# 8.—THE STURGEONS AND STURGEON INDUSTRIES OF THE EASTERN COAST OF THE UNITED STATES, WITH AN ACCOUNT OF EXPERIMENTS BEARING UPON STURGEON CULTURE.

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(Plates XXXVII to LIX.)



## 1. INTRODUCTION.

The following studies upon the sturgeons and sturgeon fisheries of the Eastern rivers of the United States were undertaken in the spring of 1888 at the suggestion of the U. S. Commissioner of Fish and Fisheries, Prof. Marshall McDonald.

Pursuant of these purposes, I repaired to Delaware City, Delaware, a very important center of the sturgeon fishery, in order to collect data respecting the fishing; also to study the variations presented by the individuals of the common sturgeon; to determine the number of species taken in the Delaware River; their food, relative abundance, and value; and to find out, if possible, if artificial propagation might be successfully carried on. The latter part of the month of May and nearly the whole of June, 1888, were devoted to these objects.

The results which were obtained were to some extent unsatisfactory, owing to the difficulty of obtaining an abundance of living ova, and the difficulties attending their fertilization by artificial means, as well as rearing the embryos. Notwithstanding these untoward conditions, a number of novel facts were collected and experiments were carried out which must be of great significance in any further attempts at the artificial propagation of these immense fishes. Amongst the most important of my results, the observation which I regard as of the greatest practical value, is the determination, by experiment, that it is possible to quickly obtain both living ova and spermatozoa from recently-captured fishes by Cæsarean section. The only ova which I succeeded in fertilizing were obtained from females of the common sturgeon by cutting open the abdomen of the still living fish. Forcing out the ova by pressure, as practiced with the shad and salmon, is not feasible in the case of the sturgeon, and the removal of the ripe ova from the abdominal cavity of the parent fish may be far more expeditiously effected by slitting open the body cavity, in the manner usually practiced in dressing the carcass for market.

The milt is most readily obtained in a similar way from the recently captured and living ripe males, only that in this case pieces of the enormous testes are cut out and the milt pressed from the fragments. The success which followed the usual methods of fertilization proves conclusively that vast numbers of embryos could be hatched annually from eggs thus obtained and treated. The number of millions which could be reared in this way would depend entirely upon the number of trained spawntakers promptly on duty when spawning fish are taken by the fishermen, and the extent of the facilities for hatching them and protecting them against the attacks of *Achlya* and *Saprolegnia*, forms of fungi which were found to be most seriously destructive to the life of the ova of the sturgeon in moderately quiet waters.

Other practical information which was obtained related entirely to the manner in which the eggs must be treated in the work of artificial propagation. The extent and value of the caviare industry was also investigated, as well as the determination of the number of species which frequent the Delaware and other Eastern rivers in which sturgeons are taken. The important fact was also determined that the common sturgeon (*Acipenser sturio*) is the only species which is at the present time of any commercial value in the fishery of the Delaware. It was my good fortune also to secure no less than five specimens of the *A. brevirostris* of Le Sueur, which has, so far as I can learn, not been certainly recognized since that naturalist's time; recent writers have in fact almost uniformly confounded it with the common and far more abundant species. This species was originally discovered in the Delaware, and there have been, so far as I can discover, no trustworthy identifications of the species from any other waters. That it has a wider distribution is probable; it may be that its principal center of distribution is other than the river in which it was first taken. The comparative rarity with which it is taken speaks much in favor of this view.

The embryological data of this monograph have been drawn partly from original sources, namely, from the embryos which I succeeded in rearing from artificially fertilized eggs, and partly from the work of other authors. The embryos of the common sturgeon here illustrated are, as far as I have been able to learn, the first of that species that have ever been figured. While it may occur to some persons that the attempt to complete the survey of the external features of the ontogeny of the sturgeons from the work of others is a useless duplication of labor, I wish to here state that it seems to me that, so far from that being the case, it has only thus been made possible to get something like an adequate notion of the remarkable changes through which these fishes pass, from the time the egg is fertilized until adolescence is reached. To this end I have had no hesitation in laying under contribution the labors of Knoch, Salensky, Parker, and Balfour, on the larval stages of the sterlet, in addition to what I have been able to glean in regard to the development of the common species.

Upon reaching the fishing grounds I was first made aware of the great unlikeness in the outward appearance of the young, from 5 inches to 3 feet in length, as compared with adults of the common species. This fact led me to examine somewhat closely into the visceral anatomy of the young, with the result of finding that the internal differences are as great as the external ones, as the accompanying plates displaying the viscera will testify. Between the youngest obtainable material and the embryos studied by Balfour, Knoch, Parker, and myself, there still remained a gap so great that, in the time allotted me for the completion of my work, it was impossible to obtain the required missing stages. Fortunately those gaps are almost completely bridged by the oldest larvæ figured by Parker, and the post-larval stages of the sterlet figured only two years ago by Zograff. Zograff's figures, in conjunction with an old figure of a very young specimen of the gigantic *Huso* of eastern Europe, published in 1833, by Brandt and Ratzeburg, enable us to trace very satisfactorily the history of the dermal armature of the genus. Comparisons of these disclose the fact that the dorsal row of scutes on the body appears first, then the lateral, and last of all the ventral rows. Other changes in outward appearance also occur, which can only be fully appreciated by reference to the figures which have been reproduced in the plates accompanying the text of this paper. These facts it seems to me are a sufficient warrant for my having drawn so largely from other sources. Moreover, since this report is intended, not simply for the information of naturalists, but more especially for those interested in the practical question of the propagation of the sturgeon as a source of food, I have felt it incumbent upon me to give as full and popular an account of its natural history as it was in my power to produce. Some of the most important literature on the subject being in German, French, and Russian, it is necessarily inaccessible to the general reader in this country. It has therefore been with much pleasure that I have here brought together the figures from such out-of-the-way or generally unreadable foreign authorities as will give such a reader a fair notion of the singular changes which these huge fishes undergo in the course of their lives.

The illustrations of the adults are from photographs, reproduced by one of the many recent and highly successful photogravure processes. These give an adequate notion of the forms of the heads of the adults and an idea of the texture of the surface of the skin of the fresh fish such as is impossible except at the hands of an exceedingly skillful but expensive artist. I have been impelled also to offer these new illustrations of the common sturgeon in view of the fact that there are not now in existence half a dozen illustrations of the external appearances of this species that are trustworthy as to details. Nearly all the figures in existence are either poorly executed or taken from distorted or "stuffed" specimens.

The illustrations of the young, 20 inches in length, are also photogravures, and serve to contrast the wide differences, in the form of the head especially, with that of the adults. The contrasts between these and the *Acipenser brevirostris* figured along with them are equally striking, and the latter may be also profitably compared with the illustrations of the heads of the adults. The photogravures of *A. brevirostris* also show the great difference in the dermal armature of that species in comparison with that of the young of the common species. In the former the strong spines of the bucklers have disappeared, while in the latter of the same age they are still retained.

## 2. SYSTEMATIC REVIEW OF THE STURGEONS OF THE EASTERN COAST.

The following systematic review of the sturgeons of the Eastern coast is here offered. The definitions of the order, family, genus, and the two Eastern species are modified and corrected so as to correspond with the present state of our knowledge of the group. This has been found necessary, since a few minor errors as to matters of fact have crept into the definitions given in Jordan and Gilbert's "Synopsis of the Fishes of North America," upon which the ones here given are based.

## Order GLANIOSTOMI.

A præcoracoid arch; symplectic represented by cartilage, but without membranous ossification; maxillary present; no suboperculum or præoperculum; interoperculum present; mesopterygium distinct; interclavicles present; basihyals and ceratohyals without membranous ossifications; branchihyals partially invested by ossifications in membrane.

### Family ACIPENSERIDÆ.

*The Sturgeons.*

Body elongate, subcylindric; skin armed with five rows of bony bucklers, each with a median longitudinal carina, terminating in a retrorse spine in the young and in some small species. A median dorsal series, and a lateral and abdominal series on each side, some of the abdominal series in later life (the preanals of *A. sturio*, and abdominals of *A. rubicundus*) becoming covered and more deeply embedded in the integument, so as to become invisible from the surface. The lateral rows of scutes give passage to the canal of the lateral line. Between the rows of large scutes the skin is rough with small, irregular, embedded dermal ossifications. Snout produced, depressed, conical or subspatulate, with sensory areolæ on inferior surface. Mouth small, inferior, protractile, with thickened lips, produced into characteristic marginal lobes. No teeth, except in the larval stages. Four barbels in a transverse series on the lower side of the snout in front of the mouth. Eyes small; nostrils large, with two openings, and with olfactory membrane with a smooth central disk, surrounded by a rosette of folds. Gills 4; branchial arches 5; an accessory opercular gill. Gill membrane united to isthmus. No branchiostegals. Maxillary distinct from premaxillary. Head covered by bony scutes or dermal ossifications united by sutures. Fin-rays slender, all articulated, except first spine-like ray of pectoral. Caudal with fulcra, pectorals placed low. Ventrals many-rayed, behind middle of body. Dorsal placed posteriorly; anal somewhat behind it, similar. Tail heterocereal; the lower lobe developed. Air-bladder large, simple, connected with the œsophagus by a spacious laterally compressed, short pneumatic duct. Pseudo-branchial or spiracular gills very small or obsolete. Stomach without blind sac. Rectum with spiral valve. Mushroom-shaped pancreas, divided internally into cæcal appendages, the external interspaces between which are filled up with connective tissue, so as form an apparently solid organ, the cavities in which open into the upper-end of the duodenum through three passages.

"Large fishes of the seas and fresh waters of Northern regions. Most of the species are migratory, like the salmon which are found in the same waters. Genera two, species about twenty, although more than five times that number have been described. The American species especially have been unduly multiplied, particularly by Auguste Duméril, who has found upwards of forty of them in the museum at Paris. The actual number of American sturgeons does not exceed seven, and is more likely still less. The changes with age are considerable; the snout in particular becomes much shorter and less acute, and the roughness of the scales is greatly diminished. * * * The number of plates, although one of the best specific characters, is subject to considerable variations."

### ACIPENSER Linnæus.

*Sturgeons.*

Snout subconical above, more or less depressed below the level of the forehead; more or less nearly flat below. Spiracular opening nearly twice as far behind the tip of the snout as the eye. Caudal peduncle of moderate length, deeper than broad, the lateral rows of bony scutes distinct to the base of the caudal fin. Tail not produced into an abortive filament or opisthure, as in *Scaphirhynchops* (shovel-nose sturgeons), but with its tip bearing caudal rays. Gill-rakers small. Pseudo branchiæ or spiracular gills present. Only two sharply defined species found in the waters along the Atlantic coast of the United States. Possibly three other good species inhabit the United States; one of these is the very distinct lake or fresh-water sturgeon of the lake region, and two others are said to be found on the Pacific coast.

1. **A. sturio** L. Common Sturgeon.

Snout one-third of the length of the head; rounded above, nearly flat below, bluntly rounded in outline at tip, as seen from above, in the adult. Snout of young much more acute and produced than in the adult, and about half the length of the head. Barbels arising nearly midway between mouth and tip of snout, not reaching mouth; in the young longer and more slender. A median, lanceolate smooth fenestra or area between the parietal and frontal plates in the young, which entirely disappears with age. Gill-rakers small, slender, pointed, sparse, not longer than the pupil. Small dermal plates between dorsal and lateral rows tending to form successive oblique rows, in which many of these small plates tend to become lozenge-shaped. Average number of plates in dorsal row, 11; in lateral rows, 28; in ventral rows, 10; 4 or 5 preanal scutes. Opisthocentrous in young, mesocentrous in adult. Mouth narrow. Dorsal, 40–44; anal, 26–30; ventral, 26; pectoral, 35; caudal, 90; lower caudal lobe short; peritoneum never deeply pigmented, so that the viscera when exposed are nearly white. Color of skin olive-greenish above. Variety *oxyrhynchus* is based partly upon the young of this species and partly upon old individuals which retained their unusually lengthy snouts. My own opinion is that the snout of this species undergoes actual shortening and loss of substance during growth. The actual variability of this species can not be appreciated unless one has had the opportunity to compare hundreds of recent individuals. Atlantic Ocean; ascending rivers of Eastern sea-board.

2. **A. brevirostris** Le Sueur. Short-nosed or Blunt-nosed Sturgeon.

Snout of half-grown individuals about one-third the length of the head, but proportionally wider at base than in the preceding species. Barbels usually arising a little nearer to tip of snout than to the mouth; not reaching mouth. Little or no difference between the form of the snout of the young and adult. No smooth area or fenestra on the top of the head of the young, between the parietal and frontal plates in the median line. Top of head less deeply concave between the eyes than the preceding species. Small dermal plates between the dorsal and lateral rows of scutes never tending to form oblique rows. Smaller dermal ossifications never tending to become lozenge-shaped, except on the sides of the upper lobe of the caudal fin. Dorsal, lateral, and ventral scutes not so closely crowded together as in the preceding species. Average number in dorsal row, 10–11; in lateral row, 25; in ventral, 7–8; no preanal plates. Mesocentrous very early in life and in both sexes. The smaller dermal ossifications can scarcely be perceived by the touch in stroking the skin between the dorsal, lateral, and ventral rows of scutes in a fresh specimen. The species is in fact almost absolutely smooth over the unarmored parts of the skin when compared with the preceding. Mouth very wide; one-sixth wider in proportion than in the common species. Dorsal, 33; anal, 19–22; ventral, 17–21; pectoral, 30–31; caudal, 60; lower lobe of caudal long. Peritoneum dark brown, sometimes very dark, so that the viscera are nearly black when exposed upon opening the body cavity. Color of the skin above reddish brown; nearly white below.

This species occurs in the Delaware River, whence the author of its name obtained it, somewhere about 1817. Since no absolutely distinctive characters have been yet offered by which the species might be recognized, it has afforded me great pleasure to supply this lacking information in the entirely new diagnoses given above of this as well as the common species. How much more extensive than the Delaware River its range may be I have no means of knowing, as I have found only one specimen, besides the five obtained by myself at Delaware City, which can be regarded as an authentic example of the species. This single specimen is in the museum of the Academy of Natural Sciences of Philadelphia, and consists of a dried and stuffed varnished skin marked in white paint "84." It agrees in every essential external particular with my own alcoholic specimens, but no record of its history is accessible amongst the catalogues of the collections of that institution; all traces of the old manuscript catalogues of the Bonaparte and the other old collections of fishes belonging to the Academy's museum having been lost. I have, however, the strongest suspicion that this specimen, which is evidently very old, judging from its present condition, may be one of the originals of Le Sueur's description published in the Transactions of the American Philosophical Society for 1818, though it does not correspond in minor details. That it may possibly be one of the types of the species seems to me not at all improbable, from the fact that Le Sueur was also one of the early members of the Academy and may have presented the specimen. There can be no doubt of its identity with the fresh specimens which I have made out to be the true *A. brevirostris*, and I have, therefore, incorporated it in the list of material which I have used to frame the specific diagnoses of both forms. The figures of *A. brevirostris* on Plate I of Brandt and Ratzeburg's work, is from a specimen belonging to the Bloch collection and agrees closely with the dried skin in the museum of the Academy of Natural Sciences of Philadelphia, the lateral line being indicated in the figure as in the specimen mentioned, as a well-marked canal extending across the wide interspaces between the lateral plates. The figure reputed to be of this species which was published in the plates pertaining to the natural-history volumes of the quarto report on the Fisheries Industries of the United States is really that of the adult of the common species. The figure intended to represent the common species, *var. oxyrhynchus*, in the same work, is merely the young of the latter, and the figure of *A. rubicundus* is also from an immature young specimen, and far inferior to the beautiful etching of the adult, done by Le Sueur himself, and published with the same paper in which he described *A. brevirostris*. I append the original description of that form in order that the evidence as to the distinctness of this singularly well-defined species may be made more accessible.

"2. **A. brevirostrum.**

Head large, convex; snout short, pointed, with a black spot near its extremity; the four beards are flat, disposed in pairs, and placed nearer the nostrils than the end of the snout; nostrils near the eyes, though lower, the posterior one larger than the anterior one, which is small and almost round; pupil of the eye round, irides golden; the length of the head, from the tip of the snout to the end of the operculum is a fifth part of that of the body; body elongated, with five ranges of tubercles; back with nine tubercles and one at the base of the dorsal fin—these plates are pretty regular, oblong, radiated, and surmounted with a sharp keel; sides with twenty-six tubercles, irregular, largest on the anterior part of the body, and oblong on the posterior part, the latter presenting a small carina. Sometimes one remarks between these tubercles the rudiments of others; the plates of the abdomen are oblong and small, on the left side five, on the right side three, placed opposite to the center of the former; before each abdominal fin there is a small tubercle; the skin above is of a blackish color, tinged with olive, with oblique black bands, and other corresponding ones, of a paler hue, on the sides; the deep color of the upper parts does not transgress the lateral line formed by the tubercles; sides reddish, mixed with violet; abdomen white; the fins are of a medium size.

"The head, which is remarkable in this species, varies a little in the varieties which follow; in this it is short in proportion to its breadth, between the eyes it is depressed, and in width 2¼ inches, between the auricular orifices [spiracles] 3 inches, from the end of the snout to the eye 2¼ inches, length of the whole head 6½ inches; the auricular orifices are situate 1½ inches behind the eyes, and near the rim of the bony shield of the head; the plates in general of this species are rugose and regularly radiated; the skin which appears smooth, is nevertheless furnished with small spinous asperities which render it disagreeable to the touch, and there is a kind of regularity observable in the dispositions of these spines, which are scattered equally over the whole skin; the regularity is not perceptible in the *A. rubicundus* and its varieties, the spines of which are more numerous and more serrated.

"The individual described was a female; its length 2 feet 9 inches from the tip of the snout to the fork of the tail, which was furnished with lozenge-formed plates.

"This species is rare. I have been enabled to behold but two specimens. It inhabits the Delaware.

"First variety. Length 1 foot 7 inches; body with five rows of tubercles, all very entire, well defined, and radiated, surmounted with a carina, projecting behind into a spine; the two first abdominal plates are imbricated, the remainder at equal distances, and seven on each side; side plates twenty-six, dorsal plates nine, and one at the base of the fin; between the dorsal fin and the tail, and likewise between the anus and anal fin, and the last and caudal fin, there are sometimes one simple plate, and sometimes several plates, in this species; the head only presents the difference of its snout being a little more elevated, and it is not convex between the nostrils; the small asperities of the body are nearer together and more numerous than in the preceding. Inhabits the Delaware.

"Second variety. Dorsal plates ten, including that at the base of the fin, lateral plates twenty-three, abdominal seven; all pretty regular and radiated, without carina and spines—these plates appear to have replaced those of the first growth, they not having been worn or rubbed; head large, short, and resembling that of the first described of this species; snout larger and rounder than in the first variety; length of specimen 2 feet 4 inches. Taken in the Delaware.

"Third variety. This individual resembled the last in its form and size, but had its snout more pointed, flatter above, and more elongated, narrower, and more concave; body with five rows of tubercles, those of the back nine, including the one at the base of the fin, regularly radiated, raised into a sharp keel, and terminated in a central point; lateral plates twenty-three, slightly carinated; the plates of the abdomen are seven with a hardly perceptible keel—the form and disposition of the tubercles are pretty regular; between the lateral plates there are several smaller ones. It is very remarkable that the left side only of this specimen had a range of eleven tubercles and several rudiments of others, situate between the lateral and abdominal rows. Inhabits the Delaware.

"This species, which is not the object of a special fishery, is nevertheless more sought after, and commands a higher price, than the large common species, which attains to the length of about 10 feet. The *A. brevirostrum* and its varieties are brought to the Philadelphia market in the vernal season and fetch from 25 to 75 cents apiece. They are eaten by the common people only."

(These last remarks, as to the estimation in which the *A. brevirostris* was held in Le Sueur's time, do not hold at present. It does not seem to be eaten at all by the present generation of Delaware fishermen.)

The foregoing descriptions, based on the five specimens which fell into Le Sueur's hands, agree in all essential respects with my own observations. He gives the color perhaps too dark, as is also shown by the skin in the museum of the academy, but that specimen shows the dark bluish oblique cloudings or bands which he refers to as occurring on the sides, and which are faintly perceptible even below the level of the lateral rows of plates. Some of my specimens are much darker than others, deep brown on the back, verging to a warmer, richer brown on the sides, but reaching only, as he observes, to the lateral rows of plates.

Le Sueur also distinctly confirms my conclusion that the species is always small; his largest example was a female measuring but 33 inches; the largest one that I obtained was only 23 inches long. He also states that it is rare, just as I learned was the case upon making an attempt to get a series of examples, all of which were taken in herring and shad gill-nets. The characteristic dark-brown or brown color of the animal; its small size, wide mouth, comparatively smooth skin, early maturity, render it impossible to question the identification which is thus established. The color alone is diagnostic; none of the young of the common species are dark-colored, while the characteristic dirty olive green or brownish, with a shade of green in it, is always markedly characteristic of the common species at all stages of its growth. Le Sueur's incidental remark as to the length of the common species in his day shows, if his report signifies an average, that it has since then diminished in size.

*A. brevirostris* is never taken in the large gill-nets used in capturing the common form, for the reason probably that it never reaches a large enough size. This conclusion is confirmed by the fact that sexual maturity is reached much earlier than in the common form as is proved by the condition of the reproductive organs of the suite of examples in my possession. Out of the series of five specimens the sex may easily be made out by inspection of the young roes and milts of four of them. The smallest specimen even, although only a little over 18 inches in length, has the internal reproductive organs far more developed than specimens of the common species of the same size. In fact, I have not been able to make out the sex with certainty by simple inspection with the naked eye, in specimens of the common species, as large as my largest examples of *A. brevirostris*, measuring 23 inches in length. These data, taken in connection with the presence of the long lanceolate median fontanelle or fenestra on the top of the head of the sharp-nosed young of the common species, show that the latter matures much later and only after becoming much larger than the *A. brevirostris*. The latter probably corresponds to the sterlet of Europe as respects size and precocious maturity, but differs entirely from it in its dermal armature, which is essentially mesocentrous, while in the sterlet the dermal armature is opisthocentrous.

### 3. THE DERMAL ARMATURE OF THE BODY.

The armature of the body and tail is subject to a good deal of variation in both of the species of sturgeons found in the Delaware. This is well shown by the following table, giving the number of dermal scutes found in the dorsal, lateral, and ventral rows in the young and adults of *Acipenser sturio*, and in the young and probably two-thirds mature stage of *A. brevirostris* Le S.

(The vulgar fractions in this table are used to indicate the number of scutes in the lateral and ventral rows of opposite sides of the body.)

| Specimens. | Dorsal scutes. | Lateral scutes. | Ventral scutes. | Preanal plates. | Remarks. |
|---|---|---|---|---|---|
| No. 1. *A. sturio* | 10 | 29 | 10 | Present | Young. |
| No. 2. *A. sturio* | 11 | 26 | 11 | ....do | Do. |
| No. 3. *A. sturio* | 12 | 30 | 11 | ....do | Do. |
| No. 4. *A. sturio* | 13 | 30 | 11 | ....do | Do. |
| No. 5. *A. sturio* | 11 | 28 | 10 | ....do | Do. |
| No. 6. *A. sturio* | 11 | 29 | 10 | ....do | Do. |
| No. 7. *A. sturio* | 10 | 28 | 10 | .. do | Do. |
| No. 8. *A. sturio* | 11 | 29 | $\frac{9}{11}$ | ....do | Do. |
| No. 9. *A. sturio* | 11 | 29 | 9 | ....do | Adult. |
| Average | $11\frac{1}{9}$ | $28\frac{2}{3}$ | $10\frac{2}{9}$ | | |

| Specimens. | Dorsal scutes. | Lateral scutes. | Ventral scutes. | Pectoral. | Ventral. | Anal. | Caudal. | Total length. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | *M.* | |
| No. 10. *A. sturio* ....... | 10 | $\frac{28}{30}$ | $\frac{9}{10}$ | .......... | .......... | .......... | 90 | 2.085 | Adult specimen in Cope's Coll |
| No. 11. *A. sturio* ....... | 11 | $\frac{28}{30}$ | $\frac{10}{10}$ | 35 | 26 | 26 | 90 | .49 | Delaware City. |
| No. 12. *A. brevirostris* .. | 12 | $\frac{24}{28}$ | $\frac{7}{8}$ | 31 | 17 | 19 | .......... | .54 | Do. |
| No. 13. *A. brevirostris* .. | 11 | $\frac{28}{27}$ | $\frac{8}{8}$ | 30 | 20 | .......... | 60 | .46 | Do. |
| No. 14. *A. brevirostris* .. | (9½) 10 | $\frac{29}{28}$ | $\frac{7}{7}$ | .......... | .......... | .......... | .......... | .58 | Do. |
| No. 15. *A. brevirostris* .. | 11 | $\frac{23}{26}$ | $\frac{7}{7}$ | .......... | .......... | .......... | .......... | .56 | Do. |
| No. 16. *A. brevirostris* .. | 11 | $\frac{29}{28}$ | $\frac{8}{7}$ | 31 | 21 | 22 | 60 | .812 | Mus. Acad. Nat. Sci., Phila. |

Frequently the last dorsal scute, just in front of the dorsal fin, is divided in the median line as indicated in the formula of the dorsal scutes of No. 14, or, there may be two small scutes partially intercalated between the tenth and eleventh dorsal on either side of the median line.

The contrasts between the dermal armature of the dorsal, lateral, and ventral rows of plates is sufficiently well marked to constitute a good specific mark of distinction; but these are not the only differences which the integuments of the two species present when compared together.

In the young of *A. sturio*, the most deeply pigmented portion of the integument lies above the lateral row of scutes, while the abdomen presents almost a silvery white tint. In the adult, on the other hand, the pigment is extended somewhat farther down the sides and becomes different in color; so that instead of being greenish-brown, as in the young, there is a more decided greenish or olive tint observable over the back and sides.

The skin of *A. brevirostris* in specimens up to nearly 2 feet in length is nearly smooth, in a fresh specimen, between the dorsal, lateral, and ventral rows of scutes, and of a richer and darker brown than in *A. sturio.*

In the young of a *A. sturio*, on the other hand, the skin in the same region is beset with minute, retrorse, dermal denticles, having an acuminate tip and a flat expanded base embedded in the integument. There can be little doubt that the sharp tips of these denticles represent, in part at least, the enamel caps of the dermal denticles of other fishes, while the expanded flat bases represent the cementum plates of such teeth.

As the animal becomes adult the well-marked roughness or shagreen-like feel of the skin in *A. sturio*, becomes less marked; the fine points or denticles projecting above the general level of the integument are no longer observable unless one exerts some pressure upon the skin, especially along the sides and ventral surface. The small, isolated denticles, with their circular basal plates, as seen in the young of *A. sturio*, are replaced in the adult by small lozenge-shaped integumentary ossifications standing in oblique rows between the dorsal and lateral rows of scutes. The edges of these lozenge-shaped pieces approximate each other much more closely than do the edges of the basal plates of the small integumentary denticles of the young. It is also clear that these latter stand in a genetic relation to the lozenge-shaped plates on the sides of the body of the adult sturgeon; that the basal plates of a number of the small dermal denticles of the young have fused together by their edges to form the larger rhombic scutes, just as in all probability the dorsal, lateral, and ventral rows of scutes were in part formed, but at a very much earlier stage.

