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**CONGENITAL MALFORMATIONS OF UPPER INCISORS  
IN EXENCEPHALIC MOUSE EMBRYOS, INDUCED  
BY HYPERVITAMINOSIS A**  
**II. MORPHOLOGY OF FUSED  
UPPER INCISORS**

*by*

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INTRODUCTION

Fusion of the incisor germs in the upper jaw is the most common tooth malformation in exencephalic mouse embryos, whose brain deformity is induced by vitamin A overdosage. Division into three main types: fusio partialis, subtotalis and totalis, according to the degree of fusion, can be made without difficulty, as described in Part I of this work (*Knudsen, 1965*). It is more difficult to give a complete description of the morphology of the fused germs, because of the many variations encountered. This difficulty is greatest with fusio totalis, which is the commonest and most variable form. The purpose of this article is to summarize the most important morphological variations in fusio dentium and further, on the basis of models, to describe one representative of each of the three main types.

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## MATERIAL AND METHODS

The material comprises 130 frontally sectioned exencephalic mouse embryos with fused upper incisors (*Knudsen, 1965*). The morphological investigation was based on careful examination of all histological sections where upper incisors were present. A large number of photographs was used, particularly in order to make comparison between normal incisor germs and various types of fused incisors. Finally, wax plate models were constructed. The exterior outline of the enamel organ and oral epithelium in the roof of the mouth was traced at high linear magnification ( $200\times$ ). The models were made solid to increase strength. Four models showing upper incisor germs from 18-19 day-old embryos were made, viz., from embryos one normal and three exencephalic with various degrees of fusio dentium. In addition, after tracing the inner outlines of the dentine layers in the same four tooth germs, four solid models of the pulps were constructed. The models were very valuable, in conjunction with the photomicrographs, in ascertaining the shape of the tooth germs. Photographs and drawings of the models were prepared in order to illustrate the description.

## RESULTS

## SUMMARY OF THE MOST IMPORTANT MORPHOLOGICAL VARIATIONS

On the basis of histological sections, the outline (contour), symmetry and greatest diameter are described. As, for instance, the outline can differ in the same germ, depending on the locality of the section, this summary is based on frontal sections which engage the germ immediately in front of the root opening. The reliability of the method will be considered later (see Discussion).

*Outline.* The outline of the incisor germs varies considerably. The most numerous and the greatest variations are found in fusio totalis. There are fewer with fusio subtotalis, and fusio partialis shows least variation. Four types of outline are distinguished. They can be described as approximately (1) rectangular (Fig. 1), (2) trapezial (Figs. 2-7), (3) triangular or drop-shaped (Fig. 8), or (4) H-shaped (Figs. 9, 10, and 11).

The frequency of the various forms is shown in Table I. The trapezium dominates in fusio totalis, where the H-shape is rarest. The H-shape is, however, the commoner of the two types occurring in fusio subtotalis and the only one in fusio partialis. In the total material, without reference to the degree of fusio dentium, the trapezoidal and H-shaped forms are the commonest.

*Symmetry.* Tooth germs, the right and left sides of which are roughly equal in frontal sections, are termed "symmetrical" (Figs. 1, 2, 3, and 6). When there is a clear difference between the two sides, "light asymmetry" (Figs. 4, 5, 9, and 10) or "mean to heavy asymmetry" (Figs. 7, 8, and 11) are distinguished.

The relative frequency of symmetrical and asymmetrical germs

Table I

*Outlines of 130 incisor germs, frontally sectioned, in the case of fusio dentium.*

	Fusio partialis		Fusio subtotalis		Fusio totalis		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Rectangular	---	---	---	---	11	10.7	11	8.5
Trapezoidal	---	---	2	11.8	81	78.6	83	63.8
Triangular	---	---	---	---	6	5.8	6	4.6
H-shaped	10	100.0	15	88.2	5	4.9	30	23.1

Table II

*"Symmetry" of 130 incisor germs, frontally sectioned, in the case of fusio dentium.*

	Fusio partialis		Fusio subtotalis		Fusio totalis		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
"Symmetry" (right and left)	5	50.0	13	76.5	63	61.2	81	62.3
Light asymmetry	3	30.0	3	17.6	19	18.4	25	19.2
Mean to heavy asymmetry	2	20.0	1	5.9	21	20.4	24	18.5

Table III

"Symmetry" of the trapezoidal and H-shaped outlines of incisor germs, frontally sectioned, without reference to the degree of fusio dentium.

	Trapezoidal		H-shaped	
	Number	Per cent	Number	Per cent
"Symmetry" (right and left)	50	60.2	20	66.7
Light asymmetry	19	22.9	6	20.0
Mean to heavy asymmetry	14	16.9	4	13.3

is examined for the three types of fusio dentium. The results are presented in Table II. The symmetrical germs dominate, while the two degrees of asymmetry are almost equally frequent in fusio totalis and in the total material.

Whilst the rectangular germs are symmetrical and the triangular ones are all asymmetrical, the symmetry of the trapezoidal and H-shaped germs varies as shown in Table III, in which only outline is considered, irrespective of the degree of fusio dentium.

*Greatest diameter.* In frontal sections normal incisor germs are oval, with their greatest diameters directed apically and distally. In fusio dentium, however, the orientation of the greatest diameters in the frontal sections is variable and often difficult to establish. A comparison of the greatest vertical and transversal diameters in frontal sections was made, and although the meth-

Table IV

*Greatest diameters of the various outlines of the incisor germs in frontal sections.*

Greatest diameter	Rectangular		Trapezoidal		Triangular		H-shaped		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
transversal	1	9.1	10	12.1	—	—	30	100	41	31.5
vertical	10	90.9	40	48.2	—	—	—	—	50	38.5
oblique	—	—	6	7.2	6	100	—	—	12	9.2
transversal = vertical	—	—	27	32.5	—	—	—	—	27	20.8

od employed is rather crude, an excellent impression of the morphological variations can be gained, as shown in Table IV.

H-shaped germs all have their greatest diameters transversally (Figs. 9, 10, and 11). The greatest number of variations occur among the trapezoidal germs. Almost half of these have their greatest diameters vertically (Figs. 2 and 4), whilst the transversal and vertical diameters are nearly equal for about a third (Fig. 3). In germs with heavy asymmetry, as for example in the triangular germs, the vertical diameter is disregarded, as the longest diameter is distinctly oblique (Fig. 8).

DESCRIPTION OF ONE NORMAL AND THREE FUSED INCISOR GERMS ON THE BASIS OF WAX PLATE RECONSTRUCTIONS

It was first in studying the models that the considerable changes in the relief of the oral epithelium became apparent. This applies to both the free surface and that covered by connective tissue. The account is therefore opened with a description of that part of the epithelium in the roof of the oral cavity, which lies opposite the incisor germs.

**Normal mouse embryo** (Figs. 12—16 and 41).

The oral epithelium forms a trapezoidal plate, which is widest posteriorly (Figs. 12 (E), 15, and 16). The epithelial plate has two surfaces, an inferior *oral surface* which is free and corresponds to the roof of the oral cavity, and a superior *basal surface* corresponding to the junction between epithelium and connective tissue in the cavity roof, but which is free on the model. The back and front margins of the model are artificial. The same is true of the two narrow borders on the oral surface near the lateral edges of the plate.

The anterior part of the *oral surface* is almost flat (Fig. 15). Behind this region are three longitudinal rounded elevations (C). The middle one is the widest and most prominent, but it does not reach the posterior edge of the epithelial plate, as it is replaced by a flat depression in the final portion. The lateral elevations, which reach the posterior edge of the plate, are separated from the middle one by two narrow grooves (S).

The *basal surface* has three longitudinal grooves, lying opposite the elevations of the oral surface, without there being any correspondence either in shape or size (Fig. 16). The grooves are bordered by four longitudinal crests.

The middle groove, which arises at the anterior end of the epithelial plate as a broad rounded indentation, becomes narrower and deeper to the centre of the basal surface. Further back, the depth is again less, and near the posterior border of the epithelial plate the groove disappears entirely. Both lateral grooves are "boat-shaped" being narrow and flat anteriorly and posteriorly, whilst the central part is broad and deep.

The grooves are separated by two crests, which converge posteriorly to become part of the two epithelial laminae, here called "dental laminae", connecting the incisor germs with the oral epithelial plate. The two crests, which are now broad and low, continue behind the dental laminae and disappear entirely near the posterior edge of the epithelial plate.

The boat-shaped lateral grooves are each limited laterally by a rounded crest having an obliquely lateral direction in front and forming quite a high side wall of the groove. Posteriorly, the crest changes direction and the lateral wall of the groove disappears.

A *normal incisor germ* is elongated, with its long axis directed apically and distally (Figs. 12, 13, 14, and 41). Four oval surfaces are found, viz., labial (L), lingual (LI), mesial (M), and distal (D), separated by rounded edges. In addition, there is an apical (A) (basal or posterior) end characterized by the apical root opening (Ao), and an incisal (I) (anterior) end, which continues as the dental lamina (DL).

The *labial surface* is everywhere convex (Figs. 12 and 13). Most of the surface is broad, but it includes a narrow apical portion near the root opening. It continues incisally in the labial edge of the dental lamina.

The *lingual surface* is short and narrow, having greatest resemblance to a rounded edge (Fig. 14). It extends apically as far as the root opening and continues incisally in the lingual edge of the dental lamina.

The *mesial surface* is slightly convex and apically bears a notch corresponding to the root opening (Figs. 12 and 13).

The *distal surface* is concave centrally and convex apically and incisally (Figs. 12 and 13).

The *apical end* bears the root opening, which is oval, with its longest axis vertically. It is everywhere bordered by a distinct rim, which forms a bud-like prominence against the lingual and labial surfaces (Figs. 13 and 14).

The *incisal end* is laterally compressed and, apart from a very small free portion labially, passes over its entire length into the dental lamina (Figs. 12 and 13).

The *dental lamina* is plate-like with a convex mesial surface and a concave distal surface (Figs. 12, 13, 14, and 16). The labial edge is free, whilst the broader lingual edge passes gradually into the crest which continues posteriorly, as described under the oral epithelium. The attachment of the two laminae follows a mesially convex arc.

### Fusio dentium

#### *Oral epithelium (collective description)*

In the three types of fusio dentium the *epithelial plate* is in the form of a trapezium with its base posteriorly (Figs. 20, 24, and 28). In *fusio totalis* the anterior edge is considerably shorter than the posterior edge, whilst there is only a small difference in length in *fusio partialis*. The epithelial plate is locally very thin in all types of fusio dentium.

The *oral surface* is slightly concave, but differs from the oral surface of normal embryos in almost entirely lacking relief. Only in *fusio partialis* is there a weak median groove, while in normal embryos a strong crest is present.

The *basal surface* is slightly convex, with a relief which is entirely different along the mid-line from that of a normal embryo (Figs. 20, 24, and 28). This is a consequence of the presence in fusio dentium of only one dental lamina. In fusio dentium the deep median groove of the normal embryo is divided into two grooves by the dental lamina, and anteriorly, where the latter is absent, by a rounded crest, which extends from the lamina to the anterior edge of the epithelial plate. The grooves are deepest in *fusio totalis* and shallowest in *fusio partialis*. They end slightly behind the centre of the plate, where the dental

lamina broadens. In *fusio partialis* and *fusio subtotalis* the grooves are entirely separate, whilst they join in front of the lamina in *fusio totalis*. The grooves are each bordered laterally by a rounded crest, extending from the anterior edge of the epithelial plate rearwards to the centre of the plate, where it passes into the dental lamina. Each crest follows a laterally convex arc and presumably corresponds to the crest to which the dental lamina is attached in normal embryos. The rest of the relief is similar to that of normal embryos, but is much less pronounced. Behind the incisor germ, the basal surface is smooth. In *fusio dentium* the basal surface has, in other words, *four grooves* as against *three* normally and *five elevations* as against *four* normally. The middle elevation is connected to the dental lamina.

