The anatomical differences in the structural arrangement of the muscles in the cleft lip and palate are characterized by the fact that the muscles, during their embryonic growth in a lateromedial direction, fail to meet in the midline and thus seek other attachments. These substitute attachments prevent the muscles from becoming fully functional, and their development is incomplete. Atypical insertions and varying degrees of hypoplasia constitute the main pathologic features of the cleft lip and palate musculature.

On the basis of this knowledge, detachment of the muscle stumps from their substitute insertions and their distal folding become prime requisites for any successful operation on the cleft lip and palate. Such a maneuver joins the muscle fibers in an end-to-end fashion: this assures subsequent adequate development and function of the musculature.

The Muscles of the Lip

The principal muscle of the lip is the orbicularis oris muscle. It passes around the entire oral fissure and is in intimate contact anteriorly with the skin and posteriorly with the mucous membrane. The orbicularis oris muscle consists anatomically and functionally of two parts, the superficial and the deep layers.

The fibers of the superficial portion of the orbicularis oris muscle connect with the maxilla and septum above and with the mandible below. In the upper lip these fibers consist of two bands: the lateral band arises from the alveolar process of the maxilla, opposite the lateral incisor tooth; the medial band connects the muscle with the septum. It is joined by the muscles of expression, which intermingle with it and participate in its function by their dilating or stabilizing effect or both. The superficial portion of the orbicularis oris muscle also brings the lips together and its fibers contract independently to provide fine shades of expression.

The deep layers of the muscles encircle the orifice of the mouth and function solely as mouth constrictors.

The circular bundles of the orbicularis oris muscle are originally interspersed by a few fibers of musculi labii proprii (compressor labii, musculus cutaneomucosus, musculus rectus labii), passing obliquely between the skin and mucous membrane. These muscle fibers can be more easily found in the lateral parts of the lip than in the philtrum. They are supposed to draw the lip to the jaw when the child is sucking; they disappear after the nursing period.

The Muscles of the Unilateral Cleft Lip

In a complete unilateral cleft, the fibers of the orbicularis muscle, proceeding horizontally from the corner of the mouth towards the midline, turn upwards along the margins of the cleft. They terminate laterally beneath the base of the ala of the nose and
medially beneath the base of the columella, where most of them attach themselves to the periosteum of the maxilla, a few disappearing in the subcutis.

In the more advanced cases of incomplete cleft, in which only narrow bridges are formed, the muscle has similar characteristics.

In the lesser forms of incomplete cleft, in which the cleft does not exceed two-thirds of the lip height, the muscle fibers reach over the tip of the cleft and pass from the lateral to the medial lip segments. The muscle within the cleft, however, is interspersed by the trabeculate of the collagenous connective tissue.

A protrusion of excess muscle may be seen and palpated on the lateral aspect of the cleft in complete as well as incomplete clefts. This is caused by the contraction or heaping up of the muscle, which was prevented from developing to its normal length. The musculature on the medial side, on the other hand, is underdeveloped and does not extend as far forward to the edge of the cleft as it does on the lateral side. This observation was originally made by Veau (1938), who wrote: "la berge interne est sterile" (the medial border is sterile). In autopsies and during cleft lip operations, one can observe a striking thinning of the muscle layer in the entire half of the philtrum adjacent to the cleft.

In the lesser form of incomplete cleft characterized by a small coloboma in the lower part of the lip, a groove on the skin passes upward to the threshold of the nostril. This external finding is always manifest on the muscle ring of the lip, which is depressed beneath the cutaneous groove.

Similar findings have been seen in the arterial network. The superior labial artery on the lateral side of the cleft follows the course of the orbicularis muscle bundles and the edge of the cleft upward to the nasal ala, where it anastomoses with the lateral nasal or angular artery. In incomplete clefts, the artery in the form of a thin, terminal branch passes through the bridge. On the medial side of the cleft, the artery behaves in a similar way, but its diameter is visibly smaller and its branches are fewer than on the lateral side. The lesser degree of arterial development corresponds to the lesser degree of musculature development on the medial aspect of the cleft. Its terminal branches extend into the columella, where they anastomose mainly with the posterior septal arteries.