The decreased roughness of the skin as observed in the adult of *A. sturio* is due in part to the erosion of the apices of the dermal denticles and the loss of the acuminate tips of the larger scutes, and in part also to the fact that the integument gradually thickens and the basal ossifications sink into it more deeply. This is well illustrated by the history of the preanal plates. These plates in the young are very obvious externally as a closely aggregated group, but in the adult they frequently become so deeply embedded in the integument that one must feel for their presence through the abdominal walls of this region.

The gradual loss of integumentary asperities is apparent in other regions in the transition from youth to age. This is especially noteworthy in regard to the pair of large, nearly rhombic bucklers between the bases of the pectorals just behind the isthmus. In the young of *A. sturio* these bucklers have strong carinæ along their inner, longitudinal borders; in the adult, on the contrary, these carinæ are quite obliterated externally.

The young sturgeon, as a consequence, is provided with a dermal armor which is in some respects much more efficient than that of the adult. One is reminded very strongly of the strong, sharp spines which are found on the heads and edges of the opercles of the young of many strictly marine fishes, where in some forms, such spines are so strongly developed as to render it difficult to realize that they are eventually suppressed so as to be practically without any spinous defensive apparatus in the adult stage.

That such a change occurs in the sturgeons generally is proved by the very prominent retrorse spines found surmounting the posterior moiety of each of the dorsal, lateral, and ventral plates of the young from 9 to 18 inches in length.

In still younger stages of *A. huso* under 2 inches in length, according to the figures of Brandt and Ratzeburg, Plate XLIV, Fig. 22, this central, thorn-like portion of each of the bucklers is still more prominent than in specimens a few inches longer. As the animal grows still larger, as in examples of from 6 to 10 feet in length, the retrorse, thorn-like character of the median prominence on each buckler vanishes, and all that remains to indicate its former presence is a very low conical, or ridge-like elevation in the middle of each plate. This change in the external armature of the bony plates is due partly to the manner in which they increase in size and partly to the erosion of the prominent external median portion.

The advantage of the markedly rougher armature of the young in the struggle for existence is obvious, as it is clearly adapted to render the young animals less convenient of deglutition or mastication by the more ravenous predaceous forms inhabiting the same waters.

The marked difference in external features between the young and the adult has invited the misguided attention of systematic writers, chief amongst whom must be mentioned Auguste Duméril, who has divided the genera found in various parts of the world upon the basis of the position of the armature of the bony integumentary plates. As a little acquaintance with the development of these fishes would enable any one to predict, the spinous prominences are found in a posterior position in the small species, while in the larger species this prominence is about the center of each plate. The groups, *Opisthocentres* and *Mesocentres*, of Duméril are therefore founded upon more or less unreliable and transient characters, as is proved by the fact that upward of forty American species have been discovered by this reckless author amongst the materials preserved in the Museum d'Histoire Naturelle at Paris. The actual number of American species of sturgeons is seven, according to Jordan and Gilbert (Synopsis Fishes, N. Am., p. 85), and probably even less according to these authors. The fictitious species, *A. oxyrhynchus*, has clearly been based for the most part upon the young of *A. sturio*, as is shown by some of the reputed figures of the former. Referring to the original description by Mitchill of *A. oxyrhynchus*, it is clear from a letter which he quotes from a Mr. De Witt, that then, as now, it was supposed by some of the fishermen that the sharp-nosed, small sturgeons were a distinct species. This belief is widely prevalent amongst the sturgeon fishermen of the Delaware River, where the young animal is popularly known as the "Mamoose," probably an Indian name, as I hear from my friend Mr. John Ford.

It argues very unfavorably for the sagacity of Mitchill that he should have omitted to note that in the young, sharp-nosed forms, the roe is never developed to maturity.

Only one large example of the long-snouted form amongst hundreds of specimens of *A. sturio* has fallen under my observation, and this specimen did not appear to me to be essentially different from the usual blunt-nosed adult form, except in a proportionally longer snout. Further observation also showed that no two individuals presented exactly the same form and proportions of the snout and head; it is therefore clear that the *Acipenseridæ* are variable to a high degree, and that the selection of a marked variation as the type of a distinct species, without the study of a great many specimens, is to say the least, a very unscientific proceeding. The extreme rarity of adult instances of this variation is further proof that it is scarcely fair to consider it a subspecies, especially since it is known that such individuals are taken in association with the usual form of *A. sturio*.

A careful study of the dermal plates of the young of *A. sturio* shows that they increase in breadth and length in the course of further growth, to some extent, at least, by the fusion of the basal plates of the dermal denticles to their edges. This is also very evidently shown by their greater height as compared with their breadth in still younger specimens, as shown by the illustrations of the very young of *A. huso* given by Brandt and Ratzeburg. This method of their growth is continued until the dermal plates measure 3 or 4 inches across, so that as a result the growth in length and breadth is much more rapid than their growth in height. This method of growth also serves to explain in what manner the distinction between the opisthocentrous and mesocentrous plates arises; as a consequence, it is easy to see that there can be no hard and fast line between the one and the other form, both being merely younger and older stages of the development of the dermal plates.

This conclusion may be still further fortified by the circumstance that it is only the species which are smallest that are markedly opisthocentrous, while the larger are mesocentrous, as shown by Duméril's own comparisons.

Of what value such characters are in classification may safely be left to those who have the proper morphological training to use them with discrimination. That these characters have not been used with discrimination is shown by the remark (Jordan and Gilbert, Synopsis Fishes, N. Am., p. 85), that "the same species at different ages may frequently belong to two or more of these subgenera," meaning those proposed by Duméril.

The figures of the young of *A. ruthenus*, the sterlet, given by Zograff, Figs. 19, 20, and 21, show that the dorsal scutes are developed before the lateral or ventral. This is also shown by the young of *A. huso*, figured by Brandt and Ratzeburg, but in not so marked a manner. The young of *A. ruthenus*, figured by Zograff, also shows that the scutes develop from before backwards. That is to say, there are as yet no fulcra shown on the dorsal margin of the tail, nor does the lateral series of scutes extend much beyond the vertical from the anterior end of the dorsal, as seen in Fig. 21.

The tail is, in fact, fringed above and below only by fin-fibers or actinotrichia, such as are usually the supports of the fins of young fishes. The narrow scutes or overlapping fulcra of the dorsal margin of the tail are developed later, and derive their origin in the main from tissue elements which lie deeper than those which give origin to the actinotrichia and ultimately to the fin-rays proper of the adult.

I am not inclined to agree entirely with Zograff as to the method in which the dorsal scutes are developed, as given in No. 29, cited in the list of papers at the end of this monograph. In other fishes the actinotrichia or fin-fibers become embedded in the calcifiable matrix deposited around them, as my studies upon the development of the fin-rays of the salmon prove. That the scutes of the dorsal median line in sturgeons do develop partly at the expense of the embryonic fin-fibers is doubtless a fact, but that they are the sole basis of origin of the calcifiable matrix of the scutes in these forms does not seem probable, judging by what is known of the rays of other types.

The so-called "fulcra" of the lower side of the caudal, at its anterior end, are not true fulcra, but ordinary fin-rays much modified. The same remark applies to the anterior elements of the dorsal. They are best developed in the adult in which they are much obscured by the increased thickness of the integument in the fully developed animal.

## 4. THE ORGANS OF LOCOMOTION.

The principal organs of locomotion are not the pectoral and ventral fins of the sturgeon, as might be inferred upon superficial inspection, but rather the powerful heterocercal tail, together with the dorsal and anal fins. The paired fins are subordinated in the main to the business of maintaining the equilibrium of the animal, that is, to keeping the dorsal aspect directed upward, and the ventral aspect turned in the opposite direction.

The quite young sturgeon, as shown by the appended Figs. 13, 14, 16, and 18, has a continuous dorsal and anal fin-fold the same as larval Teleosts. In other words, the sturgeon passes through a protocercal stage, as it was termed by Wyman, or a lophocercal condition, as the same stage has been called by the writer. Later, this continuous fin-fold finds support from within by the development of a continuous series of what have been inaptly called horn fibers, and which the writer has named *actinotrichia*. A large part of this continuous fold is absorbed and fails to develop, and only three portions persist and undergo further differentiation and growth as the dorsal, anal, and caudal fins.

The dermal rays which are most obvious and easily counted in the dorsal, number from forty to forty-four in the adult sturgeon, and are about the same in number in the young of 7 inches in length. These rays are derived, in part at least, from the actinotrichia mentioned above. They support only the outer thin portion of the fin, the rays of which are jointed at close intervals in the adult, but in the young the joints in the individual rays are fewer.

The dermal rays of the dorsal are supported at their lower ends upon about thirteen cartilaginous neural bars or processes which do not in turn rest in immediate contact by their lower ends upon the neural arches. The lower ends of the series of cartilaginous rods which support the dorsal fin extend over about five neural arches with their intercalary pieces.

The twenty-six to thirty dermal rays of the anal fin are supported on about ten cartilaginous hæmal processes, and these in turn are supported proximally by about four pairs of cartilaginous hæmal arches and intercalary pieces.

In the lower lobe of the caudal, that is, below the posterior part of the notochord, to its termination, in the caudal fin, there are about ninety dermal rays in the common species. These are supported on about twenty-five cartilaginous hæmal processes, which diminish in size toward the end of the tail so as to appear as if totally degenerate toward the last of the series. On the dorsal side of the caudal a series of fulcra are developed; these are merely a continuation of the more anterior series of median dorsal plates the development of which has been modified. The reason for this conclusion is the fact that, as Zograff has shown, in *A. ruthenus*, the dorsal series of scutes develop in the median fin-fold, which involves actinotrichia embedded in the membranous portions of the fold which intervene between the sharp tips of the scutes. The latter also in the earlier post-larval stages overlap much as do the scutes known as "fulcra" along the dorsal margin of the tail. These facts are of the greatest possible significance as giving us a more comprehensive view of the origin of the so-called fulcra of ganoid forms. This much is at least assured, viz, that the method of evolution of the fulcra in all ganoids will be found to be essentially the same. That the deduction reached above is true is further fortified by the fact that in young sturgeons 7 inches long there are present true primitive fin-fibers or actinotrichia behind the last formed fulcra and inclosed within the persistent continuation of the median dorsal fin-fold over the tip of the tail. Actinotrichia or primitive fin-rays are certainly involved in this process, to which other calcifiable matter is doubtless added in the later development of scutes and fulcra. The phylogeny of the fulcra as displayed by the sturgeon, by *Chondrosteus* and *Crossopholis*, the extinct sturgeons, is significant of how such consecutive modifications arose in other forms.

The further conclusion which is of some importance from a morphological standpoint, is the fact that the main parts of the fulcra are not wholly comparable with true fin-rays, but are derived from the cells of a deeper portion of the corium, which, as in the case of the large lateral, ventral, and dorsal scutes, involves the very deepest layers of the integument. Few or no true primitive fin-rays therefore persist along the dorsal margin of the tail, except at its extreme posterior extremity. The inferior side of the caudal fin may therefore be said to be the only portion which supports true "soft" rays. The expressions "upper" and "lower lobe" are therefore simply names for parts of the caudal which stand in dorsal and hæmal relation to each other, and have no real morphological significance, for even the rays of the upper and lower lobes of the caudal of symmetrically homocercal forms are really ventral to the primitive caudal axis or notochord. In the adult sturgeon this arrangement clearly persists in a comparatively embryonic form, with all of the true fin-rays in a ventral position.

The efficient portion of the caudal as a propelling flange is therefore in the main the wide inferior part supported by the jointed rays. The axial support and musculature of the tail are much nearer its dorsal than its ventral border. It results from this that the inferior flange or membrane of the tail, with its supporting rays, as it is swayed from side to side, is made to act in much the same way as an oar in sculling. The development of the wide inferior lobe of the tail has also effected an upward flexure or adjustment of its axis and musculature which could not, for mechanical reasons, have happened if the dorsal fin-fold had been as wide as the ventral one. This view seems to be proved by the chorda or axis keeping its perfectly straight primitive position along the center of the spatulate or diphycercal tail of *Protopterus* and *Ceratodus*, where the dorsal fold, with its rays, is as wide as the ventral one. This view is further strengthened by the fact that the tail of the embryonic sturgeon is spatulate or diphycercal, with the end of the notochord dividing it into two equally wide dorsal and ventral moieties, as shown in Plate V. That is, the tail of the sturgeon, in the beginning, is of the same type as that of *Ceratodus*. The cause of the upward flexure of the axis of the tail of *Acipenser* is, therefore, to be sought in whatever it was that induced the absorption or reduction of the dorsal fin-fold and the persistence of the ventral or inferior fold. The cause of that variation began to act early in the line of the true fishes since we for the first time detect it obviously manifested in *Chimæra*, one of the lowest types where the inferior fold begins to widen, and as a result we have the first faint inklings of the heterocercal state, that is, the posterior extremity of the notochordal axis is slightly bent upwards. This adumbration of the heterocercal condition in *Chimæra* is pronounced in proportion to the degree to which the difference in width between the dorsal and ventral fin-folds of the caudal is developed. This seems to be a rule or law of caudal differentiation in fishes.

The origin of the mechanism in question can not, however, be understood without reference to the mode in which its functional use would continually tend to intensify the hetorocercal condition, premising, of course, that some antecedent cause tended to widen the inferior caudal fold to begin with. That antecedent cause we do not know nor can we do more than guess what it may have been. The conditions under which the tail fin is used in life is similar to that of an oar in sculling, and it is quite plain that the parallelograms of force which are thus developed by the interaction of the tail moving laterally and alternately in opposite directions against the resistance of the surrounding water must bring about a constant tendency to induce an upward flexure of its notochordal axis. This effect can actually be imitated by means of a card-board model, cut out in the form of a heterocercal tail and vibrated from side to side under water. In this manner only can the origin of the heterocercal form of the tail of fishes be explained. Natural selection is utterly incompetent to do so, because it must first explain the concurrent or simultaneous variation of about six thousand species belonging to no less than three independent phyla. If the tendency was all in the same direction, in three independent series, composed of a multitude of species, it involves the conclusion that there was no selection. The effect is manifestly the result of a habit of movement the initiation of which may, in part at least, be ascribed to the intelligence of the creature manifesting such a habit.

The soft or jointed rays of the sturgeon, as well as of all other soft-rayed fishes, owe their jointed condition to the interaction between the fins and the resistance offered passively by the surrounding water. This conclusion might be demonstrated beyond any possibility of question were this the proper place to discuss the matter. At any rate, I now possess irrefragable evidence of the truth of the conclusion that some six thousand species of living forms furnish a demonstration of Lamarck's theory that the use of an organ may and does modify its structure, or that the actions of an animal react upon its structure, and modify the latter in the same way at every succeeding generation. Whether these modifications are inherited is immaterial, since the doctrine of the direct effect of use and disuse is now demonstrable, and with all the rigor of method required in proving a proposition in Euclid.

## 5. THE VISCERA OF THE STURGEON.

The abdominal viscera of the sturgeon embrace only, as here considered, the alimentary canal and its appendages. The appendicular organs derived from the alimentary canal are the liver and gall-bladder, pyloric apparatus, and air-bladder. The organ mentioned by anatomists as pancreas in the sturgeon is not a diverticulum of the intestine, but belongs to the series of ductless glands, and therefore represents the milt or spleen, and is of mesoblastic, not of hypoblastic origin, as would be the case were it a true pancreas.

The alimentary canal proper is differentiated into three very clearly defined regions.

The first of these is the œsophageal portion, and extends as far back as to the opening into the air-bladder. It is the narrowest portion, and leads directly out of the branchial or pharyngeal region, beginning with the fifth and smallest and most posterior of the five branchial arches. The branchial arches as they narrow by degrees from the first to the fifth form a kind of funnel-shaped framework which directs the food into the anterior end of the œsophagus or gullet. The gullet proper is then somewhat narrowed at a short distance from its anterior end, and upon being laid open is found to be covered within for some distance, with backwardly-directed, soft, fleshy processes, into which its mucous membrane is elevated. At some distance, in its course farther back, its lining membranes again become smooth, but slightly folded longitudinally, and at a distance of an inch from its commencement, in a young specimen 9 inches long, it curves upon itself over to the left, and then forward and to the right, forming a loop, and becomes more spacious. At the point mentioned it in fact widens into the stomach, which lies slightly to the right of the median line. The stomach, especially at its pyloric end, is found to have very thick walls. This feature is so strongly marked in the adult that the organ acquires to a striking degree some of the characteristics of the muscular stomach or "gizzard" of a bird. This portion of the stomach of the sturgeon is, in fact, referred to by the fishermen in some localities as the "gizzard," no doubt on account of this resemblance.

Immediately following the thick-walled stomach proper there occurs a very marked constriction of the alimentary canal. This constriction corresponds to the pylorus of other vertebrates, and also marks the beginning of the duodenal portion of the alimentary canal, into the upper portion of which the pyloric apparatus or pancreas and liver discharge their secretions.

Just behind the constricted pylorus proper a fold of the wall of the upper end of the duodenum is developed, which partly conceals the three wide openings into the pyloric apparatus or pancreas.

The pyloric apparatus is so obviously a diverticulum of the intestine that it may very appropriately be considered at this point. Three very wide openings lead from the dextral and ventral sides of the upper end of the duodenum into the pyloric apparatus, showing that this organ, in its simplest embryonic form, must be regarded as a system of pyloric appendages, three in number. Further examination shows that the three primary pyloric diverticula have become divided at their terminations as development proceeded into a number of cæcal pouches after the manner of a compound, racemose gland. These branches of the original three diverticular, however, remain invested by a solid tunic of connective tissue and peritoneum, so that there is but little indication externally that the internal structure of the pyloric apparatus is that of a system of branching cæcal tubes. In the young animal this outer tunic of the pyloric apparatus though quite thick is not nearly so thick as in the adult.

The attachment of the pyloric apparatus in the fully developed animal embraces about half the circumference of the duodenum.

The expanded distal end of the pyloric apparatus is attached by fibrous cords (originally derived from the mesentery) to the posterior side of the terminal part of the stomach. The external form of the pyloric apparatus is that of an irregular lenticular body, the longest diameter of which is antero-posterior, with a narrower transverse diameter. The long diameter of the pyloric apparatus in the young of 9 inches is three-fourths of an inch, the short diameter one-half inch. The thickness of the organ in a vertical direction is about one-fourth inch in the young of the size mentioned above. It fits into and lies partly embedded in the first loop of the alimentary canal, formed, as above described, by the œsophagus, stomach, and upper end of the duodenum. Upon opening the body cavity the pyloric apparatus is one of the most conspicuous structures brought to view, as is shown in the accompanying figures 27, 52, and 53, which show its relations far better than can be done in a lengthy description.

In young sturgeons, 9 inches long, just as the œsophagus begins to widen and pass into the stomach, and at a point about 1¼ inches from the point where the gullet begins as a continuation of the pharynx, it gives off a very important dorsal diverticulum—the air-bladder. This organ communicates by way of a longitudinally widened, but short canal, known as the pneumatic duct, with the œsophagus, and is closed by a sphincter muscle, while muscular fibers radiate from the edges of the passage and traverse for a little distance the ventral walls of the air-bladder or pneumatocyst. The pneumatic duct joins the pneumatocyst at its anterior fourth.

The whole air-bladder has a compressed, oval form as viewed from above, and its thin walls may be distended so as to fill nearly one-third of the body cavity. The convex dorsal wall of the air-bladder lies in direct apposition to the body-wall, little or no peritoneum intervening, while its lower convex face is covered by a peritoneal investment which is continuous in the median line with the mesentery and at the edges of the air-bladder with the inner serous covering of the muscular wall of the belly. The air-bladder extends for two-fifths of the length of the body cavity. Its walls are quite thin in the young, except at the entrance of the pneumatic duct; in the adult they are relatively somewhat thicker, while the coating of peritoneum and connective tissue is also thicker. In a large sturgeon the capacity of the air-bladder would probably exceed 2 gallons; its walls are smooth, glistening white, and not vascular, thus contrasting markedly with the structure of the same organ in *Lepidosteus*, in which the highly vascular transverse trabeculæ give to the organ the aspect of a rudimentary lung.

The economic use to which the air-bladder of the sturgeon is applied makes it of some interest to know how it is treated when it is intended to prepare fish glue, ichthyocolla or isinglass, as its gelatinous product is called, when isolated for commercial purposes. The air-bladders are removed and the peritoneal and connective tissue coverings carefully scraped off. The bladders are then dried and afterwards treated in a digesting apparatus to extract the gelatine which they contain.

In the young sturgeon the course of the remainder of the intestinal tract is comparatively simple, and it maintains the same arrangement in the adult, except that the proportional length of the duodenum, small intestine, and spiral valve are not the same. In the young the duodenum is proportionally longer than in the adult, and the same may be said of the small intestine.

The duodenum extends from the pyloric valve or origin of the pyloric apparatus, backward and slightly to the left as far as a little beyond the beginning of the posterior third of the abdominal cavity, where it suddenly bends upon itself and passes forward to the right. This anteriorly deflected limb, or continuation of the duodenum, is the homologue of the small intestine of higher forms. It ends abruptly at the point where it passes into the hind-gut or spiral valve. The caliber of the spiral valve is somewhat greater than that of the small intestine and duodenum.

The spiral valve is formed by a spiral fold which is developed along the walls of the hind-gut of the embryo.

Beginning at the point where the small intestine bends upon itself abruptly to pass into the region of the spiral valve which takes a course straight backward, the spiral fold is seen to turn from left to right, or in the direction of the hands of a watch or dextral. The spiral fold makes seven complete turns or revolutions in the hind-gut, the last turn extending almost to the anus. In *Lepidosteus* there are but one and one-half turns in the spiral valve, and it does not extend to the anus. In *Chimæra* there are three turns in the rudimentary spiral valve; in the Dipnoans it becomes more developed, and in the Selachians reaches the maximum number of turns, though it would appear that the spiral valve in young embryos (*Mustelus*) have but three turns, while in the adult there are seven, so that at least four are added during the later development. This recapitulation by the embryo Selachian of the permanent condition found in *Chimæra* is interesting as throwing some light upon the phylogeny of the spiral valve. The function of the spiral valve is to increase the surface of the mucous membrane brought in contact with the intestinal contents without lengthening the intestine itself.

The minute structure of the hind-gut or spiral valve is of considerable interest on account of the remarkable development of lymphoid tissue which is found along the edge of the spiral fold. In cross-sections of the intestine through the region of the spiral valve, the edge of the latter is found to be so greatly thickened as to form a cord-like swelling along the whole extent of its free margin. When this thickened margin is examined microscopically it is found that its thickening is due to the presence of a strand of lymphatic tissue, subdivided by partitions of fibrous tissue into nodules, so that it presents a strong resemblance to the structure of the lymphatic glands found in certain parts of the bodies of higher animals. The resemblance to the lymphoid nodules of Peyer's patches in the walls of the ileum of higher forms is also suggested, and the presence of the largest lymph-cells gorged with nutritive substances along the surface of the glandular cord of the spiral valve of the sturgeon shows that the cells of this tissue are active here, as in other forms, in taking up the nutriment from the food which passes through the alimentary tract. The mucous membrane of the spiral valve is covered with villi, which are as well developed over the sides and edge of the spiral fold as upon the proper walls of the intestine of this region. The relations of the parts described are well shown in a cross-section of the region of spiral valve represented in Fig. 47.

The mesentery which suspends the hind gut, or spiral valve, to the dorso-median line of the body-cavity is entire, and six or seven blood-vascular branches are given off from the posterior mesenteric artery which take the curved spiral direction of the spiral valve after they reach and traverse the wall of the intestine. The mesentery of the hind gut is nearly one-fourth of an inch wide in a young fish 9 inches long. Farther forward at the V-shaped loop formed by the duodenum and small intestine together, the mesentery is much wider, and at the apex of the loop is perforate, and in this widened part of the mesentery of the last loop the spleen is embedded as a V-shaped glandular mass, having the same general curvature as the intestinal loop itself. The histological structure of this organ leaves no doubt of its spleen-like nature.

Still farther forward the dorsal median mesentery becomes narrower, so that the alimentary canal comes to lie in immediate contact with the dorsal wall of the abdominal cavity. Below, the median anterior ventral mesentery gives passage to the portal vessels from the liver, which pass to the auricular end of the heart. The Cuvierian ducts pass downward through the pericardium on either side of the œsophagus to join the venous end of the heart, thus collecting all the blood from the systematic circulation to return it to the heart. This is spoken of here since the pericardium, on its posterior face, is continuous with the serous lining of the body-cavity and the anterior median mesentery.

The liver is the largest glandular viscus of the young sturgeon, and it is lighter colored than in the adult. Its right lobe is considerably larger than the left, and both lobes have their thin posterior and inferior margins reflected over the pyloric end of the stomach. The gall-bladder lies in a fossa, or depression, on the median face of the right lobe, and between the latter and the thick-walled pylo ric end of the stomach. The anterior portions of both the right and left lobes of the liver are so conformed to the shape of the anterior part of the body-cavity as to fit with great nicety to the configuration of the lateral walls of the abdomen and pericardium in this region.

The histological structure of the liver of the sturgeon has not been investigated by the writer, as it has not been the purpose to deal with especial minuteness with organs the functions and character of which are well known. The minute structure of the "pancreas" (so called by Weidersheim, Lehrbuch der Vergleichenden Anatomie, second edition, 1886, pp. 533–535), but correctly identified as the milt, or spleen, by Brandt and Ratzeburg (Medizinische Zoologie, 1833), is of more interest, since it displays the typical structure of spleen in a very simple form. In a matrix of lymphoid tissue, lymphoid nodules, or masses, very irregular in form, are embedded and traversed by blood-vessels. In sections of the organ, before staining and clearing is resorted to, very characteristic globular cells are found embedded in the lymphoid nodules of the organ; these cells are uniformly granular, opaque, and quite unlike the rest of the cells of the organ, and about three times as large as the usual type of cells which form the greatest proportion of the spleen pulp. They are very numerous in some of the lymphoid nodules, less so in others; the granules which they contain are quite small and uniform in size, but much smaller than the blood corpuscles of the animal. No traces of a racemose, glandular structure is visible anywhere in sections of the organ, such as would be necessary in order to constitute it a true pancreas.

The viscera hitherto considered lie either altogether, or for the most part within the body-cavity, as the air-bladder, for example, and all are intimately connected with or form a part of the alimentary apparatus. The ovary and testis which are to be next described lie within the body-cavity, but their functions are carried on in connection with passages or outways, the genito-urinary canals, which lie immediately external to the general body-cavity, and just dorsal of it on either side of the median line.

The great size of the ovary and testis or milt in the adult contrasts most remarkably with their small size in the young animal, 7 to 9 inches long, in which the internal generative organs, ovary and spermary, are represented by a pair of very slender whitish cords or low folds which lie on either side of the mesentery and on the dorsal wall of the abdominal cavity and diverge from each other from behind forward. Posteriorly, as shown in the Figs. 51 and 52, the genital folds *G R*, as the rudiments of the reproductive organs may be called in the young sturgeon, lie just internal to the course of the spacious genito-urinary ducts which converge to a common median outlet situated immediately behind the anus. They do not extend for the whole length of the abdominal cavity, but only along the middle half of its length.

In this first stage of the development of the reproductive tract there are protova present, as the first traces of the reproductive elements are called, and which in the early stages are very similar in both the ovary and the testis.

