Resumen por el autor, Edgar Davidson Congdon,
Universidad Leland Stanford Junior.

La distribución y modo de orígen de los tabiques y paredes del seno esfenoidal.

En 212 senos esfenoideos, diez y siete tabiques y filas de espuelas están situadas total o parcialmente en la zona generalmente ocupada en un periodo anterior por la sincondrosis concoesfenoidal. Cuarenta y tres estaban situadas en la zona prebasiesfenoidea, treinta en la alarbasiesfenoidea, nueve en la alaralisfenoidea y sesenta y nueve en la alispresfenoidea o concoalisfenoidea. La anchura de estas zonas fué tomada de tal modo que se incluyó el territorio ocupado por todas las sincondrosis, menos las mas aberrantes. Solamente se encontraron algunos tabiques que no correspondían a ninguna de las zonas. Los tabiques situados entre los senos tienden a colocarse en los planos de las sincondrosis mencionadas, asi como las paredes lateral y posterior de los senos. Por la relación entre el tiempo transcurrido entre el desarrollo del seno y la osificación de las sincondrosis esfenoideas es probable que la mayor parte de los tabiques resulten del encuentro del seno en vías de crecimiento con partes de las sincondrosis que no se han osificado todavía. No se sabe si persiste una condensación del hueso esponjoso después de las sinostosis de las sincondrosis intraesfenoideas ayudando de este modo en la formación de los tabiques. Cortes transversos de sus planos de fusion en treinta y un casos de esfenoides fetales no demostraron la presencia de tal condensación. El autor no pudo examinar secciones de cráneos de niños. La posición primitiva de la sincondrosis esfenoccipital puede marcarse por una condensación en el cráneo adulto. El carácter de los tabiques esfenoideos no favorece el supuesto de que estas estructuras se retienen después del periodo de crecimiento como soportes de las paredes del seno. Parecen ser productos del desarrollo imperfecto del seno los cuales no conservan función alguna importante, bien sea mecánica o de otra clase.

Translation by José F. Nonidez
Carnegie Institution of Washington

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THE DISTRIBUTION AND MODE OF ORIGIN OF SEPTA AND WALLS OF THE SPHENOID SINUS

E. D. CONGDON

Anatomical Department of Leland Stanford Junior University, California

THREE PLATES (ELEVEN FIGURES)

The sphenoid sinus has been described as the most variable in form of any bilateral cavity or organ of the human body. Its proportions have taken on a practical interest since its drainage has become a practice of surgery. The bony plates and rows of spurs which project from its walls also affect drainage by increasing the variety of its relief. In 212 sinuses, 122 septa and rows of spurs were found. In spite of the variety in form and position of these projections, their description and explanation have received scant attention. Doubtless if they had been visible in skulls uncut or with cranial cavity exposed, such as make up a large part of most collections, they would have long ago been given the same careful scrutiny which nearly every detail of the skull has received.

Two writers have given attention to the septa. Toldt in 1883 discussed the sagittal plates which project from the lateral or posterior sinus wall in connection with his description of the development of the sphenoid. He believes that they coincide with the plane at which the alisphenoid ossification centers unite with the body of the bone and that they have arisen because for some reason the tissue here was able to resist absorption during the growth of the sinus.

Cope has recently ('17) applied the same principle to the explanation of the partial septa in general making use of a number of the numerous fusion planes which occur in the sphenoid. He also believes that the various forms assumed by the sinus are to be explained by the halting of its walls during development at various of the fusion planes. His interesting effort to find a common explanation for the amazing variety of sinus forms is based upon the examination of nearly three hundred sinuses. Because of the largely descriptive character of the paper, it suggests the need of testing the frequency of the coincidence of the septa and walls with the synchondrous planes statistically.

The present study is devoted in large part to a statistical examination of this kind. Attention is also given to the nature of the resistance which may have been offered to the growing sinus at the synchondrosis planes. In conclusion, another explanation of the presence of the septa is considered, based upon their possible function as a support to the walls of the sphenoid.

Complete sinuses were studied with the aid of large windows cut in their superior walls or in the intersinus septum.[1]

Pantagraph drawings were made of the superior surface of forty-eight sphenoids and the septa plotted upon them. These were later discarded for written descriptions of the septa in order to better indicate their position in three dimensions and their relation to the markings of the early fusion planes. A graphic method was retained for the records of the intersinus septum. Its course midway of floor and roof was marked on a stenciled outline of the superior surface of the sphenoid.

All markings which could be found in the adult bone for recognizing the former position of the synchondroses were made use of in deciding whether the septa coincided with them. It is possible to find the position of some synchondroses very exactly, while others vary in position rather widely with reference to the adult landmarks of the sphenoid. The writings of Toldt ('83), Sappey ('67), Cleland ('62), Sternberg ('90), and von Spee ('76) were directly consulted in determining the position and time of fusion of synchondroses. References were obtained from the studies of Rambaud and Renault ('64), Hannover ('81), and Virchow ('59). Sections of thirteen late foetal and early infantile heads were utilized, as well as four somewhat older skulls.