Only rarely (in two of the 28 dissected stillborn children with cleft lip) did the muscle fibers show a tendency to run horizontally, entering the edge of the cleft and disappearing in the connective tissue. The blood supply in these specimens was also atypical, as can be seen in the arteriograms of a complete right-sided cleft.

The underdevelopment of the muscles and the poorer blood supply in the medial portion of the lip, extending to the midline of the philtrum, suggest that the ability of the muscular stump of the orbicularis muscle to grow across the midline of the lip (which ontogenetically represents its anatomical midline border) is to some extent limited. It is as though the orbicularis musculature of one-half of the lip is not really capable of supplying musculature to the contralateral side.
The Muscles of the Bilateral Cleft Lip

In the complete bilateral cleft lip, the muscle stumps and arterial network of the lateral segments of the lip are similar to those of the unilateral cleft. The medial lip segment or prolabium, on the other hand, is composed only of collagenous connective tissue, penetrated, however, by a rich vascular network originating in the septal and columellar arteries.

In order to ascertain possible postoperative changes in the prolabium after its fusion with the lateral segments, a threefold histologic examination of 30 children was undertaken. During the suture of the first side of the lip, performed at the age of five to seven months by means of rotating the muscle stump downward into the margin of the prolabium, only collagenous, fibrillar connective tissue was found in the excised parts of the prolabial tissue. During the suture of the contralateral side, performed after an interval of six to weeks to six months, proliferation of muscle fibers from the lateral into the medial lip segment appeared to be very active.

The greatest number of more or less differentiated muscle fibers proliferating from the lateral muscle stump into the prolabium was found in the vicinity of the previous repair. Towards the center of the prolabium, the number of fibers decreased, until finally only isolated fibers were discerned. The number of muscular fibers and the degree of penetration into the prolabium differed in each case. In order to obtain an overall orientation, the distance between the cleft line and the furthest extent of ingrowth of the muscle fibers was measured by a millimeter scale placed on the slide after previously fixing the starting line; it was noted that the fibers had penetrated an average distance of 2 to 5 mm, which represents one-fourth to one-third of the width of the average prolabium at each side. Twenty patients of the original series of 30 required secondary reconstruction, ie, deepening of the labial buccal sulcus, one to ten years after primary lip closure. Biopsies of the contents of the repaired lip at the same time revealed that many muscle fibers had been gradually replaced by connective tissue. The fibers of the collagenous connective tissue were mostly parallel to the longitudinal axis of the lip and at some points suggested a tendonlike arrangement, particularly in the central part of the prolabium. Many muscle fibers, however, were preserved, and these, together with the collagen fibers, were collected into horizontal rows, providing a favorable elastic link between the contractile ends of the orbicularis muscle.

In this way the restoration of the mouth constrictor is quite satisfactorily achieved in the wide bilateral cleft, even when the approximation and suture of muscle stumps from each side without excessive tension are impossible.

In the incomplete bilateral clefts, the muscle bundles of the lateral segments cross the bridge above the cleft into the medial lip segment and completely fill it.

There is a striking difference between the soft tissue bridges in unilateral and bilateral incomplete clefts. In the incomplete unilateral cleft, the muscles do not, as a rule, cross the cleft unless the bridge occupies at least one-third of the height of the lip. In contradistinction, in an incomplete bilateral cleft, the bridges are usually well filled with muscle fibers, even when the bridges are very narrow. The muscle fibers penetrate from the lateral to the medial portion of the lip, where they expand in a fanlike fashion. Such bridges in incomplete bilateral clefts tend to be cylindrical in shape; in unilateral clefts they are generally quite flat.
A convenient explanation for the different behavior of the musculature in the incomplete bilateral cleft is the fact that the central or prolabial segment of the lip, partially isolated by the cleft and originally without any muscle fibers, is capable of receiving the necessary tissue for each half of the segment from the ontogenetically corresponding lateral segment, which is rich in musculature.