*Fusio partialis* (Figs. 17-20 and 43)

The shape is influenced by the incomplete fusion, the left and right halves of the germ being separated apically by a broad deep notch and incisally by a small vertical groove (Figs. 17, 18, 19, and 43). The outline of the germ seen from the labial surface resembles a letter H with a very wide cross-piece and diverging upper arms.

The *labial surface* is strongly concave about the mid-line near the apical notch (Figs. 17 and 18). The rest of the surface comprises two convex areas separated incisally by the vertical groove and extending to the two apical tips of the germ.

The *distal surfaces* are rectangular and, as in normal germs, slightly convex apically and incisally, but concave centrally. The root opening extends on to the distal surfaces and forms a notch corresponding to the apical part (Fig. 18).

The *lingual surface* is in the form of a trapezium, with the base along the root opening. The surface is slightly concave and passes smoothly into the dental lamina (Fig. 19).

The *apical end* bears one root opening, which is shaped like an hour glass, with the constriction lying opposite the posterior niche (N) of the dental lamina. The expanded parts of the root opening on each side of the constriction are oval and extend slightly on to the distal surfaces (Fig. 19).

The *incisal end* is only free nearest the labial surface (Fig. 18). It bears a V-shaped groove in the middle. This groove is a continuation of the narrow vertical groove on the labial surface of the germ. Most of the incisal end is hidden by the dental lamina.

*Fusio subtotalis* (Figs. 21—24 and 45).

The vertical groove in the incisal portion of the germ is missing, and the apical notch is shallower than in *fusio partialis*, as the fusion is more complete.

The *labial surface* is in the shape of a trapezium with its base apically (Fig. 21). The surface is concave about the mid-line near the apical notch, but otherwise convex.

The outline of the *distal surfaces* is triangular with its base placed lingually (Fig. 22). The distal surfaces are flat in their labial, and slightly convex in their lingual portions. The root opening forms a U-shaped notch on their apical parts. The characteristic curvatures of the distal surfaces of normal germs are lacking.

The *lingual surface* is in the form of a trapezium with its base located apically along the root opening (Fig. 23). The surface is concave and passes into the dental lamina.

The *apical end* is the root opening, which is oval with a transverse long axis and a slightly constricted portion in the middle of the germ (Fig. 23).

The *incisal end* is broad, and the free portion in front of the dental lamina is slightly prominent (Figs. 21 and 22).

*Fusio totalis* (Figs. 25—28 and 47)

In this type of *fusio dentium*, there are no outwardly visible signs of cleavage. The outline of the germ is triangular seen from the labial side and has little resemblance to a normal incisor germ.

The *labial surface* is triangular with an apical base (Fig. 25). It is convex except apically, where there is a slight concavity.

The *distal surfaces* are triangular with lingual bases (Fig. 26). They are slightly convex and the apical thirds bear notches lingually, as parts of the root openings.

The *lingual surface* is in the shape of a trapezium with the base apically along the root opening. The surface is slightly concave (Fig. 27).

The *apical end* is the root opening, which is oval with a transverse long axis (Fig. 27).

The *incisal end* is only free in the labial portion, the rest passing into the dental lamina (Figs. 25 and 26).

*The dental lamina (collective description)*

In *fusio partialis* the dental lamina expands lingually and ends in the centre of the basal surface of the epithelial plate (Fig. 20). On the labial edge of the dental lamina, at a short distance from the basal surface of the epithelial plate, a small recess or niche with a triangular outline is found (Figs. 17 and 20). The lingual edge or end of the dental lamina bears a large oval niche, extending up on to the incisor germ. Its lower end is limited by the basal surface of the epithelial plate (Figs. 19 and 20).

In *fusio subtotalis* the dental lamina has, as in *fusio partialis*, a smaller labial and a larger lingual niche (Figs. 23 and 24).

In *fusio totalis* the lamina has the form of a plate, which is narrow labially, but lingually is as broad as the tooth germ. There are no niches (Figs. 25, 27, and 28).

DESCRIPTION OF THE PULP IN ONE NORMAL AND THREE FUSED INCISOR GERMS  
ON THE BASIS OF WAX PLATE RECONSTRUCTIONS

The shape of the pulp corresponds closely to the exterior shape of the incisor germ both in the normal embryo and in embryos with *fusio dentium*. A systematic description of the pulp surfaces is therefore omitted. Only marked differences in relief will be described. The root opening is marked on the pulp models, but will not be discussed.

The pulp of a normal incisor germ in a 19-day old mouse embryo is first described. There follows a description of the pulp in germs with *fusio partialis* and *fusio subtotalis*, the pulps of these two germs being so similar that a single description will suffice. Finally, a short description is given of the pulp in a germ with *fusio totalis*.

**Normal mouse embryo** (Figs. 29, 30, 37 and 42).

The incisal third of the *lingual surface* bears a longitudinal broad groove, separated from the distal surface by a crest (Fig. 30).

The *incisal end* of the pulp differs markedly from the external surface of the germ, an oval depression surrounded by a sharp edge on all sides being present in the pulp (Fig. 37, F and C). The two "pulp horns" seen in histological frontal sections are formed by the mesial and distal portions of this edge. Lingually there is a notch (IN) formed by the incisal end of the groove on the lingual surface.

**Fusio dentium**

*Fusio partialis* (Figs. 31, 32, 38 and 44) and *fusio subtotalis* (Figs. 33, 34, 39, and E 46).

The incisal portion of the *labial surface* consists of two parts separated by a central notch, which is deepest in *fusio partialis* (Figs. 31 and 33). Each part bears a longitudinal flat groove, bordered in the mesial, distal and incisal directions by a U-shaped crest. Apically the groove passes evenly into the rest of the surface and soon vanishes.

The *lingual surface* has two incisal portions as has the labial surface, but the notch separating them is wider (Figs. 32 and 34). Each portion bears a deep vertical groove, which, unlike the labial grooves, is open incisally and passes into the apical part of the surface to end near the root opening.

The *incisal end* is divided by a central notch into two parts, which are oval with a labio-lingual largest diameter (Figs. 38 and 39). Each carries an approximately circular depression surrounded by a sharp edge, which is lowest and narrowest mesially and distally. Lingually to each depression is a notch formed by the open incisal end of the groove on the lingual surface.

*Fusio totalis* (Figs. 35, 36, 40 and 48)

The pulp, in contrast to the external surface of the incisor germ, shows clear indications of a division into right and left halves.

The *labial surface* has a weak central groove in the incisal two thirds (Figs. 35 and 48).

The incisal two thirds of the *lingual surface* bear a central longitudinal broad groove, bordered by a flat elevation on both sides (Fig. 36). The groove is open incisally, where a broad and quite deep notch is present on the edge.

The *incisal end* forms a rectangular surface (Fig. 40). Its *labial* part has two rounded depressions, separated by a *narrow, sharp, median crest*, but otherwise bordered by a broad edge. *Lingually*, the incisal end has a central notch, formed, as stated, by the groove on the lingual surface. This notch is limited by two broad, rounded projections, which begin at the labial depressions and reach the lingual surface.

#### DISCUSSION

The morphological outline given in this article on the basis of histological sections, is of necessity broad. In several instances it was difficult to decide which type a germ should be referred to on the basis of its outline. It was likewise difficult to classify the germs according to symmetry, as a strictly geometrical approach is naturally precluded. Determination of the greatest diameter in a cross section was based on estimate or, in case of doubt, rough measurement, as it was not the intention to conduct a quantitative investigation, only to supplement the description. In spite of these shortcomings, the method employed does give an impression of the most important morphological variations.

Study of the models made a spatial appreciation of normal and deformed germs possible. Such an appreciation cannot be acquired from histological sections alone. The reconstruction method being very demanding as to time and work, it is only feasible to use a limited number of reconstructions. Although the method is therefore unsuitable for a more comprehensive study of morphological variations, even a limited number of models permits a better and more correct interpretation of histological sections. In the present study the reconstructions were particularly useful in an appreciation of the contours of the individual surfaces.

Models have thus been of great importance in pulp studies,

where a good insight into the morphological conditions was acquired. Of special interest is the form of the incisal end, where the normal pulp bears a single rounded depression, whilst all types of fusio bear two. In fusio totalis, where the external surface of the germ gives the impression of complete fusion, it is surprising that the pulp appears exempt. Another peculiarity in the pulp is the grooves which mark the labial and lingual surfaces in fusio partialis and subtotalis. The pulp surface thereby becomes quite different both from the external surface of the germ and from the pulp surface in a normal germ.

The change in relief which takes place in the basal surface of the oral epithelium in fusio dentium can be explained by the attachment of the unpaired dental lamina along the mid-line by which the normally occurring median groove is divided. It has, however, neither been possible to explain the almost complete lack of relief in the oral surface, nor the presence of areas with very thin epithelium.

As the incisor germs with fusio totalis have a lesser extent from side to side than the germs with the other types of fusio dentium, it is natural that the front edge of the oral epithelial plate is shortest with fusio totalis, increases in length with fusio subtotalis and has almost "normal" length with fusio partialis, where the transverse diameter of the germ is especially large. It is not at the moment possible to decide whether the reason for this pattern is that there is a primary formation of incisor germs demanding less room, or whether fusio totalis arises specifically because there is too little room in the primordial jaw for the development of separate incisors. The latter possibility cannot be excluded, but newly completed studies of young embryos with fused tooth germs at the bud stage indicate that the form of the incisor germs with fusio dentium is evolved at an early stage constituting a quite "independent" process, which it is difficult to imagine being controlled or influenced to any extent by local space conditions.

Another consideration which makes it difficult to attribute a primary role to lack of space in the primordial jaw is the very considerable size variations which occur in fusio totalis, where in several cases a small germ is found occupying only a modest portion of the available space. For further illustration of this

problem exact information on size relationships is, however, necessary, and a quantitative study of tooth germs with fusio dentium has therefore been initiated.

The presence of a proper dental lamina in the development of the incisors is denied by *Pourtois* (1961) among others. The term "dental lamina" is used in the present study for the epithelial lamina which is in connection with the basal surface of the oral epithelium. It consists mainly of the portion of the stellate reticulum and outer dental (enamel) epithelium which comprises the incisal portion of the enamel organ. Labially, it consists of cells with the same appearance as that of the cells of the oral epithelium, thus representing an ingrowth of these cells. The term "dental lamina" is therefore not entirely unjustified. Furthermore, it is a useful term in the present description of models, because it obviates confusion with the oral epithelial plate. As the largest part of the lamina consists of parts of the enamel organ, the formation of a niche labially and lingually for fusio subtotalis and partialis confirms that the fusion of the enamel organs in these two forms is only partial, whilst the lack of niches in fusio totalis is in agreement with complete fusion.

The most constant types with reference to outlines and greatest diameters are to be found with the lighter degrees of fusion, all the germs with fusio partialis and most of those with fusio subtotalis being H-shaped and having their greatest diameters transversally. With total fusion the outline is more variable, and all types are represented. It is a remarkable feature in a material comprising so many malformed or anomalous organ germs, that only 18.5 % show mean to heavy asymmetry and not less than 62.3 % are "symmetrical". This tendency to symmetry, even with fusio totalis, can possibly be taken as evidence that the cause of malformation is of a fundamental nature, and that the processes which lead to such a "regular" organ transformation begin very early, namely at the point where the development of the organ is initiated. A change in developmental processes at a later stage would hardly give such uniform heavy changes. One of the most interesting results of this investigation is, that morphodifferentiation in fusio dentium can be considered complete as "anomalously" fused germs are not formed. They differ in shape and size from normal incisor germs, but the special form towards

which the development of the individual germ proceeds, will apparently be attained just as a normal germ attains its characteristic form. The original morphological plan is followed, apparently without fortuitous processes causing changes on the way.

Histodifferentiation and incipient hard tissue formation also seem to proceed normally, as far as can be ascertained on the basis of the available material, which has only been subject to standard histological investigations. The various types of fusio dentium reach a stage of development which by and large corresponds to that of normal germs of the same age. The development of the surrounding tissues and of the incisor germs at the end of embryonic life both suggest that a further post-natal tooth development could proceed, if only it were possible to keep exencephalic animals alive after birth.

