1971

Macroscopic anatomy of the nasal cavity and paranasal sinuses of the domestic pig (Sus scrofa domestica)

Daniel John Hillmann
Iowa State University

72-5208

HILLMANN, Daniel John, 1938-
MACROSCOPIC ANATOMY OF THE NASAL CAVITY AND PARANASAL SINUSES OF THE DOMESTIC PIG (SUS SCROFA DOMESTICA).

Iowa State University, Ph.D., 1971
Anatomy

University Microfilms, A XEROX Company, Ann Arbor, Michigan

Macroscopic anatomy of the nasal cavity
and paranasal sinuses of the domestic pig
(*Sus scrofa domestica*)

by

Daniel John Hillmann

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Veterinary Anatomy

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

For the Graduate College

Iowa State University
Ames, Iowa

1971

TABLE OF CONTENTS

INTRODUCTION

A severe economic loss is incurred by the swine industry as a result of diseases affecting the respiratory system. The nasal cavity, the most directly exposed portion of the respiratory system, represents a major site of infection. Switzer (1965) reported that hypoplasia and resorption of the nasal turbinates is the most common lesion affecting the nasal cavity of swine, and that any alteration of the morphology can subsequently result in alteration of the normal physiological processes.

In recent years, the domesticated pig has become increasingly popular in physiological, surgical, and gerontological investigations (Bustad, 1966). The pig's many similarities to man and its usefulness as a laboratory animal promise to increase its future importance in experimental biology. In spite of this, adequate morphological descriptions of the respiratory system of swine are lacking. Both the importance of respiratory disease to the swine industry and the need for more specific morphological information in burgeoning research, make essential the availability of detailed anatomical investigations of the respiratory system.

The research reported here provides certain detailed information regarding the macroscopic anatomy of the nasal cavity and the paranasal sinuses.

Definition of the terms nasal cavity (cavum nasi) and paranasal sinuses (sinus paranasales) may prove helpful in understanding the limits of the investigation. The nasal cavity is the cavity of the "nose", (the term "nose" used in a general sense and referring to the entire respiratory-olfactory organ) lined with specialized mucosa, communicating between the nares rostrally, the nasopharynx caudally, and the paranasal sinuses through their respective orifices. It is divided medially by the nasal septum into right and left portions, with the turbinates (conchae) projecting medially into the nasal cavity from the lateral walls. The cribriform plate, along with the nasal bones and cartilage forms the roof while the floor is formed by the hard palate.

The paranasal sinuses are excavations into the bones of the face and head, that are lined with mucous membrane derived from and continuous with that lining the nasal cavity. These definitions imply the limitations of this dissertation.

Major emphasis is placed upon the osteology of the nasal cavity and paranasal sinuses. This detailed osteological description is used as a basis for further observations regarding the associated tissues and structures.

Terminology used in the dissertation will correspond whenever possible, to that recommended and published in Nomina Anatomica Veterinaria, (1968).

REVIEW OF LITERATURE

Historical

Awareness of the nose and its significance to life dates back into ancient history. More than three thousand years before the birth of Christ, recorded evidence points toward recognition of the nose as part of the respiratory system. Wright (1914) stated that evidence, in the form of an inscription on stone, was uncovered from the tomb of an old Egyptian king. The king had publicly recognized his medical attendant and rewarded him for making his nostrils well. Even though the king may have been referring to the "breath of life" when he mentioned "nostril", there existed, at that point in history a recognition of the relationship between life, respiration, and the nasal organ.

Even before the earliest records of civilized man, there is evidence that man was concerned with anatomy, not only of himself, but also with the anatomy of the animals which surrounded him. Schreiber (1960), stated that this concern was evident in meticulous outlines carved on the walls of early dwellings. These illustrations only give evidence of an awareness of the appearance of the exterior of the nasal cavity. Nevertheless, the interest in anatomy was present at a very early time.

The anatomy of the nasal cavity and paranasal sinuses is essentially the history of anatomy itself. Before the birth of

Christ, any knowledge of the anatomy of the nose was very general and directed toward the explanation of the more common ailments.

Aristotle (354 B.C.), indicated his concept of the anatomy of the upper air passages. He described a lid existing at the top of the nostrils that raised during inspiration thus permitting various odors to enter the brain.

After limited dissection of the human and the animal body became regularly practiced, considerable information was accumulated at the schools of Pergamos and Alexandria. Even though this knowledge was not directly transferred, Galen (160 A.D.), utilized some of the anatomy that he probably acquired from the previous anatomists, and described the internal nose as having a median dividing wall and two conspicuous openings, one for each nostril. And further, that each opening was divided into two portions. One division led to the mouth, and the other division led upward to the brain. He also described the sieve like bones and related them to the function of straining the fluid which was conceived to flow from the brain. He referred to the porosity of the bones of the head and suggested this porosity would aid in lightening the skull. Schaeffer (1920), also credited Galen with knowledge of the adult maxillary sinus.

During the eleventh and twelfth centuries, the study of anatomy was revived by the Arabians at the School of Salerno.

Here for the first time, the pig was regularly dissected by the students, instead of the human cadaver. Haviland (1961), reported that a small treatise entitled Anatomia Porci first appeared in print in 1531. It was later appended to Dryander's Anatomia in 1537, when it appeared that Copho was the author. At one time this treatise of one thousand words represented the entire required professional knowledge of anatomy. Anatomia Porci was appended to various anatomy books extending up until the seventeenth century. According to Haviland (1961), Anatomia Porci, which is attributed to Copho, recognized the similarities of the pig to man. As it was translated by Crummer (1927), it states: "Although some animals, such as monkeys, are found to resemble ourselves in external form, there are none so like us internally as the pig, and for this reason we are about to conduct an anatomy upon this animal". Reference to the upper respiratory structures in Anatomia Porci is very limited. There is a description of the larynx, pharynx, recurrent laryngeal nerves, and the trachea. There is no direct reference to the nasal cavity or the paranasal sinuses.

Turbinated bones

Hippocrates (400 B.C.), speaking of the whole bony structure of the internal nose, applied the term sieve or ethmoid, whereas Galen (160 A.D.) asserted the bone in this region would better be called spongy rather than sieve like.

Colombo (1500) and Ingrassias (1563), described the inferior turbinated bones in man. However, a little later Casserius (1610), described all of the turbinated bones and identified them as such. He stated "there are, hidden in the depths of the nostrils, oblong little bones which may be called spongy, and seem like steps of a ladder, because one is placed above the other (human description). 'Cuculla' some call them I know not through what comparison, unless perchance they wish to liken the two superior to a hood which, I would rather compare to Concha veneris. Hippocrates not inaptly calls them sleeves. Turbines I would call them from their own form and function. They are bones, not cartilages. Turbinated bones (Turbinata Ossa) they are rightly called... ." Casserius (1610) further mentioned the cavities of the turbinates and stated their function was to break the force of the air, as well as warm and cleanse it. Bauhinus (1620), according to Wright (1914) indicated the turbinated bones filled the nasal cavity. He also described the region in animals.

Paranasal sinuses

Wright (1914), credited Berengar del Carpi (1520) as being the first to describe the presence of the paranasal sinuses in man. Del Carpi described the sphenoid sinus and rejected the idea of fluid filtration through the ethmoid plate. In turn, he suggested the idea that drainage from the brain probably took place through the sphenoid sinus.

Vesalius (1542), also rejected the concept of drainage through the cribriform plate. He further declared that Galen had never dissected the human body and refused to accept much of the information of his predecessors. Instead, he ascribed to the perforations in the cribriform plate, the function of transmitting air and odors to the brain.

Recently, Blanton and Biggs (1969), reviewed eighteen hundred years of controversy over the paranasal sinuses. Aside from references already made to scientists such as Galen, del Carpi, Vesalius, Flottes _et al_. (1961), credited Leonardo da Vinci (1480) as having discovered the sinuses of the face. The classic illustrations by da Vinci depict the maxillary antrum and the frontal sinus. According to Flottes _et al_. (1961), da Vinci referred to the maxillary sinus as being a cavity of the bone which supports the teeth. Colombo (1500) studied the maxillary bone and suggested the term, "Os ampullosum" because it contained an ampulla or sinus.

Nevertheless, Highmore (1651) is credited with the detailed description of the maxillary antrum. Occasionally, the maxillary sinus is given the term "antrum of Highmore".

Development

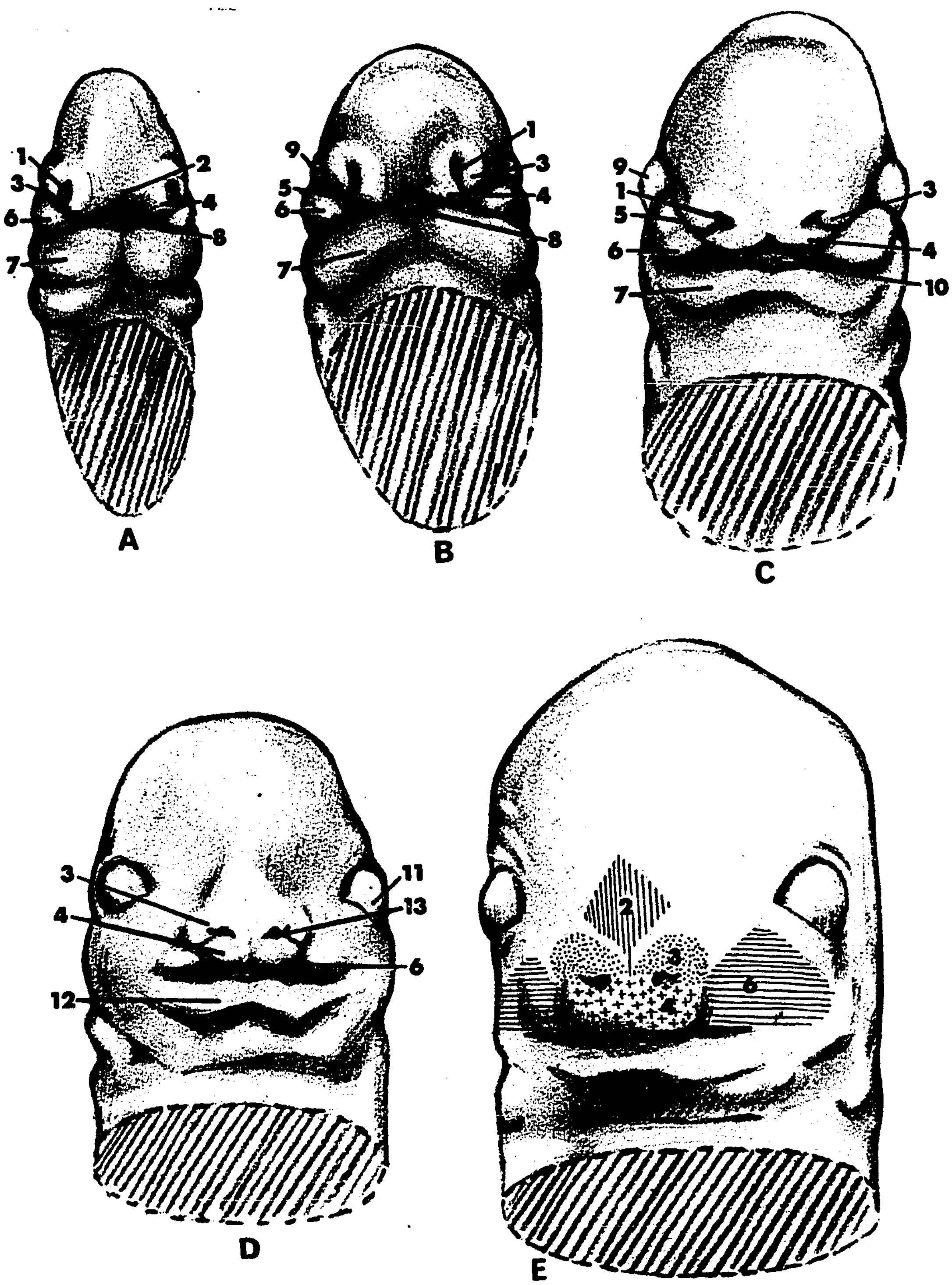
A clear, concise description of the development of the anatomical structures of the nose, nasal cavity and paranasal sinuses of the pig is not available in the literature. Therefore, the following description of the external appearance and development of the face, with accompanying illustrations, has been modified from Patten (1944).

In the pig embryo seven millimeters in length, the essential structures taking part in the formation of the face and upper jaw are already clearly distinguishable. They consist of the frontal process (Figure 1(2)), which is a singular structure, overhanging the rostral end of the oral cavity. On either side of this frontal process are the olfactory pits (Figure 1(1)) surrounded by horseshoe-shaped elevations. The median limbs of these elevations are the nasomedial processes (Figure 1(4)) and the lateral limbs are the nasolateral processes (Figure 1(3)). Immediately below and caudal to these olfactory pits are the maxillary processes (Figure 1(6)) which are growing medially to eventually fuse with the nasomedial processes. From these primitive tissues, the nose and the upper jaw are formed. A distinct groove between the maxillary process and the frontal process, extends rostrally from the nasal angle of the eye to the olfactory pit. It is termed the nasolacrimal groove (Figure 1(5)) and eventually will enclose the nasolacrimal duct. As the embryo

Figure 1. Face of a pig embryo illustrating the progressive development of the nose (redrawn after Patten, 1944)

A. 7.0 mm. pig embryo, x 15
B. 11.5 mm. pig embryo, x 12
C. 16.0 mm. pig embryo, x 10
D. 17.5 mm. pig embryo, x 10
E. 21.5 mm. pig embryo, x 10

1. Olfactory pit
2. Frontal process (in E represented as vertical hatching)
3. Nasolateral process (in E represented as stippling)
4. Nasomedial process (in E represented as small crosses)
5. Nasolacrimal groove
6. Maxillary process (in E represented as horizontal hatching)
7. Mandibular arch
8. Oral cavity
9. Optic vesicle
10. Tongue
11. Eye
12. Mandible
13. Nares


1
2
3
4
6
8
7
A
9
1
3
5
4
6
8
7
B
9
3
1
5
6
4
10
7
C
3
11
13
4
6
12
D
2
3
4
6
E

increases in age, the maxillary processes continually increase in size and push the nasal processes rostrally. The nasal processes in the sixteen millimeter pig (Figure 1(C)), have grown so much that they overshadow the reduced frontal process and have almost fused with each other along the midline. The incisive bones form in the naso-medial process. The maxillary bones form in the maxillary processes and the nasal bones form in the frontal process. As the embryo develops, the olfactory pits deepen and eventually perforate to communicate with the oral cavity. The septum of the nose is formed by fusion of the nasomedial processes and is continuous into the nasal cavity as a ventral extension from the frontal process and a rostral extension into the rostral bone. Coincident with the growth of the nasal septum, the maxillary processes give off toward the midline a palatine process which eventually fuses with the nasal septum, thus lengthening the nasal cavity and separating it from the oral cavity. This description represents only a portion of the structures being formed within the nasal cavity during development.

Parker (1874), has offered a detailed description of the structure and development of the pig skull. He studied seventy pig embryos and described the corresponding development stage by stage. He stated in regard to the great difficulty of the task; "If the nasal and auditory sense-capsules were as easy of elimination as the eyeball, the skull and face would present a much less complex problem; but they soon become part and parcel of a most intricate cranio-facial unity, and everywhere intrude themselves upon the observer". In summary, Parker (1874), stated that in the pig embryo not exceeding two-thirds of an inch: "the olfactory sacs are surrounded by a cartilaginous capsule, which has coalesced below with the trabecula of its side; while, within, the mucous membrane lining the capsule presents elevations which indicate the position of the future turbinal outgrowths of the capsule. The outer end of the cleft between the trabecula and the secondary preoral arch appears to be the rudiment of the lacrimal duct, while its inner end is the hinder nasal aperture".

In an embryo, one inch in length: "the olfactory capsules are well chondrified, and their descending inner edges have coalesced with each other and with the trabecula below to form the great median septum; the turbinal outgrowths are apparent. The swelling below the down-turned roof is the rudiment of the 'nasal turbinal' scarcely developed in the adult. And the mass which lies beneath the rudiment of the olfactory crus becomes the upper and middle turbinal (one mass in the pig) and the olfactory region. The trabecula form a cartilaginous floor to the nasal passages and on either side lie the depths of the nasal sacs which will eventually form the 'sphenoid sinus'. The space between the rudimentary olfactory crus and the budding upper turbinal is composed of an almost structureless, gelatinous stroma. It slowly forms cartilaginous bands which creep between the olfactory filaments, thus forming the cribriform plate."

In the second stage embryo, one inch long: "considerable chondrification has set in. Ossification was seen in the nidus of the vomer and maxillary bones. In the snout region the alae nasi have chondrified and fused with the prenasal and trabecular cartilages. In the ethmoid region the turbinal folds have begun to grow. There is endostosis of the vomer bone."

In the third stage embryo, one and one-third inches long: Parker (1874) observed complete coalescence of the alinasal cartilages with the trabecular cartilages rostrally, the prenasal part of the trabecular commissure, and the septum nasi.

In an embryo of one and one-third inches: "the primordial cranium is completely constituted as a cartilaginous whole including the coalescence of the olfactory capsules. The trabecular arches form the base of the septum between the olfactory capsules: in front where they form the azygous prenasal or 'basitrabecular' element, they are developed backwards as 'recurrent bands', elongations of the free curved cornua. The olfactory capsules have now the turbinal outgrowths all marked out as alinasal, nasal upper, middle, and lower turbinals."

And finally: "the pigs of larger size, the form and portions of all the parts of the cranium become greatly altered, and ossification takes place on an extensive scale, but no new structures are added."

During this period, there was considerable interest to investigate the question of primordial skull development. Decker (1883), Mead (1909) and Lebedkin (1918), applied their interest to the chondrocranium of the pig. Mead (1909) suggested a considerable number of terms to be used. He stated that the nasal region approached very closely the definitive form of the adult skull and that lengthening represented the major change after birth. He described the nasal capsule as two closely opposed cylinders and suggested a narrowing of the cartilaginous nasal septum just inside the nares. Mead (1909) described a transverse lamina forming a ventral connection between the septum nasi and the lateral cartilaginous extension (paries nasi). Further, he observed that the maxilloturbinal was formed by the inrolled edge of the paries nasi. The nasoturbinal was described as being the low, flat lamella projecting internally into the nasal cavity. Finally, he suggested that the ethmoturbinal system was not greatly developed.

Lebedkin (1918) observed that the nasal capsule was primarily cartilaginous. He agreed with Parker (1874) and described the cartilage in the septum nasi and its more rostral nasal part. He also observed that the roof of the nasal capsule, not entirely true cartilage, was represented by a prechondral tissue.

De Beer (1937) and Mead (1909) observed that the nasal capsule occupied about one-third of the total length of the chondrocranium in the pig. De Beer (1937) identified rostral and caudal transverse laminae in the developmental stage. He also noted that paraseptal cartilages projected caudally from the rostral transverse laminae. These caudal projections were earlier described by Parker (1874) and were referred to as the recurrent cartilages arising from the original trabecular bars of cartilage.

Sturm (1937) studied the development of the cartilaginous nasal skeleton in pigs from 30 mm. embryos to mature specimens. He observed that the immature nasal skeleton (49.3 mm., rostrum to rump length) resembled the final stage in the mature swine. He agreed with Mead (1909) that the main difference in age was in the relative length. Within the anterior cupula, he observed the incisura narina was not especially large. However, prominent on the laterorostral aspect of the nasal skeleton was the lateral fenestra. It was located immediately caudal to the narina. Caudolateral to this opening was the epiphaniale foramen. The paired halves were divided on the dorsal midline by a deep supraseptal sulcus, which was continuous caudally into the ethmoid region as the crista galli. As Mead (1909) had described, Sturm (1937) was not able to identify the thin part in the rostral part of the nasal septum. At this stage, the maxilloturbinale was not extensive but it was located in the ventrolateral edge of the lateral wall. It was continuous rostrally as the atrioturbinale. Internally, the semicircular crest divided the rostral part from the caudal part. Extending rostrally from the dorsal enlargement of the crest was the nasoturbinale. Just caudal and ventral to the enlargement of the semicircular crest was the maxillary recess already with access to the nasal cavity.

In the second stage (71.8 mm., rostrum to rump length), Sturm (1937) described the gradual resorption of the cartilaginous nasal skeleton in certain areas. As the epiphaniale foramen enlarged, the lateral wall immediately rostral to it began to perforate. This happened as a result of the significant growth of the nasal bones which enlarged and encroached upon the laterodorsal aspect of the wall, thus emphasizing the anterior lateral sulcus.

A second resorptive area, extending in a rostrodorsal direction from the lateral fenestra, was observed and found to be persistent as a fine incisure in the mature nasal cartilages. A third area of resorption was located in the lateral wall just dorsal to the developing basal lamella of the maxilloturbinate. This resorption initiated the separation of the maxilloturbinale as a cartilaginous anlage which was completed in the later stages. In this stage the ventral scroll of the maxilloturbinale was well developed, with the dorsal scroll being only slightly enlarged.

The third stage (39.8 mm., rostrum to ear canal) presented continued development of the structures already mentioned.

The fourth stage (62.5 mm., rostrum to ear canal) exhibited extensive resorption of the cartilaginous nasal capsule. In this stage, Sturm (1937) reported that the first ossification of the nasal skeleton had occurred in the caudal aspect of the maxilloturbinale. He also described the development of the maxilloturbinale as it formed the larger, dorsal scroll and the smaller, ventral scroll. During this stage, resorption was so extensive it actually isolated the maxilloturbinale except for the rostral cartilaginous continuation into the atrioturbinale.

In a fifth and final stage, ranging from three days after birth to maturity, Sturm (1937) studied the continued development. He observed the continued rescrption of the nasal capsule to the extent of those structures that represent the structural components of the nose, rostral to the osseous structures of the face. In the mature pig, the nasal cartilages were well developed and the origin of the various fenestra and incisures remained obvious. Finally, he described the ossification of the nasoturbinale and maxilloturbinale. The nasoturbinale changed from a three-edged form to a flattened plate in its rostral two-thirds. The final formation of the maxilloturbinale (ventral nasal concha) was discussed.

Neukomm (1933), discussed the ossification of the fetal skull bones and observed that early and rapid development of the parietal and frontal bones, as well as the nasals, lacrimals, and vomer presented no special features.

Of the membrane bones important to the nasal cavity and paranasal sinuses, de Beer (1937) indicated that the frontal bones developed from single centers of ossification in the 24 mm. pig embryo. The premaxillary (incisive) bone appeared to ossify at 50mm. or 36 days. The maxillary bone apparently arose from four centers of ossification on each side at 38 days.

Concurrent with the maxillary bone, the vomer (two centers) and the jugal (zygomatic) (one center) arose at 38 days. The lacrimal appeared to ossify later at 59mm. or 40 days and the nasal bone had begun ossification at 44mm. The prenasal (os rostrale) was not found to ossify until after birth.

Ethmoid

Literature, pertaining to the development of the skull indicates that considerable emphasis has been placed upon the ethmoid bone and its corresponding development in relation to the nasal cavity and paranasal sinuses. This is understandable, for the ethmoid bone plays a significant role in the subsequent development of the paranasal sinuses and the olfactory organ.

Zuckerkandl (1887), in an early investigation of the olfactory apparatus in mammals, observed numerous rows of ethmoturbinates in the pig. In the medial row, he identified eight turbinates, the first of which was very long and the remaining seven were very short. He also noted that the upper nasal turbinate was derived from two components. Rostrally, it was derived from the nasal bone and caudally it was derived from the ethmoid bone.

Paulli (1900), in a classical contribution to the subject of pneumatization of the skull, for the first time discussed in detail the anatomy of the ethmoid bone and its subsequent relation to the paranasal sinuses in the pig. He observed that the ethmoid bone possessed only a small part of the very long nasal cavity. Also, that it contained only seven endoturbinates with eight terminal scrolls. The caudal part of the nasoturbinate, which he referred to as Endoturbinate I, was simply scrolled, whereas its rostral part was excavated. The remainder of the endoturbinates (II-VII) were small, with the most caudal lying in the excavation of the sphenoid bone. Paulli (1900) indicated a total of twenty ectoturbinates were found in the pig and stated that they were arranged in a series of two rows.

Paulli (1900), described the evagination of the nasal mucous membrane as occurring between the basal lamella of the ethmoturbinates, giving rise to the small excavations or paranasal sinuses. The nomenclature used by Paulli (1900) was formulated to correspond to the origin of the basal lamella with which it was related. This terminology is no longer in use today. For example, the sinus resulting from the excavation into the surrounding bone between the basal lamella of the first and second endoturbinates was designated as the sinus I' (Höhle I'). Similarly, the excavation corresponding to the lamella of the ectoturbinates was designated as sinus 1' (Höhle 1'). This terminology was very easy to understand except that it necessitated the specific determination of each basal lamella.

Paulli (1900) studied and identified thirteen different excavations or paranasal sinuses in eleven specimens. In general, he noted that the excavations began as small evaginations of the mucous membrane of the fundus of the nasal cavity. Eventually each sinus presented a small communication which he labeled a 'defect'. It communicated with the nasal cavity. It appeared that the sinuses excavated the cranial part of the skull more vigorously and rapidly than the facial part of the skull. He observed that considerable variation existed between specimens as well as within each specimen, for there were many specimens that exhibited asymmetrical right and left halves. The largest excavation identified was the Sinus (Höhle) I'. It was present in specimens at one or two months of age as a small excavation extending into the rostral part of the frontal bone. Occasionally, it was greatly reduced. In that case, its normal area of coverage was taken over by the subsequent sinus. Conversely it was sometimes found to be very extensive, reaching into the frontal, parietal, occipital and temporal bones. It was found to extend into the caudal portion of the nasal bone. Sinuses II'-IV', were variable in size, but were much reduced and usually associated with the medial orbital wall. They were not observed until the animal had reached an age of two years. Sinus V', which did not appear before six months of age, was constant in all the specimens examined. It was found to excavate the sphenoid bone.

As for those sinuses related to the ectoturbinate lamella, Sinus 4' was present in all of the specimens examined. This sinus was found to excavate the rostral part of the frontal bone and did not attain a very large size. Sinus 11' was irregularly large in some cases and excavated the frontal, parietal, temporal and even occasionally bordered the Sinus V'.

Generally speaking, Paulli (1900) found that when pneumatization did occur, it covered a distinct area with a distinct pattern. To do this, when one sinus was reduced, another sinus increased to invade the area not occupied by the original sinus.

Andres (1924) investigated the ossification and formation of the ethmoid bone in the pig. He observed that ossification first appeared in the ethmoid bone region (potential cribriform lamina) of the ten centimeter pig embryo as perichondral ossification. This ossification arose in the cartilaginous nasal septum. In an embryo of 18.4 cm., the crista galli commenced formation. At 20.3 cm., the ethmoturbinates were covered laterally with a fine bony plate termed the lamina papyracea.

Vogler (1926) mentioned that ossification of the scrolls of the ethmoturbinates was not observed until approximately 13 weeks or 24.3 centimeters. This initial ossification was very slight at first and occurred in the largest most dorsal turbinate. It is not clear if he was referring to the first or second (Endoturbinate I or II) endoturbinates. He did not indicate the relationship of the nasoturbinate, and the first endoturbinate. Clear cut ossification was not indicated in the ethmoturbinates until 25.3 centimeters (Vogler, 1926). Finally, as the age of the specimen increased, the ossification increased to form the lamina cribrosa.

Červený (1965) considered as artifact the observations made by Andres (1924). He observed that in regard to ossification of the ethmoid bone, artifacts were produced as a result of imperfect methods of treating the ethmoid bone.

De Beer (1937) indicated that the ethmoturbinates began ossification at 190 millimeters, and that the cribriform lamina and the crista galli were not ossified before birth.

He also observed that the pig embryo does not have a mesethmoid region.

Červený (1965) disagreed with de Beer (1937) and described the presence of an osseous mesethmoid region in the pig. He further stated that it ossified from two centers. One center was found in the crista galli and the other one was found in the rostral area of the presphenoid bone. From these two points, the ossification extended into the cartilage of the nasal septum. It did not, as Andres (1924) indicated, originate within the cartilage of the nasal septum.

For a description of the anatomy of the ethmoturbinates in swine, most authors of veterinary textbooks have referred to the classical work of Paulli (1900). Zimmerl (1930), Kolda (1936), Ellenberger and Baum (1943), Sisson and Grossman (1953), Koch (1960), and Nickel _et al_. (1968) have all made reference to the work of Paulli (1900) in discussions of the ethmoid bone. However, they have not all accepted the work in all details. Nickel _et al_. (1968) did not differentiate the ethmoturbinates into a medial and a lateral series. Sisson and Grossman (1953) differed with Paulli and suggested the pig possessed only five endoturbinates and eighteen ectoturbinates. According to Červený (1970), Klimov (1950) and Akaevskij (1962) both described seven endoturbinates and eighteen ectorubinates. Regarding the ethmoturbinates, Loeffler (1959a), in a description of the nasal cavity and paranasal sinuses, discussed the first and second endoturbinates (endoturbinates I and II). He observed that the basal lamella of the first endoturbinate arose from the cribriform plate and extended rostrally along the ethmoid crest of the nasal bone and finally reached the level of the nasoincisive notch. He indicated the second endoturbinate was small, but did give rise to a second, terminal scroll.

Červený (1970) described the ethmoidal labyrinth in the pig. He observed seven constant endoturbinates (endoturbinate I-VII), five prominent ectoturbinates and a variable number (approximately twenty) of the remaining ectoturbinates. The seven endoturbinates bordered and gave rise to six ethmoidal meatuses (meatus ethmoidales I-VI).

Červený (1970) described the various lamina associated with the ethmoidal mass. These were introduced by Ellenberger and Baum (1943) and Nickel _et al_. (1968) as the roof plate, lateral plate and the basal plate. According to Červený (1970), the basal lamina of the ethmoid bone was formed as a thick, bony plate, separating the fundus of the nasal cavity from the nasopharynx. It was fused laterally with the lateral lamina of the ethmoid and medially with the vomer bone. The lateral lamina of the ethmoid bone is a collective term for the maxillary lamina, the orbital lamina and the dorsal part of the lateral lamina. The maxillary lamina is connected rostrally with the ventral nasal concha and the maxillary bone. Dorsally, it is fused with the lacrimal bone. Its lateral face forms the medial wall of part of the maxillary sinus and the semilunar hiatus. The orbital lamina is formed as part of the lateral wall of the ethmoidal labyrinth and it also forms part of the medial wall of the orbit. The dorsal part of the lateral lamina was described by Červený (1970) as a thin covering of bone, placed between the basal lamella of the first and second endoturbinates. He indicated that it is a part of the floor of the medial oral frontal sinus.

Finally, the roof lamina, was described as the bony plate forming the roof of the nasal fundus. It was fused medially with the crista galli and laterally with the dorsal part of the lateral lamina.

In addition to the ethmoid bone, considerable work has been done regarding the ossification of the remaining bones associated with the nasal cavity.

Vomer

Vogler (1926), working on the intrauterine ossification of the facial bones in swine, described the first, obvious ossification in the vomer as occurring in the middle of the sixth week (5.5 cm.). He indicated that they were paired and situated close to the midline. As ossification ensued, the centers extended rostrally and caudally into the vomer. At the end of the fifteenth week (24.0 cm.) it had extended toward the palatine process of the maxilla and the horizontal part of the palatine. However, complete fusion with these bones had not occurred before birth.

Maxilla

Fuchs (1909), in a study of some of the "deck" bones in mammals, described the maxillary bone. He did not consider the pig in his studies. However, Vogler (1926), in a description of the ossification centers, identified four centers initially appearing in the maxillary bone. They appeared about the middle of the sixth week, and were located in the following areas: at the rostral end of the facial crest, the rostral end of the body, the middle of the body, and in the palatine part. Gradually, these four centers fused and a fifth center was added. It was located in the caudal end of the palatine process and formed the basis for the maxillary tuberosity.

Vogler (1926) also mentioned the maxilloturbinate, which is related to the maxillary bone. Andres (1924) indicated ossification had already begun at seven weeks of age. Vogler (1926) disagreed and observed no ossification until the twelfth week (22.2 cm.). The maxilloturbinate structure, at this age, possessed paired centers, located one in each scroll (dorsal and ventral). The largest center was in the dorsal scroll with the ventral center lying somewhat rostral to the position of the dorsal. By 25 cm., the maxilloturbinate centers have fused together and extended into the basal lamella.

Incisive

Vogler (1926) found ossification in the incisive bone already at the beginning of the sixth week. One center was located in the palatine part as a fine line lying near the midline. Another center was found caudal to the first on the nasal surface. At eight weeks, it made contact with the maxillary bone and the nasal bone. With the latter it formed the nasoincisive notch.

Zygomatic

Ossification appeared in the zygomatic bone, according to Vogler (1926), similar to the other developing facial bones, at six weeks intrautero.

Lacrimal

Since the lacrimal bone relates itself to the nasal cavity it will be considered here. Near the beginning of the sixth week, Vogler (1926) indicated that two centers appear near the orbital border. Within one week, these two centers have fused and project dorsally and rostrally. As the orbital border is formed during the fusion, a single lacrimal foramen is formed. Gradually, by the eighth week (10.5 cm.) a bony bridge separates the original foramen and paired foramen are formed.

Nasal

Perna (1906) studied the development and ossification of the nasal bones in man. Vogler (1926) also studied the facial bones as well as the nasal bones and described two centers of ossification appearing at six weeks of age. A very long center appeared medially while the other center, somewhat roundish, was located laterally. By the seventh week, both centers were fused and the ossification extended orally into an apex. Complete fusion of the facial bones did not take place until after birth.

According to Vogler (1926), the nasoturbinate, received its ossification from those centers originating in the nasal bone. However, he described a center of ossification, located in the lateral nasal wall, situated between the nasoturbinate and maxilloturbinate, in the 22.2 cm. embryo. Vogler (1926) did not make clear the situation regarding the ossification between the rostral (nasal bone part) and the caudal (ethmoid bone part) portions of the dorsal nasal concha. However, near the time of birth (28 cm.) he described the extensive rostral growth of the nasoturbinate and the caudal cartilaginous part. This statement was not entirely clear.

Current Anatomy

Nasal cavity and paranasal sinuses

The most recent, general description of the anatomy of the nasal cavity and paranasal sinuses in the pig, was published by Nickel *et al*. (1967). However, Loeffler (1959a) published a dissertation on the topographical anatomy of the nasal cavity and paranasal sinuses which formed the basis for the textbook of Nickel *et al*. (1967).

From the viewpoint of comparative anatomy, Graeger (1958), Wilkens (1958), Nickel and Wilkens (1958), Loeffler (1958) and Loeffler (1959b) have all published somewhat similar topographical descriptions on the dog, horse, cow, sheep, goat, and cat. These papers have provided an excellent contribution to anatomy and have provided Nickel *et al*. (1967) with the necessary material for a textbook.

Numerous textbooks, other than Nickel *et al*. (1967) have similarly covered the anatomy of the nasal cavity and paranasal sinuses in the pig. Chauveau and Arloing (1890), Ellenberger and Baum (1943), Bruni and Zimmerl (1951), Sisson and Grossman (1953), Koch (1963), Dobberstein and Hoffman (1964), Bourdelle and Bressou (1964) and Barone (1966) have all described or referred to the area under investigation.

Atlases outlining or illustrating the anatomy of the nasal cavity and paranasal sinuses have dealt with the subject in only a superficial manner (Popesko, 1971; Getty, 1964; and

Stokoe, 1967).

<u>Nasal cavity</u> The nasal cavity, being very difficult to define specifically, presents a number of anatomical structures that have an osteological relationship.

<u>Concha nasalis dorsalis</u> The dorsal nasal concha, or nasoturbinate as it is commonly referred to, is represented as a very long, somewhat tapered structure. It has as its bony base the first endoturbinate which extends for a considerable distance rostrally on the crest of the nasal bone. Thus the ethmoid bone and the nasal bone both contribute to the formation of the dorsal nasal concha (Loeffler, 1959a). Chauveau and Arloing (1890) described the concha as the "ethmoidal coronet" indicating that he recognized the contribution of the ethmoid bone. Chauveau and Arloing (1890), Sisson and Grossman (1953) and Dobberstein and Hoffmann (1964) all have suggested the turbinated bones as resembling those of the ruminants.

<u>Concha nasalis media</u> Sisson and Grossman (1953) and Chauveau and Arloing (1890) have indicated that there is no middle turbinate. However, most authors have not specifically referred to a middle nasal concha in the pig as they have preferred to group the remaining ethmoidal turbinates as the ethmoidal labyrinth. Ellenberger and Baum (1943) and Loeffler (1959a) have identified a poorly developed middle nasal concha

in the pig. Actually, Loeffler (1959a) has discussed it as the second endoturbinate. He observed the middle nasal concha as being small and the dorsal, terminal spiral of the second endoturbinate lamella. A sinus, excavating the concha in some species, was not observed in the pig.

