AN INQUIRY INTO THE ANATOMY AND PATHOLOGY OF THE MAXILLARY SINUS.

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Methods of Investigation.

Examination of Dried Skulls.

By cutting sections, or examining those already cut.

By observation of the interior of antra through holes and imperfections of the walls, aided by an electric light sufficiently small to be introduced into the nasal passages.

Of the sections forty were cut on purpose, principally transversely, about half an inch above the level of the floor of the nose. One half of each section shows the floor of both antra and the floor of the nose, the other half showing, of course, the upper parts corresponding. All of these forty, with the exception of three, were adult—one was that of a child about $5\frac{1}{2}$ years of age.

In addition to these human skulls I was enabled, by the kindness of Professor Keith, to examine a series of sections of skulls of anthropoid apes.

These were further supplemented by the number of skulls and specimens, human and comparative, already dissected for museum purposes.

The examination by means of a small electric light through holes in the walls of the antra added an almost endless series of skulls for examination, and these of varying races and different degrees of civilisation.

Transillumination from the mouth showed little, owing to the lower part of the cavity being masked by the thickened walls, where the roots of the molar teeth were embedded in them.

I have also obtained a certain number of X-ray photographs of living antra, and these give very clear pictures showing the size of the cavity and the presence or absence of anything in it.

Section I.

Development of the Maxillary Sinus.

The development of the sinus is intimately connected with that of the cheek teeth. In it the temporary molars are formed and, later on, the permanent bicuspids and molars; and just as the alveolar process of the

maxilla comes into existence for the express purpose of supporting the teeth, and is removed by absorption after their loss, so this cavity appears to come into existence in order to contain the bony crypts of the developing cheek teeth, and to enlarge as the series increases in number, and finally to be slowly filled up from below after their loss.

During the formation and eruption of the milk molars the sinus is comparatively small, only large enough, in fact, to contain the crypts of the developing teeth. The posterior portion where the permanent molars will eventually be formed does not exist. Fig. 1 shows the condition in a child of about 5½ years of age, in which the posterior limit of the maxilla

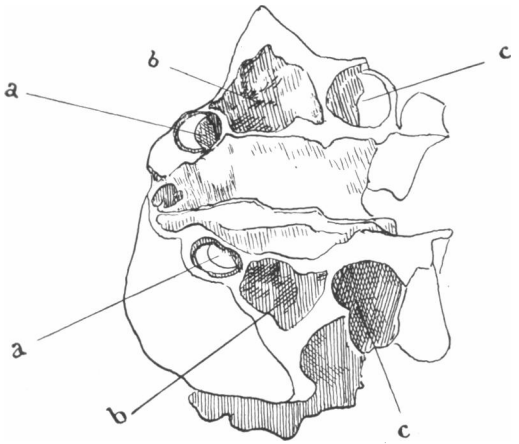

FIG. 1.—Section cut through both antra ¼ in. above the level of nasal floor, in a child of 5½ years.

is situated immediately behind the posterior margin of the crypt containing the second permanent molar germ.

I do not believe the canine is ever in any nearer relation to the cavity than its anterior boundary. In the anthropoid apes the posterior bony wall of the long socket of the canine is always in front of the sinus. The bicuspids occupy crypts in the sinus immediately over and between the temporary molar roots. Before discussing the relations of individual teeth to the maxillary sinus I propose to examine the relationship which is common to them all, from the first premolar to the third molar in the second dentition and the milk molars in the first.

The relations of the temporary dentition to the antrum are shown in the accompanying drawing (fig. 1), which shows a section cut transversely through both antra, about a quarter of an inch above the level of the floor of the nose, in a child aged about 5½ years. It shows the sinus at this

stage roughly divided into three compartments. Of these the anterior (*a.a.*) is occupied by a crypt which the section has laid open, containing the partly formed germ of a bicuspid tooth. This crypt occupies a very small portion of the cavity of the sinus, but it is noteworthy that it is a portion frequently separated from the rest of the cavity by a septum (see fig. 6, *a.*).

The middle compartment (*b.b.*) is comparatively deep, and corresponds to the area occupied by the first molar; but as that tooth is only partly erupted, the deepest portion of the antral floor in this situation is still well above the level of the floor of the nasal passage. The posterior compartment (*c.c.*), consisting of a bony crypt (laid open by the saw), contains the calcified portions of the second molar (removed), and the germ of the third molar remains in the upper part of the cavity over the second molar crypt, and is therefore in the other half of the section which is not shown. The nasal duct is very wide.