[1] This term has been adopted in the absence of any satisfactory name for the partition between the two sinuses. The commonly used expression, 'median septum,' is not correct, because it is more frequently lateral than median.

The numerical expressions obtained from the tabulation of the septa are ratios expressing the frequency of occurrence of septa in the regions of the synchondroses planes. Because synchondroses would have an opportunity to form septa only if a sinus extended into their territory, a condition by no means always fulfilled, the frequency of septa at each synchondrosis plane was expressed in relation to the number of sinuses that included a third or more of their plane, and not with reference to the total number of sinuses examined.

SEPTA IN THE REGION OF THE LATERAL FUSION PLANES

Three synchondroses meet below the posterior root of the lesser sphenoid wing at about the time of birth. One of these extending anteriorly from their line of union is between the alisphenoid and the presphenoid centers. The presphenoid may give way anteriorly to the concha to form an alisphenoid-conchal synchondrosis. The two posterior synchondroses lie on either side of the wedge-shaped center of the alar process, and may be termed the alar-alisphenoid and alar-basisphenoid, respectively. In the region at or near these plane approximately three-fifths of all the septa of the sinuses were found.

Near the posterior root of the lesser wing is situated the passageway extending from the upper to the lower surface of the bone, which Sternberg has termed the lateral craniopharyngeal canal. It either disappears or is reduced to a very small caliber in the adult. As Sternberg pointed out, part or all of it may be retained in the free edges of anteriorly facing septa. Since the canal is the remnant of the gap between the ossification centers at the confluence of the three synchondroses, it was found helpful in determining their previous position in the adult bone.

The canal marks the center of an accumulation of compact bone as long as the synchondroses remain, because their cartilages are each covered on both surfaces by a thin layer of compact bone (fig. 8). This may be likened for a portion of the developmental period to a hollow column with flutings corresponding to the compact layers.

The remnants of the lateral craniopharyngeal canal lying in the free edges of the anteriorly facing septa have a very characteristic course, which is often traced by the margin of the septum even where no vestige of the canal is present. It is convex forward with the upper end terminating near the posterior root of the lesser wing. It is inclined laterally in its lower part and bends more markedly in this direction as it nears the roof. The posteriorly facing septa forming the anterior group also may show canal remnants, but not so frequently.

One hundred and twenty-eight laterally placed septa were found to converge toward the region of the canal and lateral column. Some came from the anterior and anterolateral and others from the posterior and posterolateral walls. Between the two groups there is a lateral region with but few septa. A not inconsiderable number of the septa are mere ridges or rows of spurs, but the majority are plates of considerable width.

Among 162 sinuses containing a third or more of the fusion planes of the two posterior synchondroses, fifty-two anteriorly facing septa were found. This gives a frequency of thirty-two and a fraction per cent. Because these septa lie in the region not only of the lateral column, but of the alar-alisphenoid and alar-basisphenoid synchondroses, the question is raised of the relative importance of the column and of the planes as possible factors in producing the septa. Cope ascribed the septa to the alar-basisphenoid synchondrosis. Toldt expressed the belief that they arose at the alar-alisphenoid plane. Another possibility is that the lateral column may have given rise to them after the smaller accumulations of compact bone of the synchondroses has disappeared. In that case we must suppose that the two recesses formed as the sinus advanced on either side of it did not fuse after having extended past it, but still remained separated by a thin partition. This reaction of the osteogenic layer of one sinus wall toward the periosteum of an adjacent sinus wall is the rule in development, as is shown by the numerous thin partitions separating various sinuses of the skull.

The position of the anteriorly facing septa relative to the planes of the two synchondroses was tabulated to find whether they fell in the zones usually occupied by these planes or whether they indicated by extending out from the lateral column in some other direction that it alone could be responsible for their formation. In the adult the alar-basisphenoid plane is marked on the lower surface of the bone by a shallow, often poorly defined groove which is the remnant of a deep cleft in the new-born sphenoid. The position of the anterior end of the plane is indicated by the lateral column. A zone about 6 mm. wide lying partly under the carotid groove and partly internal to it was taken as the territory of the synchondroses in the moist preparations. The markings of the cleaned bones often allowed a closer delimination. Thirty of the fifty-two septa and rows of spurs pointing anteriorly toward the canal were classified in this plane (fig. 10, b). In many cleaned sphenoids it could be shown that the groove on the under surface of the bone extended up for a few millimeters into the septa and spurs. Frequently the septa, while keeping to the plane antero-inferiorly, were deflected from it posteriorly and above. This is to be expected, because the posterosuperior portion of the synchondrosis disappears long before it could exercise any influence upon septum formation.

The former position of the posterior end of the alar-alisphenoid synchondrosis is defined in the adult by the opening of the canal of the pterygoid nerve below and the lateral border of the lingula above (fig. 3, a). Anteriorly it is marked by the lateral column. Nine of the fifty-two anteriorly facing septa lay in its plane (fig. 3, b). In one sinus there were septa in both the alar-alisphenoid and the alar-basisphenoid planes.

Thirteen of the posterior group of lateral septa which do not fall within either of the synchondrosis planes can be better interpreted after the distribution of the second group of lateral septa is considered.

