THE EPIPHYSIS OF TELEOSTS AND AMIA.¹

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PREVIOUS to 1882 our knowledge of the epiphysis in fishes was limited to the brief notices of Cuvier ('05), Carus ('14), Gottsche ('35), Stannius ('54) and others, who content themselves with references to its existence and macroscopic appearance. Cattie ('82) carefully describes the external features of the organ in adult Teleosts, Plagiostomes and Ganoids, and speaks in some detail of its histological structure. It consists of a granular matrix in which are embedded round, pear-shaped or bipolar cells, the processes of which anastomose with those of neighboring cells.

Rabl-Rückhard ('82) gives a detailed description of the early stages in the development of the epiphysis in *Salmo salar* and *Salmo fario*, and also shows by figures the development of the organ in embryos between 3.5 mm. and 22.5 mm. in length. Its history in embryos longer than 22.5 mm. does not appear to be known.

During the last ten years the attention of morphologists has been turned to the epiphysis in *Petromyzon* and *Reptilia* to the exclusion of nearly all other forms. Hoffmann ('85) in a paper on the development of *Reptilia* records an observation on the development of the epiphysis in *Salmo salar* and *Salmo fario* to which I shall refer in another part of this paper.

This work was begun at the suggestion of Professor J. E. Reighard with the purpose of completing the history of the development of the epiphysis in Teleosts, and of establishing as accurately as possible its adult histological structure.

¹ Work from the Morphological Laboratory of the University of Michigan, under the direction of Prof. J. E. Reighard, accepted as a thesis for the degree of Master of Science.

In what follows the description of *Salmo* 7 mm. in length is based on the study of living embryos, but has been verified and extended by the examination of sections. In older stages the presence of pigment prevented a study of the living embryo, and the descriptions are therefore based altogether on sections. The description of the organ in other Telosts is taken from living embryos, while in *Amia* it is again based exclusively on sections.

As a fixing reagent, Flemming's stronger solution was found to give satisfactory histological results. In older stages, in order to secure a better penetration of the fixing fluid and in order to overcome the difficulty of cutting the lens, the lateral eyes were removed and only the dorsal part of the head immersed in Flemming's fluid. This part was subsequently stained in toto in carminic acid and then sectioned in paraffin. In order to give the nerve fibres a deeper stain the sections, after being fixed on the slide, were immersed for twenty-four hours in saturated carminic acid in 80% alcohol kept at a temperature of 45° C.

In the study of living embryos the egg membranes were always removed. A piece of fine copper wire about two inches in length was twisted into a loop, the diameter of which was a little less than the diameter of the yolk sac of the embryo. The ends of the wire were then bent in such a way that they formed a support for the loop so that when placed in a flat dish filled with water the loop was raised 1 or 2 mm. from the bottom of the dish. The embryo was taken into a wide-mouthed pipette, held in a vertical position, and forced into the loop tail foremost in such a way that the loop, by constricting the yolk sac, held the embryo firmly in position. By bending the wire supporting the loop the embryo could be brought into any desired position, and any view of the head could be obtained.

I desire here to acknowledge my indebtedness to the United States Commissioner of Fish and Fisheries who on several occasions has had sent to me a very liberal supply of *Salmo* material. I am under equal obligations to the Michigan Fish Commission for a supply of *Coregonus* and *Stizostedion* eggs.

SALMO.¹

Salmo 7 mm. long. — In Salmonidae, as in all other vertebrates, the epiphysis has its origin in the roof of the primary fore-brain just cephalad of the posterior commissure. Two small dorsal evaginations of this brain-roof may be found in the embryos of all the species of *Salmo* that I have studied. In *Coregonus albus* I ('91) have designated them as the posterior and the anterior epiphysial vesicles, and I shall use the same words for the corresponding structures of *Salmo*.

Posterior epiphysial vesicle. — In *Salmo 7 mm. long*, the posterior epiphysial vesicle (Figs. 1, 2, 3 and 4, *E*) is a small, nearly globular evagination in the posterior part of the roof of the primary fore-brain. In its center there is a cavity, the middle of which lies a trifle to the right of the median line of the brain so that the vesicle is turned a little to the right. This cavity has the form of a compressed funnel with concave lateral surfaces, and opens ventrally by its narrower end into a short passage which is common to it and the cavity of the anterior epiphysial vesicle. The lateral walls of the vesicle are biconvex. In their thickest middle portion they are about twice as thick as the dorsal wall at its middle. The dorsal wall is also biconvex and its outer surface has a lesser radius of curvature than its inner surface. The vesicle is thinnest at the junction of its dorsal and lateral walls.

Anterior epiphysial vesicle. — The anterior epiphysial vesicle is a club-shaped or ob-ovoid body (Figs. 1, 2, 3 and 4, *E'*). It lies to the left of the median plane of the brain and close against the posterior vesicle. Its bulk may be estimated at two-thirds that of the anterior vesicle. Its distal end is bent slightly caudad, and its long axis is directed laterad and dorsad so as to form with the dorso-ventral diameter of the posterior vesicle an angle of about 75 degrees. It lies in such a position that in a profile view its anterior border coincides with that of the posterior vesicle. Along its middle there is a narrow cavity which curves in conformity with the anterior border of

¹ *Salmo fontinalis* Mitch. *S. purpuratus*, Pallas, and *S. fario* L.

the vesicle, and opens into the common passage which leads from the brain cavity. This passage, which is median, rises for a distance of .021 mm. and then bifurcates, one branch passing to the right to form the cavity of the posterior vesicle and the other to the left to form the cavity of the anterior vesicle (Fig. 4).

As may be seen in a transverse section the left wall of the posterior vesicle passes directly into the right or dorsal wall of the anterior vesicle, while the right wall of the posterior vesicle and the left wall of the anterior vesicle are each continuous laterally with the brain-roof (Fig. 4). Thus the two vesicles are attached to the brain-roof by a common stalk. These vesicles may have been formed in any one of three ways: (1) They may be thought of as independent and separate outgrowths which have subsequently come to be borne on a common evagination of the brain-roof; (2) it is possible to think of them as formed by the division of an originally single vesicle; (3) it is possible to think of the anterior one as formed by constriction from the posterior. It was, perhaps, under the influence of the latter point of view that Strahl and Martin and Béraneck have described the anterior vesicle of *Lacertilia* as formed at the expense of the posterior. I have not obtained satisfactory sections of embryos younger than that which yielded the section shown in Fig. 4, and if one judges by this figure alone there is little to choose between the three methods of origin mentioned above. In Fig. 3*a* there is shown a view of the roof of the fore-brain in an embryo thirty-seven days old, and in this the two epiphysial vesicles appear as slight and entirely independent elevations of the outer surface of the brain-wall. Beneath each of these elevations is seen a slit-like lumen leading from the brain-cavity toward the outer surface of the brain-wall. These lumina are entirely separate from one another. Unfortunately this observation was made on but one living individual and, owing probably to the rapidity with which the stage is passed through, I was unable to verify it on others.