The reproductive elements are derived from the germinal epithelium of the genital folds; this epithelium, however, covers only a small portion of the surface of the genital folds and only becomes distinctly marked off to the naked eye at a considerably later stage. At this stage the tract of genital tissue is a more distinct, flattened, yellowish cord than in the younger 7-inch stage, and varies in width from one-eighth to one-fourth of an inch. On its inferior side in the young female there is present a well-marked band of closely opposed transverse ridges which extend across about one-third or one-half its lower surface. This series of transverse ridges is guarded by a flap or fold at either edge, and sections show that the ridges contain the young ova. The development of the testis does not show this longitudinal series of short transverse folds at any stage. In cross-section at this stage, the reproductive tissue proper is found to include only about one-fourth of the whole genital fold, the remaining part of the organ being composed of minute undifferentiated connective tissue which continues to grow for some time, and represents the homologue of the fatty body appended to the internal reproductive organs in anurous batrachians and reptiles. The numerous transverse ridges which are found on the inferior side of the genital cords are in fact parallel laminæ which extend down into the substance of the organ for about half of its thickness. These laminæ are far more numerous at this stage than the lobules of the mature ovary, so that it is obvious that some of them must degenerate in the course of the further development of the organ.

The subsequent stages by which the genital ridge is converted into the ovary or testis with an accompanying establishment of the sex of the individual has not been fully traced, but it is certain that the conditions observed in the stage last described are not much subsequent to the time when the protova or primitive germinal cells common to young individuals of both sexes, first make their appearance. The method of the further differentiation of the protova and the manner in which the small laminæ with the involuted germinal epithelium between them becomes indifferently converted into ovarian lobules or seminiferous tubules remains to be worked out.

All of the data bearing on the development of the internal reproductive organs given above have reference to the common sturgeon, *A. sturio*, but I fortunately happen to be in possession of materials from young individuals of the smaller species *A. brevirostris*, which will probably throw light upon this aspect of the subject.

All of the young specimens of *A. brevirostris* which I have been able to obtain show the internal reproductive organs in a more advanced condition of development than young individuals of *A. sturio* of the same size. In *A. brevirostris* measuring from 18 inches to 2 feet in length the sexes could be very readily distinguished, since the internal reproductive organs were either testes or ovaries according to the sex. In the ovaries the young ova were distinguishable as such in the ovarian tissues, with a pocket lens, and in the males the testes had assumed the opaque pinkish-white tint of those organs in the adult male. In the young female of *A. brevirostris*, however, the young ova had not yet shown any tendency to develop pigment granules within their superficial protoplasm; in other words, they were found to be of the same very pale amber color as the completely spent roes of the adult female of *A. sturio*. The young male of *A. brevirostris* showed the seminiferous tubes of the testes developed, but there were as yet no signs of the production of spermatozoa in sections of the organ.

In both sexes of the young of *A. brevirostris* the reproductive organs, both ovary and testis, are found embedded in depressions on the inner face of a rich, creamy-yellow body which is considerably more voluminous than the reproductive tissue itself. This yellow body is composed in great part of fatty tissue, and there is but little doubt that it is developed from the non-reproductive portion of the genital fold lying on either side of the tract of transverse laminæ already described as being found in a much earlier stage of the reproductive organ in *A. sturio*.

The later history of this fatty body shows that it does not keep pace with the growth of the proper reproductive tract, which becomes more and more voluminous as sexual maturity is reached until the ovary becomes the bulkiest organ in the body-cavity, as shown in the ventral view of the adult female with the nearly mature roes exposed, as shown in Plate LI. In the mature male there is relatively more of the fatty body present than in the female, in which it is completely concealed from view by the great size and width of the lobules of the ovary. What remains of the fatty body underlies, and is closely adherent to, the basal membranes by which the ovaries and testes are suspended to the dorsal walls of the abdominal cavity. These membranes form a mesovarium and mesorchium in the female and male respectively. These structures are, in both cases, derived from the basal part of the genital folds, which remain narrow at the base in cross-section, while the reproductive tract widens and becomes very voluminous at its distal end and depends into the abdominal cavity.

The changes which take place in the course of the development of the roes to maturity, as a result of the increase in the size of the vast number of ova of which they are largely composed, is of great interest. While the young ova are still embedded in the narrow ovarian lamellæ they show a tendency to aggregate the yolk material at one side, while the globular nucleus, with numerous chromatin spherules adherent to its walls in a single layer, is more or less peripheral in position. As soon as the ovum has reached the size of one-hundredth of an inch the nucleus is obviously shifted from its central position. From this time onward the ova present much the same appearance till sometime after the period when they reach somewhat more than one-half the diameter of the mature egg. They then begin to show signs of pigmentation which vary in amount, as already stated, in different individuals. This pigment, like that found in the ovum of the frog, is mostly superficial in its distribution and consists of minute granules, nearly opaque, which form a thin stratum just beneath the egg membrane and embedded in the superficial protoplasm. This pigment is also finally distributed, in varying quantity, at different points at the surface of the egg, so that the darkened discoidal germinal area is marked out by it, as shown in Figs 1 and 2. This definite distribution of the pigment is accomplished by the time the ovary reaches its maturity when the whole organ assumes its characteristic dark color, due to the presence of the pigment in the individual eggs.

Sections of the mature roe show that each egg is inclosed in a vascular capsule or follicle in which it reaches its full size. A thick homogeneous egg membrane is developed just external to the pigmented layer of the ovum. This membrane resists the action of carmine and remains colorless when treated with an alkaline solution of that dye. A layer of substance just external to the egg membrane and of about the same thickness is readily stained by carmine. This outer layer is the partly soluble glairy substance by means of which the ovum adheres to foreign bodies, and which finally hardens and cements them firmly to whatever they touch. The next layer is the vascular capsule or follicle which is traversed by a delicate plexus of capillary vessels which nourish the maturing ovum. This follicle is finally ruptured when the ovum drops into the abdominal cavity, from which it escapes by way of the genito-urinary passages presently to be described.

The ovaries, after the ova have been discharged from their follicles, present a shredded or torn appearance. This is due to the presence of the great number of collapsed egg follicles and to the more or less degenerate vessels which traverse the stroma or supporting substance of the tissue of the ovary, and which are undergoing retrogressive changes. These retrogressive processes, after the ova which have been matured for that season have been set free, go on until the ovary again contains nothing but very immature eggs, each of which must grow greatly in size in order to bring up the ovary to the size it had reached before ovulation began. Since the "spawning," as the process of ovulation is called, takes place but once a year, it is clear that it is a periodic phenomenon, just as the process of ovulation is even amongst higher animals. There is a period of preparation for the business of ovulation, and this begins for the next year with the cessation of the process for the preceding season. This preparation involves the collapse and diminution of the caliber of the blood-vessels which have supplied the ovary during its period of greatest functional activity, and also the absorption of the ruptured follicles in which the last crop of ova were matured.

Some few mature ova do not seem to be discharged at all, but undergo absorption within the follicle, together with their enveloping membranes or zonæ radiata, and glairy coverings of mucigen. Such degenerating ova, in sections of the "spent" recuperating roe, are found to contain a large yolk mass somewhat irregular in form and thrown into folds or wrinkles superficially with the pigment granules not aggregated at the surface, but irregularly distributed throughout the substance of the yolk mass.

The outgoing passages from the abdominal cavity are somewhat difficult to understand without reference to Figs. 51 and 52, to which the reader's attention is directed in the accompanying Plate LVIII. The oviducts of the sturgeon (Müller's ducts) open into the abdominal cavity by capacious funnel-shaped mouths on either side of the air-bladder. They open forward and are so spacious at their anterior extremities that the whole hand may readily be thrust into them at that point in the adult fish. They gradually narrow in their backward course and extend for a few inches only as separate canals which overlie the more deeply embedded urinary passages into which they open at their posterior terminations. After the oviducts open into the urinary passages, from that point backwards the latter become properly entitled to the designation of genito-urinary, since they then form a common outlet for the escape of the renal secretion from the Wolffian body as well as the generating products set free by the ovary. The common genito-urinary passages of either side are then continued backwards till they become confluent near the vent, just behind which they open to the exterior.

In the male the arrangement appears to be somewhat different. The spermatic ducts from each testis open directly into the urinary duct (segmental or Wolffian duct), though the oviducts are also well developed in the male and not at all rudimentary as in the males of higher animals. The spermatic secretion or milt does not therefore pass out of the testes by way of the oviducts, but takes a more direct course into the urinary duct (Wolffian), which extends in both sexes much farther forward than the oviduct. The urinary passages, which are as spacious in the male as in the female, therefore become, for a greater portion of their length than in the latter, efferent genito-urinary outlets.

The mesonephros, Wolffian body, or permanent kidney of the sturgeon, discharges its secretion into the primitive segmental or Wolffian duct, which widens as it passes backward just before it receives the oviduct which joins it. Upon slitting open the widened posterior portion of the urinary or segmental duct the mouths of the collecting ducts of the segmental tubules of the kidney are exposed, and are seen to be scattered over its dorsal wall, showing that the renal secretion is poured out directly into it. There is no dilatation of the posterior portion of the segmental duct into a urinary vesicle or bladder as occurs in many Teleosts.

The posterior portion of the mesonephros of the sturgeon is most strongly developed; and in this region it lies just internal to the segmental ducts as a flattened and widened series of renal lobules composed of closely agglomerated uriniferous tubules and Malpighian glomeruli. In the region of the air-bladder, and overlying it on either side of the vertebral column, the renal lobules become suddenly much smaller in the young, while in front of it they again increase in size. How much of the pronephros or head-kidney persists is not known, nor has it been determined in just what way the secretion from the anterior part of the mesonephros reaches the segmental ducts. The proportions of the glandular portions of the renal apparatus at different points of its extent is shown in Fig. 51, Plate LVIII, showing the dorsal wall of the body-cavity as viewed from below.

The foregoing account of the viscera of the sturgeon deals in the main with the naked-eye appearance of its parts.

## 6. THE LATERAL LINE SYSTEM OF THE STURGEON.

This structure is not mentioned by systematic writers, or at least by none that I have been able to consult. In specimens 9 inches in length the lateral line is traceable as a distinct canal which perforates the posterior lateral plates just below the longitudinal ridge which extends along their outer faces. It is traceable from the exterior as far forward as the vertical cutting across the dorsal and anal fins, and opens by way of pores to the exterior between the edges of the last two or three lateral plates. Behind the last lateral plates the lateral line suddenly changes its course and follows the general inclination of the upper or longest lobe of the tail, traversing a narrow armored strip of the lateral caudal integument just below the lateral caudal armature, which consists of a pavement of small rhombic plates, without strong carinæ or points. In the young animal, the lateral line developed along the sides of the upper lobe of the tail is a simple tubular canal traversing the integument, and at short intervals it opens to the exterior by way of pores.

In the adults it is not so easy to trace the lateral line forward, but on the sides of the upper lobe of the tail it may be observed to open by a series of pores in close proximity to the site of the lateral line in the young, but the pores are no longer linear in their arrangement, indicating that the canal has branched and gives off short lateral branches as adolescence is attained. This description applies to *A. sturio.*

It is unfortunate that the failure to obtain a complete set of the stages of development will not enable me to give a fuller account of the ontogeny of this structure in *A. sturio.* Fortunately, in a memoir by N. Zograff (Studies from the Zoological Laboratory of the Museum of the University of Moscow, in Russian, t. LII, pt. 3, Moscow, 1887, p. 44), the lateral line of the head and trunk of *A. ruthenus* is figured at a stage which shows that there is a supra- and infraorbital, occipital, lateral, rostral, and supra-opercular system of canals with punctiform end-organs. This arrangement of the lateral sensory nerve-hills is probably very easily made out in quite young stages of the sturgeon, before the epidermal lateral canal closes and sinks down into the deeper layer (corium) of the skin. A careful dissection of the lateral line region of young individuals of *A. sturio* 8 to 9 inches in length shows that the lateral branch of the vagus nerve is present along the middle line of the side as a very conspicuous cord, just beneath the lateral row of scales and slightly embedded in the lateral muscular mass, invested by a connective tissue sheath. Careful inspection also shows that the lateral scutes along the sides as far forward as the opercle are perforated by a canal, which is supplied, as described by N. Zograff, in *A. ruthenus*, with small twigs from the lateral branch of the vagus nerve. These small twigs terminate in groups of hair-cells—nerve hills—forming part of the ectodermal lining of the system of lateral canals. The structure of the system of canals on the head is of the same character, but the end-organs and canals are not as numerous and complex as in *Amia* and many Teleosts.

Another sensory apparatus of some complexity are two pairs of barbels in front of the mouth. These appear in *A. sturio* to be innervated by a large sensory branch of the fifth nerve, which is very easily traced upon removing the integument on either side of the middle line, on the under side of the snout. The barbels themselves are considerably longer in proportion in the young sturgeon of 10 inches to 2 feet than in the full-grown *A. sturio* measuring 7 to 10 feet in length, while the transverse incisures on their surfaces also become deeper and the lateral flattening of these organs is also more apparent in the adult.

When the young sturgeon first leaves the egg there are no outward indications of the barbels. The anterior and inferior part of the head is bluntly rounded, and there is little or no indication externally of the presence of a suctorial disk such as is seen in the larvæ of *Lepidosteus*, where this disk subsequently degenerates and is carried to the tip of the snout. This is well seen in the recently hatched larvæ of the common sturgeon figured in the appended plates.

The barbels grow out a few days after hatching at a point just in front of the mouth as two pairs of short, blunt, fleshy processes on either side of the median line, as shown in Figs. 54 and 55, p. 89, Vol. II, of Balfour's Comparative Embryology, and in Figs. 14, 15, 16, and 17 on Plates XL and XLI of this paper. This blunted, cylindrical appearance of the barbels is retained until the young sturgeon has reached some size, as shown in Figs. 19, 20, and 21, of the young sterlet before the lateral plates of the body are much more than indicated and when the snout is beginning to become pointed and grow in length rapidly. The bases of both pairs are also more closely approximated during these early stages, though there is great variation in this respect even in different adult individuals, but in the latter the pairs never seem to arise from the same base as do the barbels in the very young fish. The barbels of the embryo of the sturgeon do not grow out so precociously as do those of the cat-fish, as shown by the writer in *Ictalurus albidus*, where they, moreover, have a cartilaginous supporting axis. This fact, as well as their tactile function in both cases, militates, it seems to me, strongly against the opinion that the barbels of fishes are necessarily derived from the papillæ of a suctorial disk such as is found in the larvæ of *Lepidosteus*. Besides, the late appearance of the barbels at the angle of the mouth in *Cyprinus carpio*, and of the chin barbels in *Menticirrus*, *Gadus*, *Onos*, etc., indicates a want of community of descent.

Another epidermal system of sense organs extending over the under side of the snout of sturgeons both young and old is of interest, since it is probably a part of the system of tactile apparatus represented by the barbels. The structures now referred to are the depressed areolæ found in front of the mouth, and divided partially in the median line by the roughened carina, formed by the produced parasphenoid bone, on the lower side of the snout, into a pair of triangles with their acute extremities directed forward. The small depressed areolæ at the anterior part of this area are oblong; back near the mouth they are nearly round, with irregular margins. Zograff's results indicate that these areas are the points where sensory nerves terminate. My dissections indicate that their nerve supply comes from the most anterior branch of the fifth nerve. The position of these organs is such as to bring them into play as accessory to the barbels in seeking for food at the bottom of the estuaries where the sturgeon doubtless spends most of its time when feeding.

## 7. THE LYMPHATICS OF THE STURGEON.

The lymphatic system of the sturgeons is somewhat remarkably developed, and recalls in some respects that of the lampreys. In the lampreys, a stout triangular cord of lymphatic tissue overlies the spinal cord. This cord of lymphoid tissue, in those forms, is invested by the fibrous connective tissue which also invests the spinal canal as the dura mater and as the outermost fibrous covering of the notochord. It occupies, in part at least, exactly the position of the ligamentum longitudinale which traverses longitudinally the neural arches of the other groups, embracing the true fishes. The fibrous cords traversing this organ, as seen in the lampreys, may, through degeneration of the lymphoid tissue, have given rise to the ligamentum longitudinale, through some common ancestral type.

This lymphoid organ in the lamprey also contains black pigment cells mixed amongst the lymphatic tissue, but the organ extends for the greater part of the length of the vertebral column in the lampreys.

In the sturgeons there is no cord of lymphoid tissue extending above the spinal cord, for its whole length, but at its anterior end the spinal canal is greatly widened, and in this dilated portion of the latter there is a mass of lymphatic tissue included which is not traversed, as in the lampreys, by fibrous connective tissue, but as in them is found to contain scattered black pigment cells. This mass of lymphoid tissue in the sturgeon lies partly within the dilated anterior part of the spinal canal and partly within the skull, and extends down over the sides of the anterior end of the spinal cord and medulla oblongata. This mass of lymphatic tissue therefore occupies partly an intracranial position and does in fact extend slightly in front of the auditory region of the skull.

While it is difficult to identify the lymphoid tissue found in such close relation with the nervous system of the sturgeon with the massive trihedral lymphoid strand overlying the spinal cord in the lamprey, the comparison is at least suggestive.

A still more remarkable lymphoid organ is found investing the ventricle of the heart and the bulbus aortæ of the sturgeon. It is one of the most striking structures found in the sturgeon, and at once attracts the attention of the anatomical tyro upon opening the cavity in which the heart lies. It is, in fact, the tissue which gives to the surface of the heart of the adult a lobulated appearance entirely different from that of the heart of all other fishes. These lobules are the outward expression of compartments in a thick layer of lymphoid tissue, which are found to be lined with processes that are produced into plates, or lobes, internally that are often dentritic or branched as seen in cross-section. In portions of this structure lymphatic tissue has been found of the usual type met with in higher types, but no muscular fibers have been observed. Besides this there have been found masses of a homogeneous substance in some of the lobules, which recall the masses of similar matter seen in the closed sacks of the thyroid body throughout the vertebrates generally. Its function has never been clearly determined, but my own opinion is that it probably belongs to the category of ductless glands and that it may have some relation to the thymus or thyroid, probably the latter, as long ago suggested by J. F. Meckel. The history of this singular organ can only be made out definitely by a study of its development, from fresh materials, extending over a great many more stages than are at my command for that purpose. Until that is done it will be useless to speculate as to the true nature of the singular lymphoid structure which covers nearly the whole heart of the sturgeon. It completely covers the ventricle and bulbus; is firmly attached to their outer surfaces, and forms, so to speak, a second, and highly differentiated wall lying external to the muscular coat of the heart. Only one other suggestion occurs to me as respects its true nature, and that is that it may possibly be a greatly thickened epicardium in which lymphatic tissue has been developed, but even this suggestion would have to be verified by further embryological research, for which the required material is not yet at hand.

A third tract of lymphatic tissue is found extending along the free margin of the spiral valve. The free margin of this spiral valve or fold is greatly thickened throughout its entire course. Cross-sections of the portion of the alimentary canal in which this structure is found discloses the fact that the thickening of the edge of the spiral fold is due to the presence of a cord of lymphoid tissue, which is indistinctly subdivided into lobules by strands of fibrous tissue. That there are true lymph-cells present in this part of the fold is readily demonstrated in stained preparations of cross-sections of this part of the intestine. Such lymph-cells, are, moreover, apparently migratory and move up and down within the papillæ or villi with which the intestinal wall is here thickly studded. They probably have an important work to perform in taking up the digested nutriment which passes through this part of the alimentary tract. The relative proportions of this cord of lymphoid tissue is indicated in the partially diagrammatic cross-section of the spiral valve, represented in Fig. 47 at *Ly.*

It is therefore obvious that in the sturgeons we have the lymphatic system quite highly developed, more so in fact than in almost any of the Elasmobranchs, Teleosts, Dipnoans, or Ganoids. No close comparisons with other types can be made with respect to the lymphoid structures of the spinal canal. The closest comparison seems to be afforded by the strand of lymphoid tissue overlying the spinal cord of the lampreys.

With respect to the spleen of the sturgeon, which has been frequently identified as pancreas, sections show that it is really lymphoid. Large Malpighian bodies are discernible in sections, which agree closely with the appearance of those seen in sections of the spleen of Selachians, some of which I have been enabled to compare with sections of the sturgeon's spleen through the kindness of Mr. W. F. W. McClure, of Princeton College.

## 8. THE DEVELOPMENT OF THE STURGEON.

The recently deposited ovum of the common sturgeon measures 2.6$^{mm}$ in diameter. That of the sterlet, upon which species the most of our information as to development is based, is much smaller, measuring only 2$^{mm}$. As already stated, besides the egg membrane a glairy viscid substance forms a considerable layer on the exterior of the eggs, which becomes soft and stringy upon contact with water, but hardens later into a firm substance which finally cements the ova firmly to whatever they may be brought into contact.

The micropylar apertures appear to be multiple in the egg of the sturgeon. There appears to be one central one in the egg of the common sturgeon, which is surrounded by a cycle of others, as represented in Fig. 2, Plate XXXVII. The micropyles from the first overlie the dark germinal area, and through these minute openings in the egg membranes the spermatozoa or male elements find their way in order to impregnate or fertilize the egg. The micropyles occupy the central position over the germinal area before the egg is mature, and set free from the ovarian follicle in which it grew and ripened. In the species of sturgeons studied by Kowalewsky, Owsjannikow, and Wagner seven micropyles were observed. Salensky found from five to thirteen in the eggs of the sterlet.

The segmentation of the egg begins at the dark pole and is unequal, and at first it is only partial. Later the segmentation furrows extend through the whole egg, as seen in Fig. 5, after segmentation is completed. About this time a segmentation cavity appears within the egg, roofed over by the smaller segmentation spheres of the dark pole, while it is inclosed below by the large spheres of the lighter pole, which comprises the yolk. Just at this point there is an inconsistency in the account given by Salensky which it is hard to reconcile with the very large persistent yolk of the later stages. The large segmentation spheres seem to have their segmentation furrows obliterated at a later stage; at any rate the yolk is said to be inclosed by the walls of the primitive entoderm of the intestine, after the segmentation of the yolk substance has become less obvious than at first, and after its nucleated segments had become pretty numerous. If the inclusion of the yolk cells by the intestine actually occurs as described by Salensky, the process is without a parallel among the vertebrates, the nearest approach being the mode of yolk absorption lately described by P. and F. Sarasin as occurring in the embryos of *Ichthyophis glutinosus*, one of the footless, worm-like batrachia of Ceylon.

The further development of the germinal area at the dark pole of the egg presents many analogies to that of the osseous fishes, especially as respects the manner in which the yolk is finally covered in and completely inclosed. Upon comparing Fig. 6 with the stage represented in Fig. 5, it will be seen that the upper pole is now covered by a cap of cells which leave only the lower coarser yolk cells exposed. This cap has resulted from the more rapid segmentation of the small cells shown at the upper pole of Fig. 5. These smaller cells of Fig. 5 have in fact, in Fig. 6, become so small by repeated division that the artist has found it impracticable to represent them according to the scale of enlargement adopted in the last-mentioned figure. The cap of cells has grown all around its margin in such a way that it has gradually extended over the yolk. At one side of the cap the rudimentary embryo is visible as a light band rounded at the upper end. A linear depression runs through the middle of the rudiment of the embryo; this represents the center of the so-called medullary plate, and is also the middle of the medullary groove to be folded in later when the margins of the medullary plate are turned upward and fuse immediately over the former to form the medullary canal or passage way through the primitive spinal cord, which is developed in the way above described.

In the next stage of development, which is reached in about twenty-four hours after impregnation, we have the appearance presented in Fig. 7. The only portion of the mass of yolk cells which now remains exposed is indicated by the little rounded, nearly black area, at the lower pole of the figure. The yolk is now completely inclosed, except this small portion, by the continued growth of the lower edge of the cap represented in Fig. 6. This small area of yolk still exposed is the yolk blastopore or prostoma.

At this time the rudiment of the embryo becomes widened in front, as shown in Fig. 7, so that the medullary plate, anteriorly, becomes expanded like the broad end of a spatula. This widened end of the medullary plate is the rudiment of the future sturgeon's brain, and behind this widened part, the edges of the medullary folds become more distinctly evident, since the development of the spinal cord of which they form a part is now more advanced than in the preceding stage. The embryonic area at this time presents some characteristic features of coloration in the common sturgeon. The area immediately around the embryo is light-colored; some little distance from it there is a darker band of color. This dark band is oblong, with the sides curved inward, so that the whole reminds one of the form of the body of a violin, with the embryo lying in the middle line, or lengthwise, in the paler central area.

While these changes have been in progress, the cap or mantle of smaller cells from which the embryo is formed, and which now almost completely envelops the yolk, has undergone internal changes. These relate mainly to the splitting or folding of its constituent cells in such a manner, over the embryonic portion especially, as to form two layers. From the outer of these the skin and nervous system of the future sturgeon will be formed, while from the inferior and thicker layer the rudiments of the muscles, blood-vessels, intestine, cartilage, etc., of the future completely developed animal will be evolved.

The changes which follow, and which are visible from the exterior, relate partly to the outermost and partly to the innermost layer of cells which cover the yolk. On either side of the embryo, in Fig. 7, there are distinct longitudinal swellings, W G. These indicate the beginnings of the kidneys, which are still more distinctly visible in Fig. 8 as a pair of narrow bands. In this figure further changes are taking place in the fore part of the medullary plate; the anterior and posterior parts of the brain are in fact becoming defined, while still further back the four pairs of blocks of cellular substance mark the rudiments of as many segments or flakes of the muscular system of the adult. Behind these the thickened rim of tissue surrounding the blastopore will furnish additional muscular segments as development proceeds, while it is also obvious that the rudiments of the posterior limbs of the kidneys embrace this ring of tissue.

These points are still better shown in Fig. 9, in which the medullary tube or rudimentary spinal canal has become folded off from the muscular segments at the sides, and which have greatly increased in number. The whole embryo has also lengthened, so that only the posterior portions of lateral rudiments of the head, *k p l*, are visible, while the blastopore has closed posteriorly. Additional muscular segments are also seen to be progressively split off, from before backwards, from the rim of tissue which in the preceding stage surrounded the blastopore. The Wolffian ducts or embryonic renal apparatus is also seen to extend to or beyond this region.

Still more advanced stages are represented in Figs. 3, 4, 10, and 11. In Figs. 3 and 10 the first visceral arches $va'$, $va''$, $va'''$ are obvious, while the first outward signs of the sense organs, the ear, eye, and nasal pits are plainly visible in Fig. 3.

In Figs. 4 and 11 are shown very nearly parallel stages of development in the common sturgeon and sterlet. Fig. 4 is from below, and Fig. 11 shows the head end of the embryo of the sterlet from above. In the latter the anterior ends of rudiments of the kidneys or Wolffian ducts are seen to have their anterior ends more recurved than in the less advanced stages shown in Figs. 9 and 10. At this time the head becomes obvious at the anterior end of the embryo, extending some distance forward beyond the fore part of the head, as a pulsating tube, which receives the embryonic blood from a paired system of vessels extending over the yolk.

Fig. 12 shows the just-hatched Russian sterlet, while Fig. 18 shows the common sturgeon just after it has left the egg, on the sixth day after impregnation. The yolk in the sterlet is now much larger in proportion to the body than in the common sturgeon. There does not seem to be any sign of the pectoral fin developed in the just-hatched sterlet; but in the common sturgeon this fin is the first of the paired ones to be developed, and is very conspicuous as a delicate but low fold on the top of the yolk-sack, a little distance from the side of the body at *f*, Fig. 18.