#### SUMMARY

A description is given of fused upper incisor germs in 130 mouse embryos with exencephaly induced by vitamin A overdosage. Three degrees of fusion are distinguished: fusio partialis, subtotalis and totalis. On the basis of histological frontal sections, the *outline* of the incisor germs is summarized for these three types of fusio dentium, four shapes being distinguished: rectangular, trapezial, triangular, and H-shaped. Trapezial germs are commonest with fusio totalis and H-shaped germs with fusio subtotalis and partialis. The number of "*symmetrical*" and "*asymmetrical*" germs is given. Symmetrical germs dominate with all types of fusio dentium. The *greatest diameters* of the germs in frontal sections may be transversal, vertical or oblique. Sometimes the transversal and vertical diameters are equal.

On the basis of wax plate reconstructions a morphological description of one normal incisor germ and one representative of each of the three forms of fusio dentium is given. The models also include the epithelium in the roof of the oral cavity opposite the incisors. An account is given of the considerable changes undergone by the epithelial relief in fusio dentium both on the free oral surface and on the connective tissue-covered basal surface. The "*dental lamina*" is an epithelial plate, mainly consisting of the incisal part of the reticular layer and the outer enamel epi-

thelium. In fusio partialis and subtotalis, niches are seen labially and lingually on the lamina as evidence of incomplete fusion.

On the basis of reconstructions the pulps of the same germs are described. The pulp in fusio totalis exhibits, in contrast to the exterior outline of the germ, signs of cleavage. This is particularly clear at the incisal end. A normal tooth germ has incisally a single rounded depression surrounded by a sharp edge, but in all degrees of fusio dentium two depressions are present. In fusio totalis they are separated by a median crest. The labial and lingual surfaces of the pulp have grooves, which are not found on the exterior surface of the germ. It is discussed whether fusio dentium arises as a consequence of lack of space in the primordial jaw or whether fusion is an independent process essentially uninfluenced by local factors. The latter possibility seems the most likely. One of the most interesting conclusions from this investigation is that *morphodifferentiation* in fusio dentium can be considered complete. This is apparent from the large number of symmetrical germs and the few "anomalous" fusions. The processes which lead to fusion, must therefore be assumed to start early and to be of a fundamental nature.

#### RÉSUMÉ

#### MALFORMATIONS CONGÉNITALES DES INCISIVES SUPÉRIEURES CHEZ DES EMBRYONS DE SOURIS EXENCÉPHALES PAR SUITE D'HYPERVITAMINOSE A

##### II. MORPHOLOGIE DES INCISIVES SUPÉRIEURES COALESCENTES

L'auteur décrit la fusion des germes d'incisives supérieures chez 130 embryons de souris présentant une exencéphalie produite par un surdosage de vitamine A. On distingue trois degrés: fusion partielle, fusion subtotale et fusion totale. En se basant sur des coupes histologiques frontales, le contour des germes des incisives pour ces trois types de fusion dentaire est ramené à quatre formes différentes: rectangulaire, en forme de trapèze, triangulaire et en forme de H. Les germes en forme de trapèze sont les plus fréquents dans les cas de fusion totale, et les germes en forme de H dans les cas de fusion subtotale ou partielle. Le nombre de germes "*symétriques*" et "*asymétriques*" est indiqué. Les germes symétriques dominent dans tous les types de fusion

dentaire. Le *diamètre maximum* des germes dans les coupes frontales peut être transversal, vertical ou oblique. Parfois le diamètre transversal et le diamètre vertical sont égaux.

En se basant sur des reconstructions en plaque de cire, l'auteur donne une description morphologique d'un germe normal d'incisive et d'un exemple de chacune des trois formes de fusion dentaire. Les modèles comprennent aussi l'épithélium du plafond de la cavité buccale en face des incisives. L'auteur donne un compte-rendu des changements considérables survenus dans le relief de l'épithélium dans la fusion dentaire, tant sur la surface buccale libre que sur la surface basale couverte de tissu conjonctif. La "lame dentaire" est une plaque épithéliale constituée principalement par la partie incisive de la pulpe de l'émail et l'épithélium adamantin externe. Dans la fusion partielle et subtotalale, on observe du côté vestibulaire et du côté lingual sur la lame des niches indiquant la fusion incomplète.

En se basant sur des reconstructions, l'auteur décrit les pulpes de ces mêmes germes. Dans la fusion totale, la pulpe, en contraste avec le contour extérieur du germe, présente des signes de division. Ce fait est particulièrement net à l'extrémité incisive. Un germe dentaire normal présente du côté incisif une dépression arrondie unique, limitée par un rebord aigu, mais dans tous les cas de fusion dentaire, il y a deux dépressions. Dans la fusion totale, elles sont séparées par une crête médiane. La face vestibulaire et la face linguale de la pulpe présentent des sillons qu'on ne retrouve pas à la surface extérieure du germe. L'auteur présente une discussion sur la raison pour laquelle la fusion dentaire se produit: est-ce la conséquence du manque de place dans la mâchoire primitive, ou est-ce un processus autonome, essentiellement indépendant des facteurs locaux? Cette dernière possibilité semble la plus vraisemblable. Une des conclusions les plus intéressantes de cette étude est que la *différenciation morphologique* dans la fusion dentaire peut être considérée comme complète. Cela ressort du grand nombre de germes symétriques et du petit nombre de fusions "anormales". Le processus conduisant à la fusion doit donc débiter très tôt et être de nature fondamentale.

## ZUSAMMENFASSUNG

## ANGEBORENE MISSBILDUNGEN DER OBEREN SCHNEIDEZÄHNE IN EXENCEPHALEN MÄUSEEMBRYONEN DURCH ÜBERDOSIERUNG MIT A-VITAMIN VERURSACHT

## II. MORPHOLOGIE DER VERSCHMOLZENEN ZAHNANLAGEN

Es wird eine Beschreibung gegeben von verschmolzenen Schneidezahnanlagen in dem Oberkiefer von 130 Mäuseembryonen mit Exencephalie, verursacht durch Überdosierung mit Vitamin A. Es wird zwischen drei Graden von Verschmelzung unterschieden: fusio partialis, subtotalis und totalis. Auf Grund histologischer Frontalschnitte wird eine Übersicht über den Umkreis der Zahnanlagen der drei Grade von fusio dentium gegeben, indem man vier Formen unterscheidet: rektangulär, trapezförmig, dreieckig und H-förmig. Trapezförmige Anlagen sind am häufigsten bei fusio totalis und H-förmige Anlagen bei fusio subtotalis und partialis. Die Anzahl der "symmetrischen" und "asymmetrischen" Anlagen wird angegeben. Symmetrische Anlagen dominieren bei allen Graden von fusio dentium. *Der grösste Diameter* der Anlagen an Frontalschnitten kann transversal, vertikal oder schräg sein. Zuweilen sind der transversale und der vertikale Diameter gleich gross.

Auf Grund der Wachsplattenrekonstruktionen wird eine morphologische Beschreibung einer normalen Schneidezahnanlage und eines Vertreters jeder der drei Grade von fusio dentium gegeben. Die Modelle umfassen zugleich das Epithel an der Decke der Mundhöhle an den Schneidezähnen. Die bedeutenden Veränderungen, die das Epithelrelief bei fusio dentium erfährt, sowohl an der freien oralen Fläche als auch an der von Bindegewebe gedeckten basalen Fläche, werden erklärt. "Die Zahnleiste" ist eine Epithelplatte, die hauptsächlich aus dem inzisalen Teil von stratum reticulare und äusserem Schmelzepithel besteht. Bei fusio partialis und subtotalis sieht man eine Nische labial und lingual an der Zahnleiste als Zeichen einer unvollständigen Verschmelzung.

Auf Grund der Rekonstruktionen wird die Pulpa in denselben Zahnanlagen beschrieben. Die Pulpa bei fusio totalis zeigt im Gegensatz zu der äusseren Kontur der Anlage Zeichen der Spaltung. Dies geht besonders deutlich bei Betrachtung des inzisalen Endes hervor. Eine normale Zahnanlage trägt inzisal eine ein-

zelne abgerundete Vertiefung von einer scharfen Kante umgeben; bei allen Graden von fusio dentium gibt es aber zwei Vertiefungen. Sie sind bei fusio totalis durch einen medianen Kamm getrennt. Die labialen und lingualen Flächen der Pulpa haben Furchen, die man an der äusseren Oberfläche der Anlagen nicht findet.

Es wird diskutiert, ob fusio dentium als Folge von Platzmangel in dem primitiven Kiefer entsteht, oder ob die Verschmelzung ein selbständiger Prozess ist, der nicht wesentlich von örtlichen Faktoren beeinflusst wird. Die zweite Möglichkeit scheint die wahrscheinlichere. Es ist eine der interessantesten Konklusionen der Untersuchung, dass *die Morphodifferenzierung* bei fusio dentium als "vollständig" betrachtet werden kann. Es geht aus der grossen Anzahl symmetrischer Anlagen und den wenigen "anormalen" Verschmelzungen hervor. Man muss deshalb annehmen, dass die Prozesse, die zum Zusammenschmelzen führen, früh anfangen und fundamentaler Natur sind.

## REFERENCES

- Knudsen, P. A.*, 1965: Congenital malformations of upper incisors in exencephalic mouse embryos, induced by hypervitaminosis A. I. Types and frequency. *Acta odont. scand.* 23: 71—89 and 16 plates.
- Pourtois, M.*, 1961: Contribution à l'étude des Bourgeons dentaires chez la Souris. I. Périodes d'Induction et de Morphodifférenciation. *Arch. Biol. (Liège)* 72 (1): 17—95.

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## PLATES

## List of abbreviations

- A = apical end.
- Ao = apical root opening.
- C = crest (elevation).
- D = distal surface.
- DL = "dental lamina".
- E = epithelium of the roof of the oral cavity.
- F = fossa.
- I = incisal end.
- IN = incisura.
- L = labial surface.
- LI = lingual surface.
- M = mesial surface.
- N = niche of "dental lamina".
- S = sulcus (depression).
- SP = septal cartilage of the nasal cavity.
- TR = tooth germ removed.

**Plate 1.**

*Fig. 1.* Exencephalic mouse embryo (91 d 1/3). Frontal section near the apical opening ( $\times 63$ ).

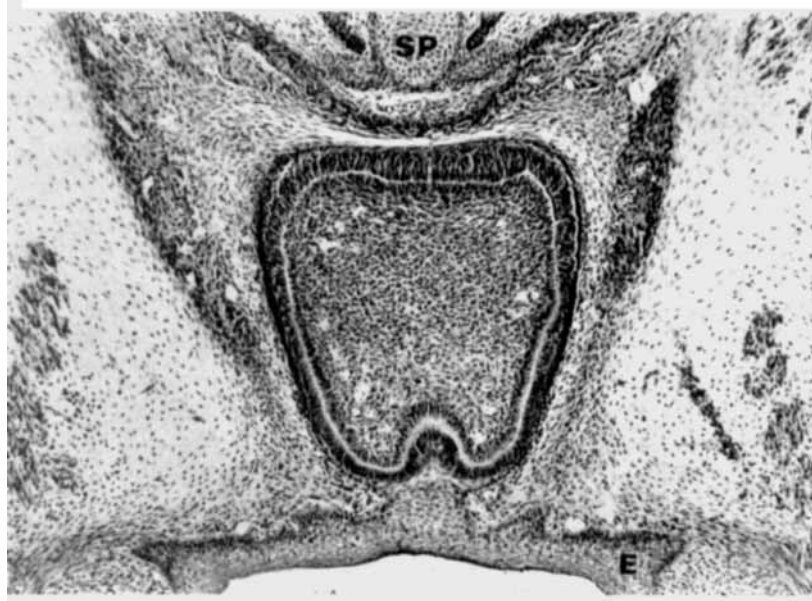
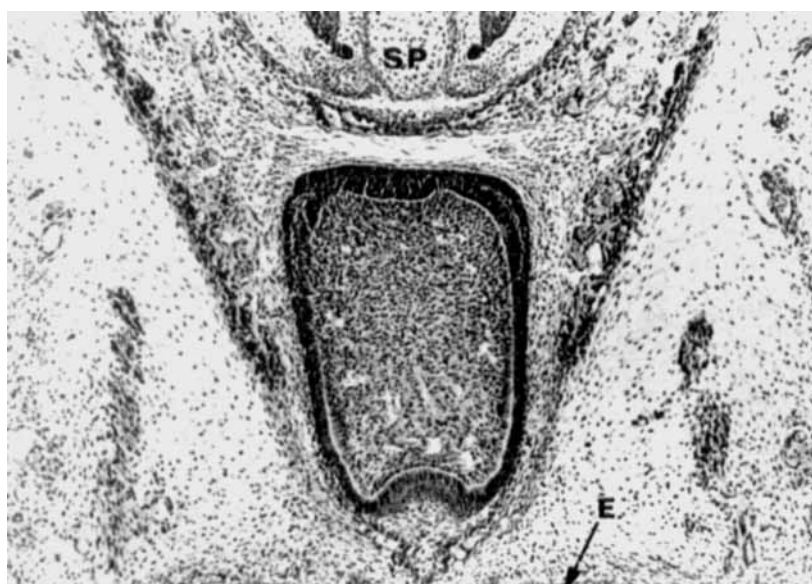
FUSIO TOTALIS.