The brain-roof at the point of union with the stalk of the two vesicles is very much thinner than the adjacent brain-

wall, so that the two epiphysial evaginations rest in a shallow depression of this roof. The epithelium dorsal to the vesicles consists of a single layer of flattened cells (Fig. 4). Between this layer and the brain mesenchyme is always present except just dorsal to the epiphysial vesicles. A section through the epiphysial vesicles parallel to a plane through the middle of the lens of the left eye and through the posterior border of the lens of the right eye passes through the cavities of both vesicles (Fig. 4). Such a section makes an angle of ten degrees with a transverse line.

At a distance of .184 mm. in front of the passage common to the two vesicles there is a small transverse fold of the brain-roof which extends in a postero-ventral direction into the cavity of the primary fore-brain in such a way that the brain-roof between it and the epiphysial vesicles has the appearance of having been evaginated in a dorso-cephalic direction (Fig. 2). Rabl-Rückhard has indicated this fold as the boundary between the prosencephalon and the thalamencephalon. Again at a distance .122 mm. caudad of this passage there is a similar fold accompanied by a thickening of the brain-roof. This is the beginning of the posterior commissure.

The two epiphysial vesicles are encircled by a blood-vessel which passes transversely across the roof of the brain and in which the blood in some embryos circulates from right to left, and in others from left to right (Fig. 3).

The histological structure of the two epiphysial vesicles at this stage of development is essentially the same as that of the adjacent brain-roof. The nuclei are ovoid and so arranged that their long axes are radial to the cavity. The walls of the vesicles are usually two cells deep, except the lateral walls of the posterior one, which are more than two cells deep (Fig. 4).

Since the posterior vesicle becomes the epiphysis of other writers, I shall in the following stages speak of it as such.

Salmo 13 mm. long (92 days old).—*The epiphysis* of *Salmo* 13 mm. long has grown forward. Its median plane coincides with the median plane of the body. Its long axis is curved and its distal portion approaches to parallelism with the axis of the body, so that what was formerly the anterior wall of the

vesicle has become its ventral wall (Fig. 11, *E*). Two parts may be distinguished, a distal enlarged portion and a proximal, narrow, cylindrical portion which connects the distal portion with the brain-roof. The distal part is flattened dorso-ventrally, and lies nearly in a horizontal position, with its distal end very close to the epidermis. Its dorsal surface is convex, while its ventral surface is nearly plane and is closely applied to the roof of the brain. The cavity of the epiphysis is reduced to a narrow cleft which is parallel with its dorsal surface so that the posterior and dorsal walls are of nearly uniform thickness. The ventral wall of the distal part is, on the contrary, three or four times as thick as the anterior wall of the proximal part with which it is continuous.

The anterior epiphysial vesicle remains connected with the brain-roof for a period of only ten days, and shows from the first a less vigorous growth than the epiphysis (Fig. 12). In embryos 13 mm. long its connection with the brain is severed, and the vesicle is wedged in between the walls of the thalamencephalon and mesencephalon at some distance beneath the integument. It lies posterior to the superior commissure against the left wall of the stalk of the epiphysis. A median longitudinal section of the head which passes through the median plane of the posterior vesicle (Fig. 11) does not include the anterior vesicle, but a section $75\ \mu$ to the left of the median plane bisects it (Fig. 12). It is an ovoid body the long axis of which is nearly perpendicular to the dorsal surface of the head. Its anterior and posterior walls are in close contact, so that its cavity is nearly obliterated.

Posterior to the point of union of the epiphysis with the brain-roof is the broad posterior commissure; and in front of this point is the transverse fold, which separates the prosencephalon from the thalamencephalon (Fig. 11 *P* and *K*). This fold is made up of a single layer of columnar cells, and projects into the cavity of the brain in a direction nearly parallel with the long axis of the epiphysis. The anterior part of the roof of the thalamencephalon appears, consequently, to have been evaginated dorso-cephalad in such a way that in a median longitudinal section it bears some resemblance in form to the

epiphysis. Its histology, as well as its method of development, is, however, very different from that of the epiphysis, and will be spoken of in detail in another place.

Lying close against the anterior border of the stalk of the epiphysis and in the dorsal part of the brain-roof is a small column of transverse fibres, the superior commissure (Fig. 11, S). Gottsche ('35, p. 455) speaks of this commissure in Teleosts as *commissura tenuissima*. Stannius ('53, p. 129) finds it in Pleuronectidae, but fails to find it in *Cottus scorpius*, while Rabl-Rückhard ('82) in his work on *Salmo* does not mention it. Ahlborn ('83) describes it in *Petromyzon*; Balfour ('78) finds it in Selachians. Osborn ('88) finds it in Amphibia and calls it superior commissure. The fibres of this commissure may be traced on either side to the structures described by Rabl-Rückhard as probably homologous with the ganglia habenulae of other forms. These fibres are first seen at the time of the formation of the epiphysial vesicles in both *Salmo* and *Coregonus albus*.

The epidermis just dorsal to the epiphysis consists of several layers of columnar cells and of scattered goblet cells opening to the external surface. Between the epidermis and the epiphysis is a plate of undifferentiated tissue into which the distal part of the epiphysis projects so as to lie with its distal end very close to the external epithelium.

Histology.—All the cells of the proximal part of the epiphysis and most of those of the distal part are ovoid and arranged radially to the cavity of the epiphysis. Scattered among the ovoid cells of the distal part are a few cells, the outer ends of which are pointed. In the posterior part of the dorsal wall some of these cells (Fig. 11, *Nrv. Cl.*) are arranged in radial groups, each of which is separated from adjacent groups by a few ovoid cells with ovoid nuclei. The pointed ends of all the cells in each group are approximated and directed toward the outer surface. This grouping of cells is more evident in *Salmo* 25 mm. long, and is described in detail under that head. A few large cells with distinct cell boundaries, and showing certain stages of karyokinesis, are usually found in the distal part of the epiphysis.