In Fig. 18 there is no outwardly visible evidence of branchial clefts as in Figs. 12 and 13 of the sterlet, but the opercular fold *op* already conceals the visceral arches from the outside. The tail fold is also much wider in the recently hatched embryo of the common sturgeon, as Fig. 18 clearly shows. A single spacious Cuvierian duct, *c v*, carries the blood from the head and body down over either side of the yolk to empty it into the inferior or venous end of the heart, H, which lies in a spacious con-cavo-convex cavity *p c*, within the anterior end of the somatic wall of the yolk-sack. This space is continuous with that of the general body-cavity posteriorly.

No barbels are developed at this stage in the young of the common sturgeon, nor are they present in the same stage of the young sterlet. The nasal sack is now a simple depression in the epidermis of both. The various portions of the brain are now differentiated, while the notochord is formed and the lateral muscle plates are numerous, nearly twice as many in fact as in most young Teleosts of the same stage. In this respect the sturgeons resemble the Elasmobranchs rather than the group of Ganoids or Teleosts. Only a few of the long-bodied Teleosts have the muscle plates very numerous in the embryo.

The spiracular cleft is very obvious in the recently hatched sturgeon, as indicated in Fig. 18 at *sp*. The eye is relatively very small, a feature in which the embryo of the sturgeon agrees with the embryonic lampreys and batrachia more closely than with any fishes except *Lepidosteus*. The mouth appears very far back from the tip of the snout and is at first almost completely concealed from below as a narrow, transverse cleft in the angle formed by the upper anterior extremity of the yolk-bag and the under side of the head of the recently hatched larva.

Later, as the head lengthens and the yolk-sack is absorbed to some extent, the mouth becomes obvious from beneath as a wide transverse opening with a row of about ten formidable teeth in each jaw, as shown in Figs. 14, 15, and 17. The barbels now appear as four papillæ placed in a transverse row in front of the mouth, as shown in Figs. 15 and 16. In front of the row of barbels there is a depression, seen in Fig. 15, which may be the homologue of the preoral disk found in *Lepidosteus* and *Amia* by Mr. A. Agassiz and Mr. Allis.

The branchial filaments now begin to grow rapidly so as to be extended beyond the posterior margins of the gill covers. They consequently become visible from the side, as shown in Figs. 14, 15, and 16. The yolk is now almost absorbed and the ventral pair of fins begins to be evident, as shown in Fig. 16, while the pectoral is quite large, but still rounded at the margin and not pointed as in the adult. A notch between the dorsal and caudal begins to separate these two, while the same thing is occurring on the ventral side, so as to separate the lower lobe of the caudal from the anal. The partial atrophy of the median fin-fold in front of the rudiment of the dorsal now begins, as shown in Fig. 16. At the same time the extensive median preanal fin-fold begins to be absorbed.

In the head region the barbels are becoming more conspicuous, while the snout is longer but still remains rounded off. The nostrils are beginning to become divided externally by the upgrowth on the dorsal and ventral borders of the nasal sack of two processes which will eventually fuse and form a bridge running diagonally across it as in the adult.

The next changes which are of interest in the progress of the metamorphosis of the sturgeons have been illustrated by N. Zograff, whose figures of the young sterlet I have not hesitated to lay under contribution. In these the snout is seen to have become distinctly more pointed and flattened underneath, as shown in Figs. 19, 20, and 21. The barbels have been lengthened, but seem to radiate from a central point, as shown in Fig. 20, from below.

The greatest interest, however, attaches to the history of the median dorsal row of scutes or bucklers. These seem to arise within the partially suppressed median dorsal fin-fold and, as shown in Fig. 26 (considerably enlarged), their points are very sharp and overlap somewhat in the same way as do the fulcra or plates on the dorsal margin of the tail in the adult. The dorsal bucklers appear first and before the fulcra. The lateral plates appear at the same time as a row of smaller calcifications in the integument of the sides, the anterior plates being the largest. The ventral rows of bucklers seem to be wanting, but they evidently appear, in some species at least, very soon after this stage has been passed over. This conclusion is supported by the condition of an older stage of another species, *A. huso*, represented of the natural size, in Fig. 22. In this figure all the bucklers seem to be present, except the fulcra of the dorsal margin of the caudal fin. The form of the head and snout also presents very nearly that which is so marked in the young of all the species, namely, the great elongation, flattening, and narrowing of the portion in advance of the eyes.

In Fig. 17 it is seen that fine cartilaginous branchial arches are developed in the larvæ behind the hyomandibular bar, which indirectly helps to support both the lower jaw in part and the hyoid arch wholly. The arrangement of these parts is still more clearly shown in Fig. 44, illustrating the cartilaginous cranium of the adult. Though there are five gill-bearing arches developed, it is only the four anterior ones which support true gills; the hindmost or fifth is reduced in length and is completely embedded in the tissues at the posterior end of the branchial chamber, and bears no branchiæ even in the adult.

The figures of the young larvæ and post-larval stages show that the head is at first without armor-plates or scutes; in other words, it is covered by the naked integument only during the early life of the animal. In the young fishes from 4 to 5 inches long the cranial plates are already formed; their arrangement over the top of the head is essentially that displayed in Fig. 45, for all the species, barring minor variations. The most constant plates are the supraoccipital, exoccipital, parietals, and frontals. These form, together with smaller plates over the top and sides of the snout, a complete bony investment for the cartilaginous skull or brain-box shown separately in Fig. 44. The armor is completed at the sides by the large single opercular plate and below by the parasphenoid. All, or nearly all of this bony investment of the skull, except the posterior portion of the parasphenoid bone, is developed from calcifications which start from separate centers in the skin, so that all of these superficial bones of the head are regarded together with those on the back, sides, and under sides of the body as dermal or integumentary bones. They grow in extent by adding more bony substance to their edges, so that their roughly-indented edges ultimately fit together at their edges so as to form a more or less close union by the method which is known to anatomists under the term sutural. As pointed out elsewhere, the last pair of plates to unite and thus completely cover in the cartilaginous cranium in the common sturgeon are the parietal and frontal pairs, so that a fontanelle or hole may be detected in the top of the head of young sturgeons up to 2 or even 3 feet in length, where the inner edges of these dermal bones have not yet developed a complete junction.

The vertebral column of the sturgeon consists of a notochord almost completely surrounded by rings of cartilage, the latter of which answer to the bony disks found in the vertebral columns of other types. Unlike all other types, except Branchiostoma, the lampreys, and a few Ganoids, and Dipnoans, the notochord of the sturgeon continues to grow uniformly in length and thickness throughout life, and does not grow between the vetebral bodies only, as happens in the great majority of fishes, nor does it even undergo partial suppression within a thickened outer sheath, as happens in the Chimæroids.

The paired fins are supported on cartilaginous basal pieces. The form of these pieces is well shown in Fig. 49, representing in stippled work the cartilaginous supports of the rays of the ventral fin of the blunt-nosed sturgeon. The curious asymmetry of the segments of the basal pieces in this figure is worthy of notice. It is obvious that the three pieces of which the basal plate of either side is composed are greatly unlike.

The further changes in the form of the head particularly, from youth to adult age, in the sturgeon, can best be realized by reference to the illustrations of the young of the common as contrasted with that of the blunt-nosed species on the three plates, XLV to XLVII, inclusive, and these compared in turn with the heads of an adult male and two females seen in three different positions, as shown in Plates XLVIII to L.

These figures are the first adequate pictorial representations of these fishes which have been published, and since they have been obtained with the help of the photographic camera, from fresh materials, they can be depended upon as being accurate. The proportionally narrower head of the adult male is well shown on Plates XLVIII and L, while the great difference in the width of the mouth of the young of *A. sturio* and *A. brevirostris* is strikingly displayed on Plate XLVII. The first loop of the intestine exposed in the young of the common sturgeon, and represented on Plate XLVII, is seen to extend proportionally much farther back than in the adult, shown with the viscera exposed, in Plate LI, where this portion of the intestine is the only part of the alimentary tract which is uncovered. The metamorphosis of the sturgeon, according to the data given in this brief sketch, is seen to extend over a prolonged period, and to involve not only the fins and integumentary plates but even the relative proportions of the viscera.

## 9. THE SOURCES OF THE FOOD OF THE STURGEON.

When the young of the common sturgeon is first hatched it measures barely half an inch in length. At this time there is still present a quite large yolk-sack filled with a yellow opaque yolk subtance, the sides and upper surface of which are shaded with brown, owing to the presence of fine granules of pigment embedded in its superficial stratum. After a few days this yolk material is absorbed and the young fish, now measuring nearly three-fourths of an inch,[1] must begin to forage for itself. As

[1] The embryos of *Acipenser sturio* are considerably larger than those of *A. ruthenus* as measured by Salensky and Balfour. This difference is doubtless due to the difference in the size of the ova of the two species, the eggs of the common sturgeon being more than half a millimeter larger in diameter than those of the sterlet. The former measure 2.6$^{mm}$, while the latter measures only 2$^{mm}$ in diameter. The larval sterlet, furthermore at the time of hatching, measures only 5¼$^{mm}$, while the larva of the common American species at the same stage measures 11$^{mm}$.

the oral opening is very small at this time it is necessary that the food taken be quite small. The mouth now becomes transverse and ventral in position, more or less protrusible as in the adult, and up to the third month the jaws support microscopic teeth of a very simple, conical type. The food taken at this time must be microscopic in character, and probably consists of rhizopods, unicellular algæ, infusoria, minute larvæ of insects and worms, crustaceans, etc., so that the range of forms upon which the life of the young sturgeon depends during its early stages of growth is a very wide one. The rhizopods, algæ, and infusoria are probably skimmed from the surface of the ooze at the bottom of the estuaries where the young sturgeon must feed during the early part of its life. That the young sturgeon does feed upon rhizopods to a large extent is to be inferred from the similar habit of the young of the *Catostomidæ* or suckers as first determined by Prof. S. A. Forbes. In slides prepared by Professor Forbes from the intestinal contents of a species of *Myxostoma* and one of *Erimyzon* (Proc. Acad. Nat. Sci., Philad'a, 1881), Professor Leidy was able to distinguish the shells of six distinct species of rhizopods or test-covered protozoa. The habits of the young sturgeon must be similar, for a time, to those of the *Catostomidæ* on account of the similarity of the mouth of both, so that, inferentially at least, there is strong probability that amœboid protozoa at first constitute an important part of its dietary.

It is thus rendered at least highly probable that there is an interdependence of the one upon the other in the struggle for existence. And one may legitimately speculate as to the still lower origin of the food of the protozoa.

The latter take into vacuoles or spaces in their sarcode minute vegetable and animal organisms which are digested and incorporated into their own substance, which is thus made to grow in amount. The rhizopods, in turn, are swallowed by the larval sturgeon, and we thus perceive that the minute accumulations of organic matter represented by the lowest protozoa are finally incorporated and become an integral part of a still larger aggregation of organic matter with a much higher grade of organization. The first process of digestion and integration took place in a mere cavity in the protoplasm of the very lowest grade of organization; the next step in the process of digestion and integration of living matter took place in a higher type in a differentiated alimentary tract with cellular walls and special glandular appendages which furnish the special food solvents or digestive ferments.

After the young sturgeon becomes somewhat older, larger forms are preyed upon. By the time the young animal has reached an inch to an inch and a half in length, the dorsal and lateral plates begin to appear, and the cartilages of the head and vertebral column have been formed, but the ribs are not yet developed, according to the sections figured by Zograff. Minute teeth are present on the pharyngeal floor and the food may be identified in the sections through the region of the stomach and intestine. The most characteristic and abundant of the intestinal contents at this time are the tests and remains of the soft parts of *Cladocera* or *Daphnidæ*, small water fleas, the summer broods of which are parthenogenetic and multiply at a prodigious rate, so as to be very abundant in the fresh-water estuaries where the young sturgeons are numerous. The figures of sections given by Zograff of the young of the sterlet, display the stomach and intestine literally packed with the remains of *Daphnidæ*, so that it is obvious that during some portion of the sturgeon's life and under certain conditions these forms stand in a vital relation to the latter as its food. Doubtless other forms, such as algæ, minute fresh-water worms, fish larvæ, insects and their aquatic larvæ, and fresh-water copepods are also taken. Many of these are again dependent upon the far more minute protozoan and microscopic plant life about them. This is notably the case with *Daphnidæ* themselves, in which certain appendages are used to sweep the microscopic infusoria and swimming algæ into the mouth, so that the water in which swarms of daphnids are kept is soon cleared of its microscopic life.

As the sturgeon grows larger and its mouth more capacious it becomes capable of capturing still larger prey. When they reach a length of from 5 inches to 2 feet, in some localities at least, they begin to prey in the main upon amphipods and isopods, two groups of crustaceans found in great abundance in the waters of the estuaries frequented by the sturgeon. These larger organisms in turn, which at this stage become the prey of the sturgeon, must feed upon smaller organisms, so that they become accumulators, so to speak, of the food of the fish at this stage, just as were the daphnids during an earlier period. The amphipods and isopods are found in great numbers in the spiral valve of young fish under 2 feet long, and besides occasionally the undigested cuticular covering of earth-worms is encountered. The remains of the larger organisms are, however, always mixed with more or less mud or ooze, which contains diatoms, rhizopods, etc., so that these low forms furnish some nutriment even in a relatively advanced stage, if not for the entire life of the animal. Of the amphipods *Amphithoë* and *Gammarus* were most abundant in the stomachs of young sturgeons. The commonest isopod found in the intestine is a species of *Idotea*. The fish from which these were taken were caught in brackish water, where these amphipods and isopods are very abundant, often adhering to the gill-nets of the shad fishermen operating in the same waters, to the number of many thousands. They are known, for this reason, to the fishermen as "shad lice."

After the sturgeon becomes adult larger organisms are sought for as food, though the writer has been surprised to find how little there remains in the digestive tract after death to indicate what formed their principal dietary. Occasionally the shells of *Mytilus* or *Modiola* are found, thus indicating that the mollusca are laid under contribution as a source of food. These mollusca, living as they do fixed to one spot, are in turn dependent upon the microscopic protozoan and larval life which is found in the surrounding waters.

From the foregoing inventory of the food of the sturgeon at various periods of its life, it is obvious that its existence is dependent upon that of a great multitude of diverse forms, which serve it merely as accumulators of pabulum to be converted into its own tissues Starting with the lowest grade of organization, the larva can feed for a time only upon forms not over a line in length, and which are minute enough to be sundered and rent by its microscopic teeth. At a later stage larger organisms are captured, measuring half an inch or more in length, while during adult life large mollusks and other organisms of 1 to 2 inches in diameter are readily taken and swallowed.

The story of the life of a sturgeon is therefore seen to be bound up with the lives of vast myriads of organisms in no way related to it in the system, but only as sources of nutriment. It is quite certain from what has preceded that if the minute life upon which the young sturgeons subsist were exterminated, the sturgeon would also become extinct. It follows from this that whatever affects the relative abundance of the minute life of the rivers and estuaries where sturgeons are found, must also affect the survival and abundance of the latter. The importance of a study of all the organisms upon which the sturgeon is directly or indirectly dependent must therefore be obvious to every one. The legitimacy of the inquiries into the life-histories of all organisms, even those in no way directly related to the economy of the State, should therefore need no apology from those engaged in the study of the problems of economic fish-culture.

## 10. HABITS OF THE STURGEON.

The habits of this fish, as might in fact be inferred from the conformation of the head and mouth, are essentially those of a scavenger and bottom feeder. The toothless, protusible mouth of the adult is in itself sufficiently suggestive of the mode in which a very large proportion of its food must be taken, notwithstanding the statements made by some European observers that the sturgeon may even rise to the surface to seize from beneath and swallow, in an entire state, such unwary water-birds as may be disporting themselves there. That the young do pursue, capture, and swallow rather active prey is proved by the fact that great numbers of the exoskeletons of amphipod crustaceans are found, together with other ingesta, in the region of the hind gut, modified to form a spiral valve. Whether these amphipods are taken while the sturgeons are swimming about through the water some distance from the bottom is uncertain, though it is probable that the young fish take them at the bottom, from the fact that large quantities of mud are found associated in the intestine with the remains of the crustaceans.

Adult sturgeons are frequently encountered, in the intestine of which the broken fragments of the shells of mollusks, bivalves as well as univalves, are met with. Fragments of *Mytilus* and other brackish-water forms are found in the alimentary tract of such individuals. This dietary is sufficiently indicative of the mode in which the animals take their food, and it is probable that annelids, nemerteans, etc., also enter largely into the dietary of these fishes. I have also met with the remains of earth-worms in the intestine of young sturgeons.

The mechanism by means of which the sturgeon is made aware of the presence of the living forms at the bottom consists of a transverse row of four pointed, highly sensitive barbels, which are placed about half way between the tip of the snout and the mouth. In the young these barbels are more slender and proportionally longer than in the adult, in which they present a series of transverse incisures or laminæ ranged side by side, and which are covered by a sensitive, tactile epithelium. This apparatus supplements the soft sensitive lobes which surround the entrance to the mouth more or less completely, and constitute a system of organs of touch by the help of which the animal is made aware of the presence of the living food at the bottom upon which it subsists.

The snout of the adult sturgeon appears to be used more or less after the manner of a digging implement. Mr. Elkington informs me that at Tampa Bay in Florida the schools of sturgeons may be observed near the shore digging up the soft bottom of shoal places with their snouts. The object of such a habit would seem to be the search for half-buried mollusks, annelids, etc., which are doubtless swallowed, together with more or less dirt, as we saw in the case of the amphipods taken by the young animals. My informant also stated that the Florida sturgeons had a shorter, more recurved snout than those of the Delaware. Whether this difference is merely varietal, or whether it is indicative of the existence of a different species in Florida can not be determined without specimens from there for comparison. It is barely possible, judging from the rarity of *Acipenser brevirostris* in the Delaware and its small size, that that species reaches its greatest development farther to the south. *A. brevirostris* is not of any commercial importance in the sturgeon industry of the Delaware, for, amongst the many hundreds of *A. sturio* which I saw at Delaware City, no specimens of *A. brevirostris* were taken either for the sake of their roes or the flesh. The shorter, plumper build, and blunt snouts of the Florida form noted by Mr. Elkington would agree very well with the view that the species there met with is the true *A. brevirostris.*

The habit which the sturgeon has of jumping up out of the water at an angle and projecting the body through the air for some distance is probably of the same nature as that of the gar-pike, which rises to the surface for the purpose of taking air into the complex, lung-like air-bladder. The sturgeon has been known in leaping to jump into small boats, and in one instance, Mr. Reeves, of Delaware City, informed me that a large individual had actually jumped from the water high enough to go through one of the dead-lights, near the water's edge, in the hull of a passing passenger, side-wheel steamer, and thus find itself an unexpected prisoner in the hold of the vessel.

The habits of the female during the spawning season are probably somewhat peculiar, and, it may be, quite characteristic. Those which had spawned and were observed by the writer exhibited a remarkably flabby, or empty appearance of the abdomen. After their ova have been discharged the spent females are known amongst the sturgeon fishermen of Delaware City as "slunkers," and are of no value to them for caviare, but for the flesh only. Later in the season these same spent roe, or "cow fishes," as they are called in the local vernacular of the fishermen, recuperate and become again quite plump, acquiring considerable additional weight. They are then more highly prized for their flesh than during the spawning season.

The roe fishes seem to get rid of their eggs by rubbing the belly against hard places on the river bottom. This would seem to be the case judging from the inflamed appearance of the skin covering the abdomen of spent fishes. This irritation of the skin may arise as the result of an attrition of the abdominal walls against hard places on the river bottom, or possibly it is induced by attrition with the surface of the bodies of the males, two or more of which are said to follow the females, according to Russian writers, the males pressing against the abdomen of the female, thus favoring the extrusion of the eggs and at the same time discharging their own milt to fertilize the ova.

As the season advances the spawning schools move upwards from the salt waters of Delaware Bay and in the neighborhood of Fort Delaware and Delaware City, 45 miles south of Philadelphia, where they pass into brackish or nearly fresh water. From this point southward 20 miles, and northward as many more, it is probable that a large part of the spawning now occurs. Those that escape the meshes of the hundreds of sturgeon nets which are every day stretched across their spawning grounds go farther north to get rid of their burdens of ova. Many more are deprived by the fishermen of the privilege of thus unburdening themselves, and are taken to the killing and butchering floats at the wharves of the dealers along the river at various points where the nearly ripe roe is removed for the purpose of being made into cavaire.

The upward movements of the schools seem to be affected to some extent by a rise of the prevalent temperature of the water and air, thus making the fishing for the time more profitable. Conversely, a decline in the prevailing temperature is often apparently followed by a diminution in the numbers of fish on their way up the river, and a cold, late season retards the appearance of the fish from the salt waters farther south. A very rainy season, which has caused an unusually abundant flow of fresh water down the river, also interferes with their early appearance in the waters above Delaware City. This is supposed to be due to the fact that the water becomes fresh farther south than usual where the schools then remain to discharge their spawn. The fishing season at Delaware City is at its height during the months of May and June, but fish are caught during the summer and autumn and until as late as September and October.

The spawning fish or "runners" (those with the eggs set free from the ovarian follicles and lying loose in the abdominal cavity) are usually most abundant about the middle or end of a "run" or school of fish. The period during which the most spawning fish have been observed at Delaware City is during the month of May, especially the last half of the month. It is then that the greatest success may be looked for in getting the eggs for purposes of artificial incubation in large enough quantities to make such an enterprise important from an economical point of view.

The young sturgeons, which are found in certain places in the river in such numbers as to be a great annoyance to the shad and herring fishermen, in whose nets they become entangled, are found mostly over certain kinds of rather firm bottom not far from the shore, where they may be supposed to feed, and where they are known to pass the greater part of the year. In none of the young sharp-nosed forms of *A. sturio* have I been able to find any evidence of a fully developed roe or milt, and I infer that the anadromous or migratory habit is probably not developed until the reproductive powers are fully matured, when the migratory impulse assumes control of the movements of the animal. The young immature fish have been taken from under the ice in the river in mid-winter, indicating that they remain in the fresh water the whole year.

The young of the common sturgeon reaches a length of about 3 feet before it begins to lose to a marked degree the sharp or acuminate snout which gives it such a characteristic appearance, and which has misled not only naturalists, but fishermen also, into the belief that these sharp-snouted forms were a distinct species. Naturalists as well as fishermen have bestowed names upon the young fish in the belief that they were specifically distinct from the large fishes.

The mature fishes seek a hard bottom upon which to deposit their spawn in from 1 to 5 fathoms of water. Except when leaping out of the water and when moving upstream rapidly they do not seem to habitually rise to the surface. The tendency of the fish to seek the bottom is taken advantage of by the fishermen in the construction of their gill-nets, the cork line of which is not made to come to the surface, but the wooden floats are attached to cords so as to leave the upper edge of the net about a fathom below the surface. The nets of about 300 fathoms length and 3 to 4 fathoms deep are laid out from sail-boats specially constructed for convenience in stowing and liming the net in a slightly raised compartment at the stern. The fishing is done during the day-time on the Delaware, each boat being manned by two men, who put out their net at the beginning of flood-tide and drift upstream. The net is fished during slackwater, and the fish are hauled on board by means of stout, long-handled hooks made of five-eighth inch round iron. The fish usually reach the wharves at the beginning of ebb-tide, and are usually alive if they have not been too much exposed to the sun. The fish as soon as they are gilled make but little effort to get free, being singularly tractable and manageable in spite of their great size, individuals of from 9 to 10 feet in length being sometimes taken. The most usual size of the "cow fishes" or females is about 8 feet, and they are also stouter and longer than the males, which are usually shorter and more slender, ranging in size from 6 to 7 feet, with a slightly more narrow head, as is shown in the accompanying plates.

The meshes of the nets used in gilling the sturgeon measure 8 inches on a side, or 16 inches across, when stretched taut. These nets will gill fishes ranging in length from about 5 to 10 feet. The smaller blunt-nosed sturgeon, *A. brevirostris*, is never taken in these large-meshed gill-nets as far as I am aware, and, judging from the advanced condition of the reproductive organs in individuals only 20 inches in length, it is probable that it never reaches a great size in the Delaware. Upon special inquiry of old fishermen, I was not able to hear of any specimens of the short-nosed species being taken which had measured over about 3, or at most 4 feet. In such cases the females of this darker-colored, short-nosed species were found to have mature roes.

## 11. THE SPAWNING FISH.

The majority of the roe fishes which are brought in to the butchering floats are not quite ready to spawn. The nearly mature roe of such fishes is hard and firm, and the eggs have not yet ruptured the walls of the follicles and escaped into the general cavity of the body. The roes of such individuals are known to the fishermen and caviare dealers as "hard roe." The hard roe, as it is called, is the kind most prized by the packers of caviare.

Occasionally fishes are taken in which the roe is quite immature. In such cases it is smaller in quantity than the kind mentioned in the preceding paragraph, and is worthless for caviare.

Another kind of roe is that which is the most valuable to the fish-culturist. This sort is the kind which is just mature and ready to be artificially fertilized. Most of the eggs of the ripe roe have ruptured their follicles, and as soon as the abdomen is cut open the ova escape in great quantities, to the amount of several gallons in the case of a large fish. The quantity of eggs yielded by a single fish may, in fact, vary between 5 and 15 gallons. Estimating by the number of pailfuls of hard roe, each holding 3 gallons, it may be assumed that the average is about 10 gallons. This is a fair estimate, as the average is probably a little above three pailfuls, each holding 3½ gallons. The eggs measure $2.6^{mm}$ in diameter, or a little less than one-ninth of an inch. At this rate we should find about 168,000 eggs to the gallon, and a total of from 800,000 to 2,400,000, according to the amount of roe in a single fish estimated in gallons.

The eggs, when in exactly the right condition, are globular, nearly a ninth of an inch through, and vary in color from a very light brown to a very dark brown. At one side a darker round disk may be observed, the diameter of which is about one-fourth of the circumference of the egg. This disk is also quite as visible in ova which have not yet escaped from the follicles in which they were developed, as in the "hard roe," for example. The darker discoidal area is the germinal area of the egg of the sturgeon, and is the point where development first manifests itself to the unaided eye through certain changes in its shape.

*The eggs of the kind above described should retain their globular form, like so many shot, and should show no signs of adhering to each other. If the round area at one side of the eggs should appear distorted or broken, it is also a sign that the eggs are probably worthless for fertilization.*

Eggs with a round disk, if they flow freely from a slit cut through the walls of the abdomen of the recently caught living fish, may be fertilized without difficulty, provided a ripe male is at hand. Eggs which do not answer to the requirements given in this paragraph it is not worth while to waste time over.

It frequently happens that running or ripe fishes are brought in which have a great abundance of loose eggs in the abdominal cavity, which are entirely worthless for purposes of fertilization. Upon examination, it will be found that in such cases the eggs either have the discoidal germinal area distorted and injured, or else many of the ova have had their thin covering or zona radiata ruptured, and the yolk has been crushed and has escaped as a slate-colored substance. This rupture and injury to the eggs is due to the entrance of water from the outside, through the oviducts and genito-urinary passages, into the body-cavity, the presence of the water causing the glairy, adhesive coating to set or harden, and with which all the ova are covered upon leaving the follicles in which they were matured. This hardening of the mucigen which covers the eggs, in the presence of water, and while still with the body of the mother fish, will cause the bursting of the egg-coverings if such fish do not get the chance to discharge their eggs at once, or happen to be roughly handled in the boats, as the ova adhere in great masses, the breaking or crushing of which also ruptures the individual eggs of which they are composed. Such roes are of no service whatever as a source of supply for purposes of artificial fertilization. Roes of this kind may be at once distinguished by their sliminess and the slate colored appearance of the contents of the broken eggs.

