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ANATOMICAL, SCANNING ELECTRON AND LIGHT MICROSCOPICAL STUDIES ON THE PRENATAL DEVELOPMENT OF THE NASAL CONCHAE OF THE ONE-HUMPED CAMEL (CAMELUS DROMEDARIUS)

(With 30 Figures)

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دراسات تشريحية وميكروسكوبية اليكترونية ماسحة وضوئية على التطور الجنينى للمحارات الأنفية فى الجمل وحيد السنام

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أجرى هذا البحث على عدد خمسة وثلاثين جنينا للجمل وحيد السنام وذلك لدراسة الصفات التشريحية والميكروسكوبية اللإلكترونية الماسحة والضوئية للمحارات الأنفية أثناء الحياة الجنينية. ظهرت المحارات الأنفية الظهرية والوسطى والبطنية بالميكروسكوب الضوئى عند طول جنينى ٤,٢سم فى شكل بروزات من الجدار الخارجى للتجويف الأنفى. أما تشريحيا، فمنذ ظهورها بشكل واضح عند طول جنينى ١٧سم وحتى الأجنة كاملة النمو، كان هناك تغيرات عينية قليلة فى المحارات الأنفية وكانت هذه التغيرات مقصورة على طول الصفائح الحلزونية وحجم الجيوب التى فى داخلها. هذا وقد كانت المحارة الظهرية ممثلة بصفيحة قاعدية فقط فى الجزء الأمامى بينما إحتوت على جيب محارى ظهرى فى الجزء الذيلى منها، بينما كانت المحارة البطنية مكونة من صفيحتين حلزونيتين ظهرية وبطنية فى الجزء الأمامى واللتين أعادتا ترتيب نفسيهما الى أنسية ووحشية فى الجزء الذيلى منها. أما المحارة الوسطى فإحتوت على جيب محارى أوسط. هذا وأظهر الميكروسكوب الإلكترونى الماسح والضوئى مجموعة من التغيرات فى تركيب المحارات الأنفية أثناء الحياة الجنينية. تميز سطح الغشاء المغطى للمحارات الأنفية عند طول جنينى ١٥سم بوجود خلايا فى مراحل مختلفة من الإنكماش والإنفصال عن هذا السطح حيث تستبدل بخلايا أخرى جديدة. عند منتصف مدة الحياة الجنينية تقريبا (عند طول جنينى٥٠سم)، كان سطح المحارات الأنفية مغطى بحلمات دقيقة وأهداب والتى كانت تزداد على حساب الحلمات كلما إتجهنا ذيليا فى التجويف الأنفى. بينما كان هناك صعوبة فى التمييز بين الجزء التنفسى والجزء الشمى بإستخدام الميكروسكوب الماسح إلا من وجود بعض البروزات النفطية وسط الأهداب الشمية، كان التمييز بين الإثنين سهلا بالميكروسكوب الضوئى حتى فى المراحل المبكرة، فقد كان النسيج الطلائى التنفسى أقل سمكا فى البداية ثم ظهرت به خلايا كأسية عديدة عند طول جنينى ٥٠سم، أما النسيج الطلائى الشمى فلم يحتوى على خلايا كأسية ولكن ظهر به دياميس

قارورية بها خلايا حسية فى الأجنة كاملة النمو. يستخلص من هذه الدراسة أن الجمل يتميز بمجموعة من المواصفات الخاصة والتى تخصه كحيوان صحراوى من أهمها كثرة الخلايا الكأسية والغدد التى تفرز كميات كبيرة من السائل المخاطى على سطح محاراته الأنفية، هذا إضافة إلى وجود كمية كبيرة من الشعر الطويل فى بطانة الدهليز الأنفى.

SUMMARY

Thirty-five camel fetuses were used in this study to investigate the anatomy, scanning electron and light microscopy of the nasal conchae of the camel during the prenatal life. The dorsal, middle and ventral nasal conchae are recognized microscopically as early as 4.2cm CVRL in the form of three evaginations from the lateral wall of the nasal cavity. From being clearly visible grossly (at 17cm CVL), the nasal conchae demonstrate little gross changes which are restricted to an increase in the length of their spiral lamellae and consequently the size of their recesses and sinuses. In full-term fetuses (105cm CVRL), the dorsal concha is represented by basal lamella rostrally, but caudally it forms the dorsal conchal sinus. The ventral concha has two spiral lamellae arranged as dorsal and ventral ones rostrally, but caudally they rearrange themselves as medial and lateral respectively. The middle concha encloses a large middle conchal sinus. Scanning electron and light microscopy reveals number of transformations in the surface epithelium of the nasal conchae in both respiratory and olfactory regions. The surface cells that acquire microvilli and short cilia in earlier stages start to be sloughed and replaced by the underlying cells around 15cm CVRL. By light microscope, these sloughing cells appear with pyknotic nuclei and vacuolated cytoplasm. From 50cm CVRL to full-term fetuses, the covering epithelium of the nasal conchae demonstrates regional variations in the distribution of ciliated and microvillous cells. In the most rostral part, the two cell types partake the surface. The ciliated cells increase gradually at the expense of the microvillous cells on approaching the olfactory region, where the ciliated cells are dominating. With exception of the presence of bleb-like apical protrusions amidst the ciliated surface of the olfactory epithelium, both olfactory and caudal areas of respiratory epithelia have the same picture of their massively-ciliated surface. Light microscopically, the respiratory and olfactory epithelia are easy to be differentiated as early as 5.8cmCVRL. At 8-12cm CVRL, the respiratory epithelium is very thin (about 28μm) when compared with the thick olfactory epithelium (about 67μm) at this stage. From mid-gestation (50cm CVRL) and on, both epithelial types are pseudostratified columnar ciliated in nature, but the respiratory

epithelium demonstrates many goblet cells. The olfactory epithelium, on the other hand lacks goblet cells but the olfactory cilia are characterized by vesicular swellings. In full term fetuses, the olfactory epithelium is characterized by flask-shaped crypts containing 5-8 bipolar sensory cells. In conclusion, the nasal cavity of the camel as a desert animal has number of peculiar features, of these is the presence of numerous goblet cells and mucous secreting glands in the surface epithelium of the nasal conchae. In addition the nasal vestibule has collection of long hairs in its cutaneous lining.