The walls of the anterior epiphysial vesicle (Fig. 12) are two or more cells deep. Some of these cells are oval and some are pointed, but the pointed cells are not definitely grouped.

Salmo, 25 mm. long (160 days old). *The Epiphysis.*—In form the epiphysis of *Salmo 25 mm. long* (Fig. 14, *E*) resembles that of the adult animal. It differs from the condition described in *Salmo, 13 mm. long*, principally in the greater elongation of the proximal portion and in its sharper differentiation from the distal portion. The proximal portion makes up about one-half the length of the organ. It is cylindrical, has a transverse diameter of .03 mm. and lies in a position nearly at right angles to the long axis of the body. The distal portion is flattened dorso-ventrally, its transverse axis measures .25 mm., while its dorso-ventral axis measures .11 mm. It is bluntly rounded at its free end and passes insensibly into the proximal portion at its attached end. It extends cephalad from the distal end of the proximal portion, with which it forms an angle of about 110°, so that it is not quite parallel with the long axis of the body. The formation of the cartilaginous roof of the skull between the distal portion of the epiphysis and the epidermis has separated the two by a considerable interval. The ventral surface of the cartilage is excavated for the reception of the dorsal surface of the epiphysis, and the excavation is deepest near its cephalic end.

The dorsal wall of the distal portion, as seen in longitudinal section, is marked on its outer surface at regular intervals by slight excavations, corresponding to which are projections of the inner surface into the central cavity. The whole dorsal wall has thus the appearance of having been thrown into transverse folds. It is necessary to distinguish these apparent folds from the actual folds formed later by the blood-vessels.

Owing to this peculiarity of the dorsal wall the cavity of the distal part is very irregular; it is flattened dorso-ventrally and communicates with the brain cavity below through a narrow passage in the proximal part. This passage, just before opening into the brain cavity, expands like a funnel, and forms what Mihalkovics ('77) has called the recessus infrapinealis.

The anterior epiphysial vesicle has the position, form and histological structure described for the anterior vesicle of *Salmo* 13 mm. long (Fig. 9, *E'*). Usually a longitudinal section of the brain through this vesicle passes also through the distal portion of the epiphysis a little to the left of the median plane. The walls of the anterior vesicle have fused, and the vesicle is thus reduced to a solid mass of cells, wedged in between the thalamencephalon and mesencephalon, and entirely without connection with any surrounding structure.

The integument dorsal to the epiphysis consists of two layers of flattened cells. The cells of the outer layer are parallel to the surface, while those of the inner layer are placed obliquely. Between this integument and the cartilage is a compact layer of tissue which becomes the frontal bones of the adult.

The apparently elevated area of the roof of the thalamencephalon, which lies immediately in front of the epiphysis, has its lateral portions thrown into secondary folds (Fig. 9). These folds project into the thalamocoele, and other similar folds appear in the roof of the thalamencephalon at the sides of the epiphysis. The epiphysis is thus walled in by these folds laterally, by the elevated area of the roof of the thalamencephalon cephalad and by the mid-brain caudad, so that it appears to lie in a median longitudinal depression of the brain roof.

Fibre tracts and nerve-cells are well developed throughout the brain. This is especially true of the anterior portion of the mesencephalon.

Histology. — The cell structure of the proximal part or stalk of the epiphysis is essentially the same as that described in the epiphysial stalk of *Salmo* 13 mm. long. In the distal end of the epiphysis the cells are all oval and have no regular arrangement, while in the rest of the distal portion, and especially in the dorsal wall, most of the cells are pear-shaped. In a horizontal section through the dorsal wall these cells are seen to be arranged in transverse bands (Fig. 13). Each band presents in section two rows of cells separated by a narrow, deeply stained line. This line has a fibrous structure and is

joined by numerous fibrillae, which pass to it from among the neighboring cells. Occasionally one of the fibrillae may be traced from an individual cell to the fibre band. The transverse bands of cells are sinuous, and are separated by lighter areas containing a granular material in which are embedded occasional nuclei. Whether the bands branch or whether they pass without interruption entirely around the epiphysis has not been determined. In a series of longitudinal sections the transverse bands of cells are seen cut across (Fig. 14). The smaller ends of the pear-shaped cells of each band approach one another and are directed toward the surface, so that the cells of each band have a radial arrangement. The pointed end of each cell passes into a nerve fibre which very soon unites with similar fibres from other cells, and these collectively pass in a radial direction to the surface of the epiphysis where they turn to pass along the inner surface of a thin membrane which corresponds to the pia-mater. Some fibres appear to pass posteriorly and others anteriorly. The nerve processes and the cytoplasm take a deeper stain with osmic acid and carminic acid than do the nuclei. The latter are oval, finely granular, and fill nearly the whole cell (Fig. 16). There is a very striking resemblance between these groups of cells and the groups of nerve-cells bordering on the cavity of the mid-brain (Fig. 14). In the two cases the cells are similarly grouped, while the form of each cell, and the direction as well as the appearance of the fibres, is the same. Between the groups of nerve-cells there are usually found a few scattered cells, which resemble the cells in the anterior end of the epiphysis.

The posterior wall of the stalk of the epiphysis is traversed longitudinally by a bundle of very small nerve fibres, which pass posteriorly in the brain-roof to blend finally with the fibres of the posterior commissure (Fig. 14). These fibres take a uniform stain with osmic acid and with carminic acid, and show no trace of the blackening which would indicate the presence of a myelin sheath. Anteriorly, as they approach the distal part of the epiphysis, the fibres diverge and pass close against the inner border of the pia-mater. In serial longitudinal sections, some of them, just before entering the

distal portion, are found to pass to the lateral and ventral walls of the epiphysis. There can be little doubt that all the fibres of this column have their origin (nutritive centers) in nerve-cells situated in the distal part of the epiphysis.