Concha nasalis ventralis Of the turbinated bones, the "coronet maxillaire", as Chauveau and Arloing (1890) referred to it, was originally not described in much detail in the pig. Ellenberger and Baum (1943) and the remaining authors have referred to the ventral nasal concha as the maxilloturbinate. Loeffler (1959a) described it as an individual bone, as it was not associated with the ethmoid bone. Nomina Anatomica Veterinaria (1968) referred to it as a separate bone under the heading of osteology. Loeffler (1959a) described its basal lamella, which inserts on the maxillary bone, as giving rise to two spiral lamellae which scroll dorsally as well as ventrally. The ventral nasal concha resembles, according to Chauveau and Arloing (1890), Sisson and Grossman (1953), and Dobberstein and Hoffman (1964), those of the sheep and the goat. However, it is considerably different in the horse. Loeffler (1959a) described a ventral and dorsal maxilloturbinate recess existing between the lateral nasal wall and the basal lamella of the ventral concha. Caudally, he observed the basal lamella as enclosing a ventral conchal sinus that is in communication with the nasal cavity, but is divided from the rostral part incompletely by a transverse septum. This detail was not covered by any of the previous authors.

Paranasal sinuses In the pig the paranasal sinuses present a well developed system of excavations into the surrounding bones. Within the literature there is varied treatment of the details relating to each sinus and the terminology used is sometimes different. Leyh (1859) noted that the frontal sinus in the pig resembled the frontal sinus in the ruminant. He also commented on the small size of the palatine and sphenoid sinuses. Chauveau and Arloing (1890) suggested that the sinuses in the pig resembled those of the sheep and goat. Bourdelle (1920) described four sinsues in the pig: the frontal, maxillary, sphenoidal and the ethmoidal. Later, Ellenberger and Baum (1932) and Martin and Schauder (1923) briefly characterized the "muschelhöhlen" (dorsal, middle, and ventral conchal sinuses), the maxillary sinus, the sphenoid sinus, the palatine sinus and six to eight frontal sinuses in the pig. Later, Ghetie (1941) described a large and a small maxillary sinus, a frontal-occipital sinus, a nasal sinus, a lacrimal sinus, a temporal sinus, a zygomatic sinus, a parietal sinus, and a palatine sinus as they excavated the respective bones of the skull. Sisson and Grossman (1953) described six to eight frontal sinuses, the maxillary sinus, and the sphenoid sinus.

They suggested, but did not identify a palatine sinus in the pig. Barone (1966) indicated the palatine sinus was absent in the pig.

Until Loeffler (1959a) additional sinuses have not been described; instead it has been a difference of interpretation of the existing sinuses and application of varying terminology. Loeffler (1959a) described the paraethmoid sinuses which lie adjacent to the ethmoidal labyrinth in the pig.

Sinus maxillaris All authors consulted in this review agreed upon the location of the maxillary sinus within the dorsocaudal aspect of the maxillary bone. In regard to the size, all authors have described it as a fairly small sinus with certain limitations. However, Koch (1963), and Dobberstein and Hoffmann (1964) have described the maxillary sinus in the older animals as extending into the palatine bone. This is not in agreement with the other authors. There appears to be a discrepancy as to the extension of the maxillary sinus into the zygomatic bone. All authors appear to agree except Ghetie (1941) who has described a separate "zygomatic sinus" in communication with the maxillary sinus. In the literature, incomplete medial and lateral compartments have been described. Sisson and Grossman (1953), Koch (1963), and Dobberstein and Hoffmann (1964) have not described such an arrangement. However, these authors have not treated the sinuses with such specific detail. In describing the boundaries and walls of the maxillary sinus, only Ellenberger and Baum (1943) and Loeffler (1959a) have described the medial wall as being a portion of the lateral, papyraceous lamina of the ethmoid bone. Part of the medial wall of the maxillary sinus is also formed by the ventral nasal concha.

Apertura nasomaxillaris The maxillary sinus is independently in communication with the nasal cavity through the nasomaxillary opening. All authors, mentioning the maxillary sinus, recognized the communication with the nasal cavity and placed it in a transverse plane through the sixth cheek tooth (M_2). However, Loeffler (1959a) described the structural course of the aperture within the pig nasal cavity.

Sinus concha dorsalis Chauveau and Arloing (1890), Sisson and Grossman (1953) and Dobberstein and Hoffmann (1964) have not mentioned this particular excavation. However, Chauveau and Arloing (1890), described an internal cavity which belonged to the frontal bone extending into the nasal bone and Ellenberger and Baum (1943) observed the frontal sinus excavation into the nasal bone in addition to the cavity within the turbinate, which he identified as the dorsal conchal sinus. The first complete description in the pig was that of Ghetie (1941) who identified a specific paranasal sinus, the "Nasenbein höhle" or nasal bone sinus. He described the sinus as occupying about one-third of the nasal bone in addition to the upper one-half of the dorsal concha. He further noted that its form varied and it was in communication with the frontal sinus. Finally, the basis for the current anatomy, has come from the description by Loeffler (1959a). He identified a conchal (Pars conchalis) and a nasal (Pars nasalis) component. The caudomedial conchal part lies in what originally was the first endoturbinate and the nasal part, somewhat more rostrolateral, lies in the nasal bone. It was observed to be in complete communication with the nasal cavity. Loeffler (1959a) also observed an independent sinus excavation within the nasal bone that communicated with the nasal cavity and did not communicate with the dorsal conchal sinus.

Sinus concha ventralis The ventral conchal sinus was described by Ellenberger and Baum (1943) as a special cavity lying rostral to the maxillary sinus. He further described it as being in communication with the "ventral cavum maxilloturbinate" and in turn with the ventral meatus. All other authors reviewed except Loeffler (1959a) and Nickel et al. (1967) have not described this sinus in the pig. Loeffler (1959a) described this sinus and placed it in the caudal one-fourth of the ventral concha. The sinus was formed as a result of an incomplete transverse septum which separated it from the ventral maxilloturbinate recess. Therefore, the sinus is in communication with the nasal cavity.

Sinus frontales   Without question, the frontal sinus system represents, in the pig, a vast system of excavations into the bones of the adult skull. Leyh (1859) first observed that the frontal sinuses in the pig resembled those of the ruminant. Since that time, Chauveau and Arloing (1890), Koch (1963), and Sisson and Grossman (1953) have made reference to the resemblence of the sinuses of the pig with those of the ruminant. Ghetie (1941), describing the "stirnhinterhaupthöhle" (fronto-occipital sinus), initially gave the most complete description of the sinuses in the adult. He described the sinus, originating as a small, paired excavation into the frontal bone. As the specimen increased in age,the sinuses extended further into the frontal, occipital and finally the temporal and parietal bones. Regarding the subdivisions of the frontal sinus, he observed that they remained divided by thin bony lamellae or plates. Thus, he identified three to four subdivisions on one side. Ghetie (1941) also observed that the septum dividing the paired sinuses usually deviated to one side and did not lie directly on the midline. In most of the cases he observed the deviation to be directed toward the smaller of the paired sinuses. This modification would allow for the increased size of the sinus opposite the smaller one. Finally, he mentioned the variability found in individuals of similar as well as different ages.

Most authors, between Ghetie (1941) and Loeffler (1959a), have referred to the frontal sinuses collectively. They have described six to eight subdivisions or three to four paired compartments.

Loeffler (1959a) classified and identified the separate compartments of the frontal sinus. He in turn, utilized the nomenclature suggested by Wilkens (1958). Basically, he divided the frontal sinuses into a rostral and a caudal system. Within the rostral system, he subdivided and identified a medial and lateral compartment. The caudal system was undivided. He suggested the comparison of the similar nomenclature in the ruminant species. Since Loeffler (1959a) similar nomenclature has been applied to the paranasal sinuses of the pig (Koch, 1963; Dobberstein and Hoffmann, 1964; Barone, 1966; and Nickel et al., 1967).

<u>Sinus frontalis rostralis medialis</u> According to Loeffler (1959a), this sinus excavates primarily the medial rostral part of the frontal bone. The sinus exhibited strong extensions into the caudal aspect of the nasal bone. Dorsally, it was bordered by the lacrimal sinus, and laterally by the lateral rostral frontal sinus. He described the communication of the medial rostral frontal sinus with the middle nasal meatus via the second, third and fourth ectoturbinate lamella.

Sinus frontalis rostralis lateralis This sinus was observed lying caudolateral to the previous sinus in the general region of the zygomatic process of the frontal bone (Loeffler, (1959a). An oblique, transverse frontal septum divided the lateral rostral frontal sinus from the caudal frontal sinus. Variations, within the frontal sinuses, were emphasized by Loeffler (1959a). He observed that when the lateral frontal sinus was reduced on one side, the medial rostral frontal sinus and the caudal frontal sinus compensated by pneumatizing a similar area. Communication, with the nasal cavity, for the lateral rostral frontal sinus was accomplished through the roof plate of the ethmoid bone between the fifth and sixth ectoturbinate lamella.

Sinus frontalis caudalis The caudal frontal sinus, the largest paranasal sinus in the pig, communicates directly with the nasal cavity in common with the dorsal conchal sinus (Loeffler (1959a). From this laterally compressed communication, the caudal frontal sinus, positioned medially between the more medial rostral frontal sinuses, extends caudally into the frontal, the parietal, and the occipital bone. All authors reviewed, recognized that the frontal sinuses in some way have extended into the above bones. The caudal frontal sinuses (right and left) are separated from one another by the sagittal interfrontal septum. As previously mentioned, this septum does not maintain the midline, but usually deviates from one side to the other according to the relative size of a given sinus.

Sinus lacrimalis There is generally no mention of the lacrimal sinus. Ghetie (1941) observed it was only present in the mature animal, but with increasing age, extended into the lacrimal bone. He further observed its relationship to the surrounding frontals. Loeffler (1959a) described the sinus as being present in the majority of swine, with its communication lying in the lateral lamina of the ethmoid bone. Its communication was associated with the fourth or sixth ectoturbinate lamella.

Sinus sphenoidalis All authors reviewed agreed and described the sphenoid sinus as rather extensive in the pig. The descriptions, as to the extent of the sinus were variable. Ghetie (1941) gave a detailed early description of the sphenoid sinus. He observed the sinus to increase in size with age to the extent that in the older animal it occupied the pterygoid process of the sphenoid bone. He described it as having two symmetrical sinuses lying in the sphenoid bone and one asymmetrical sinus extending caudally into the occipital bone. Ellenberger and Baum (1943) observed extensions of the sinus into the pterygoid part of the sphenoid bone and the palatine bones. The greatest extension was into the squamous part of the temporal bone. Loeffler

(1959a) concurred with Ghetie (1941) and Ellenberger and Baum (1943).

<u>Sinus palatinus</u> Barone (1966), Dobberstein and Hoffmann (1964) and Ellenberger and Baum (1943) all agreed on the absence of a palatine sinus. Sisson and Grossman (1953) suggested an excavation into the perpendicular part of the palatine bone. Ghetie (1941) described the palatine sinus separately and indicated it was a well developed excavation into the perpendicular part of the palatine bone. He further observed that it communicated caudally with the sphenoid sinus and rostrally with the nasal cavity. Loeffler (1959a) described an extension into the perpendicular part of the palatine bone that would be equivalent to the sphenoid sinus.

MATERIALS AND METHODS

Osteology

Materials for the osteological study were obtained from a number of different sources. Eight skulls, from pigs less than eight weeks of age, were obtained from the Department of Veterinary Physiology and Pharmacology and the Veterinary Medical Research Institute, Iowa State University. Seven skulls from animals between the ages of five and six months, were obtained from the Meats Laboratory, Iowa State University, at the time of slaughter. A series of six litter mates eleven months of age were obtained from the Veterinary Medical Research Institute. Four skulls from animals approximately two years of age, were obtained from the Department of Veterinary Clinical Sciences at Iowa State University. Five skulls, approximately five years old, were obtained from the gerontology investigation currently being conducted in the Department of Veterinary Anatomy.

In all cases the heads were skinned and placed, without further cleaning, in ten gallon containers, with tight fitting lids. The containers were immediately filled with enough warm tap water to cover the specimens. The specimens were allowed to decompose for one week through bacterial action. At the end of this time, running water was used to remove the excess debris.

After thorough washing, some of the specimens were allowed to dry in the sun. This simple technique of maceration was utilized in preference to conventional maceration methods utilizing heat, in order to preserve, without distortion or breakage, the delicate conchal bones. Of the twenty-one immature skulls, eight were completely disarticulated and then allowed to dry. Seven were partially disarticulated in order to retain adjacent bony relationships. It is necessary to disarticulate the bones when they are still moist in order to preserve the fine sutures. The littermate series was macerated as described and then five were sagittally sectioned while they were wet. The remaining one was transversely sectioned with a meat-bone saw while wet to avoid disturbing the delicate ethmoidal lamina. The first transverse section was placed at the level of the third premolar tooth (PM_3). The second transverse section was placed between the second and third molar teeth (M_2-M_3). These sections were allowed to dry and comparative observations were made on them. The macerated, sectioned skulls were photographed and the paranasal communications (represented by arrows) were superimposed over the photographs to demonstrate the actual communication pathway.

The older, mature specimens were not disarticulated, as they were partially fused, but they were sculptured with a hand drill and a router bit. Some of the remaining skulls were sectioned transversely with a standard, meat-bone saw.

They were then studied in detail. These procedures yielded excellent specimens for osteological observations.

General osteological observations were conducted with the entire skull and the individual, disarticulated bones. No special apparatus or techniques were necessary to conduct the macroscopic observations. However, the ethmoid bone, significant in both the nasal cavity and paranasal sinuses, received considerable attention. Each osseous lamella was completely dissected free of the cribriform lamina and the lateral lamina. Then the delicate scrolls, present on each individual lamella were noted and recorded. To aid in further recording and illustration, one complete series of all the bones related to the nose, nasal cavity, and paranasal sinuses was photographed and labeled with arrows to clarify relationships and structural components.

Paranasal sinuses

Observations on the paranasal sinuses required a number of specimens in the mature age group as the paranasal sinuses are not significantly developed in the immature specimen. Therefore, ten mature specimens, aged two to eight years, were obtained from the gerontology investigation within the Department of Veterinary Anatomy, Iowa State University. These skulls were obtained after the removal of the brain, eyes and pituitary. The skulls, with the dorsal part of the cranium removed, were placed separately into ten gallon containers of a ten percent formalin mixture.

Upon complete fixation, the musculature and cartilages were dissected in detail on five of the specimens. All of the specimens were eventually sectioned transversely with a standard meat-bone saw. The first transverse-section was placed at or between the first (M_1) and second (M_2) molar teeth. This transverse-section exposed both the dorsal and ventral conchal sinuses, and the entrance to the caudal frontal sinus. The next caudal transverse-section was made at a level which passed through the last molar tooth (M_3) and just slightly rostral to the rostral margin of the orbit. This section exposed the greatest width of the maxillary sinus, as well as, its communication with the nasal cavity, the nasomaxillary opening. It also exposed the lacrimal sinus, the caudal frontal sinus, usually the medial and occasionally the lateral frontal sinuses and occasionally the small excavations around the ethmoid bone (paraethmoid sinuses: Loeffler, 1959a). In addition, this section exposed more fully the nasofrontal opening.

A third transverse-section was placed caudal to the last molar (M_3) tooth to expose more fully the paraethmoid sinuses, the ethmoidal meatuses, the medial rostral frontal sinus and the caudal frontal sinus. A fourth transverse-section, about one centimeter caudal to the optic foramen, exposed the caudal frontal sinus and the dorsal and pterygoid extensions of the sphenoid sinus. The frontal section, which removed the dorsal part of the cranium, was sufficient to expose the extension of the caudal frontal sinus into the occipital bone as well as the temporal extension of the sphenoid sinus. In addition to the transverse-sections, some of the sinuses were excavated using a hand drill and small router bit.

A more complete understanding, regarding the paranasal sinuses, and their progressive pneumatization was studied in the immature, disarticulated bones. The immature specimens were helpful in studying the development of the paranasal sinuses related closely to the nasal cavity, such as the dorsal and ventral conchal sinuses.

In several cases, vinyl acetate was used to fill the sinuses. This was followed by maceration in a solution of twenty percent potassium hydroxide. This method did not prove to be a very satisfactory technique because it was difficult to obtain complete infiltration of the sinuses. However, the casts were useful in observing some of the sinuses but the reliability was questionable.

OBSERVATIONS

Osteology

Os rostrale

The rostral bone (os rostrale) (Figure 6(R)) is found as a fused, paried ossification located in the most rostral extension of the nasal septal cartilage (cartilago septi nasi). In the immature animal approximately six months of age it lacks specific shape and is the result of ossification of the cartilaginous right and left medial walls of the nasal septum. This ossification is similar to that taking place in the caudal part of the nasal septum resulting in the osseous nasal septum (pars ossea, septum nasi). In the mature animal, the rostral bone exhibits a definite shape which is a result of progressive ossification in the cartilage. Thus, its finite shape is related to its surrounding structures.

Generally speaking, the rostral bone is pyramidal in appearance, with its base directed rostroventral, and its apex directed into the cartilaginous nasal septum. The base appears as the most rostral extension of any firm structures of the nose. The mature, macerated bone presents for its base, a slightly convex surface, marked by a deep fissure. This fissure represents the line of fusion of the right and left medial nasal processes of the developing embryo. Dorsally, the base appears to split forming two rounded columns. These structures correspond to the nasal cartilages, which will form the roof of the nares. Therefore, these columns form the base for the laterally reaching nares portion of the dorsal parietal nasal cartilage (pars narica, cartilago nasalis parietalis dorsalis). Ventrally, toward the incisive bone, the base again appears to split and forms two, paired secondary projections that extend directly toward the incisive bone from the basal surface. In the unmacerated state they are bound by strong connective tissue to the rostro medio-dorsal surface of the incisive bone. Dorsally, the other two projections curve laterally and form a base for the accessory lateral nasal cartilage (cartilago nasalis accessoria lateralis). On the midline, approximately in the center of the basal surface there exists a foramen which receives a unilateral branch of the continuation of the major palatine artery that serves as the nutrient artery for the rostral bone.

The lateral face of the rostral bone is smooth, concave and forms the medial wall of the nostrils. It blends smoothly with the basal surface.

Dorsally, the surface of the rostral bone, presents a fissure resulting from fusion. Each column is deeply pitted and outlined with a smooth ridge. This ridge corresponds to the cartilaginous surface. Centrally, there exists a deep fissure which is continuous with the basal fissure. This fissure penetrates about one-half of the distance of the dorsal surface on the midline. Deep within it is a foramen that is necessary for the continuation of the unpaired arterial branch of the major palatine artery that courses dorsal to the nasal cartilages.

Ventrally, the surface of the rostral bone is deeply pitted and represents the site of the connective tissue attachment of the rostral bone to the incisive bone and adjacent nasal cartilages.

Os incisivum

The incisive bone (os incisivum) (Figures 2(A)-6(A), 25(1)) is paired and forms the greatest rostral extension (with the exception of the os rostrale) of the bony skull. The disarticulated bone presents a body, a nasal process (Figure 2(1)), an alveolar process (Figure 2(4)) and a palatine process (Figure 4(7)). It articulates with the nasal and maxillary bones and indirectly with the os rostrale. In the articulated skull, the incisive bone when properly fused, aids in the formation of the hard palate and the bony nasal aperture (apertura piriformis).

The body (corpis ossis incisivi) is elongate in shape, being rostrally thickened and tapering caudally. The alveolar process (processus alveolaris) is much reduced and is found extending ventrolateral from the body. It is responsible for containing the upper incisor teeth (particularly the first upper incisor teeth) in its alveolar sockets (alveoli dentales) along the smooth alveolar arch (arcus alveolaris). Also of interest is the groove for the continuation of the major palatine artery (Figure 4(6)) that is presented just inside the alveolar margin on the palatine face (facies palatina). The medial face (facies medialis) is smooth rostrally and slightly roughened caudally. The right and left incisive bones do not always fuse along the medial face. In the adult animal it is not uncommon to see a continuation of the groove for the major palatine artery, which occasionally is seen as a small foramen. Occasionally, there is a foramen for each side, but generally they are not completely enclosed. In the pig, the fusion of the paired bones along the midline is not complete throughout. Therefore, the incisive fissure (fissura incisiva) (Figure 4(5)) is produced.

From the body, the nasal process (processus nasalis) extends in a dorsocaudal direction. It is broad and not very thick and forms part of the lateral nasal wall. The nasal process presents two curved surfaces; one lateral or external face and the other, the internal or nasal face. The lateral face is convex and smooth. The nasal face is generally concave and actually presents two concave surfaces with a sharp ridge separating them. This crest is continuous with the crest of the maxillary bone. Dorsomedially, the nasal process articulates with the nasal bone, which is pointed rostrally, thus forming a notch between the two bones. This notch formed by the two bones is termed the nasomaxillary notch (incisura nasomaxillaris) (Figure 2(2), 3(2)). The rostral or leading edge of the nasal process forms a sharp ridge which blends and accepts the nasal cartilages.

The palatine process (processus palatina) is a vertical thin plate of bone which is found projecting from the body to articulate with the maxillary bone. In the adult it extends in a caudal direction to a transverse plane passing through the canine tooth. Medially it is fused with the bone of the opposite side and laterally it fuses with the palatine process of the maxillary bone. In doing so, it completes a notch formed in the incisive bone. It thus forms the palatine fissure (fissura palatina) (Figure 4(8)). The lateral, unfused wall of the palatine process contains a shallow groove, which receives the cartilage of the vomeronasal organ. When the right and left palatine processes are fused on the midline, a median v-shaped groove (sulcus septi nasi) is present and accepts the caudal extension of the vomer bone and the nasal septal cartilage.

Os nasale

The nasal bone (os nasale) (Figures 2(B), 3(B), 5(B), 6(B), and 15) is paired, long and forms a considerable part of the roof of the nasal cavity. Grossly, it presents an external, internal, medial and lateral face. The external face (facies externa) (Figure 15(A)) appears flattened with the exception of the supraorbital sulcus (sulcus supraorbitalis) (Figure 15(1)) which crosses the caudolateral surface in an oblique manner. The sides of the bone do not remain exactly parallel, but gradually taper to a point where the bone no longer articulates with the incisive bone. This point, where the two bones meet, forms a sharpened notch, the nasomaxillary notch (incisura nasomaxillaris) (Figure 2(2). From this point rostral, the external surface of the bone rapidly tapers to a rounded point thus forming the nasal process (processus nasalis) (Figure 15(2)). This point is free and normally extends between the laterally curved nasal cartilages and is bound firmly to them by connective tissue.

The internal face (facies interna) (Figure 15(B)) is sharply concave and presents an elongate crest, which extends from the nasomaxillary notch in a caudal direction. At first it is a simple shelf or crest of bone (crista ethmoidalis), (Figure 15(3), but as it extends caudally, it becomes two sides due to its excavation. In the immature animal this excavation is extensive and extends rostrally to the level of the 2nd premolar (PM_2). This accounts for about one-half the length of the bone. In the mature animal the crest is continued toward the fundus of the nasal cavity as the ventral free edge of the dorsal nasal concha. This results from the fusion of the ventral and medial walls of the nasal bone with the corresponding walls of the first endoturbinate.

Laterally, the wall of the first endoturbinate fails to fuse with the lateral wall of the nasal bone. This defect results in the communication of the dorsal conchal sinus and the nasal cavity via a narrow passageway on the lateral aspect of the endoturbinate portion of the dorsal nasal concha (Figures 5(K); 11(F); 12(I) (white); 15(4); 24(f) and 31(5)).

The medial face of the nasal bone fuses with the corresponding bone of the opposite side along its entire length. They form part of the roof of the nasal cavity after fusion. Characteristically, there is a very long projection from the first endoturbinate which extends the endoturbinate onto the crest of the nasal bone. In the mature specimen this forms the ventral free edge of the dorsal nasal concha. On the medial face of the conchal crest there is a deep groove that carries the ethmoidal nerve. As it reaches the rostroventral border of the crest it penetrates and is continued on the lateral surface of the snout. The lateral face of the nasal bone fuses with the maxilla along about three-fourths of its length. Caudally, it is flattened and somewhat broader.

Maxilla

The maxillary bone (Figures 2(C)-6(C); 12(2)-14(2); 16-18 and 29(1)-34(1)) is extensive and forms a considerable part of the lateral wall of the nasal cavity. It is roughly pyramidal and presents facial and nasal surfaces. In both the immature and the mature specimens it presents all of the upper cheek teeth.

The external or facial surface (facies facialis) (Figure 16(A)) is smoothly concave and has the following features for consideration. Near the center of the bone is the infraorbital foramen (foramen infraorbitale) (Figures 16(1)-18(1); and 29(8)), which transmits the infraorbital nerves and vessels. Occasionally the foramen is found as a paired external opening with a common infraorbital canal. Located in the rostral part of the infraorbital foramen is the small maxilloincisive foramen (foramen maxilloincisivum). Leading caudally from the infraorbital foramen is the facial crest (crista facialis) (Figures 16(15)-18(15)), which is not very prominent and extends onto the zygomatic process (processus zygomaticus) (Figures 16(9)-18(9)). It is continued as a crest across the zygomatic and lacrimal bones and arrives again on the dorsolateral external face of the maxilla. It is in this depression, surrounded by this crest, that the muscles of the snout originate.

The zygomatic process is found as a strong projection from the caudolateral surface of the body of the maxilla. It is short but is firmly a part of the body. Laterally, it does not appear to be extensive but it is overlapped by the zygomatic bone (Figures 2(D)-4(D) which, in part, hides the zygomatic process of the maxilla. In the mature animal, this process is excavated by the cavity of the maxillary sinus.

This sinus is found to reach into the zygomatic bone by an extension of the nasal mucous membrane. Dorsal to the facial crest the external surface is slightly more concave than the remainder of the bone due to the attachment of the muscles of the snout. Dorsally, where the maxilla fuses with the nasal bone, the edge is thickened in the mature animal and is marked by a groove at the midpoint. This is for the dorsal nasal vein which is returning from the nasal cavity. Projecting from the ventrolateral part of the body is the alveolar process (processus alveolaris) (Figure 18(2)), which houses the upper cheek teeth. Normally seven upper cheek teeth are present in the mature animal. Located at the rostral extent of the maxillary bone, in the alveolar process, is the fossa of the canine tooth (fossa canina). Projecting in a dorso-caudal direction is the projection for the canine tooth (juga canina).

In the immature specimen, projecting from the pterygopalatine surface is the maxillary tuberosity (tuber maxillae) (Figures 16(14)-18(14)), which houses the last two cheek teeth. As the animal matures, this tuberosity regresses and fuses (Figures 2(2) and 2(4)) more intimately with the lateral face of the palatine bone. The maxillary foramen (foramen maxillare) (Figures 2(12); 4(12)) is located just medial to the zygomatic process and dorsal to the maxillary tuberosity. It is quite large and oval in shape with the edges of the oval directed mediolaterally.

The medial edge of the maxillary foramen is smooth and from it course the depressions of the sphenopalatine foramen (foramen sphenopalatinum) and the palatine canal (Figure 16(20)). These structures are not complete in the disarticulated bone. The maxillary bone only aids in the formation of the palatine canal and the sphenopalatine foramen. The infraorbital canal (canalis infraorbitalis) (Figures 16(7)-18(7)) connects the infraorbital foramen with the maxillary foramen. It is straight and extends from a transverse level through the first and second molar teeth (M_1, M_2) in the immature animals to a transverse level which passes through the third and fourth premolar teeth (PM_3, PM_4).

In the immature animal the nasal or internal surface (facies nasalis) (Figure 16(D)) presents (when the ventral nasal concha is removed) a simple concave surface. On the lateral wall, one-half of the distance dorsal to the floor of the nasal cavity, is the crest of the ventral nasal concha. It extends rostroventral from a point dorsal to the maxillary hiatus. This latter opening is incomplete in the immature pig. The horizontal or palatine process (processus palatinus) (Figures 16(10)-18(10)) projects from the alveolar portion of the body. It fuses at the midline to its fellow from the opposite side.

The internal surface presents a smoothly rounded surface which corresponds to the nasal cavity and nasopharynx.

Projecting dorsally from the midline is the nasal crest (crista nasalis) (Figures 16(18)-18(18)) which rises to meet the vomer bone forming a ventral bony septum. The external or oral surface of the palatine process presents approximately ten to twelve transverse ridges which correspond to the rugae of the hard palate. These ridges are separated equally by a deep longitudinal sulcus, the major palatine sulcus (sulcus palatinus major) (Figure 4(13)). It continues rostrally from the major palatine foramen across the palatine surface of the maxillary bone.

Concha nasalis ventralis (N.A.V., 1968) The ventral nasal conchal bone (concha nasalis ventralis) (Figures 5(M); 6(M); 7(4)-12(4); 16(E)-18(E); 19; 26(5); 29(f)) arises from a separate center of ossification and is easily removed in the disarticulated, immature skull. Eventually it fuses with the maxilla, lacrimal, and ethmoid bones and presents a more complex structure than the dorsal nasal concha. It is composed of a basal lamella (Figure 19(A)) from which the dorsal (Figure 19(2)) and the ventral scrolls (Figure 19(3)) originate. In the rostral two-thirds, the basal lamella, which approximates the conchal crest (crista conchalis) (Figure 16(17)) of the maxilla, lies in a horizontal plane. Caudally, this lamella changes to a vertical position as it courses dorsal and attaches to the maxilla. In the immature specimen, the lamella extends caudally from the nasomaxillary notch (incisura nasomaxillaris) to a transverse plane passing through the last premolar tooth. In the mature specimen it reaches from one centimeter caudal to the nasomaxillary notch caudally to the second molar tooth.

Arising in a dorsal direction from the medial edge and at right angles to the basal lamella is the dorsal spiral lamella. The dorsal scroll (Figures 5(M); 19(2); 27(4)-30(4)) consists of one and one-half lateral turns throughout its entire length. Rostrally, the scroll is open and caudally it ends in a closed spiral. Enclosed within its simple scroll is the dorsal conchal recess (recessus conchalis dorsalis).

The ventral spiral lamella (Figures 5(m'); 19(3); 27(7) and 28(7)) is more complex and does not form a simple scroll throughout its entire length. In the mature specimen, approximately three-fourths of the ventral spiral lamella consists of one to one and one-half turns toward the ventral lateral wall. Extending from the ventral scroll there is often a perpendicular shelf of bone. Caudally, one-fourth of the conchal bone is recessed and eventually forms the ventral conchal sinus (sinus concha ventralis) (Figures 5(m"); 29(5); 30(7); 31(8); 32(8)). Considerable variation is found in the arrangement of the ventral spiral lamella. In the immature specimen it is usually found as a simple scroll. However, in the mature specimen, it is quite common to observe small, shallow transverse septa extending from the medial wall of the scroll to the lateral wall. These septa form incomplete cells within the ventral scroll, thus causing a greater turbulence of the air flow. Caudally, in the majority of the specimens there exists a relatively complete transverse septum (Figure 5) representing the rostral wall of the ventral conchal sinus. This sinus communicates freely with the ventral conchal recess by a dorsal opening in the septum which is quite variable in size. In the mature specimen, this communication occurs at the transverse level between the third and fourth premolar teeth. In one case the conchal sinus was in direct communication with the maxillary sinus.

Opening into the ventral conchal sinus from a caudodorsal direction is the lacrimal canal (Figures 31(11)-34(11)). In the immature specimen a deep groove exists between the medial wall of the maxillary sinus and the caudal vertical part of the basal lamella (Figure 19(1)). It is continuous and fuses with the extension of the lacrimal canal in the lacrimal bone. Part of the wall of the lacrimal canal is formed by the maxilla. In the immature specimen, the caudal portion of the ventral nasal conchal bone is unique in that it forms the rostromedial wall of the maxillary sinus (Figure 19(4)). This caudal portion consists of a triangular plate of bone which is in most cases thin and papyraceous. Extending laterally from the rostrodorsal and rostroventral edges of this triangular plate is an additional thin lamella, which, in the articulated bone lies inside the recess of the maxilla. This, the caudal part of the ventral conchal bone forms the rostromedial wall of the maxillary sinus. The caudal edge of the thin triangular piece of bone articulates with the lateral lamina of the ethmoid bone, thus completing the medial wall of the maxillary sinus (Figure 18(19)).

Immediately rostral to the caudal edge of the ventral conchal bone is a shallow groove which carries the vessels and nerves to the maxillary sinus and laterodorsal nasal cavity. Occasionally, the dorsal portion of this groove bridges over in the mature specimen, forming a very short canal. In this case, the vessels and nerves course through the canal.

Os frontale

The frontal bone (os frontale) (Figures 2(K)-4(K); 5(F); 6(F); 7(1)-10(1); and 31(2)) shows no evidence of pneumatization in the very young pig. Not until one month of age does the frontal bone exhibit evidence of the impending excavation relative to the extension of the narrow ethmoidal meatuses. The initial excavation continues to increase in size until in the mature specimen the frontal sinuses occupy a major portion of the skull (Figure 5). The first paranasal excavation into the frontal bone is observed as a small evagination of the nasal mucous membrane into the rostromedial aspect of the frontal bone just caudal to the frontonasal suture. Communication with the fundus of the nasal cavity and the initial excavation is situated so that the lateral wall or floor of the passageway is part of the basal lamella of the first endoturbinate (Figures 8(5); 9(5)). At approximately twelve months, this basal lamella (dorsal part of the lateral lamina of the ethmoid) fuses with the corresponding septum of the frontal bone. Thus, the caudal frontal sinus is formed within the frontal bone. As the animal matures, a considerable number of changes and variations occur within the frontal sinuses. The total size of the sinus varies (Figures 7-10) in addition to the passageway for communication with the nasal cavity. The passageway is laterally compressed by the growth of the adjacent sinuses (Figure 11) resulting in a reduced size. The paired right and left sinuses maintain their independence from each other, but the frontal sinus septum usually deviates somewhat to the right or left of the midline. Consequently, the size of one sinus or the other is reduced (Figures 7-10).

Lateral to the medial excavation, forming the caudal frontal sinus, there is formed a series of excavations, which at first correspond to the basal lamella of the ethmoid bone. Each one (Figures 13 and 14), potentially has the opportunity to form a paranasal sinus upon further excavation.

However, all of the initial evaginations of the nasal mucous membrane do not persist to form large, independent sinuses. The prominent ones do continue to excavate the surrounding skull bones. The primitive excavations into the orbital wing of the frontal bone do not persist and therefore present only small depressions in the frontal bone.

Os zygomaticum

The zygomatic bone (ox zygomaticum) (Figures 2(D)-4(D) and 12(3)-14(3)) does not contribute to the formation of the nasal cavity although it is important with respect to the paranasal sinuses. Therefore, a detailed description of it will not be presented. In the immature specimen, the maxillary sinus has already excavated this bone in its rostromedial portion where it articulates with the zygomatic process of the maxilla (Figures 13(J) and 14(J)). In the mature animal the maxillary sinus extends well into the zygomatic bone. There is a depression, located ventrolateral, which serves as the site of origin of the levator labii maxillaris proprius muscle. It also serves to form the orbital margin.

Os lacrimale

The lacrimal bone (os lacrimale) (Figures 2(F)-4(F) and 12(6)-14(6)) is closely related to the nasal cavity, for it eventually excavates to form the lacrimal sinus (sinus lacrimalis) (Figures 13(J) and 14(J)). This bone aids in the formation of the nasomaxillary opening, and transmits the lacrimal canal. It is located in the rostral margin of the osseous orbit and articulates with the maxilla, zygomatic and ethmoid bones.

Its orbital face is concave and presents a muscular fossa and a prominent depression which contains the Harderian gland. Lateral to these depressions is located a crest which represents the line of attachment of the strong orbital fascia. This crest is interrupted by an oblique groove which receives the malar artery as it courses dorsally.

The external or facial surface, is concave and also presents a crest (crista facialis), which is continuous on the maxillary and zygomatic bones, as it outlines the fossa of the levator labii maxillaris muscle. Immediately caudal to this crest and occasionally occuring within the crest are the lacrimal foramen (foramina lacrimalia). In every case the foramen are paired. Extending through the body of the lacrimal bone in an oblique fashion, is the lacrimal canal. It courses rostromedial and lies lateral and slightly ventral to the nasomaxillary opening. The canal is immediately continuous upon leaving the lacrimal bone, with the notch formed in the separate ventral conchal bone. This course constitutes the only osseous part of the lacrimal canal.

The nasal surface of the lacrimal bone is very complicated and is somewhat "V" shaped. Dorsally, it articulates with and eventually fuses with the frontal and nasal bones. Just ventral to this suture, the nasal surface is marked by a series of smooth depressions. These depressions, lined on each side with a shallow crest, correspond to the ethmoidal compartments. Each crest is continuous with a basal lamella of the ethmoid bone. As age increases, the depressions between the lamellae increase and thus the corresponding paranasal sinuses are formed within the lacrimal bone. Immediately ventral and rostral to the depressions, is the lateral wall of the nasomaxillary opening. The lacrimal bone curves dorsally and then ventrally forming an inverted "c" which appears to empty into the maxillary sinus. In the immature specimen the lacrimal bone contains a large extension of the maxillary sinus (Figures 13(H) and 14(H)). This is not true in the mature specimen. When the paranasal sinus is present in the mature specimen, it always arises as a result of the continued excavation of the ethmoidal compartments. The extension of the maxillary sinus in the immature specimen also possesses a caudal extension, which is very thin-wall and can be compared to the lacrimal bulla (bulla lacrimalis) present in the other species.