The teeth germs are formed in bony crypts which, during the early stages of development, are in a sense *in* the antrum. The thin layer of paper bone which forms the roof of the crypt causes a dome-like projection on the floor of the sinus (*cf.* fig. 20 of infant gorilla). As the tooth develops its roots and erupts, the part of the antral floor which is crypt-roof follows the tooth and, becoming slowly concave instead of convex (upwards), descends between the palatine and buccal roots, so that these roots are embedded in the lowest part of the inner and outer walls of the sinus respectively, with a bony basin between them, which forms the deepest part of the floor of the antrum.

The relationship of the individual teeth to the cavity in man must be considered in connexion with the attitude of the tooth germs during eruption.

This attitude is not, as generally believed, that of a succession of germs, formed and descending one behind the other in order. The molar series descend into place more after the manner of the spokes of a wheel, so that when the first molar is first in position, and functional, the crown of the second molar faces backwards as well as downwards, and its roots, if they existed, would lie obliquely over those of the first molar, while the crown of the third molar looks directly backwards, and lies just above the crypt of the second molar.

When the first bicuspid is fully erupted, its root lies normally beneath, or slightly in front of, the anterior portion of the antral floor. This floor is not flat, but more or less the shape of the bottom of a boat, deepest in the middle and rising at the front, back, and sides, and frequently interrupted by bony septa which vary greatly in height and thickness.

These septa (which will be discussed in detail in Section II.) frequently divide the floor of the sinus into three basins, a small anterior one over the

premolar region, a large median one descending between the roots of the first and second molars, and a small posterior one corresponding to the third molar region, and extending backwards and upwards slightly beyond the third molar roots.

The irregular development (irregular as to period as well as shape, size, and position) of the third molar in civilised man results in an irregular relationship of its roots to the antral floor. The apices of the roots of this tooth frequently occupy little bony dome-shaped elevations of the antral floor, sometimes causing small perforations which are, in health, probably covered in by mucous membrane. When the third molar erupts early, and is fully and normally formed, as is generally the case in the uncivilised races of mankind, its roots have much the same relationship to the cavity as those of the other molars, save that they are closer together, and the intervening basin is consequently narrower.

These three sections of the floor of the sinus, which are often marked off by ridges, rising sometimes to distinct septa, correspond to three defined periods of tooth activity, which are separated from each other by intervals of time.

The anterior portion corresponds to the position of the eruption of the milk molars (between 8 months and 2 years), and is subsequently the site of premolar eruption.

The middle portion corresponds to the eruption of the first and second permanent molars (from 5 to 10 years).

The posterior portion corresponds to the eruption of the third molars (16 to 30 years, roughly).

The septum shutting off the third molar region, which is more frequent and more developed than other septa, represents a more considerable interval of time.

Section II.

The Normal Anatomy of the Maxillary Sinus.

Fig. 2 shows the normal condition and relations of the sinus, viewed antero-posteriorly. The lower half is, as has been said, much the shape of a short tubby boat. The roots of the molar teeth are shown, the palatine root embedded in the inner bony wall and the buccal in the outer. The deep basin between these roots is seen to descend a good way (quite half an inch) below the level of the floor of the meatus of the nose. The thickness of the walls of this deeper portion is well seen.

Fig. 3 shows the shape viewed from above to be roughly triangular, the nasal wall being the base of the triangle. The apex is seen to slightly penetrate the root of the zygomatic process. Fig. 3 is that of a young

person whose third molars are in process of eruption. At the back of the right antrum a white patch is shown, which indicates a lump on the floor of the cavity, caused by the upper surface of the crypt of the third molar.

Figs. 4 and 5 show the position of the two most frequent ridges or septa which mark off the premolar region in front and the third molar region behind. It will be seen that they do not run straight across the cavity, but separate obliquely as they approach the outer wall, where they are much wider apart.