Key word: *Nasal conchae – development t- scanning and light microscopy - camel.*

INTRODUCTION

The arrangement and structure of the nasal conchae in the nasal cavity plays an important role in conditioning of the inspired air. Although this function is important in all mammalian species, it seems to be much more important in the camel as a desert animal.

The anatomy and histology of the nasal conchae have been studied in canines (Kumar *et al.*, 1994), cattle (Pass *et al.*, 1971; Menco *et al.*, 1978; Adams, 1986), goat (Kumar *et al.*, 1992), horse (Kumar *et al.*, 2000) camel (Badawi and Fath El-Bab, 1973) and man (Davis and Smallman, 1988). The development of the nasal surface epithelium has been reported in mouse (Cuschieri and Bannisten, 1975), rat (Menco and Farbman, 1985, 1987) and man (Pyatkina, 1982). A developmental study on the nasal conchae and their covering epithelium in the camel is lacking in the available literature. The paucity of literature on the development of the nasal conchae in domestic animals has evoked the need for exploration of the gross anatomical, scanning electron and light microscopy of the camel nasal conchae during the prenatal life.

MATERIALS and METHODS

Thirty-five camel fetuses ranging from 4.2cm to 105cm (full term) crown vertebral rump length (CVRL) were used in this study. Twelve fetuses were used for gross anatomy, 9 for scanning electron microscopy and 14 for light microscopy. Younger fetuses (4.2-30cm CVRL) were totally perfused via the umbilical arteries by a paraformaldehyde (2.5%) and glutraldehyde (2.5%) solution in 0.1M

phosphate buffer (pH 7.4). In older fetuses (More than 30cm CVRL), only the head were perfused with the same fixative.

For gross anatomy, the heads were sectioned sagittally and crossly to investigate the shape and arrangement of the nasal conchae in different stages. For scanning electron microscopy, pieces of the nasal conchae were post-fixed in osmium tetraoxide 1% in phosphate buffer for 2 hours followed by washing in the same buffer. The samples were then dehydrated in ascending grades of ethanol followed by critical point drying in carbon dioxide then sputter-coated with gold and examined with a JEOL-5400LV scanning electron microscope. For light microscopy, the heads of the younger fetuses (4.2-12cm CVRL) were processed for paraffin embedding, sectioned (5-7μm thick) and stained with H & E. In older fetuses, small pieces of all nasal conchae from different locations were post-fixed in osmium tetraoxide 1% in phosphate buffer for 2 hours followed by washing in the same buffer. The samples were then dehydrated in ascending grades of ethanol and embedded in ERL. Semithin sections (1-2μm) were stained with toluidine blue and examined light microscopically. The epithelial height in all regions and stages was measured using an image analysis system (Leica Q500).

RESULTS

Fetuses less than 12cm CVRL:

The nasal conchae (dorsal, middle and ventral) are recognized microscopically in an earlier stage (4.2-5.8cm CVRL) in the form of evaginations from the lateral wall of the nasal cavity (figs. 1, 2). At this stage, the nasal conchae have thick and dense mesenchymal core, which is not yet differentiated into cartilage. The surface epithelium is thick (about 65μm) and pseudostratified with few short cilia and microvilli. This epithelium appears covering the three nasal conchae and the nasal septum at 4.2cm CVRL, but soon and in 5.8cm CVRL, it starts to recede from the ventral concha (Fig. 2). An incomplete subepithelial vascular network is demonstrated in all parts of the nasal cavity.

At 8-12cm CVRL, each nasal concha has a cartilaginous supporting plate covered by a thick mesenchymal envelope and a surface epithelium. The rostral part of the ventral nasal concha appears formed of a basal lamella and two short spiral lamellae; dorsal and ventral (Fig. 3), but in the caudal part they are not yet well-recognized (Fig. 4). The covering epithelium is now easily differentiated into two types. The first type covers the caudal part of the dorsal nasal concha and its adjacent

nasal septum as well as most of the middle concha, in addition to the ethmoidal conchae. It is thick and pseudostratified (about 67μm), some of its cells (sensory cells) develop axonal fibres that pass toward the forebrain (Fig. 5). The second one is thinner than the above (about 28μm). Few scattered short cilia and microvilli can be demonstrated specially in the caudal part of the nasal cavity.

Fetuses ranging from 15-105cm CVRL:

In this period, it is convenient to describe the nasal conchae grossly at first then by scanning electron and light microscopy.

Gross anatomy:

The dorsal, middle, ventral and ethmoidal conchae are clearly-recognized grossly at 17cm CVRL (Figs. 6, 8, 10). The dorsal nasal concha is represented by a more or less uniform long elevation that fades out caudally dorsal to the middle and ethmoidal conchae. It extends rostrally in the nasal vestibule forming a clear straight fold. In cross section, the dorsal concha is represented only by a basal lamella in its rostral two thirds, while caudally it forms a small dorsal conchal sinus which communicates with the small frontal sinus in this stage. The ventral nasal concha has a fusiform shape with narrow rostral and caudal ends. The rostral end bifurcates in the nasal vestibule forming alar and basal folds. The caudal part of the ventral concha constricts and inclines in a caudoventral direction ventral to the middle concha. In its rostral two thirds, the ventral concha forms two spiral lamellae long dorsal and short ventral ones enclosing two recesses. In the caudal third, the dorsal spiral lamella inclines ventrally to lie below the middle concha. In this part the dorsal and ventral spiral lamellae of the ventral concha become rearranged as medial and lateral lamellae respectively. The middle nasal concha has a triangular shape, the caudally placed base is continuous with the ethmoidal conchae. In cross section, the middle concha appears enclosing a small sinus.

