelf below the choanae. The bony palate in mammals is prolonged posteriorly and a muscular sphincter, the soft palate, separates the oral and nasal cavities.

The elongated olfactory capsules of mammal-like reptiles are squeezed together; their median walls form a bony partition, the mesethmoid, which bears scroll-like outgrowths that offer a wide surface for the testing of odors. The sense of smell is highly developed in mammals, as evidenced by the large scroll-like turbinates in the nasal fossae. The cartilaginous nose is supported by a median cartilage which rests in a groove in the vomer, and is continuous posteriorly with the mesethmoid bone.

The first primitive primates, small and long-snouted, much like tree shrews of today, were evolved in the Eosene, some 60 million years ago. They were tree dwellers; the subsequent development of the higher primate face seems to be largely dependent upon this mode of life (Hooton, 1946). The primitive ground-dwelling animal must be provided with a long, pointed snout, tipped by the nose which is the principle organ of touch and the sole organ of smell; since he cannot see above the long grass, he is forced as Wood-Jones has said, to "nose his way through life," depending for the detection of food largely on the tactile and olfactory functions of his soft, damp muzzle. Beneath the elongated snout is the mouth, provided with teeth and dental arches corresponding to the elongated shape of the snout. When the ancestors of these primitive primates took to the trees, arboreal life resulted in considerable diminution of the function of the face. Tree life placed a premium upon the sense of vision as contrasted with the olfactory sense upon which the small, weak ground-dweller depended for his existence. Agility and motor co-ordination were required to permit an animal to move about the trees without falling; keen eyesight supplanted the sense of smell as the principle survival faculty. A change in the shape of the face occurred, characterized by the recession of the muzzle and a lessening of the transverse dimension of the nasal cavity. The recession of the nasal cavities permitted the forward progression of the orbits and the shortening of the jaws. With the shortening of the snout in the higher primates, a true external nose emerges between the nostrils. The nostrils are widely separated in the New World or platyrrhine monkeys, and open outwardly on each side of the broad tip and columella of the nose. In the Old World or catarrhine monkeys, and in apes and man, the nostrils are drawn downward and inward toward the mid-line (Fig. 4).

The Zygomatic Arch and the Orbits

The evolution of the zygomatic arch is observed in the extinct mammal-like reptiles of South Africa. The upper surface of the skull in the earliest fossil fishes, amphibians and reptiles is covered by a bony mask, with openings for nostrils, eyes, and ears; the temporal jaw muscles lie beneath this mask. The bony shell which covers the temporal muscles is absorbed in the early mammal-like reptiles, leaving a round fossa behind the orbit and lateral to the side wall of the braincase (Fig. 5*D, E*).

The skull approaches the mammalian type in the development of a temporal fossa and a cheek arch (Fig. 5*D, E, F*). The temporal muscles overflow on top and the roofing bones sink beneath the surface. Thus, in primitive mammals like the opossum, the jaw muscles cover the parietal and a portion of the frontal bone, whereas in earlier stages they lie beneath these bones. This may be seen by comparing the skull of the opossum (Fig. 5*G*) with that of a mammal-like reptile (Fig. 5*F*). Man inherits only two of the five original bones which surrounded the orbit; these are the lacrimal and the zygomatic bones. The maxilla separating these two bones increases the width of the face (Fig. 2). The decrease in the number of circumorbital bones is accompanied by a forward progression of the orbits from their more lateral position, thereby permitting binocular vision, and by a progressive diminution in the number of bones in the skull, a phenomenon referred to as "Williston's law" (Fig. 5).

The face, seat of the principal sense organs, began, in the early Eosene primates, to undergo changes consisting of a progressive development of all the senses except that of smell which was destined to partial retrogression. A greater dependence upon vision tended to enlarge the visual areas of the brain at the expense of the primitive olfactory areas. The brain expanded laterally and posteriorly in accordance with the location of the visual centers in the occipital lobes of the cerebrum and with the concomitant shrinking back of the muzzle. The head tended to become balanced upon the erect spine, thus facilitating the upright position without the muscular effort required by the vast overbalancing of a protrusive muzzle. The increase in the size of the brain in man achieved the vertical development of the face by increasing the size of the frontal region. Sagittal sections of the skull of the gorilla and man reveal that the frontal region of the brain in man has grown forward above the olfactory chamber (Fig. 6).