The deepest part of the floor of the sinus in normal cases, where no

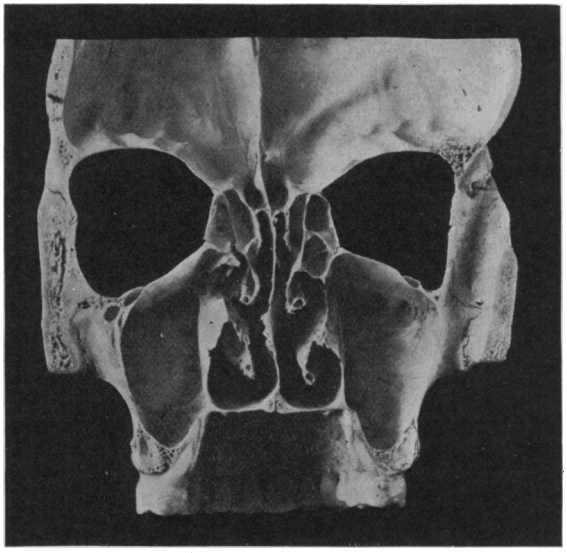

FIG. 2.—Shows normal condition of maxillary sinus.

teeth have been lost, descends about half an inch below the level of the floor of the inferior meatus of the nose (see fig. 2).

The septa, to which allusion has already been made, present many points of interest. The frequency of their occurrence surprised me greatly. Out of the first forty-five skulls I examined, thirty contained more or less well-developed septa, between a quarter and half an inch in height. They were much more frequent on the left side than the right (about in the proportion of 3 to 1). These skulls had no history, but were obviously European.

In twenty-six skulls of Negroes from the Congo, varying in age from five years to middle age, only two showed septa, and both these were on the left side.

The majority of these septa rise from the floor of the cavity and divide

it imperfectly into compartments, something after the manner of the divisions of an old-fashioned third-class railway carriage, only not straight across but radiating outwards.

These common septa always arise *between* the areas of two adjacent teeth, never opposite the middle of a tooth. They are very thin and fragile at the upper margin, and, looked at from the front, present a sickle-shaped appearance, reaching up the inner and outer walls a little way.

I must here describe two very remarkable extensions of these septa, shutting off, in one case the area of the third molar, and in the other the premolar region, from the rest of the cavity. Both skulls were normal in other respects; in fact, one was so perfect and typical, that it had been used

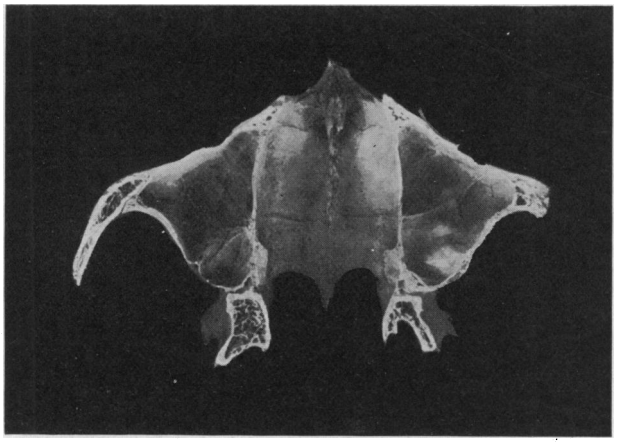

FIG. 3.—Shows lump on floor of antrum, caused by erupting wisdom tooth.

for teaching purposes by the late Mr Luther Holden. This skull is that of an adult Englishman (fig. 6). In the left antrum a septum arises from the floor of the cavity, just in front of the third molar region, and continuing upwards reaches and fuses with the roof of the sinus. It completely shuts off the posterior portion of the sinus, except for a tiny hole marked "a" in the drawing, about a quarter of an inch in height and an eighth of an inch in breadth. This hole is touching the nasal wall (indicated by dotted lines in the figure), and is rather nearer the roof than the floor of the cavity.

When I first looked through the hole made in the front of the antrum in order to expose it, I thought I was looking at the posterior wall of the antrum, then, finding that it was in front instead of behind the third molar, I found the tiny hole, which in life would have been still further hidden by mucous membrane. In an inflamed condition of the latter it might easily have escaped detection altogether, but any fluid washed through

the anterior division of the cavity might have found its way through, and in a recumbent position pus might have drained through into the unsuspected posterior division. An X-ray photograph would have cleared the matter up.