By advancement of fetal ages, the nasal conchae display no great gross changes except for the increase in their size where the spiral lamellae attain more elongation leading to enlargement of their recesses and sinuses. In full term fetuses (Figs. 7, 9, 11), the dorsal nasal concha becomes uniform in width along its rostral two thirds, but on approaching the middle concha, it enlarges in a ventral direction then retracts again dorsally. In cross section, it still has only a basal lamella rostrally, but caudally its large conchal sinus is in a partial continuity with the cellule of the frontal sinus. The ventral nasal concha attains more fusiform shape occupying most of the rostral two thirds of the

nasal cavity. Its rostral end bifurcates in the nasal vestibule forming an alar fold dorsally and basal one ventrally. In the rostral two thirds, the ventral concha still has dorsal and ventral spiral lamellae. The dorsal lamella encloses a long narrow recess and ends in a small bulla, while the ventral one forms a short and wide recess and terminates in a large bulla at its free end. In the caudal third, the ventral concha, rearranges its spiral lamellae in a medial (formerly dorsal) and lateral (formerly ventral) ones to leave a space for the middle and ethmoidal conchae. The middle nasal concha together with the ethmoidal conchae occupy most of the caudal part of the nasal cavity. The middle conchal sinus which is enclosed in the middle concha is crescent in cross section with a concave ventral border. The nasal vestibule in full-term fetuses demonstrates excessive hair collections in its cutaneous lining.

Scanning electron and light microscopy:

At 15cm CVRL, the scanning electron microscope reveals that the surface epithelium has different pictures from region to another. The rostral parts of the dorsal and ventral nasal conchae demonstrate a different picture in comparison to the middle and caudal parts. Rostrally, the covering cells are mixture of oval and globular shaped cells (Fig. 12). The globular cells are almost bare (with no microvilli nor cilia) and have wrinkled appearance, while the oval cells carry short microvilli. In addition, scattered punches of cilia appear emanating amidst the forgoing cells. In the middle part of the nasal cavity, the surface cells are mostly globular with wrinkled surfaces (Fig. 17). Few cells demonstrate short microvilli while some other cells appear invaginated or collapsed. Several collections of long cilia are displayed in between the surface cells. In the caudal part of the nasal cavity, the putative olfactory epithelial cells are also globular with large intervening spaces filled with collections of long cilia that seem to be emanating from deeper cells (Fig. 18). Although the olfactory (about 68μm thick) and respiratory (about 29μm thick) epithelia are easily differentiated light microscopically at this stage, both are not yet well-developed. The globular or oval surface cells described by scanning appear here loosing contact with the basement membrane and in different stages of sloughing process. These sloughing cells have pyknotic nuclei and lightly stained vacuolated cytoplasm (Figs. 25, 26).

By advancement of fetal ages, the conchal surface of both respiratory and olfactory regions becomes more ciliated as revealed by scanning electron microscopy. At 50cm CVRL the surface epithelium displays the presence of ciliated and/or microvillous cells. Rostrally and

at the boundary of the nasal vestibule, only microvillous cells cover the surface (Fig. 13). At the beginning of the middle part of the nasal cavity, the ciliated and microvillous cells share the surface (Fig. 14). Moving caudalwards, the ciliated cells increase at the expense of the microvillous cells (Fig. 19). The latter picture is the same in the olfactory region (Fig. 20). Several openings are demonstrated on the surface of the nasal conchae in both respiratory and olfactory regions. Light microscopically, the respiratory and olfactory epithelia start to attain their known histological characters. In the respiratory region (Fig. 27), the epithelium (about 54 μm thick) demonstrates numerous goblet cells and ciliated surface. The subepithelial connective tissue layer shows tubular glands and vascular venous plexus. The olfactory epithelium (about 70 μm thick) in this stage is also pseudostratified columnar ciliated, vesicular swellings are demonstrated along the olfactory cilia. The olfactory receptor cells are clearly recognized in a mid-position between the basal and apical cells. These receprtor cells have almost spherical nuclei (Fig. 28).

In full term fetuses (105cm CVRL), the scanning electron microscope reveals that the epithelium covering the nasal conchae in the respiratory area is also variable from area to another. Rostrally, the surface is partially ciliated and partially microvillous (Fig. 15, 16). Caudalwards, the ciliated cells also increase at the expence of the microvillous cells, where the former cells almost cover the surface near the olfactory area (Figs 21, 23). The glandular openings mentioned in the previous stage are now increased in both number and size. The cells surrounding these openings are always microvillous. In the olfactory region, the surface is also ciliated with many openings in between (Figs. 22, 24). Apart from the presence of bleb-like protrusions amidst the massively ciliated surface, it is difficult to differentiate the olfactory from the respiratory surfaces (Compare figs. 23 and 24). In addition, the openings of the Baumans glands, found in the olfactory region, have almost uniform size and are surrounded by long cilia. By light microscope, the respiratory epithelium (about 65 μm thick) demonstrates little changes in comparison to the previous stage, the tubular glands are now well-developed (Fig. 29). The olfactory epithelium (about 71μm thick), on the other hand, displays the presence of flask-shaped crypts containing groups of 5-8 receptor cells (Fig. 30). These cells are bipolar with superficial dendrites and basal axons. Additionally, the subepithelial connective tissue contains many variably sized nerve fascicles.

DISCUSSION

The dorsal, middle and ventral nasal conchae could be recognized microscopically as early as 4.2cm CVRL in the form of three evaginations from the lateral wall of the nasal cavity. Although the nasal conchae are not yet fully-developed, their general arrangement is already established at this stage. This finding disagrees with the previous statement of Patten (1953) and Arey (1965) in man that the nasal conchae arise as a series of elevated folds which decrease in number later on and become reduced to the three permanent conchae after birth.

The present study supports the previous statement that both respiratory and olfactory epithelia differentiate from the same epithelium i.e., the earliest olfactory placode (Vidic *et al.*, 1972). The dorsal, middle and ventral nasal conchae are covered by a thick pseudostratified columnar epithelium in the very early stage of development (4.2cm CVRL), but soon this epithelium starts to recede from the ventral concha, which is now covered by thin pseudostratified epithelium. Although some early reports (Cohn, 1903; Street, 1937; Weber, 1950) simulate this finding, others (Patten, 1953; Arey, 1965) ascertained that the olfactory epithelium is confined from the beginning to the ethmoidal conchae, parts of the middle and dorsal conchae as well as the adjacent part of the nasal septum.