Fossils discovered in Africa and in Asia have many characteristics resembling those of the anthropoid apes. The resemblance becomes closer in the Australopithecus of South Africa which possessed an erect posture, a characteristic considered specific in man. Added knowledge of the links between man and the anthropoids followed the discovery of Pithecanthropus and Sinanthropus.

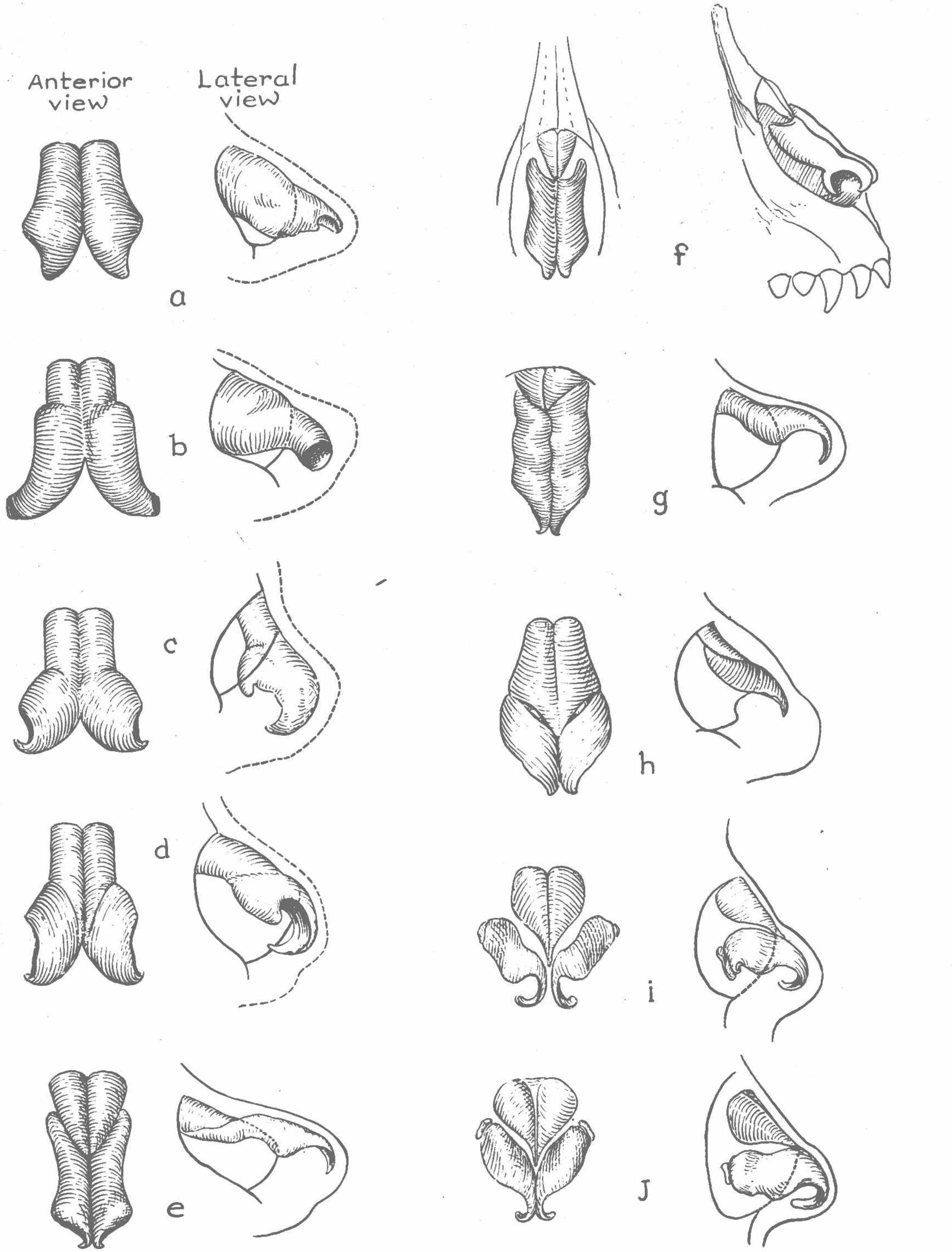

FIG. 4. Ontogeny and phylogeny of the nasal cartilages in primates, after I. C. Wen. (*Contributions to Embryology*, Carnegie Institution, Washington, 414:109, 1921).