**The Muscles of the Palate**

To become acquainted with the anatomy of the cleft palate and to determine common deviations from the normal, autopsies were performed on the palatopharyngeal region in 26 mature stillborn children with all of the usual types of palatal clefts. Four stillborn children without clefts served as controls. Twenty-two autopsies were performed on fresh bodies, four after fixation in 10 per cent formalin.

**The Tensor Veli Palatini Muscle**

The tensor is a flat muscle arising from the *scaphoid fossa* at the base of the medial pterygoid plate, from the spina angularis of the sphenoid, and from the anterolateral aspect of the cartilage of the eustachian tube. It runs anteroinferiorly and narrows toward the hamulus, where some of its bundles become attached. However, most of the bundles pass into a tendon which turns at a right angle around the hamulus and widens like a fan toward the center of the palate. It terminates either on the oral side of the aponeurosis, which occupies the whole anterior third of the velum, or directly into it.

The tensor muscles stretch the aponeurosis at the level of the hamulus and, in addition, elevate the soft palate to the level of the hamuli. If, however, the starting position of the soft palate is higher, they depress it to the level mentioned. The tensor is, therefore, either synergistic or antagonistic to the levator muscle, according to circumstances. It is also the most important dilator of the orifice of the eustachian tube.

**Autopsies in Newborns With Clefts.** The tensor was somewhat thinner than in a normal newborn child. By pulling on it, a few bundles attached to the hamulus and the tendon itself (appearing quite atypical) were clearly identified. The front part of its bundles extended along the rudimentary palatine aponeurosis toward the posterior nasal spine or laterally to the posterior edge of the palatine bone. Some of the tensor fibers radiated into the aponeurosis. The main part of the tendon, however, arched backward to the cleft edge of the soft palate, where it terminated in two different manners: (1) the tendon sometimes became partly dispersed, and then a triangular portion passed into the anterior bundles of the levator muscle; (2) the tendon did not disperse at all but passed into the anterior bundles of the levator muscle as a coherent and unexpectedly thick and free single muscular-tendinous bundle. The second arrangement was found in more than two-thirds of autopsies.

**The Levator Veli Palatini Muscle**

The levator is a cylindrical muscle, the posterior bundles of which come from the undersurface of the apex of the petrous portion of the temporal bone and anteromedially from the edge of the canal for the passage of the internal carotid artery. The anterior bundles arise from the posteromedial side and from the base of the cartilaginous part of the eustachian tube.
The levator runs in a groove below the tube medioinferiorly and fans out over the entire posterior portion of the soft palate. It ends in the raphé.

The levator elevates and shifts the soft palate backward (the muscles of both sides form a sling suspended from the base of the skull like a swing). It also, in a complicated fashion, affects the shape of the eustachian tube - mainly by constricting the opening of the tube. According to Riu, Flottes, Bouche and LeDen (1966), it dilates the tube synergistically with the tensor.

**Autopsies in Newborns With Clefts.** The levator muscles in all cases investigated were considerably hypoplastic bilaterally. Sometimes they did not exceed half the muscle thickness seen in normal newborn children. The thinner the muscle belly, the thicker was the layer of loose connective tissue in its bed.

In most cases the posterior bundles ran posterolaterally toward the bundles of the palatopharyngeus, penetrated the posterior palatine arch to the vicinity of the base of the uvula, and joined them. The medial bundles radiated like a fan into the margin of the cleft. The anterior bundles were either (1) attached by a triangular tendinous area coming laterally from the posterior nasal spine to the posterior edge of the hard palate, while the lateral distinct part of these tendinous bundles arched into the tensor tendon; or (2) directly linked up with the compact portion of the tensor tendon.