Canalis lacrimalis

The bony lacrimal canal (canalis lacrimalis) (Figures 31(11)-34(11)) is located mainly within the lacrimal bone. It begins as the paired lacrimal foramen (foramina lacrimalia) (Figures 2(18) and 3(18)) in the orbital ridge of the lacrimal bone and is continued by paired canals which unite after a short distance and form a single canal. As the canal courses through the lacrimal bone it is continued by a bony tubular extension which articulates with a deep groove formed in the caudodorsal portion of the ventral nasal conchal bone (Figure 19(1)). The lateral wall of the canal, after it leaves the lacrimal bone, is formed by the nasal surface of the maxillary bone immediately ventral to the conchal crest (crista conchalis). As soon as the canal, formed by the lacrimal, ventral nasal concha and maxillary bones, reaches the ventral conchal sinus it is no longer continued as a bony canal. Therefore, the bony canal does not extend beyond the fourth premolar tooth (PM_4) in the immature specimen. In the mature specimen, the canal ends at the level of the first molar tooth (M_1). However, the nasolacrimal duct, which lies within the bony lacrimal canal does not, in every case, empty or terminate in the ventral conchal sinus. Occasionally a rostral remnant may be found in some specimens.

Essentially the canal courses through the lacrimal bone in a proximal direction and is completed by the canal formed as a result of the fusion of the ventral nasal concha and the maxillary bone.

Os palatinum

The palatine bone (os palatinum) (Figures 2(E); 4(E); 5(D); 6(D)) is not extensively related to the nasal cavity proper, but it is included because it continues the horizontal lamina and forms the lateral wall of the nasopharynx. It articulates with the ethmoid bone and is excavated by the paranasal sinuses. It is also necessary for the formation of the caudal palatine foramen as well as the palatine canal when fused to the maxilla and the ethmoid bone. It presents a horizontal and perpendicular lamina. Also it presents a nasal and maxillary surface. The horizontal lamina, along with the lamina of the opposite side forms, when fused on the midline, the caudal one-fourth of the hard palate. The nasal surface of the horizontal part of the palatine bone is deeply hollowed and has a medial crest which extends dorsally and articulates or approximates the vomer palatine process. Thus, they form the complete bony septum in the caudal part of the nasopharynx, keeping it separate from the nasal fundus. Caudally, it is notched and generally presents a spine or process which projects caudally. The surface here is triangular with the base caudal and the apex rostral. The palatine surface is smooth, with the exception of an oblique transverse ridge that occurs as the palatine crest.

The perpendicular lamina is slightly concave on the nasal surface, smooth and quite thin as it forms the lateral wall of the nasopharynx. It is roughly triangular with the apex being found in the pyramidal process (processus pyramidalis). Rostrally, and dorsally it is heavily notched to complete the sphenopalatine foramen. Dorsally, the lamina splits and forms a deep excavation. This excavation is in communication with the meatus of the ethmoid bone. Laterally and rostrally, the ethmoid bone articulates with the lateral leaf of the palatine bone. Medially, the medial leaf articulates with the vomer bone which projects a septal process to meet the septal process of the palatine bone. Thus, the right and left halves of the nasopharynx are formed. Rostrally, the lateral face curves slightly as it articulates with the maxilla to form the palatine canal. It is continued into the maxilla and eventually the foramen. Ventrally, the perpendicular part of the palatine bone is marked by an area of fusion with the maxillary tuberosity of the maxilla. The major palatine canal (canalis palatinus major) is also grooved by small, narrow channels which represent the minor palatine canals (canales palatini minores).

Os ethmoidale

The ethmoid bone (os ethmoidale) (Figures 20-24) lies deep within the skull and is situated between the cranial and facial parts of the skull. It lies between the right and left medial walls of the orbital cavities and is further surrounded by the excavations of the nasal cavity. It is characterized by its mass-like form which is a result of its extensive primary and secondary lamina which form the numerous bony scrolls. It is situated so as to restrict and direct the circulation of air within the paranasal sinuses.

In the immature specimen, the ethmoid bone along with the fused vomer is easily disarticulated from the surrounding bones. In addition to the very early fusion with the vomer, fusion with the presphenoid bone occurs very early.

The ethmoid bone, as it is seen in the immature specimen, presents bilateral masses that are united to each other by the lamina cribrosa (Figures 20(6); 22(6); 23(1) and 24(1)). The fusion of the basal lamina of the ethmoid to the wings of the vomer occurs at a very early age. The time of fusion was not specifically determined, but was complete at eight weeks of age. Therefore, the ethmoid bone is relatively easy to disarticulate, provided the vomer and presphenoid bones are included.

Progressive ossification of the ethmoidal labyrinth occurred in the preformed, cartilaginous structure of the immature specimens. This ossification initially extends from the lateral lamina of the ethmoid toward the ossification center of the cribriform lamina.

Ethmoidal labyrinth The ethmoidal labyrinth (labyrinthus ethmoidalis) forms the bulk of the extensive lateral mass. It is composed of numerous delicate bony lamellae, arranged in a parallel manner and extending from the lateral lamina to the cribiform plate. Upon each basal lamella there is a variable number of secondary and tertiary bony scrolls which are termed ethmoturbinates (Figures 20(10)-

22(10). They are arranged so as to be perpendicular to the surface of the cribriform plate in all areas allowing the olfactory nerves to extend toward the brain (olfactory bulb).

About twenty well developed basal lamina arise from the lateral lamina of the ethmoid bone. Of these, only seven ethmoturbinates are well developed. The remaining thirteen lamina, plus five to seven poorly developed lamina, many times only a single scroll, are designated as ectoturbinates for they do not develop sufficiently to reach the midline or perpendicular lamina.

Endoturbinates Seven of the ethmoturbinates extend from the lateral lamina in a scrolling manner and actually reach the midline with their terminal scrolls. These seven ethmoturbinates are termed endoturbinates. They are designated as Endoturbinates I-VII (Figures 23 and 24).

Endoturbinate I The basal lamina of the first endoturbinate (Figures 7(I)-12(I) and 21(I)-24(I)) arises from the dorsomedial surface of the lateral lamina (actually the medial wall of the maxillary sinus) of the ethmoid bone. The basal lamina of the first endoturbinate is very unique in that it is only scrolled on one surface (Figures 23(7) and 24(7)); the other (dorsomedial) surface is smooth and forms the floor of the primitive frontal sinus and eventually the nasofrontal opening (Figure 22(2")).

The basal lamina of the first endoturbinate contains, on the scrolled surface, four ventrolaterally directed scrolls with a terminal scrolling that is considerably different when it is compared to its fellow scrolls (Figure 23(7)).

The peculiar formation of the first endoturbinate presents a medial face which appears to take origin at the cribriform plate and extends rostrally after increasing in size. Located at the level of this enlargement is the cavity of the first endoturbinate which always remains in contact with the nasal cavity from its lateral and dorsal surfaces (Figures 24(d,e and f)). The cavity of the endoturbinate is actually part of the dorsal conchal sinus. Projecting rostrally and continuing the flattened medial face of the endoturbinate, is a narrowed projection which continues along the crest of the nasal bone (Figures 23(10) and 24(10)). This projection, plus the ventrally directed shelf of the nasal bone, forms the dorsal nasal concha (Figure 5(K) and 6(K)).

This horizontal, lateral projection continues the ventrolateral face of the endoturbinate and fuses with the maxilla. The ventrolateral surface is continuous with the squared caudal part of the nasal bone and completes the dorsal nasal concha. This makes it necessary for air, within the middle meatus, to circulate or pass to a level through the fourth premolar (PM_4) tooth to enter the dorsal conchal sinus. To do this, it must make a dorsolateral turn, then course to the lateral face of endoturbinate and enter the cavity by coursing in both a rostral and caudal direction (Figures 24(e) and (f)). As the animal reaches maturity, the opening is found at the level of the last cheek tooth and is greatly reduced in that part of the concha contributed to by the nasal bone. Caudally, the frontal sinus has enlarged considerably and still communicates with the nasal cavity via the same opening, which is now greatly reduced.

Endoturbinate II A second endoturbinate (Figures 21(II) and 23(II)), much smaller than the first, is present and sometimes is designated as the middle nasal concha. Due to its small size it is questionable to designate it as such in the pig. Its development is not from the next successive basal lamina, but from the tenth basal lamella (Figure 24(II)) of the well developed basal lamina. It arises from the lateral lamina at a point that coincides with the origin of orbital portion.

The second endoturbinate takes origin from the lateral lamina at a point where the maxillary sinus portion of the lateral lamina meets and becomes the orbital portion. It consists of seven to eight scrolls on the rostrolateral surface, with the terminal scroll being lengthened to form one-half of the second endoturbinate. On the caudomedial surface of the primary lamella it appears that seven individual scrolls complete its surface. However, of these, the first four are secondary which consist of one additional tertiary scroll on each internal surface. The last three scrolls all result from a single secondary lamina and further consist of two alternately scrolled pieces and a terminal scroll. It is this terminal scroll that appears smaller than the main terminal scroll of the second endoturbinate and therefore both terminal scrolls must be considered as the second endoturbinate. On the caudomedial surface, lying beneath the branched part of the second scroll, one finds three secondary scrolls.

<u>Endoturbinate III</u> Endoturbinate III (Figures 5(N); 6(N); and 23(III)) represents the next consecutive well developed lamina. This lamina is set so that it is oriented at an oblique angle to the midline. It is directed caudolateral. On its rostral face, it presents six simple scrolls with the seventh or terminal scroll being the visible, medial part. On its caudal surface it presents six, simple scrolls.

<u>Endoturbinates IV, V, VI and VII</u> The remaining four endoturbinates (Figures 5(N); 6(N); 23 and 24) are similar to each other and they can be summarized in the following table.

Table 1. Summary of the secondary scrolls present on the rostral and caudal surface of the original basal lamina. Endoturbinates IV-VII

Endoturbinate	Number of scrolls	
	Rostral	Caudal
IV	5	4
V	3	2
VI	2	2
VII	1	1

Ectoturbinates Of the total number of ethmoturbinates, only seven approximate the midline and are termed endoturbinates (Figures 23(3) and 24(a and b)). The remainder of the small scrolls, some presenting only single scrolls, are designated as ectoturbinates. Of these ectoturbinates all are similar in origin and structure, but only ten are well developed and somewhat constant. The well developed ectoturbinates are generally located between the lamina of the first and second endoturbinates. Of these, some extend closer to the midline (similar to the endoturbinates but not reaching the midline), and arrange themselves in a medial and a lateral series. Only the larger lamina are constant.

Lamina perpendicularis The perpendicular lamina (lamina perpendicularis) (Figures 21(1) and 22(1)) is an ossified sheet, situated between the two lateral masses of the ethmoid and serves to unite the right and left cribriform plates. It is a very compact bone, and is found to fuse very early with the presphenoid bone. Ventrally, it is fitted into a groove located in the vomer bone. The lamina perpendicularis, in the immature specimen fuses with the presphenoid bone caudally at an early age, but does not uniformly fuse with the vomer at the same age. Therefore, there exists in the macerated bones, a canal immediately ventral to the lamina that persists in the adult. It contains small blood vessels which enter the cartilage of the nasal septum. Also, in the immature specimen, it appears to be the result of a progressive ossification of the cartilaginous septum. Caudally, in the area of the fourth, fifth, sixth, and seventh endoturbinates, numerous depressions corresponding to the endoturbinates occur on the lateral surface of the lamina perpendicularis. A strongly developed crista galli (Figures 20(8)-23(8)), which is the dorsal extension of the lamina perpendicularis, exists between the cribriform plates. Eventually, the crista galli fuses rostrally on the midline with the frontal bone.

Lamina externa In the immature specimen, the only portion of the external lamina that is obvious, is that part which forms the medial wall of the maxillary sinus (Figures 20(4)-22(4); 23(6) and 24(6)). It is, as the medial wall, completely ossified and provides origin for the ethmoidal lamellae. In addition, there is a thin, lateral plate of bone caudal to the medial wall of the maxillary sinus. It is visible in the medial wall of the osseous orbit and is termed the orbital lamina (lamina orbitalis) (Figure 21(5). It forms part of the medial wall of the orbit. The remainder of the lateral mass of the ethmoid is covered by the surrounding bones, such as the frontal and lacrimal bones.

Lamina cribrosa In the pig, the lamina cribrosa or cribriform plate (lamina cribrosa) (Figures 20(6); 22(6); 23(1) and 24(1)) is paired and separated by a medial structure rising dorsally, the crista galli. In the immature animal, where the ethmoid is easily removable, a smooth ridge (Figure 24(9)) exists around the periphery and the perforated portion is concave from side to side and end to end. It is situated in a horizontal plane in the posterior part, and rises to almost vertical in the rostral part. It is perforated by well over one-thousand foramina. Some of these foramen are quite large and arranged around a crest which corresponds to each basal lamella. Just lateral to the crista galli, one finds a row of large foramina possessing smaller secondary foramina within the primary larger one. This arrangement of the foramina accounts for the extremely high number of foramina. Parallel to the medial row is an additional series of foramina that are not so uniform in their arrangement.

Within the surface of the ethmoid plate there is a smooth crest which is devoid of all foramina. It corresponds to the basal lamina of the second endoturbinate. Continuous with the above, non-perforated crest, there is a similar smooth, slightly elevated area, devoid of foramina. It radiates slightly lateral and represents the area of the cribriform that is the last to ossify. It bridges the basal attachment of the ethmoturbinate and separates all of the lamina occurring prior to that of the second endoturbinate.

Relationship of the ethmoid bone to the adjacent bones

The ethmoid bone is related to the following bones:

Vomer The ethmoid bone fuses very early with the vertical wing of the vomer. The external lamina and the basal lamina also fuse with the vomer (Figures 22(2"")). Thus, fusion of the ethmoid bone to the vomer forms the basal lamina (lamina basalis) (Figure 24(5)). The basal lamina separates the nasal fundus from the nasopharynx. The vomer also exhibits slight undulations which correspond to the adjacent scrolls of the ethmoturbinates.

Os presphenoidale In the immature specimen, the ethmoid bone has fused to and is continuous with the presphenoid bone. The crista galli along with the medial lamina appear to fuse with the presphenoid bone. Therefore, it is difficult to disarticulate the ethmoid bone from the presphenoid bone as well as the vomer.

Os palatinum The palatine bone articulates with the vomer medially and the ethmoid bone dorsolaterally. Specifically, the palatine bone articulates in such a manner, that the orbital lamina of the ethmoid continues onto the lateral face of the palatine bone, forming the pterygopalatine fossa. In the immature animal, the articulation mentioned is hidden by the projection of the maxillary tuberosity.

Paranasal Sinuses

Sinus maxillaris

The maxillary sinus (sinus maxillaris) (Figures 12(H)-14(H); 16(19)-18(19); 31(7)-34(7)) is located mainly within the maxilla, and is completed by the presence of the zygomatic, lacrimal, ethmoid and ventral conchal bones. In most specimens, it is a well developed paranasal sinus.

In the immature specimen, it is represented as a well developed sinus. In fact, it is the first paranasal sinus to develop and achieve significant size in the young pig. If all the surrounding bone is removed, the remaining mucous membrane sack is presented with medial, lateral and dorsocaudal extensions. The medial and lateral extensions are formed as a result of an incomplete, smooth bony lamella that projects from the bony floor, thus, incompletely dividing the sinus into two compartments (Figure 33(7)). The dorsocaudal extension involves an excavation into the lacrimal and zygomatic bones. Dorsally, this sack exhibits an elongate indentation for the bony lacrimal canal. Medial and dorsal to this depression is the laterally compressed nasomaxillary opening (apertura nasomaxillaris) (Figures 31(6)-34(6)).

In the mature specimen, the maxillary sinus presents many variations in its final form. Dorsally the sinus does not usually extend above the bony lacrimal canal. Therefore, it no longer possesses the lacrimal extension found in the young specimen. In most cases, the lacrimal canal parallels the dorsal limit of the sinus and is separated from it by a thin bony lamella. Ventrally, the floor, interrupted by the incomplete bony septum, is slanted laterally and forms as well, the roof of the infraorbital canal (Figure 33(7). The cheek teeth in the pig do not project into the floor of the maxillary sinus but they do form the floor of the infraorbital canal. The floor of the maxillary sinus does not usually extend more than one centimeter below the facial crest. Rostrally, the sinus ends about one to two centimeters caudal to the infraorbital foramen or in a transverse plane through the first molar tooth (M_1). Projecting into the floor, from a caudal direction, is the incomplete bony septum. This septum results in an incomplete division of the maxillary sinus into medial and lateral compartments. In most cases, this septum is excavated from the caudal aspect by the paraethmoidal sinuses (Figures 13(I) and 14(I))

(Loeffler, 1959a). Thus it forms a triangular chamber in the floor of the maxillary sinus. In one specimen, the intimacy of the ethmoid and maxillary sinuses resulted in a communication, by means of an imperfect nasomaxillary opening. Caudally, the maxillary sinus does not extend beyond a transverse plane through the last molar tooth. In one-half of the specimens, a thin walled, bony bulla existed lying ventral and medial to the nasomaxillary opening. They are excavated and usually connect with an ethmoidal meatus either directly or through a rostral frontal sinus.

In the mature specimen, the extension of the sinus into the zygomatic bone had increased. In several cases, the maxillary sinus was greatly reduced in size. Some of these reductions resulted in the following: increased caudal excavation of the paraethmoid sinuses, increased size of the ventral conchal sinus, and increased bulla formation from the ethmoidal meatus.

Apertura nasomaxillaris

The nasomaxillary opening (apertura nasomaxillaris) (Figures 5(4); 12(H); 31(6)-34(6)) serves to connect the nasal cavity with the maxillary sinus. It is represented in all specimens by an elongate, laterally compressed passageway. In the immature specimen, it is formed by the dorsal nasal surface of the maxilla (Figure 16), the independent ventral nasal conchal bone (Figure 19), the nasal surface of the lacrimal bone, and the dorsolateral surface of the external lamina of the ethmoid bone (Figures 21(4) (white arrow); 22(2); 24(c)). It empties into the maxillary sinus on its dorsomedial wall. In the immature specimen, it extends from a transverse plane through the fourth premolar tooth (PM_4) in a caudodorsal direction to empty into the sinus in a transverse plane caudal to the first molar tooth (M_1) to finally empty into the sinus in a transverse plane through the last molar tooth.

Sinus frontales

In the domestic pig, the frontal sinuses (sinus frontales) (Figures 5(f and g); 6(f and g); 7(A,B and C); 14(A, B, and C); and 29(6, 9 and 10) and 34(6, 9 and 10)) represent the greatest excavation as well as the most complex of all the paranasal sinuses. Developmentally, they appear to be separable into two entities. These are the rostral and caudal frontal sinuses. However, the caudal frontal sinus develops and retains a direct connection with the nasal cavity similar to the maxillary sinus. This is not the case with the rostral frontal sinuses which clearly communicate through the ethmoidal meatuses. Therefore, it is apparent, that two separate systems exist. Considerable variation exists between specimens and should be taken into consideration.

Sinus frontalis caudalis The caudal frontal sinus (sinus frontalis caudalis) (Figures 5(f); 7(B)-10(B); 11(A); 13(B); 14(B) and 31(9)), in the mature pig represents the largest of the paranasal sinuses. It excavates the frontal, parietal, occipital and, to a variable extent, the temporal bones.

Developmentally, this frontal sinus is usually the first to show any appreciable excavation into the frontal bone. In two cases, the medial rostral frontal sinus was larger (Figures 7(A and B) and 10(A and B)). In the young specimen, the floor of the sinus, depending upon the extent of excavation, represents the basal lamina from which the first endoturbinate develops. It is the first basal lamina of the ethmoidal labyrinth and it presents four additional scrolls on the side away from the floor of the developing sinus. The opening (Figure 24(d)) into the developing sinus, from the nasal cavity, occurs at the level of the first molar tooth and varies somewhat depending on the length of the nasal cavity. In this respect, the communication of the caudal frontal sinus can be compared to the subsequent development of the medial and lateral rostral frontal sinuses, the lacrimal and the ethmoidal sinuses. The caudal frontal sinus communicates with the nasal cavity and is therefore regarded as the most dorsal component of the ethmoturbinates. As the animal increases in age, the excavation becomes more extensive and invades the frontal, parietal and occipital bones. In most of the specimens, the passageway between the nasal cavity and the frontal sinus (apertura nasofrontalis) (Figure 5(2) arrow) usually becomes laterally compressed as the ethmo-turbinates undergo subsequent development. In one mature specimen, the caudal frontal sinus, had never developed beyond the original flattened, blind, mucous membrane lined pouch about three centimeters long. In one other specimen, the development was arrested unilaterally, except the blind sinus was slightly larger than in the previous specimen. Generally, a septum (septum sinuum frontalium) extends from the nasal region to separate the sinuses. There was considerable variation in placement of this septum. In the case of the obliterate unilateral sinus, only the interfrontal septum (septum interfrontale) remained. The position of this transverse septum was also variable.

In the mature specimen the nasofrontal opening occurs at the level of the last molar tooth. It is usually compressed laterally as a result of the increase in the size of the neighboring frontal sinuses. In many specimens it appears that the mucosa lining the opening is in contact, whereas others maintain a relatively open nasofrontal communication. Generally, in mature specimens, this narrowed passage way is approximately three centimeters in length. In the mature specimen, the caudal frontal sinus is usually extensively excavated resulting in only a thin outer and inner lamella of bone. This hollowed structure is greatly strengthened by the presence of numerous compartments which freely communicate with each other, but not with those of the opposite side.

Sinus frontales rostrales

Sinus frontalis rostralis medialis The medial rostral frontal sinus (Figures 5(g); 7(A); 10(A); 13(A); 14(A); 29(6) and 30(9)-34(9)) occurs as the next subsequent ethmoidal compartment lateral to the caudal frontal sinus. In some immature specimens, this sinus had achieved greater excavation than the caudal frontal sinus at an early age (Figures 7(A) and 10(A)). This is similar to the case in the old animal where the nasofrontal opening is unilaterally or bilaterally imperfect. This sinus and its increase in size is responsible for the compression of the nasofrontal aperture in most specimens. The right and left halves are separate in the adult specimen. This sinus is usually located close to the median plane and in the rostral part of the frontal bone. In general it corresponds, in the immature specimen, to one ethmoidal meatus. It is therefore bound by two basal ethmoidal lamina which fuse or ossify with two corresponding lamina of the frontal bone. The subsequent excavations and sinus formation in the surrounding bones are the result of an increase in the ethmoidal meatuses. Normally, the excavations of the frontal bone only communicate with the nasal cavity by connecting through the ethmoid compartments. However, in one case, the medial rostral frontal sinus communicated directly with the dorsal conchal sinus as well as the nasal cavity. In some cases, the medial rostral frontal sinus was extensive enough to extend into the nasal bones as well as caudal to the level of the medial wall of the orbit. In one specimen, where the caudal frontal sinus was absent, all of the limited excavation into the bones of the skull occurred from the right medial frontal sinus. In this case the interfrontal septum was lost at the level of one of the medial rostral frontal sinuses.

Sinus frontalis rostralis intermedius   The intermediate rostral frontal sinus (Figures 33(17 and 18) and 34(17 and 18)) exists as a separate entity, with individual connection to the ethmoidal meatuses. In several of the specimens, it was a relatively small chambered sinus, occurring between the extensive medial and lateral compartments. This sinus is associated with the sequentual development of the ethmoidal compartments.

Sinus frontalis rostralis lateralis   The lateral rostral frontal sinus (Figures 13(C) and 14(C)), exists as a relatively large paranasal sinus only in the mature animal. It develops independent of the neighboring frontal sinuses, and is located more caudolateral to the medial frontal sinus. It is generally located in the medial wall of the orbit, but also excavates the processes of the frontal bone.

Sinus lacrimalis

The lacrimal sinus (sinus lacrimalis) (Figures 13(G); 14(G) and 32(16)-34(16)) in the pig possesses a variable development, but can be defined as that ethmoidal component that excavates the lacrimal bone. It may be greatly reduced, absent or occur as a part of the lateral rostral frontal sinus or as an independent ethmoidal excavation into the lacrimal bone.

In the young specimen, prior to the development of the frontal sinuses, the only excavation involving the lacrimal bone is that of the maxillary sinus. As the animal increases in age, the importance of this extension is reduced. Concurrently, the excavation of the frontal-ethmoidal sinuses takes place and the lacrimal bone becomes excavated. When the lacrimal sinus is independent it usually corresponds to the fourth or fifth ethmoidal compartment. When present, its ventral border is the lacrimal canal and the maxillary sinus. Medially, dorsally and caudally, the rostral frontal sinus forms its borders. Caudally, the rostromedial wall of the orbit forms one of its borders. The lacrimal sinus is connected with the fourth and fifth ethmoidal meatuses. The size of the lacrimal sinus is quite variable and in some cases it is completely absent as an individual sinus. Of those cases in which the lacrimal sinus was absent, about fifty per cent appeared to have the area incorporated as part of the lateral rostral frontal sinus. In some cases, the intermediate rostral frontal sinus excavated the lacrimal bone which may be confusing. In one case, the lacrimal sinus was a result of communication or extension of the medial rostral frontal sinus.

Sinus sphenoidalis

The sphenoid sinus (sinus sphenoidalis) (Figures 5(h); 6(h); 7(D)-11(D)) achieves a very complex development, unlike that in any of the other domesticated animals. Complete growth of the sinus results in the excavation of the presphenoid, basisphenoid and the temporal bones.

In the immature specimen, the sphenoid sinus develops as a bilateral ethmoidal excavation into the presphenoid bone. As growth occurs, the excavation proceeds into the basisphenoid bone. In the finite form the sinus presents three extensions. The first extension is ventral into the pterygoid process of the basisphenoid. Eventually, this excavation may reach the palatine bone, but only one specimen possessed this extension. Laterally, the sinus extends into the temporal bone, with a large excavation. From here, the sinus further extends dorsally into the squamous part of the temporal as well as into the zygomatic process. The sinus in the temporal bone excavates very close to the structures of the inner ear in most cases. In one specimen, a separate extension was found extending from the central cavity within the basisphenoid in a rostrodorsal direction to excavate the frontal bone in the region of the medial orbital wall. This chamber received an independent connection with the ethmoid meatus. The lateral compartment of the sphenoid, gives rise to the temporal and pterygoid extensions and communicates with the caudoventral aspect of the ethmoidal meatus. As the sphenoid sinus opening (apertura sinus sphenoidalis) (Figures 5(n) arrow) matures, an additional extension, found only in two specimens, extended caudally into the basioccipital bone. In the majority of specimens, there exists a septum (septum sinuum spheno-palatinum) which separates the right and left sphenoid sinuses.

Sinus paraethmoidei

The paraethmoid sinuses, (sinus paraethmoidei) (Loeffler, 1959a)(Figure 13(I)) include any independent excavations into the surrounding bones not previously identified as specific sinuses. They connect with the ethmoidal meatuses and are similar in development to the rostral frontal, lacrimal and sphenoidal sinuses. They develop as a result of progressive excavation into surrounding bone and maintain their continuity with the nasal cavity via the ethmoidal meatuses.

One of the prominent ethmoidal excavations, (paraethmoid sinus), progressed rostrally into the medial ventral wall of the orbit, and finally invaded the bony septum of the maxillary sinus. It was formed between the roof of the infraorbital canal and the walls of the shallow septum. The sinus appears in the form of a triangle. Rostrally, the sinus does not extend beyond the middle of the maxillary sinus, or to a level where the septum is so shallow that it no longer projects into the maxillary sinus. In other cases, when the sinus was present, it was in direct communication with the maxillary sinus. However, the maxillary sinus did not communicate with the nasal cavity via the nasomaxillary aperture as it did in the majority of the specimens.

In some cases, the paraethmoid sinuses were observed as extensions into the basal lamina of the ethmoid bone. These excavations extended the ventral ethmoid meatuses into the palatine bones in the region of the vomeroethmoid and vomeropalatine sutures (Figure 5(j)). These sinuses might correctly be interpreted as palatine sinuses.

Occasionally, small excavations were found within the rostromedial wall of the orbit. They were small and poorly developed, existing as minute extensions of the ethmoidal meatuses. They exist as paraethmoid sinuses and are not specifically identified.

Sinus concha dorsalis

The dorsal conchal sinus (sinus concha dorsalis) (Figures 5(k); 12(I); 23(10); 24(10); and 30(5)) is an excavation within the nasal bone, the ethmoid bone and occasionally the frontal bone. It consists of a conchal portion, (pars conchalis) and a nasal portion (pars nasalis).

The conchal part, lying within the cavity of the first endoturbinate in the immature specimen, is large and extends from slightly rostral to the attachment of the endoturbinate to the cribriform plate, to a transverse plane passing between the 3rd and 4th premolar (PM_3) and (PM_4). The largest part of this sinus occurs slightly caudal to its rostral limit at a transverse plane passing through the 4th premolar tooth (PM_4). In the mature specimen, the rostral limit of the conchal part occurs in a transverse plane passing through the 2nd molar tooth (M_2). The greatest part in the mature specimen occurs in the transverse plane passing the 2nd and 3rd molar teeth (M_2) and (M_3).

The nasal part of the dorsal conchal sinus (Figure 15(4)) lies within the nasal bone and reaches rostrally into the bone to a level about midway along the bone. In one specimen the nasal extension was paired and did not extend all the way into the nasal bone. The length of the excavation into the nasal bone was variable in most of the specimens observed.

In the mature specimen the excavation into the nasal bone is continuous with the conchal part occurring within the ethmoid bone. It is reduced in size and does not usually extend into the nasal bone beyond a transverse plane passing through the first molar tooth (M_1). However, in one specimen, it did extend to the level of the 4th premolar.

Sinus concha ventralis

The ventral conchal sinus (sinus concha ventralis) (Figures 5(m"); 30(7)), located in the caudal part of the ventral concha, was not seen as a sinus in the immature specimen. Instead, it occurs as a caudal enlargement of the ventral conchal recess. Medially, in the young specimen, it is bordered by the basal lamina of the conchal bone and laterally by the rostromedial wall of the maxillary sinus. This thin, papyraceous wall is a modification of the ventral scroll of the concha. Dorsolaterally, the cavity is bordered by the nasal surface of the maxilla just ventral to the conchal crest (crista conchalis). At this stage of development, the transverse septum, which, in the mature specimen separates the recess of the ventral concha (Figure 5(m')) from the sinus, is not fully formed. The formation of the septum was variable in most of the specimens observed. In some cases, the septum was complete, and in others it was low and incomplete. As age increases, the sinus usually increased in size, however, in some specimens it was reduced in size. A very distinct feature of the sinus in the immature as well as the mature specimen, was that the bony lacrimal canal terminates as it opened into the caudodorsal aspect of the osseous cavity. However, in all cases observed, the nasolacrimal duct did not open directly into the ventral conchal sinus. In some cases, resulting from the variable length of the duct, it was found to empty at different places along its rudimentary course. In two cases, it appeared that the rostral portion of the duct was patent but the middle portion was open to the nasal cavity directly.

In the mature specimens, the ventral conchal sinus was located just medial to the facial crest between rostrocaudal limits passing through the fourth premolar (PM_4) and the second molar (M_2). In those specimens of considerable size, the sinus would encompass a greater relative rostrocaudal length.

DISCUSSION

In a discussion of the structures of the nasal cavity and paranasal sinuses it is difficult to separate, into two entities, structures that are functionally and morphologically related to each other. Morphologically, within the nasal cavity, the most outstanding and interesting structures observed were the dorsal, middle and ventral nasal conchae. With equal emphasis the remaining conchal structures of the ethmoidal labyrinth presented intriguing morphological structures within the nasal cavity. However, it is the ethmoidal labyrinth, intimately related to the formation of the paranasal sinuses, that provides a structural component capable of linking together the nasal cavity (fundus) and the paranasal sinuses. One exception is the maxillary sinus which is not directly related to the ethmoidal labyrinth as are the other paranasal sinuses.

Nasal Cavity

Concha nasalis dorsalis

Comparatively, the dorsal nasal concha presents a simplified structure in the pig (Graeger, 1958; Wilkens, 1958; Loeffler, 1958; Nickel and Wilkens, 1958, and Loeffler, 1959a). For the earliest detailed description of the turbinated bones in general, Casserius (1610) was credited with describing and naming them in man.

Parker (1874) described the "nasal turbinal" in the young pig embryo as being the "...swelling below the down-turned roof as the rudiment of the "nasal turbinal", scarcely developed in the adult of this type". With this statement he demonstrated two significant points: the recognition of the dorsal nasal concha and reference to its reduced (simple) status in the adult pig.

Since the original observations, textbook descriptions have usually been insufficient in detail or totally absent (Chauveau and Arloing, 1890; Martin and Schauder, 1923; Zimmerl, 1930; Ellenberger and Baum, 1943; Bruni and Zimmerl, 1951; and Sisson and Grossman, 1953).

Zuckerkandl (1887) described the upper nasal turbinate as being derived from two parts, the nasal bone portion and the caudal ethmoid bone portion. Chauveau and Arloing (1890) recognized the contribution of the ethmoid bone by referring to the concha as the "ethmoidal coronet", and Loeffler (1959a) described the basis of the dorsal nasal concha as the first endoturbinate. The present investigation substantiates the observations of Loeffler (1959a) and has described and illustrated (with disarticulated bones) both the nasal and ethmoid bone components. To observe these relationships it is necessary to study different stages in the development of the skull. Červený (1970) has described the first endoturbinate and shown its relationship to the nasal bone as it forms the dorsal nasal concha. The present observations are in agreement with the observations of Cervený (1970).

Sinus concha dorsalis Chauveau and Arloing (1890) described a cavity within the nasal bone, but Ghetie (1941) was the first to describe and label the "nasenbeinhöhle". Ellenberger and Baum (1943) described the nasal bone sinus and added the observation regarding the sinus within the caudal part of the dorsal nasal concha. The present author agrees with the observations of Loeffler (1959a) and Cerveny (1970) regarding the macerated, disarticulated specimen. However, in the unmacerated state in some of the specimens, it was observed that the excavation was rostrolaterally excluded from communication with the nasal cavity by the presence of a continuous membrane covering the opening. The absence of communication was observed in young specimens (six months old). In the mature specimens the size of the sinus, was significantly reduced, resulting in increased space for communication between the frontal sinuses and the nasal cavity.

A comparable relationship between the frontal sinus, nasal cavity and the conchal sinus exists in the equine species. However, the total size of the cavities is greatly reduced in the pig.

Červený (1970), in a description of the basal lamina of the first endoturbinate, stated that it formed the roof of the cavity of the dorsal conchal sinus and the floor of the rostral extension of the medial frontal sinus. However, the present author observed that it formed the floor of the passageway to the caudal frontal sinus (sinus frontalis caudalis). Use of the term medial frontal sinus, in this instance, must have indicated only the relative position of the sinus.

Regarding the terminology suggested for this sinus, Loeffler (1959a) has identified the Pars nasalis (that portion of the sinus extending into the nasal bone) and the Pars conchalis (that portion existing within the conchal or first endoturbinate). This terminology was not adopted for use in N.A.V. (1968). However, it effectively designates the specific portions of the sinus and would be recommended by the present author. Similar terminology would also apply to the equine paranasal sinuses as well as the other species. An example of common usage has been the "frontoturbinate sinus" or the "conchofrontal sinus".

Concha nasalis ventralis

Observations, regarding the development of the skull, revealed the total absence of fusion of the osseous portion of the ventral nasal concha with the maxillary bone. The ventral concha was easily disarticulated in all specimens less than eight months of age.

Sturm (1937) discussed the gradual resorption of certain parts of the cartilaginous nasal skeleton and observed an area of resorption just dorsal and caudal to the enrolled edge of the developing maxilloturbinate (ventral nasal concha). This resorption gradually isolated the ventral concha and was complete after the embryo reached seventy-two millimeters. The cartilaginous portion did continue rostrally as the "atrioturbinale". Patten (1944), with histological observations on cross sections of the pig embryo, demonstrated the isolation of the ventral conchal cartilage from the nasal capsule. Concurrent with the resorption of the cartilaginous nasal capsule, the maxillary and nasal bones developed individual centers of ossification.

Sturm (1937) identified a separate center of ossification occurring very early within the isolated ventral conchal anlage. As time passed the ossification was completed within the preformed cartilage of the dorsal and ventral scrolls.

General textbooks of anatomy have not treated the ventral nasal concha with sufficient detail to describe the independent development of the conchal bones. Loeffler (1959a) describes the ventral nasal concha as an individual bone. N.A.V. (1968), in the section "Osteology", recognized the osseous nature of the ventral nasal concha and adopted the term "concha nasalis ventralis". The term is not, as are many of the bones, preceded with the term "os".