The anterior group occurred with the surprising frequency of forty and a fraction per cent in 171 sinuses. The ali-presphenoid synchondrosis extends through this region, except where it is occasionally replaced anteriorly by the concha-alisphenoid union. It extends from the lateral craniopharyngeal canal and its lateral column anteriorly and laterally to reach the inferior orbital fissure on its anterior border and close to its medial end. All of the septa of this group fall within the region of the synchondrosis if we make the reasonable assumption that its zone of distribution varies from the anterior border of the fissure through a band about 8 mm. wide (figs. 2, c, and 11, a).

All but twenty-two of the 130 lateral septa are situated in synchondrosis zones, and were very probably derived from these structures. Nine septa of the twenty-two point toward the lateral column from the sinus wall a little posterior to the inferior orbital fissure. While they lie behind the zone marked out for the ali-presphenoid, it may be that especially aberrant synchondroses gave rise to them because they are in an adjacent region and few in number. The explanation seems improbable for those farthest behind the fissure. In two instances they could not possibly have arisen in this way, because ali-presphenoid septa were also present (figs. 1 and 6). It is probable since the nine septa faced the canal region that some of them were formed from the lateral column without aid of other portions of the synchondroses in the manner already described. The thirteen posterior septa of the lateral group which did not lie in either synchondrosis zone were situated near to one of them. It is probable that they also arose either from aberrant synchondroses or from the lateral column alone.

Not all septa in the lateral zones can have begun their development at the lateral columns. Sometimes an ali-presphenoid and an anteriorly facing septum occur in the same sinus. Then the sinus must have extended laterally past the column either in front or behind it. Most commonly it passed anteriorly to it. It is also not rare to find a single septum traversing the alar-basisphenoid and the posterior part of the ali-presphenoid zones. The sinus in these instances evidently broke through the anterior synchondrosis plain far forward.

Not only are there septa occupying territory in two zones, but several were found with a triradiate arrangement (figs. 2, 8 and 1). Those of this type in which the bone had been denuded of mucoperiosteum showed the remnant of a lateral craniopharyngeal canal at the line of confluence of the three plates. In all of the triradiate septa two and usually three of the plates lay in different zones. These structures are the most striking illustrations of the apparent coincidence of the septa and zones.

The septa vary from broad plates to mere ridges or rows of spurs. The ridges frequently are found in small sinuses which had passed but a little way beyond the region of the lateral column. These are usually thick and rounded at the edge. Toldt believes that the broad lateral septa first appear as ridges and that when the posterior wall of the sinus retreats they elongate backward correspondingly. He points out that all stages in this process are to be found in adult sphenoids. Toldt's observations can be easily confirmed. The same series can be found for the posteriorly facing septa also. It has been seen, however, that not all of the lateral septa begin at the region of the lateral craniopharyngeal canal. The process of septum growth is apparently the same, no matter where in a synchondrosis plane the ridge first projects into the sinus.

Another type of ridge is found which probably represents the last remnant of a septum, the rest of which has been resorbed. It has a thin edge and may lie on a wall or floor far removed from the region of the canal. The intermediate stages between these and the original complete septa are present.

During childhood and youth the sinuses are enlarging while the synchondroses are disappearing. It is necessary to know the relative time of the two processes to find how the synchondroses could affect septum formation. The cleft in the alar-basisphenoid was found to have become shallow in the skull of the adolescent period, but to still project far up into the bone in a sphenoid of about the seventh year. From Sternberg's observations, based upon twenty skulls of ages from six to eight years and from a small amount of other data, the sinus is probably usually in contact with the canal before the tenth year and has progressed far enough to expose part of the cleft marking the alar-basisphenoid union by the twelfth year. The conditions are evidently present for a frequent encounter between the sinus and the upwardly projecting compact bone of the cleft.

The alar-alisphenoid synchondrosis is more remote and would be reached later by a growing sinus. It is already obliterated, according to Toldt, by the sixth year. In agreement with the supposition that synchondroses give rise to septa, few projections were found in this zone. The ali-presphenoid synchondrosis is also closed by six, though many septa mark its position. The great frequency of septa at this plane is a cause for surprise, because the sinus is not supposed ordinarily to reach the region till several years later.

SEPTA OF THE CONCHA-PRESPHENOID PLANE

The most anterior of three more or less frontally placed planes of fusion encountered by the expanding sinus lies at the junction of the concha and the presphenoid ossification centers. It can usually be distinguished on the inferior surface of the body of the adult sphenoid if the alae of the vomer be removed, though it is not always to be seen even then. The conchae appear as two triangular plates applied to either side of the sphenoidal crest and rostrum with apices lying well posteriorly on the lower surface of the bone. Anteriorly the fusion line is not usually visible on the adult bone, but it is said by Toldt ('83), Sappey ('69), and Cleland ('62) to come out at the level of the sinus aperture. The concha shows a wide range of variation which affects the position of the plane of fusion with the presphenoid. The most useful feature of the plane for determining its former situation in the adult bone aside from its location is that it faces anteriorly laterally, and inferiorly unlike the pre-basisphenoid plane behind it.