A. Prosimian: *Lemur variegatus*; B. Prosimian: *Tarsius saltator*; C. Platyrrhine: *Callithrix jacchus*; D. Platyrrhine: *Allonata palliata*; E. Catarrhine: *Erythrocebus plas*; F. Catarrhine: *Pygathrix entellus*; G. Anthropoid ape: *Hylobates pileatus*; H. Anthropoid ape: *Pongo pygmaeus*; I. Man: negro; J. Man: white.

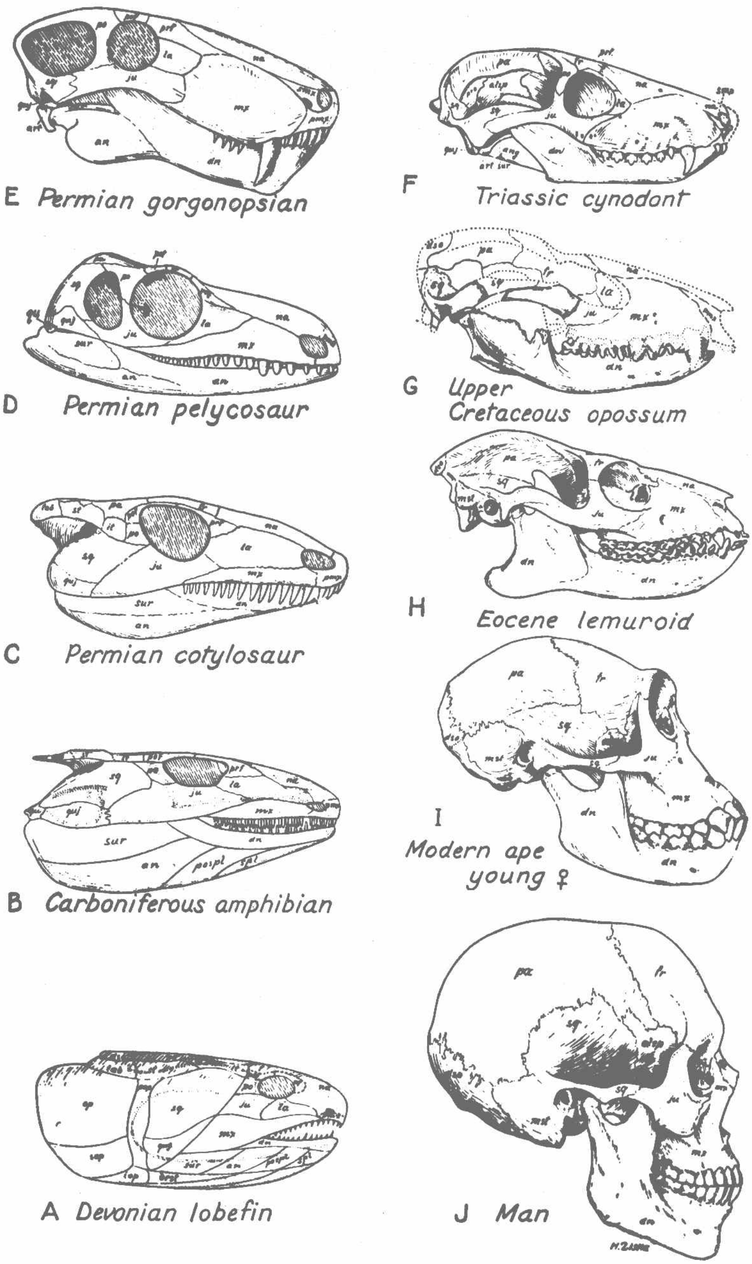

FIG. 5. Evolution of the bones of the skull

Figures A to J give excellent examples of "Williston's Law": the progressive diminution in number of the elements of the skull in passing from fish to man (Gregory).