In the right antrum of the same skull a similar partition exists, as shown in the figure, differing only in one respect from that on the left side, namely, that the perforation is larger, and reaches up to the roof of the antrum. It is about a quarter of an inch in width, and two-thirds of an inch in height in the dried skull (fig. 6, *b*).

The second case was also in the skull of a well-formed adult English male. In this antrum the septum was almost complete, stretching from

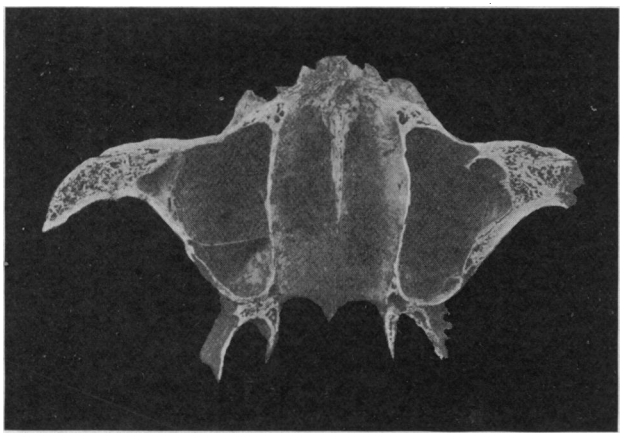

FIG. 4.—Shows septum in left antrum.

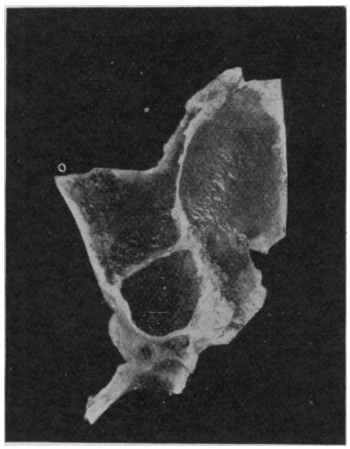

FIG. 5.—Shows septum in left antrum.

the zygomatic process on the outside to the nasal wall on the inside, and completely shutting off the premolar region, except for a very small perforation a little more than half-way up the line of juncture with the nasal wall. This septum would have been more readily suspected in life, because the sinus would have looked so suspiciously shallow.

Besides these simple bony septa which divide off areas of special teeth, there are other ridges and septa of different nature, and I think of a different origin, and suggesting a different anatomical explanation. They are not so regular in position and arrangement as the other class, and are not apparently in any particular relation to the teeth. In their edge-margins they contain minute canals for the transmission of vessels and nerves from one side of the cavity to the other. The branches of the infraorbitals are often conveyed in such conduits through the sinus.

The walls, floor, and roof of the sinus are frequently traversed by bony

canals for the transmission of vessels and nerves. The infraorbitals are contained in a canal which sometimes hangs down into the cavity of the sinus. This I have seen very markedly several times in the antra of the anthropoid apes. Sometimes these little canals are incompletely covered in by bone, and small tracts lie open, like patent drains open for inspection, covered during life by mucous membrane. These septa are arranged irrespective of tooth development; in fact, the one in the figure does not radiate outwards as the ordinary septa do.

In life these septa would be difficult to distinguish from ordinary forms, but if they were broken down during an operation they might give rise to

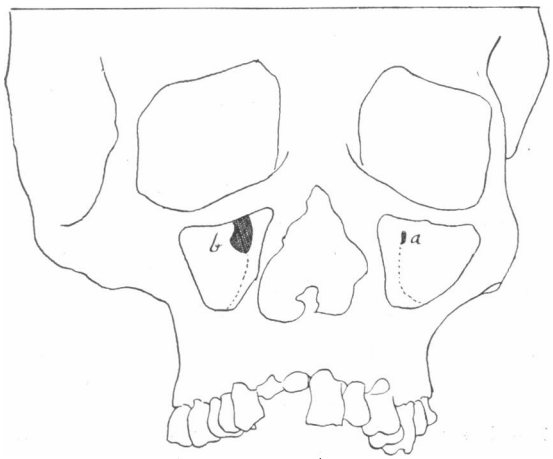

FIG. 6.—Holden skull. The anterior bony walls of the antra have been removed to show the septum.

tiresome complications, especially if the torn end of a small nerve became entangled in the crushed bone. Possibly this may explain the occasional nervous complications following the Caldwell-Luc operation.