Outline: rectangular. "Symmetry". Greatest diameter: vertical.

*Fig. 2.* Exencephalic mouse embryo (146 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

FUSIO TOTALIS.

Outline: trapezoidal. "Symmetry". Greatest diameter: vertical.



## **Plate 2.**

*Fig. 3.* Exencephalic mouse embryo (236 d 1/3). Frontal section near the apical opening ( $\times 63$ ).

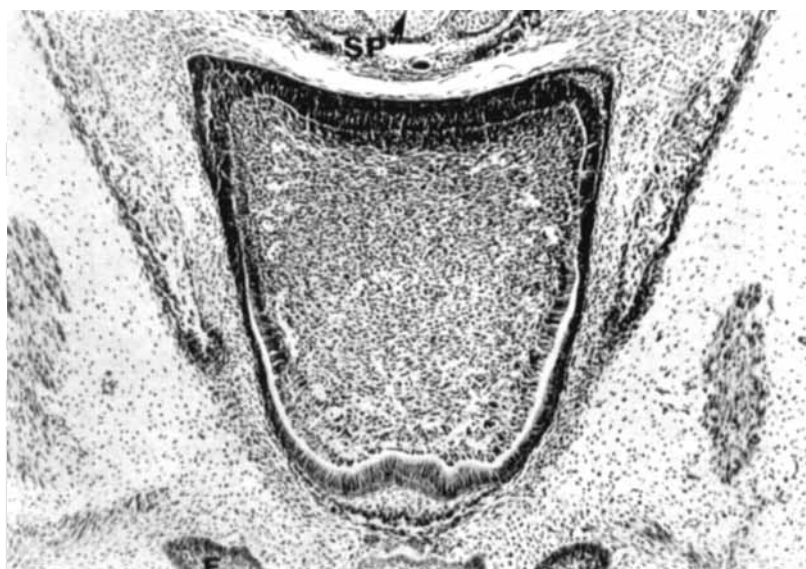
FUSIO TOTALIS.

Outline: trapezoidal. "Symmetry". Vertical and transversal diameters are nearly equal.

*Fig. 4.* Exencephalic mouse embryo (37 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

FUSIO TOTALIS.

Outline: trapezoidal. Light asymmetry. Greatest diameter: vertical.



### **Plate 3.**

*Fig. 5.* Exencephalic mouse embryo (154 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

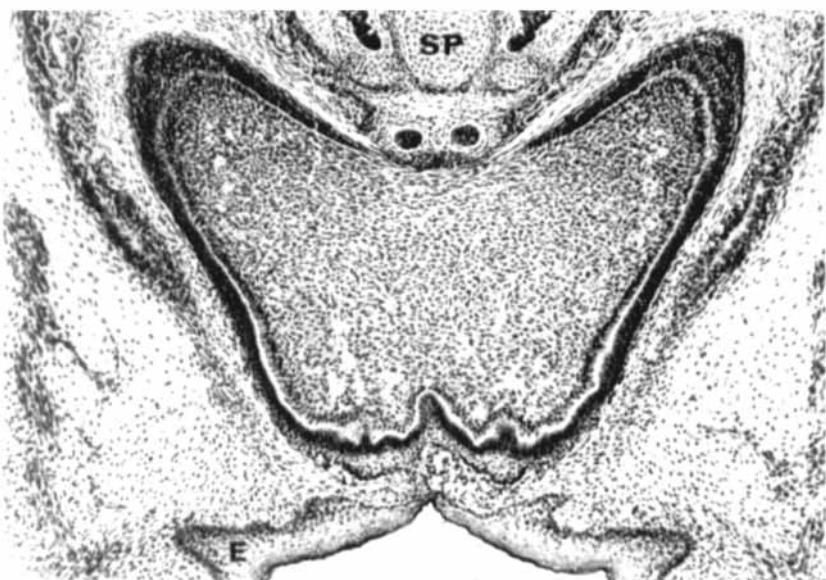
FUSIO TOTALIS.

Outline: trapezial. Light asymmetry. Greatest diameter: transversal.

*Fig. 6.* Exencephalic mouse embryo (198 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

FUSIO SUBTOTALIS.

Outline: trapezial. "Symmetry". Greatest diameter: transversal.



#### **Plate 4.**

*Fig. 7.* Exencephalic mouse embryo (119 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

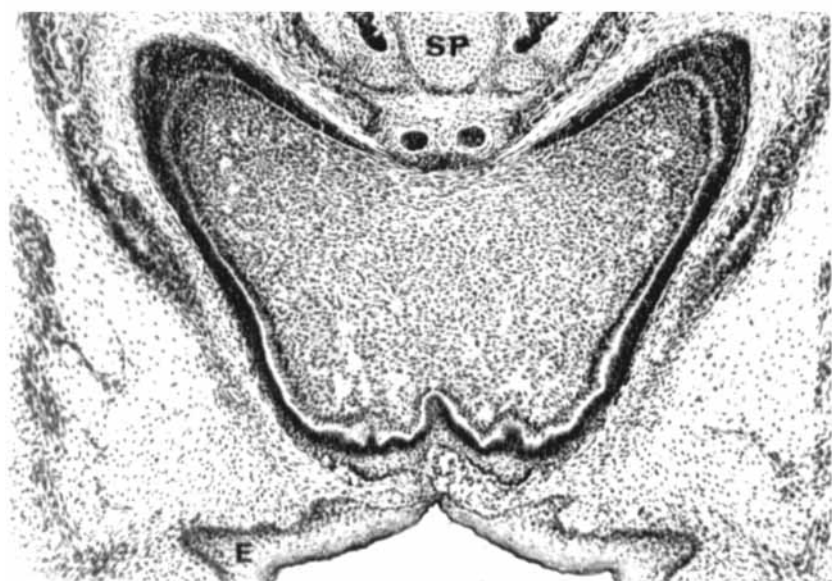
FUSIO SUBTOTALIS.

Outline: trapezial. Mean asymmetry. Greatest diameter: transversal.

*Fig. 8.* Exencephalic mouse embryo (43 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

FUSIO TOTALIS.

Outline: triangular. Heavy asymmetry. Greatest diameter: oblique.



## Plate 5.

*Fig. 9.* Exencephalic mouse embryo (33 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

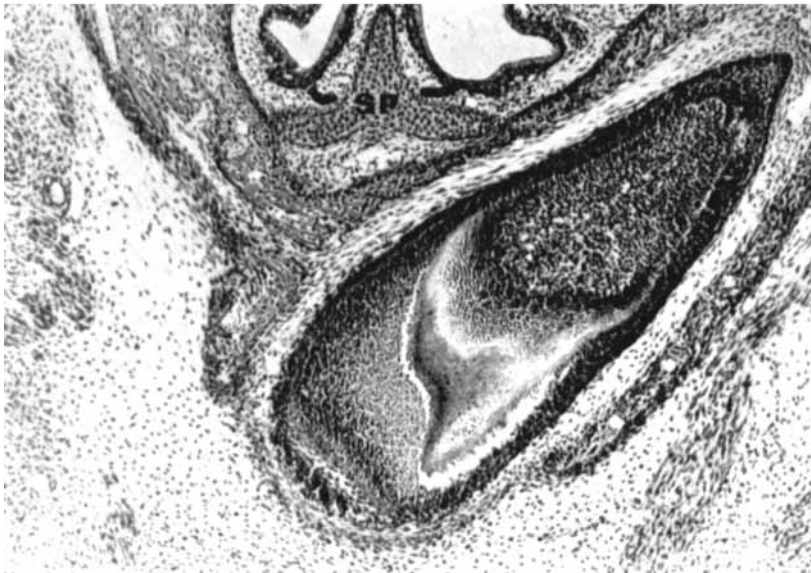
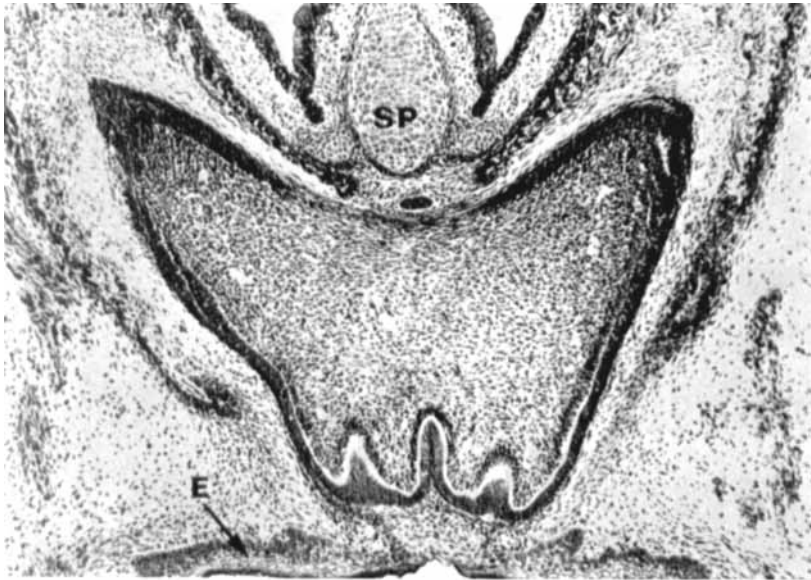
FUSIO PARTIALIS.

Outline: H-shaped. Light asymmetry. Greatest diameter: transversal.

*Fig. 10.* Exencephalic mouse embryo (106 d 1/2). Frontal section near the apical opening ( $\times 63$ ).

FUSIO PARTIALIS.

Outline: H-shaped. Light asymmetry. Greatest diameter: transversal.



