11. FACIAL AND PALATAL DEVELOPMENT

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READING ASSIGNMENT: Larsen 3rd edition: p.352; pp.365-371; 398-404.

SUMMARY:

The external human face develops between the 4th and 6th weeks of embryonic development. Facial swellings arise on the frontonasal process (2 medial nasal and 2 lateral nasal processes) and the first pharyngeal arch (2 mandibular and 2 maxillary processes). By a process of merging and some localized fusion these processes come together to form the continuous surfaces of the external face. The primary palate is formed in this period by fusion/merging of the medial nasal and maxillary processes. Subsequently, between 6th and 12th embryonic/fetal weeks, the secondary palate is formed as the result of fusion between palatal processes growing from the oral surfaces of the maxillary processes. Each merging and fusion site is also the site of a potential facial or palatal cleft.

LEARNING OBJECTIVES

You should be able to:

a. Demonstrate on a frontal image of a human face those parts of the face that are formed by contributions from the frontonasal process and those that are formed by contributions from the first pharyngeal arch.
b. Describe the following as to site, composition, time of appearance, and fate: oropharyngeal membrane, oronasal membrane.
c. List the derivatives of the four pairs of facial processes and the pair of palatal processes.
d. Describe the development of the nose and primary palate.
e. Explain the differences between the processes of merging and fusion.
f. List all possible sites where facial or palatal clefts may develop, and for each indicate what facial or palatal processes are involved.
g. Describe the following and list which facial/palatal processes participate in their development: primary palate, secondary palate, and definitive palate.
h. Explain the extrinsic and intrinsic factors that may affect the normal development of the secondary palate.

GLOSSARY:

Buccopharyngeal membrane. See oropharyngeal membrane**.**
Choana. Communication between oral and nasal cavities. When posterior to the primary palate: primitive (primary) choana. When posterior to definitive palate: definitive (secondary) choana.
Definitive palate. The structure that is composed of primary and secondary palate and that separates the fully developed oral and nasal cavities**.**
Frontonasal process. Embryonic facial swelling of tissues that cover the surface of the forebrain.
Fusion. The process by which two facial processes, that were initially separated by a space, grow together.
Globular process. The lower extension of the merged medial nasal processes which will become the philtrum of the upper lip.
Intermaxillary process. See globular process.
Lateral nasal process. An embryonic facial swelling on the frontonasal process, developing lateral to the nasal placode.
Mandibular process. Embryonic facial swelling formed directly by tissues of the first pharyngeal arch.
Maxillary processes. Embryonic facial swelling which is formed as an outgrowth of the proximal part of the first pharyngeal arch.
Medial nasal process. An embryonic facial swelling on the frontonasal process, developing medial to the nasal placode.
Merging. The process by which the groove between two facial processes is eliminated.
Nasal placodes. Two ectodermal thickenings that appear on the frontonasal process. They are the precursors of the olfactory epithelium.
Oral membrane. See oropharyngeal membrane.
Oronasal membrane. Located posterior to the primary palate, composed of ectodermal layers from fused oral and nasal epithelium.
Oropharyngeal membrane. A membrane composed of ectoderm and endoderm only which closes off the cephalic end of the developing digestive tract.
Primary palate. The structure that is formed by the two maxillary and two medial nasal processes, and that separates the developing oral and nasal cavities.
Secondary palate. The structure that is formed by two palatal processes (outgrowths of the maxillary processes).

TEXT:

The human face begins to form during the 4^{th} week of embryonic development. By the 6th week the external face is completed. Between the 6^{th} and 8^{th} weeks the development of the palate subdivides nasal and oral cavities. This development continues into the 12^{th} week with completion of the soft palate.

Occurrence of abnormalities throughout a complicated developmental process is inevitable. The incidence of congenital malformations of the face is approximately 1 in 700 births. This number includes major defects incompatible with life and minor defects that are surgically correctable. The most severe congenital problems are those that develop early in facial development (4^{th} –8^{th} weeks); relatively minor problems develop later (8^{th} – 12^{th} weeks). Clinically, it is important to realize that the tissues surrounding the forebrain: **frontonasal process** - see below- develop separately from the tissues of the first pharyngeal arch: **mandibular** and **maxillary processes** - see below. Therefore you may find a developmental problem in one or the other but usually not in both places.