Another type of roes are those of the entirely spent fish, which has discharged all of its mature eggs. The roes of such fishes are no longer brown, and the leaflets of which they are formed are made up of very small pinkish or pale, and very young ova. Such fishes may be distinguished by the flabby, collapsed, or shrunken abdomen, since the remnant of immature roe left behind in the body-cavity is hardly a tenth part of the volume of the ripe ovaries as seen in fishes with mature or "hard roe." The remnant of the roes of a fish which has only recently got rid of its burden of eggs looks ragged when the ovary is wetted and floated out with water; this is due to the presence of the collapsed leaflets formed of the vascular and cellular tissue from which the ova have escaped. These leaflets of the roes are disposed transversely on either side of the mesentery, or thin membrane, which fastens the alimentary tract to the middle line of the dorsal wall of the body-cavity.

While the nearly mature roes of the females are relatively of great size—greater in fact than any other viscus of the body—they are also usually dark in color, as may be gathered from the figure in Plate LI, showing the roe exposed. The color of the nearly mature or "hard roe" is also subject to some variation. Occasionally fishes are found in which the roe is quite pale, and hardly darker than the other viscera. This is due to the nearly complete absence of pigment granules in the yolk of the individual eggs, the pigment being diffused in fine particles throughout the substance of the egg of the sturgeon, somewhat as it is throughout the ovum of the batrachia. The next grade of coloration of the roe is a very much darker one; brownish, with a decided shade of gray or lead color, when the roe is viewed as a whole. This last-mentioned shade of roe, which is quite common, is known as "light roe" amongst the packers of caviare. Several gradually darker shades may be recognized between this last-named variety and the next, or the quite "dark roe" as it is called by the dealers, who are careful not to mix the lighter and darker kinds together in the manufacture of caviare; the reason for which is, that the light and dark eggs when mixed together give to the caviare so prepared a "pepper and salt" appearance which is not considered desirable by dealers.

These differences in the color of the roes is wholly due to the presence of more or less pigment in the individual eggs. The germinal area or disk of the eggs of the dark roe is almost black, while in the light roe this area is not so dark, and there is a distinct dark dot or spot in the center which is surrounded by a light zone, outside of which there is a much darker superficial ring of pigment which marks the edge of the germinal area.

The internal reproductive organs or testes of the male sturgeon are not nearly so large as the roes of the females, which may vary in weight from about 50 to as much as 120 pounds. The testes probably never much exceed 10 or 15 pounds in weight, and are cream-colored, with a shade of pink, instead of having the dark tint which characterizes the roes of the females. The form of the testes is that of a compressed irregular series of bodies, separated from each other by narrow constrictions, and present as paired organs on either side of the mesentery. In cross-section the segments of the testes are oval, the mature, sexually active organs being nearly 2 inches thick and 3 to 4 inches wide, and extending for a distance of 18 inches to 2 feet on either side of the body-cavity. The transverse subdivisions of the testes is subject to variations in different individuals, some having them subdivided into a greater number than others.

When the testes are mature, upon cutting them across, the larger ducts will be made apparent from the readiness with which the milk-white, viscid seminal secretion escapes from their cut ends. The testes may be removed from the living male and the semen, or milt, pressed from the fragments, especially from the larger ducts found along the dorsal border of the organ. I have upon two occasions tried to fertilize the eggs with milt pressed from fragments of the testes, but without success; yet this experience is not to be taken as conclusive that it may not be done. In both cases the ova which were at my disposal were probably not in condition to be fertilized. Where large numbers of the eggs of the sturgeon are to be fertilized, I think that it may be necessary to resort to this method, as I find that it is somewhat difficult to press out much milt from the testes by means of pressure upon the abdomen of the sexually mature male. If the abdomen is firmly pressed with the foot, accompanied by a firm backward stroke of the leg, a few drops of a milky secretion are forced out of the genito-urinary opening just behind the vent. The secretion forced out in the manner described is thin and watery, not being much more consistent than skimmed milk, whereas the secretion from the ducts of the testes is intensely white, glairy, and viscid, but readily breaks up and thins out in the presence of water to form a milky mixture, swarming with spermatozoa. The only successful results in fertilizing the eggs were with the thin milt forced out from the abdomen and testes by pressure and strokes upon the abdomen with the foot, though there is no reason why good results should not be obtained by pressing the milt from fragments of the testes, in the same manner as the spermatozoa of the oyster, star-fish or of worms are obtained, when it is desired to artificially fertilize the ova of these forms. That good results may be thus obtained in dealing with the milt and eggs of the sturgeon I have no doubt whatever, since the only good lot of eggs which I had the opportunity of successfully fertilizing was one batch which were removed from the old fish by cutting open the abdomen.

In practice I should recommend such a method of pseudo-Cæsarean section above every other, because in attempting to forcibly press out the ova of the sturgeon through the genito-urinary passages I believe that they would probably be far more liable to injury than if removed from the old fish by slitting open the belly.

In getting all the eggs out of the abdominal cavity, I would suggest that the abdomen of the live fish be slit open in the median line, and its head raised so that the eggs may be run out into large pans to a depth of 2 or 3 inches, a little water added and the live milt put with them and gently stirred about with a feather so as to mix the eggs and milt. The very important steps which must *immediately* follow the removal and fertilization of the ova are very important and may be stated under the head of

### 12 HANDLING THE EGGS.

Not more than twenty minutes should be allowed to elapse after the time the milt and eggs are mixed together till they are spread upon cheese-cloth trays, one egg deep, or in a single layer. If this is not done immediately the eggs will stick together in large masses, causing those at the center of these masses to be asphyxiated for want of oxygen, which under such circumstances cannot find access to them. Other equally serious evils follow from allowing the eggs to adhere together in large masses, and the principal one is that if such masses are irregular and of any size, if broken, the eggs along the line of fracture of the mass will be broken and destroyed.

It is therefore very important that a large number of trays properly constructed be at hand upon which to spread the eggs if any extensive hatching operations are to be conducted. The eggs will adhere very firmly to the surface of the cheese-cloth in a few hours, after which further watchfulness is necessary, in order to keep down any fungus which may appear upon the dead eggs, of which there will always be some. It may be possible that panes of glass would serve the same purpose as the cheese-cloth trays, if a current of water were allowed to flow very slowly between a superimposed series of glass plates properly disposed in a trough.

The experience of European investigators, Knoch, in 1871, being amongst the earliest, has been the same as that of myself in finding that the ova of the *Acipenseridæ* were adhesive. Knoch worked with the eggs of *A. ruthenus*, or the sterlet, and his account of the adhesiveness of the eggs of that species agrees closely with my own.

I find that the ova are more or less adhesive immediately upon their removal from the abdominal cavity, so that if one tips for an instant a vessel to one side in which the eggs are contained they at once form a coating of a single layer over the surface to which they have been thus momentarily exposed. Upon admixture with water the adhesive material with which the eggs are covered seems to be dissolved somewhat and becomes diffused through the water, so that the whole becomes ropy. If a lot of the eggs is taken up in the hand from the water glairy filaments formed of the ropy solution will trickle down between the fingers, and if the wind is blowing these may be drawn out for the length of 2 feet or more.

This glairy or ropy character of the partly dissolved coating of the eggs persists for some time, usually for thirty minutes or so, after which time the glairy substance hardens or coagulates in the presence of the water and the gases held in solution by it. In process of hardening the glairy, sticky coating of the eggs firmly fastens them to whatever they are brought into contact with, and after that has occurred it is scarcely possible to detach them without injury to their delicate, thin envelops and their soft, viscid contents, consisting of yolk substance and protoplasm. The sticky coating of the eggs finally remains as a grayish-white, tough, slightly elastic covering enveloping the egg membrane proper, and varies in thickness at different points on the surface of the ova. It is also the material which will cause the eggs to adhere in clusters or masses, sometimes as large as a man's head, if they are left together in large quantities in a vessel with a little water.

The trays used at Delaware City, on board the steamer *Fish Hawk*, were made by tacking cheese-cloth to light wooden frames a foot wide and 18 inches long, then loading the edges of the frames with strips of sheet lead to keep them immersed. These trays placed on ledges in a superimposed series, in a trough through which the water is allowed to flow gently, is a very efficient hatching device. Floating hatching boxes with brass wire gauze bottoms and small openings at the sides covered with the same kind of gauze have been successfully used by the Germans, one having been brought from Germany by Mr. S. Feddersen, of Port Penn, Del., from Hamburg. This device is quite simple and was placed at my disposal through the courtesy of Mr. R. Anderson, of Delaware City. It seems to me very well adapted for the purpose for which it is designed.

The floating box in which the writer succeeded in hatching out a batch of the eggs of the sturgeon was exceedingly simple in construction and consisted of a soap box with the top and bottom removed, the bottom for which was then replaced by tacking cheese-cloth to the lower edge of the rim, and by nailing wooden strips to serve as floats to the sides of the box, a very efficient hatching device was extemporized. These boxes so modified were placed at the edge of the large fresh-water pool near the extreme eastern end of the Chesapeake and Delaware Canal at a point where there was a constant flow of fresh water under them. The only lot of fertilized eggs which the writer succeeded in obtaining were spread on the bottoms of these boxes and left to hatch. In six days from the time of fertilization the young fish made their appearance. The rapid appearance of a parasitic fresh-water fungus, however, caused such extensive mortality amongst the eggs that very few embryos survived to escape from the egg membranes. This fungus, which appeared to be a *Saprolegnia*, is developed from spores which seem to be almost everywhere present in fresh water. The mycelium spreads very rapidly, attacking dead eggs first, and spreading from them to the live ones, which are then invaded and killed or asphyxiated by the fungus. The only way in which this pest can be kept down is to go over the trays and with a small forceps pick off the dead eggs and keep the living ones as clean as possible. Where the work of propagation was being conducted upon a large scale the attendants would probably have to be very vigilant in their attention to the eggs in order to keep the fungus under control.

The method of incubating the eggs upon trays of cheese-cloth, will enable the attendants to readily handle the attached eggs in shallow troughs of running water, and in a good light all the dead eggs or those with any fungus attached may be very readily removed. With close attention to the details of the work of propagation very important results might be attained and the work of restocking the Delaware and other streams might be undertaken with a very fair prospect of success. This view I think may be assumed as fully warranted when it is remembered that as many as 800,000 eggs may be obtained from a single fish. These would cover fifty trays measuring 12 by 18 inches, or about 75 square feet of surface.

This large number of trays might be operated in a small space in troughs aboard a vessel adapted to fish-hatching or the trays might be placed in wire cages to keep out predaceous fishes, insects, etc., and partly sunk into the water in such a place as the fresh water pool near the canal lock at Delaware City. With a small pumping engine the supplies of fresh water might be supplied for the purpose of cleaning and overhauling the eggs in a small building near by which might be provided at a slight expense for this purpose.

## 13. OBTAINING THE EGGS.

The best source of supply for eggs the writer has found to be the live fish which are brought to the Delaware City butchering floats, directly from the gill-nets. These fish, if they have been handled with a slight amount of care, will be found alive and in condition to yield living spawn. Two precautions may be taken by the fishermen which will be of great service in keeping the fish alive in the boat. These are to cover them so as to keep the sun off, and to occasionally sprinkle the head with water to keep the gills wetted. As an inducement to the fishermen to take extra precautions with the fish it might be found expedient to offer them the same compensation for a fish with good ripe roe, suitable for fertilization, as they could get for a hard roe from the dealers in caviare. In order to get the male fish in good condition it might be well to offer an equal consideration for a male with flowing milt. Fishes of either sex would then be handled by the fishermen with such care as to aid largely in guarantying the availability of their spawn.

It has also been suggested that the spawning fish be "haltered." The haltering is accomplished by passing a rope through the mouth and gills and tying the animal to a boom or post near the shore. The difficulty in that case is the ease with which lampreys and eels attack the sturgeon; besides, it is said that the eggs of such fishes as have been haltered or kept in confinement become valueless for purposes of fertilization. Such, at least, has been the experience of the Russian investigators who have undertaken to obtain their supplies of embryo from fishes kept in confinement. It is probable that the eggs of the sturgeon, as has been found in the case of the clupeoids or herrings, when kept in confinement, become disorganized and incapable of fertilization. In the case of certain members of the herring family, the mature eggs of fishes kept in confinement undergo such changes of disorganization as to be readily noticeable under the microscope. This singular effect of confinement upon the ripe eggs in the roes of fishes has been supposed to be due to fright. Such an explanation of the fact would seem to find some confirmation in the circumstance that many feral mammals when placed in confinement refuse to breed and become practically sterile.

Judging from the number of live spawning fishes brought into Delaware City, Port Penn, and other places on the Delaware, there is but little doubt that several millions of ova for hatching purposes might be obtained each season by vigorous and faithful exploitation of all the sources of supply. To get the eggs will require that spawn-takers be distributed to each of the principal points where the caviare is packed and to closely watch the character of the fish as they come in and to immediately take the spawn in pans. If no mature or milting males are at hand the eggs are, of course, of no value.

Owing to the great size and weight of the fish, taking the spawn from them directly in the sturgeon boats of the gillers will be found impracticable, since there would be too little room in which to work comfortably; besides, the fishermen would object to having their boats littered with the adhesive eggs, which stick to everything with which they come in contact.

Pennsgrove, Port Penn, and perhaps other points besides Delaware City, will be good points to operate, provided the water is not too brackish, which is greatly dependent upon the season, the river, as remarked before, being fresh much farther south during one season than during another.

Important aid has been promised the agents of the U. S. Fish Commission by the State commissioner of New Jersey, and I have found that intelligent fishermen and caviare packers were also very ready to lend valuable assistance at Delaware City. Amongst those at the latter place to whom I have been under great personal obligations I must not omit to mention Mr. Reuben Anderson.

## 14. METHODS OF STERILIZING THE WATER USED IN HATCHING THE STURGEON.

Our experience with adhesive eggs of all kinds has always shown that it is difficult to prevent the lodgment and rapidly fatal germination of the spores of *Saprolegnia* or *Achlya*, genera of fungi or moulds, found in all fresh waters upon dead as well as living fish eggs, and the rapid and fatal spread of the mycelium from affected to unaffected ova. So rapidly does this fungus grow that in a very short time its ravages will extend over an entire tray of adhesive eggs, so that in the course of four or five days the whole lot will be found to be covered with a mycelium, which by that time has not only passed into the fruiting or spore-producing stage, but has completed its work of destruction.

The eggs are destroyed by the fungus sending filaments into their substance, while the mesh of the mycelium also affords lodgment for dirt, so that the two together effectually shut off the possibility of oxygenating the ova, so that they are smothered. The ova so affected are finally appropriated as nutriment by the fungus, which rapidly produces its spores or germs in vast myriads, only to pollute the water still more plentifully with its destructive germs.

How to prevent the inroads of this pest is a matter of the very highest importance, since upon the successful solution of this difficulty depends the success or failure of the artificial propagation of the sturgeon from artificially fertilized ova.

My experience with eggs of the sturgeon at Delaware City proved that they were particularly subject to the destructive attacks of this type of fungus, and that unless some practical method was devised of overcoming losses from this cause it would be of little use to attempt to do much in the artificial propagation of this fish. In the course of about five days the eggs, which were placed on the cheese-cloth bottoms of the floating hatching boxes, which I had arranged in the large fresh-water pool connected with the eastern end of the Chesapeake and Delaware Canal, were for the most part attacked so as to be beyond the possibility of rescue. Not more than about 5 per cent. of the whole number were by that time free from the parasitic fungus, so that those which survived to hatch on the sixth day were very few in number.

A serious difficulty was also encountered in the firmness with which the affected eggs adhered to the cheese-cloth and to the good ones, so that it was found to be very hard to remove the damaged ova without injury to the good ones in attempting to thus prevent the spread of the scourge. In consideration of this circumstance the only practicable remedy seems to be prevention; that is, the germs of the fungus must be removed from the water used in treating the ova when they are fertilized and in hatching them. Or, the water used in fertilizing and hatching the eggs must be sterilized. Of these two methods the first seems to be the simplest and easiest of application, since the spores of the *Saprolegnia* are comparatively large, so that they may be removed from the water by a system of filtration.

If a system of cotton-wool filters were attached to the supply from the pumps in such a way that the water could be continuously forced through one of a series of filters, while others of the system were being cleaned and renewed, it would probably be possible to get the water used in the hatching operations free from the noxious spores or germs of the fungus. This plan would not involve the expenditure of any additional steam-power and but little additional labor and expense. The hatching troughs, with their trays of eggs, would of course have to be provided with tight-fitting covers to exclude the dust and possible contamination from the air.

Another more expensive but perhaps more thorough method would be the sterilization of the water used in the hatching operations. This could only be accomplished by means of heat, supplied by the superheated steam from the boilers of the pumping-engines conveyed into a closed iron chamber with an outlet for the condensed steam. Through a coil of pipe placed in this heating chamber, the water used in the hatching operations would be forced and heated up to a point in its passage through the coil at which the germs of the fungus would be killed. The heated water for hatching would then have to be passed through a second coil, submerged in the cold running water of the river, to again lower its temperature to that of the water before heating, after which it would be safe to let it flow over the eggs. The water if heated in this way, however, might be so deprived of air which it had contained, that it would be necessary to aerate it. This could probably be done by allowing it to flow under pressure from fine nozzels in a fine spray, so as to carry air into the water in the tanks, the nozzles being so disposed as to have their outlets elevated several inches above the surface of the water, in the same manner as the water is aerated for the aquaria at the Central Station of the U. S. Fish Commission at Washington, and in the hatching rooms in the laboratory buildings at Woods Holl, Mass.

Another method which suggests itself, is to force the water for purposes of sterilization through a coil of copper pipe, suspended over a furnace grate arranged somewhat after the manner of a Herreshoff steam coil-boiler, then conveying the water through a second coil submerged in running water at the ordinary temperatue, and then through an aerating apparatus similar to that described above, to fit it for hatching purposes.

These methods if carried out rigorously will assure the success of hatching out the eggs of the sturgeon to the extent of many millions, so that the chances of survival of great numbers of protected young may be reasonably counted upon, and thus enable the Fish Commission to increase the source of a good supply, the value of which can only be appreciated by those who have investigated the magnitude of the sturgeon fisheries of the United States, and the large annual value of the caviare now very extensively exported to Europe.

## 15. SKINNING THE STURGEON AND PREPARING THE FLESH FOR MARKET.

Except the eel and cat-fish the sturgeon is one of the few fishes which is skinned and dressed before it is sent to market. Attempts have been made to convert the skin of the sturgeon into leather; the microscopic structure of the integument of this animal is in some respects very favorable to its conversion into leather, since the deeper layer of the skin contains a great abundance of fibrous tissue. The presence of the great dermal bony bucklers or scutes, however, interferes with the necessary processes of manipulation in tanning, so as to leave holes in the tanned skin. These bucklers are so firmly embedded and form such an integral part of the skin that it is not probable that it can be successfully or profitably converted into leather.

The fish, when brought in to the floats to be opened to remove the caviare and dressed, are laid upon the side and the operator proceeds to cut about eight short longitudinal slits in pairs on either side of the middle line in the inferior part of the abdominal walls. These are very quickly made by thrusting the point of the butcher's knife through the abdominal walls with a rapid stabbing motion.

The abdomen is then slit open along a line midway between the four pairs of short slits, from a point just behind the inferior part of the pectoral arch backward to the anus. The short slits which are thus left near the edges of the great flaps formed by slitting open the abdomen, serve as "hand holds" and assist in a most important way in removing the skin, which is removed from the flesh of the trunk and anterior caudal region by freeing it first along the ventral and lateral region and at last along the back.

The head is removed with a cleaver, cutting through the fore part of the trunk and so as to remove the lower part of the pectoral arch and pectoral fins. The tail is also cut off across the narrow peduncle. The tail is often cut off first in order that the fish may bleed freely from the caudal aorta and die quickly, as the powerful tail, if the fish is still alive and struggling, may strike the operators disagreeable or even dangerous blows. The heads, tails, skins, and viscera are carried off from the floats, where the fish are dressed, by small vessels which gather this offal and take it to guano factories where the oil is extracted and the remaining flesh, bones, and cartilage dried for the purpose of converting it into guano.

After the removal of the skin the carcass of a large female sturgeon will weigh about 100 pounds, usually somewhat less. The value of the dressed carcass varies, according to the condition of the market, from 3 to 10 cents per pound. The dressed carcasses are packed in ice for shipment in the usual way. When the shippers are waiting for advance in the price the eviscerated carcasses with the heads and tails removed are packed in their ice-houses without removal of the skin. This is done because it has been found that the flesh keeps longer and in better condition in ice, under those circumstances.

## 16. THE MANUFACTURE OF CAVIARE, AND THE VALUE OF THIS INDUSTRY ON THE DELAWARE.

The "cow-fish" with "hard roe" is the only kind that is available in the manufacture of caviare. In this type the roe is firm and the individual eggs are sufficiently resistant, with their double covering consisting of the egg-membrane and the investing vascular follicle, not to be readily ruptured and discharge their contents while being separated. The roe is carefully removed from the abdominal cavity so as to not bring it in contact with water, and as soon after the capture of the fish as possible. From three to five pailfuls of roe, each holding $3\frac{1}{2}$ gallons of eggs, are removed from a single fish. This includes the investing membranes of the ovary, the vessels, and supporting tissues of the organ. These portions are in reality a very small part of the organ, so that there is but little waste from this source. This waste from the sturgeon roe is a favorite bait with fishermen who fish for eels, the eel-pots being baited with this refuse by the fishermen operating near the caviare packing establishments.

The process of "rubbing the roe," as it is called, is very simple. The fresh masses of roe are placed upon a screen, which fits over a zinc-lined trough 18 inches deep, 2 feet wide, and about 4 feet long, and with its bottom sloping to one end, where an outlet is arranged. The meshes of the wire screen are just large enough to let the separated eggs fall through as the masses of ova are rubbed back and forth over it by the operator. The separated ova fall into the trough and are drawn off at one end through an opening closed by a sliding door into clean half-barrel tubs. After the roe is brought into the condition in which the eggs are all separated a certain proportion of the best German salt, from Lüneburg, is added and carefully stirred in with the eggs in the tubs. The manipulation of the eggs is done altogether with the hands, and at first, when the salt is added to it, the effect is to dry the mass, but very soon the strong affinity of the salt for the watery constituents of the ova causes it to abstract their water and a brine is formed which soon becomes so copious that the contents of the tubs may be poured. The brine, formed as above, appears in about ten or fifteen minutes after the salt is added. The salted eggs are then poured into sieves which hold from 8 to 10 pounds of the salted eggs. These sieves, with their contents, are then placed upon sloping planks with a strip nailed on each side in order to drain off the brine. After several hours the draining is completed and the product is the caviare of commerce. From the sieves the caviare, as the separated and salted ovarian eggs are henceforth known, is transferred to small, oaken casks, holding about 150 pounds apiece. Into these casks the caviare is carefully packed so as to fill the vessel completely, and when closed is ready for the market.

Careful packers keep the dark and the light varieties of roe separate, since mixing the two gives a speckled appearance to the product which is not desired by the dealers. Cleanliness in handling the product is also insisted upon by experienced caviare packers. The finest caviare made in America goes to Europe; the inferior grades are retained for the less critical home market. The import duties paid to the German Government by packers of the American product is about 18 cents a pound, and the amount of the tax thus paid into the Imperial Treasury of the German Empire must be considerable, since a single dealer, operating on the Delaware during the season of 1888, put up about 50 tons of it for the German market. The principal port of entry for this product into the European market is Hamburg.

The caviare produced from the lake sturgeon (*Acipenser rubicundus*) is said to be the best, the eggs being somewhat larger than those of the common species, *A. sturio*. The whole of the caviare produced upon the eastern coast of the United States is made from the roes of *A. sturio*, the short-nosed species, *A. brevirostris*, not being found in sufficient numbers or size to make it an object to collect its roes for caviare. Caviare is also prepared from the *A. transmontanus*, white sturgeon, Columbia River, or Sacramento sturgeon as it is variously called, although this industry is not yet conducted upon so extensive a scale upon the Pacific as upon the Atlantic coast. The roe of the green sturgeon, *A. medirostris*, of the west coast, does not seem to be used for caviare. The white sturgeon is the largest, rivaling in size the common eastern sturgeon, while the lake sturgeon is smaller, not usually much exceeding 100 pounds in weight.

On the eastern coast the Delaware River and Bay is now the principal resort of the common sturgeon and the seat of the only profitable fishery of this species, unless the Florida sturgeon should prove to be the same form. The amount of capital invested in boats, nets, and small sloops engaged in this business on the Delaware is very considerable. The experience of the dealers and fishermen shows that a steady falling off has occurred in the catch within a few years. This, coupled with the circumstance that the fishery is now only profitably conducted south of Wilmington and that the Delaware now has the only profitable sturgeon fishery north of Florida, is sufficient to prove that it is high time that something was being done to stay the extinction of this fish. The total value and enormous yield of eggs of the Delaware fishery may be inferred from the fact that a single caviare packer collected and shipped, as stated above, about 50 tons of this product to Europe during the season of 1888. The great demand for the caviare has, within a very recent period, made the fishery profitable to the fishermen, many of whom own their boats and gill-nets. From all the information that I can gather, it is safe to assume that the annual value of the sturgeon fishery of the Delaware must be somewhere between $100,000 and $200,000 per annum. This industry may be maintained by prompt and efficient action, and to this end it is the hope of the writer that the foregoing account of experiments, results, and observations may successfully contribute. The only means of maintaining and increasing this industry is through the artificial propagation of this fish, which I have every reason to think may be successfully accomplished at a comparatively insignificant outlay.

## 17. LITERATURE RELATING TO THE STURGEON.


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7. DUMÉRIL, AUGUSTE. Prodrome d'une monographie des esturgeons, et description des espèces de l'Amérique du Nord qui appartiennent au sous-genre Antaceus. Nouvelles Archives du Muséum, tome III, 4to, Paris, 1867, pp. 131–186. (Fourteen nominal species described which are founded on young or immature and distorted specimens from various parts of the United States.)
8. DUMÉRIL, AUGUSTE. Sur trois poissons de la collection du Muséum, un esturgeon, un polyodonte, etc. Nouvelles Archives du Muséum, tome IV, 4to, Paris, 1868, pp. 93–116, plates 22–23. (*A. Dabryanus* and *Psephurus gladius* figured, the former from a specimen .035m long.)
9. EGERTON, SIR PHILIP DE MALPAS GREY. On *Chondrosteus,* an extinct genus of the Sturionidæ found in the Lias formation at Lyme Regis. Philos. Transactions, Roy. Society, London, 1858, pp. 871–885, pls. LXVII–LXX.
10. GILL, THEODORE. Article "Sturgeon" in Johnson's Universal Encyclopedia. Vol. IV, pp. 610, 611. (In this article the adult of *A. sturio* is apparently confounded with the *A. brevirostris* of Lesueur.
11. GOODE, G. BROWN, and a staff of associates. The fisheries and fishery industries of the United States. Vols. I and II, 4to, Washington, 1884. (The American Sturgeons and Sturgeon fisheries are discussed on pp. 660–663 of vol. I, and figures of five nominal species are given on plates 242–244 of vol. II. The figure of *A. sturio* is from a young specimen. The figure purporting to represent *A. brevirostris* is in all probability taken from an adult of the Common Sturgeon, while the figure of the Lake Sturgeon is from a young specimen.)
12. GÜNTHER, ALBERT. Catalogue of the Fishes of the British Museum. 8vo, vol. VIII, London, 1870. (Nineteen species of *Acipenser,* one of *Scaphirrhynchus,* two of *Polyodon,* total 22; pp. 332–347.)
13. HERTWIG, R. Die lymphoiden Drüsen auf der Oberfläche des Störherzens. Arch. f. mik. Anatomie, vol. IX, pp. 80–100, pl. VII. (The fullest account of the singular investment of lymphatic tissue covering the heart.)
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15. KNOCH, J. Die Beschreibung der Reise zur Wolga behufs der Sterlettbefruchtung, zugleich ein Beitrag zur Entwickelungsgeschichte der Sterlette. Bull. de la Société Impériale des Naturalistes de Moscou, tome XLIV, 8vo, Moscou, 1871, première partie, pp. 254–289, pl. VI. (Development of *A. ruthenus.* This author describes the adhesive character of the eggs, and is the first to figure and describe the teeth of the larval Sturgeon.)
16. KOWALEWSKY, A., PH. OWSJANNIKOW, and N. WAGNER. Die Entwickelungsgeschichte der Störe. Vorläufige Mittheilung. Bull. de l'Académie Impériale des Sciences de St.-Pétersbourg, tome XIV, 4to, 1870, pp. 318–324. (Seven figures in text, relating to the early stages of development of *A. ruthenus.*)

17. LE SUEUR, C. A. Description of several species of chondropterigious fishes of North America, with their varieties. (Read October 17, 1817.) Transactions Amer. Philos. Society, New Series, vol. I, 4to, Philadelphia, 1818, pp. 383–394, pl. 12. (Contains the original figure and descriptions of two varieties of *A. rubicundus* or Lake Sturgeon; describes *A. brevirostris* for the first time, with three varieties, and *A. maculosus.* *A. oxyrhynchus* Mitch. mentioned.)