The ventral conchal bone, during its development, undergoes considerable changes as it forms its typical scrolled structure. Comparatively, it is not as complex as the same turbinate in the other domestic species (Graeger, (1958)); Wilkens, (1958); Loeffler, (1958) and Nickel and Wilkens, (1958). Observations by this author have confirmed the previous description regarding the nature of the dorsal and ventral scrolls.

The dorsal scroll, consisting of one and one-half turns, was constant in all normal specimens observed. Occasionally, one small transverse septum was observed causing the dorsal scroll to become slightly spiralled in nature. This observation is in contrast to the extensive scrolling in the ruminant and the horse which produces numerous, small isolated cells within the rostral portion of the concha. This spiral contributed to the turbulence of air flow.

The ventral scroll presented a more complex form with an incomplete transverse lamella which separated the rostral, spiralled portion from the caudal, sinus portion. Loeffler (1959a) demonstrated a transverse septum of the ventral scroll and described the communication of the maxilloturbinate recess with the ventral conchal sinus. Observations of the present author have confirmed the description of the ventral nasal concha and its division into a rostral turbinated portion and a caudal sinus portion.

The sinus associated with the ventral concha was not present at all ages. The ventral scroll at six months of age was only a simple coiled lamina throughout its entire length. Gradually this simple coiled lamina was transformed into a septum which separated the turbinate into its two components.

The participation of the ventral conchal bone in the formation of the maxillary sinus was not mentioned in the existing literature. Gradually, as the pig embryo develops, the maxillary recess forms immediately caudal and slightly dorsal to the ventral concha. This proximity provides the ventral conchal bone with the opportunity to participate in the formation of the rostromedial wall of the maxillary sinus. In the specimen, six months old, as the ventral conchal bone was disarticulated, the caudal aspect presented a triangular, papyraceous portion which blended smoothly with the neighboring maxillary bone. Completion of the maxillary sinus required the lacrimal bone and the ethmoid bones before all of the boundaries were obvious.

Concurrent with the changes resulting in the formation of the maxillary sinus, the incomplete transverse septum gradually increased in height while the depression caudal to the septum also increased. This activity resulted in the formation of the ventral conchal sinus.

Sinus concha ventralis Ellenberger and Baum (1943) first mentioned a special cavity lying rostral to the maxillary sinus. From this original description, little information was available regarding the ventral maxilloturbinate recess and the nasal cavity. Until Loeffler (1959a) no further recognition was given to the sinus of the ventral conchal bone by any of the authors of veterinary anatomy textbooks. The present observations have confirmed the observations of Loeffler (1959a) and extended the description relating the development of the sinus to its terminal appearance.

Gradually, as the age of the specimens increased, a small depression was formed immediately caudal to the developing transverse septum of the ventral conchal bone. This depression was located medial to the medial wall of the maxillary sinus where it gradually enlarged as the transverse septum increased in height. Eventually the ventral conchal sinus increased until it resembled a medial compartment of the maxillary sinus. However, the wall separating the maxillary sinus and the ventral conchal sinus persisted at all times, thus forming a complete separation between the two sinuses. The ventral conchal sinus varied in size and in only one case there was communication with the maxillary sinus. In some specimens there were small extensions toward the maxillary sinus, but they failed to penetrate the medial wall of the maxillary sinus. This was not the case with the ventral conchal sinus and the nasal cavity. At all times there was a complete freedom of communication with the middle meatus and the ventral conchal sinus. Ellenberger and Baum

(1943) pointed out that the special cavity they observed remained in communication with the nasal cavity at all times. This communication persisted as a result of the incomplete formation of the transverse septum formed within the ventral nasal concha.

The present author also observed that the rostral opening of the nasolacrimal duct was located in the region of the ventral conchal sinus. It appeared as a defect in the roof of the sinus which permitted the duct to communicate freely with the nasal cavity ventral to the basal lamella of the ventral conchal bone. This opening into the nasal cavity was considerably more caudal than the opening in the other domestic species. However, it was possible to observe the rostral continuation of the nasolacrimal duct in the area immediately caudal to the vestibule of the nasal cavity. In most of the cases observed the rostral portion was not functional.

Ethmoidal labyrinth

The ethmoid bone in the pig certainly represents the most complex bone of all those considered with the nasal cavity. It is not difficult to understand (simple observation will yield understanding) but it is most difficult to describe.

Most of the original authors consulted were content to simply identify the number of endoturbinates that existed in a given species. Illustrations of this area deliberately were rendered slightly vague in the region of the ethmoturbinates. The ethmoid bone was never clearly illustrated as it appeared in the disarticulated state. With these limitations the author has attempted to provide some help in regard to the understanding of the ethmoid bone. Gradually greater emphasis has been placed on the anatomy of the ethmoid bone in order to understand its role in the formation of the paranasal sinuses.

Zuckerkandl (1887) first observed and described a medial row of eight endoturbinates in the pig. Paulli (1900) discussed the ethmoid bone and began to relate the ethmoidal meatuses to the formation of the paranasal sinuses. He originally described seven endoturbinates which possessed a total of eight terminal scrolls. Since Paulli (1900), numerous authors have chosen to interpret rather than to observe and as a result considerable confusion still remains regarding the ethmoturbinates. Some of the confusion is with the terminology that has been applied to the ethmoturbinates. Sisson and Grossman (1953) cited Paulli (1900) but failed to do so correctly and suggested that the pig possessed five endoturbinates and eighteen ectoturbinates. Certainly, to recognize only five endoturbinates they must have failed to recognize the largest of all the endoturbinates, the first endoturbinate. The total number of ectoturbinates is variable but eighteen represents a rare minimum.

Since the very first description of the ethmoturbinates, there has been a considerable degree of confusion among authors. In the present study all of the basal laminae were first determined and subsequently sculptured and observed more closely as individual bones. This technique of examination permitted the accurate assessment of each individual basal lamina and the tabulation of the observations.

The observations reported here are in agreement with those of Červený (1970). He proposed a classification and applied a terminology useful to the description of the ethmoidal labyrinth during any stage of its development. He did not relate the ethmoidal meatuses to the development of the paranasal sinuses as the present author attempted to do.

The author has described seven endoturbinates which provide the basis for the classification of the ethmoidal meatuses. Recognition of seven endoturbinates is in agreement with the observations of Červený (1970). He has suggested six ethmoidal meatuses to be designated as Meatus ethmoidalis I-VI. Each meatus is further subdivided into compartments by the presence of a variable number of ectoturbinates. Within an individual meatus, the remaining ectoturbinates are further arranged into a medial and a lateral series. Of the medial series of ectoturbinates, within the first ethmoidal meatus, Červený (1970) observed four prominent basal laminae. The present observations disagree and recognize only three prominent ectoturbinate laminae. This is because, the four scrolls appearing on the ventral surface of the dorsal part of the lateral lamina belong as secondary scrolls to that basal lamina. Basically, the three prominent ectoturbinates of the medial series in the first ethmoidal meatus are in agreement. The present observations agree with the division of the four compartments within the first ethmoidal meatus.

Červený (1970) has described the lateral series of ectoturbinates and suggested they are extremely variable. The total number of lateral series ectoturbinates, within the first ethmoid meatus, varies from seven to twenty-five with an average of about fourteen. The observations of the present author showed that an average of eighteen would be more correct. Nevertheless the ectoturbinates are quite variable and there is a reasonable degree of error in determination of the ectoturbinates.

The present author has observed that ten ectoturbinates are prominent and constant in all specimens observed. Three of these are found within the first ethmoid meatus and are recognized by Červený (1970) as all but one of the medial series of ectoturbinates. The remaining seven were prominent and observed by the author between the remaining endoturbinate laminae. The results of Červený would place all seven of these remaining ectoturbinates in the lateral series. Other observations of the author confirm those of Červený (1970). He has suggested the total number of ectoturbinates to range from twenty-two to thirty-three in number with an average of twenty-six. The observations of the present author have been to suggest that twenty ectoturbinates arise from the lateral lamina of the ethmoid bone. However, this figure is less than the least number of ectoturbinates observed by Červený (1970).

Paranasal Sinuses

The paranasal sinuses in the domestic pig presented numerous well developed excavations into the surrounding bones of the skull. The frontal sinuses, first described by Leyh (1859), have frequently been compared to the paranasal sinuses of the ruminant. Chauveau and Arloing (1890); Sisson and Grossman, (1953), and others referred to the similarities of the paranasal sinuses in the pig and ruminant. Other comparative relationships can be established regarding the similarities between species, only after investigation and understanding of the development of the sinuses.

Maxillary sinus

Of all the paranasal sinuses in the pig, the maxillary sinus presented the least disagreement among authors. However, there are some points where confusion still exists.

The present author observed a medial and a lateral extension of the maxillary sinus. The portions (medial and lateral) were separated by a shallow septum extending dorsally from the floor. This observation was not limited to the mature specimens, for the septum was observed in the immature specimens also. Similar to the horse, the septum is related to the course of the infraorbital canal through the maxillary bone, although in the pig it is less prominent. Ghetie (1941) described a "grosse Kieferhöhle" and observed the separation of the maxillary sinus into inner and outer compartments.

In addition to the main maxillary sinus, Ghetie (1941) described a "kleine Kieferhöhle" which he found only in aged pigs. The present author observed a similar sinus extending rostrally into the shallow septum of the maxillary sinus just dorsal to the infraorbital canal. This sinus was an extension of the ethmoidal meatus between the second and third endoturbinates. It did not communicate with the nasal cavity in the same manner (nasomaxillary aperture) as the maxillary sinus. Loeffler (1959a) did not specifically describe such a sinus in the pig. However, this sinus may have been considered by him as one of the paraethmoid sinuses.

Ghetie (1941) has described a "Jochbeinhöhle" in the pig. According to him, this sinus developed independently within the zygomatic bone. The present author did not observe this sinus develop as a separate entity. Instead, the author observed the sinus within the zygomatic bone to be a caudolateral extension of the maxillary sinus. According to the pneumatization theory, the mucous membrane of the nasal cavity must accompany the progressive excavation of bone. In this case, Ghetie (1941) recognized spontaneous pneumatization of the bones of the skull, which is an assumption that has not yet been proved. Marrow cavities in bone do develop, but they are not lined with respiratory epithelium.

Frontal sinuses

Ghetie (1941) briefly described the frontal sinuses in the domestic pig and mentioned their extensive, irregular nature. He did not identify or apply a specific anatomical term to each individual frontal sinus. Instead, he recognized three to four (one-half of the skull) separate compartments, each one associated with an ethmoidal meatus. Following Ghetie (1941) many authors of veterinary textbooks suggested six to eight frontal sinus compartments.

Nickel and Wilkens (1958) and Wilkens (1958) introduced a scheme of nomenclature and applied it to the horse and bovine respectively. Comparatively, Loeffler (1959a) utilized this nomenclature, investigated the paranasal sinuses in the pig and finally suggested the terminology to be used. He identified three frontal sinuses in one-half of the pig skull.

Caudal frontal sinus The term caudal frontal sinus refers to a specific excavation that is related to the first endoturbinate and its corresponding ethmoidal meatus. The term does not necessarily indicate position, origin or final structure. The relative positions occupied by the paranasal sinuses and their final structure are variable factors and do not constitute suitable criteria for naming. The terms "caudal" and "frontal" refer to the location of the sinus in its final form. However, the sinus may be very extensive and extend caudally into the frontal region and finally into the occipital region. Or, it may be greatly reduced, compressed and located in the rostral aspect of the frontal bone. In the latter case, the neighboring rostral frontal sinuses compensate by increasing their total surface area. Loeffler (1959a) observed considerable variation in the size of the caudal frontal sinuses. Sixty per cent of the specimens observed by the present author presented, on one side, a reduced caudal frontal sinus.

No mention in the literature was found regarding changes that accompany the development of the nasofrontal opening. In most of the specimens observed, as the paranasal sinuses matured, the medial rostral frontal sinus caused the communication between the nasal cavity and the caudal frontal sinus to be reduced and compressed laterally. With this reduced aperture it is doubtful that significant drainage of the caudal frontal sinus even occurs in the adult. This change in communication with the nasal cavity was observed only in the mature specimens. In the immature specimens the communications was larger and would provide better drainage during a period of life when it would be necessary.

Observations by the present author have demonstrated the origin of the caudal frontal sinus. By disarticulating the bones of the skull it was possible to determine the exact components necessary to complete the entrance into a particular paranasal sinus. Therefore, disarticulation of the ethmoidal bone from the frontal bone revealed the primitive excavations into the frontal bone along with the corresponding basal laminae of the ethmoid bone.

Observations on the disarticulated bones, revealed the opening into the caudal frontal sinus to be slightly medial and dorsal to the lamina of the first endoturbinate. The lamina was smooth on the surface toward the opening and possessed scrolls on its ventrolateral or external surface. In the mature specimens, there was evidence of narrowing and in some cases unilateral absence of continued excavation into the frontal bone.

<u>Rostral frontal sinuses</u> Observations by the author were not in complete agreement with those of Loeffler (1959a) regarding the frontal sinuses. However, it was agreed that a rostral group of frontal sinuses did exist in the pig.

Loeffler (1959a) identified both medial and lateral rostral frontal sinuses. Basically, this terminology used by Loeffler is accurate and useful in regard to the final position and form of the frontal sinuses. However, the observations of the present author were not entirely consistent with those of Loeffler. Instead, the actual origin (in terms of an ethmoidal meatus) of the paranasal sinuses would provide a more suitable method of naming the subsequent sinuses.

During the development of the bony skull and the nasal cavity, a tremendous change occurs before the structures of the nasal cavity and the bones accompanying the sinuses have reached a static point. Thus, nomenclature that applies to the final structure (which may relate to bones, position, shape and size) is not useful in a description regarding development. This predicament is usually the result of an incomplete study which involves observations on the final or terminal structure and subsequent application of terms to structures which have no relationship to their development.

The medial rostral frontal sinus is the next successive sinus (following the first or caudal frontal sinus) and it is related to the corresponding ethmoidal meatus. The development of the ethmoid bone to form the paranasal sinuses is so arranged that each basal lamina forms the walls of an ethmoidal meatus. Each meatus then has the opportunity to develop and evaginate into the surrounding bones. Therefore, each meatus has the potential to become an individual paranasal sinus through continued excavation. However, this is not always the case, for occasionally adjacent meatuses will coalesce and form a single excavation. This results in a paranasal sinus being formed from more than one ethmoidal meatus.

It is the belief of the present author that the paranasal sinuses are identified as they are observed in the adult specimen with little concern for their development. For example, in the immature specimen, it is incorrect to designate a primitive sinus as a frontal sinus when it is certain that it will eventually occupy part of the lacrimal bone. Similarly, the lacrimal sinus may not only occupy the lacrimal bone in its definitive state but also the maxillary bone. Therefore, the author feels it may be simpler and more accurate to designate the paranasal sinuses, developing as a result of enlargement of the ethmoidal meatus, as Sinus paranasales I. Similar designations, identifying the sinuses with respect to their corresponding ethmoidal meatus, would be desirable. Paulli (1900) identified the paranasal sinuses according to their respective meatuses and designated the first paranasal sinus as Höhle I (that sinus related to the first endoturbinate (Endoturbinate I)). This nomenclature was easy to follow, but it did require the identification of the specific meatus leading to the sinus. It also served to integrate the development of the ethmoid bone and the paranasal sinuses which is necessary for complete understanding of the significance of the pneumatization of the skull. Červený (1970), studying the ethmoidal labyrinth, has proposed a nomenclature for the ethmoid bone that recognizes both the endoturbinate and ectoturbinate laminae and the primary meatuses. Secondarily, he has identified meatuses that do not contribute significantly to the formation of the paranasal sinuses.

The present author observed a constant rostral frontal sinus between the medial and lateral rostral frontal sinuses in the pig. It was found as an excavation existing in the primitive state between the medial and lateral rostral frontal sinuses. The lateral rostral frontal sinus is easy to identify as it is formed from the next successive ethmoidal meatus in the surrounding bone. The intermediate rostral frontal sinus, observed by the present author, was described in the ruminant species (Wilkens, 1958).

<u>Lacrimal sinuses</u>

Within the literature, there was little mention of the lacrimal sinus in the pig. Ghetie (1941) described a lacrimal sinus occupying the lacrimal bone in the adult animal but noted the absence of such a sinus in the immature animal. The observations of the present author agree with the observation regarding the absence of the sinus in the immature specimen. However, the potential ethmoidal excavation was present slightly medial and dorsal to the maxillary sinus which occupied the lacrimal bone at the age of six months. As the age of the specimens increased the potential sinus gradually excavated the lacrimal bone. And in the adult aged animal (three years) a sinus occupying the lacrimal bone could be easily identified. In some cases the origin of this sinus was variable and could be found to originate from different ethmoidal meatuses. Also, in the cases where the lacrimal sinus was absent the neighboring lateral rostral frontal sinus excavated the area normally occupied by the individual lacrimal sinus.

Sphenoid sinus

The descriptions of the sphenoid sinus presented little disagreement between the authors reviewed. Ghetie (1941) offered a detailed description examining the various extensions of the sphenoid sinus. The observations of the present author have described three well developed extensions into the surrounding bone. The caudal extension into the basioccipital bone (Loeffler, 1959a) was not observed as a frequent extension of the main sinus. Usually, the caudal extension did not extend beyond the basisphenoid bone. Another extension into the pterygoid portion of the sphenoid bone was observed by the author as well as a continuation into the pterygoid process of the palatine bone. The later observation was not frequent, but it confirmed the observation of Loeffler (1959a). The other extension, into the temporal bone eventually was demonstrated as pneumatization into the squamous and zygomatic parts of the temporal bones. The later observations were only possible in the aged specimen (four to five years).

Paraethmoid sinuses

Loeffler (1959a) described a system of small sinuses excavating the bones adjacent to the ventral part of the ethmoid bone. He described a regular occurring sinus which excavated the maxillary bone between the infraorbital canal and the maxillary sinus. Ghetie (1941) designated this sinus as an individual sinus and identified it as the "kleine Kieferhöhle". However, it is unlike the maxillary sinus in that it does not communicate with the nasal cavity via the middle meatus but instead via the ethmoid meatus.

The author observed an excavation extending from the ethmoidal meatus into the basal lamina of the ethmoid bone, the vomer bone and a part of the palatine bone. The sinus formed is usually small and does not compare with the palatine sinus described in the bovine species. It is in direct communication with the lateral ventral part of the ethmoidal meatus and the fundus of the nasal cavity. It is also in direct communication with the sphenoid sinus and in that respect compares somewhat with the other domestic species. This sinus compares to the paraethmoid sinuses observed and described by Loeffler (1959a).

Numerous other small sinuses, located in the rostromedial wall of the bony orbit were observed by the author. These sinuses correspond with the description of the paraethmoid sinuses in that they are small sinuses related to the ethmoid meatuses.

SUMMARY AND CONCLUSIONS

This dissertation involved an investigation into the macroscopic anatomy of the nasal cavity and paranasal sinuses of the domestic pig. Major emphasis was placed upon providing a detailed anatomical description of the bony structures of the nasal cavity. Further observations were conducted regarding the development of the paranasal sinuses and their subsequent relationships to the nasal cavity. The final structure of the paranasal sinuses was determined and described.

Observations were conducted on materials consisting of the heads of forty pigs. The specimens ranged in age from eight weeks to eight years. Thirty of the specimens were macerated and then disarticulated or sculptured in order to observe more closely their bony relationships. The remaining ten specimens were dissected and then transected to determine the adjacent relationships of the paranasal sinuses.

1. The rostral part of the cartilaginous nasal septum presented a distinct rostral bone. The rostral bone, similar to that found in the bovine species, continued to develop after birth. In the mature specimen it presented a relatively immobile, integral part of the snout offering the necessary stability for the function of "rooting". The ossification of the rostral part of the cartilaginous septum is comparable to

the progressive ossification occuring in the caudal aspect of the septum.

2. The incisive bones articulated with the nasal and maxillary bones and formed the bony nasal aperture. Together the nasal bone and the incisive bone formed a distinct notch, the nasoincisive notch.

3. The paired nasal bones formed a significant portion of the roof of the nasal cavity. Caudally, on the internal surface of each bone was an excavation (nasal part, dorsal conchal sinus), which was related indirectly to the caudal frontal sinus. The depth of penetration into the nasal bone by the excavation was variable. It was in direct communication with the nasal cavity via a distinct passageway lying ventral and lateral to the dorsal nasal concha. The passageway, located at the transverse level of the second molar tooth, was a continuation of the middle nasal meatus.

4. The maxillary bone formed a considerable portion of the lateral wall of the nasal cavity as well as contributing significantly to the floor. Caudally, it was excavated by the maxillary recess which eventually formed the major lateral portion of the maxillary sinus. On its medial surface, it fused with the basal lamella of the ventral conchal bone. Fusion of the maxillary bone and the ventral conchal bone was not complete until two years of age.

5. The ventral conchal bone was ossified as a separate,

ventrolateral portion of the cartilaginous nasal capsule. Basically, it was composed of a basal lamella and a dorsal and ventral scroll. Each scroll, at the level of the second premolar tooth, consisted of a one and one-half spiralled lamina. Caudally, it formed the rostromedial wall of the maxillary sinus as it fused with the maxillary and ethmoid bones. Rostromedial to this, it formed a transverse septum within the ventral scroll which resulted in formation of the ventral conchal sinus.

6. At birth, no evidence of excavation within the frontal bone was observed. However, at eight weeks, excavation, corresponding to the ethmoidal meatuses was evident. Gradually, as the age of the specimens increased, the frontal bone and the surrounding bones such as the lacrimal, parietal, temporal and occipital were excavated. This activity produced a very extensive sinus system. The frontal sinus system resembled that of the ruminant species.

7. The ethmoid bone, situated deep within the nasal cavity, consisted of complicated, paired lateral masses. The ethmoidal labyrinth, was bordered laterally by a lateral, external lamina which was in turn fused to the perpependicular lamina by means of a tectal (dorsal) and basal (ventral) lamina. The basal lamina in the pig was observed to extend rostrally for a short distance as it formed a horizontal shelf. This shelf separated the fundus of the nasal cavity from the

nasopharynx.

8. Twenty, well developed basal laminae arose from the rostromedial surface of the lateral lamina, and projected themselves toward the midline. Numerous scrolls were formed on the surface of the lamina creating the massive ethmoidal labyrinth.

9. Of the ethmoidal lamina, only seven were designated as endoturbinates. They were referred to as Endoturbinates I-VII. Most significant of the endoturbinates, was the first one (Endoturbinate I) which formed the caudal part of the dorsal nasal concha. It was excavated and formed the dorsal conchal sinus which remained in communication with the middle nasal meatus in a manner similar to the nasal part of the dorsal conchal sinus. The second endoturbinate (Endoturbinate II) was much smaller and devoid of any sinus excavation. It is sometimes referred to as the middle nasal concha. It presented a split basal lamina which gave the appearance of an additional endoturbinate. Close examination revealed the terminal scrolls did not form true sinuses. The remaining endoturbinates (Endoturbinates III-VII) were similar to each other in arrangement except for a consecutively reduced number of secondary scrolls.

10. The remainder of the ethmoturbinates were designated as ectoturbinates. They consisted of ten well developed laminae which resembled the endoturbinates. They did not

reach the midline as did the endoturbinates. The ectoturbinates were consistently arranged into a medial series (extending close to the midline) and a lateral series (near the lateral lamina). They possessed secondary scrolls similar to the endoturbinate laminae.

11. The external lamina of the ethmoid bone was observed to be extremely important in the formation of the medial wall of the maxillary sinus and the nasomaxillary aperture.

12. The relationship of the ethmoid bone to the vomer and the presphenoid bones demonstrated that very early fusion of these bones takes place. It was difficult to disarticulate the ethmoid bone as a result of this early fusion.

13. The maxillary sinus was evident as a small lateral recess at the time of birth. In the mature specimen it was represented as a large sinus, possessing medial and lateral compartments. The compartments were separated by a shallow, incomplete septum which arose from the floor. The lateral compartment was larger and usually lower, whereas the medial compartment was smaller and slightly more dorsal. The nasomaxillary aperture, an extension of the middle nasal meatus, was located at the level of the second molar tooth (M_2) as it communicated with the sinus.

14. The frontal sinuses presented, in the mature specimens, a well developed sinus system. They consisted of rostral and caudal groups. The caudal frontal sinus was paired and

quite extensive as it reached caudally into the occipital bone and laterally into the temporal bones. It was the first of the frontal sinuses to develop and usually maintained a laterally compressed nasofrontal communication with the middle nasal meatus. The rostral frontal sinuses developed laterally as successive evaginations of the ethmoidal meatuses. Both a medial and a lateral rostral frontal sinus were observed. The medial sinus was responsible for the compression of the nasofrontal communication of the caudal frontal sinus. The lateral sinus was easily confused with the lacrimal sinus as it occasionally occupied the lacrimal bone, along with the corresponding lacrimal sinus. Occasionally in the developing stages an intermediate rostral frontal sinus was observed.

15. A lacrimal sinus was observed occupying the lacrimal bone in the mature specimen. However, it was not present in the immature specimens. It developed in succession with the rostral frontal sinuses and was occasionally reduced in size. In the case of the reduced sinus, the lateral or intermediate rostral frontal sinus usually compensated.

16. The sphenoid sinus was present as an extensive excavation into the basal part of the skull. It extended the ethmoidal meatus into the sphenoid bones and the temporal bones.

17. A system of small sinuses, related to the ethmoidal meatuses extended (in the mature specimen only) into the bones

which surrounded the ethmoid. One prominent extension was into the septum dividing the maxillary sinus. Another extension, expanded the ethmoid meatus into the basal lamina of the ethmoid bone. It involved the vomer and the palatine bones. These sinuses were designated by Loeffler (1959a) as the parethmoid sinuses.

18. The dorsal and ventral nasal conchae both exhibited sinuses. Respectively the dorsal conchal and ventral conchal sinuses occupied the conchal bones. Their communications have been noted under the respective concha.

LITERATURE CITED

Akaevskij, A. I. 1962. Original not available; cited in Červený, C. 1970. Das Siebbeinlabyrinth des Hausschweines (Sus scrofa forma domestica). Zentbl. VetMed. 17: 68-84.

Andres, J. 1924. Untersuchungen über das Auftreten und die weitere Entwicklung der embryonalen Hirnschädelknocken des Schweines. Morph. Jb. 53: 259-303.

Aristotle. 354 B.C. Original not available; cited in Ross, W. B. 1910. The works of Aristotle translated into English. Vol. 4. Historia Animalium. Clarendon Press, Oxford, England.

Barone, R. 1966. Anatomie comparée des mammifères domestiques. Ostéologie. Laboratoire D'Anatomie, Ecole National Veterinare, Lyon, France.

Bauhinus. 19620 Original not available; cited in Wright, J. 1914. A history of laryngology and rhinology. 2nd ed. Lea and Febiger, New York, New York.

Blanton, P. L. and Biggs, N. L. 1969. Eighteen hundred years of controversy. The paranasal sinuses. Am. J. Anat. 124: 135-148.

Bourdelle, E. 1920. Original not available; cited in Ghetie, V. 1941. Die Lufthöhlen des Schweinekopfes. Anat. Anz. 92: 169-180.

Bourdelle, E. and Bressou, C. 1964. Anatomie régionale des animaux domestiques. Vol. III. Le Porc. J. B. Bailliere et Fils, Paris, France.

Bruni, A. C. and Zimmerl, U. 1951. Anatomi degli anamali domestici. 2nd ed. Vol. II. Casa Editrici D. Francesco Vallardi, Milano, Italy.

Bustad, L. K. and McClellan, R. O. 1966. Swine in biomedical research. Science 152: 1526-1528.

Casserius. 1610. Original not available; cited in Wright, J. 1914. A history of laryngology and rhinology. 2nd ed. Lea and Febiger, New York, New York.

Červený, C. 1965. Beitrag zur Strukurkenntnis der basikranialen Achse bein Hausschwein (Sus scrofa domestica). Morph. Jb. 108: 401-412.

Červený, C. 1970. Das Siebbeinlabyrinth des Hausschweines (Sus scrofa forma domestica). Zentbl. VetMed. 17: 68-84.

Chauveau, A. and Arloing, S. 1890. The comparative anatomy of the domesticated animals. 2nd ed. D. Appleton and Company. New York, New York.

Colombo. 1500. Original not available; cited in Wright, J. 1914. A history of laryngology and rhinology. 2nd ed. Lea Febiger, New York, New York.

Crummer, L. 1927. Copho's "Anatomia Porci" Ann. Med. Hist. 9: 180-182.

de Beer, G. R. 1937. Development of the vertebrate skull. Oxford University Press, London, England.

da Vinci, L. 1480. Original not available; cited in Skillern, R. H. 1920. Accessory sinuses of the nose. 2nd ed. Lippincott Company, Philadelphia.

Decker, F. 1883. Über den Primordialschädel einiger Säugethiere. Z. wiss. Zool. 38: 190-233.

del Carpi, Berengar. 1520. Original not available; cited in Wright, J. 1914. A history of laryngology and rhinology. 2nd ed. Lea and Febiger, New York, New York.

Dobberstein, J. and Hoffmann, G. 1964. Lehrbuch der vergleichenden Anatomie der Haustiere. Band I and II. S. Hirzel Verlag, Leipzig, Germany.

Ellenberger, W. and Baum, H. 1932. Handbuch der vergleichenden Anatomie der Haustiere. 16th ed. Springer Verlag, Berlin, Germany.

Ellenberger, W. and Baum, H. 1943. Handbuch der vergleichenden Anatomie der Haustiere. 18th ed. Springer Verlag, Berlin, Germany.

Flottes, L., Clerc, P., Rui, R. and Devilla, F. 1961. La physiologie des sinus. Ann. Otolaryng. 78: 92-94.

Fuchs, H. 1909. Ueber die Entwickelung einiger Deckknochen (Vomer, Ptėrygoid, Maxillarė) bei Säugetieren (und ihr Verhältnis zum Knorpel skelette). Anat. Anz. 34: 85-102.

Galen, C. 160 A.D. Original not available; cited in Singer, C. 1956. Translation of the surviving books with introduction and notes. Oxford University Press, London, England.

Getty, R. 1964. Atlas for applied veterinary anatomy. 2nd ed. Iowa State University Press, Ames, Iowa.

Ghetie, V. 1941. Die Lufthöhlen des Schweinekopfes Anat. Anz. 92: 169-180.

Graeger, K. 1958. Die Nasenhöhle und die Nasennebenhöhlen beim Hund unter besonderer Berucksichtingung der Siebbeinmuscheln. Dt. Tierärztl. Wschr. 65: 425-429 and 468-472.

Haviland, T. N. 1961. "Anatomia Porci". A twelfth century anatomy of the pig used in teaching human anatomy. Wien. tierärztl. Mschr. (spec. no.): 246-265.

Highmore, B. 1651. Original not available; cited in Schaeffer, J. P. 1920. The nose, paranasal sinuses, nasolachrymal passageways and olfactory organ in man. P. Blakiston's Son and Company, Philadelphia, Pennsylvania.

Hippocrates. 400 B.C. Original not available; cited in Singer, C. 1925. The evolution of anatomy. Alfred A. Knopf, New York, New York.

Ingrassias. 1563. Original not available; cited in Wright, J. 1914. A history of laryngology and rhinology. 2nd ed. Lea and Febiger, New York, New York.

Klimov, A. 1950. Original not available; cited in Červený C. 1970. Das Siebbeinlabyrinth des Hausschweines (Sus scrofa forma domestica). Zentbl. VetMed. 17: 68-84.

Koch, T. 1960. Lehrbuch der Veterinär-Anatomie. Band I. Veb Gustav Fisher Verlag, Jena, Germany.

Koch, T. 1963. Lehrbuch der Veterinar-Anatomie. Band II. Veb Gustav Fisher Verlag, Jena, Germany.

Kolda, J. 1936. Original not available; cited in Červený, C. 1970. Das Siebbeinlabyrinth des Hausschweines (Sus scrofa forma domestica) Zentbl. VetMed. 17: 68-84.

Lebedkin, S. 1918. Zur Frage der Entwickelung des Primordial craniums beim Schwein (Sus scrofa). Anat. Anz. 50: 539-546.

Leyh, F. 1859. Original not available; cited in Ghetie, V. 1941. Die Lufthöhlen des Schweinekopfes. Anat. Anz. 92: 169-180.

Loeffler, K. 1958. Zur Topographie der Nasenhöhle und der Nasennebenhöhlen bei den kleinen Wiederkauren. Berl. Munch. tierärztl. Wschr. 71: 457-465.

Loeffler, K. 1959a. Zur Topographie der Nasenhöhle und der Nasennebenhöhlen beim Schwein. Dt. tierarztl. Wschr. 66: 237-242 and 270-273.

Loeffler, K. 1959b. Zur Topographie der Nasenhöhlen und der Nasenbenhöhlen bei der Katze. Berl. Münch. tierärztl. Wschr. 72: 325-328.

Martin, P. and Schauder, W. 1923. Lehrbuch der Anatomie der Haustiere. Schickhardt und Ebner Verlag, Stuttgart, Germany.

Martin, P. and Schauder, W. 1938. Lehrbuch der Anatomie der Haustiere. Band I and II. Schickhardt und Ebner Verlag, Stuttgart, Germany.

Mead, C. S. 1909. The chondrocranium of the embryo pig, Sus scrofa. A contribution to the morphology of the mammalian skull. Am. J. Anat. 9: 167-210.

Neukomm, A. 1933. Development foetal du neuro-crâne chez le porc (Sus scrofa domesticus). Arch. Anat. Physiol. 17: 49-83.

Nickel, R. and Wilkens, H. 1958. Zur Topographie der Nasenhöhle und der Nasennebenhöhlen beim Pferd. Dt. tierärztl. Wschr. 65: 173-180.

Nickel, R., Schummer, A., and Seiferle, E. 1967. Lehrbuch der Anatomie der Haustiere. Band I. 2nd ed. Paul Parey Verlag, Hamburg, Germany.

Nickel, R., Schummer, A., and Sieferle, E. 1968. Lehrbuch der Anatomie der Haustiere. Band II. 3rd ed. Paul Parey Verlag, Hamburg, Germany.

Nomina Anatomica Veterinaria. 1968. International committee on veterinary nomenclature. Adolf Holzhausen's Successors, Vienna, Austria.

Parker, W. K. 1874. On the structure and development of the skull of the pig. Phil. Trans. of the Royal Soc. of London, Series B. 164: 289-336.

Patten, B. M. 1944. The embryology of the pig. 2nd ed. The Balkiston Company, Philadelphia, Pennsylvania.

Paulli, S. 1900. Über die Penumaticität des Schädels bei den Säugethieren. Morph. Jb. 28: 147-251 and 483-564.

Perna, G. 1906. Die Nasenbeine. Eine embryologische und vergleichend anatomische Untersuchhung. Arch. Anat. EntwicklungGesch. 1906: 119-145.

Popesko, P. 1971. Atlas of topographical anatomy of the domestic animals. W. B. Saunders, Philadelphia, Pennsylvania.

Schaeffer, J. P. 1920. The nose, paranasal sinuses, naso-lachrymal passageways and olfactory organ in man. P. Blakiston's Son and Company, Philadelphia, Pennsylvania.

Schreiber, J. 1960. Problems of veterinary anatomical nomenclature. Br. vet. J. 116: 1-14.

Singer, C. 1925. The evolution of anatomy. Alfred A. Knopf, New York, New York.

Sisson, S. and Grossman, J. D. 1953. The anatomy of the domestic animals. 4th ed. W. B. Saunders Company, Philadelphia, Pennsylvania.

Stokoe, W. M. 1967. A guide to comparative veterinary anatomy. Baillière, Tindall and Cassell, London England.

Sturm, H. 1937. Die Entwicklung des präcerebralen Nasenskelete beim Schwein (Sus scrofa domestica) und beim Rind (Bos taurus). Z. wiss. Zool. 149: 161-220.

Switzer, W. P. 1965. Atrophic rhinitis today. J. Am. vet. med. Assoc. 146: 348-351.

Vesalius, A. 1542. Original not available; cited in Wright, J. 1914. A history of laryngology and rhinology. 2nd ed. Lea and Febiger, New York, New York.

Vogler, A. 1926. Intrauterine Verknöcherung der Ossa faciei des Schweines. Morph. Jb. 55: 568-606.

Wilkens, H. 1958. Zur Topographie der Nasenhöhle und der Nasennebenhöhlen beim Rind. Dt. tierärztl. Wschr. 65: 580-585 and 632-637.

Wright, J. 1914. A history of laryngology and rhinology. 2nd ed. Lea and Febiger, New York, New York.

Zimmerl, U. 1930. Trattato di Anatomia Veterinaria. Vol. I. Casa Editrici Dottor Franesco Vallardi, Milano, Italy.