DEVELOPMENT OF THE EXTERNAL FACE - SEQUENCE OF DEVELOPMENTAL EVENTS

During the third week of development an **oropharyngeal membrane** (buccopharyngeal , or oral membrane) is first seen at the site of the future face, between the primordium of the heart and the rapidly enlarging primordium of the brain (Fig.11-1). It is composed of ectoderm externally and endoderm internally. It lies at the beginning of the digestive tract and breaks down during the fourth week in order to form the opening between the future oral cavity (primitive mouth or stomodeum) and the foregut. The oropharyngeal membrane breaks down when it stops growing. While tissues around it expand very rapidly, the oropharyngeal membrane's non-proliferating cells are gradually pulled apart because they cannot fill the expanding area.

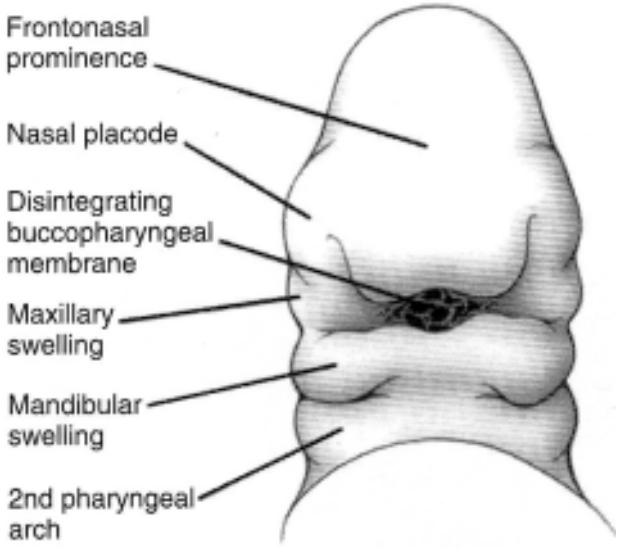

Fig. 11-1. Origin of the human face and mouth. The face develops from five primordia that appear in the fourth week: the frontonasal prominence, the two maxillary swellings, and the two mandibular swellings. The buccopharyngeal membrane breaks down to form the opening to the oral cavity.

The external face forms from two sources that surround the oropharyngeal membrane (Fig.11-2):

- the tissues of the **frontonasal process** that cover the forebrain, predominantly of neural crest origin; and
- the tissues of the first (or **mandibular)** pharyngeal arch, of mixed mesoderm and neural crest origin.

A series of individualized tissue swellings gives rise to the different parts of the face. These are known as **facial processes** (prominences). The following facial processes may be recognized (Fig.11-3):

a) the **frontonasal process** gives rise to:

- a pair of ***medial nasal processes***
  (that later contribute to a ***single globular*** [intermaxillary] ***process***), and
- a pair of ***lateral nasal processes***.

b) the **first pharyngeal arch** gives rise to:

- a pair of ***mandibular processes*** (actually the pharyngeal arch itself), and
- a pair of outgrowths of the arch: the ***maxillary processes***
  (that later give rise to a ***pair of palatal processes***).

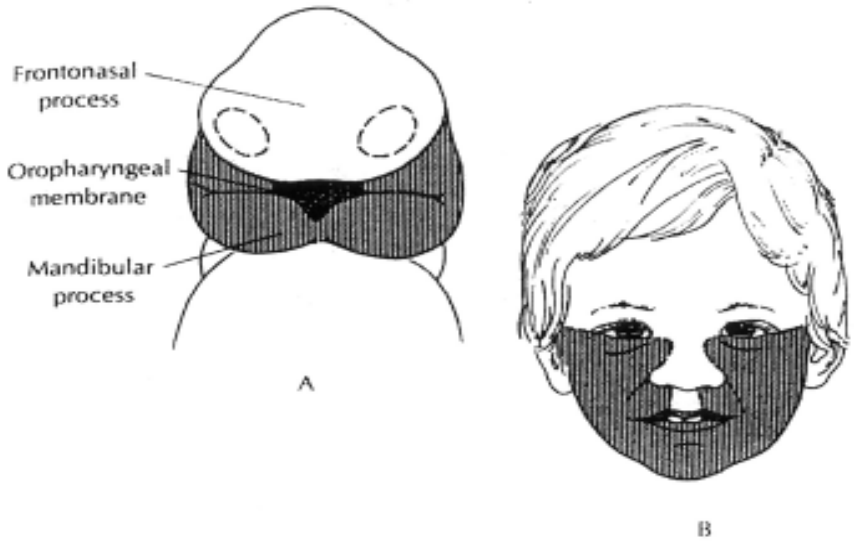

Fig. 11-2. The facial region of a 4-week-old human embryo, **A,** and of a young child, **B,** are shown, seen from front. The lightly stippled frontonasal process in **A,** will give rise to forehead, nose, and midsection of upper lip, similarly stippled in **B**. The mandibular arch darkly shaded in **A,** will give rise to a large part of the midface and all of the lower face, similarly shaded in **B**.