Salmo, 8 cm. long (one year old). — *The epiphysis* of *Salmo* of 8 cm. is much larger than the epiphysis of *Salmo* 25 mm. long, but resembles it in both form and position. Its distal part is flattened dorso-ventrally, and lies dorsal to the cerebrum in a median ventral excavation of the cartilaginous plate (Fig. 15). The principal difference to be noted from the preceding stage concerns the relation of the distal part of the epiphysis to the surrounding blood-vessels. In the preceding stage there had already been formed over the surface of the epiphysis a network of transverse and longitudinal capillaries. In the stage in question the vessels of this network no longer lie on the surface of the epiphysis, but have sunk beneath it. This in-sinking is probably not due to any change in the position of the blood vessels, but to an increase in the size of the epiphysis, which has forced its walls against the capillary network. The result is that the walls of the epiphysis have been forced into numerous folds, each of which occupies one of the interspaces of the network. The vessels on the other hand lie sunken between these folds and at a distance from the surface of the epiphysis (Fig. 15). These vessels never pass through the walls of the epiphysis, nor do they penetrate between its cells, but lie between the folds, close against its external surface. Many of the radiating bands of nerve-cells, which in an earlier stage abutted by their outer ends upon the free surface of the epiphysis, have now been carried inward by the folding of the walls so that they abut upon blood-vessels between the folds.

The anterior epiphysial vesicle lies posterior to the superior commissure between the walls of the thalamencephalon and the mesencephalon, and against the left side of the stalk of the epiphysis. It is an ovoid, compact mass of cells and is sometimes very difficult to differentiate from the surrounding structures. It is a little larger than the corresponding structure in *Salmo* 25 mm. long, but otherwise has undergone no change.

Dorsal to the epiphysis between the integument and the cartilaginous plate the two frontal bones meet in a median suture. Ventral to the distal part of the epiphysis the roof of the thalamencephalon is thrown into a great number of irregular folds (Fig. 15), and is richly supplied with blood-vessels so that it resembles the distal part of the epiphysis. This structure is usually spoken of as the choroid plexus of the third ventricle.

Histology.—The histology of the epiphysis is but little changed from that described in the epiphysis of *Salmo* 25 mm. long. The cell boundaries are less distinct, especially those of the distal end. The transverse bands of radially grouped cells and the fibres of the stalk are more numerous and lie close against each other. These fibres take a light, uniform stain with osmic acid and carminic acid, and show no trace of a myelin sheath. On leaving the stalk they pass posteriorly in a compact bundle along the dorsal part of the brain-roof, and finally blend with the fibres of the posterior commissure (Fig. 10). Just before reaching the distal part of the epiphysis they spread out along the inner border of the pia-mater, and as they pass distally dip down toward the groups of nerve-cells.

The boundaries of the cells of the anterior epiphysial vesicle have become very indistinct, but otherwise I am unable to detect any change from the appearance it presents in *Salmo* 25 mm. long.

Salmo, 16 cm. long (two years old). *The epiphysis.*—The growth of the epiphysis has kept pace with the growth of the head and with the elongation of the latter, the distal portion of the epiphysis has maintained its position dorsal to the cerebrum, where it lies in an excavation of the cartilage. At the same time the angle by which the distal and proximal portions of the epiphysis were formerly united ventrally has gradually been modified into a uniform curve to which the dorsal wall of the epiphysis now conforms (Fig. 15*a*). The distal part and the distal portion of the stalk retain the cavity, but the proximal portion of the stalk (not shown in the figure) has become solid.

Owing to the further increase in the size of the epiphysis, and owing also to the greater number of blood-vessels on its

surface, the folds present in the preceding stage have deepened, and from them secondary folds have been formed. They have increased in number, depth and complexity, and involve nearly the whole distal part of the epiphysis. The cavity of the epiphysis extends into both primary and secondary folds. In individual sections those portions of the central cavity which extend into the folds often appear to be independent of the central cavity and widely separated from it, but in series of sections it is always possible to trace a connection between the two. Between nearly all the folds are to be found blood-vessels which frequently lie far from the surface, but, just as in *Salmo* one year old, they never lie between its cells. On the contrary, they are always removed from the cavity of the epiphysis a distance equal to the thickness of its walls.

Anterior epiphysial vesicle.—The anterior epiphysial vesicle is present as a small mass of cells occupying the same position as that described in younger forms. I have found it in only one individual of this age, and in this its size was about two-thirds that of the anterior epiphysial vesicle of the yearling fish. Its structure was unchanged.

Histology.—It is convenient to distinguish four regions in the epiphysis at this stage. These are: 1. The distal one-fourth of the distal portion of the epiphysis. 2. The remainder of the distal portion. 3. The distal part of the stalk. 4. The proximal end of the stalk. The regions pass into one another by insensible gradations but differ in their histological characters.

The first region has retained its embryonic structure. The wall is here made up of about two layers of round cells uniformly distributed in a granular matrix, and is neither folded nor penetrated by blood-vessels.

The second region.—As one passes from the first part of the epiphysis toward the stalk the folds of the wall and their accompanying blood-vessels gradually make their appearance and increase in depth and complexity to about the middle of the length of the distal portion. The folds then become again less pronounced and finally disappear at the distal end of the stalk. In this part of the distal portion are found the bands

of radially grouped cells. Each group is now made up of a larger number of cells than in the preceding stage, and is consequently larger. Many of the groups project for a considerable distance into the cavity of the epiphysis. The cells composing the groups are pear-shaped, and are held together in a bundle by their nerve processes. Fig. 16 is a camera-drawing of such a group of nerve-cells as seen in a longitudinal section at the point marked X in Fig. 15*a*. In order not to confuse the figure only a few have been drawn of the large number of cells that could be seen in the section.

If the group is a deep-seated one, its fibres may abut upon the walls of a blood-vessel between two of the folds; if the group is superficial, its fibres may reach the free surface of a fold and pass along the pia-mater. The fibres of each group may pass to the surface independently, or those of two or more adjacent groups may join into a single band, which passes to the surface. If the fibres reach the wall of a blood-vessel, they are seen to turn in a curve and follow the course of the vessel. Individual fibres soon become so intimately associated with the wall of the vessel, that it is not possible to distinguish them from it. These fibres probably follow the blood-vessels to the external surface to join the column of fibres in the stalk.

The third region: In the distal part of the stalk there are no folds and no blood-vessels. The projection into the cavity of the stalk of the groups of nerve-cells gives its walls the appearance of being folded; but this appearance should be distinguished from the actual folds which occur in the distal part of the epiphysis. The fibres coming from the groups of cells in the dorsal wall of the stalk all turn toward the brain, and pass directly into the column of fibres which traverses the stalk. In this respect they appear to differ from the fibres in the distal part of the epiphysis; but it is likely that in all stages the fibres from each group of cells pass in one direction, *i.e.*, toward the brain. The appearance which is sometimes presented of fibres passing in both directions does not probably correspond to the reality. It is more likely that it is to be explained by the fact that the fibres of each bundle separate from one another as the bundle approaches the pia-mater, in

order that each fibre may execute a curve which shall bring it at once and independently in contact with the pia-mater. At least, in every case in which (as in Fig. 16) one can trace the fibres individually for some little distance after they leave the bundle, they are seen to pass toward the brain.