Before leaving these septa I would suggest that the origin of the class first described is wholly dental, and that it is due to the persistence of the intervening partitions when the rest of the bony floor sinks down between the dental roots. The sinking of the portions of the floor between the roots makes the inner plate of the alveolus, and it is reasonable that where this is not required the sinking should be more or less incomplete. It is also reasonable to suppose that in cases where there is a general tendency to osteogenetic activity, ridges should become septa, and, as in the cases just described (see fig. 6), this exaggeration of the septa should be excessive. In one case where the septa were specially developed the internal pterygoid plate was nearly an inch in width.

If vessels and nerves traverse parts which are destined to become sinus, the bony sheaths enclosing them would naturally persist in any situation where these structures happen to be.

In one case only have I met with a transverse septum apparently dividing the sinus into an upper and lower chamber (see fig. 7). I say apparently, because several anatomists to whom I have shown the specimen agree that the upper chamber is not a part of the sinus at all, but an abnormal lateral extension of the ethmoidal cells, intervening between the sinus and the orbit. On the left side the division was complete, and extended to the outer wall. The upper chamber was about half an inch deep at its deepest point, the lower chamber, or antrum proper, attaining

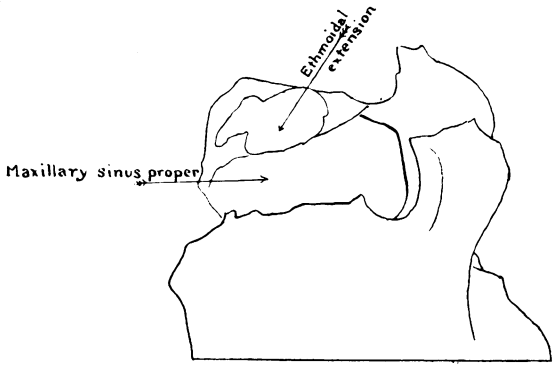

FIG. 7.—The specimen is tilted so that the nasal side of the left cells shows above the right orbital floor.

at its deepest a depth of about three-quarters of an inch. On the right side there was a similar extension reaching not nearly so far, and terminating about midway between the inner and outer walls. There was no communication between the true maxillary sinus and the ethmoidal extension.

SECTION III.

Pathological Phenomena.

I have endeavoured in previous sections to show that the development and normal anatomy of the maxillary sinus is largely governed and modified by the development, eruption, and arrangement of the cheek teeth, deciduous and permanent. These are formed in a sense in the sinus, which appears to exist for that purpose.

It is also true that when the dental series is lessened by removal, or modified by root disease, the corresponding area of the floor of the sinus is

consequently modified also. When teeth are lost the sinus floor corresponding to them is both thickened and raised, until eventually it may become level with, or even elevated above, the level of the nasal floor. I have examined the sinuses in a large number of aged and edentulous persons, and in every case the antral floor was so raised and thickened. In some cases the loss of the teeth had occurred on one side only, and in these cases the floor of the cavity was raised on that side alone. If one or two molar teeth were lost, the floor of the cavity would be raised in exactly the corresponding area. If a slight relic of the alveolar ridge remained in an edentulous case the floor would be to that extent thickened, but the cavity would not descend into the ridge as it had done between the roots of the standing teeth.

It would appear that the deep portion of the sinus is morphologically dental, just in the same way that the alveolus is morphologically dental, being formed to enclose and protect the area of tooth development and to support the organs during their functional activity, and finally to be removed by absorption when the loss of these organs had removed the reason of its existence.

Dental abscesses affect the sinus in a radically different manner according as they are acute or chronic.

In acute abscesses the bony floor of the cavity may be rapidly absorbed. In several cases there were large perforations of the sinus over the seat of the abscess. In one (an adult male from the Congo) there was a hole over the second upper molar as big as the entire crown of the tooth. In some cases smaller perforations occurred in connection with acute abscesses affecting one or two roots only. Sometimes, no doubt during life, such perforations would be prevented from penetrating the sinus itself by the mucous lining of the cavity being unbroken.

In chronic abscesses over the roots of the cheek teeth there was an abundant formation of bone thrown up between the abscess and the sinus, causing the floor of the latter to retreat from the neighbourhood of the root trouble, and thus protecting the cavity from perforation. There were many of these cases among the skulls examined, especially in uncivilised races, where dental treatment had not been attempted.