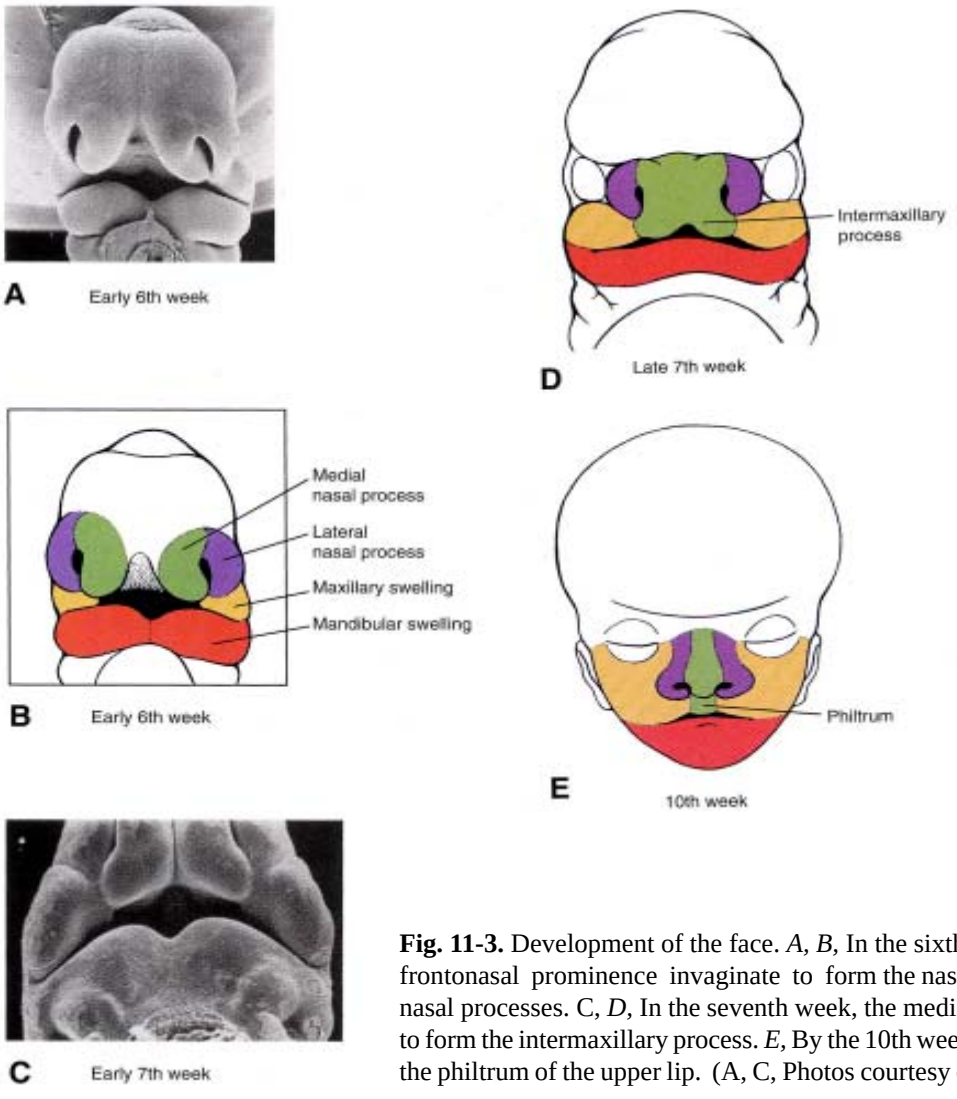

Fig. 11-3. Development of the face. *A, B,* In the sixth week, the nasal placodes of the frontonasal prominence invaginate to form the nasal pits and the lateral and medial nasal processes. C, *D,* In the seventh week, the medial nasal processes fuse at the midline to form the intermaxillary process. *E,* By the 10th week, the intermaxillary process forms the philtrum of the upper lip. (A, C, Photos courtesy of Dr. Arnold Tamarin.)

The traditional images of the development of the face show the contributions of these different facial processes. It is possible to indicate the approximate positions of the boundaries between these areas. If the processes do not mold together normally during development, a congenital malformation, known as a **facial cleft**, will occur at that boundary.

At the end of the fourth week, two ectodermal thickenings: **nasal placodes**, appear on the frontonasal process. They are the precursors of the olfactory epithelium, responsible for the sense of smell. During the fifth week, **lateral nasal and medial nasal swellings** that surround the nasal placodes appear on the frontonasal process. These four nasal processes grow forward, while the nasal placodes remain relatively stationary. This gives the impression that the nasal placodes "invaginate". They actually stay behind and come to lie in **blind nasal pits**, surrounded by the nasal processes. This is the first step in the development of the nasal cavities (Fig.11-4).