From being visible grossly, the nasal conchae of the camel demonstrate little gross changes that are restricted to the increase in the length of their spiral lamellae and consequently the size of their recesses and sinuses. Unlikely, Romanoff (1960) inferred that the elongation of the nasal cavity, during development, causes the spatial relationships between the conchae to be somewhat altered.

In full term fetuses, the arrangement of the three conchae is almost the same like that reported by Badawi and Fath El-Bab (1973) in adult camel. However, the dorsal conchal sinus found in the caudal part of the dorsal concha of full term fetuses is partially communicated with the frontal sinus. In addition, the ventral concha extends in the nasal vestibule forming the alar and basal folds. The separation between the dorsal conchal and frontal sinuses and the absence of the basal fold, as described by Badawi and Fath El-Bab (1973) in adult camels, seem to be postnatal events.

During its development, the surface epithelium in both respiratory and olfactory regions undergoes a number of transformations as revealed by scanning electron and light microscopy. The major one of

these transformations seems to occur around 15cm CVRL where some of the epithelial cells start to loss their covering microvilli and cilia, become shrunken and seem to be in their way of sloughing. Light microscopy revealed that these cells have pyknotic nuclei, vacuolated cytoplasm and have lost their contact with the basement membrane. Sloughing of ciliated cells, during development of the respiratory passages, has been recorded by many researchers (Rhodin, 1966; Sayed, 1996; Sayed *et al.*, 1998).

Still in the above-mentioned period (around15cm CVRL), punches of long cilia are demonstrated amidst the sloughing cells and seem to be emanating from deeper cells. These deeper cells may be in their way to replace the sloughing cells. In the same connection, Menco and Farbman (1985,1987) postulated that the olfactory and respiratory epithelia acquire primary and secondary cilia, but they have mentioned nothing about the sloughing process. It can be assumed that the surface cells in both respiratory and olfactory regions acquire short cilia and microvilli in early stages of development, but soon these cells become sloughed and replaced by new cells that also develop cilia even before they get access to the surface.

The current study proves that ciliogenesis of both respiratory and olfactory epithelia occurs during the first halve of prenatal life. With exception of the rostral part of the dorsal and ventral conchae (near the nasal vestibule), the ciliated cells are predominating at the mid-gestation period (50cmCVRL). The timing of ciliogenesis is a matter of controversy among researchers, possibly due to species and/or regional differences. Although Menco and Farbman (1985, 1987) reported that ciliogenesis is a prenatal event in the nasal cavity of the rat, Smolich *et al* (1976) in rat and Kawamata and Fujita (1983) in mice ascertained that the development of ciliated cells in the larynx and trachea occurs postnatally. However, the ciliated cells are fully developed at birth in the trachea of rabbit (Leeson, 1961) and man (Gaillard *et al.*, 1989). In addition, Sayed (1998) mentioned that most of ciliary differentiation in the fetal bronchial epithelium occurs around the mid-gestation period.

In full term camel fetuses, the lining epithelium demonstrates regional variations in the distribution of ciliated and microvillous cells. In the rostral parts of the dorsal and ventral conchae, the two cell types partake the surface. However, the ciliated cells increase gradually at the expense of the microvillous cells on approaching the olfactory region where the ciliated cells are dominating. This finding agrees with the statements of Morgan *et al.* (1984) as well as Menco and Farbman (1987) in a developmental study on the nasal cavity of rat. It can be

postulated that parts of the nasal mucous membrane away from the direct air ways i.e. near the cull-de sac of the olfactory region posses more ciliated surface to facilitate getting red of the excessive mucous secretions and foreign particles.

With exception of the presence of bleb-like apical protrusions amidst the ciliated surface of the olfactory epithelium, both olfactory and caudal areas of respiratory epithelia have the same picture of their massively-ciliated surface during the second halve of the prenatal development. Menco and Farbman (1985) have described similar protrusions in the developing olfactory epithelium of the rat and postulated that they are supporting cell protrusions. Unlikely and in adults, several researchers have reported many distinctive differences between the two epithelial types. Kumar *et al.* (2000) have reported the presence of olfactory vesicles from which olfactory cilia are radiated in areas of the olfactory region with less intensive ciliary meshwork. In addition, Byrum et al. (2001) have described small spherical structures that appear to be ciliary swellings in the olfactory region of the shrew. It can be assumed that these characteristics of the olfactory epithelium may be masked by the massively ciliated surface in camel fetuses.

Light microscopically, the respiratory and olfactory epithelia are easy to be differentiated as early as 5.8cmCVRL. Although both are pseudostratified ciliated in nature, the respiratory epithelium demonstrates numerous goblet cells around the mid-gestation period (50cm CVRL). The olfactory epithelium, on the other hand lacks goblet cells but the olfactory cilia are characterized by vesicular swellings, a finding that has been reported in Shrew by Byrum *et al.* (2001). Later in development and in full term fetuses, the olfactory epithelium demonstrates a peculiar feature characteristic to the camel, which is the development of flask-shaped crypts containing number of bipolar sensory cells. This finding has been recorded in adult camel by Badawi and Fath-El-Bab (1973).

In conclusion, the nasal cavity of the camel as a desert animal has a number of peculiar features, of these is the presence of numerous goblet cells and mucous secreting glands in the surface epithelium of the nasal conchae. In addition the nasal vestibule has collection of long hairs in its cutaneous lining.

LEGENDS

Figs.1-5: Parrafin sections of the nasal cavity stained with H & E. X25.

Fig.1, 2: The caudal part of the nasal cavities in 4.2 and 5.8cm CVRL camel fetuses demonstrating the premordia of the dorsal (D),

middle (M) and ventral (V) nasal conchae. The mesenchymal core has a differentiating cartilaginous support. The olfactory epithelium starts to recede from the ventral concha at 5.8cm CVRL (Fig. 2). Note the nasal septum (S).

