MONSTROSITIES IN SALMON EMBRYOS.

DONALD M. ROSS.
Dept. of Biology, Dalhousie Univ., Halifax, N. S.

(Received May 21, 1934).

ABSTRACT.

Twelve abnormal salmon embryos were examined alive as well as in serial sections. They showed three types of monstrosity: (1) a tendency to form twins; (2) cyclopean abnormalities of the eyes; (3) unnatural relations of the embryo to yolk sac. Twenty illustrations are contained in the contribution; fourteen sketches of various embryos and six photomicrographs of serial sections.

The following provisional generalizations are made: (1) in double embryos in which union takes place posterior to the head, the ventral structures become united before the dorsal ones; (2) in double embryos in which union takes place in the head, the dorsal structures become joined earlier than the ventral ones; (3) in double embryos the duplication of the fins and tail may persist posteriorly beyond the point of union of the trunks; (4) the internal organs of partial twins are frequently mirror images.

INTRODUCTION.

At all times the occurrence of monsters has aroused a great deal of curiosity, and various investigators from Aristotle downwards have used teratological data in the derivation of certain principles in embryology. The result has been an abundance of descriptive reports upon this subject. However, information concerning monsters in fishes has been compiled only very slowly and this paper describes a study of a small group which was found recently. This type of work involves an attempt to observe the guiding principles which govern abnormal development. We know that very definite laws operate in normal embryology, but the question arises as to whether any such definite laws operate in abnormal embryology.

By way of approach to the subject, it will be to advantage to discuss briefly the available literature. At various stages in their careers Cuvier, Rauber, von Baer, Spemann, Loeb and Morgan have prepared contributions to this branch of biology. In the twentieth century, however, the field has been broadened and consolidated most of all by the work of Gemmill and Stockard. To Gemmill we are indebted for

a series of morphological studies [1-2] as well as an excellent monograph[3]; to Stockard[4-5] for physiological and experimental investigations.

Gemmill's monograph, which deals with the structural aspect of abnormalities in fishes, is a complete summary of the literature previous to 1912. The work is especially valuable in referring to general topics such as the classification of monsters and their occurrence, causation and development.

Stockard[4-5] opened up a new line of investigation by the artificial production of monstrosities due to the environmental adjustments of certain teleost embryos. His "magnesium embryos" which exhibited cyclopia with astonishing regularity were raised in a medium of excess magnesium chloride. Some years later Stockard[5] was able to produce a high ratio of double monsters in trout by altering the developmental rate at a very early stage. These results indicate that monsters in nature do not arise only as spontaneous germinal variations, as was hitherto supposed, but that the environment is a factor to be considered.

The Abnormal Embryos.

The abnormal specimens of *Salmo salar* used in this investigation were obtained from a small hatchery in the Dalhousie Zoology Laboratory. Its capacity was five thousand eggs. The eggs had been transferred from the Dominion Government Hatchery at Bedford, N. S., in November, 1932. This piece of work was carried out during February, 1933, some two weeks after hatching had commenced. Sketches were made of the living embryos. Then the embryos were fixed in Bouin's picro-formol and serial sections were prepared at a later date. The results of the investigation will be presented for the most part in pictorial form as a series of sketches of the embryos and photomicrographs of certain serial sections.

[1] Gemmill, J. F. *London Proc. Zool. Soc.* 1903 (4-23).
[2] Gemmill, J. F. *London Proc. Roy. Soc.* **68**, No. 444 (129-134), 1901.
[3] Gemmill, J. F. *The Teratology of Fishes*—Glasgow—James Maclehose, **1912**
[4] Stockard, C. R. *Jour. Exp. Zoo.*, Vol. VI, No. 2, 1909.
[5] Stockard, C. R. *Amer. Journ. Anat.*, **28**, No. 2, Jan. 1921.

Figures I and II picture the state of affairs in the normal salmon embryo at an age corresponding to that of the monsters. The main points of the internal and external anatomy are indicated, and these figures should be compared with the sketches of the various abnormal embryos.