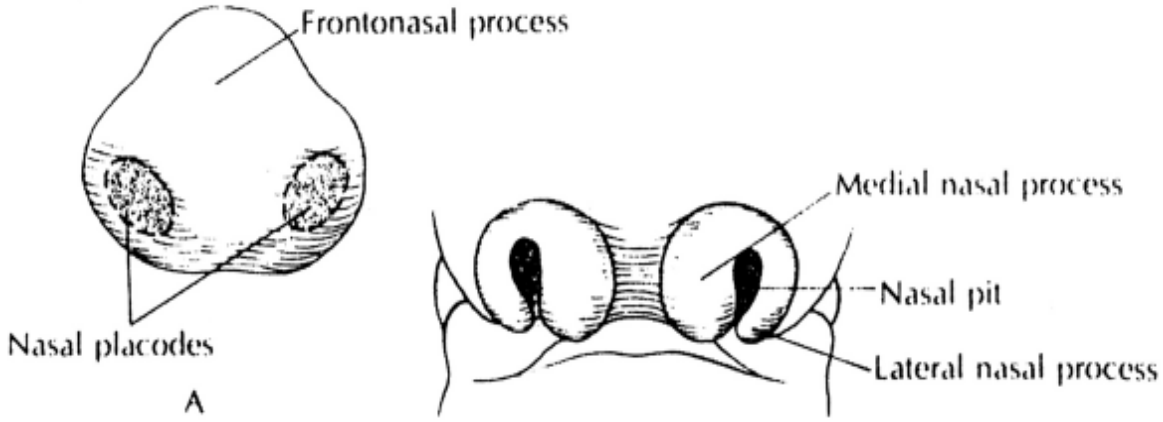

Fig. 11-4.

Simultaneously, paired **maxillary processes** develop near the base of the first pharyngeal arch (mandibular arch). They enlarge and grow ventrally and medially, surrounding the future oral cavity. The maxillary processes grow rapidly, first meeting the lateral nasal processes, and then the lower extension of the medial nasal processes. This lower extension is known as the **globular or intermaxillary process** and will give rise to the midstructure (**philtrum**) of the upper lip.

It is important to realize that diagrams representing facial development between 4 and 6 weeks generally don't depict the enormous increase in dimension within this period; the face actually **grows 10-fold** in linear dimension! While the eyes are located initially on the sides of the head, they face forward by 8 weeks. The eyes don't actually move together, the rest of the face is growing.

MERGING VS. FUSION OF FACIAL PROCESSES

Most facial processes begin as two separate swellings separated by a groove. **Merging** is the process by which the groove between two facial processes is eliminated (Fig.11-5). The ***tissues in the groove "catch up" by proliferating more rapidly*** than the surrounding tissues, causing the groove to become progressively shallower until it smoothes out. Merging is critical. Without it, a deep depression (a **facial cleft**) remains between what used to be the facial processes. **Examples** of merging are: merging of the 2 mandibular processes (the former mandibular arch) in the midline, merging of the 2 medial nasal processes in the midline, merging of lateral nasal and maxillary processes, and the merging of mandibular and maxillary processes. **Fusion** is the process by which two facial processes, that were

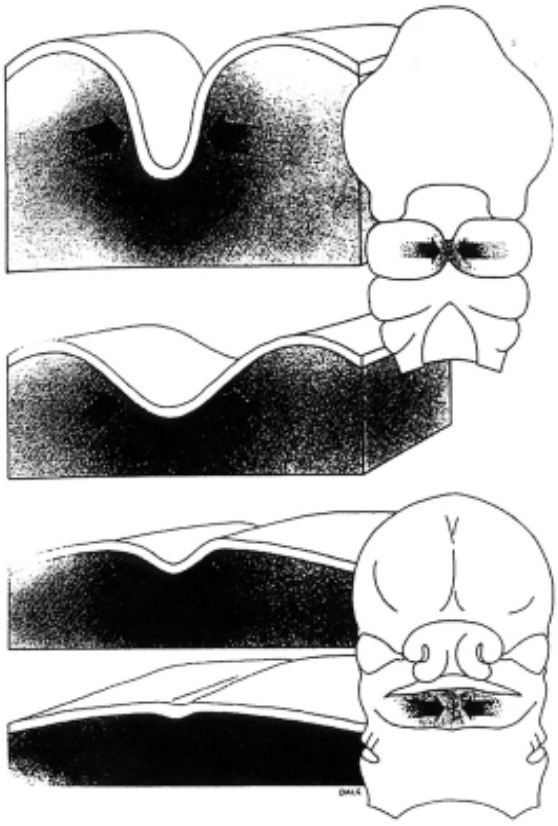

Fig.11-5. Apparent fusion of facial processes by the elimination of a furrow between them.