In the distal ends of many of the groups of cells seen in the ventral wall of the stalk are found spherical cavities, one in each group, filled with a slightly granular colloid-like mass (Fig. 15a, mt. col.). Such groups of cells are near the central cavity, and their cells have not been seen to give off nerve fibres. A few of them are found also in the distal part of the epiphysis on the ventral side. It is possible that we have here to do with a process of degeneration.

The fourth region: The groups of nerve-cells gradually disappear in the proximal part of the stalk, and are replaced by cells similar to those in the distal end of the epiphysis. A few of the same cells are to be found scattered between the groups of nerve-cells throughout the organ.

Along the dorsal wall of the whole stalk there is a bundle of fine nerve fibres which passes to the posterior commissure. These fibres at first sight appear to have the double contour which is common to medulated fibres, but on careful examination it is found that this appearance is caused by two parallel fibres running close together, and that what seems to be the axis cylinder is merely the line of contact between these fibres. Cross-sections fail to show any myelin sheath, so that these fibres probably never pass beyond the condition of embryonic nerve-fibres. As these fibres are traced into the epiphysis, many are seen to be continuous with the nerve-cells in the dorsal wall of the stalk. Although they are collected into a compact bundle in the proximal end of the stalk, they separate from one another distally, and are difficult to follow.

CATOSTOMUS.

In *Catostomus teres*, Mitch., 8 mm. long (25 days old), Fig. 5, the epiphysial vesicles have the position and form described for *Salmo*, 7 mm. long, and it is therefore unneces-

sary here to enter into a detailed description. The two vesicles lie nearly in a transverse plane, and appear to rise from a common median point in the posterior part of the roof of the primary fore-brain. The cavity of each passes into a common median passage which opens into the brain cavity below. The bulk of the anterior vesicle is less than one-sixth that of the posterior vesicle, and it is therefore not easy to find it.

STIZOSTEDION.

In *Stizostedion vitreum*, Mitch., 5 mm. long (10 days old), the posterior epiphysial vesicle is a small cone-shaped body which is attached to the posterior part of the primary fore-brain by a short, narrow stalk (Fig. 6). It lies in the median plane, with its distal end close against the epidermis of the head. In the living embryo I was unable to detect a cavity in this vesicle.

The anterior epiphysial vesicle is an obovoid body which lies just in front of the posterior vesicle and a little to the left of the median plane (Figs. 6 and 7). Its position corresponds very closely to the position of the anterior epiphysial vesicle in *Coregonus albus*. Its bulk is less than one-seventh that of the posterior vesicle. In a left profile view it appears to lie between the anterior border of the posterior epiphysial vesicle and the brain-roof, and seems to have lost its connection with the latter. The pointed end is turned ventro-caudad towards the union of the posterior vesicle with the brain (Fig. 6). Because of its very small size, this vesicle is not as readily found as the anterior epiphysial vesicle in *Salmo*.

LEPOMIS.

In *Lepomis pallidus*, 2.5 mm. long (Fig. 8), the two epiphysial vesicles have the same position as in *Stizostedion*. In a dorsal view the anterior one lies just to the left of the median plane, while the posterior one occupies a median position. At this stage of development the anterior vesicle is connected with the

brain-roof, and in a left profile view appears to lie between the latter and the anterior border of the posterior vesicle.

I have made no sections of *Catostomus*, *Stizostedion*, and *Lepomis*, but have worked exclusively on living forms.

AMIA.

In *Amia calva* there are two epiphysial vesicles, just as in *Salmo* and the other Teleosts described. These vesicles arise from a common median point in the posterior part of the primary fore-brain between the posterior and superior commissures. I have studied their development in *Amia* 10 mm. long to *Amia* 15 mm. long, but owing to lack of material I am unable to describe their earliest condition, or to give their subsequent history. My study of *Amia* is confined to sections.

The posterior epiphysial vesicle or epiphysis, in *Amia* 10 mm. long, is an obovoid body which tapers a little towards its distal end. It is attached by a narrow short stalk to the roof of the thalamencephalon in the median plane and between the posterior and the superior commissure (Fig 22). Its middle point lies a little to the right of the median plane, while its distal end is turned caudad and lies dorsal to the posterior commissure. Its dorsal surface is convex and lies close against the integument, while its ventral surface is plane and is applied to the brain-wall. This vesicle contains a narrow cavity which extends nearly to the distal end and which communicates with the brain cavity below. This cavity separates a thick ventral wall, three or four cells deep, from a thin dorsal wall of but a single layer of cells. The boundaries of the cavity are sharply contoured only where it opens into the thalamocoel, and here they diverge to inclose the funnel-shaped recessus infrapinealis.

In *Amia* 13 mm. long the formation of a fold has carried the posterior commissure ventrally into the thalamocoel and the epiphysis has assumed a nearly vertical position. It lies close against the integument with its distal end some distance removed from the posterior commissure. In *Amia* 15 mm. long this separation of the epiphysis from the posterior commissure

is carried still further, and the epiphysis is now turned a little cephalad and has the form of an equilateral triangle (Fig. 19). The posterior commissure not only passes further into the thalamocoel, but the fold which separates the mesencephalon from the thalamencephalon has been carried further into the brain cavity in a caudo-ventral direction. The epiphysis in shifting its position has become bent near its middle, so that while as a whole it is turned cephalad, its distal end is, nevertheless, directed caudad (Fig. 19). Along its middle there is a narrow cavity, the borders of which are very indistinct. This cavity extends from the recessus infrapinealis, and follows the anterior and dorsal borders of the epiphysis, so that it is V shaped with its apex turned cephalad.

Anterior epiphysial vesicle. — The anterior epiphysial vesicle in *Amia* 10 mm. long is an ellipsoid body which lies close against the posterior epiphysial vesicle and to the left of the median plane of the brain. It is united to the brain-roof by means of a very short stalk which is common to it and the posterior vesicle (Fig. 21 *E'*). Its distal end is turned a little cephalad of the common stalk, and its long axis makes an angle of a few degrees with a transverse line. Along its middle there is a small cavity which communicates with the thalamocoel in a manner very similar to that described in the anterior vesicle of *Salmo* 7 mm. long. In *Amia* 13 mm. long this vesicle extends further cephalad so as to lie directly dorsal to the superior commissure and with its long axis nearly parallel to the median plane. It still retains its connection with the brain in a manner similar to that in *Amia* 10 mm. long.