Zuckerkandl, J. 1887. Original not available; cited in Červený, C. 1970. Das Siebbeinlabyrinth des Hausschweines (Sus scrofa forma domestica). Zentbl. VetMed. 17: 68-84.

ACKNOWLEDGMENTS

The author wishes to express sincere appreciation to the late Dr. Robert Getty for his supervision, constructive criticism, and encouragement during the course of this investigation. It is most unfortunate that Dr. Getty passed away prior to the completion of the investigation.

Next, the author would like to express sincere appreciation to Dr. W. P. Switzer for officially completing the duties as major professor. Dr. Switzer facilitated the procurement of the excellent specimens and was very much a part of the investigation from the very beginning.

Appreciation is expressed to the author's graduate committee: specifically the late Dr. R. Getty along with Drs. W. P. Switzer, M. A. Emmerson, J. H. Magilton, N. R. Cholvin and R. Bryan.

Next, appreciation is extended to all of the academic staff of the Department of Veterinary Anatomy as well as the technical staff for their assistance and encouragement during the course of this investigation.

The author wishes to acknowledge the support in the form of funds provided by the General Research Support Grant, Iowa State University, Ames, Iowa. These funds made possible the procurement of some of the materials utilized during the course of the study.

Finally, the author expresses sincere appreciation to

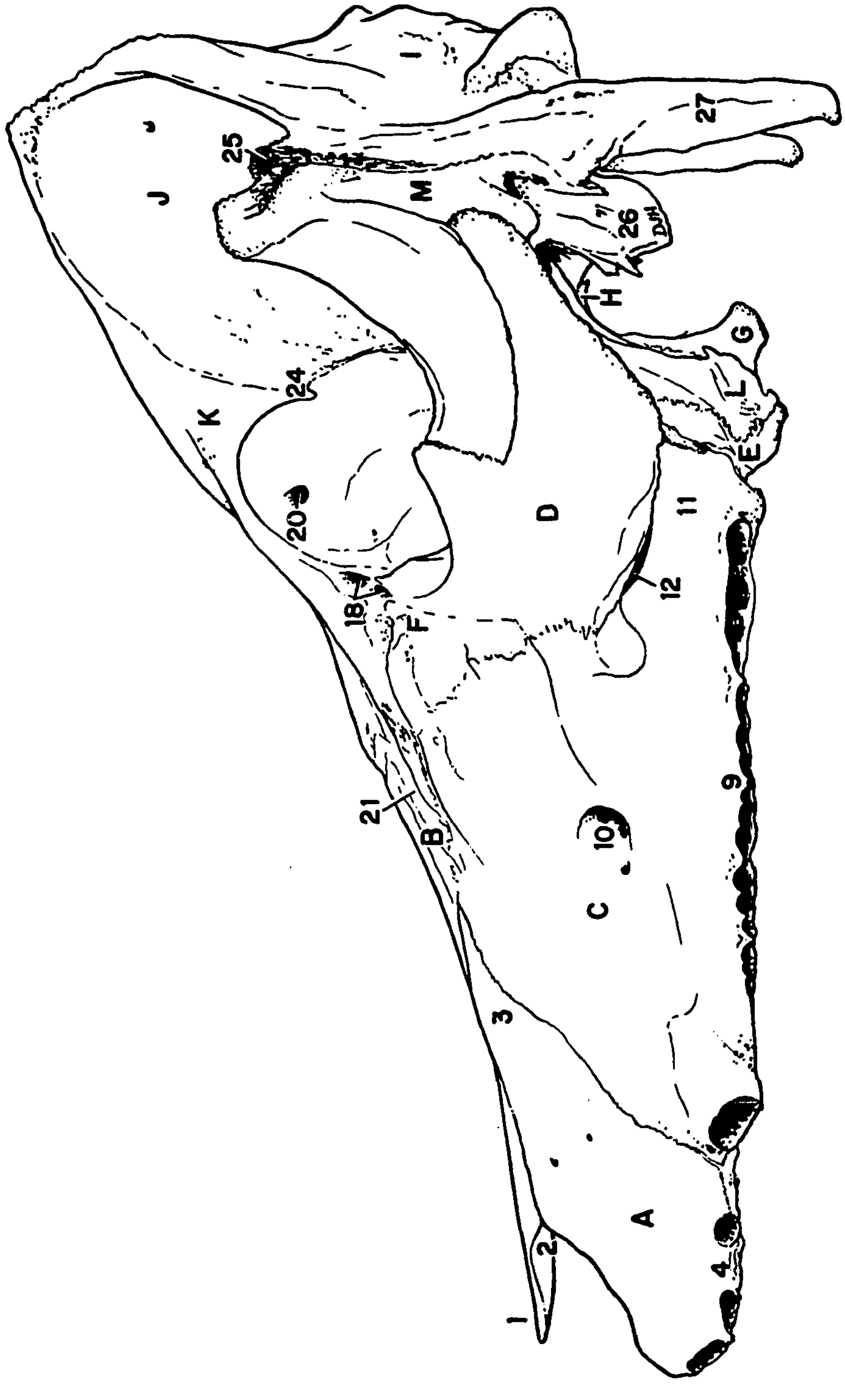
his wife, Nancy for cheerfully completing her part during those long hours and to Pam for her continued interest and anticipation of things to come.

APPENDIX

Figure 2. Osteology: Mature swine skull, lateral view, mandible removed

A. Os incisivum
B. Os nasale
C. Maxilla
D. Os zygomaticum
E. Os palatinum
F. Os lacrimale
G. Os pterygoideum
H. Vomer
I. Os occipitale
J. Os parietale
K. Os frontale
L. Os presphenoidale
M. Os temporale

1. Processus nasalis (of the nasal bone)
2. Incisura nasomaxillaris
3. Processus nasalis (of the incisive bone)
4. Processus alveolaris (of the incisive bone)
9. Processus alveolaris (of the maxillary bone)
10. Foramen infraorbitale
11. Tuber maxillae
12. Foramen maxillare
18. Foramina lacrimalia
20. Canalis supraorbitalis (the orbital opening)
21. Sulcus supraorbitalis
24. Processus zygomaticus (of the frontal bone)
25. Meatus acousticus externus
26. Bulla tympanica
27. Processus jugularis



J
25
I
27
M
26
D.H
H
G
L
E
11
12
D
K
24
20
18
F
21
B
9
10
C
3
A
2
4
1

Figure 3. Osteology: Mature swine skull, dorsal view, mandible removed

A. Os incisivum
B. Os nasale
C. Maxilla
D. Os zygomaticum
F. Os lacrimale
I. Os occipitale
J. Os parietale
K. Os frontale
M. Os temporale

1. Processus nasalis (of the nasal bone)
2. Incisura nasomaxillaris
3. Processus nasalis (of the incisive bone)
4. Processus alveolaris (of the incisive bone)
9. Processus alveolaris (of the maxillary bone)
10. Foramen infraorbitale
18. Foramina lacrimalia
19. Foramen supraorbitale
21. Sulcus supraorbitalis
24. Processus zygomaticus (of the frontal bone)
25. External acoustic meatus

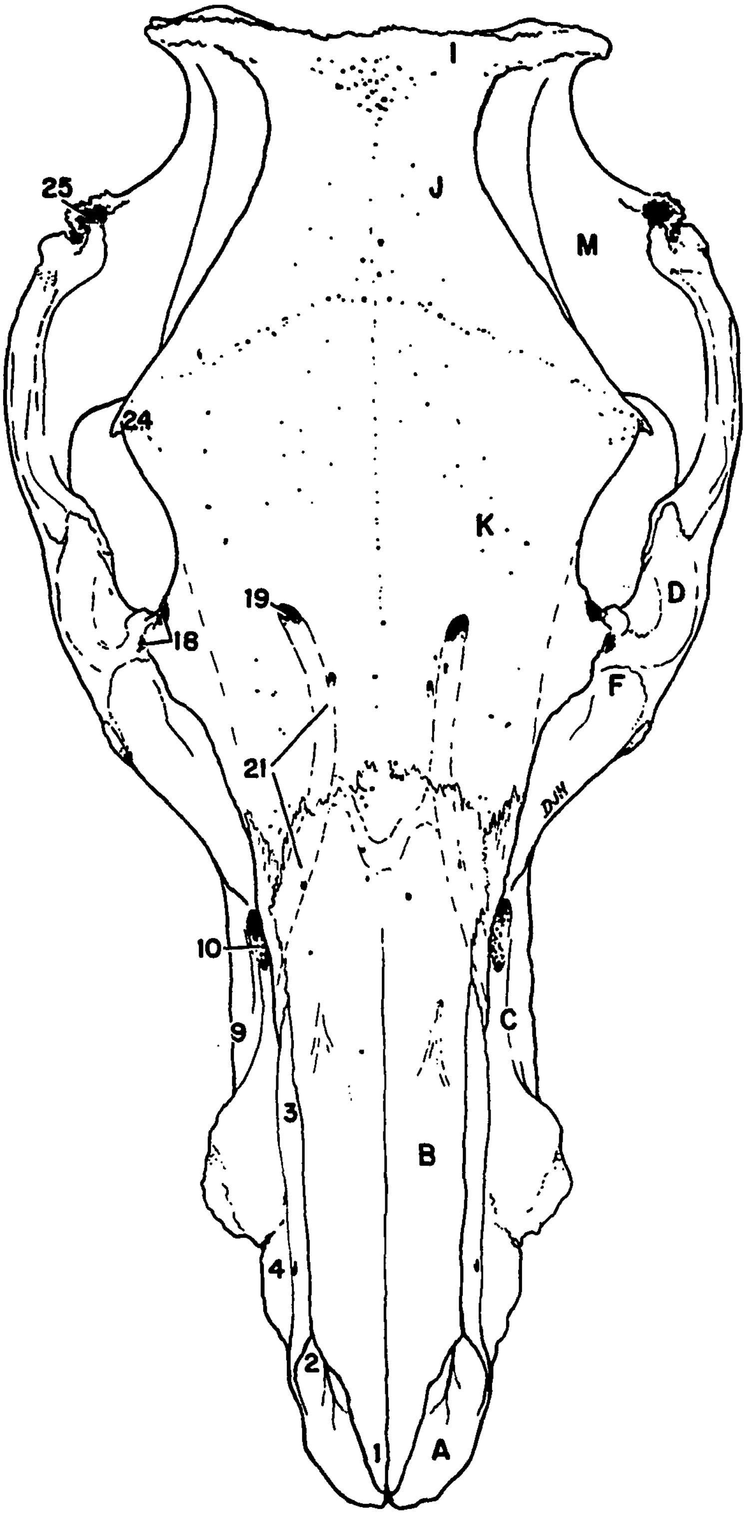

I
J
M
25
24
K
D
19
18
F
21
DJH
10
9
C
3
B
4
2
1
A

Figure 4. Osteology: Mature swine skull, ventral view, mandible removed

A. Os incisivum
C. Maxilla
D. Os zygomaticum
E. Os palatinum
G. Os pterygoideum
H. Vomer
I. Os occipitale
K. Os frontale
L. Os presphenoidale
M. Os temporale

5. Fissura incisiva
6. Sulcus incisivum
7. Processus palatinus (of the incisive bone)
8. Fissura palatina
9. Processus alveolaris (of the maxillary bone)
9'. Processus palatinus (of the maxillary bone)
11. Tuber maxillae
12. Foramen maxillare
13. Sulcus palatinus major
14. Foramen palatinum majus
15. Foramina palatina minora
16. Lamina horizontalis (of the palatine bone)
17. Lamina perpendicularis (of the palatine bone)
22. Hamulus pterygoideus
23. Ala (of the presphenoid bone)
24. Processus zygomaticus (of the frontal bone)
26. Bulla tympanica
27. Processus jugularis
28. Foramen magnum

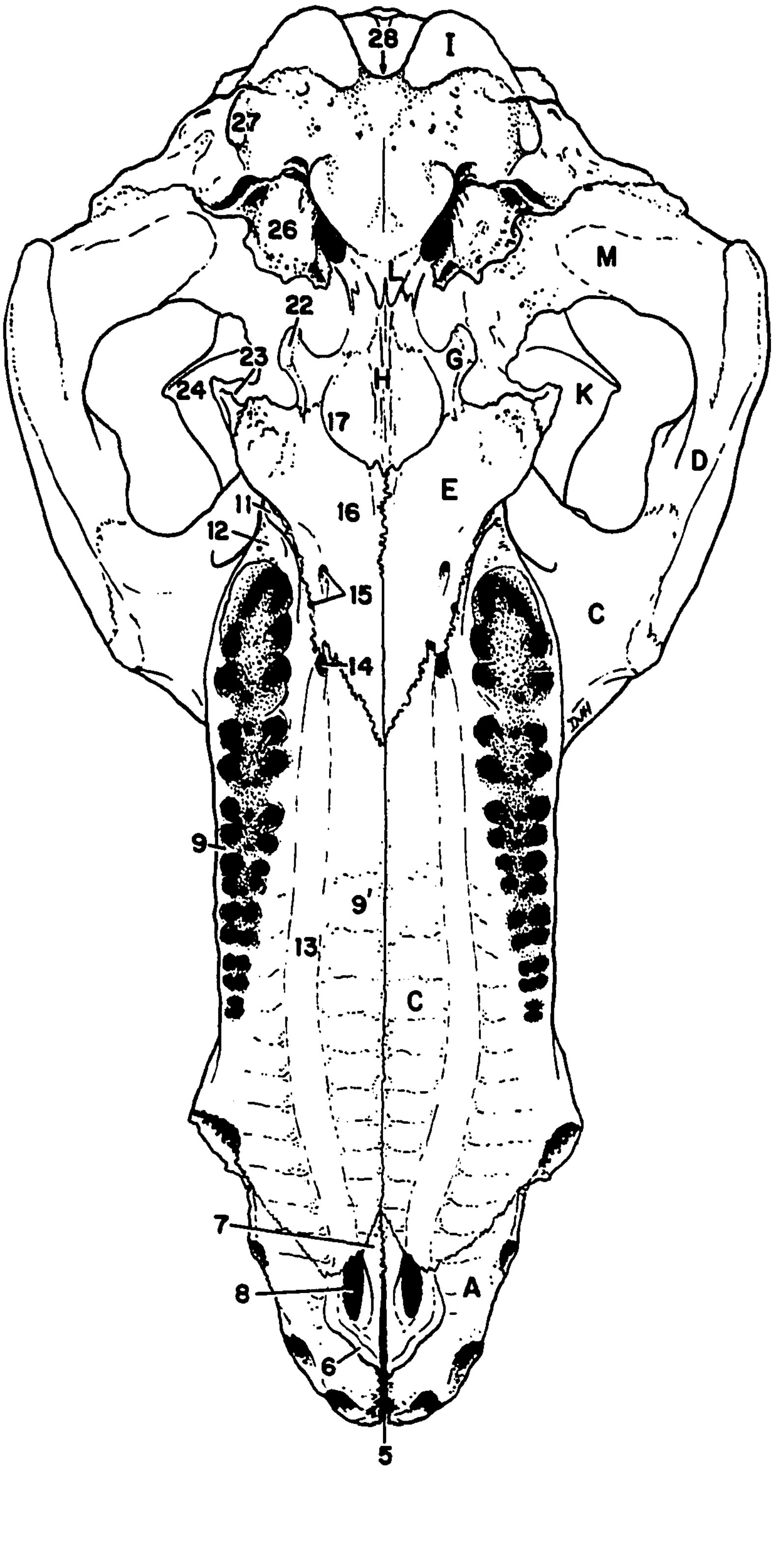

28
I
27
26
M
22
23
G
24
H
K
17
D
E
11
16
12
15
C
14
DAH
9
9'
13
C
7
8
A
6
5

Figure 5. Osteology: Mature swine skull, sagittal view, right side, the skull has been sculptured to illustrate the osteology of the nasal cavity and the paranasal sinuses

A. Os incisivum
B. Os nasale
C. Maxilla
D. Os palatinum
E. Os pterygoideum
F. Os frontale
G. Os occipitale
H. Os sphenoidale
I. Vomer
J. Os ethmoidale (crista galli)
K. Concha nasalis dorsalis
L. Concha nasalis media
M. Concha nasalis ventralis
N. Ethmoturbinalia

I_1 First incisor tooth

PM_1 First premolar tooth

M_1 First molar tooth

f. Sinus frontalis caudalis (sinistra) (note deviation of the frontal sinus septum)
f'. Sinus frontalis caudalis (dextra) (arrow #2 passes into the caudal extension of the sinus and beneath the partially removed frontal sinus septum)
g. Sinus frontalis rostralis medialis
h. Sinus sphenoidalis (arrow passes through the sphenoid sinus aperture, thus communicating with the fundus of the nasal cavity)
j. Sinus paraethmoideus (after Loeffler, 1959)
k. Sinus concha dorsalis (arrow #2 indicates diverticulum into this sinus)
m. Concha nasalis ventralis (dorsal scroll and its corresponding recess)
m'. Concha nasalis ventralis (ventral scroll and its corresponding recess)
m". Sinus concha ventralis (arrow #3 is shown leading to this sinus)
n. Foramen sphenopalatinum
o. Foramen ethmoidale

Arrow #2: represents the communication pathway from the nasal cavity into the paranasal sinuses
Arrow #3: represents the communication pathway from the nasal cavity into the ventral conchal sinus
Arrow #4. represents the communication pathway from the nasal cavity into the maxillary sinus via the nasomaxillary aperture

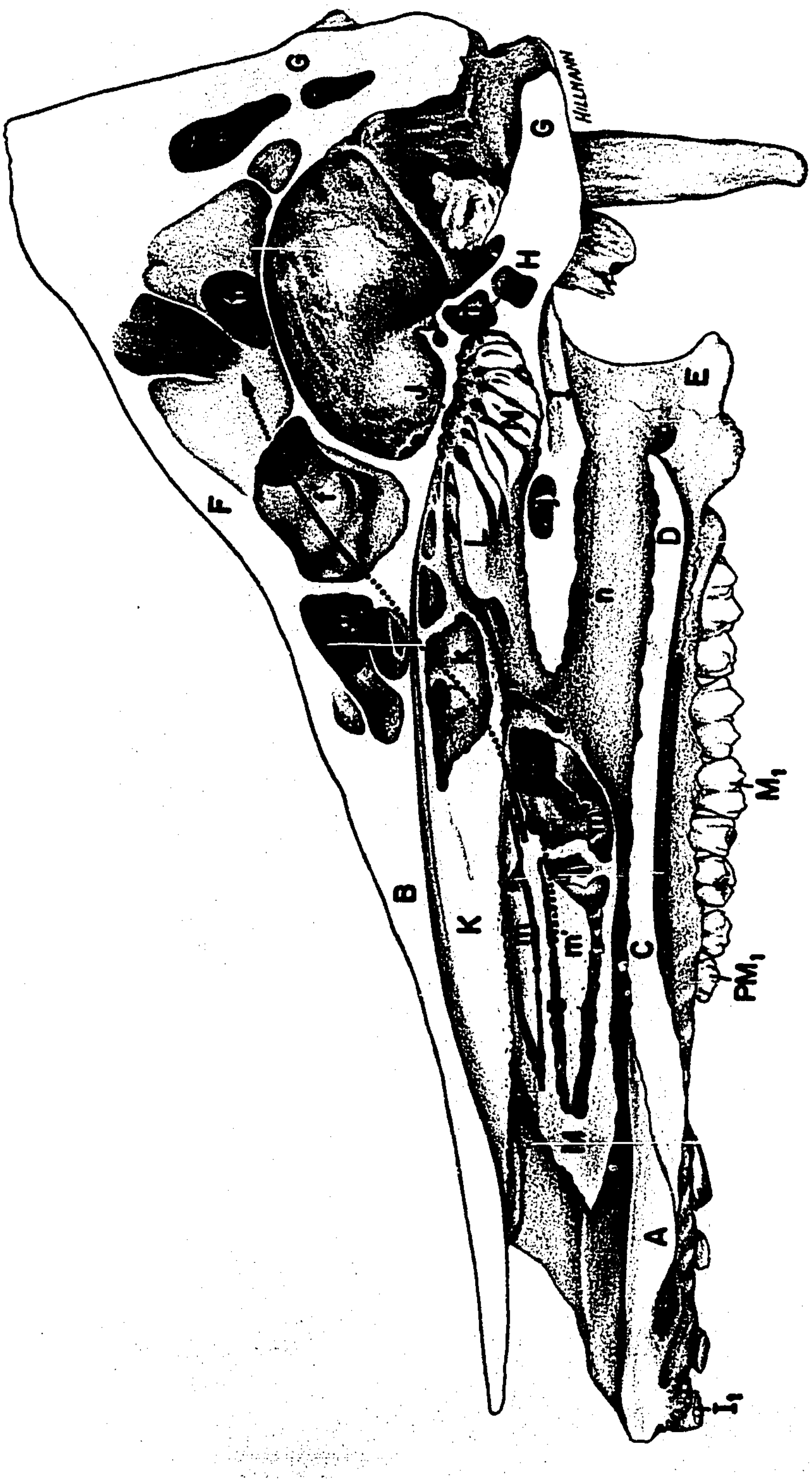

G
G
HILLMANN
H
E
F
D
L
B
K
C
M
A
M1
PM1
I1

Figure 6. Nasal cavity and paranasal sinuses: Five months old swine, sagittal view, right side. The cartilaginous nasal septum has been removed to illustrate the structure of the nasal cavity

A. Os incisivum
B. Os nasale
C. Maxilla
D. Os palatinum
F. Os frontale
H. Os sphenoidale
I. Vomer
K. Concha nasalis dorsalis
K'. Plica recta
L. Concha nasalis media
M. Concha nasalis ventralis
M'. Plica alaris
O. Choanae
P. Os parietale
Q. Palatum molle
R. Os rostrale
S. Rostrum
T. Lingua
U. Encephalon

f. Sinus frontalis rostralis medialis
g. Sinus frontalis caudalis
h. Sinus sphenoidalis (as it surrounds the label)

Figure 7. Osteology: Ten to eleven months old swine skull, sagittal view, right (upper photo) and left (lower photo) sides. The nasal bone has been disarticulated and the perpendicular lamina of the ethmoid bone has been sculptured to illustrate the ethmoidal labyrinth. The sphenoid sinus has been partially sculptured to adequately expose it. The vomer bone has been partially removed

1. Os frontale
2. Maxilla (sutura nasomaxillaris)
4. Concha nasalis ventralis
5. Os ethmoidale
7. Os palatinum
8. Os pterygoideum
9. Os presphenoidale
10. Os parietale
11. Lamina basalis
12. Lamina perpendicularis (crista galli)

A. Sinus frontalis rostralis medialis (note the absence of the rostral projection on the left side)
A'. Sinus frontalis rostralis medialis (note the rostral projection on this side)
B. Sinus frontalis caudalis (greatly reduced in this specimen)
C. Sinus frontalis rostralis lateralis
D. Sinus sphenoidalis

I Concha nasalis dorsalis (first endoturbinate portion)
II Concha nasalis mediae (second endoturbinate portion)
III-VII Endoturbinates III-VII

Arrows: indicate communication of the paranasal sinuses with the nasal cavity

Solid portion: is found lying within the space of the nasal cavity or paranasal sinuses
Dotted portion: is found lying beneath bone or tissue

Broken line: indicates limitation of the paranasal sinus for clarification of the photographs

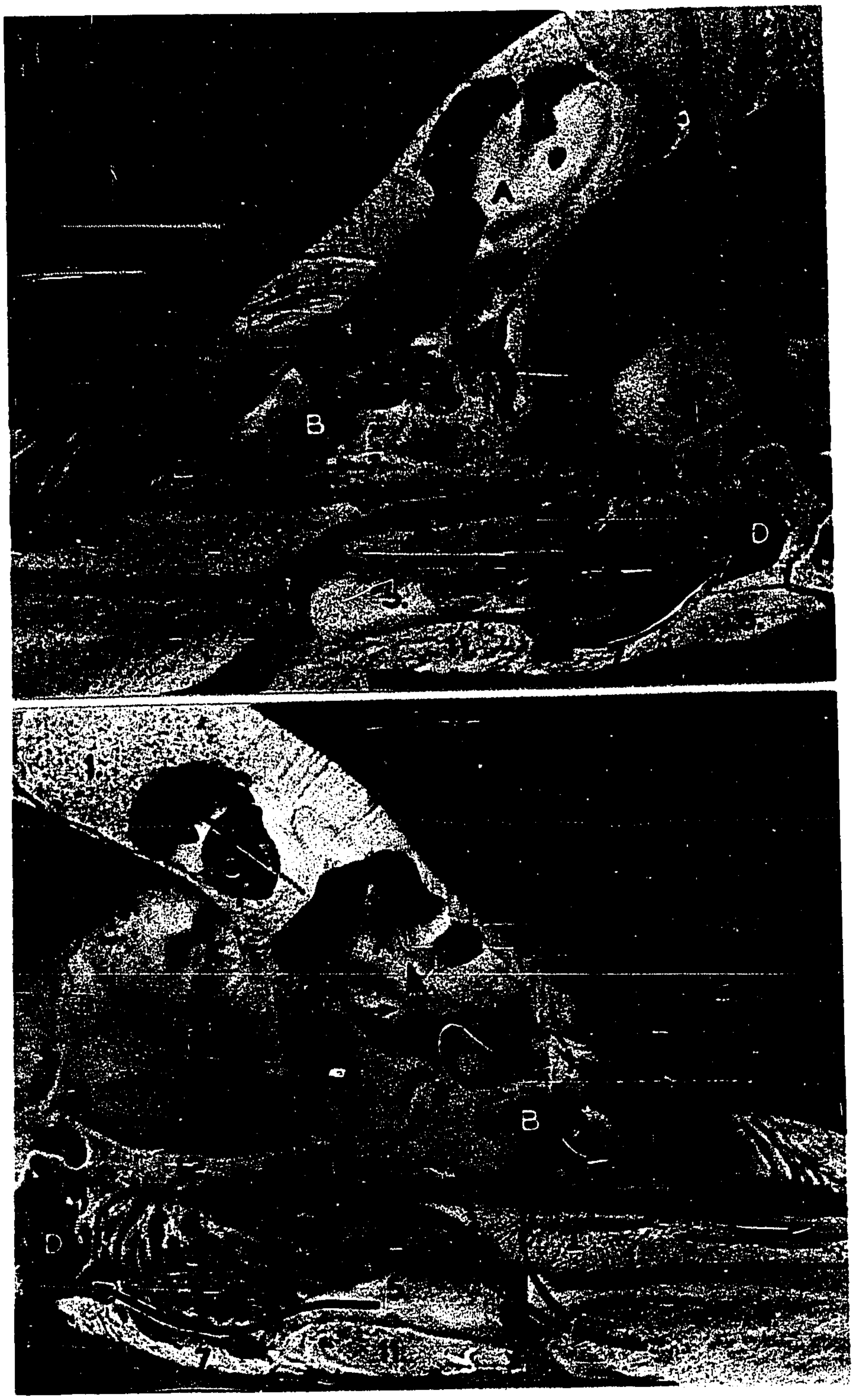

B
D
B
D

Figure 8. Osteology: Ten to eleven months old swine skull, sagittal view, right (upper photo) and left (lower photo) sides. The nasal bone has been disarticulated and the perpendicular lamina of the ethmoid bone has been sculptured to illustrate the ethmoidal labyrinth. The sphenoid sinus has been partially sculptured to adequately expose it. The vomer bone has been partially removed

1. Os frontale
2. Maxilla (surtura nasomaxillaris)
4. Concha nasalis ventralis
5. Os ethmoidale
5'. Ethmoidal meatus with surrounding lamina (note the fine line of fusion of the delicate ethmoid lamina with the frontal bone)
7. Os palatinum
8. Os pterygoideum
9. Os presphenoidale
10. Os parietale
11. Lamina basalis
12. Lamina perpendicularis (crista galli)

B. Sinus frontalis caudalis (frontal sinus septum lies, in this specimen, just slightly to the left of the midline)
B'. Sinus frontalis caudalis (note the rostral projection of the left caudal frontal sinus)
D. Sinus sphenoidalis

I Concha nasalis dorsalis (first endoturbinate portion)
II Concha nasalis mediae (second endoturbinate portion)
III-VII Endoturbinates III-VII

Arrows: indicate communication of the paranasal sinuses with the nasal cavity.

Solid portion: is found lying within the space of the nasal cavity or paranasal sinuses
Dotted portion: is found lying beneath bone or tissue

Broken line: indicates limitation of the paranasal sinus for clarification of the photographs

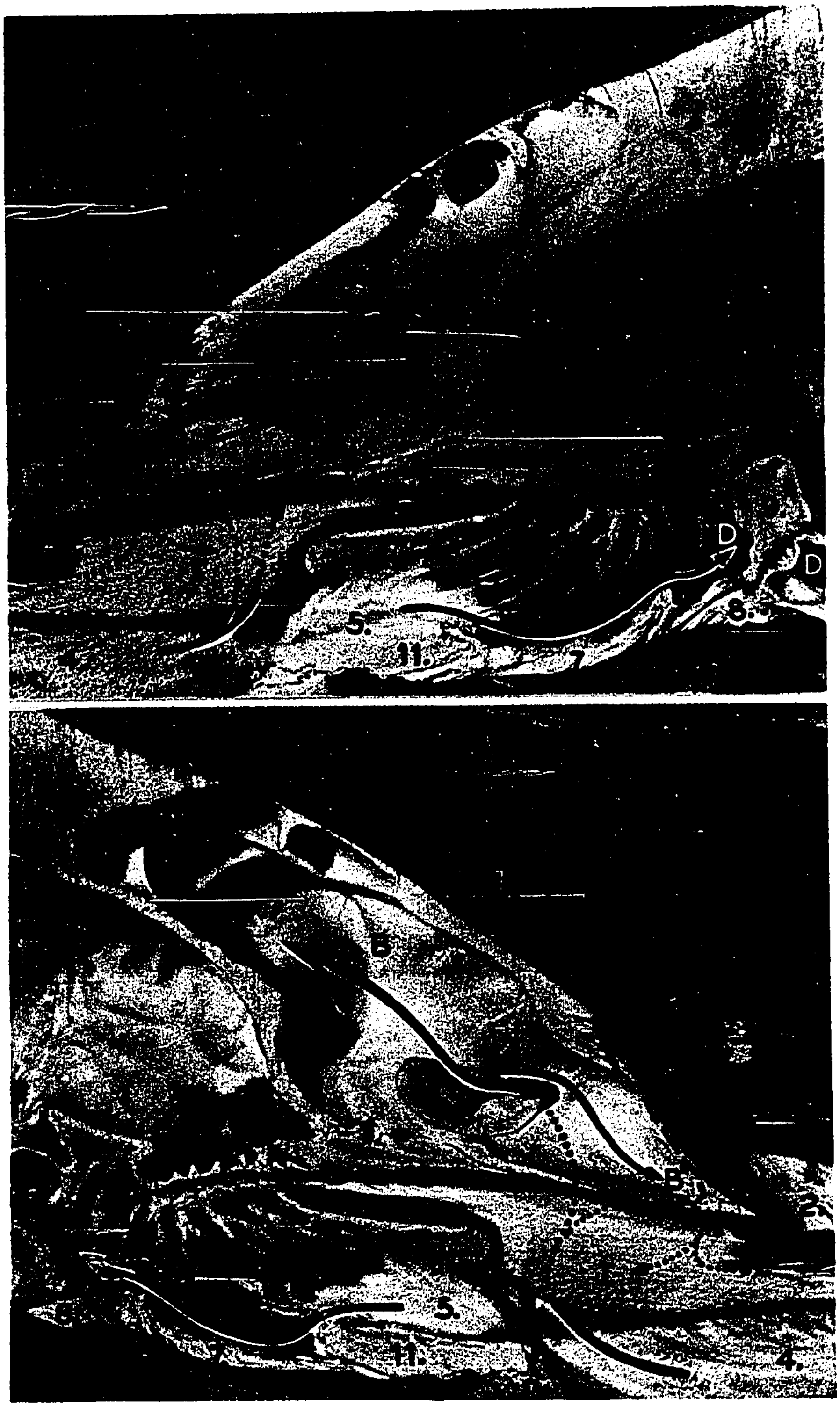

D
D
5.
11
8.
5.
11
4.

Figure 9. Osteology: Ten to eleven months old swine skull, sagittal view, right (upper photo) and left (lower photo) sides. The nasal bone has been disarticulated and the perpendicular lamina of the ethmoid bone has been sculptured to illustrate the ethmoidal labyrinth. The sphenoid sinus has been partially sculptured to adequately expose it. The vomer bone has been partially removed

1. Os frontale
2. Maxilla (sutura nasomaxillaris)
4. Concha nasalis ventralis
5. Os ethmoidale
5'. Ethmoidal meatus with surrounding lamina (note the fine line of fusion of the delicate ethmoid lamina with the frontal bone)
7. Os palatinum
8. Os pterygoideum
9. Os presphenoidale
10. Os parietale
11. Lamina basalis

B. Sinus frontalis caudalis (specimen is sectioned slightly to the left of the midline, thus allowing the frontal sinus septum to remain) (further note the absence of the rostral projection of the sinus)
D. Sinus sphenoidalis
E. Sinus concha dorsalis (note the rostral projection arising in this case from the cavity within the dorsal nasal concha)

I Concha nasalis dorsalis (first endoturbinate portion)
II Concha nasalis mediae (second endoturbinate portion)
III-VII Endoturbinates III-VII

Arrows: indicate communication of the paranasal sinuses with the nasal cavity

Solid portion: is found lying within the space of the nasal cavity or paranasal sinuses
Dotted portion: is found lying beneath bone or tissue

Broken line: indicates limitation of the paranasal sinus for clarification of the photographs

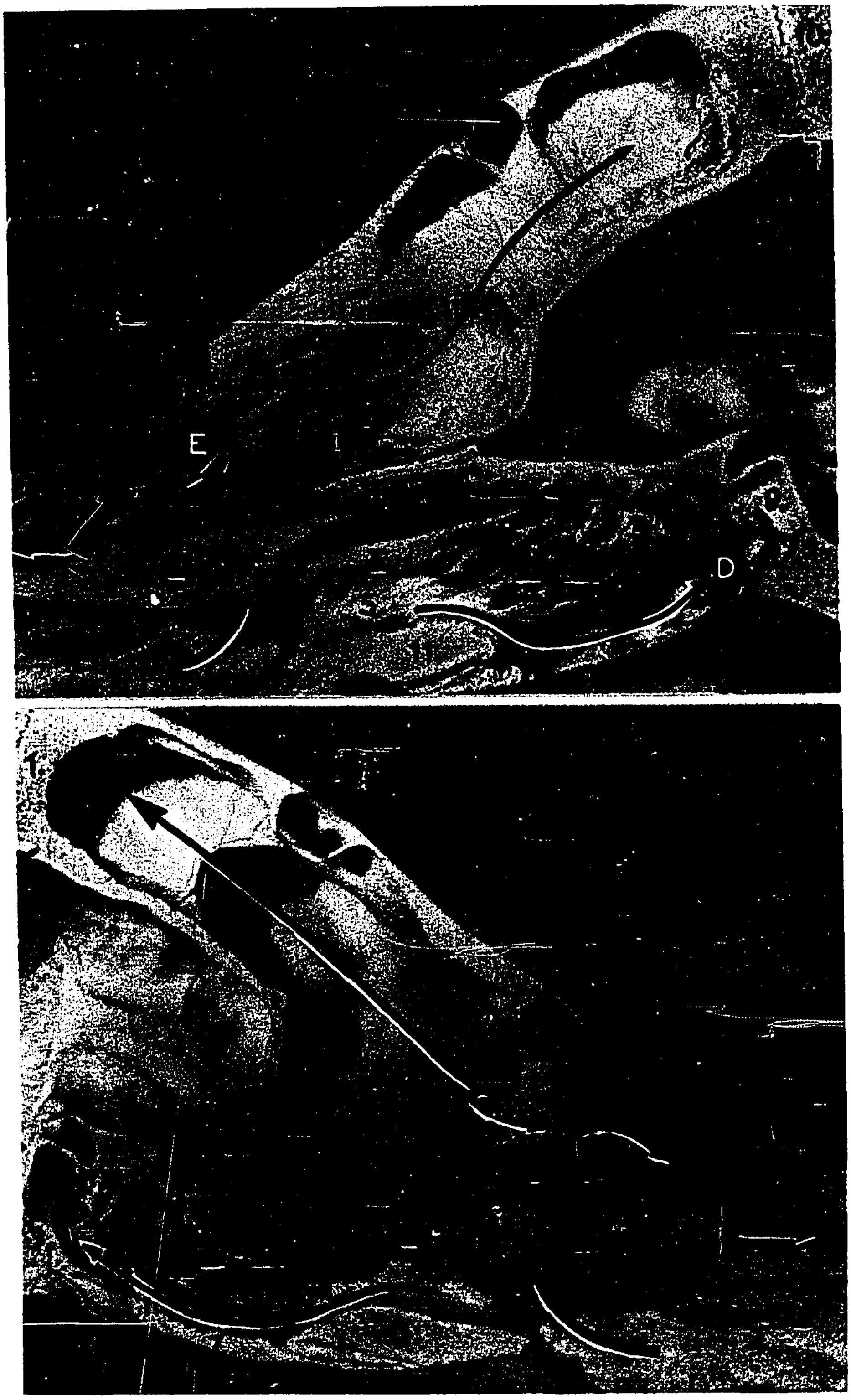

E
D

Figure 10. Osteology: Ten to eleven months old swine skull, sagittal view, right (upper photo) and left (lower photo) sides. The nasal bone has been disarticulated and the perpendicular lamina of the ethmoid bone has been sculptured to illustrate the ethmoidal labyrinth. The sphenoid sinus has been partially sculptured to adequately expose it. The vomer bone has been partially removed

1. Os frontale
2. Maxilla (sutura nasomaxillaris)
4. Concha nasalis ventralis
5. Os ethmoidale
5'. Ethmoidal meatus with surrounding Lamina (note the fine line of fusion of the delicate ethmoid lamina with the frontal bone)
7. Os palatinum
8. Os pterygoideum
9. Os presphenoidale
10. Os parietale
11. Lamina basalis
12. Lamina perpendicularis (crista galli)

A. Sinus frontalis rostralis medialis (note the absence of the rostral projection from both the right and left sides)
B. Sinus frontalis caudalis (greatly reduced on the right and the left sides)
C. Sinus frontalis rostralis lateralis
C'. Sinus frontalis rostralis lateralis (right side)
D. Sinus sphenoidalis

I Concha nasalis dorsalis (first endoturbinate portion)
II Concha nasalis mediae (second endoturbinate portion)
III-VII Endoturbinates III-VII

Arrows: indicate communication of the paranasal sinuses with the nasal cavity.