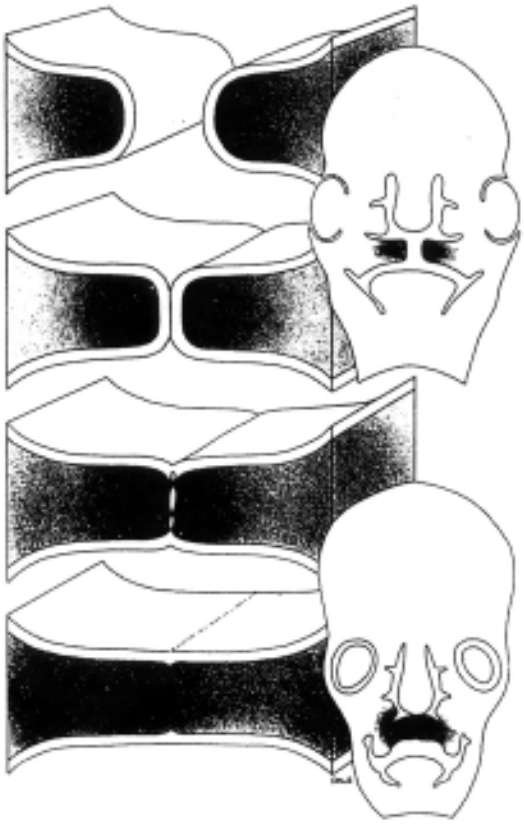

Fig.11-6. True fusion of processes (e.g., the palatal process). Such fusion involves breakdown of surface epithelium.

initially separated by a space, grow together (Fig.11-6). An example of fusion is the formation of the secondary palate (see below) where two facial processes grow toward each other, touch each other and then fuse in the midline. In fusion, unlike merging, ***the epithelium is broken down*** where the two processes meet.

PALATE FORMATION

Tissue intervening between nasal and oral cavities is known as the palate. By the 6th week the **primary palate,** formed by the two maxillary and two medial nasal processes, separates the developing oral and nasal cavities.

Subsequently, between 6th and 8th weeks, the **secondary palate** is formed from two palatal processes (outgrowths of the maxillary processes).

Primary and secondary palates together form the **definitive palate**.

DEVELOPMENT OF THE PRIMARY (PRIMITIVE) PALATE

The primary palate develops at the same time as the external face (fifth and sixth weeks). The maxillary processes undergo extensive growth, first coming into contact with the lateral nasal processes and secondly with the globular process of the merged medial nasal processes (philtrum).

Initially the medial nasal and lateral nasal processes come into contact, and secondarily, the medial nasal and maxillary processes come together (just below and in front of the contact site between the medial and lateral nasal processes) and pinch some epithelium between them. This sheet of epithelium is composed of future nasal epithelium superiorly, and future oral epithelium inferiorly. The

two layers of epithelium are then pulled apart, making the mesenchyme between medial nasal and maxillary processes continuous (Fig.11-7): the core of the **primary palate**.

Posteriorly, behind the primary palate, the nasal epithelium continues to touch the oral epithelium. This patch of epithelium is called the **oronasal membrane** (Fig.11-8). Around the 6th week