## Plate 6.

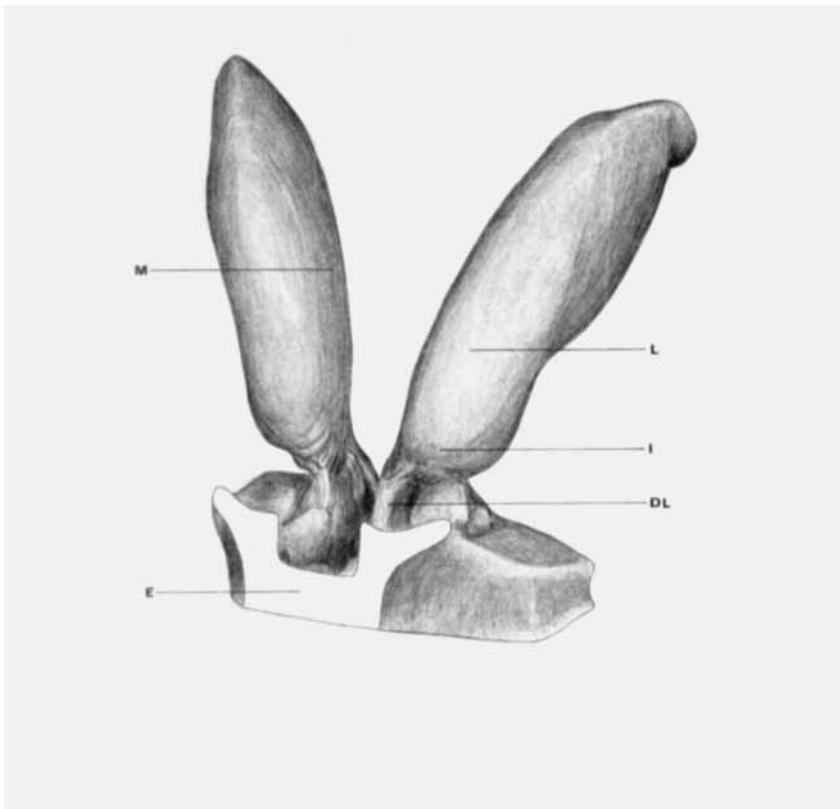
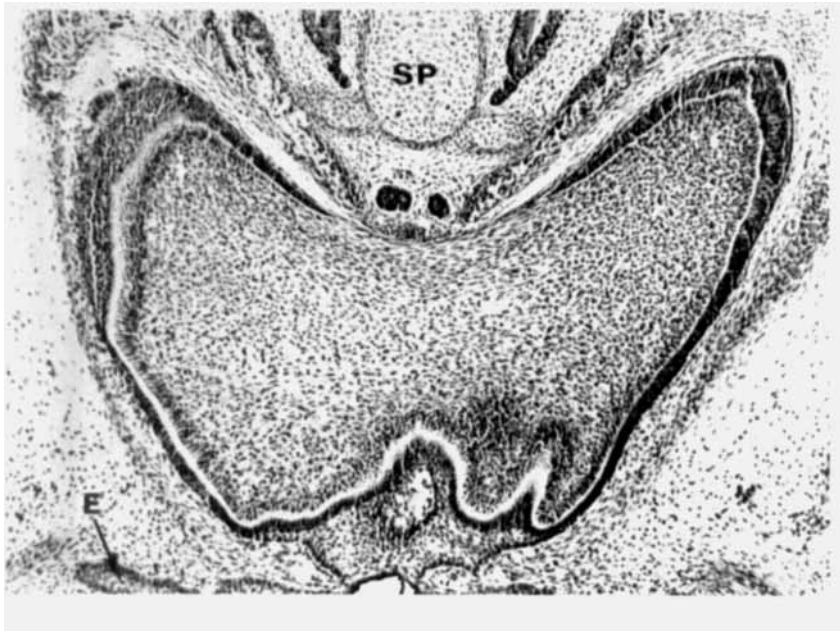
*Fig. 11.* Exencephalic mouse embryo (152 d 1/3). Frontal section near the apical opening ( $\times 63$ ).

FUSIO PARTIALIS.

Outline: H-shaped. Mean to heavy asymmetry. Greatest diameter: transversal.

*Figs. 12-16.* Normal mouse embryo. Drawings of a model of the upper incisor germ and oral epithelium.

*Fig. 12.* Labial (and distal) view.

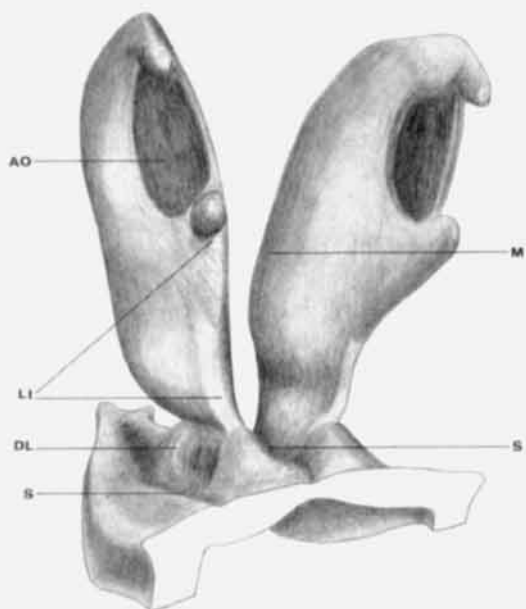
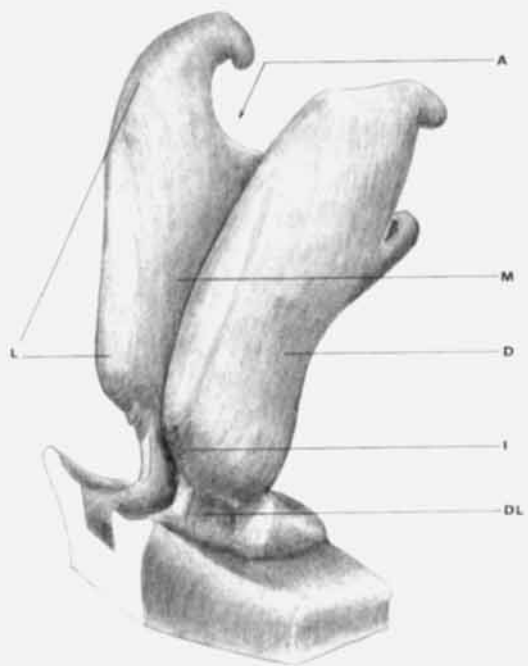


**Plate 7.**

Figs. 12-16 (continued).

*Fig. 13.* Distal (and labial) view.

*Fig. 14.* Lingual (and distal) view.



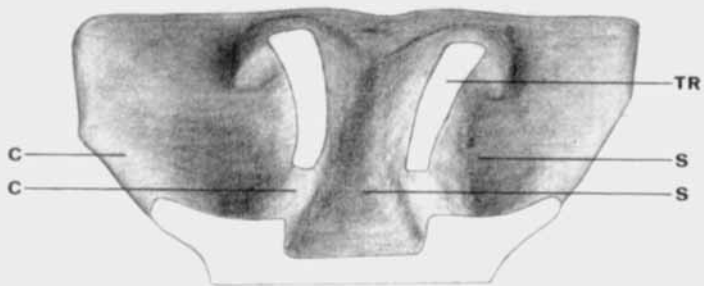
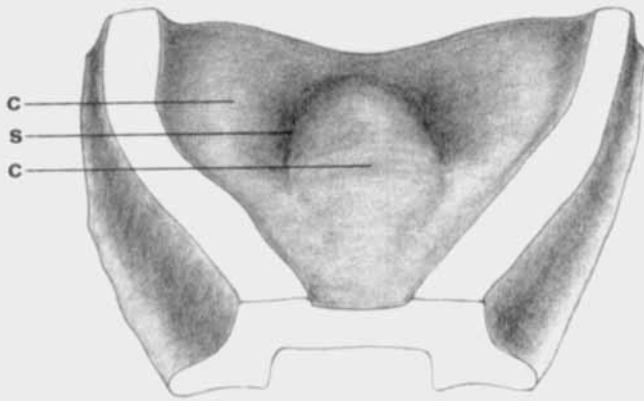
**Plate 8.**

*Figs. 12-16 (continued).*

*Fig. 15.* Oral epithelium. Oral view.

*Fig. 16.* Oral epithelium. Basal view. The incisor germs have been removed along their connection with the epithelium.

# QUESTION



# ANSWER

**Plate 9.**

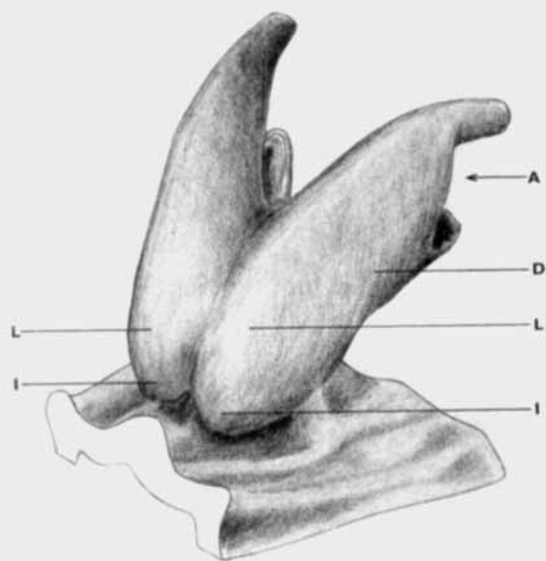
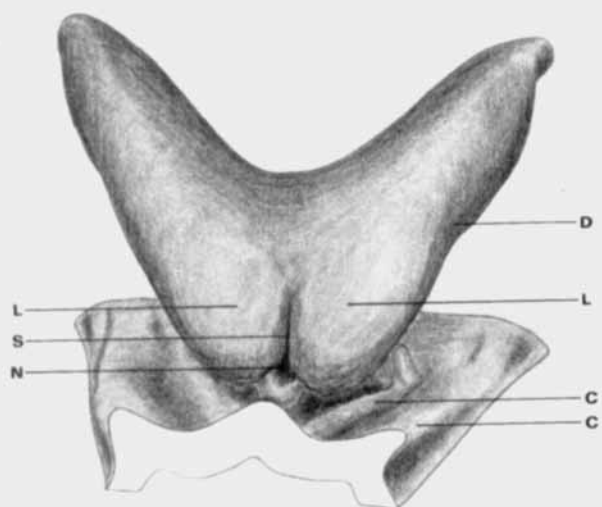
*Figs. 17-20.* Exencephalic mouse embryo.

FUSIO PARTIALIS.

Drawings of a model of the upper incisor germ and oral epithelium.

*Fig. 17.* Labial view.

*Fig. 18.* Distal and labial view.

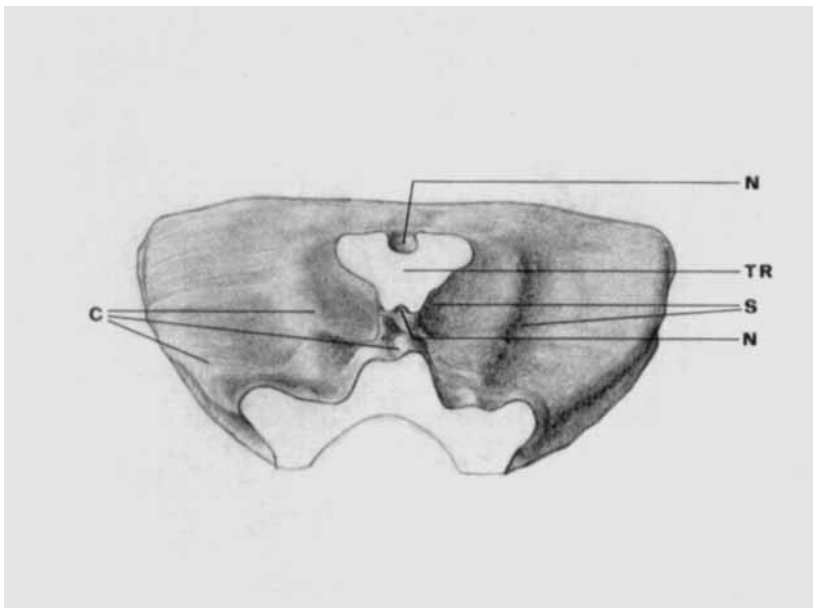
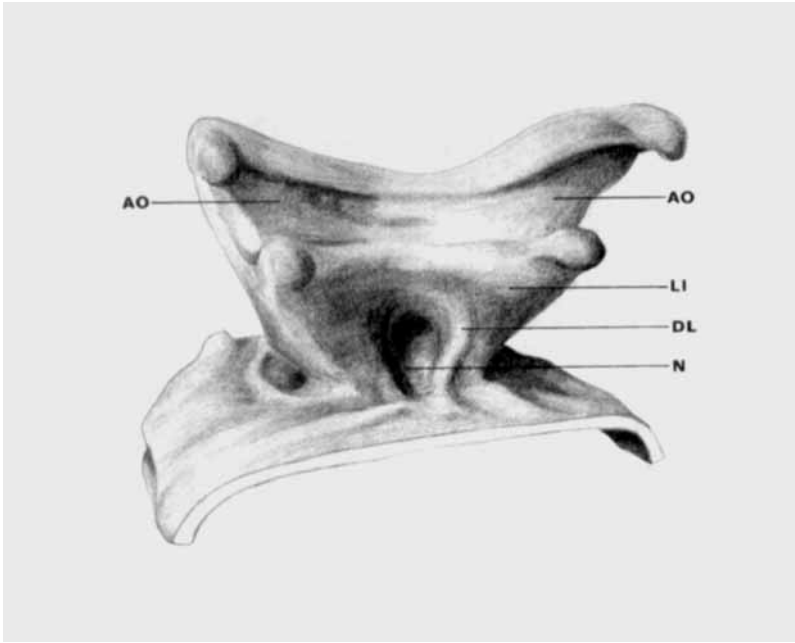


**Plate 10.**

Figs. 17-20 (continued).