Solid portion: is found lying within the space of the nasal cavity or paranasal sinuses
Dotted portion: is found lying beneath bone or tissue

Broken line: indicates limitation of the paranasal sinus for clarification of the photographs


1.
C
5.
4.
11.
9.
8.


1.
C'
C
I
5.
11.

Figure 11. Osteology: Mature swine skull, sagittal view, left side. The perpendicular lamina of the ethmoid bone has been sculptured to illustrate the ethmoidal labyrinth and the septum of the sphenoid sinus has been removed to illustrate the excavation of the sinus. The vomer bone has been partially removed

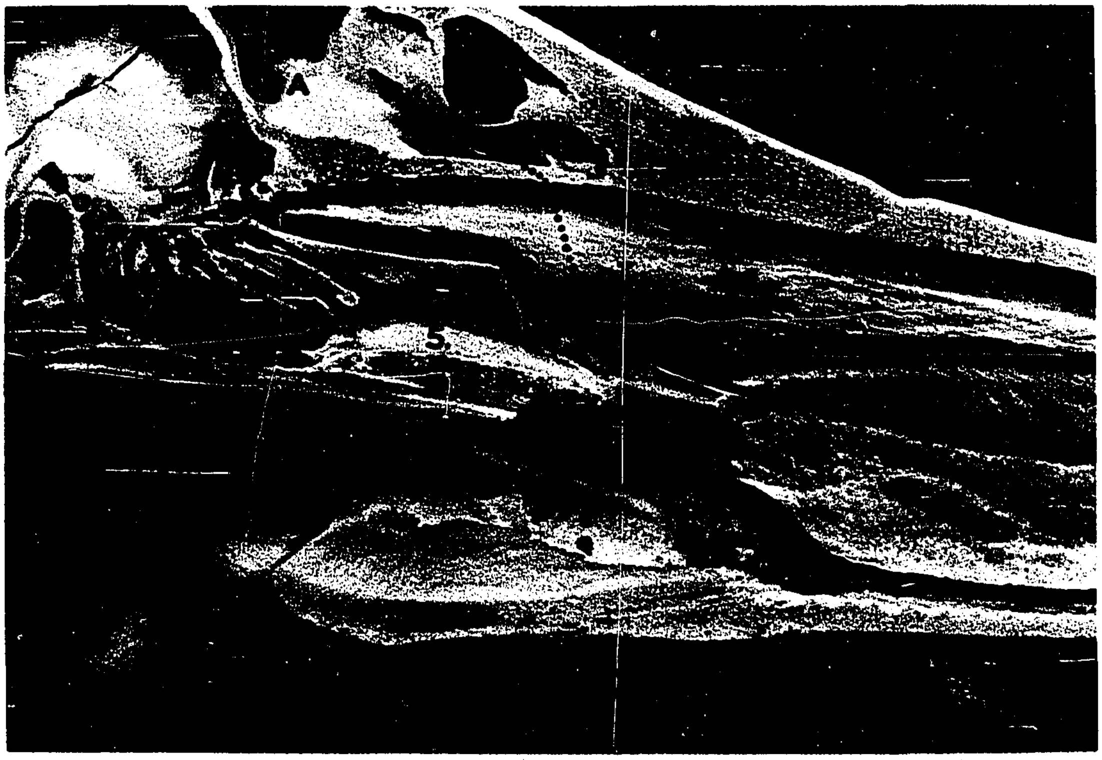
4. Concha nasalis ventralis
5. Os ethmoidale
7. Os palatinum
11. Lamina basalis

A. Sinus frontalis caudalis (note the compressed communication, represented by the arrow, which connects the nasal cavity with the frontal sinus)
D. Sinus sphenoidalis
F. Sinus concha dorsalis (note the sculptured medial and lateral walls of the first endoturbinate to illustrate the lateral communication of the frontal sinus with the nasal cavity) (note the rostral extention of the arrow into the cavity of the dorsal nasal concha)

I Concha nasalis dorsalis (first endoturbinate portion)
II Concha nasalis mediae (second endoturbinate portion)
III-VII Endoturbinates III-VII

Arrows: indicate communication of the paranasal sinuses with the nasal cavity

Solid portion: is found lying within the space of the nasal cavity or paranasal sinuses
Dotted portion: is found lying beneath bone or tissue


A

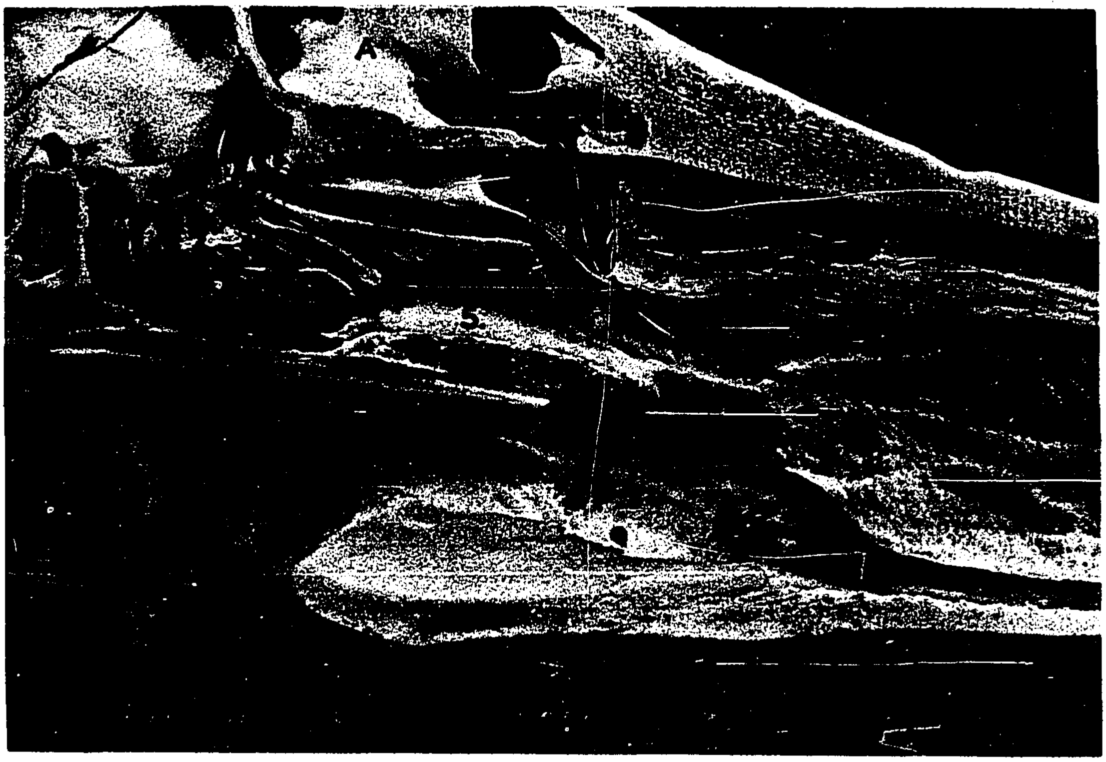

A

Figure 12. Osteology: Ten to eleven months old swine skull, rostral view, transverse section through the nasal cavity at the level of the third premolar (PM_3) tooth. The nasal septum is represented as white dots in the form of its outline

1. Os frontale
2. Maxilla

2'. Foramen infraorbitale

3. Os zygomaticum
4. Concha nasalis ventralis
6. Os lacrimale

B. Sinus frontalis caudalis (of the left side)

H. Sinus maxillaris

I Concha nasalis dorsalis (first endoturbinate portion)

black I: rostral projection of the first endoturbinate which extends along the crest of the nasal bone completing the form of the dorsal nasal concha

white I: ethmoidal part of the dorsal conchal sinus

PM_3 third premolar tooth (level at which the section was taken)

Arrows: indicate communication of the paranasal sinuses with the nasal cavity

Solid portion: is found lying within the space of the nasal cavity or paranasal sinus

Dotted portion: is found lying beneath bone or tissue

6.
3.
2.
B
PM3

Figure 13. Osteology: Ten to eleven months old swine skull, caudal view, transverse section through the nasal cavity at the level of the second molar (M_2) tooth

1. Os frontale
2. Maxilla
2'. Canalis infraorbitalis
3. Os zygomaticum
6. Os lacrimale
11. Lamina basalis (part of the ethmoid bone as it fuses with the vomer bone, forming the horizontal septum between the fundus of the nasal cavity and the nasopharynx)

A. Sinus frontalis rostralis medialis (of the right side)
B. Sinus frontalis caudalis (of the right side)
C. Sinus frontalis rostralis lateralis (of the right side)
G. Sinus lacrimalis (right side, on either side of G.)
H. Sinus maxillaris
  black H: lateral compartment
  white H: medial compartment (dotted line indicating communication between compartments)
I. Sinus paraethmoidei (after Loeffler, 1959)
J. Sinus within the zygomatic bone which will eventually communicate with the caudal extension of the maxillary sinus
K. Choanae (nasopharynx)

M_2 second molar rooth (level at which section was taken)

I Concha nasalis dorsalis (origin is from the cribriform lamina and the lateral lamina of the ethmoid bone)
II Concha nasalis mediae (second endoturbinate portion)

Arrows: indicate communication of the paranasal sinuses with the nasal cavity

Solid portion: is found lying within the space of the nasal cavity or paranasal sinus
Dotted portion: is found lying beneath bone or tissue

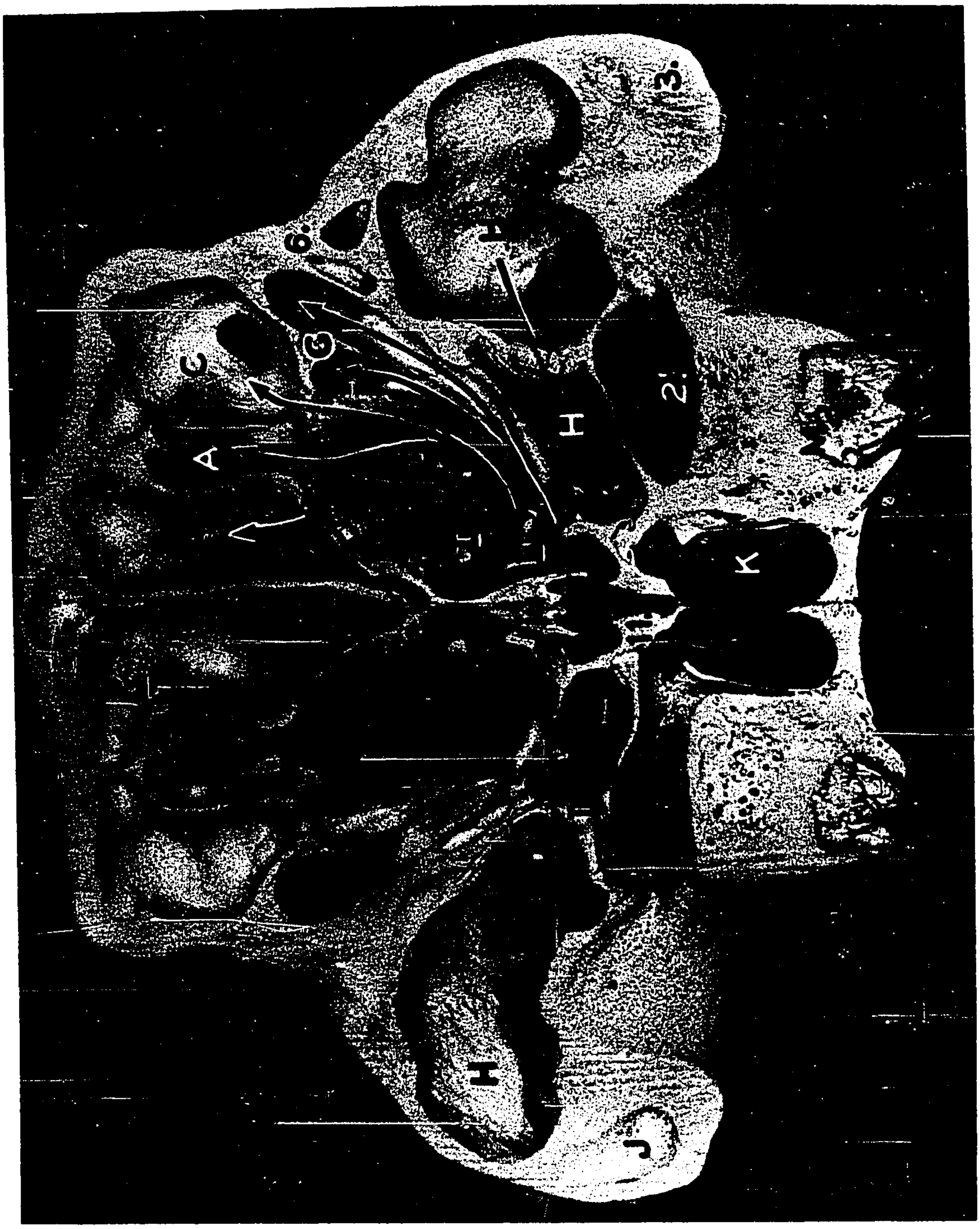

A
C
G
H
2.
3.
6.
H
K
J

Figure 14. Osteology: Ten to eleven months old swine skull, rostral view, transverse section through the nasal cavity at the level of the third molar (M_3) tooth

1. Os frontale
2. Maxilla
3. Os zygomaticum
6. Os lacrimale
10. Os parietale

A. Sinus frontalis rostralis medialis (of the left side) (note both compartments may form one sinus with a single lamina separating them)
B. Sinus frontalis caudalis (of the left side)
C. Sinus frontalis rostralis lateralis (of the left side)
G. Sinus lacrimalis
H. Sinus maxillaris (appears as a medial and lateral compartment)
I. Sinus paraethmoidei (after Loeffler, 1959)
J. Sinus within the zygomatic bone which will eventually communicate with the caudal extension of the maxillary sinus
V. Vomer

M_3 third molar tooth (level at which section was taken)

I Concha nasalis dorsalis (first endoturbinate portion)
II Concha nasalis mediae (second endoturbinate portion)

Arrows: indicate communication of the paranasal sinuses with the nasal cavity

Solid portion: is found lying within the space of the nasal cavity or paranasal sinus
Dotted portion: is found lying beneath bone or tissue

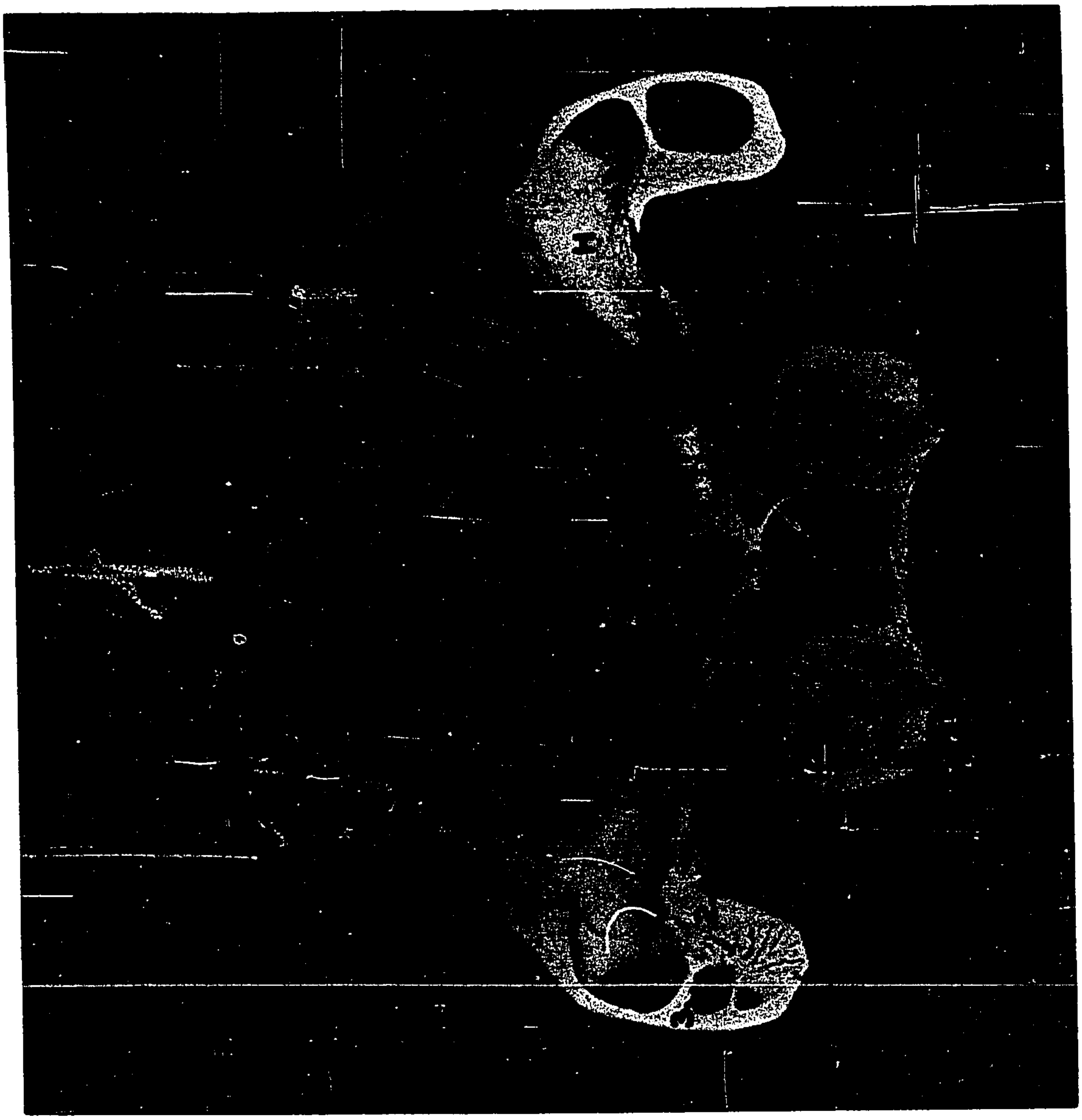


Figure 15. Osteology: Nasal bone, five months old swine skull

1 Dorsal view, right and left bones
2 Ventral view, right and left bones
3 Caudal view, right and left bones
4 Lateral view
5 Medial view

1. Sulcus supraorbitalis
2. Processus nasalis
3. Crista ethmoidalis (crest to which the extension of the first endoturbinate is attached, thus forming the dorsal nasal concha)
4. Sinus concha nasalis dorsalis (rostral extension of the sinus into the nasal bone)

A. Facies externa
B. Facies interna

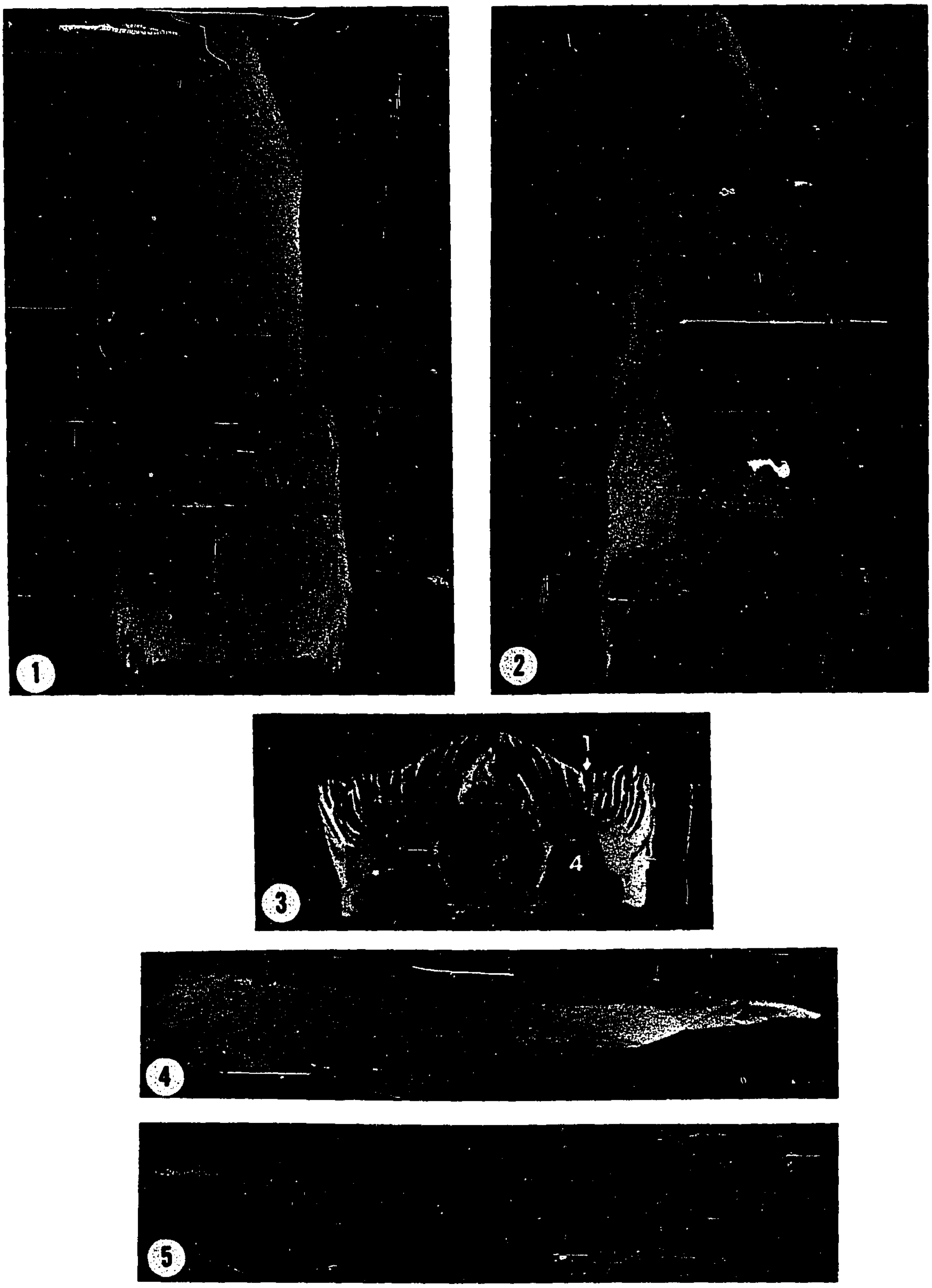


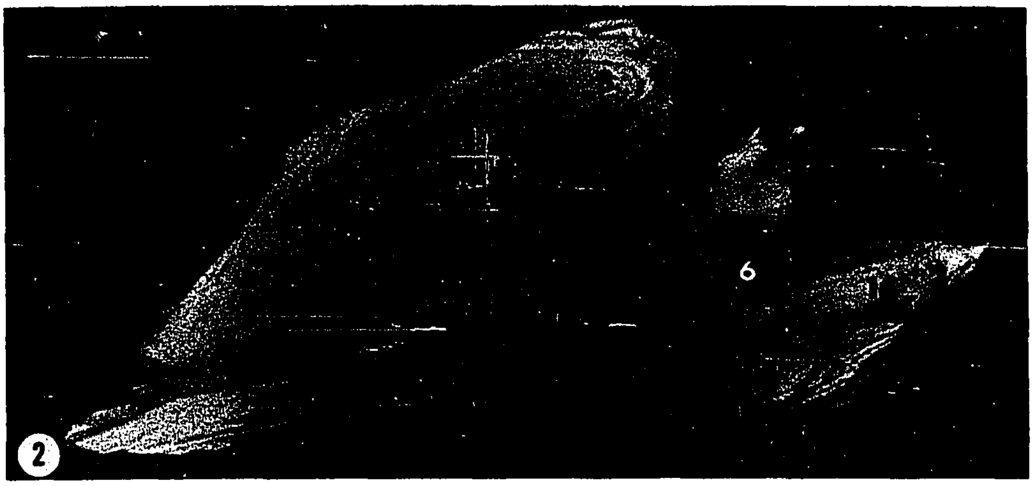
Figure 16. Osteology: Maxillary bone, five months old swine skull

1 Lateral view
2 Medial view, ventral nasal concha removed
3 Medial view, ventral nasal concha in normal position

1. Foramen infraorbitale
6. Foramen maxillare
7. Canalis infraorbitalis
8. Processus frontalis
9. Processus zygomaticus
10. Processus palatinus
14. Tuber maxillae
15. Crista facialis
16. Sulcus lacrimalis
17. Crista conchalis
18. Crista nasalis
19. Sinus maxillaris
20. Canalis palatinus
21. Canalis sphenopalatinus

A. Facies facialis
B. Facies orbitalis
C. Facies pterygopalatina
D. Facies nasalis
E. Concha nasalis ventralis (in its normal position)


1


6
2

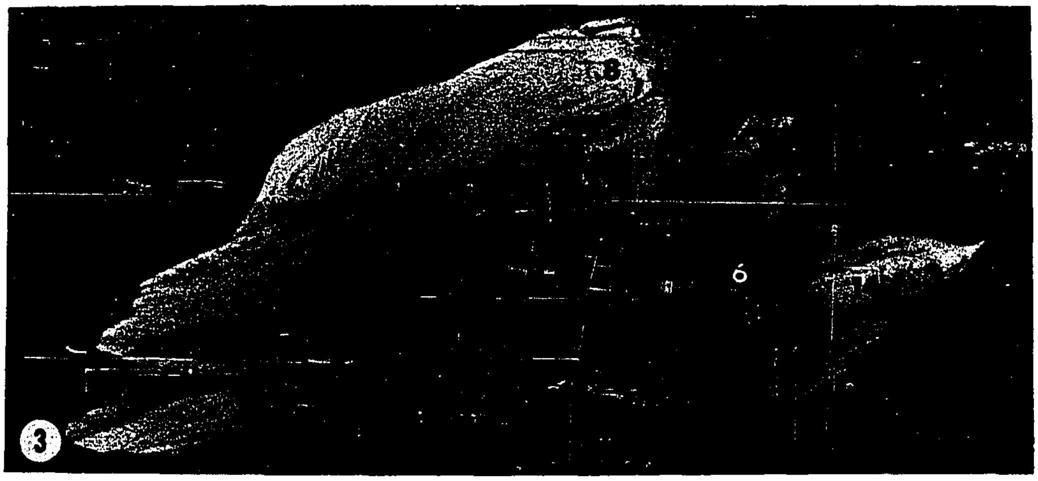

6
3

Figure 17. Osteology: Maxillary bone, five months old swine, dorsal view of the partially disarticulated bones. Both right and left bones are shown

1. Foramen infraorbitale
7. Canalis infraorbitalis
8. Processus frontalis
9. Processus zygomaticus
10. Processus palatinus
14. Tuber maxillae
15. Crista facialis
18. Crista nasalis (on the midline)
19. Sinus maxillaris (arrows indicating communication of the medial and lateral compartments)

E. Concha nasal ventralis (actual osseous part of the concha)

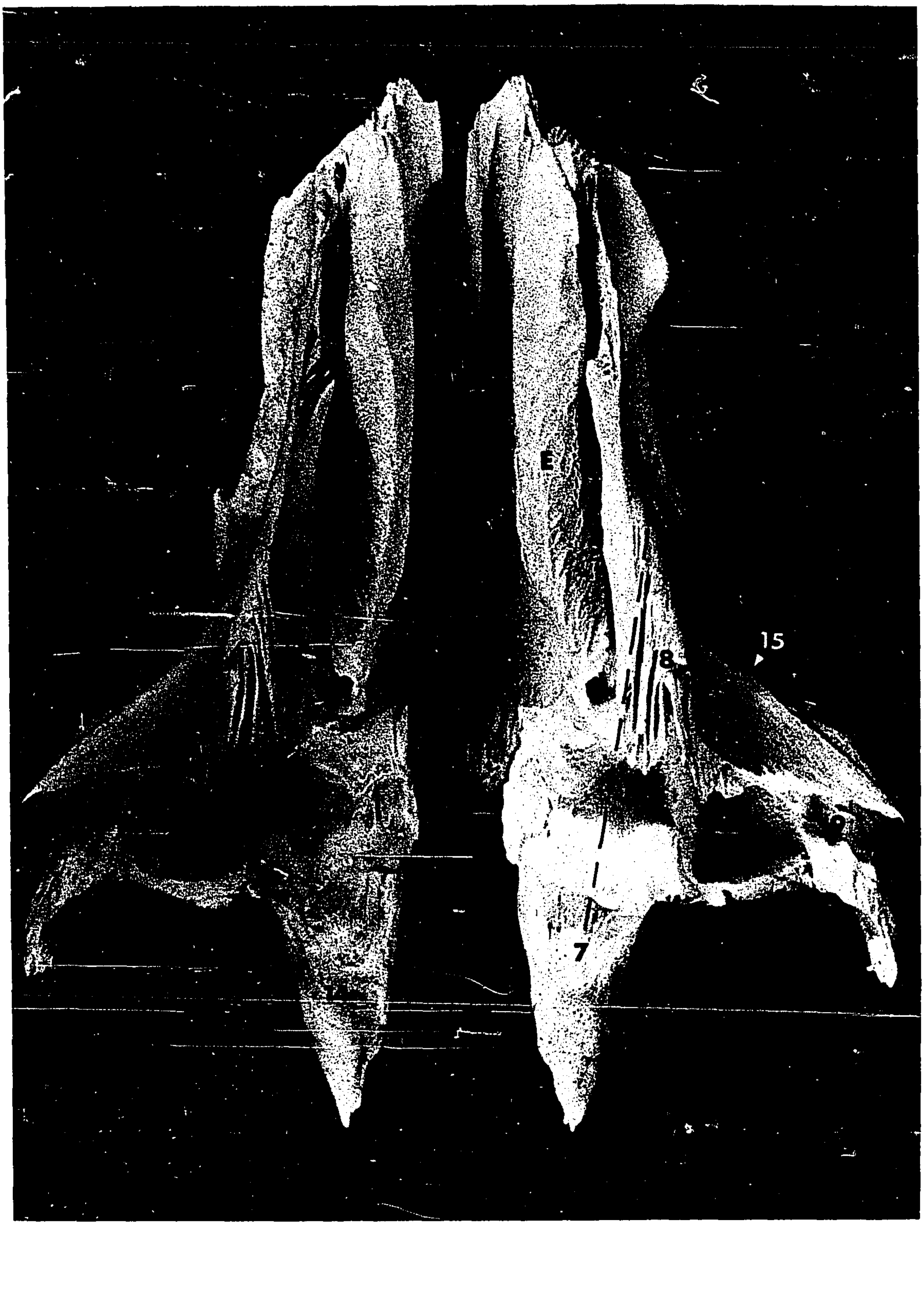
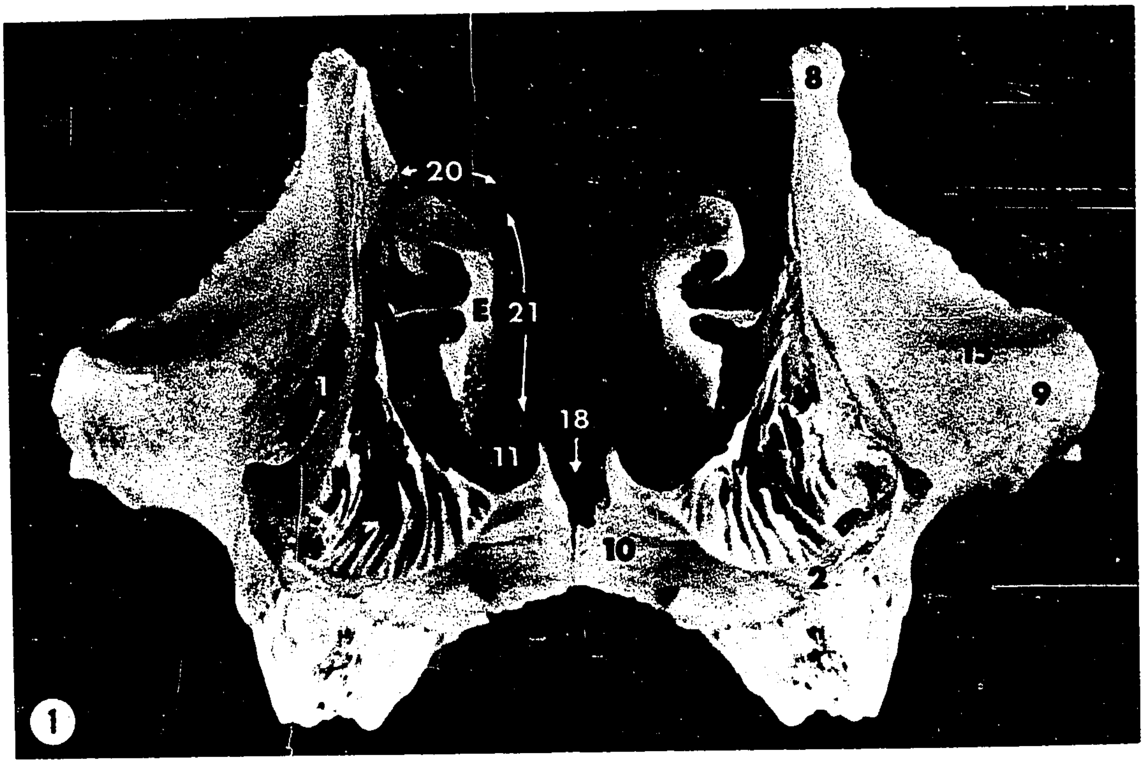

E
15
8
7

Figure 18. Osteology: Maxillary bones, five months old swine skull

1 Rostral view, ventral nasal concha in normal position
2 Caudal view, ventral nasal concha in normal position

1. Foramen infraorbitale
2. Processus alveolaris
6. Hiatus maxillaris
7. Canalis infraorbitalis
8. Processus frontalis
9. Processus zygomaticus
10. Processus palatinus (hard palate)
11. Meatus nasi ventralis
14. Tuber maxillae
15. Crista facialis
18. Crista nasalis
19. Sinus maxillaris (arrow indicates the medial and lateral compartments)
20. Meatus nasi medius
21. Meatus nasi communis