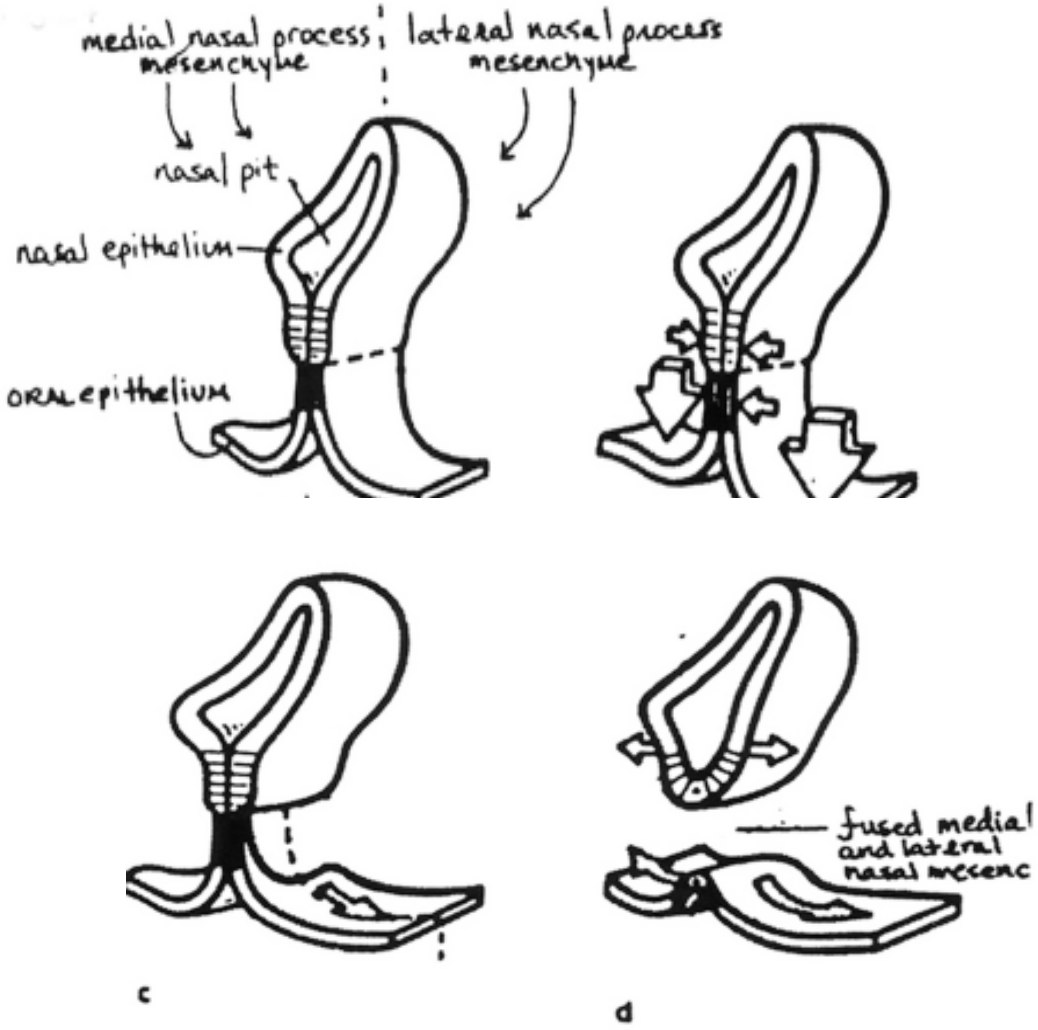

Fig. 11-7.

Fig. 11-8.

of development this membrane is ripped open in the same manner as the oropharyngeal membrane (cells stop undergoing mitosis). The resulting opening is called the **primitive choana**, and it connects the nasal cavity to the oral cavity. Remember that there are two primitive choanae, one for each nasal cavity (Fig. 11-9). Occasionally the oronasal membrane does not break apart. A choana must then be surgically established at birth.