Figs. 3,4: The arrangement of the nasal conchae in the middle (Fig.3) and caudal (Fig.4) parts of the right nasal cavity at 9.1cm CVRL. Abbreviations: D (dorsal concha), M (middle concha), V (ventral concha, S (nasal septum), Vn (vomeronasal organ), F (forebrain). Note the difference in the thickness of both olfactory (arrow) and respiratory (arrowhead) epithelia. In addition, a subepithelial vascular plexus (double arrowheads) and the olfactory nerve fibres in cross section (double arrows) are demonstrated.

Fig.5: Part of the olfactory epithelium (E) covering the caudal part of the dorsal concha and the adjacent forebrain (F) at 10cm CVRL. Note the olfactory nerve fibres (arrows) that have already contacted the forebrain. X100

Figs. 6, 7: Sagittal sections of the right nasal cavities of camel fetuses at 17cm CVRL (Fig. 6) and full term (Fig. 7). With exception of the size difference, no apparent gross change could be observed. Abbreviations: D (dorsal choncha), M (middle concha), V (ventral concha), S (straight fold), A (alar fold), B (basal fold).

Figs. 8, 9: Cross sections of the rostral parts of the right nasal cavity at 17cm CVRL (Fig. 8) and full term (Fig. 9) demonstrating the dorsal and ventral conchae. The dorsal concha (D) is represented only by basal lamella while the ventral one (V) has two spiral lamellae, dorsal (arrow) and ventral (double arrow) enclosing two recesses.

Figs. 10, 11: Cross sections of the caudal parts of the right nasal cavity at 17cm CVRL (Fig. 8) and full term (Fig. 9) demonstrating the dorsal (D), middle (M) and ventral (V) conchae. The dorsal choncha encloses a sinus that communicates partially with the frontal sinus (F). The middle concha has also a sinus, while the two spiral lamellae of the ventral concha rearrange themselves in medial (m) and lateral (l) positions respectively.

Figs. 12: Scanning electron micrograph of the rostral part of the ventral nasal concha at 15cm CVRL. The surface cells are of different size and shape. They are either bare and shrunken (arrows) or microvillous (arrowheads). Few punches of cilia (double arrows) appear emanating from deeper cells. X800.

Figs. 13, 14: Scanning electron micrographs demonstrating the surface cells covering the rostral parts of the nasal conchae at 50cm

CVRL. The covering cells at the boundary of the nasal vestibule carry only microvilli (Fig.13), while slightly caudally, the microvillous and ciliated cells partake the surface (Fig. 14). X800.

Fig. 15: Scanning electron micrograph of the rostral part of the ventral nasal concha demonstrating the presence of longitudinal grooves (arrows) and few glandular openings (arrowheads). X150.

Fig. 16: Magnification from the previous picture demonstrating ciliated (C) and microvillous (M) cells around a glandular opening (G). X800.

Fig. 17-24: Scanning electron micrographs demonstrating the pictures of the respiratory epithelium on the ventral nasal concha in the middle part of the nasal cavity and the olfactory epithelium on the ethmoidal concha during three stages of prenatal life.

Figs. 17,18: The respiratory (Fig.17) and olfactory (Fig.18) epithelia at 15cm CVRL. The surface cells are almost globular and either bare (arrow) or carrying short microvilli (arrowheads), some of them are shrunken (asterisk). Punches of cilia (double arrows) are demonstrated amidst these cells. Theses punches are more numerous in olfactory region. X1000

Figs. 19, 20: The respiratory (Fig.19) and olfactory (Fig.20) epithelia at 50cm CVRL. Both surfaces are heavily ciliated with some glandular openings in between. X1000.

Figs. 21, 22: The respiratory (Fig.21) and olfactory (Fig. 22) epithelia in full term fetuses. Note the differences in the size and distribution of the glandular openings. X100.

Figs. 23, 24: Magnifications from Figs. 21, 22 showing the pictures of respiratory and olfactory epithelia. In both types, the surface is massively ciliated and contains glandular openings (G). The glandular opening, in the respiratory epithelium (Fig. 23), is surrounded by microvillous cells. Note the presence of bleb-like protrusions amidst the cilia in the olfactory epithlium (Fig. 24). X1000.

Figs. 25, 26: Paraffin sections stained with H & E of the respiratory (Fig. 25) and olfactory epithelia (Fig. 26) at 9.1cm CVRL. The olfactory epithelium (E) is more than three times as thick as the respiratory epithelium. Many cells near the surface are pyknotic and vacuolated (arrows). Note the subepithelial vascular plexus. X400.

Figs. 27, 28: Semithin sections stained with toluidine blue of the respiratory (Fig. 27) and olfactory (Fig. 28) epithelia at 50cm

CVRL. Although both are ciliated, the respiratory epithelium is characterized by the presence of goblet cells (G) while the olfactory epithelium is characterized by the presence of the sensory bipolar cells (arrow) and ciliary swellings (arrowheads). Note the subepithelial gland in the respiratory epithelium with mitotic figure (double arrow). X400.

Figs. 29, 30: Semithin sections stained with toluidine blue of the respiratory (Fig. 29) and olfactory (Fig. 30) epithelia in full term fetus. The respiratory epithelium is characterized by the presence of goblet cells (G) while the olfactory epithelium is characterized by the presence of ciliary swellings (arrowheads) and flask shaped crypts containing 5 sensory bipolar cells (arrow). Note the glandular duct traversing the respiratory epithelium (thick arrow). X400.