In seventeen sinuses septa and spurs were found in its territory (fig. 8). They arose from lateral wall, floor, or intersinus septum and extend in the direction characteristic of this plane. Toldt describes in detail the gradual absorption by the growing sinus of the posterior compact wall of the concha and its entrance into the presphenoid. In examining the position of the intersinus septum, it will be later seen that there is reason for believing that it sometimes follows this plane for a greater or lesser distance. Occurrences of this kind here are as infrequent as is the formation of partial septa. It would be interesting to know why septa are so rare here when they are so very frequent at the ali-presphenoid plane, though it comes in contact with the sinus at a later period.

SEPTA OF THE PRE-BASISPHENOID PLANE

The plane of contact between the presphenoid and basisphenoid usually faces frontally, but its situation in nine late foetal and early infantile sphenoids was found to vary through a rather wide range in an anteroposterior direction. A zone was accordingly marked off as its territory which included the region under the tuberculum sellae and below the anterior third of the hypophyseal fossa.

Forty-three septa and rows of spurs were found in 143 sinuses, giving a frequency of thirty and a fraction per cent. They were found most commonly on the roof near the midline and on the medial septum. Their grouping in the medial part of the plane is probably explained by the well-known fact that there is a much later retention of the synchondrosis here than in its lateral part. Cope finds the septa to be present in 20 per cent. The agreement is as close as is to be expected, in consideration of the probable differences in the methods of deliminating the zone of the synchondrosis used in connection with the two computations.

The disappearance of the synchondrosis may not be complete till the thirteenth year, according to Kölliker ('79) and from Toldt's observations ('83) not until the end of the growing period. From the evidence already given upon the rate of growth of the sinus in childhood, it is probable that it would frequently reach the basisphenoid in time to come into contact with remnants of the synchondrosis.

A GROUP OF SEPTA APPARENTLY NOT ORIGINATING FROM A SYNCHONDROSIS

Eleven septa were found among those not lying in any synchondrosis plane which were of a common type (fig. 7). They extended anteriorly from the posterior wall of basisphenoid sinuses parallel to the plane of the hypophyseal fossa. Sometimes the wall had receded farther above than below them during the backward extension of the sinus so that they came off from the edge of a step. An explanation for their appearance is suggested in several late foetal and early infantile sphenoids by a bony plate lying in the plane of the septa at the center of the basisphenoid. It is connected with the fact that osseous tubes occur which carry blood-vessels into the bone and serve as the support for a vascular plexus at the center of the sphenoid not unlike that which is associated with the basivertebral veins in the centers of the vertebrae. It is probable that a sufficient portion of the layer occasionally remains in youth to give rise to the septa. In two foetal sphenoids the spongy bone was much more compact below the plate than above it. It may be that a condition of this kind retards the progress of the posterior wall below the plate relative to the part above it, thus producing the step.

DISTRIBUTION OF THE INTERSINUS SEPTA

The septum intervening between the pair of sphenoid sinuses is frequently described as median, but it was found to keep to a median zone approximately 6 mm. broad in only twenty-five septa out of eighty-six. Sixty-nine per cent extended outside its boundaries and, as will be seen, a larger number than kept to the median line showed a deflection far to the side.

The statement is occasionally found that deflection of a septum is more frequent toward one side than the other. Of 102 septa, some of which were slightly defective, no justification for this claim was found. Thirty-eight were turned to the right and forty-one to the left. Twenty were in an intermediate position.

There is a noticeable tendency for intersinus septa to take the course of certain fusion planes. Seven septa showed the characteristics of the concha-presphenoid plain not only in being deflected to the lateral side of the sphenoid body anterior to the basisphenoid, but also by facing laterally and inferiorly (fig. 5). Eight other septa placed somewhat further back probably in some instances also were coincident with this plane.

A large number of the septa, twenty-seven in all, ended in the region of the lateral column. Sixteen ended farther back on the wall in the vicinity of the lateral synchondroses.

Cope believes that many deflected intersinus septa result from the fact that one sinus is able to expand into the opposite side of the sphenoid because its companion sinus, which would usually have preempted the space, has been retarded by the pre-basisphenoid synchondrosis. He describes a septum which kept to the midline in the presphenoid and bent at right angles to pass laterally along a pre-basisphenoid plane. In this instance one sinus was evidently completely blocked at the pre-basisphenoid plane. The failure of a sinus to pass the concha-presphenoid junction explains in a reasonable manner the presence of intersinus septa lying along this plane.

The ending of many oblique intersinus septa in the region of the lateral craniopharyngeal canal is evidence that the synchondroses do, as Cope believes, play a part in the formation of this type also by bringing an advancing sinus to a halt. Local condensations of spongiosa not originating from synchondroses, such as can often be found in the sphenoids of the new-born, probably also retard sinus growth. It may be that they are a cause of the small bulgings of septa which are those entirely unassociated with fusion planes. It is of course very probable that factors affecting the degree of activity of the osteogenic tissue also often help to determine the relative progress of a pair of sphenoid sinuses.