18. MONRO, ALEXANDER. The structure and physiology of fishes explained and compared with those of man and other animals. Folio, Edinburgh, MDCCLXXXV. (A beautiful work, illustrated with copper plates, of which those numbered VIII, IX*, and XL contain illustrations of the visceral anatomy of the Sturgeon, which have not been much improved upon since.)

19. MITCHILL, SAMUEL L. The fishes of New York arranged and described. Transactions of the Literary and Philosophical Society of New York, vol. I, 4to, New York, 1815, pp. 355–492, pls. I–VI. (It is assumed, pp. 461–462, that the Sturgeon of the Hudson River is the same as *Acipenser sturio* of Europe. The *A. oxyrhynchus* is first mentioned on pp. 462, 463, and it is stated that *it is seldom over 5 feet in length.* This statement and extracts from a letter by a Mr. De Witt, quoted by Mitchill, render it almost certain that the *oxyrhynchus* of this first American ichthyologist was founded upon the young of the common species.

20. OWEN, RICHARD. On the Anatomy of the Vertebrates. Vol. I, Fishes and Reptiles, 8vo, London, 1866. (Contains considerable information on the anatomy of the Sturgeon.)

21. PARKER, WILLIAM KITCHEN. On the structure and development of the skull in Sturgeons. Philosophical Transactions Royal Society, vol. 173, 4to, London, 1882, pp. 139–185, pls. 12–18. (Gives figures of the larvæ of *A. ruthenus*, supplied to the author by Professor Salensky.)

22. RETZIUS, GUSTAV. Das Gehörorgan der Wirbelthiere. 4to, vol. I, Stockholm, 1881. (The internal ear of the Sturgeon is very accurately figured in this great work.)

23. ROSENTHAL, FRIEDR. Ichthyotomische Tafeln. 2te Auflage, Berlin, 1839. (Plate XXIV represents the skeleton of *A. sturio.*)

24. SALENSKY, W. Zur Embryologie der Ganoiden (Acipenser). Zoolog. Anzeiger, I, Nos. 11, 12, and 13, 1878.

25. SALENSKY, W. Development of the Sterlet (*Acipenser ruthenus*). Two parts. Proceedings of the Society of Naturalists in the Imperial University of Kasan, 1878 and 1879 (Russian). See also Hoffmann and Schwalbe's *Jahresbericht* for 1878 and 1879, for abstracts in German.

26. SALENSKY, W. Recherches sur le développement du Sterlet (*Acipenser ruthenus*). Archives de Biologie, tome II, 8vo, Gand et Leipzig, 1881, pp. 233–341, pls. XV–XVIII. (Fully illustrated abstract in French of this author's work on the early stages.)

27. SEELY, H. G. The Fresh-water Fishes of Europe. 8vo, London, Cassell & Co., 1886, pp. x and 444, figures 215. (Recognizes ten valid species of Sturgeons in Europe. The illustrations are borrowed from the German work of Heckel and Kner, No. 14.)

28. ZOGRAFF, NIKOLAUS. Ueber die Zähne der Knorpelganoiden. Biolog. Centralblatt, VII, No. 6, May 15, 1887, pp. 178–183, and Nachtrag in same, No. 7, June 1, 1887, p. 224. (Discusses the palatine teeth of young Chondrosteans.)

29. ZOGRAFF, NIKOLAUS. Embryonale Rückenflosse des Sterlet. Biolog. Centralblatt, VII, No. 17, November 1, 1887, pp. 517–521.

30. ZOGRAFF, N. Material toward the study of the organization of the Sterlet. First series. In reports from the laboratory of the Zoological Museum of the University of Moscow, 4to, tome III, third series, Moscow, 1887 (Russian). (Some of the new results recorded in the above are contained in the two preceding papers by the same author. The outlines showing variations in the forms of the heads of the various species of Sturgeons found in Russian waters and the carefully prepared tables of measurements are doubtless an important contribution to the natural history of these fishes; but, unfortunately, the language in which the work is printed makes it inaccessible to naturalists and students speaking other languages.)

31. —— Article, "Sturgeon," Encyclopædia Britannica. Ninth edition, vol. XXII, pp. 611–612. (Illustrated by a finely executed figure of *Acipenser ruthenus.*)

## 18. EXPLANATION OF THE PLATES.

### EXPLANATION OF REFERENCE LETTERS IN PLATES XXXVII TO LIX.

*A*, Vent or anus; *Au*, Auditory capsule.
*B*, Barbels; *Bf*, Branchial filaments; *BA*, Bulbus arteriosus.
*Ch*, Chorda or notochord; *Cop*, Copulæ; *CV*, Cuvierian duct.
*De*, Dentary ossification.
*E*, Eye; *EO*, Exoccipital scute.
*F*, Frontal scute; *F*, in fig. 51, membranous floor of aorta.
*GB*, Gall-bladder; *GR*, Genital folds or ridges; *G*, Genital opening.
*H* or *Ht*, Heart; *Hb*, primary cerebral vesicle; *Hy*, Hyoid; *HA*, Hepatic artery; *HM*, Hyomandibular bar.
*I*, Inner coat of intestine in fig. 47; *I*, *I'*, *I''*, intestine, and first and second loops of intestine; *i*, *ii*, *iii*, *iv*, *v*, branchial arches.
*II*, *V*, *X*, Foramina for second, fifth, and tenth cranial nerves; *IA*, Inferior arches of vertebræ.
*KpL*, Embryonic, cephalic mesodermal tissue.
*LL'*, Right and left lobes of liver; *Ly*, Lymph cord of spiral valve.
*M*, Mouth; *M'* and *MK*, Meckel's cartilage; *M'''*, Mesentery; *M''''*, Bristle through opening in mesentery; *MD*, Muller's duct or oviduct; *MCA*, Anterior coraco-arcualis muscle.
*N*, Kidney or Wolffian body; also, nasal scute, fig. 45; *Na*, Nasal capsule.
*O*, Outer coat of intestine; *OE*, Œsophagus; *Or*, Orbit; *Op*, Opercle.
*P*, Pancreas.
*PA*, Abdominal pores; *PC'*, Transverse or pericardial septum; *PC*, Pericardial cavity; *PF*, Pectoral fin; *Pf'*, *Pf''*, Pre and post frontal scutes; *Pf*, Pectoral fin, in fig. 18; *PN*, Pneumatic duct; *PV*, Hepatic vessels; *Pl* and *PQ*, Palatopterygoid or palatoquadrate; *Py*, Pylorus.
*R*, Rostrum and rostral scutes; *Rm*, Adductor muscle of mandible.
*S*, *S'*, Spleen.
*Sp*, Spiracle; *Stf*, Rostral disk; *SV*, *SV'*, Spiral valve; *ST*, Stomach; *Sy*, Symplectic; *SF*, Spiral fold; *SO*, Supra-occipital scute; *Sp*, Neural spines.
*UG*, Urogenital canals or ducts.
*V*, Ventricle; *V'*, Nerves going to barbels; *VN*, Swim-bladder; *VF*, Ventral fins and their site in fig. 52; *VA'*, *VA''*, *VA'''*, Primary visceral arches in fig. 10.
*WG*, Wolffian ducts in embryos figured.

## EXPLANATION OF PLATE XXXVII.

Fig. 1. Mature egg of the common sturgeon, enlarged sixteen times, dark variety, seen in profile, showing the dark germinal pole above with the light and dark rings around it.

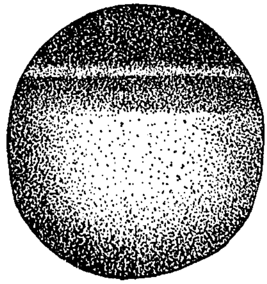
Fig. 2. Mature egg, pale variety, of the common sturgeon, from the upper pole, showing the dark spot in the center of the germinal area in which the micropyles are situated, with a pale ring around them, beyond which comes a darker zone.

Fig. 3. Embryo of common sturgeon of ninety-six hours, showing rudiments of three visceral arches, the eyes, auditory organs, cerebral vesicles, and heart; enlarged sixteen times.

Fig. 4. Ventral view of an embryo of the common sturgeon in the egg, showing the front of the head and the flattened tail curled over the yelk-bag; slightly younger than the preceding.

Fig. 5. Egg of the sterlet at the completion of segmentation of the yelk. The smaller blastomeres at the upper pole represent the germinal or embryonic area. After Salensky.

 PLATE XXXVII.



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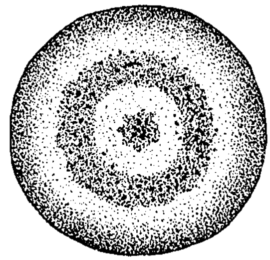

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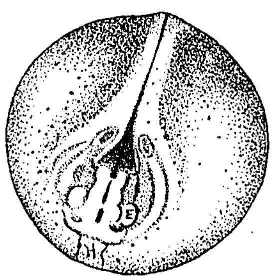

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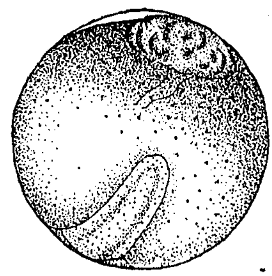

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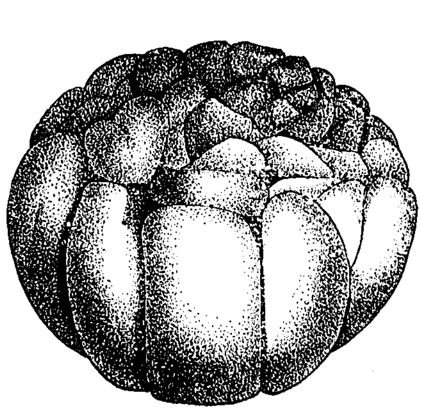

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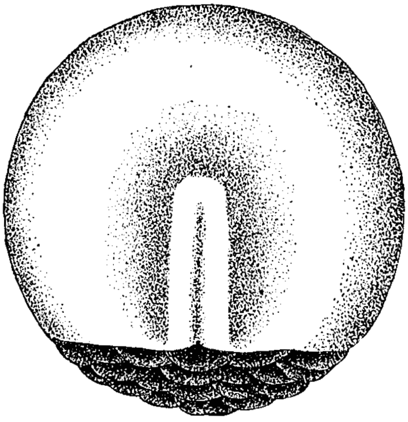
## EXPLANATION OF PLATE XXXVIII.

Fig. 6. Egg of sterlet with the large yelk cells nearly included by the embryonic membranes. The embryonic area and medullary groove is distinctly defined. After Salensky.

Fig. 7. Still more advanced embryo of the sterlet, showing the medullary groove closing in the median line, and the blastopore at the lower pole. After Salensky.

Fig. 8. Dorsal surface of still more advanced embryo of sterlet. Cerebral vesicles differentiated, while the Wolffian ducts and five somites or segments of the trunk of the embryo are visible. After Salensky.

PLATE XXXVIII.



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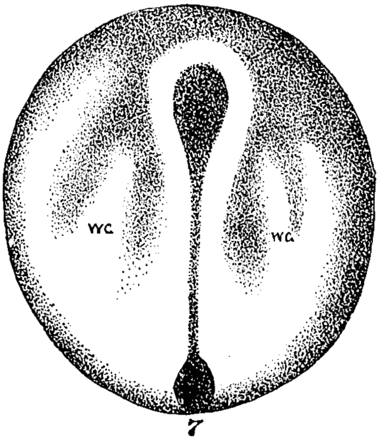


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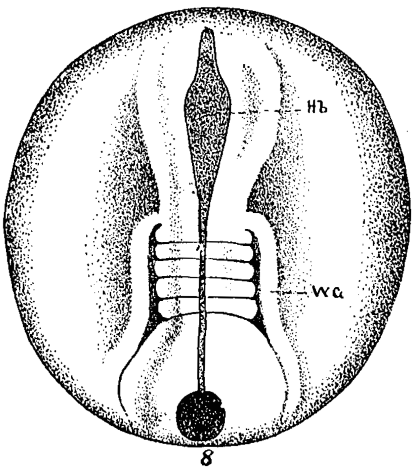


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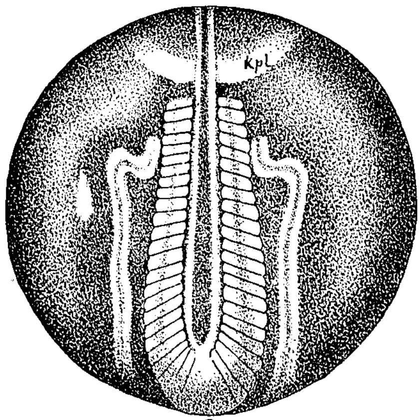
## EXPLANATION OF PLATE XXXIX.

Fig. 9. Embryo of sterlet, still more advanced, after the closure of the medullary groove and formation of spinal cord; twenty-four embryonic segments visible and the two pronephric or Wolffian canals formed on either side, while in front (upper pole of figure) the cephalic plates of mesoblast appear on either side of the rudiments of the brain. After Salensky.

Fig. 10. Embryo of the sterlet, showing its anterior end from above; three visceral arches, frontal process, the cerebral vesicles, auditory pits, Wolffian ducts, and twelve embryonic segments are developed. After Salensky.

Fig. 11. More advanced embryo of the sterlet, showing the anterior part of the body and head. Auditory and nasal organs, heart, vitelline circulation, and brain more developed than in preceding figure. After Salensky. This figure represents a stage slightly more advanced than my figure 3 of the embryo of the common sturgeon.

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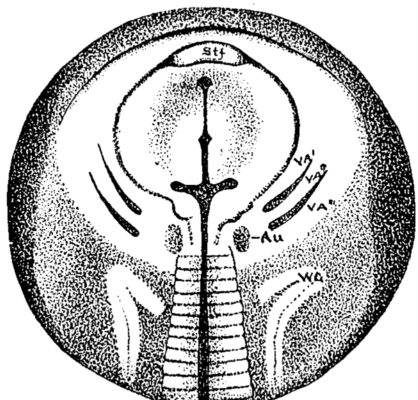


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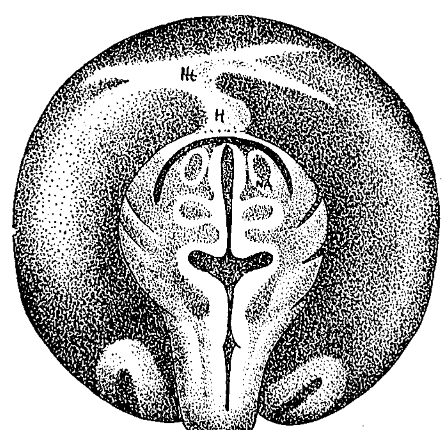


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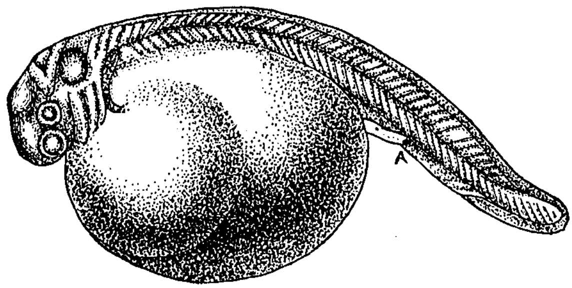
## EXPLANATION OF PLATE XL.

Fig. 12. Young sterlet, recently escaped from the egg; yelk-bag still very large. Total length, $5\frac{3}{4}^{mm}$. After W. K. Parker.

Fig. 13. Young or larval sterlet, somewhat older than foregoing, $6\frac{1}{2}^{mm}$ long. After W. K. Parker.

Fig. 14. Larval sterlet $9\frac{1}{2}^{mm}$ long, showing the branchial filaments exposed beyond the membranous operculum, the pectoral fin, the young barbels, and the strongly developed teeth with which the jaws are armed at this period. After W. K. Parker.

Fig. 15. Under side of head of larval sterlet $8\frac{1}{2}^{mm}$ long, showing the well developed teeth in the jaws at this stage, the four rudiments of barbels in front of the upper jaws, and the depression still farther forward, which probably answers to the "suctorial disk" observed by A. Agassiz and Edward Allis in the same region in *Lepidosteus* and *Amia*. After W. K. Parker.

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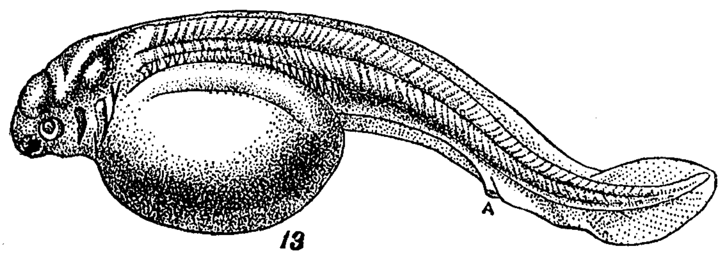


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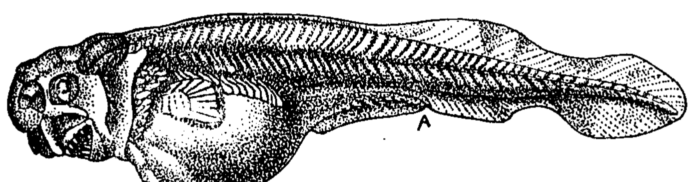


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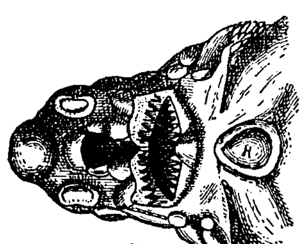

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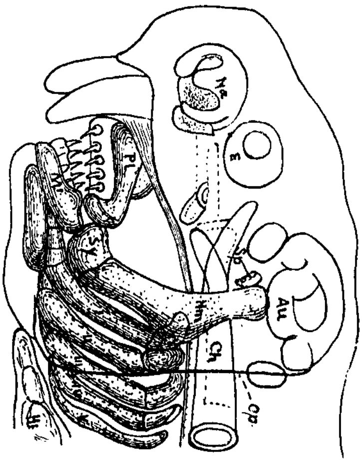
## EXPLANATION OF PLATE XLI.

Fig. 16. Larval sterlet, $13\frac{1}{2}^{mm}$ long. The median fin-fold is being differentiated into the caudal, dorsal, and anal. The sense capsules, nose, eye, and ear more developed, and the barbels are more elongated. The gill filaments are exposed beyond the margin of the operculum. The yelk is nearly absorbed. After W. K. Parker.

Fig. 17. Head of larval sterlet of the same length as the individual of the preceding figure, but dissected so as to expose the cartilages of the jaws and gills of one side. The palatopterygoid and Meckel's cartilage are seen to support teeth. After W. K. Parker.



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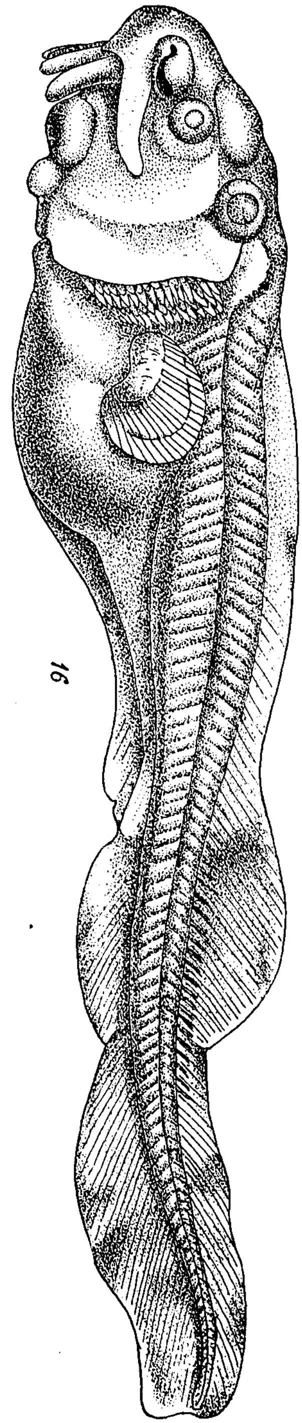

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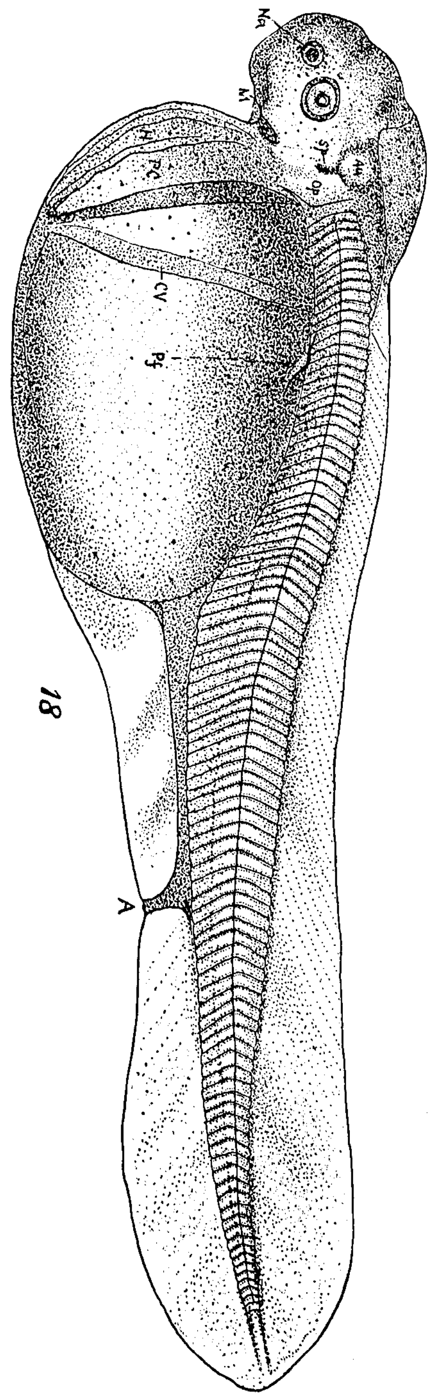
## EXPLANATION OF PLATE XLII.

Fig. 18. Side view of the just-hatched larva of the common sturgeon on the sixth day after the eggs were fertilized. There is a large cavity at the front of the yelk-sack in which the heart lies at this stage. A simple Cuvierian venous duct embraces the front end of the yelk, and extends from a point just a little in front of the still exceedingly rudimentary pectoral fin to the ventral side of the yelk. The tail is lanceolate in form and lophocercal in structure. There are no barbels, and the larva is now $11\frac{1}{2}^{mm}$ long, or more than twice the length of the just-hatched sterlet. The figure is sixteen times natural size.

PLATE XLII.

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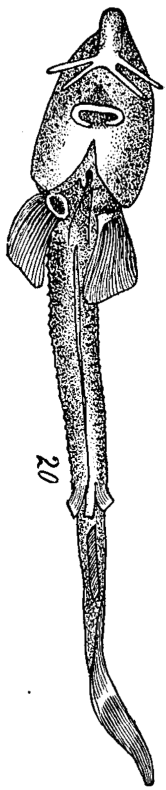
## EXPLANATION OF PLATE XLIII.

Fig. 19. Yonng sterlet, two months old, viewed from above. (How much these figures are enlarged is not stated in the original Russian monograph from which they are copied.) After N. Zograff.

Fig. 20. Young sterlet, age two months, from beneath. After N. Zograff.



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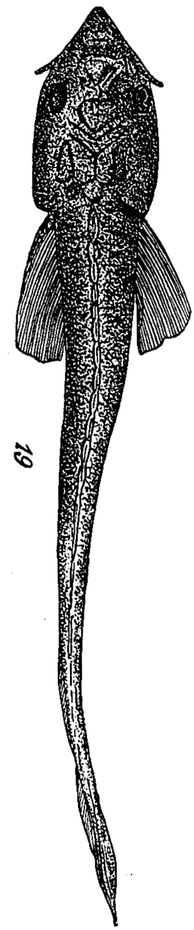

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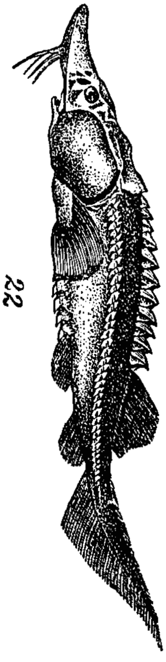
## EXPLANATION OF PLATE XLIV.

Fig. 21. Side view of young sterlet of two months. The nasal bridge is developed. The dorsal scutes are seen to now overlap, as do the fulcra of the upper margin of the tail at the later stage. The fin-folds and actinotrichia seem to have a share in the development of the dorsal scutes and fulcra. Lateral series of scutes still rudimentary, and abdominal wanting. After Zograff.

Fig. 22. The quite young of the great *Huso* of eastern Europe, *Acipenser huso.* Natural size. From a specimen brought from Russia by Ehrenberg. This specimen serves to illustrate the next advances beyond the preceding, since the lateral and ventral rows of scutes are well developed, while the operculum quite covers in the branchial processes. After Brandt and Ratzeburg.