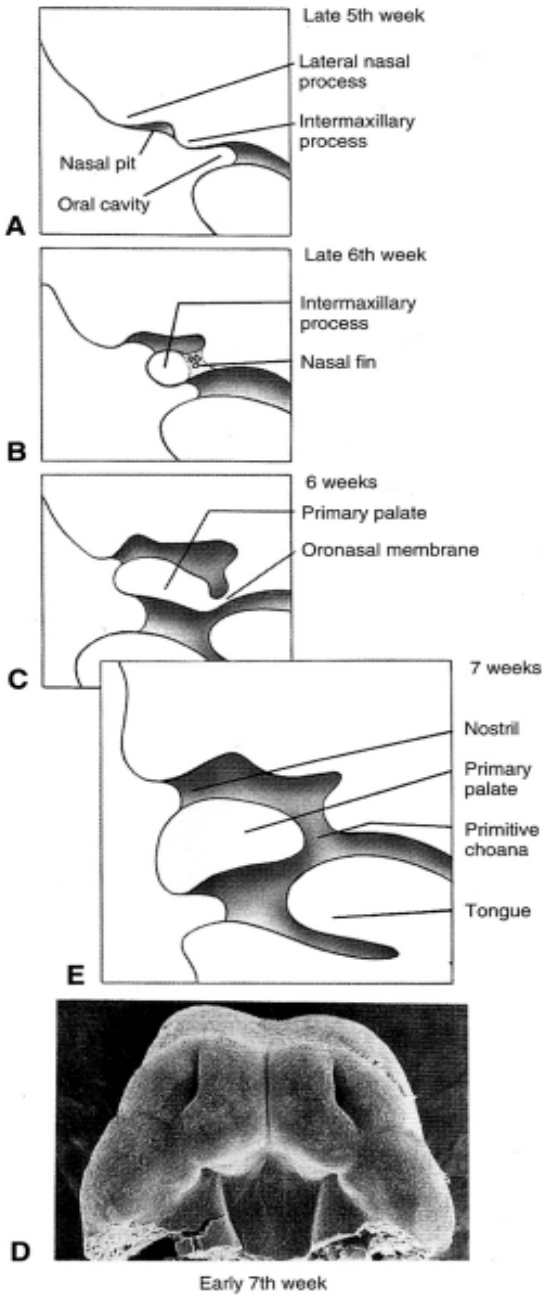

Fig. 11-9. Formation of the nasal cavity and primitive choana. *A, B,* The nasal pits invaginate to form a single nasal cavity separated from the oral cavity by a thick partition called the nasal fin. *C-E,* The nasal fin thins to form the oronasal membrane, which breaks down completely to form the primitive choana. The posterior extension of the intermaxillary process forms the primary palate. (D, Photo courtesy of Dr.Arnold Tamarin.)

DEVELOPMENT OF THE SECONDARY PALATE

The posterior border of the primary palate is located just posterior (caudal) to the site of the future incisive foramen of the skull. As the face grows in an antero-posterior (rostro-caudal) dimension, the primary palate soon is too short to provide adequate separation between the nasal cavities (respiratory function) and the oral cavity (digestive function). A new structure: the secondary palate develops to further separate these cavities.

During the seventh and eighth weeks, the medial walls (the oral surfaces) of the maxillary processes produce a pair of thin medial extensions, called the **palatal processes** (shelves). Initially these grow predominantly vertically: downward and parallel to the lateral surfaces of the tongue. By the beginning of the eighth week, however, the tongue begins to contract and move out of the way. In addition, the lower jaw drops as it grows downward and forward.

By the end of the eighth week, the palatal processes rotate rapidly upward to a horizontal position and fuse with each other and with the primary palate (Fig. 11-10). The fused palatal processes form the **secondary palate** - together with the primary palate they form the **definitive palate**.