RELATION BETWEEN SINUS WALLS AND TWO SYNCHONDROSIS PLANES

The fusion plane of the occipital and the sphenoid bones is so removed from the region of origin of the sinus that only in a small percentage of cases does the sinus invade the occipital bone. No well-marked projection could be found which could be ascribed to the synchondrosis. Its influence on the position of the posterior sinus wall can be readily examined by means of the frequent sagittal sections which occur among the dry and moist preparations.

In sections of thirteen skulls with the synchondrosis still present it was found to vary from a position a little behind the dorsum sellae to the middle of the clivus. Markings are found in varying combinations in adult skulls which give good evidence as to its former position (fig. 4). They are: *a*) a line separating a rough anterior part of the clivus from a smooth posterior portion; *b*) one or more small elevations extending across the clivus; *c*) a roughening on the under surface of the bone; *d*) a poorly defined condensation of the spongy bone. The zone of distribution of the synchondrosis was taken as extending from a plane 3 mm. behind the dorsum sellae to a little past the middle of the clivus.

The number of sinuses ending in this zone was compared with the number ending in the region of approximately equal extent intervening between it and the territory of the pre-basisphenoid synchondrosis. Twenty-three sinuses terminated in the anterior division and fifty-one in the posterior division. Eight were on the boundary line. The tendency for a normal sinus to reach the posterior zone is probably greater than the figures indicate, because any abnormal conditions retarding sinus development would tend to throw the sinuses into the anterior group. Upon the other hand the ending of so many sinuses in the posterior zone is not a strong indication that they lie in the synchondrosis plane, because the region is so extensive.

From among the sphenoids with sinuses ending in the posterior zone thirty-six cleaned skull fragments were found which permitted a closer examination of the relationship upon the surfaces exposed by a sagittal cut. In twenty-six of them there was evidence of varying value for the position of the synchondrosis plane. In nineteen the sinus appeared to touch it. In seven there was an interval between. In eight sinuses evidence for the former position of the synchondrosis could not be found. Two had passed what was probably the plane. The posterior walls of sinuses which reached the plane were sometimes in contact over a small area, but frequently they were well flattened out upon it. The inner surface of the wall occasionally had projections and pits which resembled the irregularities frequently found on the posterior surface of the sphenoid before fusion with the occipital bone.

The time of obliteration of the synchondrosis is usually given as somewhere between the thirteenth and the twenty-second year. Data regarding the time at which the sinus reaches its adult proportions seems to be very meager. It is usually stated that this occurs at puberty. Occasionally a slow growth in adult life is said to follow the early period of rapid enlargement. If the sinus reaches the synchondrosis at puberty or even somewhat later, it would probably encounter unabsorbed remnants of the synchondrosis.

Sinuses were grouped to show whether the wall stopped with especial frequency in the alar-basisphenoid or alar-alisphenoid zone. It was found that because the lateral walls are frequently rounded instead of flat like the septa they could be less satisfactorily classified. Twenty-seven out of 114 sinuses had a lateral wall touching the alar-basisphenoid zone. Sixteen were scattered over territory lying a little farther laterally. The wall of the remaining sixty-seven sinuses lay beyond the alar-alisphenoid one. There is a parallelism between the grouping of septa and walls in this region. A considerable number of each are found at the alar-basisphenoid zone, a few at the alar-alisphenoid zone, and there are a few scattered in the vicinity. Reasons for anticipating the much more frequent encounter of the sinus with the alar-basisphenoid than with the alar-alisphenoid synchondrosis were given when discussing the septa.

CLASSIFICATION OF SPHENOID SINUSES

Cope has divided sphenoid sinuses into three groups, according as they are entirely anterior to the plane of fusion of the presphenoid and basi-sphenoid, or extend back of a plane a little anterior to the clivus, or occupy an intermediate position. He found seventy-two ending in front of the basi-sphenoid, 155 of those extending most posteriorly, and sixty-five of the intermediate type.

The arrangement of ossification centers of the sphenoid in an anteroposterior series in either half of the bone furnishes a natural means of sinus classification. Four types can be distinguished from their relation to the centers. They are: 1) those anterior to the concha-presphenoid plane ('conchal' sinuses) (fig. 5); 2) those extending into the presphenoid, but not into the basisphenoid ('presphenoid' sinuses); 3) those reaching into but not beyond the basisphenoid ('basisphenoid' sinuses) (figs. 4, 5, etc.), and finally, 4) those extending into the basilar part of the occipital bone which may be termed 'occipitosphenoid' sinuses. It has been found that the concha-presphenoid and the sphenoccipital synchondroses probably bring some sinuses to a halt. Because septa are found at the pre-basiphenoid plane and from certain other considerations, it is probable that the posterior wall also frequently comes to a stop at this synchondrosis. The classification evidently corresponds to a natural grouping of the sinuses.

Nine sinuses were classified as conchal and eight were undetermined as between the conchal and presphenoid types. Forty-three are presphenoid. Both basisphenoid and occipitosphenoid are included in the remaining one hundred and twenty-one since it is not possible to distinguish except under especially favorable conditions between the two types. As has been seen, probably only a few fall in the last-named group.