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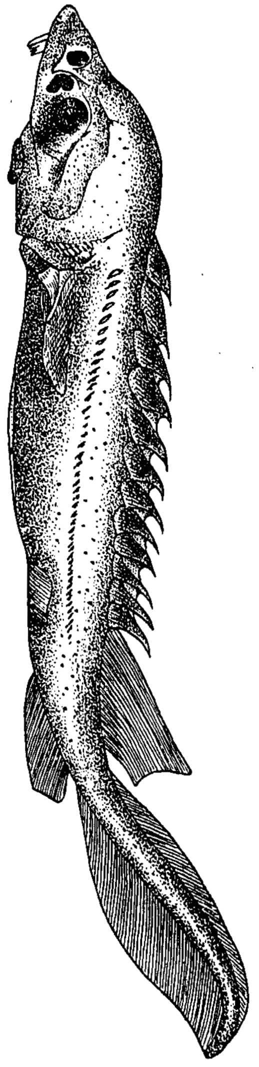

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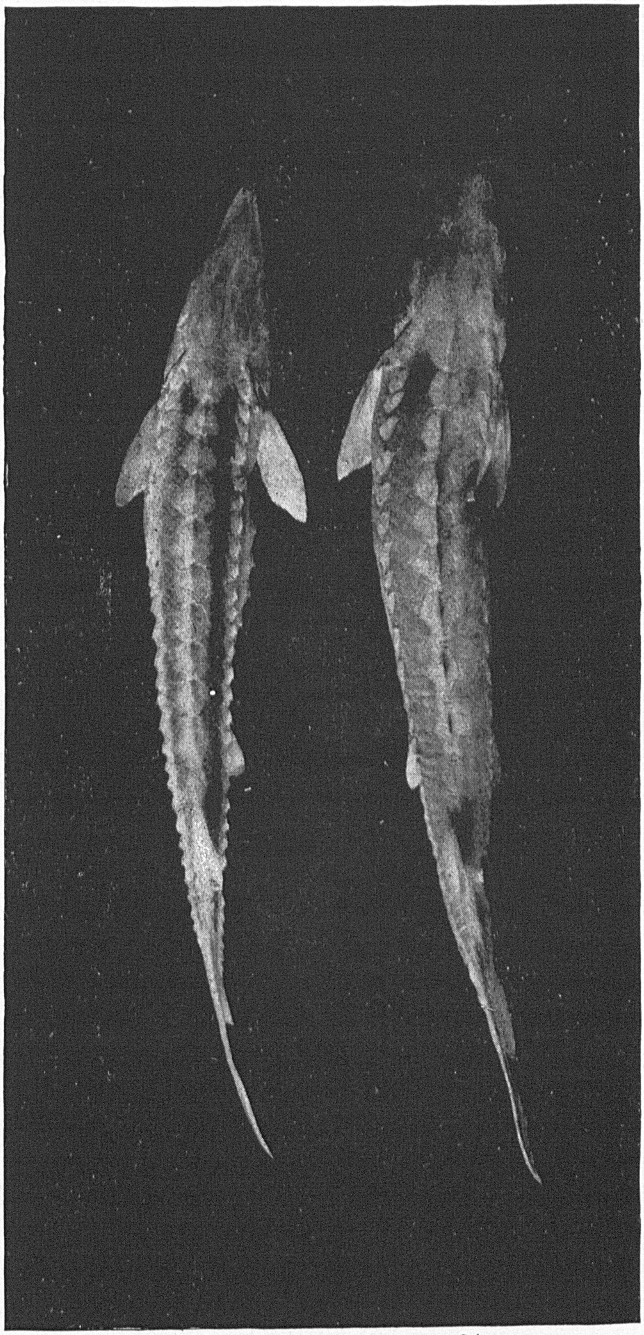
## EXPLANATION OF PLATE XLV.

Fig. 23. View of dorsal aspect of the young of the common sturgeon, 20 inches long. From a photograph.

Fig. 24. View of the dorsal aspect of the young blunt-nosed sturgeon of the Delaware, *Acipenser brevirostris* Les. Twenty inches in length. From a photograph.



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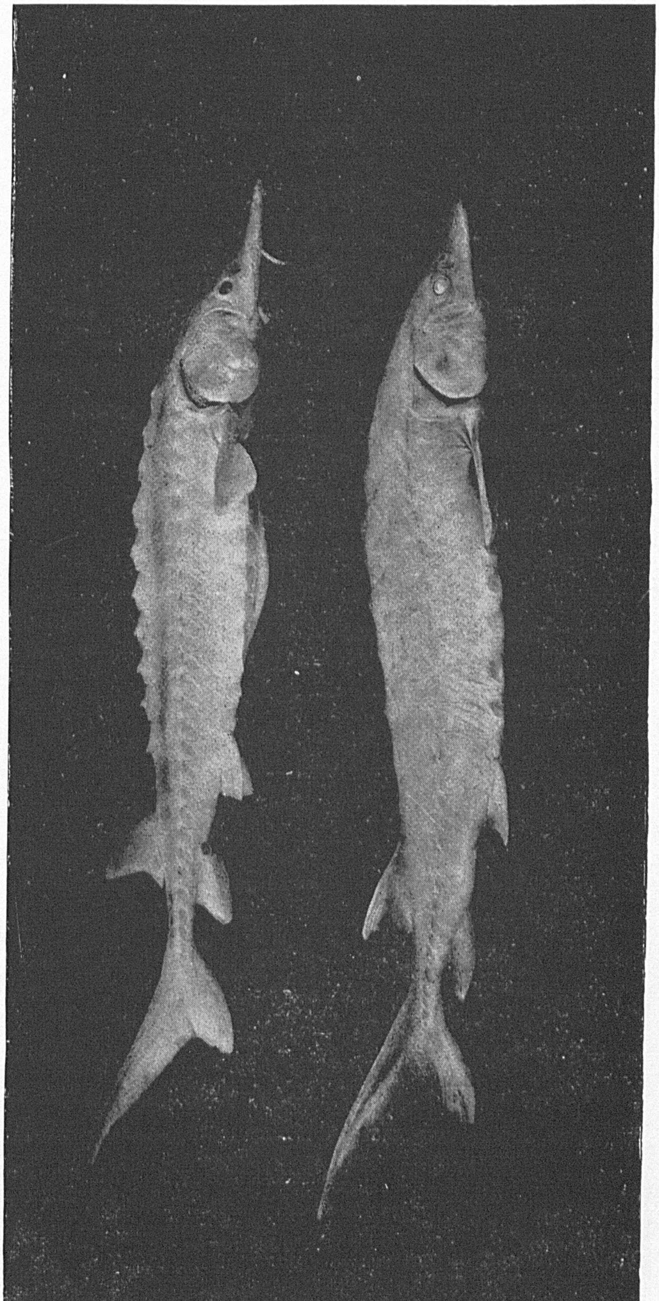
## EXPLANATION OF PLATE XLVI.

Fig. 25. Side view of a young specimen of the common sturgeon, 20 inches long. From a photograph.

Fig. 26. Side view of young specimen of the blunt-nosed sturgeon of the Delaware, *A. brevirostris* Les. From a photograph. The recurved spines on the scutes are seen to be far less prominent than in the preceding.

PLATE XLVI.



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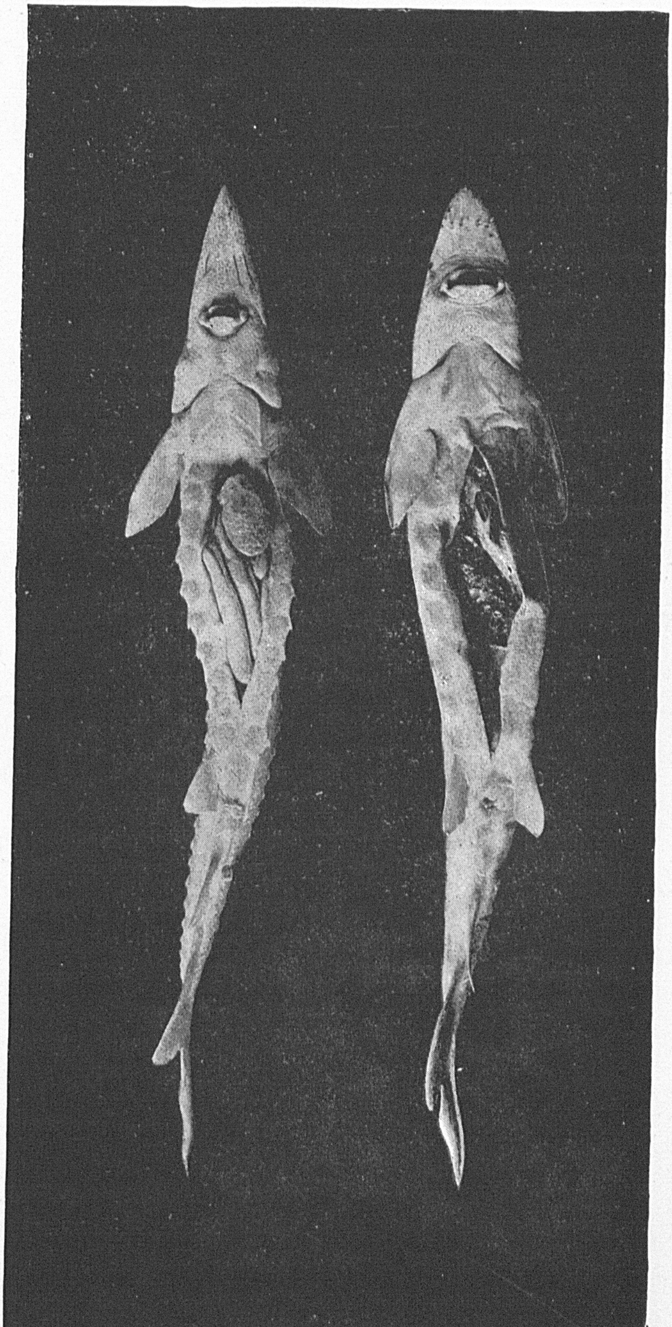
## EXPLANATION OF PLATE XLVII.

Fig. 27. View of under side of a young specimen of the common sturgeon, 20 inches long. Note the narrow mouth, the recurved spines of the abdominal and lateral scutes, the backward extension of the duodenal intestinal loop, the mushroom-like pancreas, and the very distinct areolation on the under side of the snout in front of the mouth. From a photograph.

Fig. 28. View of the under side of a young specimen of the blunt-nosed sturgeon of the Delaware, *A. brevirostris* Les. Note the very wide mouth, blunt snout, smooth ventral and lateral scutes, as compared with the foregoing. From a photograph.

PLATE XLVII.



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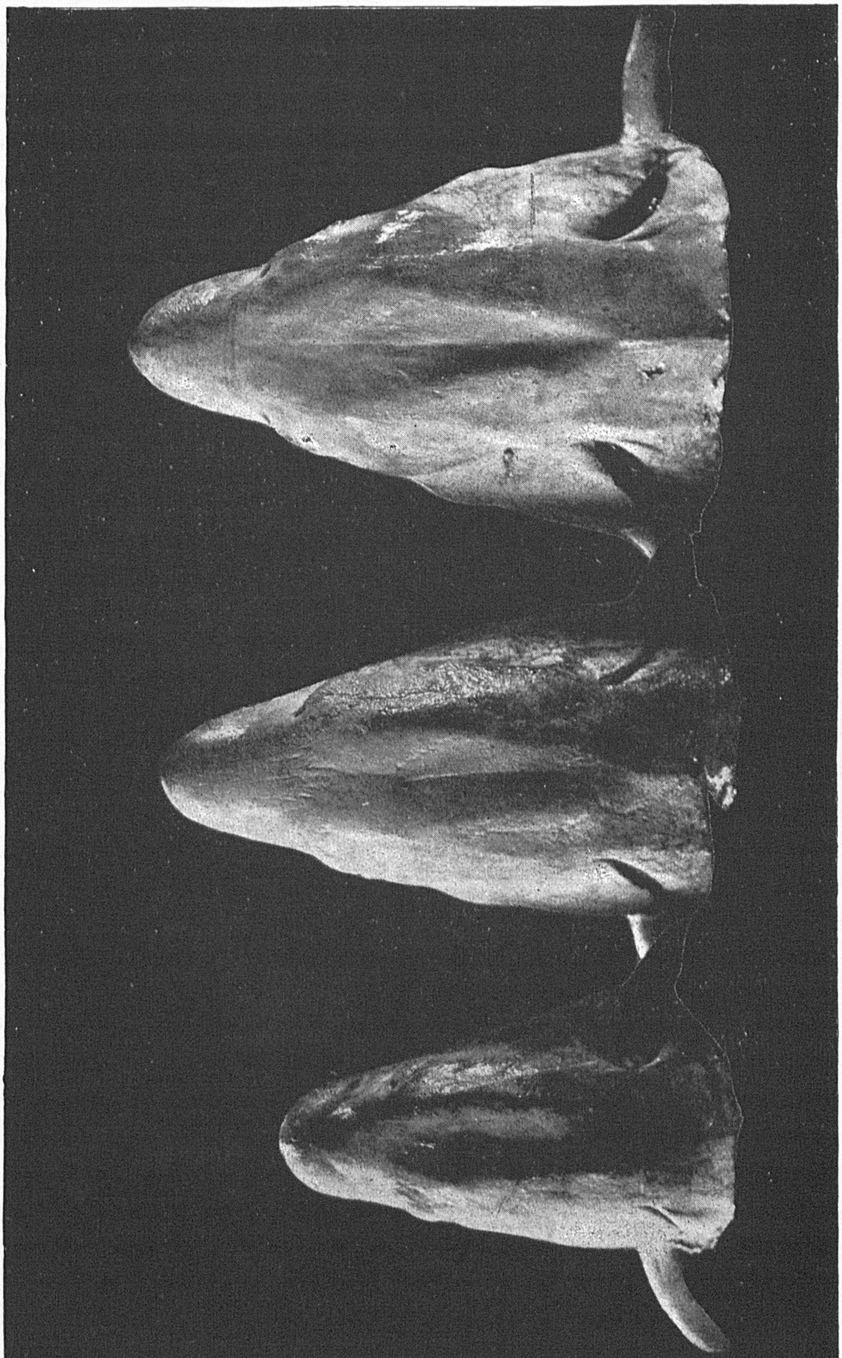
## EXPLANATION OF PLATE XLVIII.

Figs. 29 and 30. Views of the upper surfaces of the heads of recently killed females of the common sturgeon, showing variations. From photographs.

Fig. 31. View of the upper surface of the head of the adult male of the common sturgeon, showing the more gently tapering and blunter form of the snout, with relatively less width at the base of the cranium. From a photograph.



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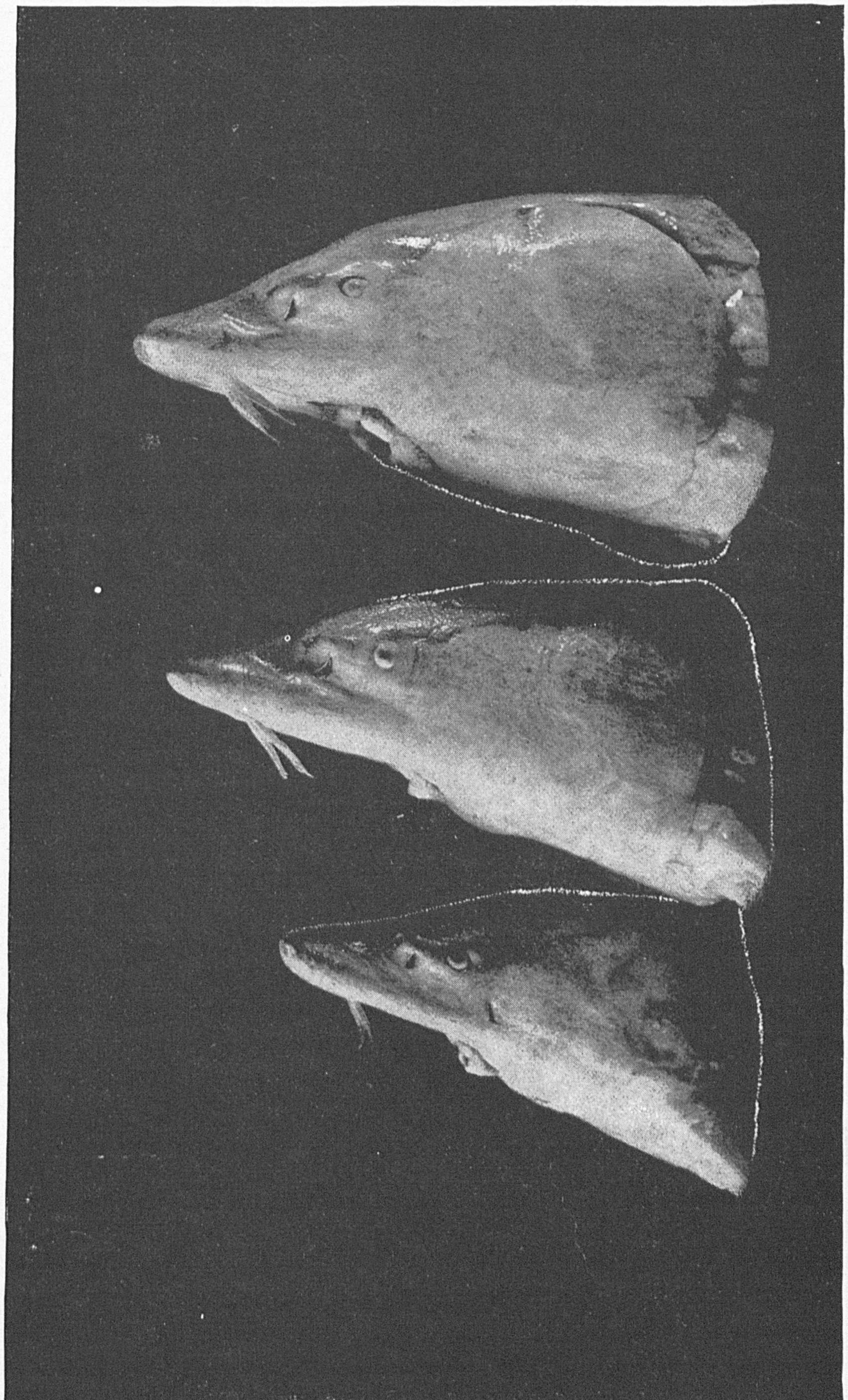
## EXPLANATION OF PLATE XLIX.

Figs. 32 and 33. Side views of the heads of the adult females of the common sturgeon. From a photograph.

Fig. 34. Side view of the adult male of the common sturgeon. From a photograph.



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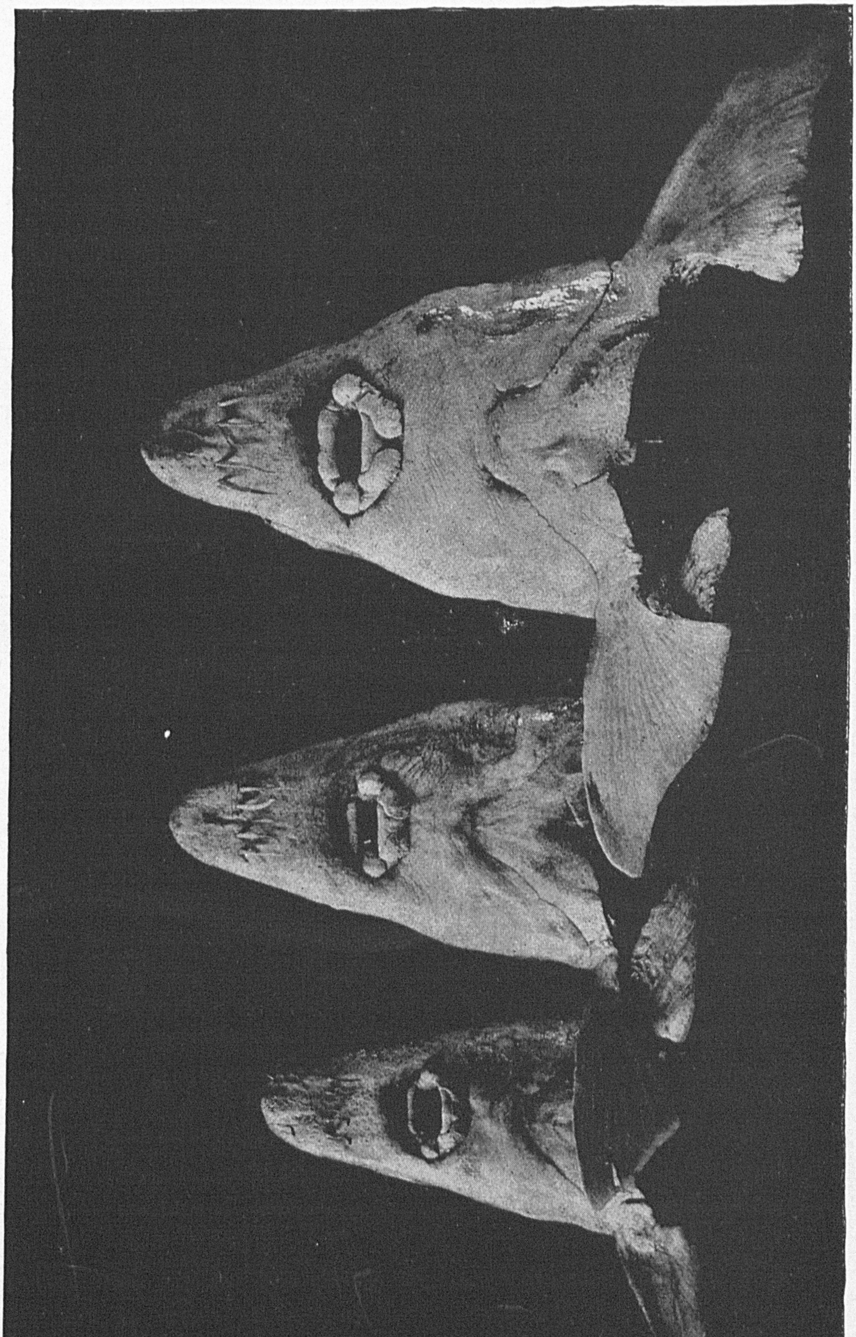
## EXPLANATION OF PLATE L.

Figs. 35 and 36. Views of the under sides of the heads of adult females of the common sturgeon, showing the relative position of the barbels and mouth, with its undistorted fleshy marginal processes as seen in the recently killed animal. From photographs.

Fig. 37. View of the under side of the head of an adult male of the common sturgeon, showing the areolation on the under side of the snout in front of the mouth, the areolæ being sensory tactile areas supplied by the fifth nerve. From a photograph.



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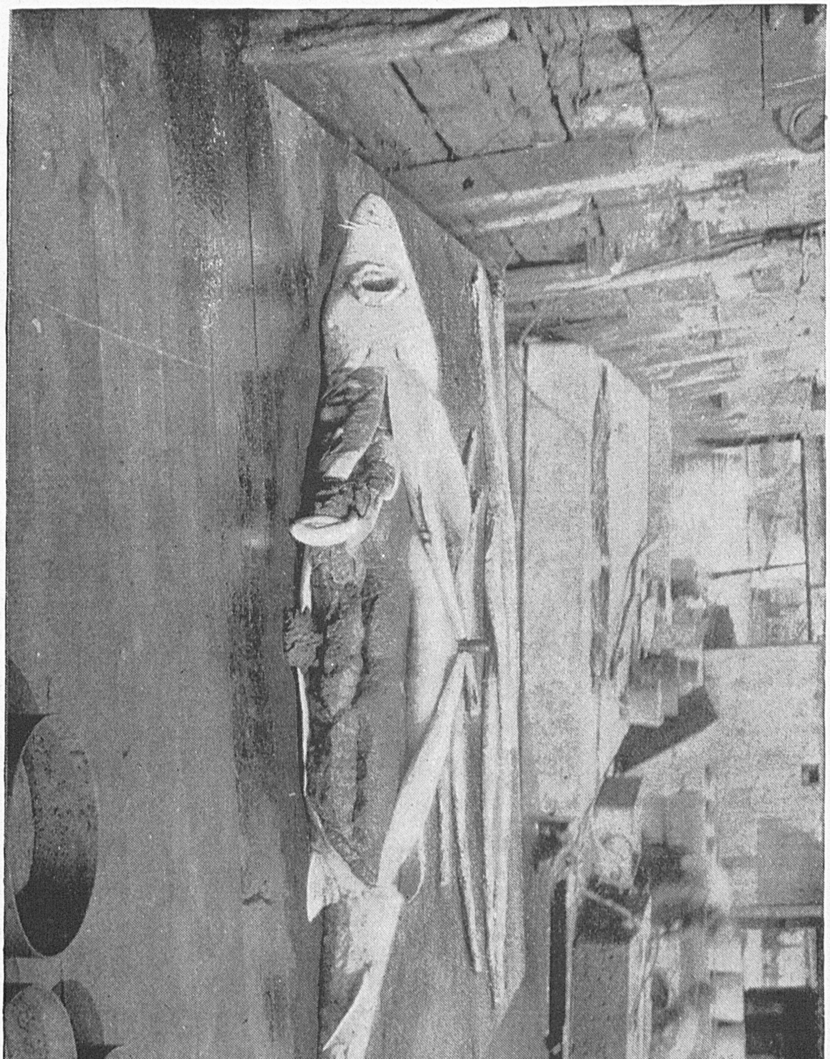
## EXPLANATION OF PLATE LI.

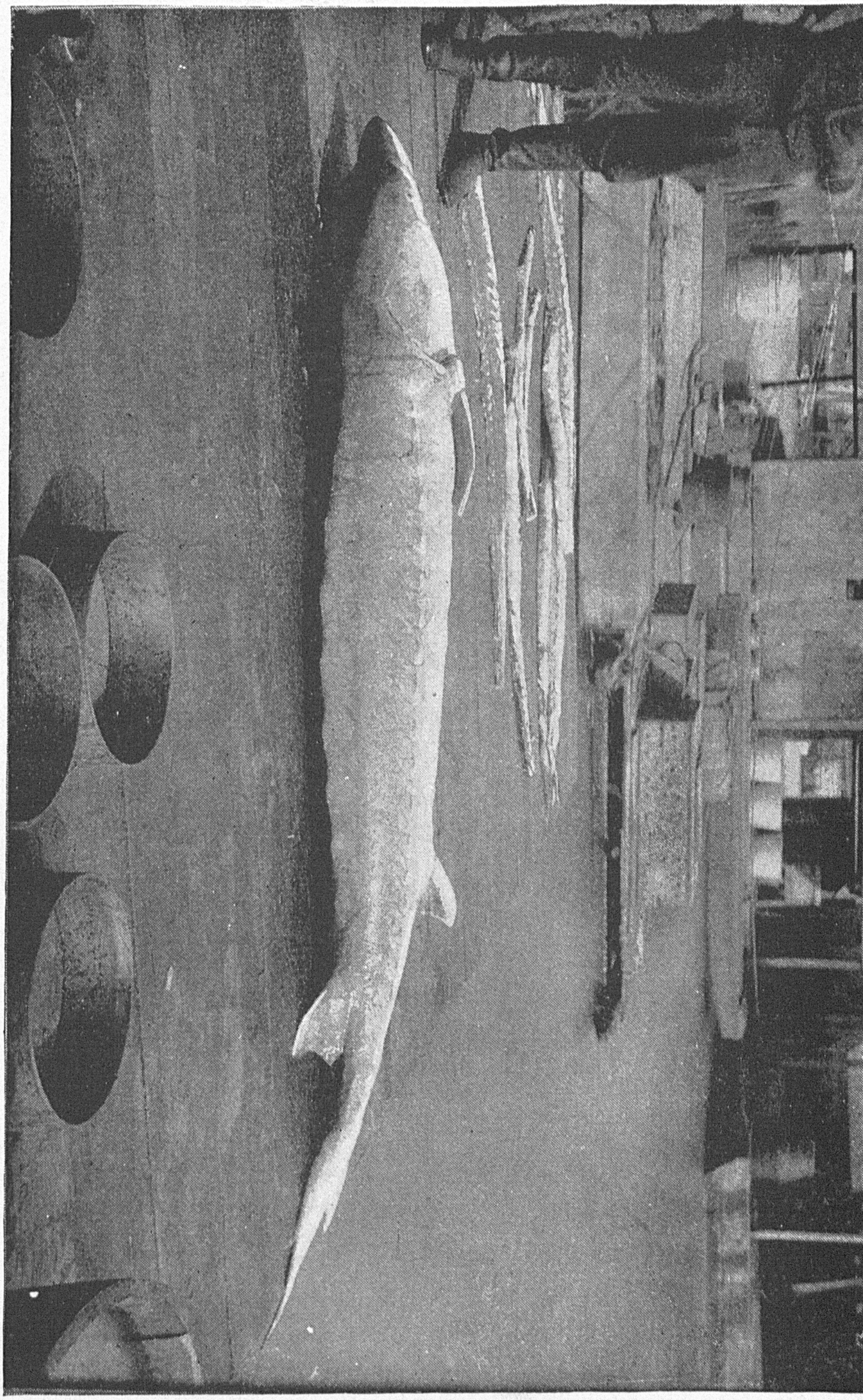
Fig. 38. View from beneath of an adult female of the common sturgeon, 8 feet long, with the abdomen cut open to expose the enormous mass of dark-colored roe. The duodenal loop of the intestine is seen to be farther forward than in the young, and to be smaller in diameter in proportion to the dimensions of the animal. On the "killing floats" are seen the sieves and tubs used in the manufacture of caviare.