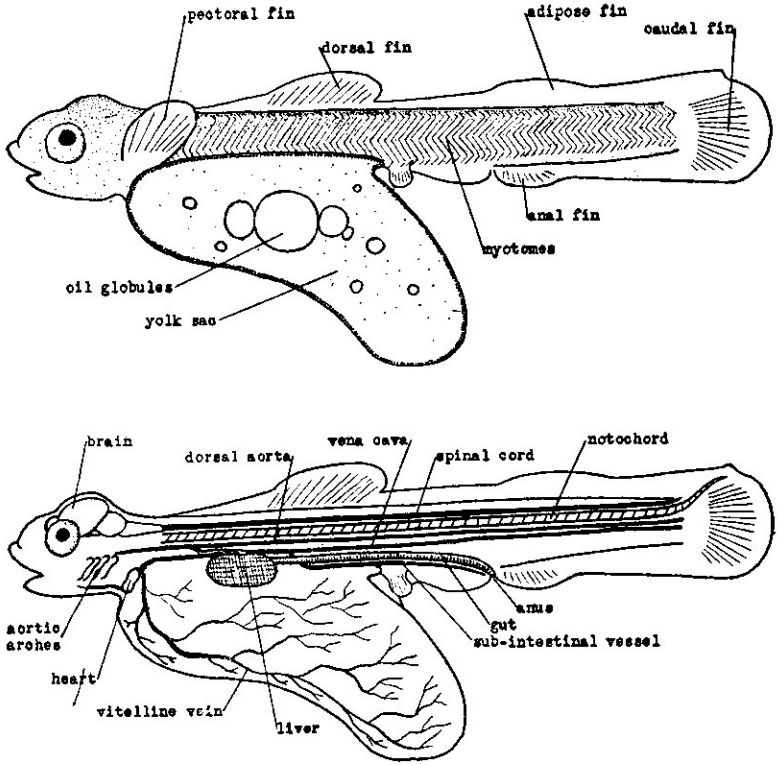


FIG. I. and FIG. II. Normal Salmon Embryo. External and Internal Anatomy.

Three types of abnormality occurred within the group of twelve specimens studied. There were (1) eight double monsters, (2) one cyclopean monster, although two of the twin embryos possessed cyclopean tendencies as well, and (3) three embryos which were attached to the yolk sac in an unnatural manner.