In the first case (and it usually occurred in the lesser forms of clefts), some anterior bundles of the levator advanced for some millimeters along the cleft margin of the hard palate as a part of the "cleft muscle". Additional views of levator attachments are shown.

**The Palatopharyngeus (Pharyngopalatinus)**

The palatopharyngeus is generally divided into three parts:

1. *The palatine part.* This passes from the thyroid cartilage and the adjacent part of the pharyngeal wall through the palatopharyngeal arch to its fan-shaped insertion in the raphé.

2. *The pterygopharyngeal part.* This part arises from the posterior and lateral parts of the pharynx and inserts on the hamulus and the palatine aponeurosis, intermingling to a high degree with the pterygopharyngeal part of the superior pharyngeal constrictor.

3. *The salpingopharyngeal part.* This is the weakest portion. Its muscle bundle detach themselves from the previous part and become inserted onto the inferior edge of the cartilage of the eustachian tube orifice.

The function of the palatopharyngeus is to narrow the pharyngonasal isthmus by bringing the palatopharyngeal arches together. The soft palate is drawn posteroinferiorly, as the palatopharyngeal arches stretch and adduct. At the same time, the thyroid portion lifts the larynx and pharynx, mainly during deglutition. The tubal portion facilitates dilatation of the eustachian tube by stabilizing its cartilage.
Autopsies in Newborns With Cleft Palate. All portions of the palatopharyngeus were relatively well developed. Its fibrous transformation was less significant, in comparison with the tensor and the levator. However, its palatine insertion differed from the normal. Even though the smaller part of its fibers ended in the cleft margin, the majority of its bundles passed forward along this margin and inserted on the posterior edge of the hard palate and on the posterior nasal spine. Some fibers finally advanced along the cleft margin, together with bundles from the levator, as a part of the "cleft muscle". In three exceptional cases of wide bilateral total clefts, most of the muscle bundles turned up to the cleft margin of the soft palate. The posterior bundles of the palatopharyngeus, turning to the base of the uvula, passed into the posterior bundles of the levator.

The circular fibres of the palatopharyngeus on the posterior pharyngeal wall were difficult to distinguish from the bundles of the superior constrictor. Thirteen newborns with various types of clefts, 50 per cent of our cases, showed condensation and even some thickening of the circular fibers of the palatopharyngeus. These bundles were crossed in the Passavant pad, which bulged visibly in the autopsy material. This was not seen in any case of sectioned normal newborns.

The powerful insertion of the pterygoid portion extended from the hamulus across the medial plate of the pterygoid, as far as the lateral portion of the aponeurosis.

The Palatoglossus Muscle

The palatoglossus is a slender muscle, arising from the transverse bundles of the tongue. It passes up into the palatoglossal arch and inserts, fan-shaped, into the muscles of the soft palate.

Together with its opposite muscle, it forms the anterior pretonsillar sphincter, which narrows the pharyngo-oral isthmus. It is antagonistic to the levator.

Autopsies in Newborns With Cleft Palates. In newborns with cleft palate, the palatoglossus passed in a posteroanterior direction in the cleft margin to the posterior edge of the hard palate. There it broadened and flattened out as it reached its insertion. It was the most superficial of the soft palate muscles, lying close to the layer of the submucous fat. Its palatal attachment extended in many cases beyond the posterior edge of the hard palate and became inserted more anteriorly, 3 to 5 mm into the oral periosteum of the hard palate.

The Uvular Muscle

The uvular muscles are a cylindrical pair, arising from the palatine aponeurosis and from the posterior nasal spine. They pass nasalward from the other palatine muscles, on either side of the median sagittal plane, to the top of the uvula, where they end. They lift and bend the uvula backward and shorten it and the entire soft palate longitudinally. Their bundles pierce the stratum of the glands on the nasal side of the velum and thus support their excretion.
Autopsies in Newborns With Clefts. The muscle passed in the cleft margin, and its bundles intermingled with those of the palatopharyngeus and the levator. The isolation of its fibers was technically difficult.