Cope found seventy-two sinuses ending in front of the pre-basisphenoid plane and 220 behind it. The Stanford material gave fifty-two anterior and 121 posterior to the plane. Expressed in percentages, the frequency of the two anterior groups were twenty-four and thirty, respectively. The correspondence between the two ratios is as close as could be expected without identity in the method of dividing the areas and of choosing the material.

The significance of the differing frequency of the four sinus types is dependent upon the manner in which their growth periods are distributed through life and upon the age of the sinuses. If, for example, they enlarge continuously and at a uniform rate throughout life, the probability would suggest itself that the conchal and pre-sphenoid sinuses came from the youngest skulls and the occipitosphenoid from the oldest. It will be possible to learn approximately the influence of these factors upon the ratio which has been given. Seven out of nine of the conchal sinuses, twenty-seven of the presphenoid type as well as eight intermediate between the two had plainly completed their development in a posterior direction because they were hemmed in behind by their companion sinuses. The two conchal sinuses not hemmed in were from an individual fifty-five years of age. Twenty-seven of the forty-three presphenoid sinuses also were bounded posteriorly by intersinuses septa. Many of the remaining sixteen were from skulls apparently from middle life or beyond. It is clear, then, that the conchal and presphenoid sinuses had most of them nearly if not completely reached their adult volume. The proportion between the basisphenoid and occipitosphenoid groups was probably changed slightly from its true value to the benefit of the larger type by old-age absorption. Taking into account these various considerations, it is clear that the frequencies obtained for the different types may be taken as only an approximation to the correct figures for the adult period. This inference is based on the fact that the dissecting-room material from which most of the bones came contained 50 per cent more bodies of individuals between the ages of sixty and eighty than of those between twenty and forty, also the skulls with the basisphenoid sinuses showed more general absorption than did the other groups.

THE RELATION OF SYNCHONDROSES TO SEPTA AND WALLS

Discussion and conclusions

Much evidence has been given to show that the septa are largely grouped in the zones formerly occupied by seven synchondroses. It is significant that precisely these joints consolidate at a somewhat advanced period in postnatal life, while the position of fusion planes which were obliterated before birth are not marked by septa. The mere occupation by a septum of the general region in which a synchondrosis formerly lay does not of course prove a causal connection between the two structures. The fluctuation in position of some synchondroses was so great that rather broad zones had to be marked out to cover the range of their former positions. Most of the septa, however, not only took the direction of the synchondroses, but over 90 per cent of them lay within their zones, although the total capacity of the zones was but half that of a sinus of average size. There were also various details of septal structure confirming the relation of septum and synchondroses, such as the presence of lateral craniopharyngeal canals in the septa and the occurrence of triradiate septa whose three bony laminae lay in three confluent synchondrosis planes. While there is not absolute proof of the formation of any single septum from a synchondrosis, the conclusion is scarcely avoidable that a large proportion of them are derived from this source.

A brief examination of a series of maxillary and frontal sinuses is sufficient to convince one that many of their septa could not have come from fusion plains of ossification centers, since they lie at a distance from the position which these formerly occupied. There were a few sphenoid septa also that are entirely independent of synchondroses. They apparently owed their origin to compact bone developed within the basisphenoid center as a support for a vascular plexus. It is of course impossible to say whether the small group of septa which did not fall in any zone were due to synchondroses in unusual positions or to some unknown cause. Some septa also evidently seem to have arisen from the lateral column of compact bone at the line of union of the three lateral synchondroses, but were otherwise independent from them.

Intersinus septa, while usually close to the median line at their anterior end, frequently take an oblique course more posteriorly which will bring them to one of the lateral fusion planes. They may assume a position which is apparently in exact correspondence with a concha-presphenoid plane.

Evidence has been given in confirmation of Cope's view that some deflected intersinus septa are in part due to the enlarging of one sinus across the midline when the other has been retarded by the pre-basisphenoid synchondrosis. It is probable that retardation may also take place at the concha-presphenoid plane, yet not all deflections can be explained in this way. The condensations of spongy bone found in the sphenoids of the new-born may also have retarded sinuses.

It was found that not only septa, but also sinus walls may show a grouping at synchondrosis planes. Observations on the position of the posterior wall of basisphenoid sinuses allow the estimate that in 50 per cent it is situated at the sphenoccipital synchondrosis. Nineteen per cent of the lateral walls of the basisphenoid sinuses probably ended at the alar-basisphenoid plane. It is to be expected that other factors, among them, the density of the spongy bone, would play a part in determining the position of sinus walls.

It was found by a comparison of the time of fusion of ossification centers and of the approach of the growing sinus that remnants of most synchondroses associated with septa would frequently remain long enough to resist the osteogenic layer and so give rise to septa. The ali-presphenoid synchondrosis is apparently an exception, because it is said by Toldt ('83) to be obliterated at six, and according to some writers at a still earlier period, while the sinus is probably usually just entering the presphenoid at this time. A possible explanation is to be found in Cope's claim that especially resistant bone remains after a synchondrosis has disappeared. He says, ". . . . there is evidence to show that the bone formed at the line of fusion of bony centers may be and often is of a denser and more resistant material than the tissue on either side of the line." He does not discuss the nature of this evidence.