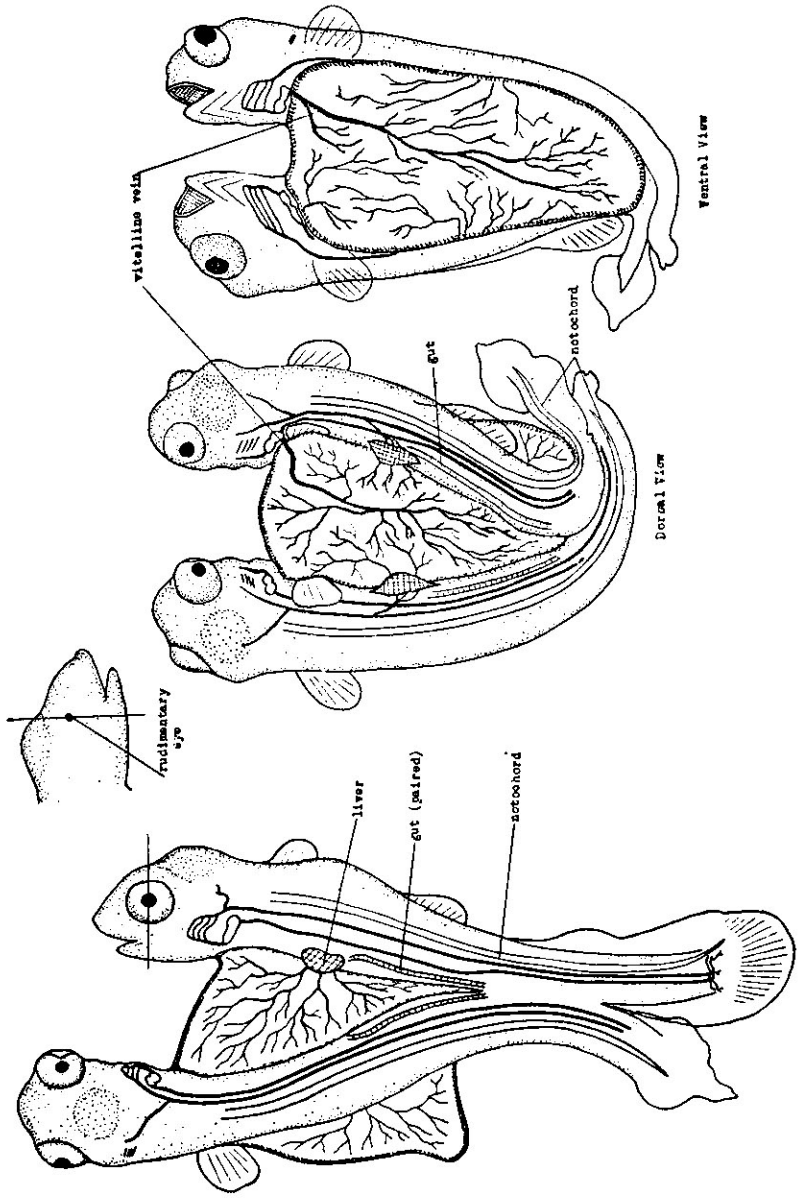


FIG. III.

FIG IV.

DOUBLE MONSTERS.

The double embryos exhibit various degrees of duplicity. In Fig. III is shown a specimen in which the two members are almost completely separated. There is doubling in both the anterior and posterior regions. This type is extremely rare, Gemmill[6] finding none in a group of three hundred abnormal trout embryos. One of the members possesses a defective eye and it will be referred to later. It is worthy of notice that in the single portion of this embryo, the double ventral structures, such as the twin guts, lie nearer to each other than the dorsal structures, such as the twin notochords. This tendency may be observed in many other cases of twinning and it is called the principle of ventral convergence. Another anomaly which this specimen presents is that the tail of the left hand member is quite defective. This is a common occurrence in embryos of this type, and in Fig. IV, a second case of anterior and posterior doubling is shown in which both tails are poorly developed. Ventral convergence can be seen in operation in this specimen. It will be noticed that in one member both the heart and the liver are situated to the right, while in the other member both these organs are to the left. Now in a normal embryo of this age, the heart is to the left and the liver to the right. Thus in a double monster there seems to be a tendency to change this situation and the result is that the internal organs in one twin are the mirror images of those in the other.

The embryo illustrated in Fig V has its point of union in its trunk and it ends in a normal symmetrical tail. The junction is approximately midway between the head and tail ends and both the principles of ventral convergence and of mirror images may be noted. The symmetry exhibited by the specimen is very rare, particularly in the region of the tail. Fig. VI shows an embryo with union at the same point, but it is notable that duplicity persists in the caudal fins so that a triangular tail is formed. The left hand member was being attacked by disease which caused the loss of its head.

[6] Gemmill, J. F. *Teratology of Fishes*, p. 24.

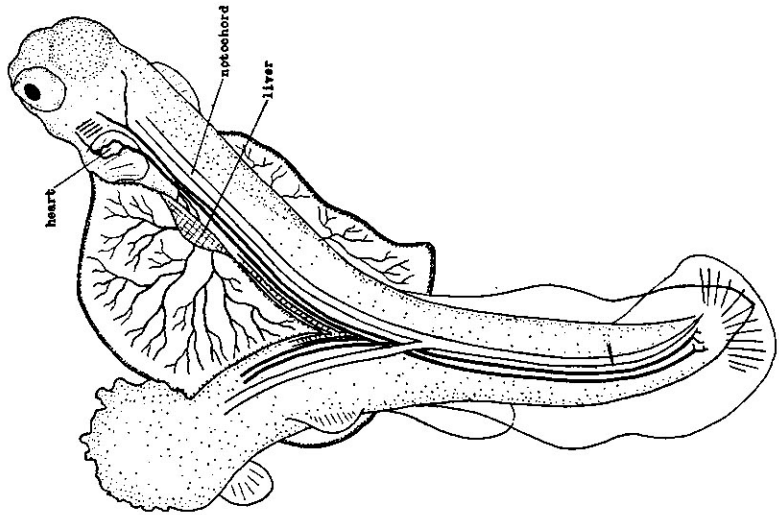

heart
notochord
liver

FIG. VI.