*Fig. 19.* Lingual (and distal) view.

*Fig. 20.* Oral epithelium. Basal view. The incisor germ has been removed along its connection with the epithelium.



## **Plate 11.**

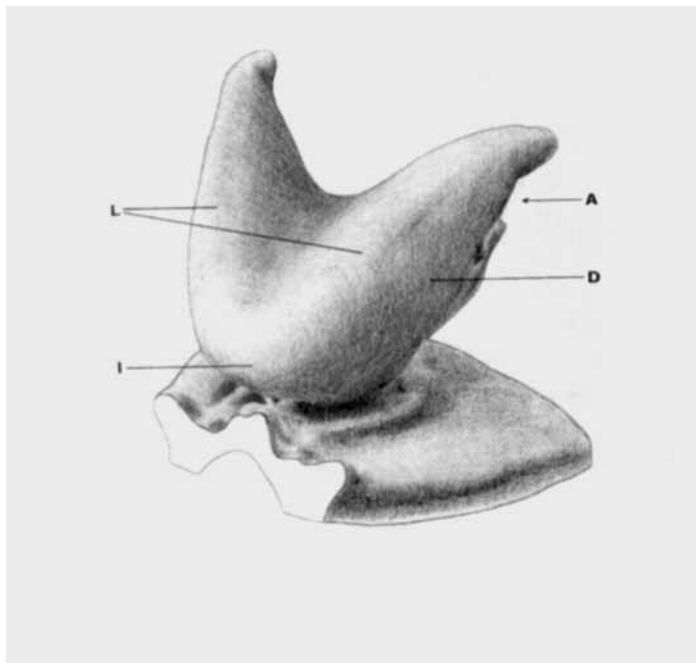
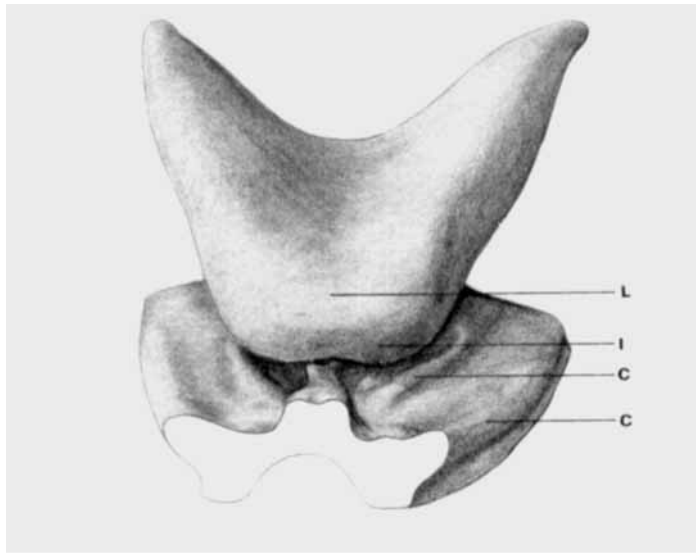
*Figs. 21-24.* Exencephalic mouse embryo.

FUSIO SUBTOTALIS.

Drawings of a model of the upper incisor germ and oral epithelium.

*Fig. 21.* Labial view.

*Fig. 22.* Distal and labial view.

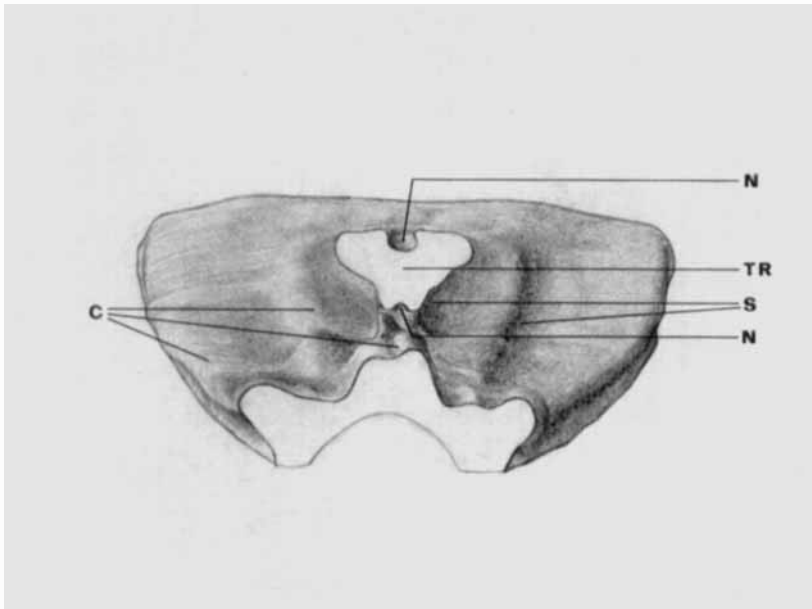
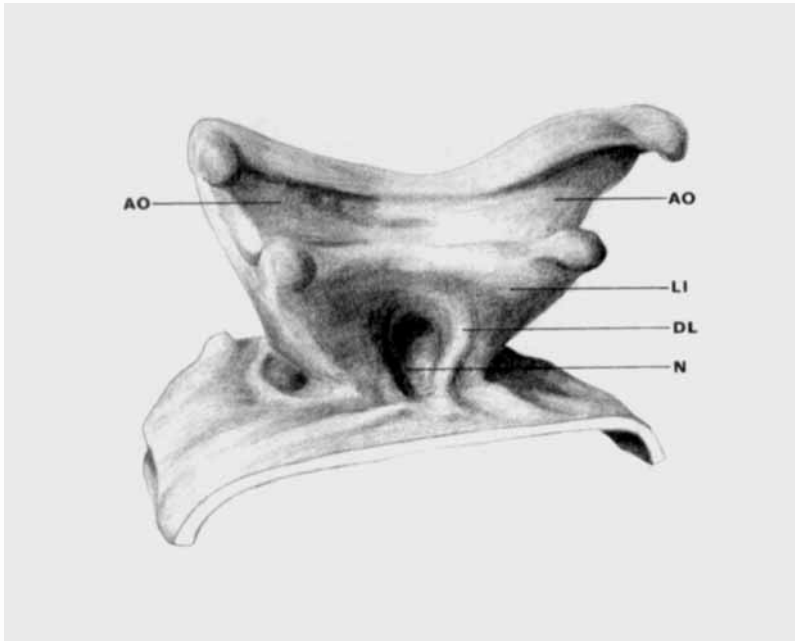


## Plate 12.

Figs. 21-24 (continued).

*Fig. 23.* Lingual view.

*Fig. 24.* Oral epithelium. Basal view. The incisor germ has been removed along its connection with the epithelium.



**Plate 13.**

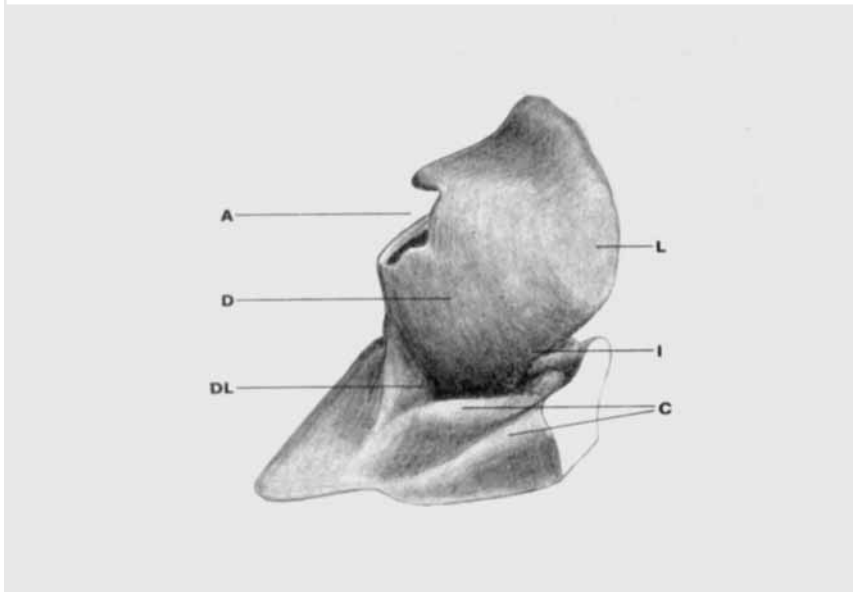
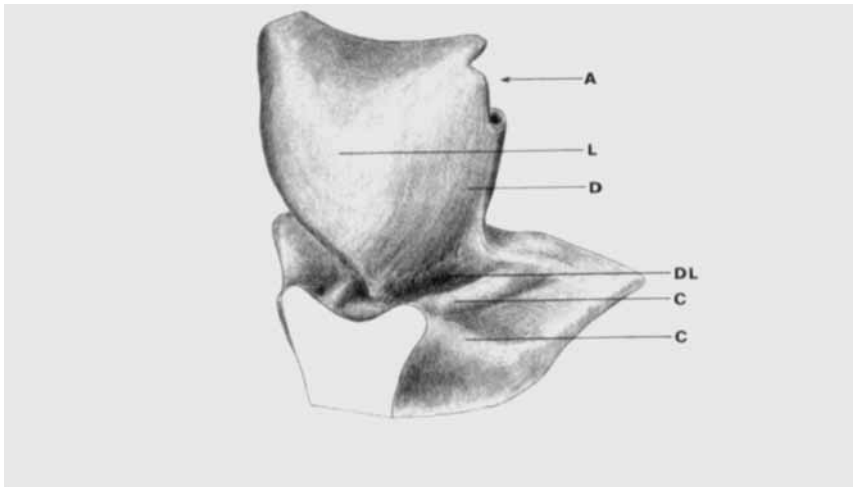
*Figs. 25-28.* Exencephalic mouse embryo.

FUSIO TOTALIS.

Drawings of a model of the upper incisor germ and oral epithelium.

*Fig. 25.* Labial (and distal) view.

*Fig. 26.* Distal (and labial) view.