The Superior Pharyngeal Constrictor Muscle

The superior constrictor is a quadrangular muscle surrounding, from behind and laterally, the upper third of the pharyngeal wall. It is the deepest of the pharyngeal constrictors. According to its insertions there are four parts: the pterygopharyngeal, the buccopharyngeal, the mylopharyngeal, and the glossopharyngeal parts.

In both normal and cleft conditions, a close intermingling of its bundles with those of the pterygopharyngeal part of the palatopharyngeus was typical. This occurred at the point of origin of the muscle in the posterior pharyngeal wall and at the point of its insertion on the pterygoid process.

Muscle Arrangement in Cleft Palate

The differences between the normal and the cleft arrangement of the muscles of velopharyngeal closure are considerable yet readily comprehensible. They occur because the muscles extending toward the central line of the soft palate cannot attach themselves to a fixed point in the raphé of the soft palate. They insert, therefore, at some substitute points. These points, however, prevent the muscles from becoming fully functional. Therefore, their development is retarded.

The ability of the muscles in a cleft palate to find suitable substitute insertions depends on the size of the angle formed by each muscle as it proceeds from its origin to the usual insertion point in the missing raphé.

The palatoglossus and palatopharyngeus muscles, through their palatine portions, do this at a very acute angle. Thus most of their muscle bundles easily bypass the margin of the cleft soft palate and find a reliable substitute insertion, in line with their long axis, on the posterior edge of the hard palate. Some bundles may proceed still further forward along the cleft margin of the hard palate like a "cleft muscle". This typical cleft arrangement of the medial bundles of the anterior insertions of the palatine portion of the palatopharyngeus, of the palatoglossus (in most cases), and of the anterior bundles of the levator was described by Veau (1931). It is more clearly seen in operations on older children than in the autopsies on stillborn children. The fact is that, in all forms of clefts, the "cleft muscle" becomes thicker in postnatal life, because of the increasing demands made upon the substitute muscular insertion.

The frequency of the substitute insertion of the palatoglossus on the hard palate and the comparatively good development of the whole muscle in all our autopsies of stillborn children were at variance with the experiences of Veau (1931). He stated that the palatoglossus in cleft palates is so hypoplastic that in autopsies it cannot be handled at all. Our findings, on the contrary, seemed to indicate that the functional significance of the pharyngo-oral sphincter in cleft palates is considerable.
The palatoglossus and the palatopharyngeus, especially its palatine portion, are alike in that each of these two muscles forms a muscular sling with a thinner compact central part and with fan-shaped ends. The ends of both muscles radiate into mobile organs, i.e., into the soft palate on one side and into the tongue or pharynx on the other, making their origins and insertions variable. In cleft palates, the palatoglossus muscles, because of their main insertion in the posterior margin of the palatine plate, have practically no effect on their respective halves of the soft palate. However, the thickness of their bellies and their firm anchorage in the tongue muscle and on the posterior edge of the hard palate prove their functional importance in lifting the base of the tongue and perhaps the walls of the pharynx.

The levator, on the other hand, as it advances to its insertion point in the midline of the palate almost at a right angle, is in a far less favorable situation. It approaches as far as the margin of the cleft. There, however, it fails to secure a sufficiently firm point of insertion and links up, by means of its substitute insertion, with the tendinous bundles of the tensor anteriorly and with the palatopharyngeus posteriorly. We consider this mutual conjugation of all three main muscles of the soft palate a typical cleft palate arrangement, because of the complete absence of the usual muscular insertions in the raphé. With little practical effect, this arrangement causes each pair of adjacent muscles joined in this way to form a new functional unit, i.e., a muscular sling, like a double-bellied muscle. Even so, the levator cannot function adequately, and this causes its atrophy.