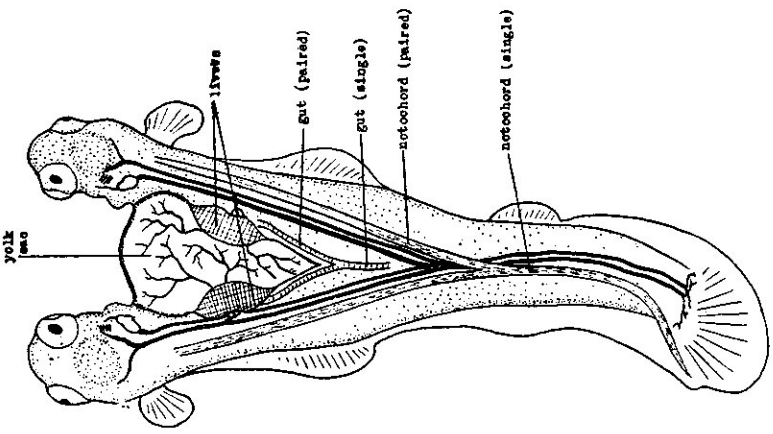

yolk
liver
gut (paired)
gut (single)
notochord (paired)
notochord (single)

FIG. V.

The growth of a fungus upon it showed that it was not due to under-development such as occurs in the two specimens to follow.

In Figs. VII and VIII embryos are illustrated in which the union takes place in the trunk region but in each case the development of one of the members is lagging behind the other. All the structures of the defective member are more or less distorted and the sections show that some structures, e. g., the notochord and the spinal cord, are missing. It is interesting also that the fins possess a double structure posterior to the point of union, and that the caudal fins are quadrangular in each specimen.

One double monster was found in which the union takes place in the pectoral region. The head of the left member is very poorly developed, no eyes being present. The two heads are very closely associated and, as Fig IX shows, a partial union occurs in the region of the gill arches. Thus the development of certain adjacent structures, e.g., the pectoral fins, has been arrested. The two hearts are partially joined and by reference to the figure it will be seen that there are two auricles but only one ventricle. The ventral aorta is common for a short distance but a complete set of aortic arches is present in each member.

In spite of this partial union in the head region, a second separation occurs and it is only far back in the body that the doubling is eradicated. A photomicrograph of a section (the position is indicated by the horizontal line through the animal in Fig. IX) is shown in Fig. XV. It will be seen that the double notochord persists although all the other structures are single. The spinal cord, however, has a triangular outline unlike the circular shape it possesses in a normal embryo, indicating that the two portions have fused a very short distance in front. This tendency for the duplicity of the notochord to persist farther than that of any other structure has been noticed by other investigators[7]. The general principle of ventral convergence, insofar as the ventral structures

[7] Gemmill, J. F. *The Teratology of Fishes*, p. 19.

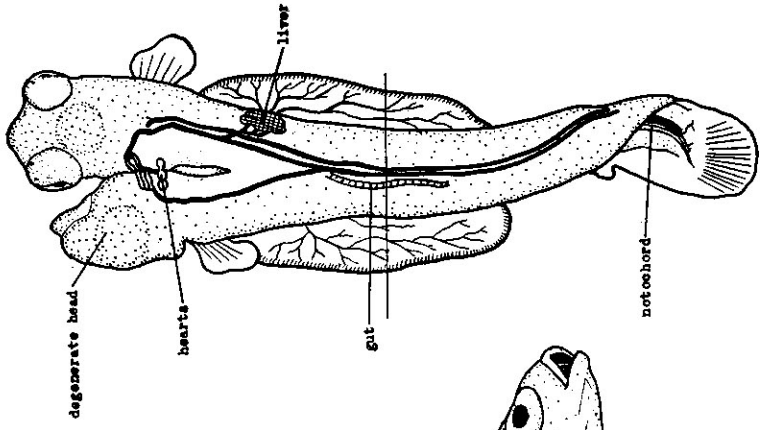


FIG. IX.

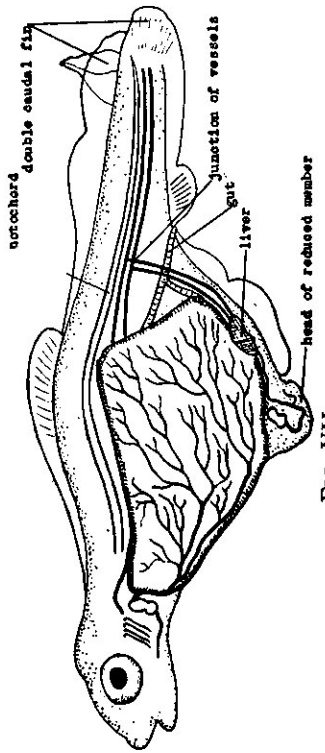


FIG. VII.