In *Amia* 15 mm. long this connection is severed. By the forward growth of the epiphysis the anterior vesicle comes to lie against its left side. It is an ovoid mass of cells lying in such a position that its long axis is nearly parallel to the median plane of the brain. Along its middle there remain traces of a cavity.

Histology. — The histology of the epiphysial vesicles of the stages just described is the same as that of the adjacent brain-wall. The cells are oval or round and are nearly filled by their

nuclei. Each nucleus is finely granular and has a distinct nucleolus. I could see no indication of the grouping of cells described in the epiphysis of *Salmo* 25 mm. long.

On each side of the epiphysial vesicles the cavity of the third ventricle pushes caudad dorsal to the roof of the mid-brain, and ends just caudad of the epiphysis in a blind sac. The dorsal and mesial walls of these sacs consist of a single layer of cells, and extend almost to a level with the dorsal surface of the epiphysial vesicles, so that the latter appear to lie in a longitudinal median groove of the brain-roof.

The posterior commissure makes its first appearance as a thickening of the brain-roof just posterior to the origin of the epiphysial vesicles. This thickening is due to a lengthening of the cells. The nuclei lie in the ventral ends of the elongated cells, while the dorsal portion of each cell becomes transparent and finely granular (Fig. 22). In the older stages this thickening becomes folded near its middle, and is thus carried ventrally into the thalamocoel (Fig. 19).

Cephalad of the point of union of the epiphysial vesicles with the brain, and at a distance of .087 mm., is a transverse fold of the brain-roof which passes ventrally into the thalamocoel and separates the prosencephalon from the thalamencephalon (Figs. 17, 18 and 22, *K*). In this manner the portion of the roof of the thalamencephalon just caudad to this fold has the appearance of being evaginated in a manner similar to that described in *Salmo*.

Just in front of the fold that separates the prosencephalon from the thalamencephalon is a glove-finger-like median evagination in the brain-roof. It makes its appearance in *Amia* 13 mm. long. The posterior wall of this evagination is a part of the fold that separates the prosencephalon from the thalamencephalon (Fig. 18). The anterior wall is a portion of the brain-roof between the two lobes of the cerebrum, while the lateral walls form a part of two invaginations which pass ventrally and laterally into the cavity of the cerebrum (Fig. 20). In *Amia* 15 mm. long this evagination becomes constricted near its union with the brain, and in this manner it approaches the form of an elongated vesicle (Figs. 18 and 20). It is

directed dorso-cephalad, and appears to recede from the ectoblast and pass ventrally with the transverse fold that separates the prosencephalon from the thalamencephalon.

Its walls are identical in structure with the adjacent brain-roof, and consist of a single layer of columnar cells with numerous fine cilia on their ventral ends. In position and method of growth this structure seems to correspond to Selenka's paraphysis. In *Amia* 15 mm. long there is nothing in the histological structure to distinguish it from a simple fold in the brain-roof. It may be thought of as an isolated portion of the roof of the fore-brain which owes its existence to the formation of the folds marked Pl. chr. in Fig. 20, and which are themselves the representatives of the choroid plexuses of the lateral ventricles. These fold into the cavity of the fore-brain, and are continuous on each side of the median plane with the previously formed fold which separates fore-brain from 'tween-brain. They are also continuous with one another in the median line in front. The portion of the fore-brain roof included between them, and thus isolated and apparently elevated through no activity of its own, is the structure marked "Par." in Figs. 18 and 20. Its absence in Teleosts is correlated with the absence of a choroid plexus of the fore-brain. If it is the homologue of the paraphysis, so briefly described by Selenka and Eycleshymer, then, as Eycleshymer has suggested, it may represent an early condition of the "true choroid plexus of the lateral ventricles."

CONCLUSIONS.

During the progress of this work I have examined nearly all of the literature on the epiphysis in every class of vertebrates, but so much still remains to be done on the development of these organs and on their relation to the central nervous system, that the time does not yet seem ripe for an exhaustive criticism. I shall therefore content myself with the examination of a few points more immediately connected with my work.

1. When we compare the account of the development of the epiphysial vesicles in Lacertilia, as given by Béraneck ('87), Françotte ('88), Strahl and Martin ('88) and Leydig ('90), with the account as I have given it for Teleosts, we find many points of resemblance.

a. In both Lacertilia and Teleosts the vesicles arise as two small outgrowths in the posterior part of the roof of the primary fore-brain. According to Béraneck, Hoffmann and Leydig, the epiphysial vesicles in *Lacerta agilis*, 3 mm. long, communicate with one another, and have a common median opening into the brain-cavity below. This statement is supported by a figure of a longitudinal section through the vesicles, in which the posterior wall of the anterior vesicle is represented as passing directly into the anterior wall of the posterior one, while the anterior wall of the former and the posterior wall of the latter are directly continuous with the brain-roof. (See Béraneck, Fig. 9, and Hoffmann, Figs. 1 and 2.) This is the same relation that the epiphysial vesicles bear to one another in Teleosts, as is shown in Figs. 4 and 5 of this paper. These two figures represent nearly transverse sections of *Salmo* and *Catostomus*, and the epiphysial vesicles in these forms therefore lie nearly in a transverse plane. In *Stizostedion*, *Lepomis* and *Coregonus* the anterior vesicle lies cephalad of the posterior one, but to the left of the median plane, and has therefore a position intermediate between the position it has in Lacertilia and the position it has in *Salmo* and *Catostomus*. In the stages earlier than that shown in Figs. 4 and 5, each epiphysial vesicle in *Salmo* probably communicates with the brain cavity by a separate opening, as shown in Fig. 3a.