Just after the fusion of a synchondrosis it is to be expected that an accumulation of compact bone would be present, since a thin layer was previously in contact with either surface of the cartilage, but its persistence through any considerable subsequent period cannot of course be taken for granted. A number of regions were examined in the sphenoids of late foetal and early infantile skulls where synchondroses had disappeared not very long before in search for material more dense than the usual spongy bone. The joints in question are the lateral part of the pre-basisphenoid and the posterior part of the alar-basisphenoid and the median presphenoid and basisphenoid. The latest of these to fuse was at the plane of union of presphenoid and basisphenoid. It disappears two or three months before birth. In the thirty-one individual regions of fusion which were examined none showed any condensation. It is to be anticipated, however, that the compact bone would be absorbed less rapidly after birth because of the general slowing up of growth as development proceeds.

Occasionally an ill-defined condensation of spongy bone was found at the plane of the sphenoccipital synchondrosis in the adult sphenoid. It is probable that its disappearance would proceed at a much slower rate than in the other synchondroses whose fusion occurred before birth. It may be that the alipresphenoid synchondrosis, since it fuses after birth, though at a much earlier period than the sphenoccipital joint, may leave not only traces of dense bone, but also cartilage or fibrous remnants long after its complete obliteration on the surface of the sphenoid has occurred. Certainly, as has been seen, portions of the wall of the craniopharyngeal canal which constitutes its posterior end are to be found occasionally even in the adult.

THE RELATION OF SEPTA TO THE SUPPORTING FUNCTION OF THE SPHENOID

Many septa give the impression after a cursory examination that they may be of importance in strengthening the walls of the sphenoid sinus, although their relationship to the synchondroses has led on the preceding pages to an entirely different explanation of their presence. Cope ('17), while also occupied in tracing their origin to the synchondroses, termed those which lay under the carotid group, carotid buttresses. Gibson ('08) is another writer who has stated that the septa serve as supports.

Many individual septa seem well adpated to a support of the sinus wall, but the location and form of others are incompatible with such a function. It is also to be remembered that the occurrence of septa is only occasional in any one locality, and it does not seem correlated with conditions especially requiring a support. They are abundant in thick-walled sinuses and young sphenoids with but small cavities may have thick ridges. On the other hand, large thin-walled sinuses usually have thin septa. Occasionally sinuses are crowded with septa though showing no especial need of wall supports, and again a very roomy and thin-walled cavity will have none. Of two companion sinuses very similar in form and thickness of wall, one may have a septum and the other not. Many septa take the form of ridges at the junction of intersinus septa and roof or upon the floor and in other positions where there is no likelihood of an especial need for support (fig. 2). The intersinus septum may cut across one corner of the body of the sphenoid, leaving a thin plate of bone under the greater part of the sella turcica entirely unsupported. Many septa have jagged or variously roughened free edges that could have no significance (fig. 11) in strengthening the walls.

Wolff ('92), Triepel ('08), and others have made familiar many details of bony architecture which seem almost perfectly adapted to resist stresses and strains. Wolff also has brought forward evidence that the osseous structure may take on a new form in adult life in response to changing mechanical demands. It may be asked whether the septa which do not conspicuously lack adaptation to such demands may not either have arisen or have been remolded in response to them, or at least have been retained after the growing period because of their utility as supports. The form and position of the septa furnish no convincing evidence for any of these assumptions. On the contrary, both the form and position of many septa indicate in a striking manner origin from synchondroses, while in these features most of the others lend themselves very readily to the same interpretation. The septa do, of course, strengthen the walls, but the view that this is other than accidental is not only unproven, but improbable.

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PLATES

PLATE 1

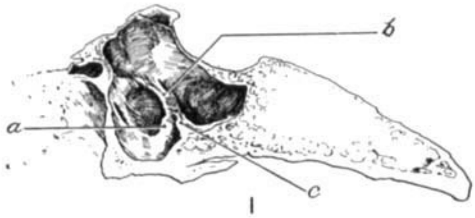
EXPLANATION OF FIGURES

1 Sagittal section. × 1. *a.* Septum in ali-presphenoid zone. *b.* Edge of septum extending laterally and not lying in plane of any synchondrosis. *c.* Septum in pre-basisphenoid zone.

2 Floor of sinus exposed. Septa on floor converging to remnant of lateral craniopharyngeal canal (*a*). × 1. *b.* Septum in alar-basisphenoid zone. *c.* Septum in ali-presphenoid zone. *d.* Septum in pre-basisphenoid zone.

3 Floor of sinus exposed. × 1. Lateral border of lingula (*a*) marking former position of alar-alisphenoid plane in line with septum (*b*).