E. Concha nasalis ventralis (in its normal position)


20
21
1
18
11
8
9
10
2
1

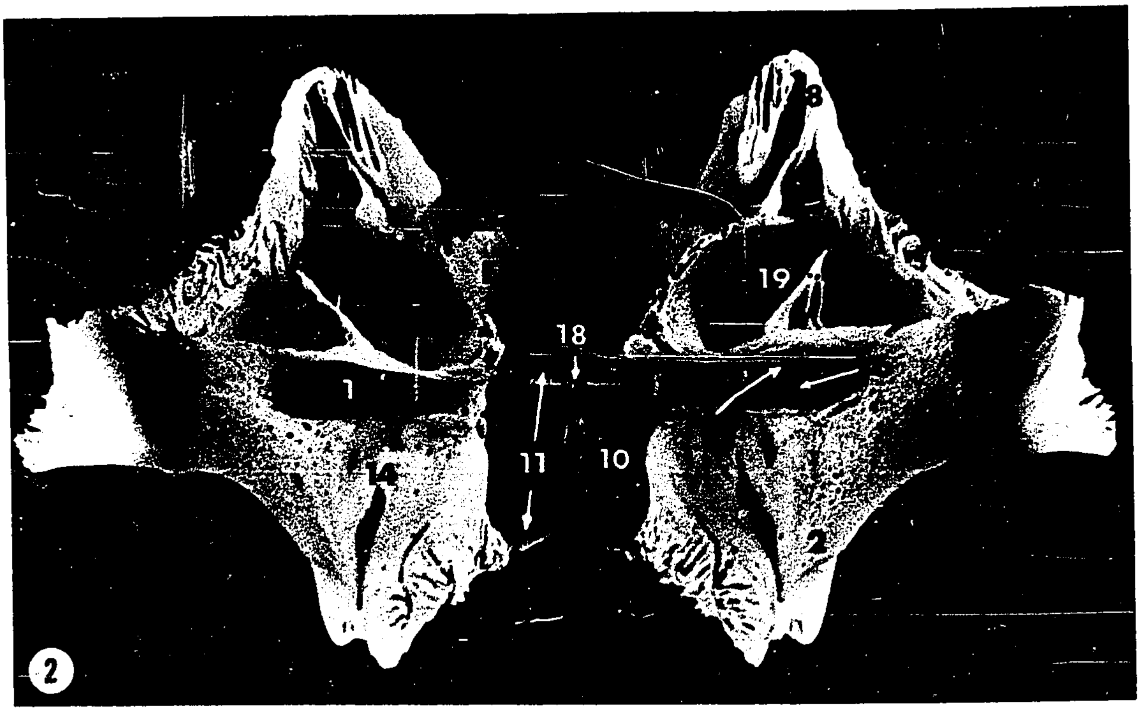

8
19
18
1
11
10
14
2
2

Figure 19. Osteology: Concha nasalis ventralis, five months old swine skull

1 Medial view
2 Lateral view
3 Dorsal view
4 Ventral view

1. Sulcus for the nasolacrimal duct
2. Dorsal scroll
3. Ventral scroll
4. Rostromedial wall of the maxillary sinus
5. Facies medialis (surface in contact with the common nasal meatus)
6. Facies dorsalis (surface in contact with the middle nasal meatus)
7. Facies ventralis (surface in contact with the ventral nasal meatus)

A. Lamina basalis (attachment for the ventral nasal concha to the medial aspect of the maxillary bone)

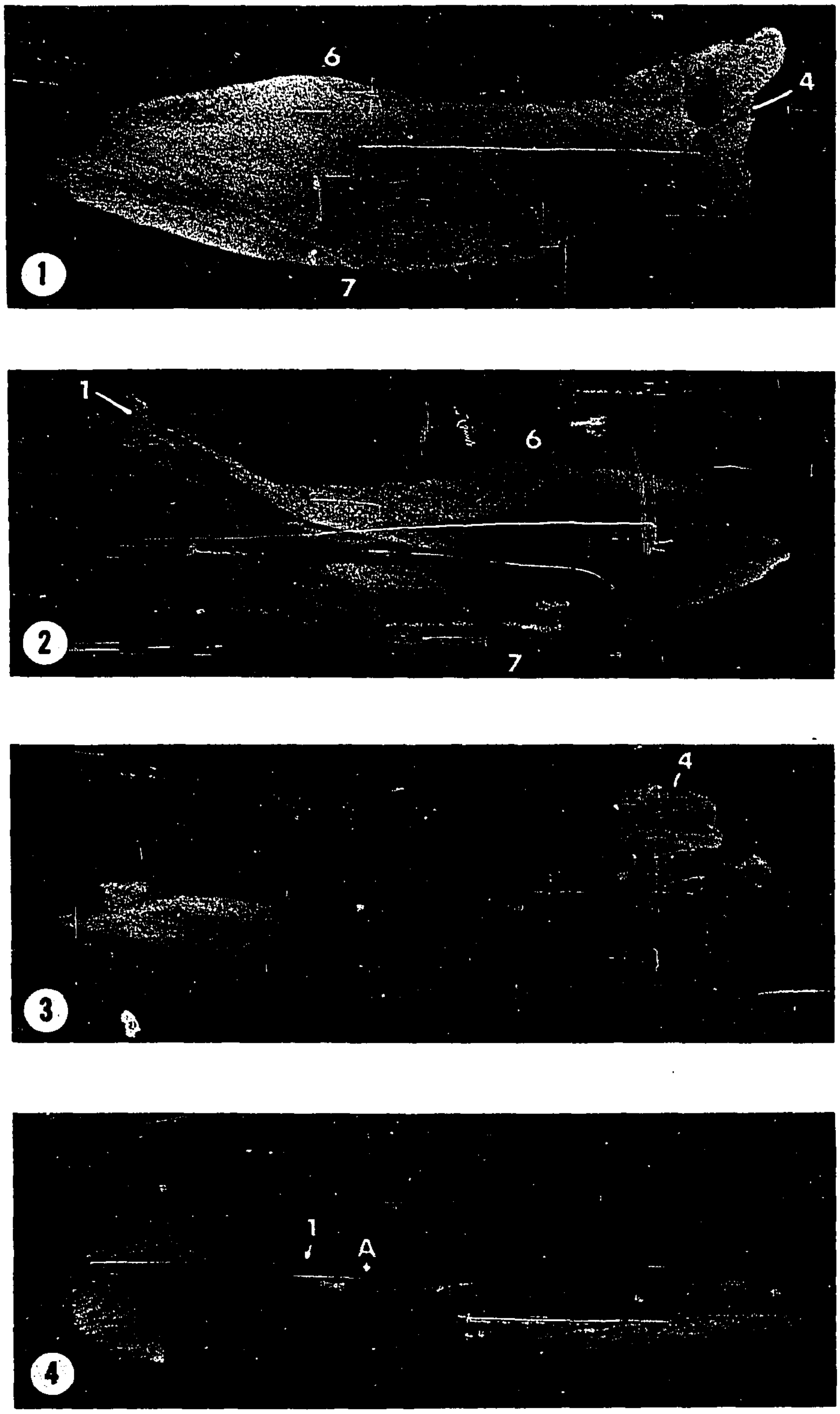

1
6
4
7
2
1
6
7
3
4
4
1
A

Figure 20. Osteology: Ethmoid bone, five months old swine skull

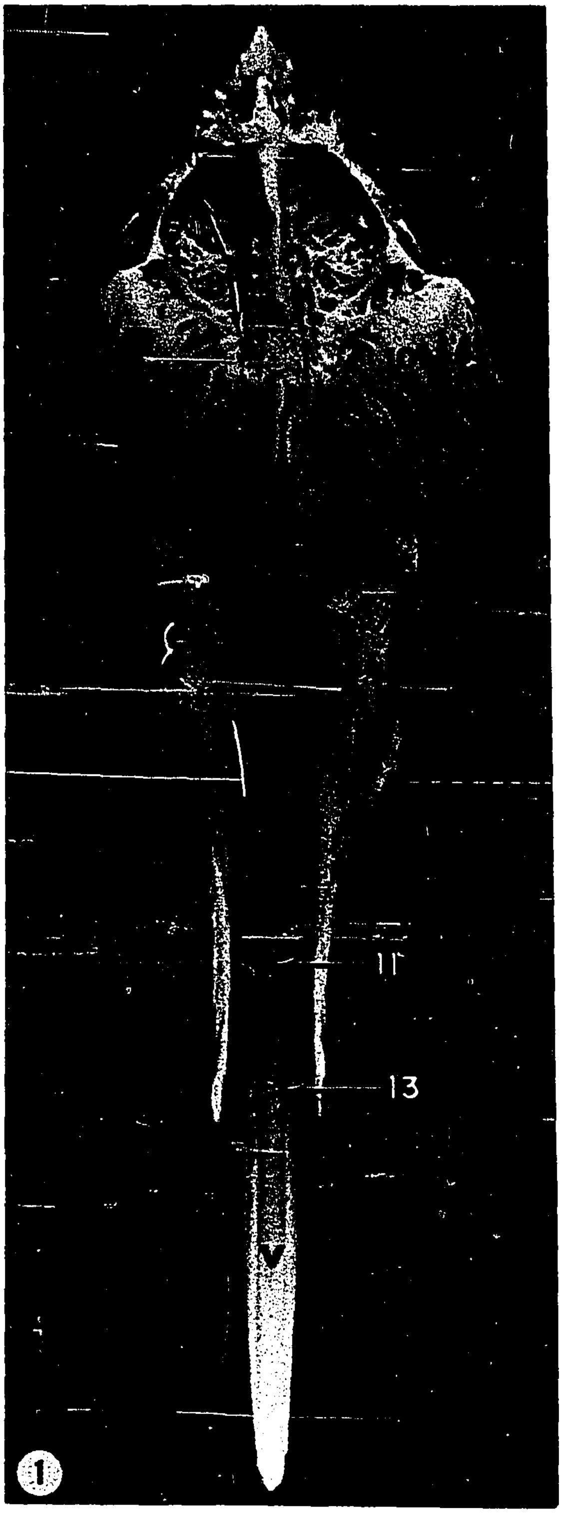
1 Dorsal view
2 Ventral view

4. Lamina lateralis (the portion forming the medial wall of the maxillary sinus)
6. Lamina cribrosa
7. Foramina in the cribriform lamina
8. Crista galli
10. Ethmoturbinalia
11. Vomer (septal sulcus)
12. Crista vomeris
13. Ala vomeris

I Endoturbinate I

Arrows: Solid, black and white: indicate the visible or superficial communication of the nasal cavity and the paranasal sinuses

Dotted, black and white: indicate the nonvisible or deep communication as it passes beneath bone or tissue


11
13
1

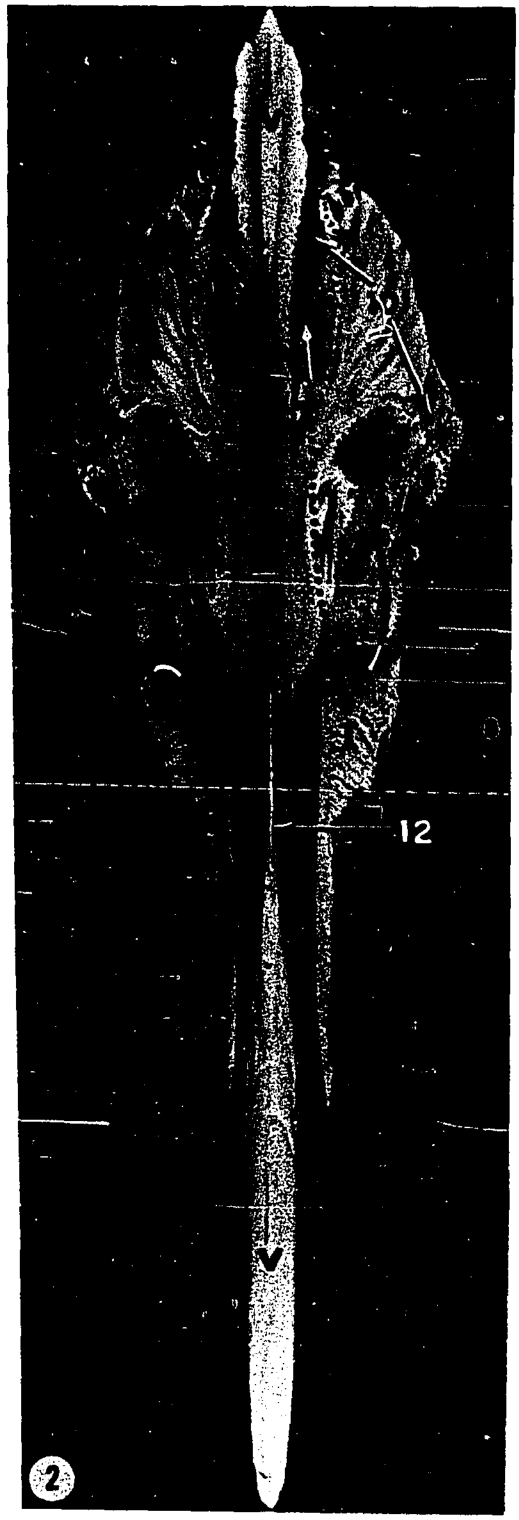

12
2

Figure 21. Osteology: Ethmoid bone, five months old swine skull

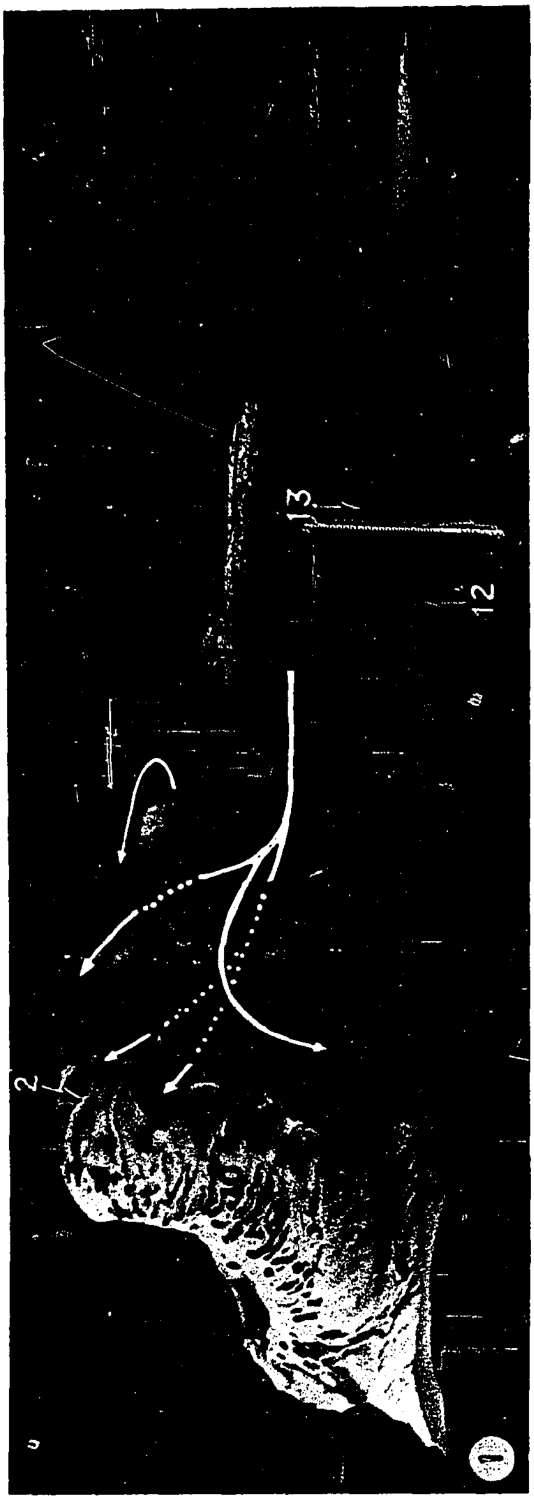
1 Lateral view
2 Medial view

1. Lamina perpendicularis (white dotted line outlines the area sculptured to illustrate the deep ethmoturbinates)
2. Ectoturbinate (its corresponding basal lamella)
3. Processus uncinatus
4. Lamina lateralis (the portion forming the medial wall of the maxillary sinus)
5. Lamina lateralis (orbital part or lamina orbitalis)
7. Foramina in the cribriform lamina
8. Crista galli
10. Ethmoturbinalia
12. Crista vomeris (vomer bone)
13. Ala vomeris

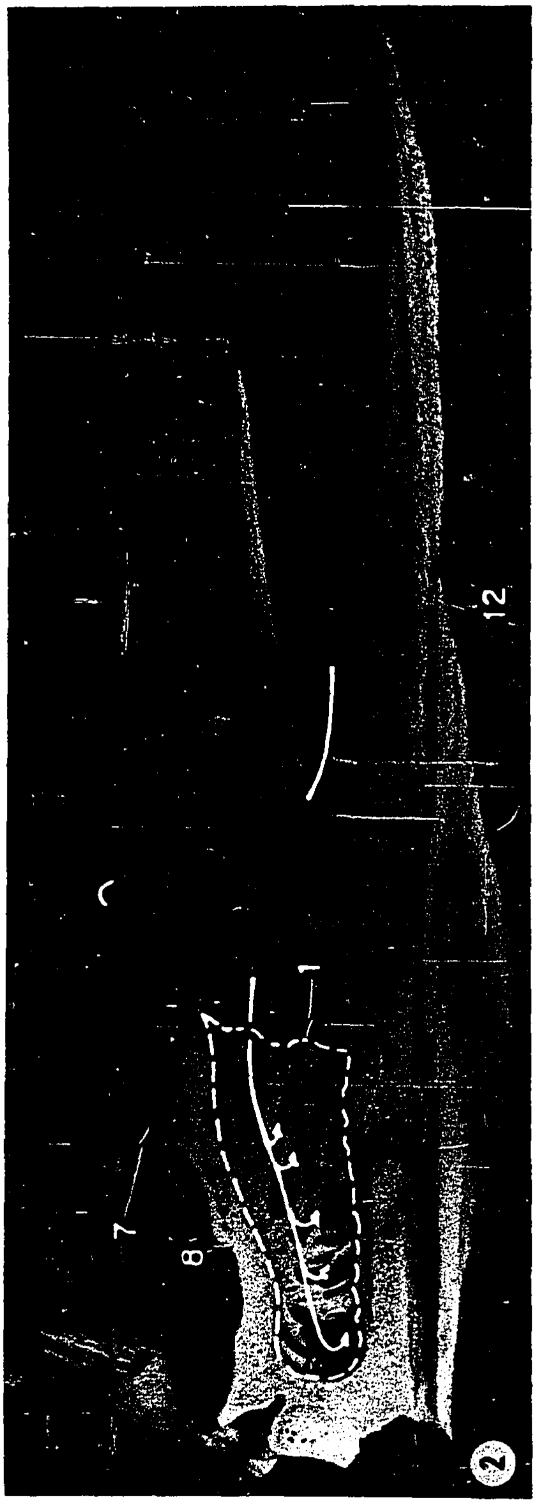
V Vomer

I-II Endoturbinalia

Arrows: Solid, black and white: indicate the visible or superficial communication of the nasal cavity and the paranasal sinuses
Dotted, black and white: indicate the nonvisible or deep communication as it passes beneath bone or tissue



2
13
12
1



7
8
1
12
2

Figure 22. Osteology: Ethmoid bone, five months old swine skull

1 Rostral view
2 Dorsolateral view

1. Lamina Perpendicularis (as it appears deep within the fundus of the nasal cavity)
2. Lamina lateralis (maxillary part as it forms the depression in the medial wall of the maxillary sinus; upper arrow indicates the portion that forms the naso-maxillary aperture; lower arrow indicates the portion that forms the wall of the maxillary sinus)
2". Lamina lateralis (dorsal part as it forms the floor of the passageway to the caudal frontal sinus)
2"'. Lamina tectoria
2"". Lamina basalis
4. Sinus maxillaris (medial wall as it is formed by the lateral lamina)
6. Lamina cribrosa
7. Foramina in the cribriform lamina
8. Crista galli
10. Ethmoturbinalia
11. Vomer (septal sulcus)
13. Ala vomeris

V Vomer

I Endoturbinate I (in the rostral view it indicates the sinus)

Arrows: Solid black: indicates the visible or superficial communication of the nasal cavity and the paranasal sinuses
Dotted black: indicates the nonvisible or deep communication as it passes beneath bone or tissue

Fine dotted line: indicates the outline of a sinus or lamina


10
2
2''
2'''
2''''
11
13
1

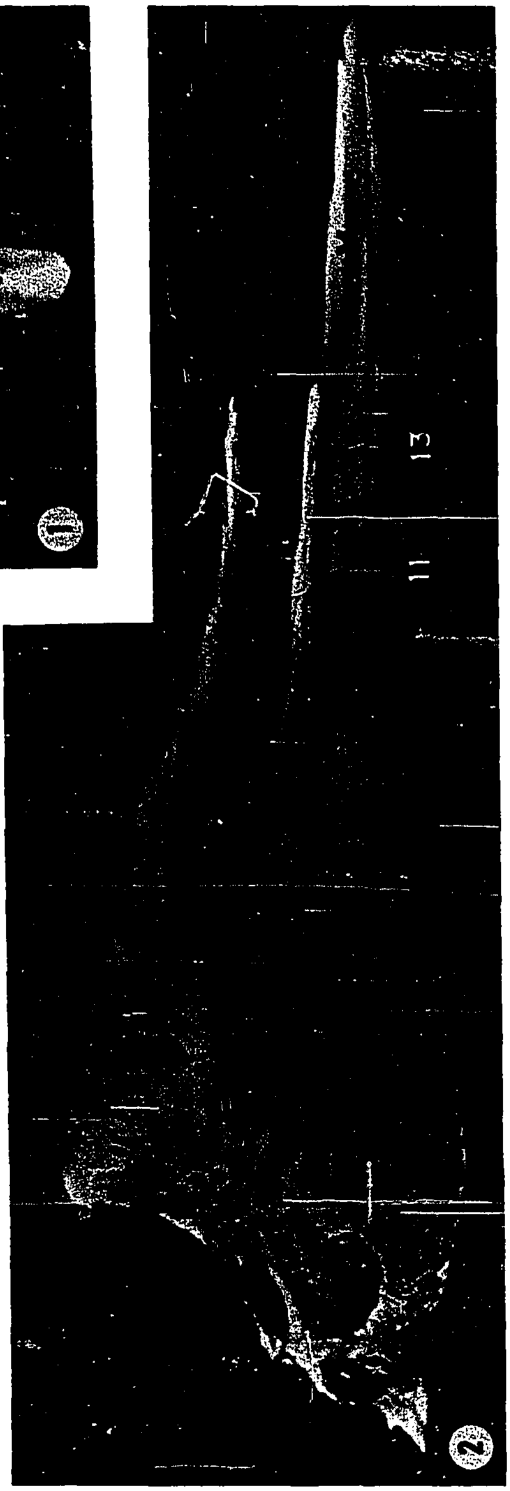

13
11
2

Figure 23. Osteology: Ethmoid bone, six months old swine skull, medial view, disarticulated and sculptured. The entire perpendicular lamina and the dorsal part of the lateral lamina have been sculptured to clarify the deep ethmoturbinates

1. Lamina cribrosa
2. Crista galli
3. Ectoturbinalia (typical ectoturbinates, medial row)
4. Lamina tectoria
5. Lamina basalis (at the level of the fused vomeroethmoid suture)
6. Lamina lateralis (as it forms the lateral wall of the ethmoidal labyrinth and the medial wall of the maxillary sinus)
7. Lamina lateralis (dorsal part, sculptured to illustrate three scrolls)
8. Ectoturbinate (basal lamina)
9. Sutura frontoethmoidalis
10. Concha nasalis dorsalis (rostral extension)

I-VII Endoturbinalia

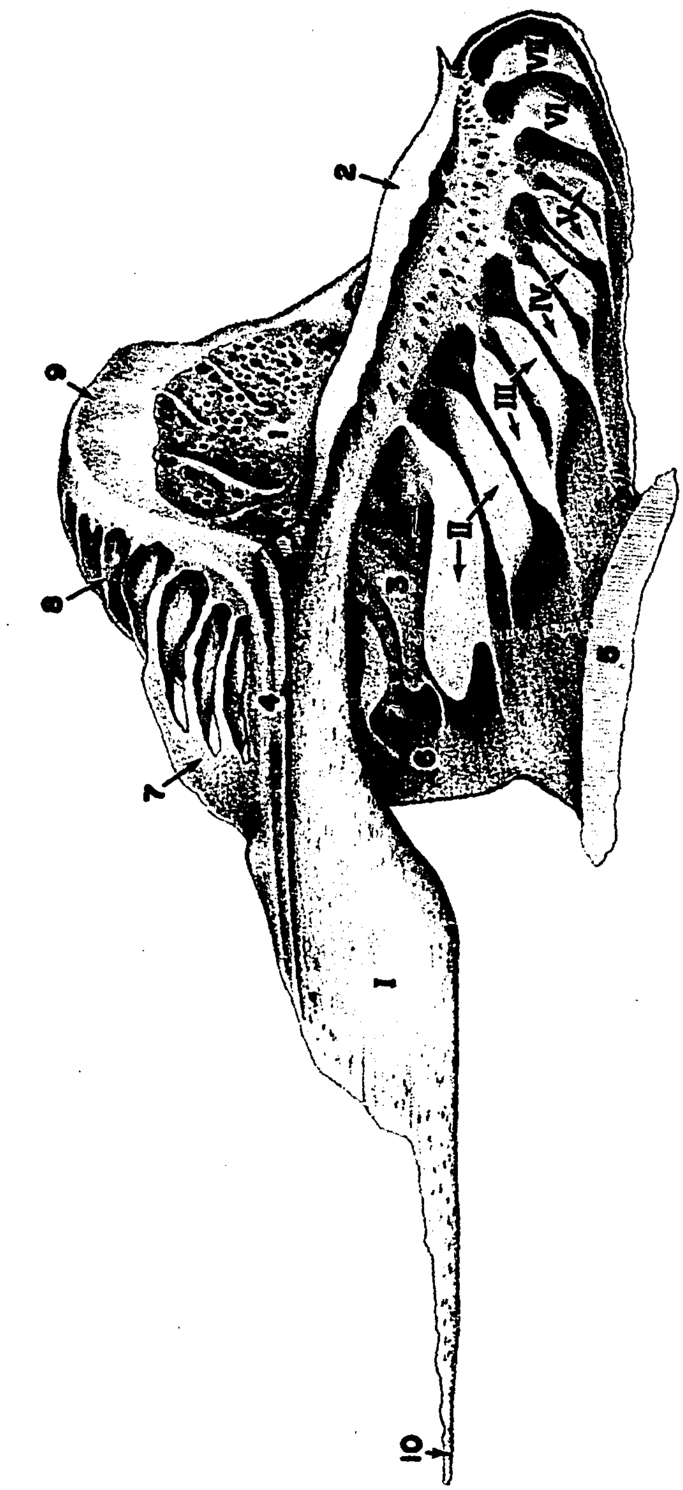

2
9
8
7
5
10

Figure 24. Osteology: Ethmoid bone, six months old swine skull, lateral view, disarticulated and sculptured. The entire lateral lamina including the orbital, maxillary and dorsal parts have been sculptured to clarify the deep ethmoturbinates

1. Lamina cribrosa
2. Crista galli
4. Hiatus semilunaris (caudal edge)
5. Lamina basalis (immediately above arrow, observe ethmoidomaxillary suture)
6. Lamina lateralis (as it forms the medial wall of the maxillary sinus)
7. Lamina lateralis (dorsal part, sculptured lateral edge)
8. Processus uncinatus
9. Sutura frontoethmoidalis
10. Concha nasalis dorsalis (rostral extension)

a. Ectoturbinalia (typical ectoturbinates, medial row with basal lamina and numerous scrolls)
b. Ectoturbinalia (typical ectoturbinates, lateral row with basal lamina and numerous scrolls)
c. Arrow (lateral to the lateral lamina) indicating position and communication of the maxillary sinus and the middle meatus, naso-maxillary aperture
d. Arrow (dorsal to the dorsal part of the lateral lamina) indicating position and communication of middle meatus and medial rostral frontal sinus
e. Arrow (lateral and dorsal to the first endoturbinate) indicating position and communication of the dorsal conchal sinus (nasal part) and the middle meatus
f. Arrow (lateral to the first endoturbinate) indicating position and communication of dorsal conchal sinus and the middle meatus

I-VII Endoturbinalia

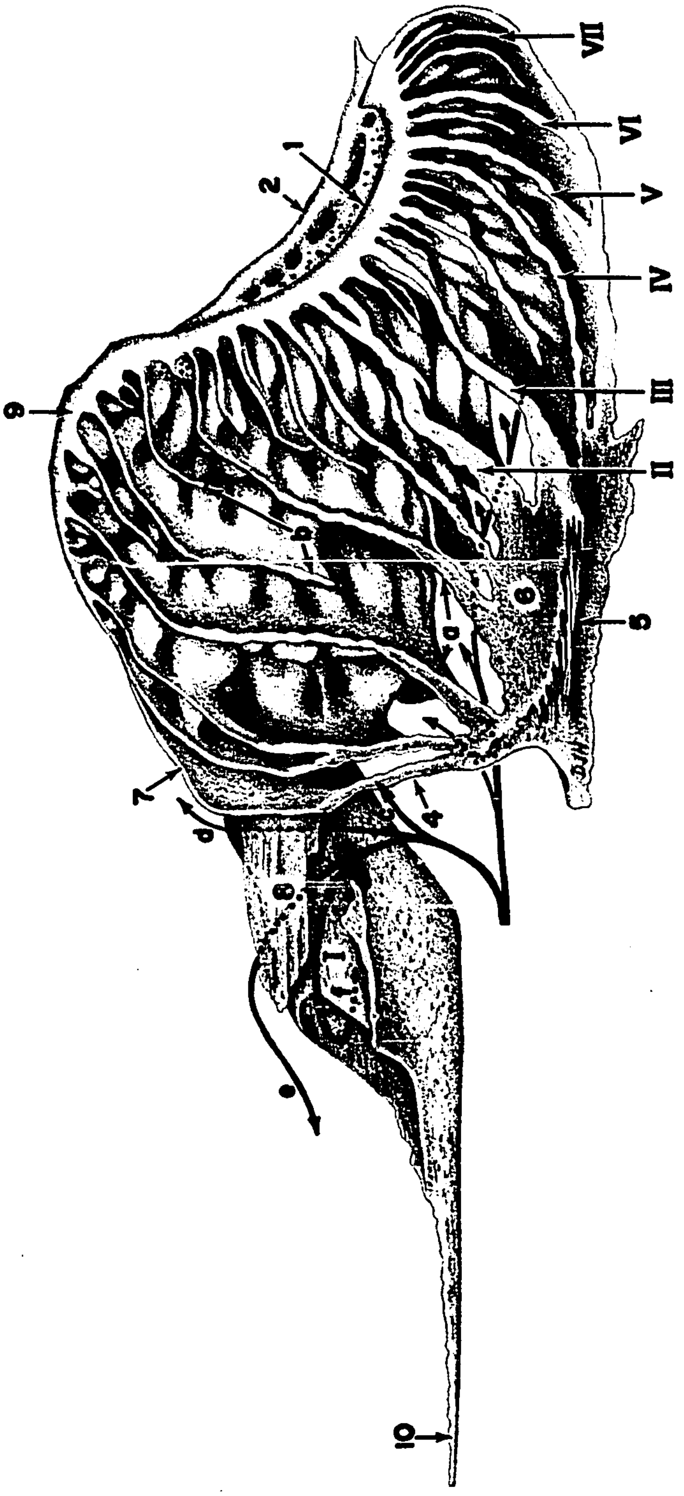

VII
VI
V
IV
III
II
1
2
9
5
6
7
4
8
10

Figure 25. Eight months old swine head, caudal view, transverse section through the nasal cavity, one centimeter caudal to the first incisor tooth (I_1). The mandible and its associated structures have been removed

1. Os incisivum
2. Os nasale
3. Septum nasi (Cartilage)
4. Plica recta
5. Plica alaris (note extensive venous sinuses)
6. Plica basalis
7. Ductus nasolacrimalis (rostral part)

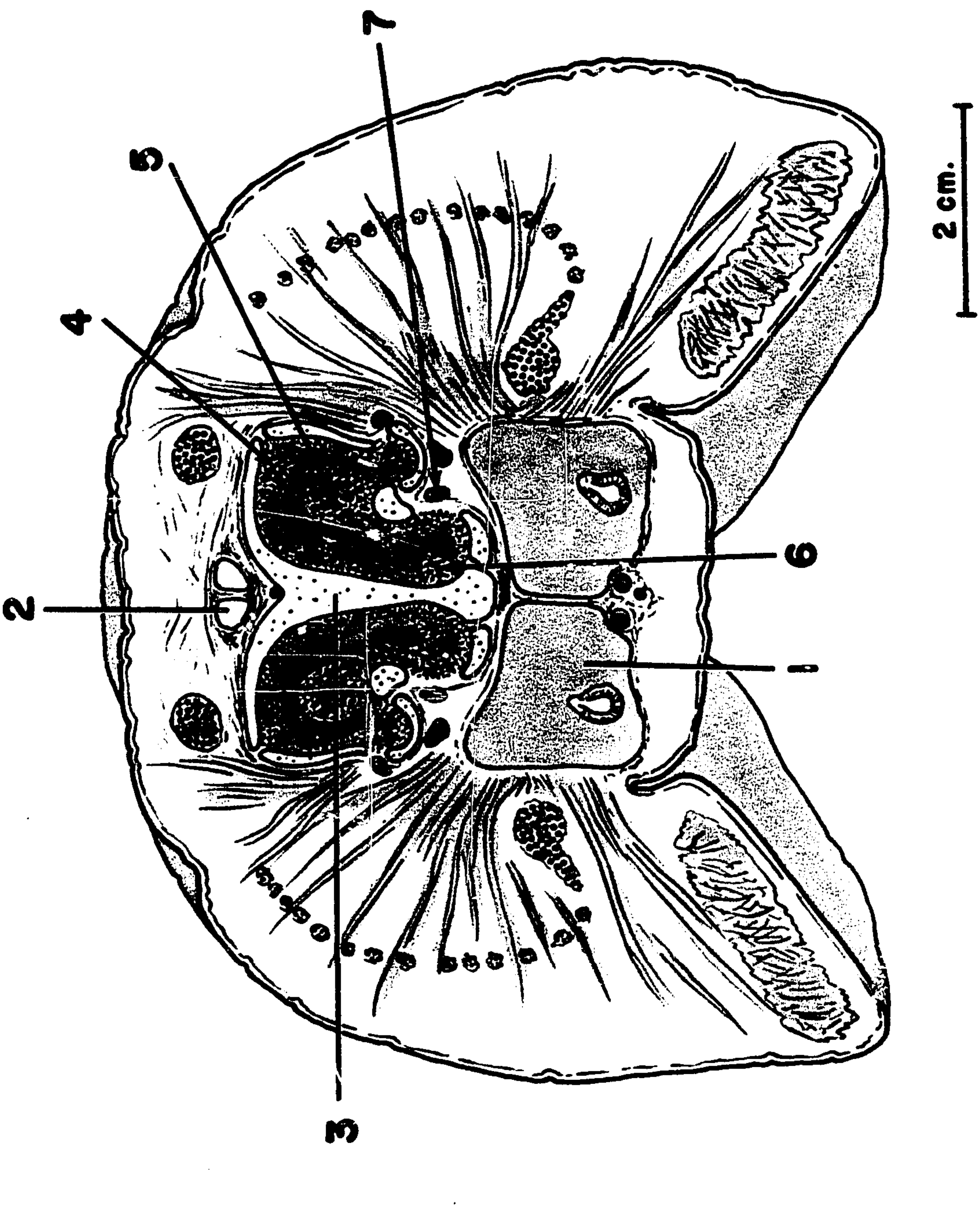
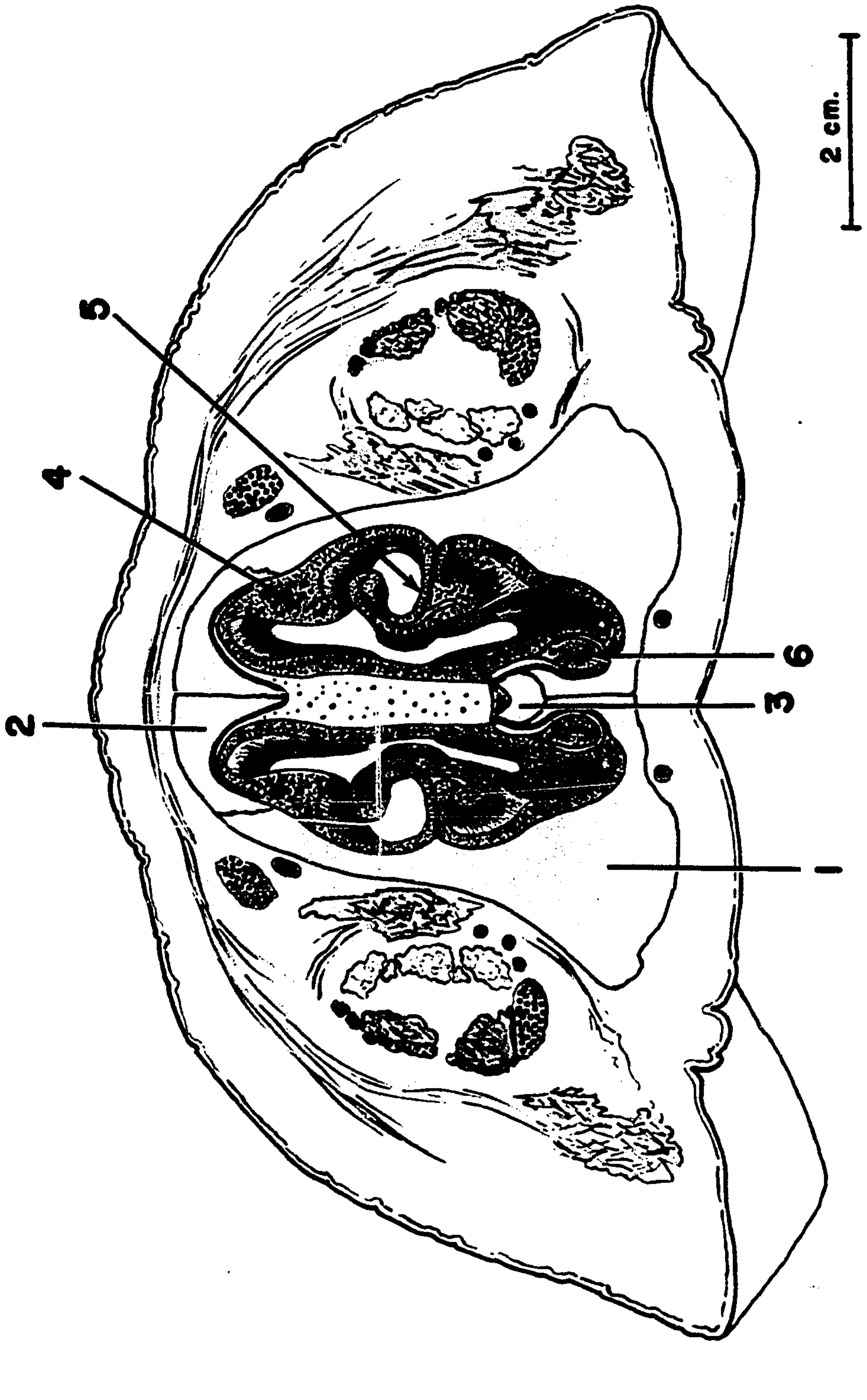

1
2
3
4
5
6
7
2 cm.