These facts seem to me to indicate that these vesicles arise separately, and that, as they grow in a dorsal direction, they carry a part of the brain-wall with them, and thus form the common median passage which is shown in Figs. 4 and 5. *The only reason for regarding the anterior vesicles as formed at the expense of the distal end of the posterior vesicle is that it is smaller, and, aside from this single fact, one might with equal force consider the posterior vesicle as formed at the expense of*

the anterior. The primitive mode of origin remains to be determined.

b. The cell structure of the vesicles in the early stages is the same in Teleosts that it is in Lacertilia. In both groups the walls of each vesicle are made up of a number of layers of rounded cells, and are consequently distinguished from the adjacent brain-wall by their greater thickness.

c. If we compare the anterior vesicle in Teleosts with the anterior vesicle in Lacertilia, we find that in both groups it very early loses its connection with the brain-roof. In Lacertilia, after this connection is severed, the vesicle passes cephalad, soon takes the form of an eye, and ultimately comes to lie dorsal to the cerebrum just beneath the integument. In Teleosts it does not pass cephalad, but remains throughout life embedded between the walls of the thalamencephalon and the mesencephalon, close against the stalk of the epiphysis, and never reaches an eye-like structure.

d. If we compare the posterior epiphysial vesicle in the two groups, we find the embryological history identical. In the adults of both groups its distal part is turned cephalad, and is very much enlarged, while its proximal part is narrow and cylindrical. The minute structure of the posterior vesicle or epiphysis has not received from morphologists the attention that has been devoted to the parietal eye. Hoffmann ('88) says that cylindrical cells, nerve-fibres and ganglion cells are present in the epiphysis of Hatteria, while Leydig ('90) finds (in Lacertilia) an inner row of columnar cells, and outside of this several layers of round nuclei without distinct cell boundaries. The two sorts of cells recognized by Hoffmann and Leydig suggest a comparison with the nerve-cells and non-nervous cells of the Teleost epiphysis. There is a further resemblance in the fact that in both Teleosts and Lacertilia the epiphysis takes on intimate relations to the blood-vessels.

In view of the resemblance noted above, it seems to me that the two epiphysial vesicles in Teleosts are homologous to the corresponding structures in Lacertilia, the anterior vesicle to the Lacertilian parietal eye, and the posterior vesicle to the Lacertilian epiphysis. If this is true, then the probability that in

Salmo the vesicles are separate outgrowths strengthens somewhat Leydig's ('90) view that they are separate and independent outgrowths in *Lacertilia*.¹

We should then interpret the position of the anterior vesicle of *Stizostedion* and *Lepomis* (in front and to the left of the posterior one) as representing a condition intermediate between that in *Salmo* (at the side of the posterior one) and that in *Lacertilia* (in front of the posterior one). In *Anguis fragilis* the position of the anterior vesicle, described by Strahl and Martin and Hoffmann as not in the median plane with the epiphysis, may also be interpreted as representing a stage intermediate between *Salmo* and *Lacerta*. If we regard the position in *Salmo* as the primitive one, some shifting must have taken place in the other forms. In this shifting the determining factor appears to have been the degree of development of the vesicles. Thus the relatively large size of the anterior vesicle of *Lacertilia*, due to its former functional importance, may have brought it into the median plane, because there was room for it only in that position. The epiphysis in *Lacertilia* may have come to lie in the median plane for the same reason. In Teleosts, on the other hand, the epiphysis alone becomes of considerable size, and the small anterior vesicle finds abundant room in its primitive position at the side of the stalk of the epiphysis. It is only in the early stages in Teleosts, when the two vesicles are large relatively to the brain and are nearly of a size, that crowding causes a partial displacement of both vesicles into the median plane.

If we adopt the alternative hypothesis that the vesicles were originally anterior and posterior, it is difficult to understand

¹ Since the above was written there has appeared a paper by Béraneck (*Sur le nerf pariétal et la morphologie du troisième œil des Vertébrés*, *Anatomischer Anzeiger*, Band VII, Nos. 21 und 22), in which a nerve is described connecting the parietal eye with the brain in embryos of *Anguis* 24-27 mm. long. As this paper goes to press Klinckowström (*Le premier développement de l'œil pineal, l'épiphyse et le nerf pariétal chez Iguana tuberculata*; *Anatomischer Anzeiger*, Band VIII, Nos. 8 und 9) records a similar observation on *Iguana*. Contrary to the conclusions of Klinckowström, these observations seem to me to go a long way toward establishing the independence of the epiphysis and parietal eye, since they indicate that the two structures are supplied by independent nerves which arise from widely separated brain-centers.

the lateral position of the anterior vesicle in Teleosts, and even more difficult to explain the asymmetry found in Anguis.

It seems to me that there is some force in this argument as indicating that the two vesicles were originally situated side by side. If this be granted, it does not necessarily follow that they were primitively paired sense organs, each with its own nerve supply. An accurate knowledge of their connection with the central nervous system, such as might be obtained by a study of larval stages, particularly those of *Petromyzon*, is necessary to a solution of this question.

2. The existence of two epiphyses in *Petromyzon* and many details with regard to them have been made known by the work of Ahlborn ('83), Scott ('87), Owsiannikow ('88), Beard ('89), Gaskell ('90) and Shipley ('87), nevertheless it may be said, in the words used by Scott in speaking of his own work, that there is "no observation which shows the mode of origin of the second epiphysial vesicle." The connection of the two vesicles with the brain also requires further study. An elucidation of these two points will do much to clear up the question of the primitive condition of the vertebrate epiphysis and until it is forthcoming it is useless to speculate on the homology of the Cyclostome epiphyses with those of other vertebrates.¹

3. It is of interest to note that the epiphysis of Teleosts may be compared in its histological structure to the inner layers of the vertebrate retina, the layer of nerve-fibres and the layer of nerve-cells. In the vertebrate retina there is an internal layer of non-medullated nerve-fibres which lie next the vitreous humor and are therefore morphologically superficial to the other elements of the retina. These fibres, or most of them, originate in a layer of ganglion cells (ganglion nervi optici) which are deeper than the nerve-fibres and are not in direct continuity with the other cellular elements of the retina. In the Teleosts epiphysis there is also a superficial layer of non-medullated nerve-fibres which arise from a deeper layer of ganglion cells.

¹ Since the completion of this work His has called attention to the importance of this subject. Zur allgemeinen Morphologie des Gehirns, Archiv für Anatomie u. Phys. Ant. Abth. 1892. — S. 346-384.

SUMMARY.

If the foregoing description of the epiphysis is correct the following facts seem to me to be established : —

1. There are two epiphysial outgrowths from the roof of the primary fore-brain of *Salmo*, *Catostomus Stizostedion*, *Lepomis* and *Amia*.

2. These outgrowths form structures that become entirely independent of one another.

3. They are histologically distinct from the choroid plexus.

4. The distal part of the epiphysis contains many nerve-cells arranged in characteristic groups.

5. The nerve-cells in the distal part of the epiphysis are connected with the brain-roof by a tract of nerve-fibres.

6. This tract passes to the posterior commissure.

7. The anterior epiphysial vesicle is rudimentary.

8. There is in *Amia* a structure comparable to the paraphysis of other writers (Selenka, Eycleshymer).

The following conclusions seem to me warranted by the facts.