Origin of the Facial Musculature

In the most primitive living mammals, the bony mask of the face was replaced by a pliable skin after the dermal bones began to sink beneath the surface (Fig. 7).

The development of the facial muscles, which gave mobility to the face and reached a high development in primates resulted in a characteristic mammalian feature. This musculature appears to owe its origin to a thin wide band of muscle in reptiles, the primitive sphincter colli, activated by a branch of the seventh cranial nerve. This muscle has grown forward along the sides and top of the face in mammals. The matrix muscle layers, platysma and sphincter colli profundus, spread over the head and face from the neck, and gave rise to the various facial muscles (Huber, 1931; Fig. 8). Whereas in all vertebrates below the mammals the superficial musculature was restricted to the region of the neck, in mammals it spread over the head onto the face where it achieved connections with the freely movable skin (Fig. 9). Certain portions of the musculature became connected with the external ear, some were grouped around the eye, others became attached to the snout, while still others were arranged around the mouth. Thus, distinct facial muscles arose from the muscular matrix of the neck, and the facial nerve which innervated this matrix supplied the facial musculature.

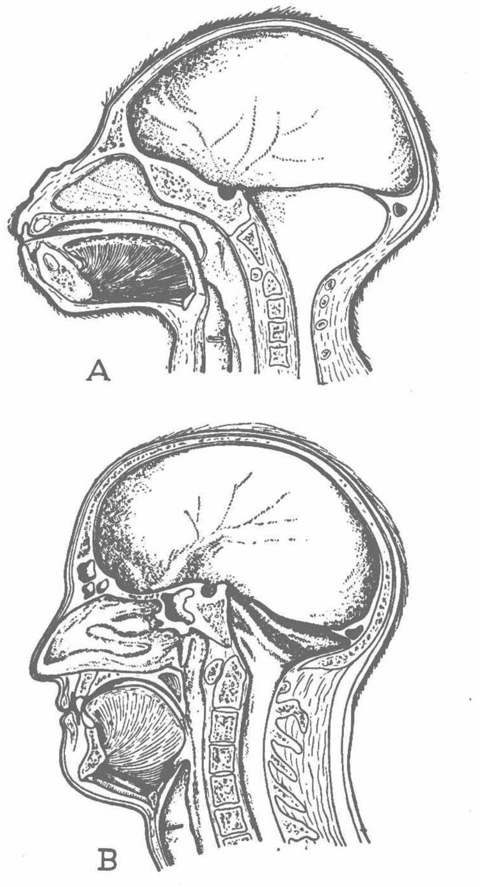

FIG. 6. Longitudinal section of head in young gorilla (A) and in man (B) showing the development of the frontal region in man and the accompanying increase in the height of the face in general and of the nose in particular. From William K. Gregory, *Our Face from Fish to Man*. G. P. Putnam's Sons, 1929.

ANATOMICAL CONSIDERATIONS

The anatomical limits of the face have been variously defined. Some anatomists have described the face as that portion of the head consisting essentially of the area which comprises the jaws, while others have also included the frontal area. Leonardo da Vinci divided the ideal face into thirds from the hairline to the chin. It is interesting to note that Malgaigne (1838) extended the area still further, delimiting the facial area as illustrated in Figure 10.

All the structures within the area covered by the muscles of facial expression are included in this description because of surgical considerations. The loss of the scalp, for example, may involve structures associated with the face; burn contractures of the neck may also result in facial deformities.