Figure 26. Eight months old swine head, caudal view, transverse section through the nasal cavity one centimeter rostral to the canine tooth. The mandible and its associated structures have been removed

1. Os incisivum
2. Os nasale
3. Vomer
4. Plica recta
5. Concha nasalis ventralis (basal lamella)
6. Organum vomeronasale



5
4
2
6
3
1
2 cm.

Figure 27. Eight months old swine head, caudal view, transverse section through the nasal cavity, at the level of the first premolar tooth (PM_1). The mandible and its associated structures have been removed

1. Vomer
2. Os nasale
3. Maxilla
4. Concha nasalis dorsalis
5. Concha nasalis ventralis (basal lamella)
6. Dorsal scroll
7. Ventral scroll
8. Meatus nasi dorsalis
9. Meatus nasi ventralis

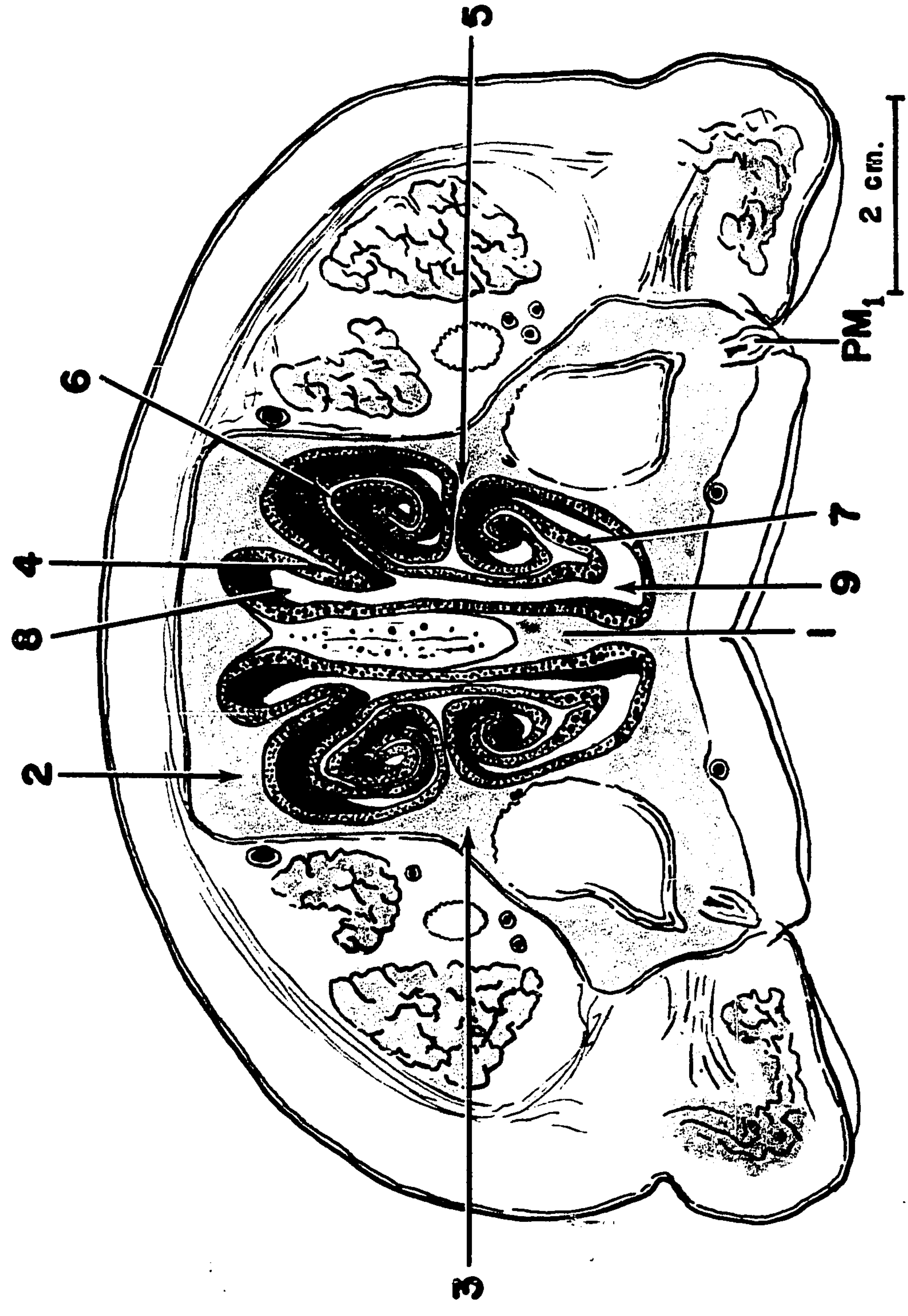

5
6
4
8
2
3
7
9
1
PM_1
2 cm.

Figure 28. Eight months old swine head, caudal view, transverse section through the nasal cavity, at the level of the second premolar tooth (PM_2). The mandible and its associated structures have been removed

1. Vomer
2. Os nasale
3. Maxilla
4. Concha nasalis dorsalis
5. Concha nasalis ventralis (basal lamella)
6. Dorsal scroll
7. Ventral scroll
8. Sinus concha dorsalis

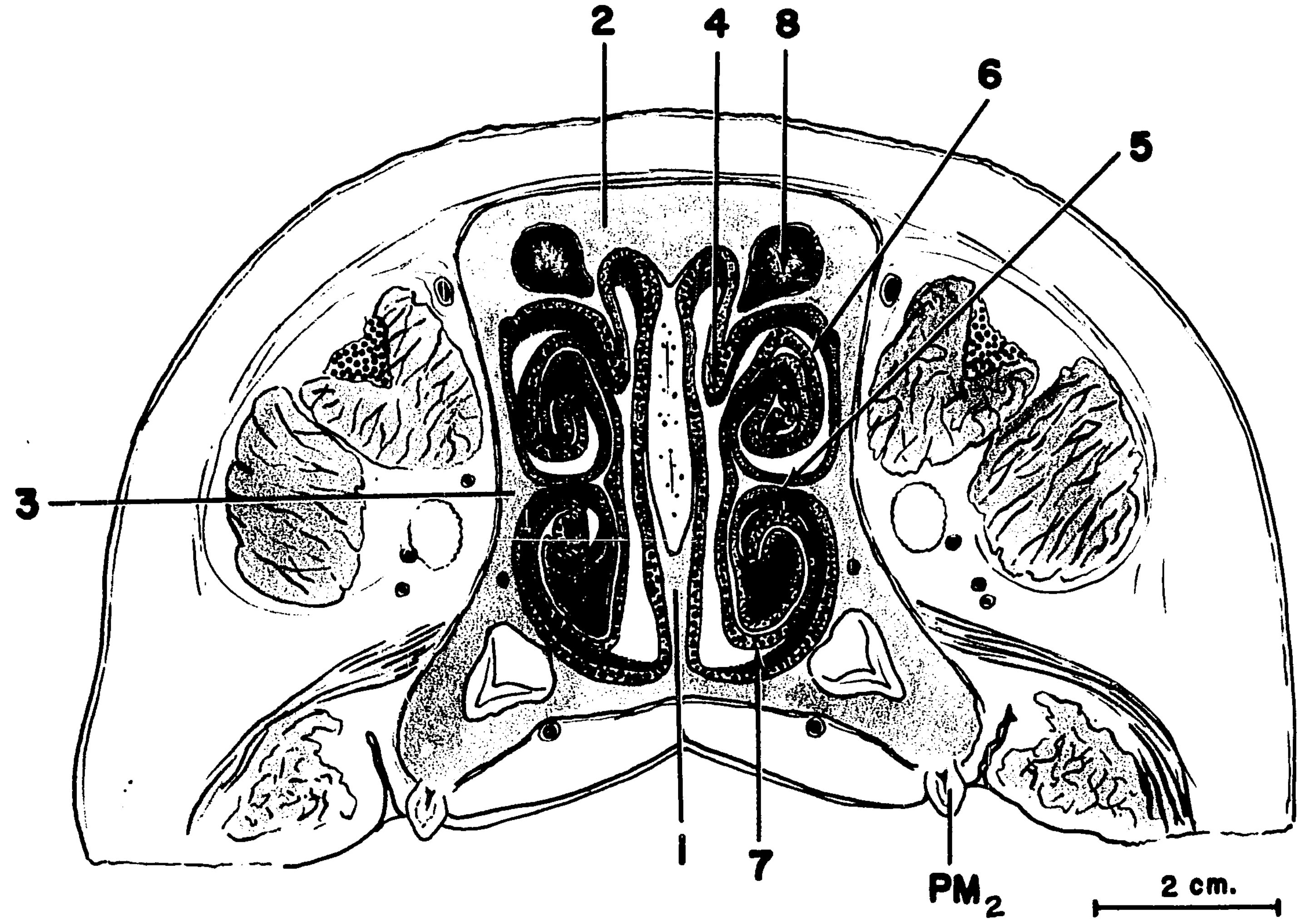

2
4
8
6
5
3
i
7
PM_2
2 cm.

Figure 29. Eight months old swine head, caudal view, transverse section through the nasal cavity, immediately caudal to the third premolar tooth (PM_3). The mandible and its associated structures have been removed

1. Maxilla
2. Os nasale
4. Dorsal scroll
5. Sinus concha ventralis (rostral extent)
6. Sinus frontalis rostralis medialis (rostral projection into nasal bone)
7. Sinus concha dorsalis
8. Foramen infraorbitale (note vessels and nerves emerging)

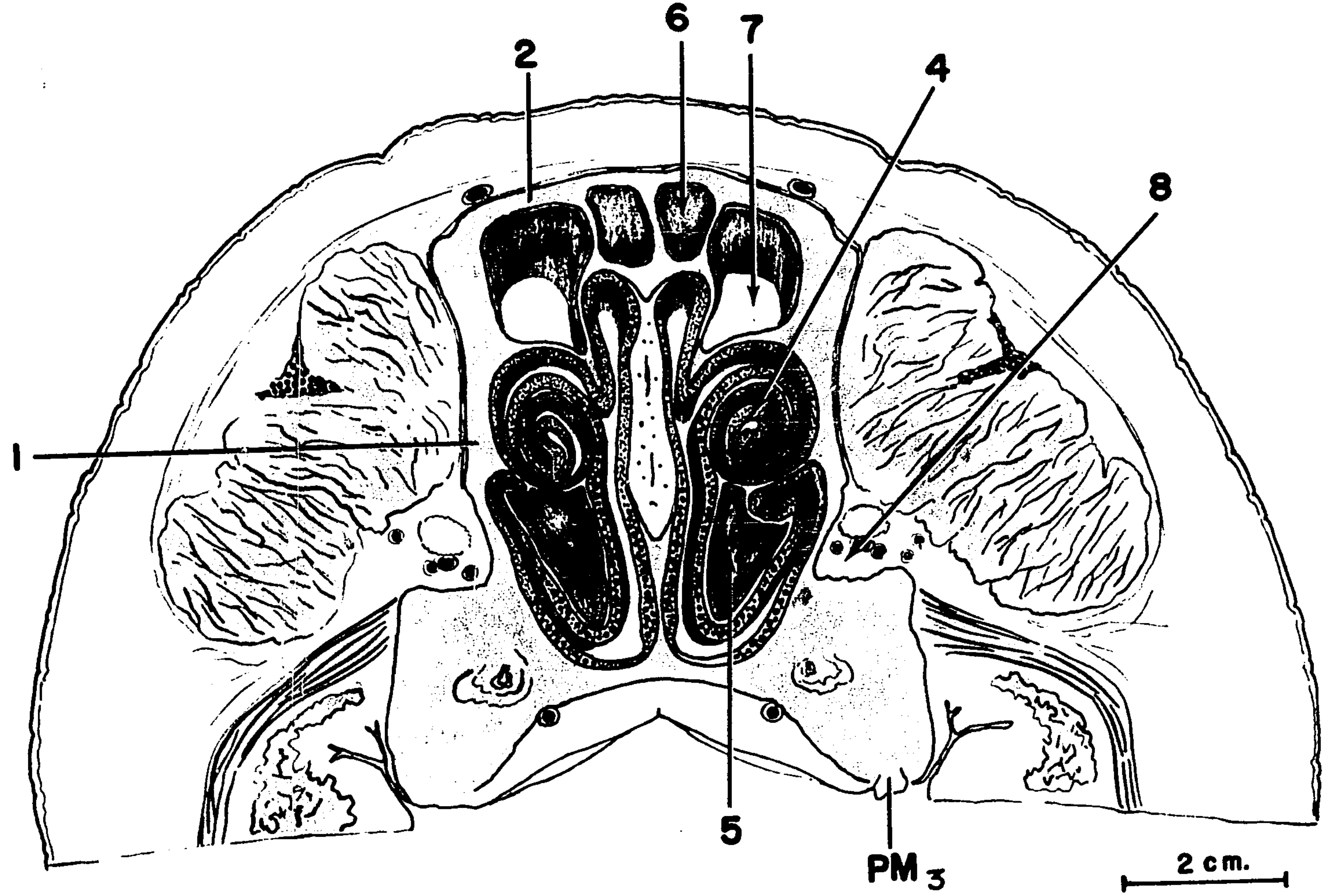

2
6
7
4
8
1
5
PM 3
2 cm.

Figure 30. Eight months old swine head, rostral view, transverse section, nasal cavity, through the rostral part of the fourth premolar tooth (PM_4). The mandible and its associated structures have been removed

1. Maxilla
2. Os nasale
3. Septum nasi (cartilage)
4. Ductus nasolacrimalis (middle, membranous part)
5. Sinus concha dorsalis
6. Dorsal scroll
7. Sinus concha ventralis
8. Fusion of ventral scroll with lateral nasal wall
9. Sinus frontalis rostralis medialis

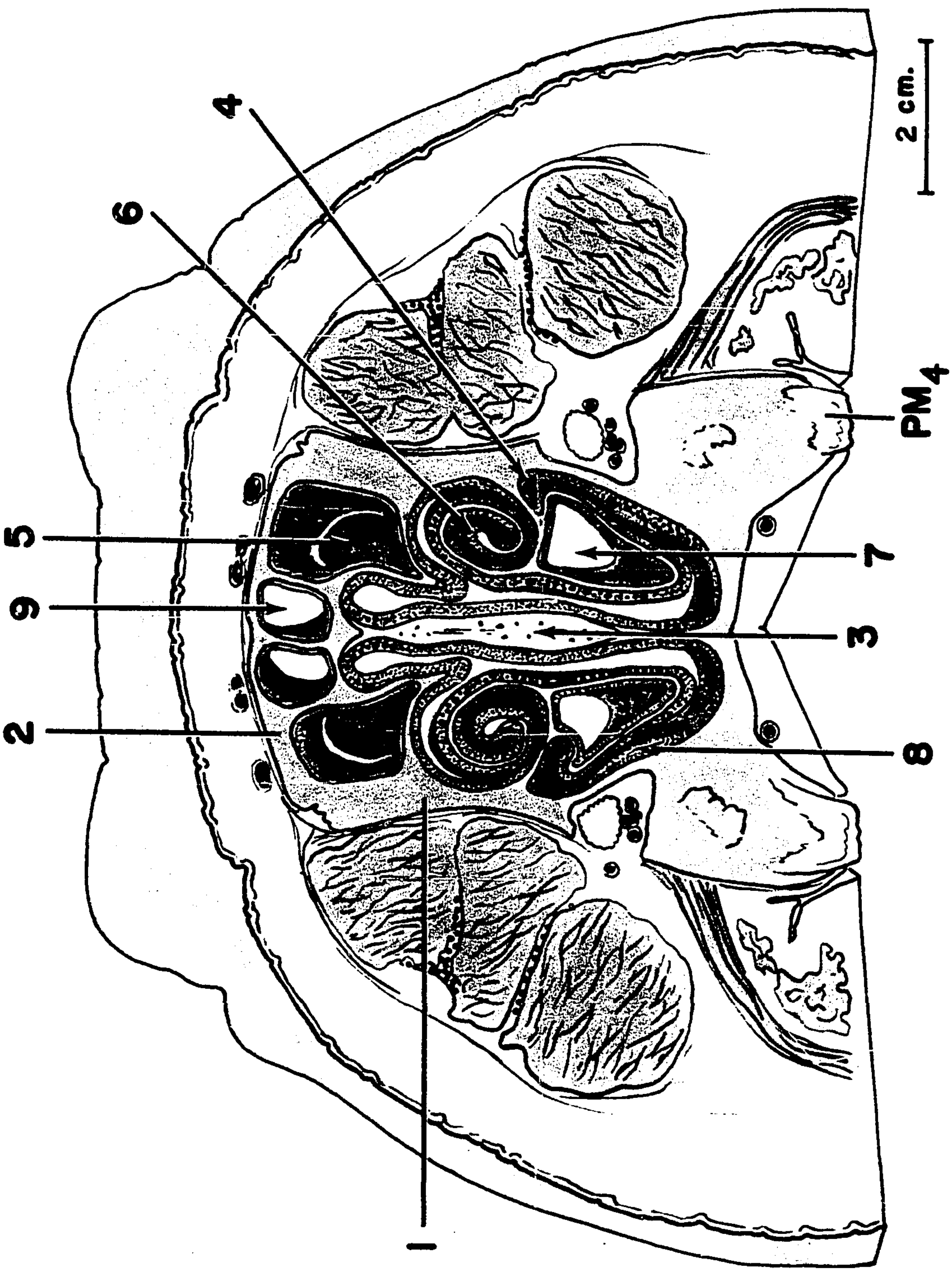

4
6
5
9
2
1
7
3
8
PM_4
2 cm.

Figure 31. Eight months old swine head, caudal view, transverse section, nasal cavity, through the rostral part of the first molar tooth (M_1). The mandible and its associated structures have been removed

1. Maxilla
2. Os frontale
3. Concha nasalis dorsalis (endoturbinate I)
4. Sinus concha dorsalis (rostral extent)
5. Lateral communication with nasal cavity and dorsal conchal sinus
6. Apertura nasomaxillaris (origin)
7. Sinus maxillaris (rostral extent)
8. Sinus concha ventralis
9. Sinus frontalis rostralis medialis
10. Sinus frontalis caudalis (rostral extent)
11. Canalis lacrimalis and Ductus nasolacrimalis
12. Canalis infraorbitalis (note blood vessels and nerve)

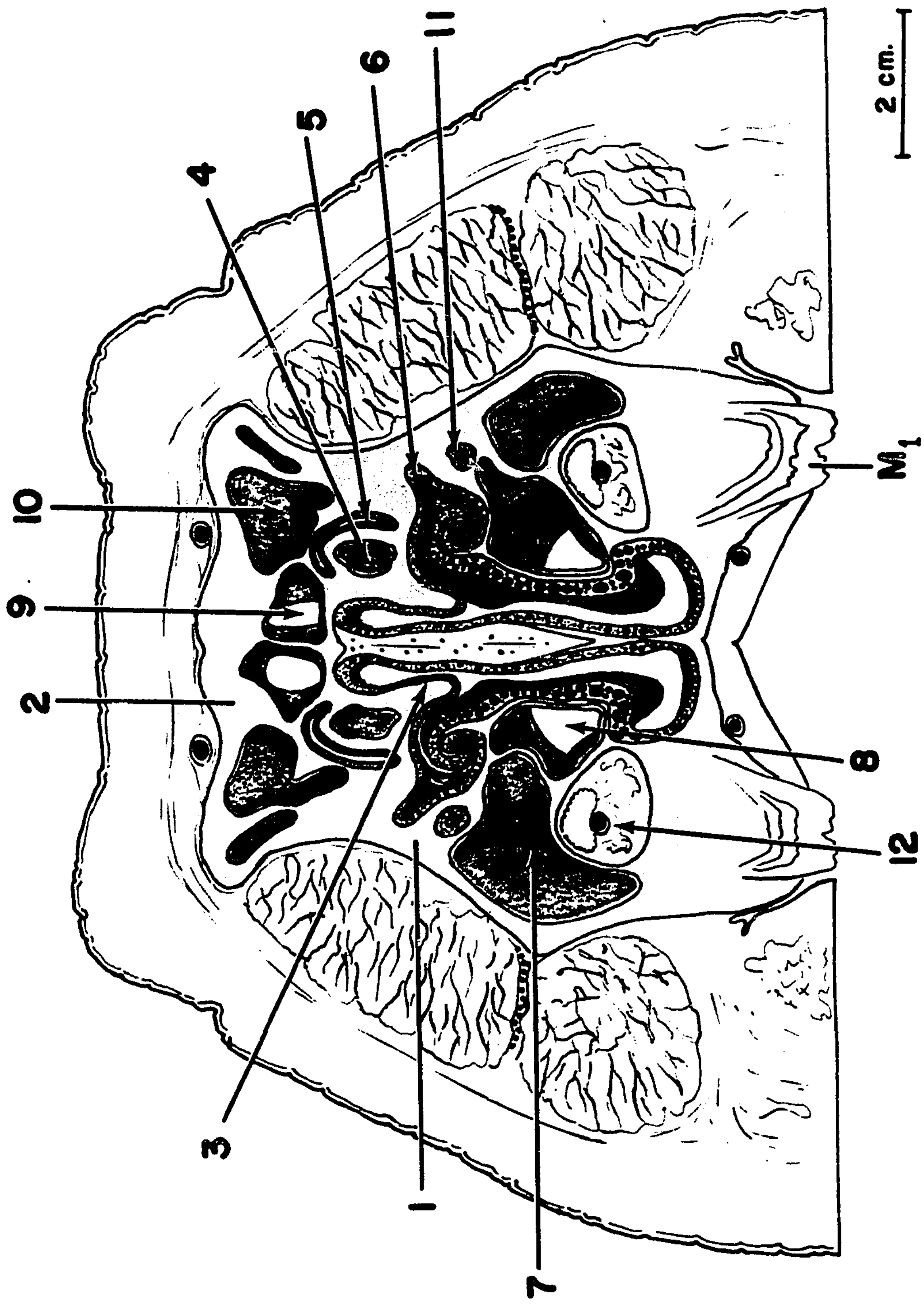

1
2
3
4
5
6
7
8
9
10
11
12
M1
2 cm.

Figure 32. Eight months old swine head, rostral view, transverse section, nasal cavity, through the rostral part of the first molar tooth (M_1). The mandible and its associated structures have been removed

2. Os lacrimale
6. Apertura nasomaxillaris (origin)
7. Sinus maxillaris
8. Sinus concha ventralis
9. Sinus frontalis rostralis medialis
10. Sinus frontalis caudalis
11. Canalis lacrimalis and Ductus nasolacrimalis
13. Lamina basalis
14. Meatus nasi dorsalis
15. Meatus nasi ventralis
16. Sinus lacrimalis

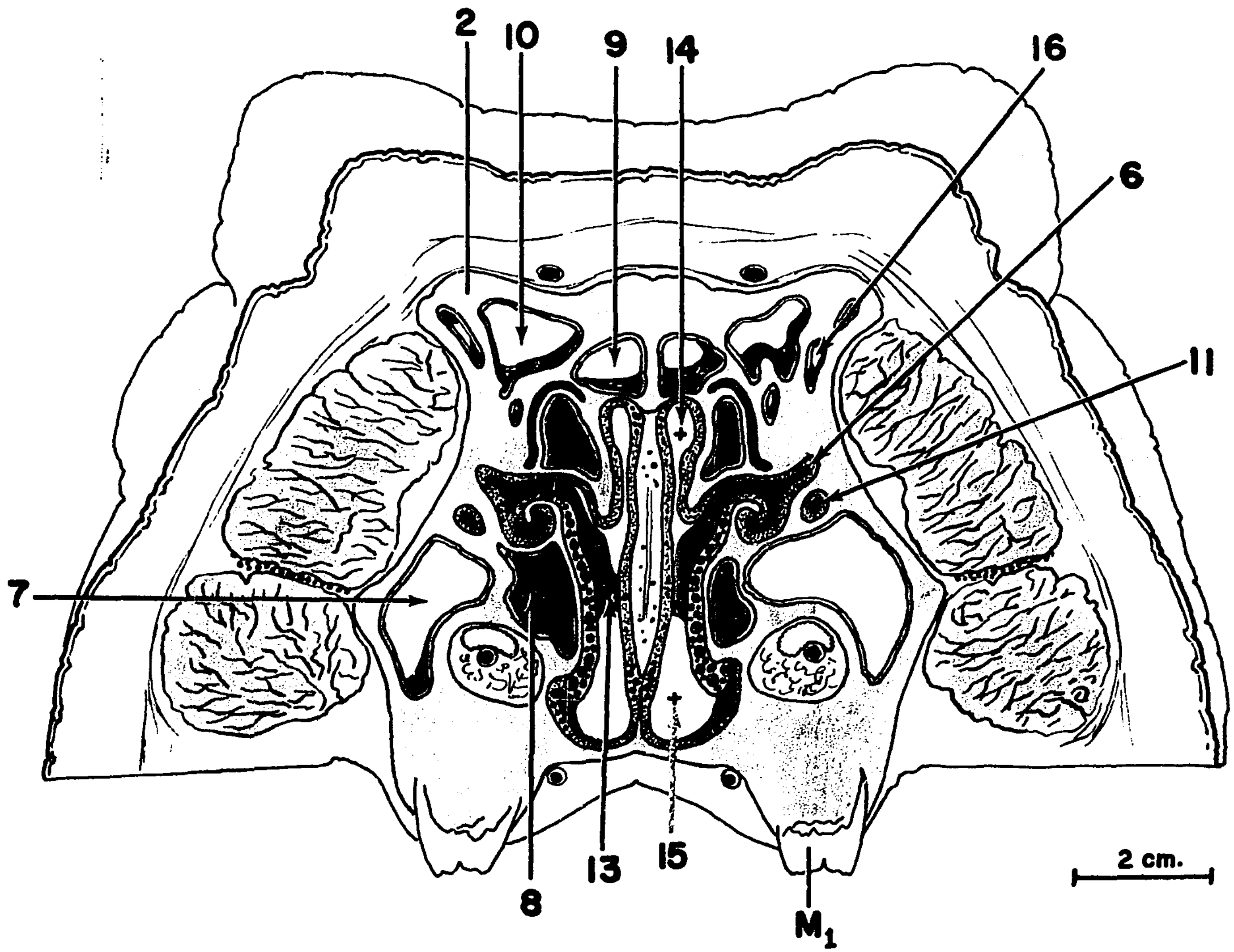

2
10
9
14
16
6
11
7
8
13
15
M1
2 cm.

Figure 33. Eight months old swine head, caudal view, transverse section, nasal cavity, through the caudal part of the first molar tooth (M_1). The mandible and its associated structures have been removed

1. Maxilla
2. Os lacrimale
3. Concha nasalis dorsalis (endoturbinate I)
4. Septum sinuum frontalium
6. Apertura nasomaxillaris
7. Sinus maxillaris
9. Sinus frontalis rostralis medialis
10. Sinus frontalis caudalis
11. Canalis lacrimalis and Ductus nasolacrimalis
12. Canalis infraorbitalis (note associated vessels and nerves)
13. Lamina basalis (horizontal lamina)
15. Choanae
16. Sinus lacrimalis
17. & 18. Sinus frontalis rostralis intermedius (separate compartments)

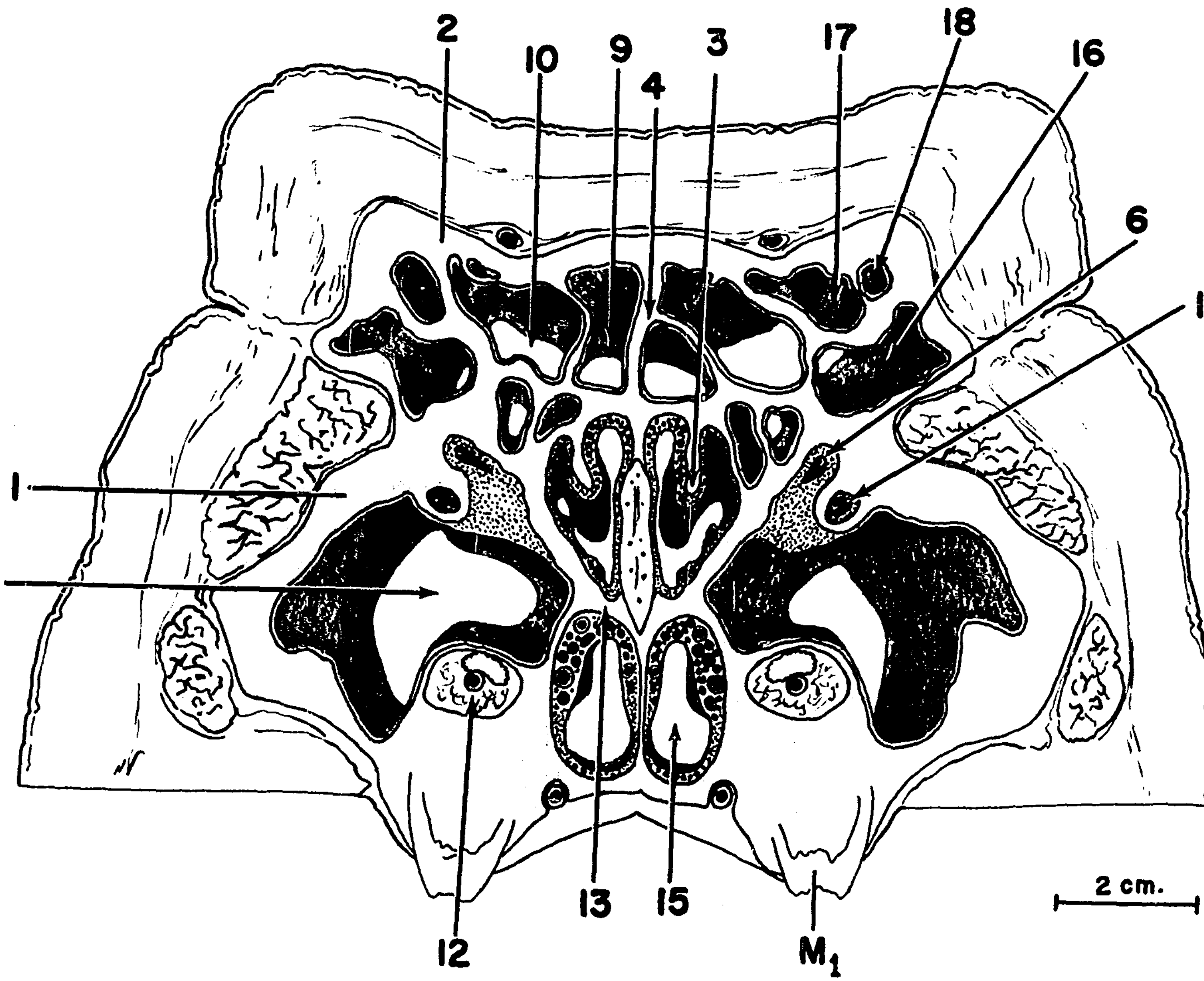
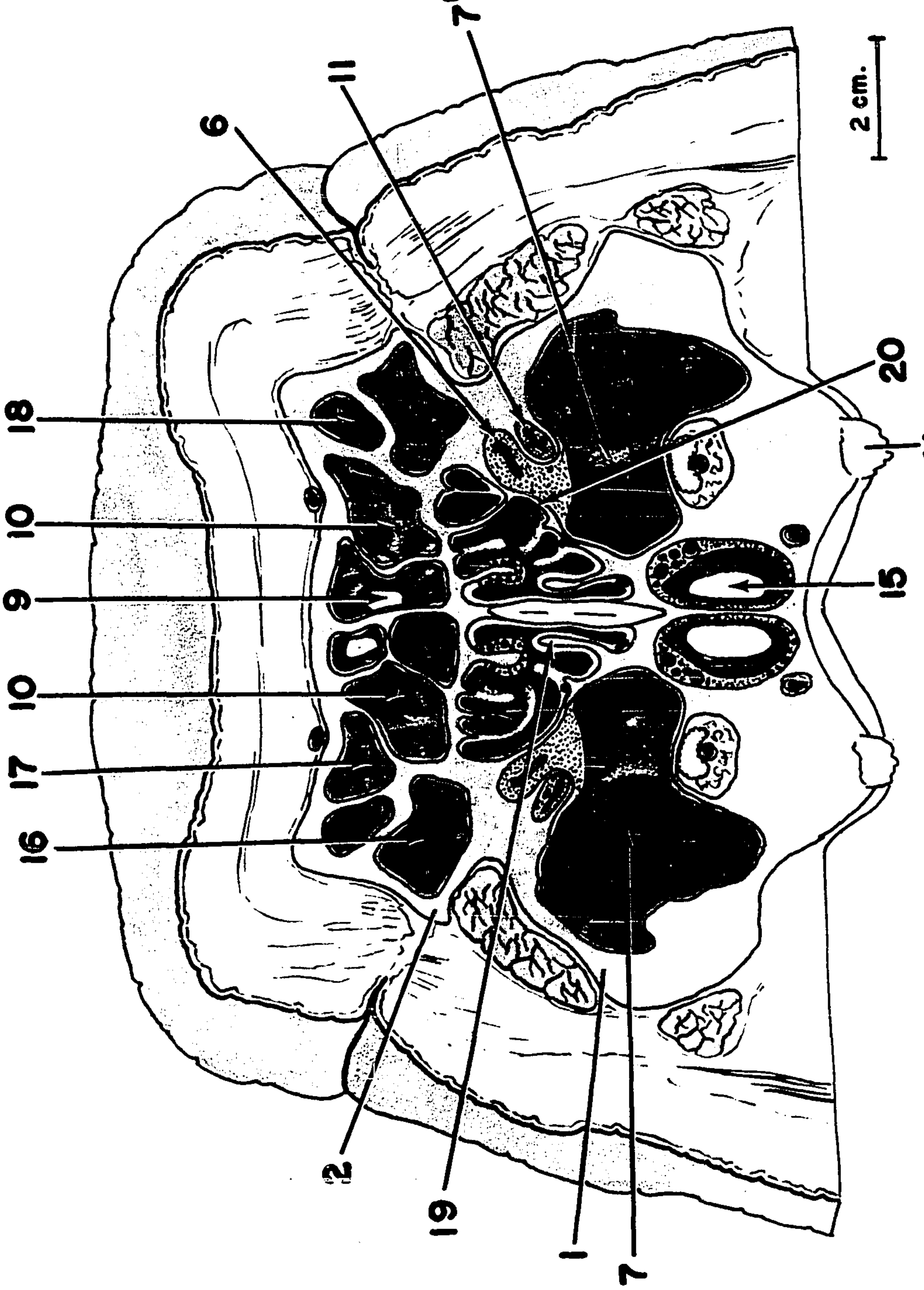

2
10
9
4
3
17
18
16
6
11
1
7
12
13
15
M$_1$
2 cm.

Figure 34. Eight months old swine head, rostral view, transverse section, nasal cavity, through the caudal part of the first molar tooth (M_1). The mandible and its associated structures have been removed

1. Maxilla
2. Os lacrimale
6. Apertura nasomaxillaris (note compressed, thick mucos membrane)
7. Sinus maxillaris (note medial and lateral compartments)
7'. Septum extending dorsally from the floor of the maxillary sinus
9. Sinus frontalis rostralis medialis
10. Sinus frontalis caudalis (right and left)
11. Canalis lacrimalis and Ductus nasolacrimalis
15. Choanae
16. Sinus lacrimalis
17. & 18. Sinus frontalis rostralis intermedius (separate compartments)
19. Concha nasalis mediae (endoturbinate II0
20. Lamina orbitalis (note it enters into formation of nasomaxillary aperture)



18
10
9
10
17
16
2
19
1
7
6
11
7'
20
M1
15
2 cm.