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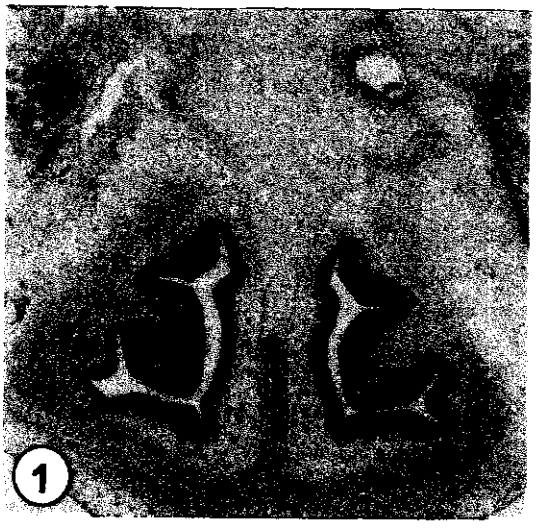
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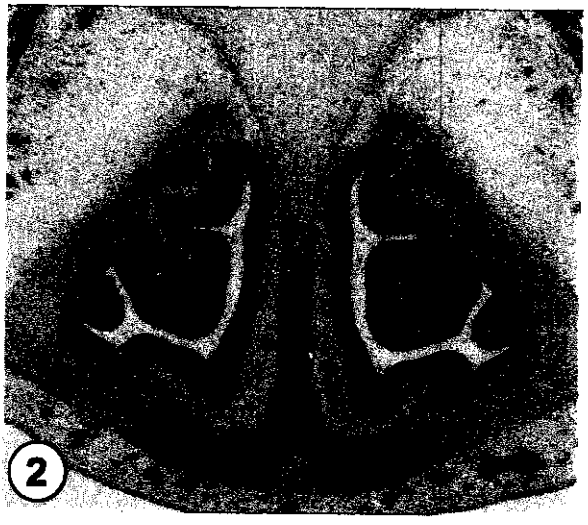
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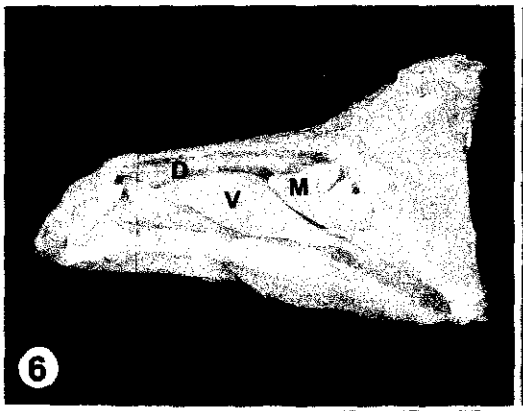
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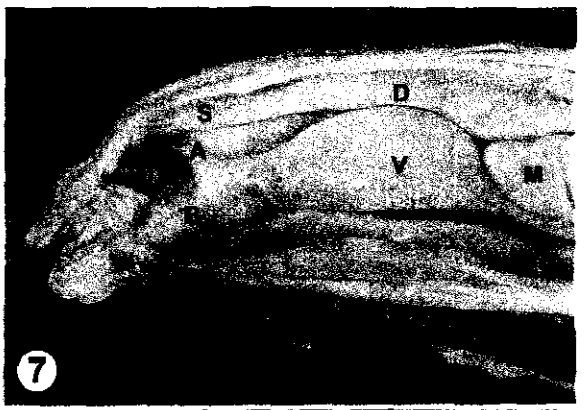
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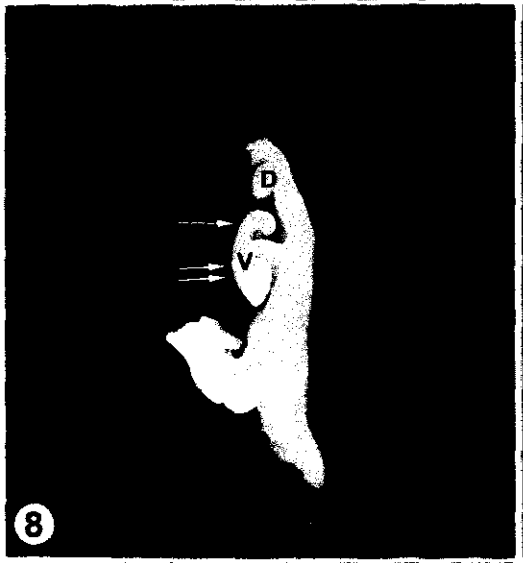
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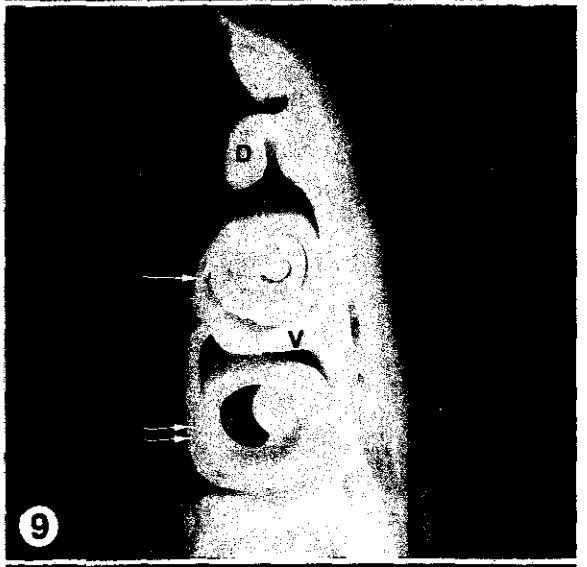
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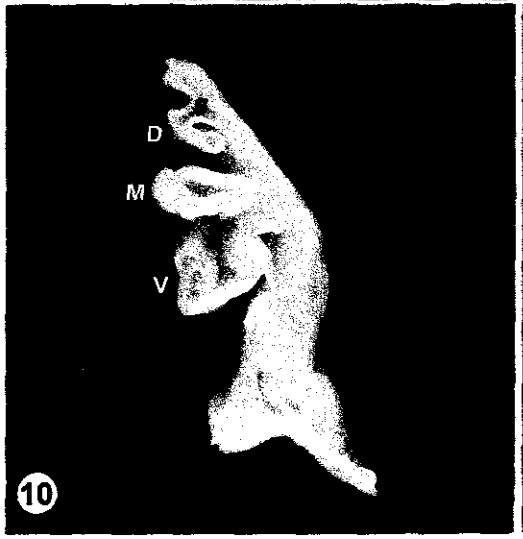
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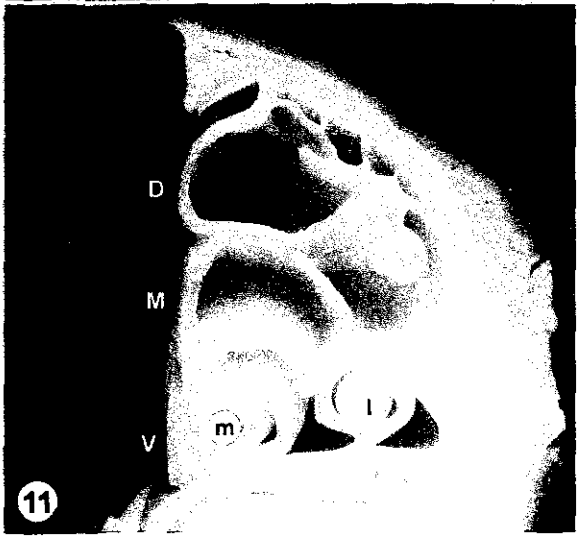