Bony Structure of the Face

The bones which form the framework of the face are divided into those of a lower

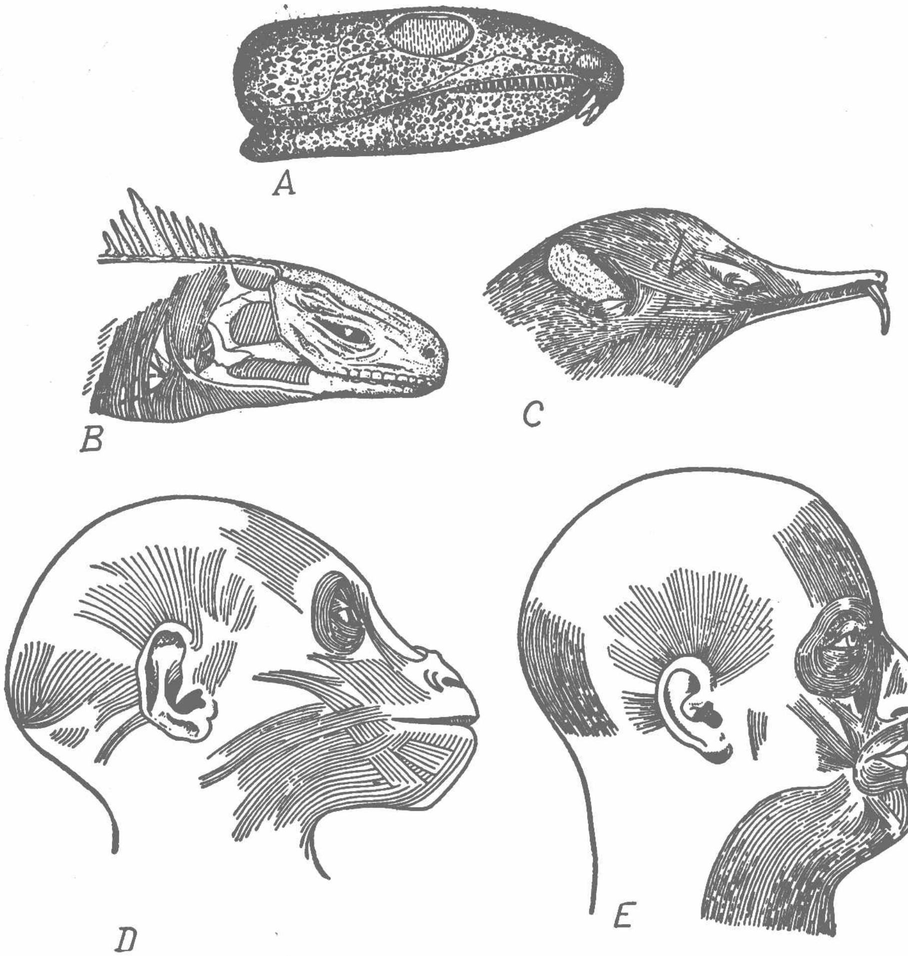

FIG. 7. Origin of the facial muscles of man

A. Primitive reptile (Labidosaurus) with continuous bony mask covering skull. The mask was covered with thick skin without muscles, as in the alligator.

B. Modern reptile (Sphenodon) with an open or fenestrated skull covered with thick, nonmuscular skin. The seventh nerve (heavy black line) is seen beneath the sphincter colli muscle, a broad band around the throat.

C. Primitive mammal (Echidna) in which the sphincter colli system has grown forward over the face.

D. Gorilla.

E. Man. From William K. Gregory, *Our Face from Fish to Man*, G. P. Putnam's Sons, 1929.

portion, the face proper or maxillofacial area, and those of the cranial area. The maxillofacial area may be delineated in the shape of a prism (Fig. 11) situated in front of the large arteries and the cranial nerves, the base of the skull and the spinal column. The architectural design is admirably adapted for the protection of these structures. The maxillofacial prism is formed by columns of compact bone and thin lamellar bone and is attached to the skull by strong abutments, two anteromedial, extending on each side from the canine fossa to the frontal bone; two anterolateral, the zygomatic arches; and two posteromedial, the pterygosphenoid abutments (Fig. 12). The frontal