Fig. 8 shows a very extreme case. The abscess may be seen at the points (*a*), (*b*), (*c*), and (*d*). Where normally the section would have opened up a large sinus the saw has cut through dense bone. At (*e*) is a tiny cup-shaped depression, which is all that remains of the antral floor. In the upper fragment, which has not been figured, the remainder of the sinus is represented by a minute cavity, not more than half an inch in its total length and height, and about a quarter of an inch in breadth; in fact, the

deposit of new bone has almost entirely obliterated the sinus. The abscess has penetrated and ramified right through the alveolar process from the

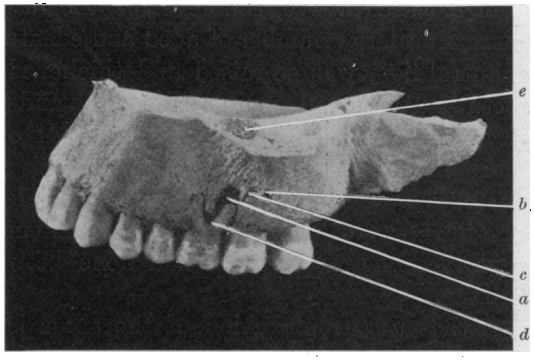

FIG. 8.—Shows raised and thickened floor of antrum resulting from a large chronic abscess on roots of first and second molar.

outer side (where it is shown in the photograph) to the palatal surface, where there are large openings.

The right antrum was quite normal.

These cases of long-standing chronic disease are not without surgical

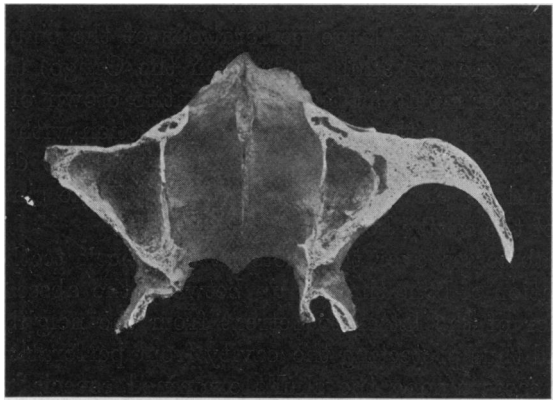

FIG. 9.—Shows reduction of capacity of right antrum resulting from chronic disease.

significance. If the extensive dental disease, accompanied by pain, sense of weight, etc., led to a diagnosis of antral abscess, transillumination would tend to confirm the suspicion, but any attempt to open the cavity would be attended with very perplexing results.

Fig. 9 shows a bony deposit filling the sinus from below upwards, consequent on long-standing abscess. In some cases the whole of the walls

of the sinus were much thickened by bony deposit. This thickening had no apparent connexion with the teeth.

In one or two cases I found small spicula of very hard white bone sticking out from the sinus walls into the cavity—starting from the front wall very near the situation of the infraorbital foramen; one was nearly half an inch long, and about the thickness of a very thick pin. I have no idea what these things are, or how they are formed. They look like ivory exostoses, and they apparently originate from the course of the infraorbital vessels and nerves.

Section IV.

An Examination of the Sinus in the Anthropomorphoid Apes.

This investigation would be incomplete without a comparison of the human sinuses with those of the animals whose skulls most nearly resemble

Fig. 10.—Chimpanzee, showing sinuses; "suprapalatine" marked *a*.

that of man. It has therefore seemed worth while to examine the conditions prevailing in the anthropoid apes.

As a general statement, it is somewhat difficult to mark off the boundaries of the maxillary sinus in the large apes, owing to the size of the patent openings by which all the air-cells of the face intercommunicate with each other, with the nasal passage, and sometimes with the nasal duct. In all of the anthropoids the passage through the sinus in all directions of large and small bony canals for the transmission of vessels and nerves is

a very common feature, that containing the infraorbitals very generally appearing as a pendant bony canal hanging from the roof of the sinus.