The situation is similar in the case of the tensor. Likewise, it has no proper change to function fully and fails to develop as it should. The absence of a fixed point in the midline, which is necessary for the insertion of the fan-shaped tendon, causes not only an incomplete and atypical growth of the tendon itself but also a severe hypoplasia of the palatine aponeurosis as well. Indeed, the very existence of the aponeurosis is due to the extension and penetration of the tensor tendon into it. Thus the aponeurosis in its lateral area is now very short. As it approaches the cleft margin, it practically disappears. The pull of the inserted bundles of the circular pharyngeal muscles contributes considerably to the improved development of the lateral parts of the aponeurosis.

In stillborn children (both normal and with cLEFTS), the upper end of the lower bundles of the pterygopharyngeal part of the palatopharyngeus passes into the corresponding portion of the superior constrictor. This is in harmony with the genesis of the palatine muscles, which originate in the pharyngeal muscles. The anterior muscles of the soft palate, the tensor, and the levator become more independent and acquire special functions, while the palatopharyngeus retains its original connection with the muscles of the pharynx from a morphologic, functional and neurological point of view.

Because of the atypical arrangement of the muscles, certain _bony changes_ usually seen in cLEFTs occur. Among these, frequently, is a rather large hamulus, which obviously became hypertrophied because of the heavy pull of the muscle bundles attached to it and the greater strain imposed on the pharyngeal sphincter by the cleft.

These muscles, the pterygopharyngeal part of the palatopharyngeus and the superior constrictors, are intended in cLEFTs to compensate for the loss of function of the soft palate on the pharyngeal side, although the elevation of the soft palate plays the main part in velopharyngeal closure under normal conditions. This compensatory burden on the above-
mentioned sphincter also explains another phenomenon often observed in clefts. In our autopsies of stillborn children, a better arrangement of circular bundles of the palatopharyngeus than is usual in normal individuals forms Passavant's pad.

In our autopsies, however, we did not find exostoses on the oral side of the palatine plates as large as we find in older children at operation. Apparently these develop only during the first years of life as a result of the excessive strain produced by the atypical insertions of the palatopharyngeus and the palatoglossus when all the functions of swallowing and speech are occurring.

In newborn children the oral mucous membrane can easily be separated from the periosteum, but in older children these layers are firmly attached and are considered from the surgical point of view as one unit - the mucoperiosteum. In most autopsies we even found an interposed layer of fat, often quite thick, generally seen medial to the greater palatine foramen. In this layer, the palatoglossus (and sometimes even the palatopharyngeus) extended as far as its insertion within the oral periosteum of the palatine plate. Apparently this fatty tissue tends to disappear postnatally, and the mucous membrane unites firmly with the periosteum as the ends of the muscle bundles move back to the posterior edges of the palatine plate.

The gradation in the development of these muscles, from the severest form of cleft to the least severe one, was clearly seen. It was most distinctly visible in the belly of the levator, which in equally developed children was almost twice as thick in an isolated soft palate cleft as in a wide complete bilateral one. In a minimal cleft including the posterior edge of the hard palate, the muscle bundles have a better chance to be inserted near the midline and thus to function. This may account for the improved development of the whole muscle, as compared to the case in very severe clefts with narrow and widely separated palatine plates.

Moreover, the levators in clefts illustrate clearly the effect of a morphologic disorder on function, from the point of view not only of quantity but also of quality. Indeed, as is generally well known, the effect of the activity of these muscles in a cleft palate is almost opposite to that in a normal one. While the muscles of both sides normally join in the raphé to form a sling lifting the palate upward, in patients with cleft palates each muscle pulls its own half of the soft palate in an entirely different direction, ie, superolaterally, causing a further widening of the cleft. Detaching the cleft insertions and joining the muscles of both halves of the soft palate in the midline must therefore be considered the basic principle of cleft palate surgery (see Chapter 45).