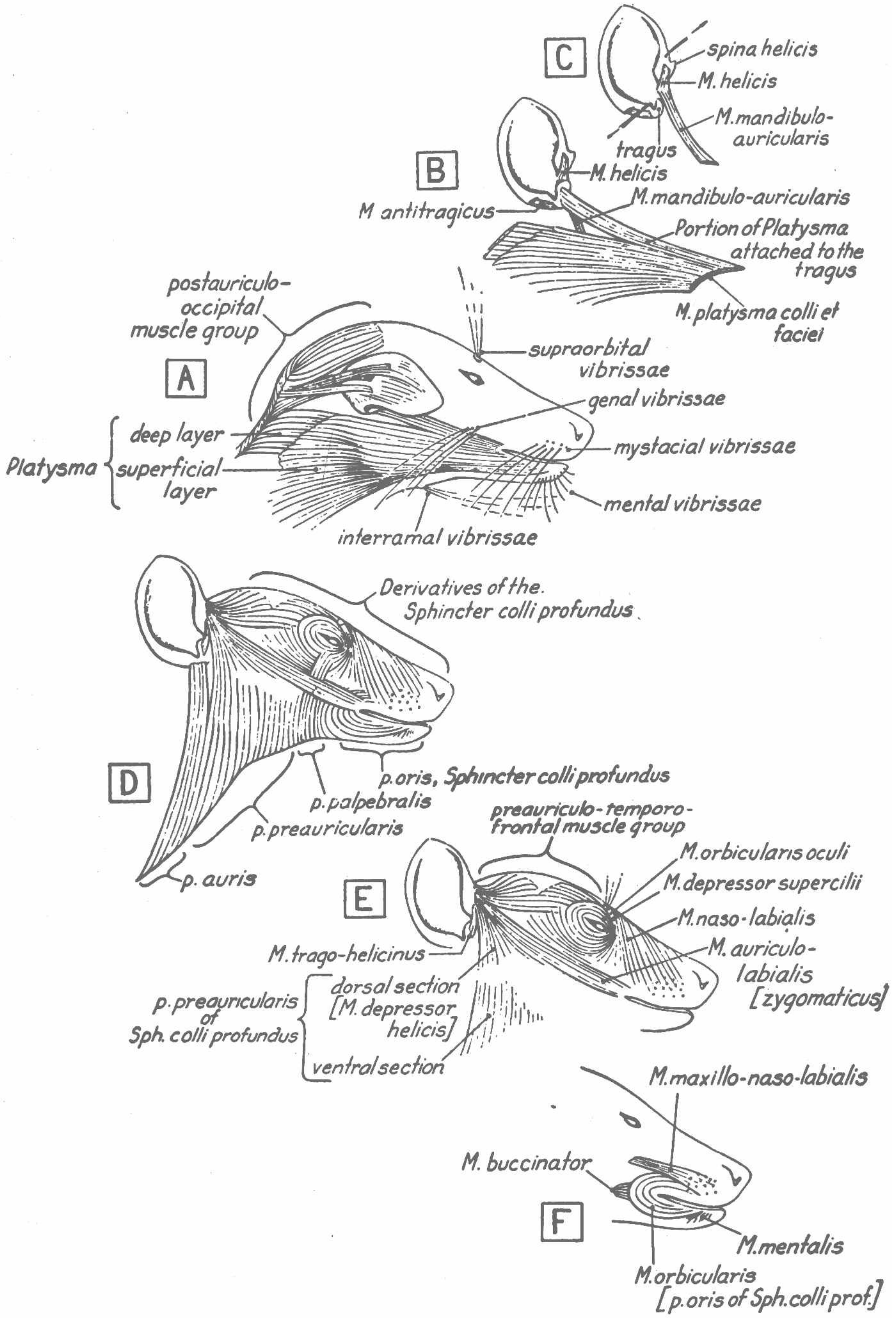

FIG. 8. Scheme of the Primitive Primate Ground-Plan of the Facial Musculature (based on investigations of Lemuroidea, Tarsius, and primitive platyrrhine monkeys) (Huber). The superficial facial musculature is a genitically uniform muscle field innervated exclusively by the facial nerve. From the neck region the matrix muscle layers, platysma and sphincter colli profundus have spread over the head into the face where they have given rise to the various muscle complexes and individual facial muscles.

A–C show the platysma and its derivatives.

D–F the sphincter colli profundus and its derivatives.

A and E moreover show the facial tactile vibrissae arranged according to the primitive mammalian ground-plan.