38. ACIPENSER STURIO. Female with roe exposed.

## EXPLANATION OF PLATE LII.

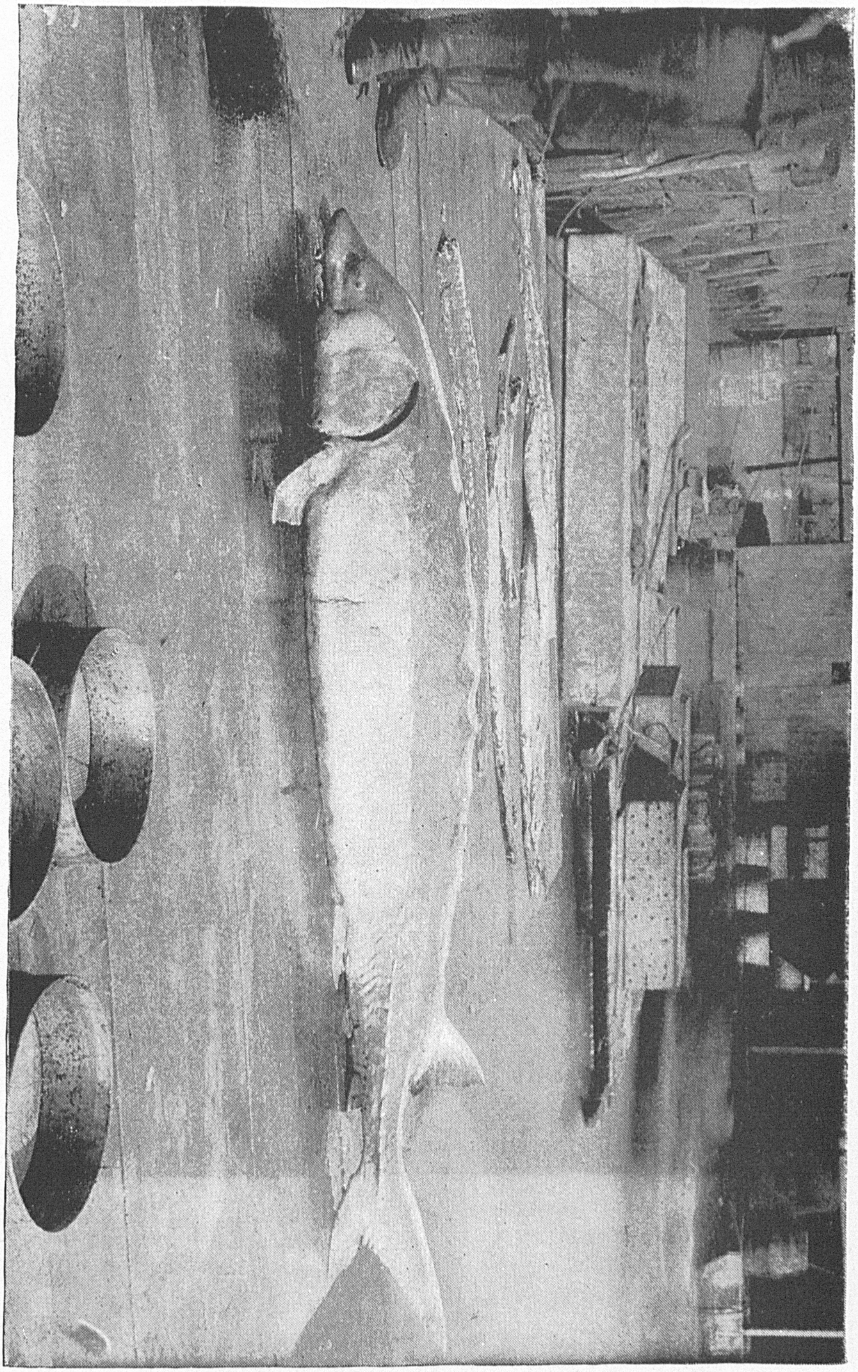
Fig. 39. View of an adult female of the common sturgeon seen obliquely from above. Photograph of a specimen about 8 feet long. Float in the distance with caviare apparatus, and shed for draining salted caviare, etc.



39. ACIPENSER STURIO. Dorsal view of female.

EXPLANATION OF PLATE LIII.

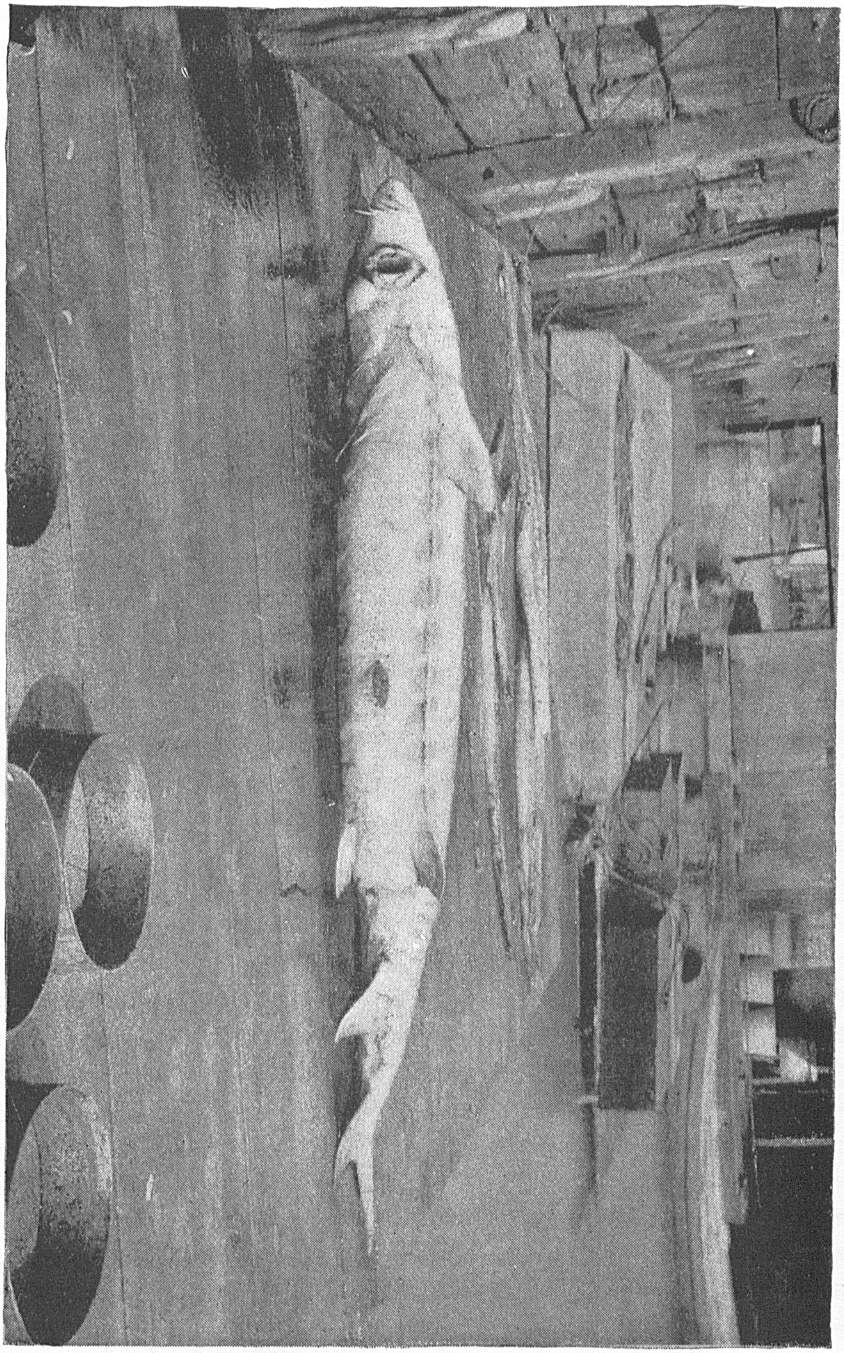
Fig. 40. Side view of adult female of the common sturgeon, 8 feet in length. From a photograph. This figure serves to illustrate the striking change in the outlines of the head and body of the adult as compared with the side view of the young of the same species on Plate XLVI, Fig. 25.



40. ACIPENSER STURIO. Lateral view of female.

## EXPLANATION OF PLATE LIV.

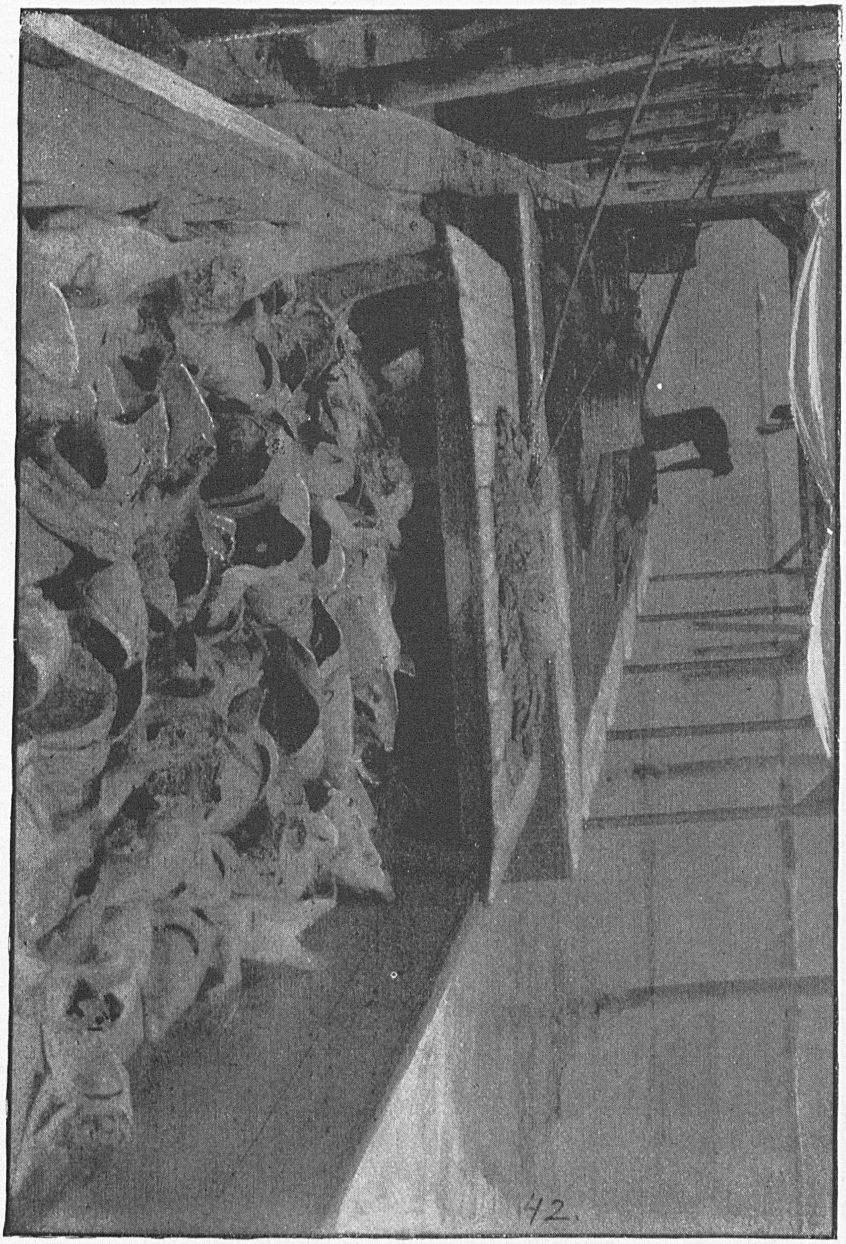
Fig. 41. View from the under side of an adult female sturgeon, 8 feet long, showing the robust proportions of a specimen containing roe, in just the right condition for purposes of caviare. From a photograph.



41. ACIPENSER STURIO. Ventral view of female.

EXPLANATION OF PLATE LV.

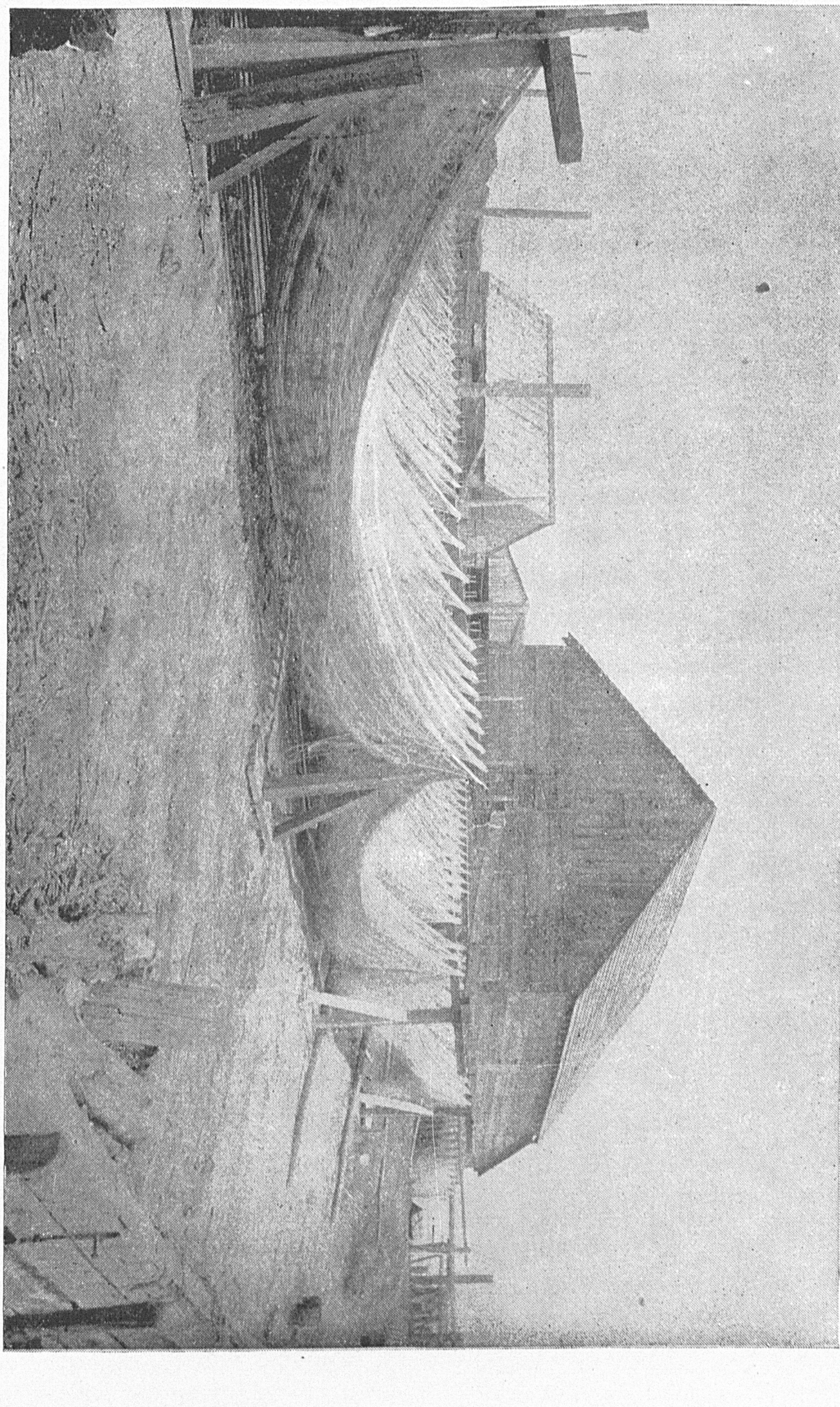
Fig. 42. Canvas-covered butchering float in the distance, with "butcher" at work cutting open and removing roe from "a cow sturgeon." Barge in the foreground, containing heads, tails, viscera, skins, etc., of sturgeons awaiting removal to the guano manufactory, and representing the accumulations of two or three days' fishing and butchering.




42. REFUSE, HEADS, ETC.

EXPLANATION OF PLATE LVI.

Fig. 43. View on the wharves at Delaware City, Delaware, to show the manner of suspending the sturgeon nets when drying or after being overhauled and repaired.



43. STURGEON NETS.

## EXPLANATION OF PLATE LVII.

Fig. 44. Side view of cranium of the common sturgeon, modified from Wiedersheim.

Fig. 45. Dorsal view of dermal armature of the head of the common sturgeon, modified from Gegenbaur.

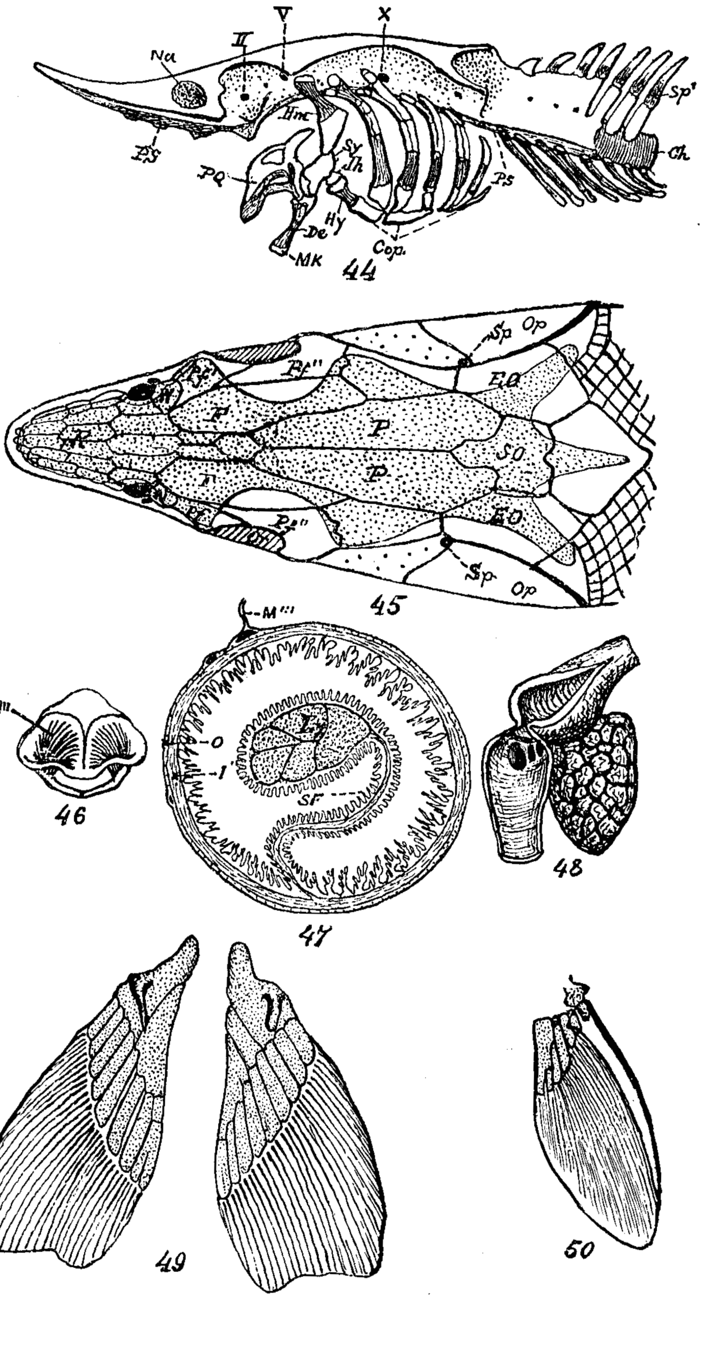
Fig. 46. Mandibles and palatopterygoid of the young sturgeon with its musculature.

Fig. 47. Cross-section through the spiral valve of the intestine of *A. brevirostris*, showing the manner of flexure of the spiral fold *S F*, and the large lymphoid cord *L* at its margin in section. The fold itself is covered with villi as well as the intestinal wall. Enlarged three diameters.

Fig. 48. Pyloric end of stomach, pylorus, and duodenum laid open so as to display the three openings into the latter from the pancreas.

Fig. 49. Figures representing the cartilaginous elements of the ventral fins of *Acipenser brevirostris*.

Fig. 50. Figure of the cartilages of the right pectoral fin of a young specimen of *Acipenser sturio*.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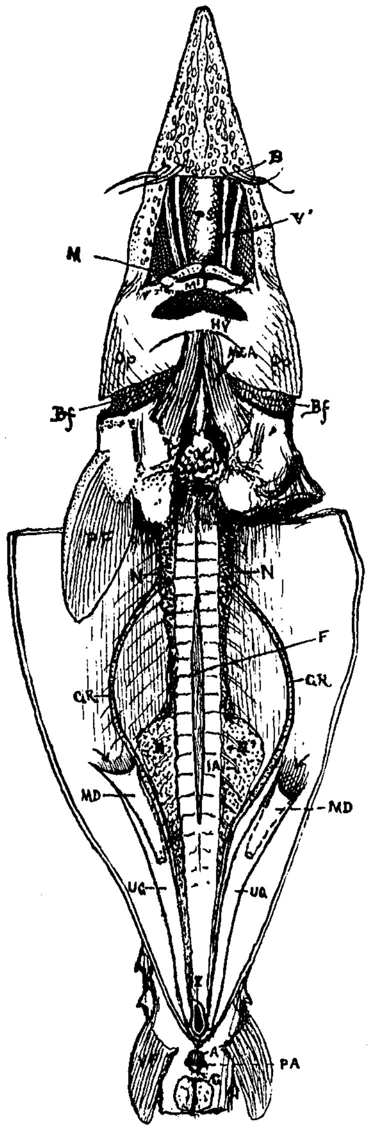
## EXPLANATION OF PLATE LVIII.

Fig. 51. Young individual of the common species of the sturgeon, 9 inches long, opened from below with the viscera removed to show the relations of the Wolffian bodies *N*, genital ridges *GR*, to the outgoing ducts *MD*, *UG*, in the sexually immature animal. Also the nerve supply to the barbels and the sensory areolæ of the under side of the snout in front of the mouth. Natural size.

Fig. 52. The same from below, to show the relations of the viscera to the abdominal walls and outlets, the internal openings of the genital canals are indicated by the arrows. Arrows within the dotted outlines of the portions of the alimentary canal, not visible from below in this figure, indicate the course of the food through the intestine. Natural size.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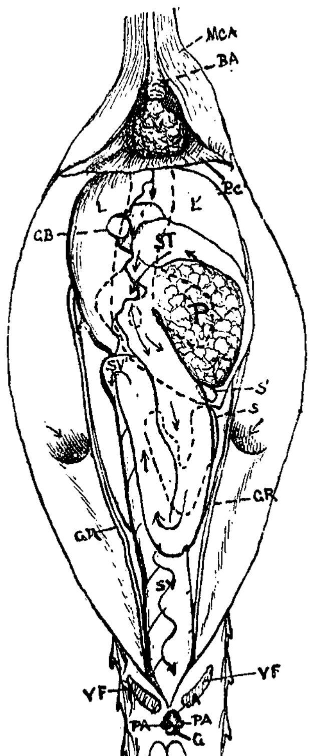
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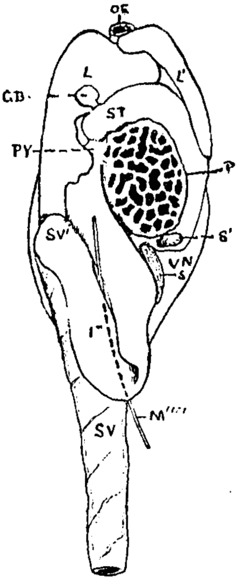
## EXPLANATION OF PLATE LIX.

Fig. 53 Abdominal viscera of young sturgeon, viewed from below, showing a bristle, M'''', passing through opening in mesentery of second loop of intestine, and with the under wall of pancreas, *P*, removed to show its glandular cavities, which are much less numerous in the young Sturgeon than in the adult. Natural size.

Fig. 54. Viscera of young sturgeon, viewed from above; swim-bladder, *VN*, intact. Natural size.

Fig. 55. Viscera of young sturgeon, viewed from above, with spiral valve laid open to show its seven turns and with the swim-bladder *VN* cut open and laid to one side to show the wide pneumatic duct *PN* joining the alimentary canal just at the beginning of the first or gastric loop of the latter. The spleen *S* and *S'* is also exposed. Natural size.

Fig. 56. Viscera of young sturgeon, viewed from above, with upper wall of swim-bladder cut away to show the cleft-like opening of the pneumatic duct into its anterior end, with the muscular fibers radiating from it into the floor of the pneumatocyst or swim-bladder. Natural size.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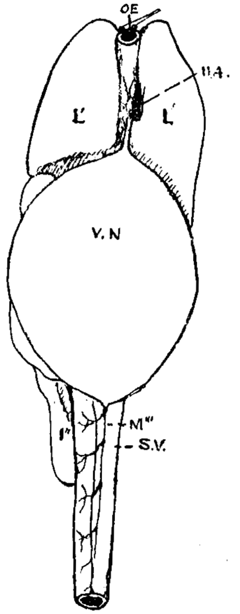
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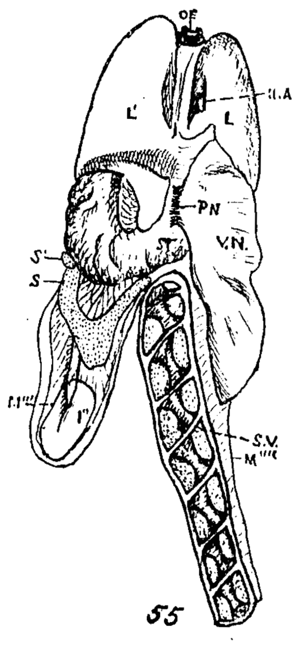
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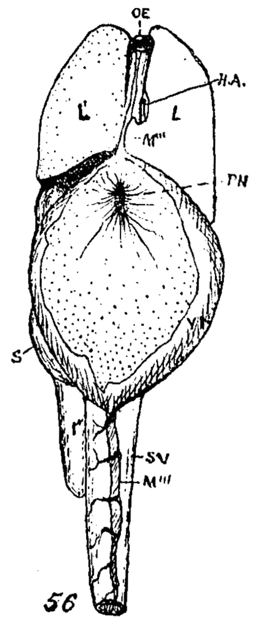
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