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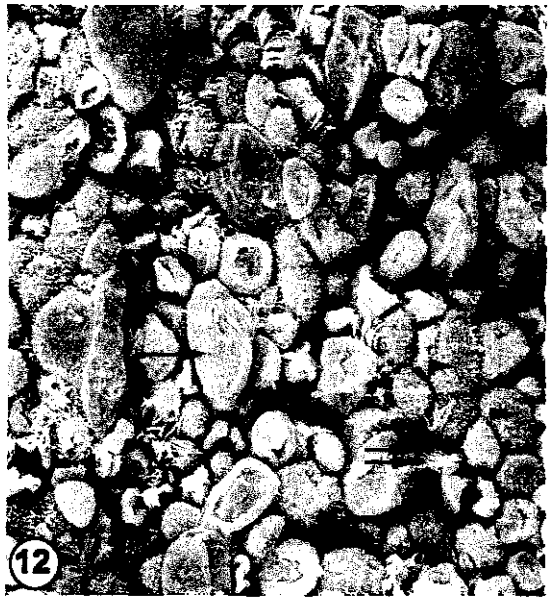
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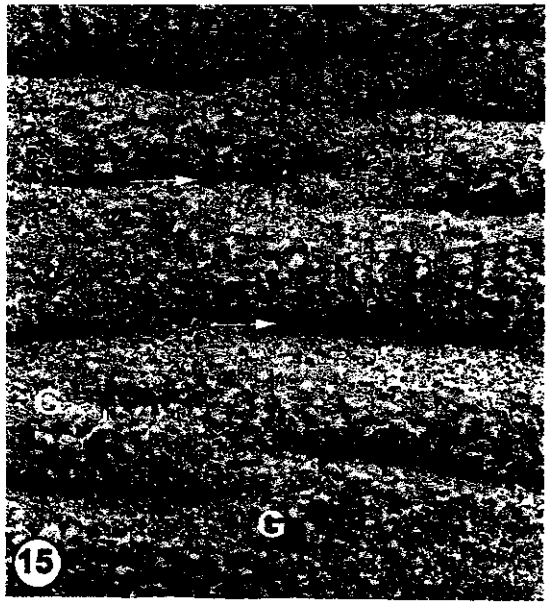
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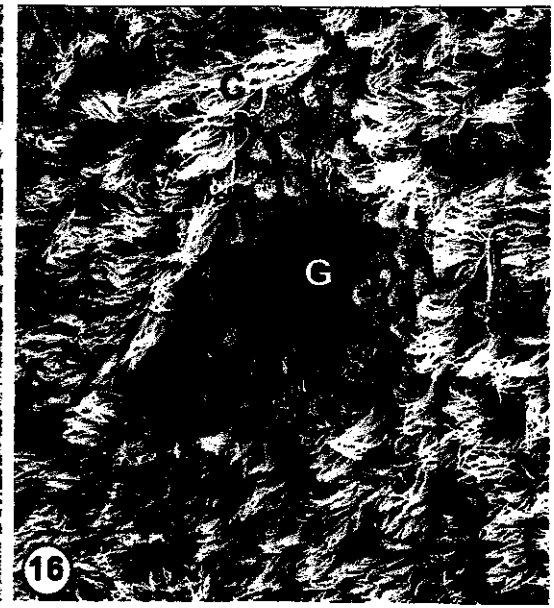
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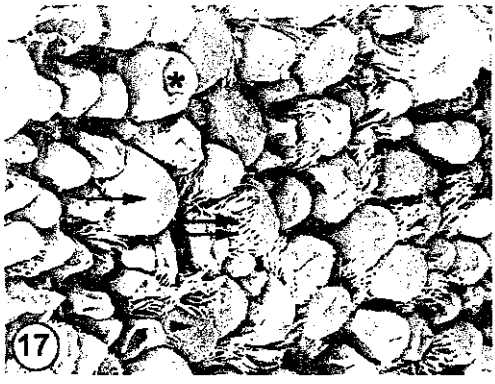
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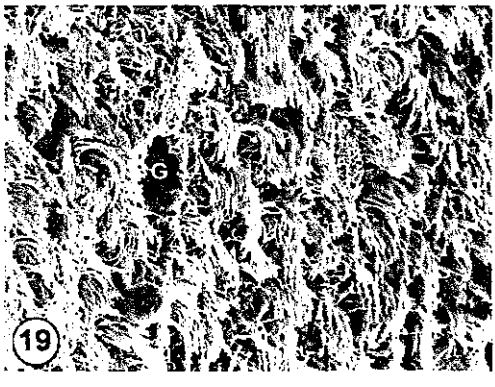
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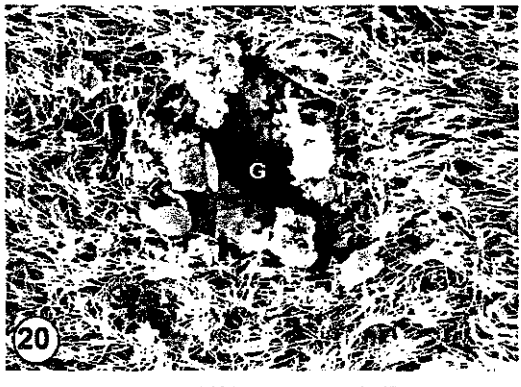
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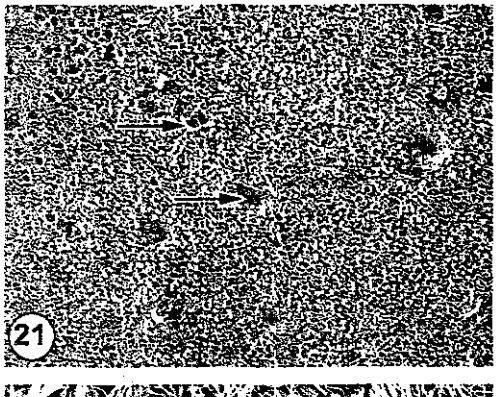