Anthropopithecus niger.—In chimpanzee the air-cells are very large. The figure 10, taken from an adult male, shows the large sphenoidal and frontal cells and their comparatively thin bony covering (for the opposite condition, see orang-outang, fig. 15). The maxillary sinus, which is very large, and extends backwards a considerable distance behind the third molar teeth, is produced, as far as its deeper part is concerned, to meet that of the opposite side in the middle line.

This accessory air-cell, which might be called a suprapalatine sinus, occupies a space intervening between the floor of the nasal passage and the roof of the palate. It is separated from the cavity of the opposite side

FIG. 11.

by a thin bony partition, and in fig. 10 is shown laid open by the saw at *a*. The bony partition is incomplete in front. The cell is about three-quarters of an inch high in front, just behind the incisor roots, and extends backwards, becoming gradually shallower, until it terminates about an inch behind the level of the roots of the last molar.

In the infant chimpanzee the partly calcified germ of the incisor occupies a situation corresponding to what in the adult is the anterior portion of the suprapalatine sinus.

In the other anthropoids, though the tooth germ occupies a similar position, the cavity is obliterated by bone after the eruption of the incisor, but in the chimpanzee it persists as the anterior portion of the suprapalatine sinus.

Fig. 11 shows a perpendicular section through the skull of an adult chimpanzee. The section has been cut well to one side through the right

orbit, laying open the antrum from the outside. A large, roughly triangular bony prominence (*a*) will be seen in the middle of the cavity, which is the antral wall of the nasal duct. A string has been passed through the duct. This specimen is shown in the open case in the Museum of the Royal College of Surgeons, England. This bulging nasal duct may be compared with the condition in gorilla (see fig. 12). It will be noted that the duct is inflated in the chimpanzee, but only its antral wall bulges into the sinus, whereas in gorilla the inflated nasal duct extends outwards to the bony wall of the cheek, the maxillary sinus proper being pushed back to the region above the third molar and behind it (*vide* gorilla, *infra*).

Gorilla (*G. savagii*).—Fig. 12 represents a perpendicular section through

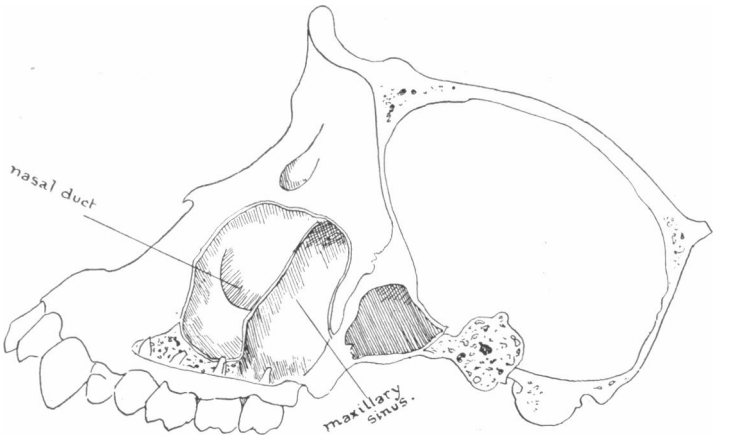

FIG. 12.

the left orbit of an adult male *Gorilla savagii*. It shows very well the enormous inflation of the nasal duct described by Professor Arthur Keith. The cavity looks like an anterior division of the sinus at first sight. It opens into the nasal passage by a large upper opening which is shown in the drawing commencing at the end of the ink line. A section through the middle line, also from an adult male gorilla, shows the frontal and sphenoidal sinuses much smaller in comparison than those of the chimpanzee. The walls are much thicker, and the enormous superciliary crest which affords attachment to the forward portion of the huge temporal muscle is very solid, at the expense of the frontal cavity. The nasal passage is, as is usual in the apes, very large. Above the incisor roots is the bony mass which takes the place of the suprapalatine sinus of chimpanzee.