4 Sagittal section. × 1. Markings giving former position of sphenoccipital synchondrosis at (*a*).



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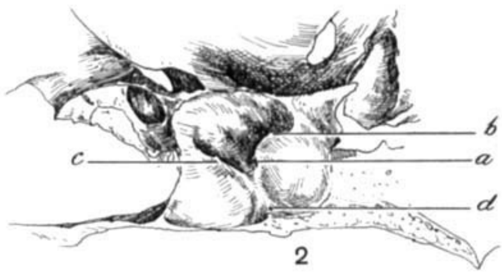

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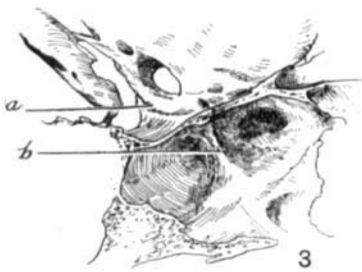

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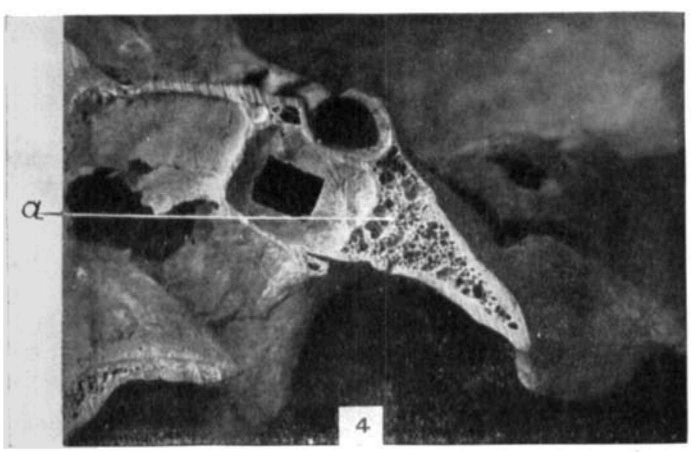

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PLATE 2

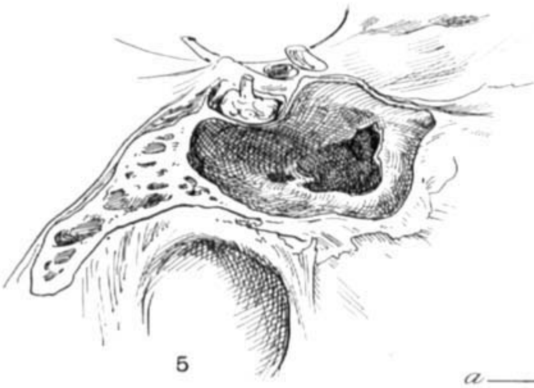
EXPLANATION OF FIGURES

5 Sagittal section. × 1. Opening in intersinus septum to show a conchal sinus.

6 Sagittal section. × 1. *a*. Free edge of septum not in zone of synchondrosis. *b*. Septum in alar-alisphenoid zone. *c*. Septum in ali-presphenoid zone.

7 Sagittal section. × 1. Septum (*a*) transverse to long axis of body probably arising from plate in sphenoid of new-born which serves as support of a vascular plexus.

8 Ali-presphenoid septum with portion of lateral column remaining at (*a*). × 1.



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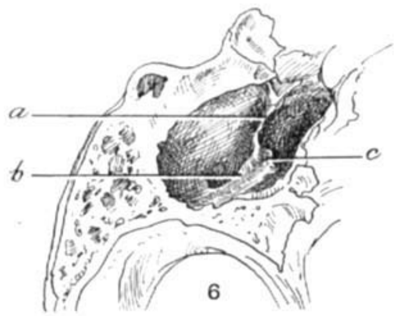

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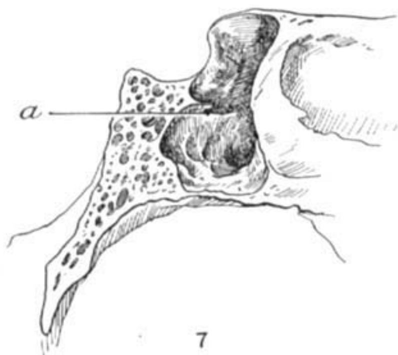

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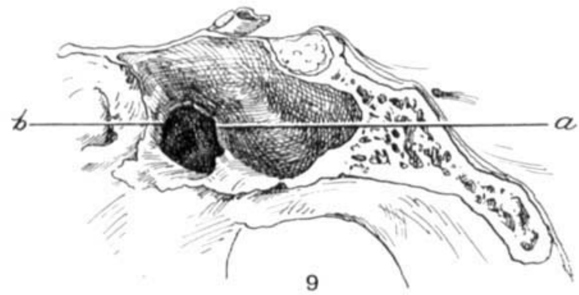
PLATE 3

EXPLANATION OF FIGURES

9 Sagittal section. × 1. *a*. Septum of concha-presphenoid zone. *b*. Aperture of sinus.

10 Frontal section. × 1. *a*. Septum in region of posterolateral group which lies too far forward to be identified. *b*. Septum in alar-basisphenoid zone.

11 Sinus opened from above. × 1. *a*. Septum in ali-presphenoid zone. *b*. Ridge made by canal of pterygoid nerve. *c*. Septum in alar-basisphenoid zone.



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