9. The anterior epiphysial vesicle of the Teleosts named above and of *Amia* is homologous with the parietal eye of *Lacertilia*.

10. The posterior epiphysial vesicle (epiphysis) of the Teleosts named and of *Amia* is homologous with the epiphysis of *Lacertilia*.

11. It is probable that in their primitive position the two vesicles were side by side.

12. The "paraphysis" of *Amia* may be explained as a portion of the roof of the thalamencephalon, which has been isolated and has taken on a tubular form owing to the formation about it of the choroid plexus.

13. A study of the epiphyses of the larvae of *Petromyzon* with special reference to their connection with the brain is likely to yield results of great importance in settling the question as to whether the epiphyses were paired ancestral sense organs.

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REFERENCE LETTERS.

<i>Car.</i>	Cartilage.	<i>Me. Sut.</i>	Median suture of frontal bones.
<i>Cer.</i>	Cerebrum.	<i>Mt. Col.</i>	Colloid (?) mass.
<i>Cer'bl.</i>	Cerebellum.	<i>Nast. pt.</i>	Nasal pit.
<i>Chd. pl.</i>	Choroid plexes.	<i>N.</i>	Nerve-fibres in stalk of epiphysis.
<i>E.</i>	Posterior epiphysial vesicle.	<i>Nrv. cl.</i>	Nerve-cells in epiphysis.
<i>E'.</i>	Anterior epiphysial vesicle.	<i>Opt. ves.</i>	Optic vesicle.
<i>F.</i>	Primary fore-brain.	<i>P.</i>	Posterior commissure.
<i>Frnt. bn.</i>	Frontal bone.	<i>Par.</i>	"Paraphysis."
<i>In.</i>	Integument.	<i>Prs. en.</i>	Prosencephalon.
<i>K.</i>	Boundary between prosencephalon and thalamencephalon.	<i>Re.</i>	Recessus infrapinealis.
<i>Lat. org.</i>	Organ of the lateral line.	<i>S.</i>	Superior commissure.
<i>M.</i>	Mid-brain.	<i>Vs. Sng.</i>	Blood-vessels.
<i>Me.</i>	Medulla.	<i>3 v.</i>	Third ventricle.

The figures were all made from camera outlines.

EXPLANATION OF PLATE I.

FIG. 1. Head of *Salmo fontinalis* 7 mm. long, 39 days old. Ventro-cephalic view of the living embryo ($\times 27$).

FIG. 2. Left profile view of the anterior part of *Salmo fontinalis*, 42 days old. Optical section of living embryo ($\times 50$).

FIG. 3. Dorsal view of epiphysial vesicles in *Salmo purpuratus* 7.5 mm. long, 43 days old. From the living embryo ($\times 50$).

FIG. 3a. Transverse optical section of epiphysial vesicles in *Salmo fario*, 37 days old. Living embryo viewed in same position as Fig. 1 ($\times 180$).

FIG. 4. Anterior surface of transverse section through the epiphysial vesicles in *Salmo fontinalis*, 37 days old ($\times 180$).

FIG. 5. Anterior face of a transverse optical section of the epiphysial vesicle in *Catostomus teres*, 8 mm. long, 29 days old. Living embryo viewed in the same position as Fig. 1 ($\times 40$).

FIG. 6. Left profile view of epiphysial vesicles in *Stizostedion vitreum* 5 mm. long, 10 days old. Living embryo ($\times 75$).

FIG. 7. Dorsal view of anterior end of living embryo. Same species and age as Fig. 6 ($\times 60$).

FIG. 8. Left profile view of epiphysial vesicles in *Lepomis pallidus* 2.5 mm. long. Living embryo ($\times 80$).

FIG. 9. Left face of a section from the same series of sections as that from which Fig. 14 is taken. It is the fourth section to the left of the section represented by Fig. 14. The sections are 10μ thick ($\times 90$).

FIG. 10. Longitudinal section of the stalk of the epiphysis of *Salmo fontinalis* 8 cm. long, one year old ($\times 110$).

FIG. 11. Right face of a longitudinal median section through the epiphysis of *Salmo fontinalis*, 13 mm. long, 72 days old ($\times 310$).

FIG. 12. From the same series of sections as that in Fig. 11, five sections to the left of the section represented by Fig. 11. The sections are 15μ thick ($\times 310$).

FIG. 13. Frontal section through the posterior part of the dorsal wall of the epiphysis of same species and age as Fig. 14. The section passes along the line *a-b* of Fig. 14 ($\times 180$).

FIG. 14. Left face of a longitudinal median section through the epiphysis of *Salmo purpuratus* 25 mm. long, 160 days old ($\times 180$).

FIG. 15. Anterior face of a transverse section through the distal part of the epiphysis in *Salmo fontinalis* 8 cm. long, one year old ($\times 60$).

EXPLANATION OF PLATE II.

FIG. 15*a*. Left face of a median longitudinal section through the epiphysis of *Salmo purpuratus* 16 cm. long, two years old. About one-third of the epiphysial stalk is shown. X indicates the area represented in Fig. 16 ($\times 75$).

FIG. 16. A group of nerve-cells in the epiphysis of *Salmo purpuratus* 16 cm. long. From the area indicated by the letter X in Fig. 15*a*.

FIG. 17. Section from the same series as Fig. 22. Four sections to the left of that represented by Fig. 22. The sections are 10μ thick ($\times 90$).

FIG. 18. Left face of a longitudinal section through the posterior part of the roof of the prosencephalon and the anterior part of the roof of the thalamencephalon of *Amia calva* 15 mm. long. This section is from the same series as that represented by Fig. 19. Figs. 18 and 19 are so arranged as to represent a single longitudinal section through the roof of the prosencephalon and the thalamencephalon ($\times 75$).

FIG. 19. Left face of a median longitudinal section through the epiphysis and brain-roof in *Amia calva* 15 mm. long ($\times 90$).

FIG. 20. Anterior face of a transverse section through the posterior part of the prosencephalon of *Amia calva* 15 mm. long ($\times 50$).

FIG. 21. Anterior face of a transverse section through the epiphysial vesicles in *Amia calva* 10 mm. long ($\times 180$).

FIG. 22. Right face of a longitudinal median section through the epiphysis and brain-roof of *Amia calva* 10 mm. long ($\times 180$).

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