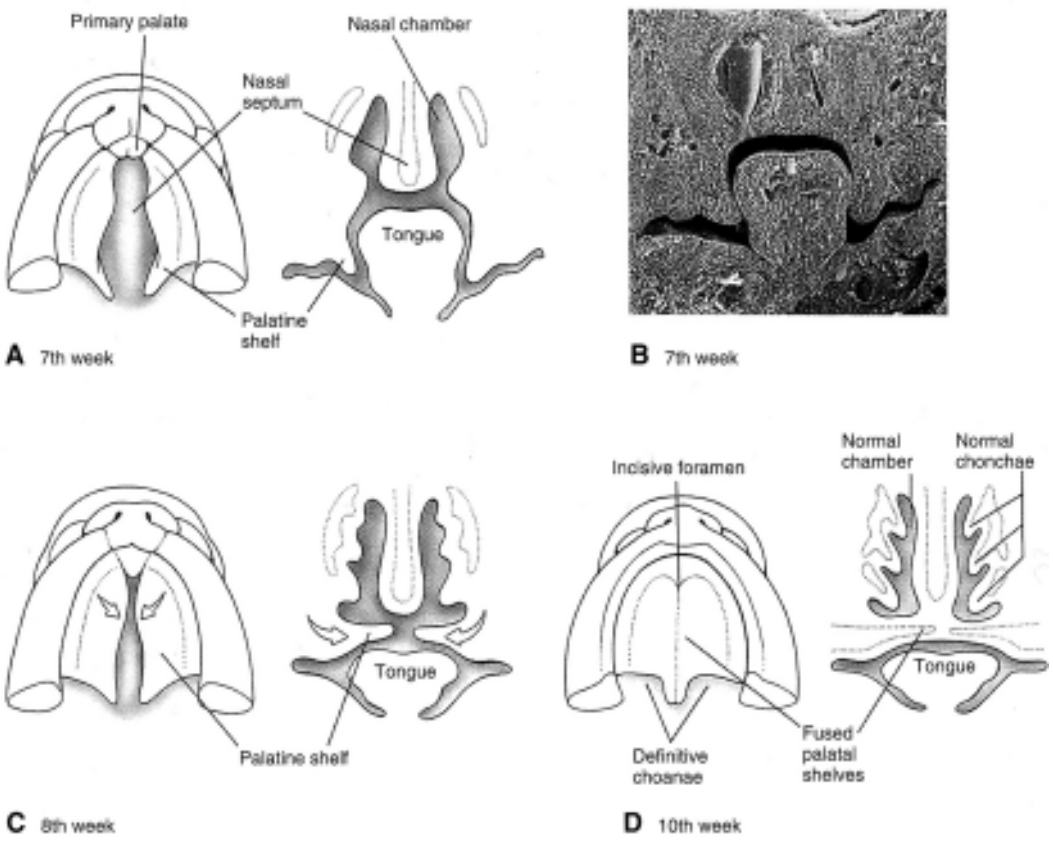

Fig. 11-10. Formation of the secondary palate and nasal septum. The secondary palate forms from palatine shelves that grow medially from the maxillary swellings. During the same period, growth of the nasal septum separates the left and right nasal passages. The palatine shelves at first grow inferiorly on either side of the tongue *(A, B)* but then rapidly rotate upward to meet in the midline (C), where they fuse with each other and with the inferior edge of the nasal septum (D). (B, Photo courtesy of Dr. Arnold Tamarin.)

The successful development of the secondary palate depends on **many factors**:

- **extrinsic factors**
  - swallowing movements of the tongue, moving the tongue out of the way from in between the two palatal processes and allowing them to move upward
  - downward and forward growth of the lower jaw and tongue complex, providing more space above the tongue for the palatal processes
  - straightening of the cranial base as the result of growth of the neural mass, establishing the mechanical environment for the palatal processes to swing upward

- **intrinsic factors in palatal processes**
  - *mesenchyme*
    cell proliferation - increasing volume- ceases hours before palatal processes swing upward
    extracellular matrix production - increasing volume
    hydration of extracellular matrix - major increase in volume and turgor of palatal processes just before they swing upward
  - *medial edge epithelium (MEE)* - covering the free edges of the palatal processes
    apoptosis of MEE surface cells immediately prior to fusion
    development of a temporary glycoprotein coat, enabling adhesion between MEE cells of the two opposing palatal processes

FACIAL MALFORMATIONS

Various types of cleft lip and cleft palate may be encountered clinically. Complete clefts indicate the maximum degree of clefting of any particular type (e.g. a complete cleft of the secondary palate, a complete cleft of lip, alveolar process and primary palate, or a combination of these two). Incomplete clefts are found when some merging or fusion has taken place during development. Clefts may be unilateral or bilateral (Figs. 11-11, 11-12). **The important thing to remember clinically is: each site where merging or fusion occurs during development of face and palate is a potential site for a facial/palatal cleft.**

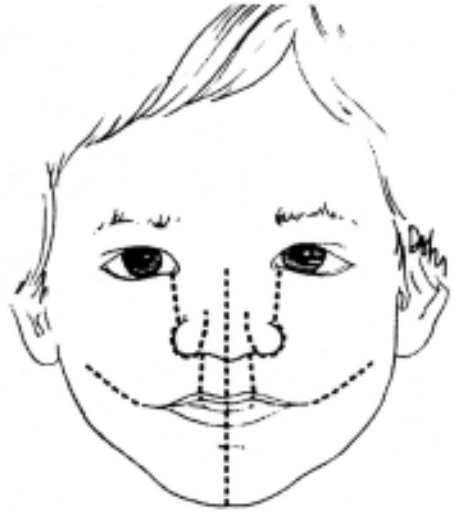

Fig. 11-11. In this diagram of a face, the broken lines indicatte the possible locations of facial clefts. The areas between the broken lines correspond with the areas formed by the original facial processes.

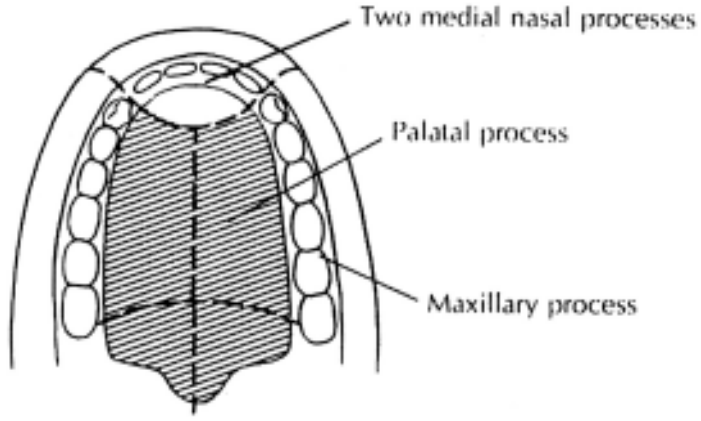

Fig. 11-12. A diagram of the hard and soft palates, as they appear viewed from below. The area of the front teeth corresponds with the primitive palate, formed largely by the two medial nasal processes. The shaded part of the palate (part of the hard palate in front, and the soft palate in the back) is formed by the two palatal processes, which come together and fuse in the midline. Clefts are possible at all “seams” between the medial nasal processes and the palatal processes and in the midline between the two palatal processes.