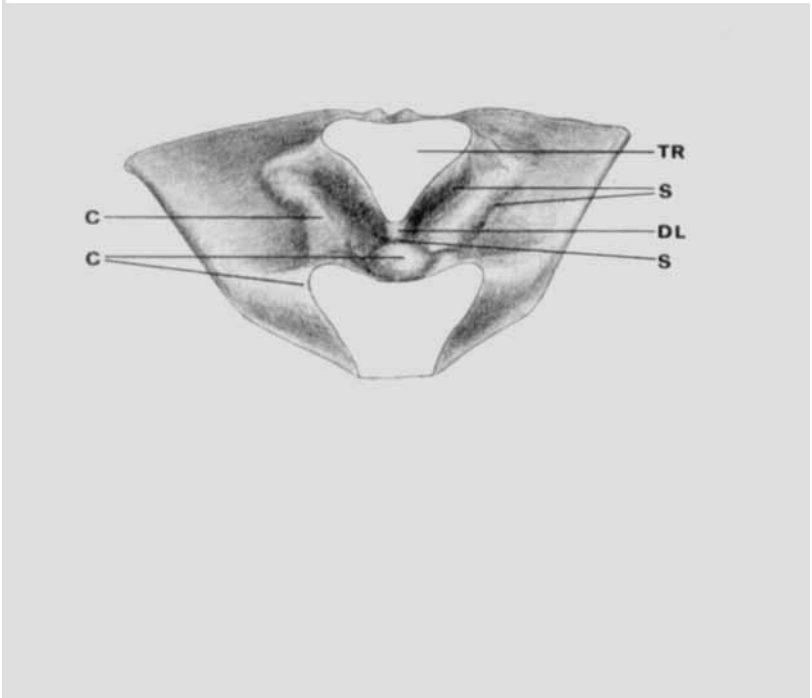
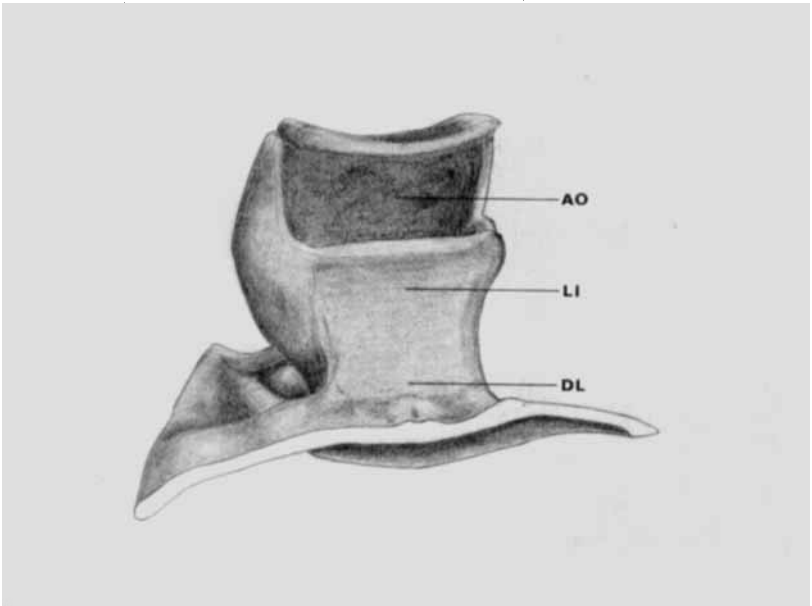


## Plate 14.

Figs. 25-28 (continued).

*Fig. 27.* Lingual (and distal) view.

*Fig. 28.* Oral epithelium. Basal view. The incisor germ has been removed along its connection with the epithelium.

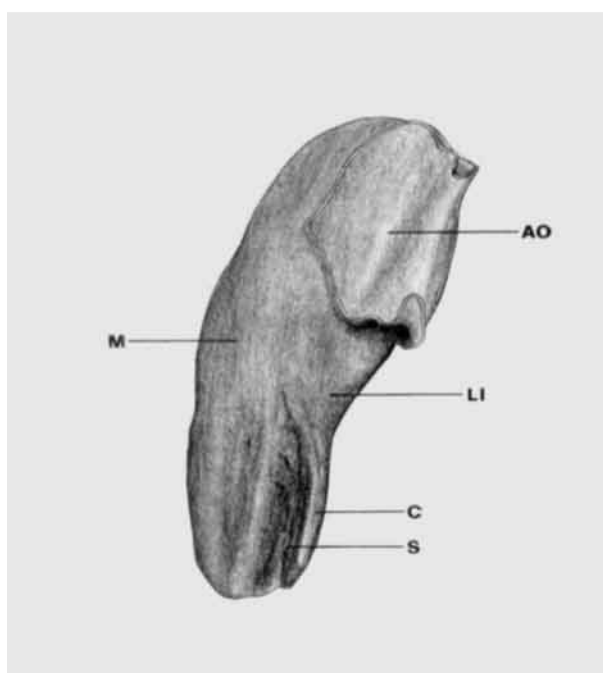
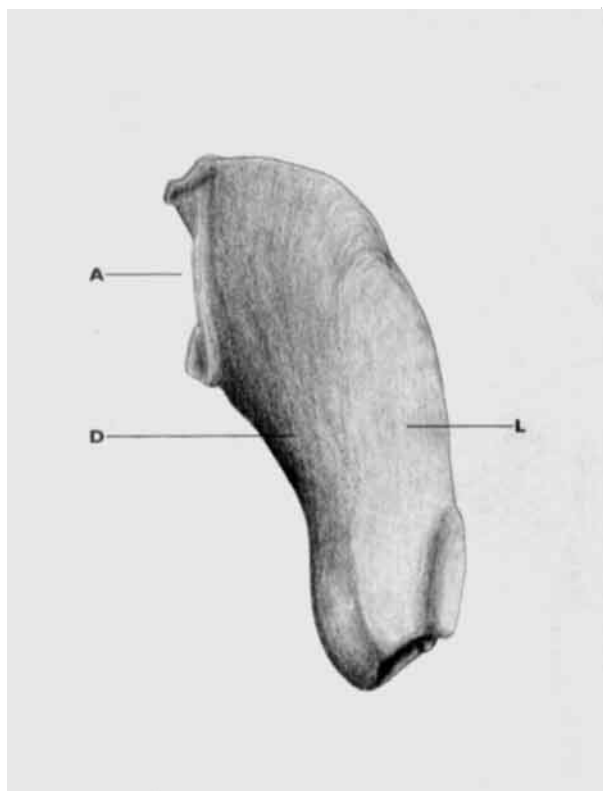


**Plate 15.**

*Figs. 29-30.* Drawings of a model of the pulp in one (the right) of the normal upper incisor germs, shown in *figs. 12-11.*

*Fig. 29.* Labial and distal view.

*Fig. 30.* Lingual and mesial view.



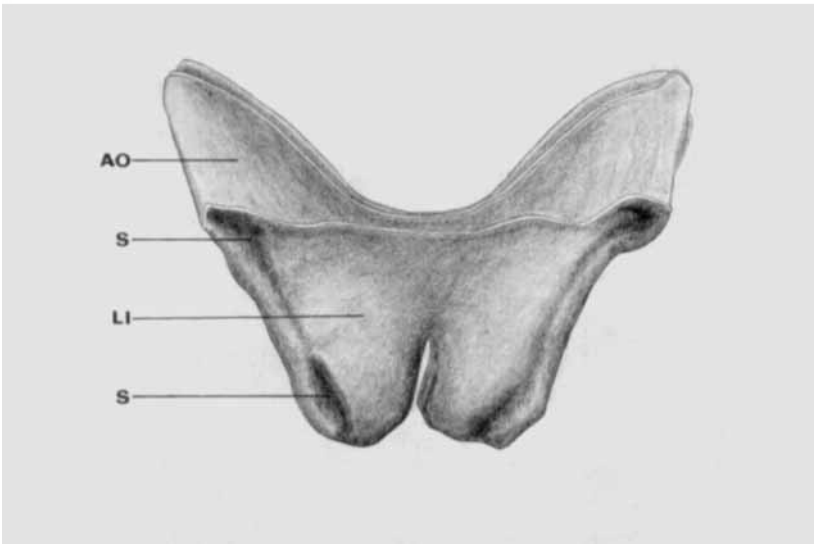
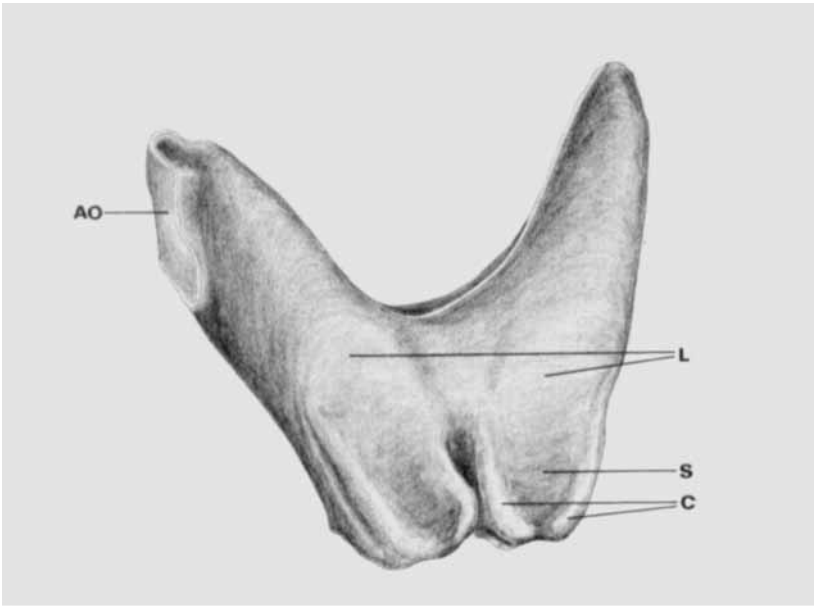
## Plate 16.

*FUSIO PARTIALIS.*

*Figs. 31-32.* Drawings of a model of the pulp in the incisor germ, shown in *figs.* 17-19.

*Fig. 31.* Labial (and distal) view.

*Fig. 32.* Lingual view.



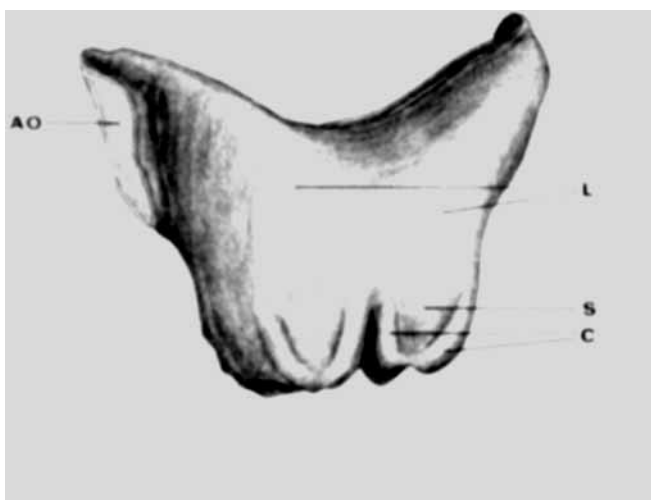
## Plate 17.

FUSIO SUBTOTALIS.

*Figs. 33-34.* Drawings of a model of the pulp in the incisor germ, shown in figs. 21-23.

*Fig. 33:* Labial (and distal) view.

*Fig. 34:* Lingual view.



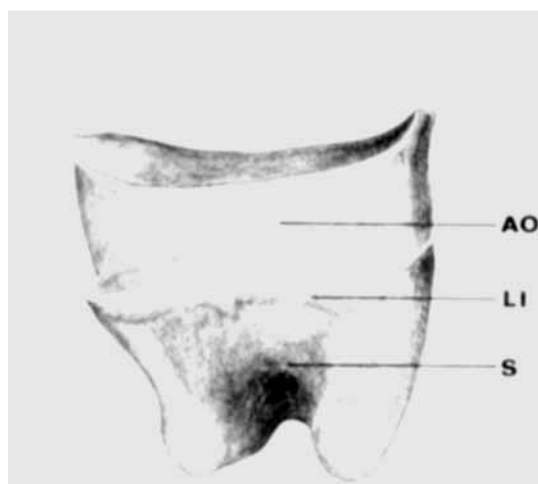
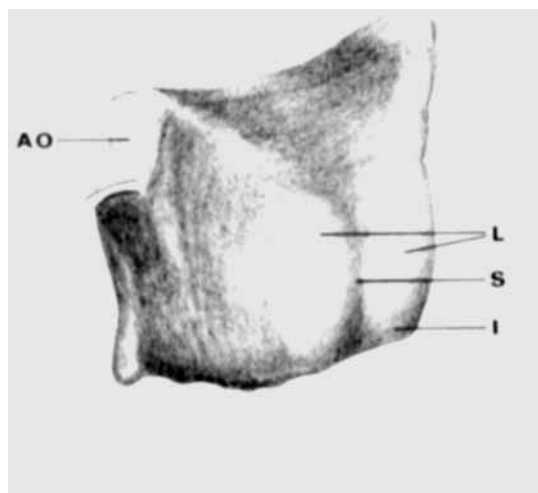
## Plate 18.