Fig. 13 shows a perpendicular section cut through the middle of the left orbit in an infant gorilla. The maxillary sinus is shown encroached

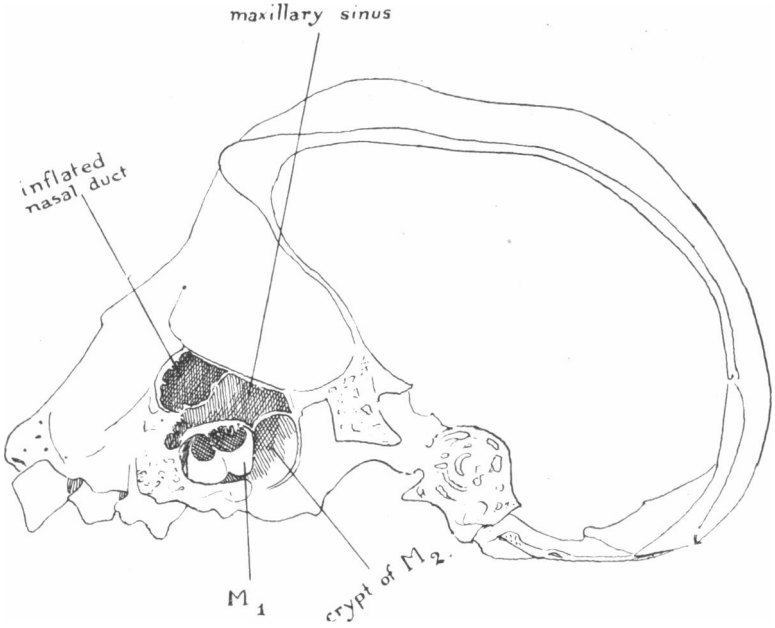

FIG. 13.

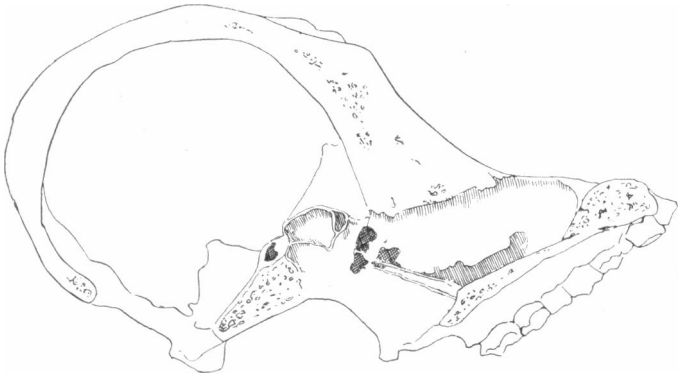

FIG. 14.

upon below by the crypt containing M_1 with the germ *in situ*, and behind and slightly above this crypt is that of M_2, from which the germ has dropped out. The deciduous molars and canine are seen in place. Above

and in front of the sinus proper is shown the inflated nasal duct laid open by the saw.

Orang-outang (*Simia satyrus*).—Fig. 14 shows a perpendicular median section of an adult orang. The comparative insignificance of the frontal and sphenoidal cells in this ape are well shown, their place, as well as that of the suprapalatine sinus, being occupied by bone. The nasal passage in *Simia satyrus* is comparatively not so large as in chimpanzee or gorilla, but the maxillary sinus is large, and extends backwards a good way. The dense character of the skull-cap in this ape is well shown.

The Maxillary Sinus in relation to Sound.

After examining and checking these observations it appeared useful to observe how far these animals, with such different air-cell capacity, differed in the character of their sound-producing power, and in this connexion I thought it might be interesting to obtain some evidence of the capacity of the sinus in a human being of great vocal power. The sound-producing power of the apes (except *Gorilla savagii*) could be studied at the Zoological Gardens. The living human sinuses could best be shown by radiography. I obtained some photographs, taken by Mr Archibald Reid, of human maxillary sinuses which, in addition to many that I possessed that had been taken from time to time for other purposes, formed a fairly representative series.

To observe the condition in a person of unusually powerful and trained vocal power I obtained a radiograph of the maxillary sinus of an eminent singer, which proved to be far beyond the normal capacity.

In the apes it is significant that the chimpanzees, whose air-cells are by far the most capacious in comparison with the size of their skulls, make infinitely more noise than any of the other large apes in captivity; whereas the orangs, in which (except the antra) the air-cells are very small, never do more than utter a low guttural grunt. The orangs were apparently as fond of Mr Pocock and caressed him as affectionately as the chimpanzees, but their greeting was an almost silent one, consisting mostly in gesture, whereas the chimpanzees no sooner perceived his approach than they filled the air with deafening screams of welcome.

This investigation appears to me to present points of interest to the operating surgeon, but I have refrained from commenting upon them as being outside the sphere of my personal studies and practice.