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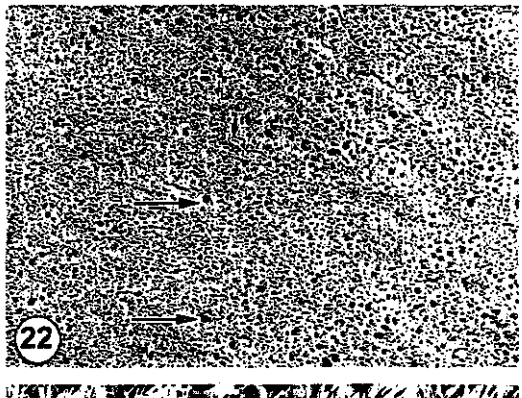
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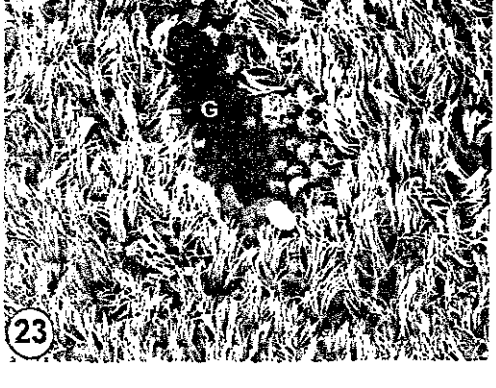
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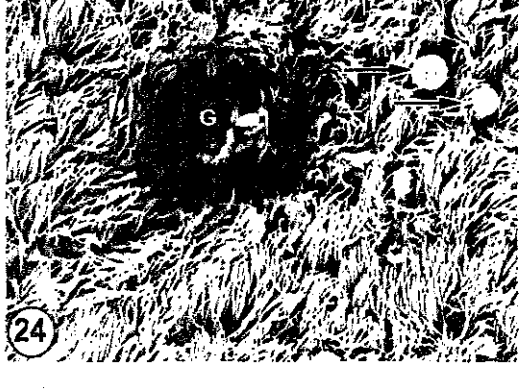
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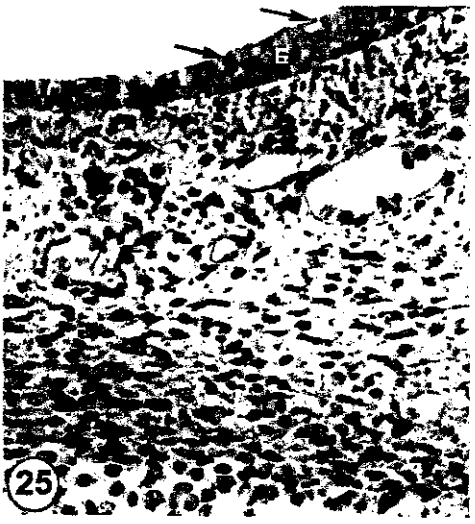
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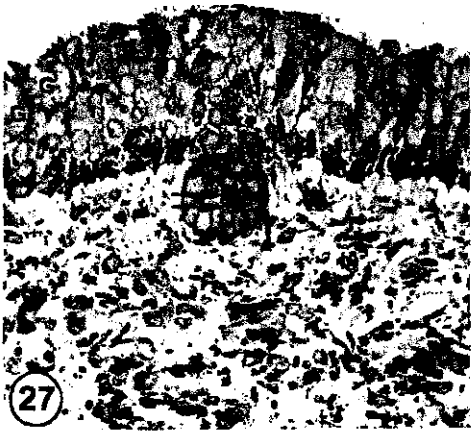
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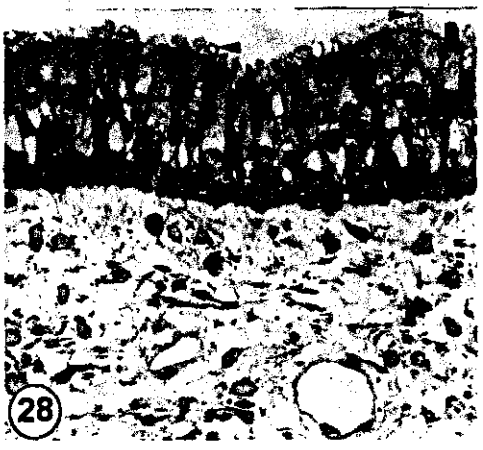
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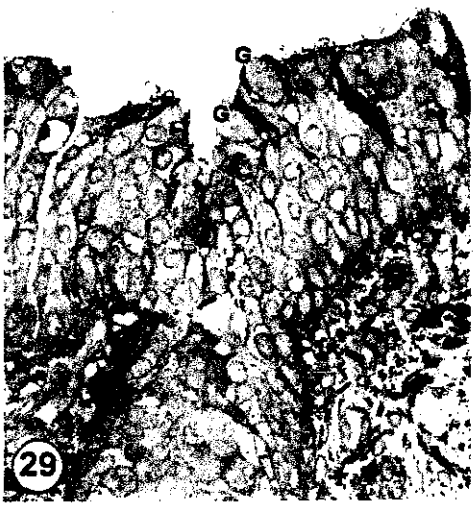
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