FUSIO TOTALIS.

*Figs. 35-36.* Drawings of a model of the pulp in the incisor germ, shown in figs. 25-27.

*Fig. 35.* Labial and distal view.

*Fig. 36.* Lingual (and distal) view.

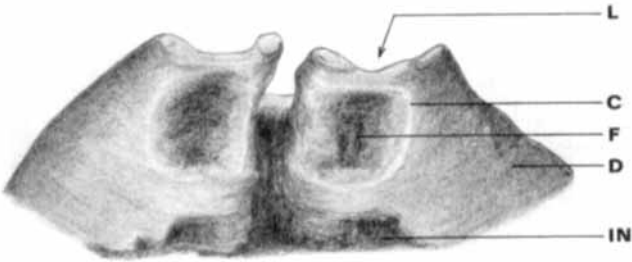
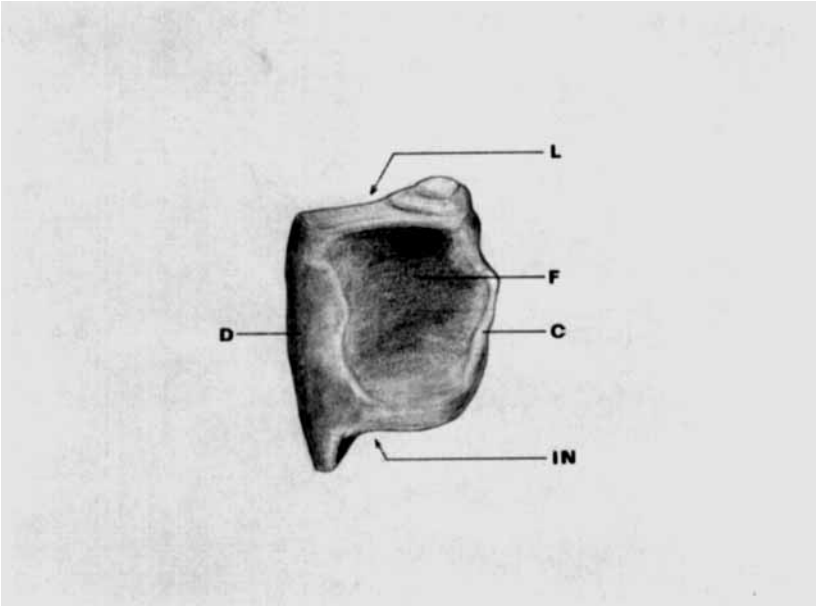


**Plate 19.**

*Figs. 37-40.* Drawings of the incisal ends of the pulp models.

*Fig. 37.* Normal incisor germ.

*Fig. 38.* Fusio partialis.

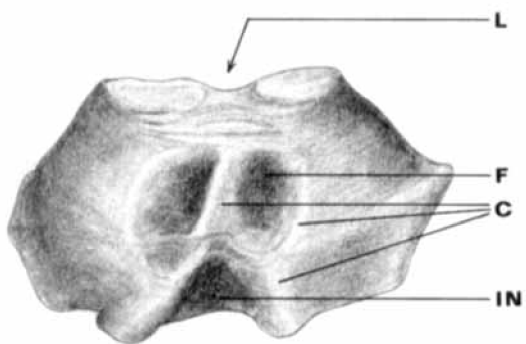
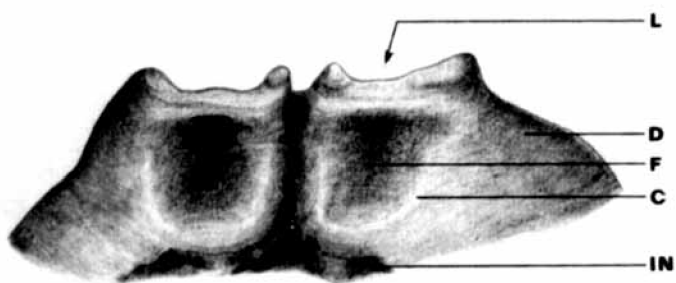


**Plate 20.**

Figs. 37-40 (continued).

*Fig. 39.* Fusio subtotalis.

*Fig. 40.* Fusio totalis.

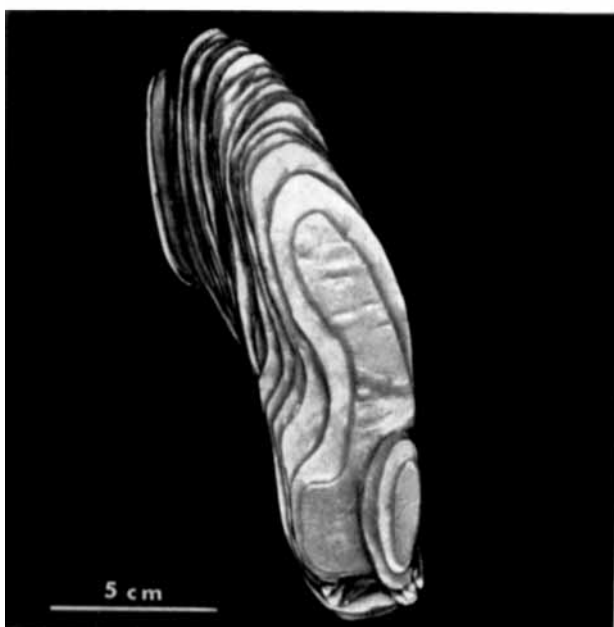
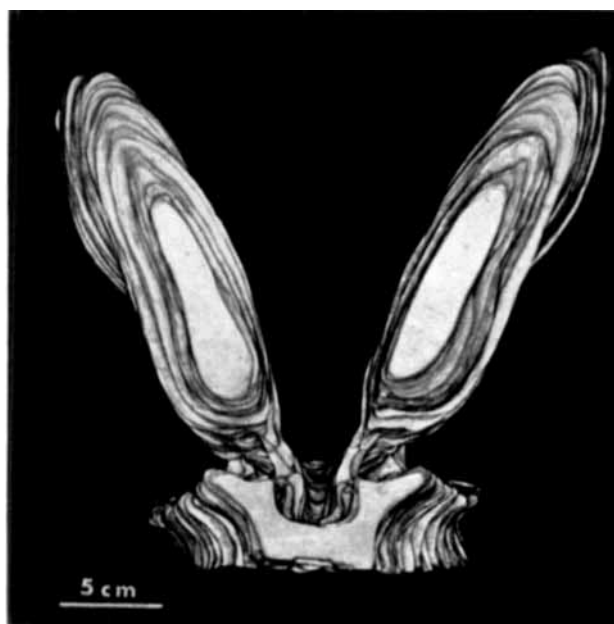


## Plate 21.

*Figs. 41-42.* Normal mouse embryo, 19 days (29 d I/4). Photographs of wax plate reconstructions.

*Fig. 41.* Upper incisor germs and oral epithelium; labial view.

*Fig. 42.* Pulp in the right incisor germ; labial (and distal) view.



## **Plate 22.**

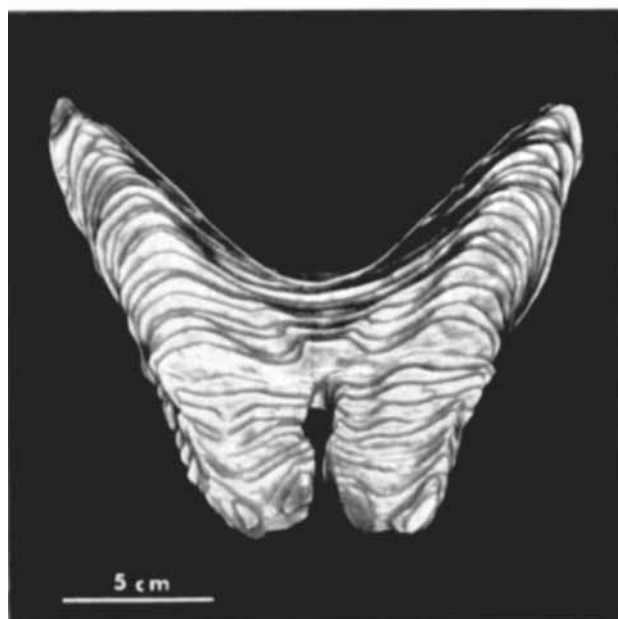
*Figs. 13-14.* Exencephalic mouse embryo, 19 days (166 d 1/3).

FUSIO PARTIALIS.

Photographs of wax plate reconstructions.

*Fig. 13.* Upper incisor germ and oral epithelium; labial and distal view.

*Fig. 14.* Pulp; labial view.



**Plate 23.**

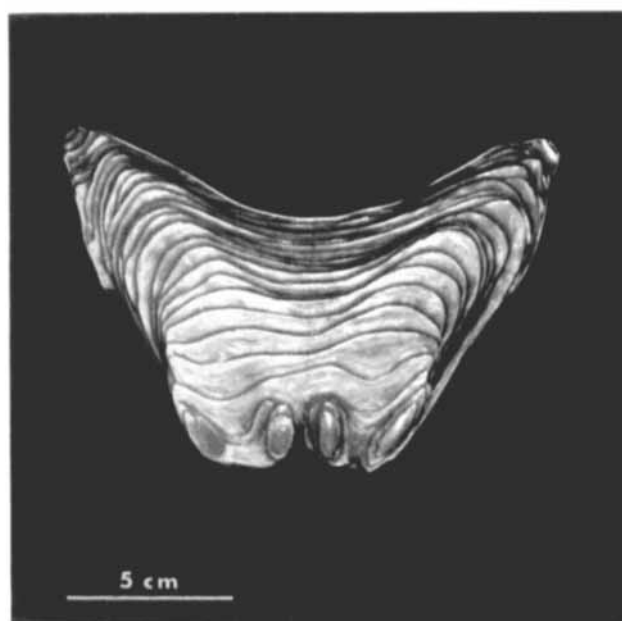
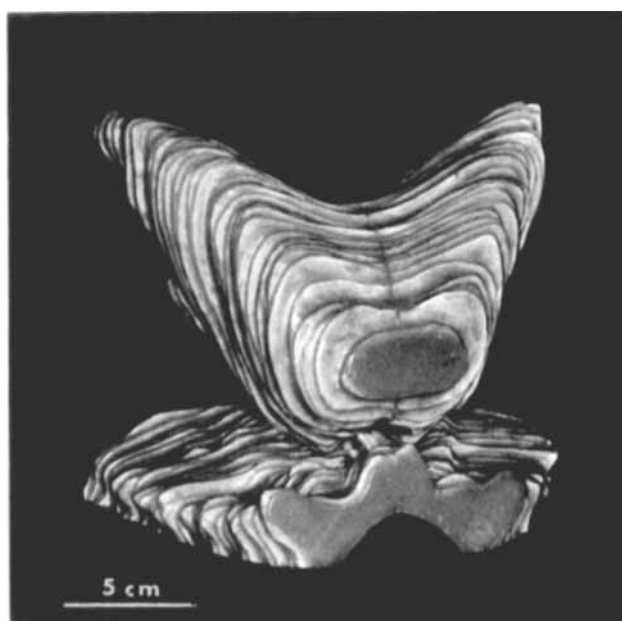
*Figs. 45-46.* Exencephalic mouse embryo, 18 days (92 d I/3).

FUSIO SUBTOTALIS.

Photographs of wax plate reconstructions.

*Fig. 45.* Upper incisor germ and oral epithelium; labial and distal view.

*Fig. 46.* Pulp; labial view.



**Plate 24.**

*Figs. 47-48.* Exencephalic mouse embryo, 18 days (189 d 1/2).

FUSIO TOTALIS.

Photographs of wax plate reconstructions.

*Fig. 47.* Upper incisor germ and oral epithelium; labial and distal view.

*Fig. 48.* Pulp; labial view.