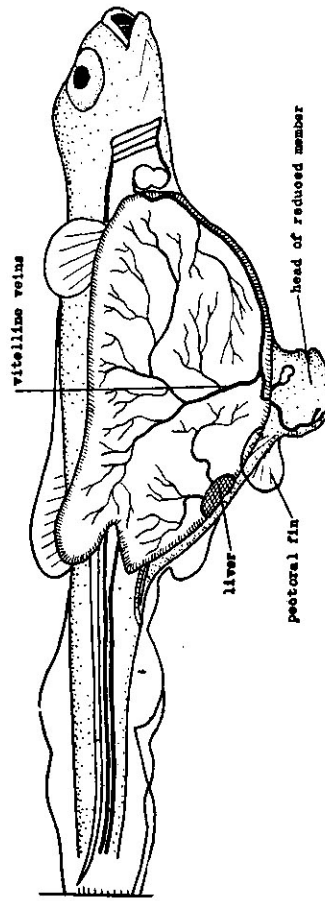


FIG. VIII.

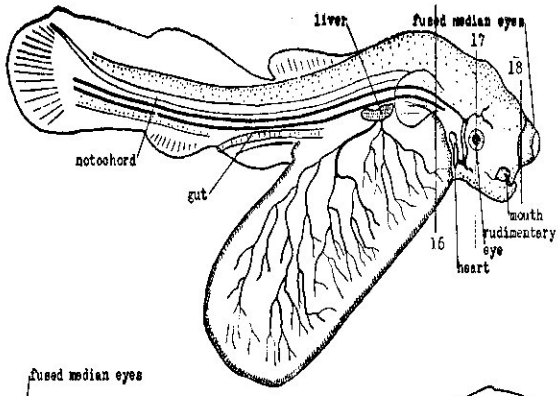
become joined first, is borne out by this as well as the other specimens.

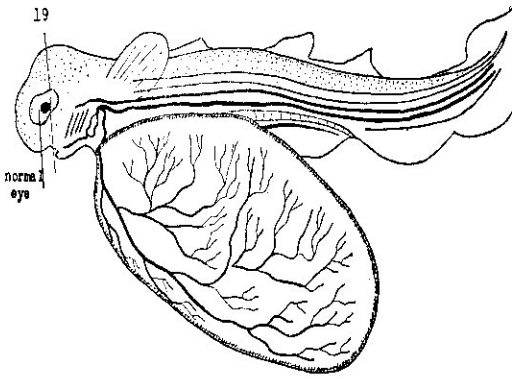
Fig. X. illustrates a double-headed monster with union in the region of the optic lobes of the brain. Externally the embryo appears to be single, but the sections point out that it is in reality a case of partial twinning. The large median eye consists of two eyes, one from each head, which have come to lie very close together (Fig. XVIII.) On the right a smaller eye appears which has no mate on the left side. The twin mouths are very noticeable, both externally and when observed in the sections, but most of the other doubled structures are obscured, especially in the more posterior parts of the head.

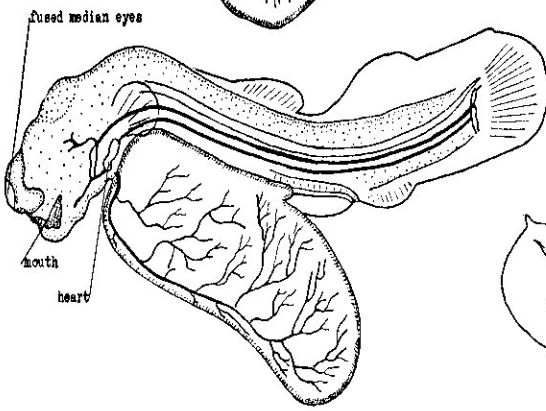
The actual state of affairs in this embryo is best shown by the series of photomicrographs, Fig. XVI, XVII and XVIII. The positions of these sections are indicated by the vertical lines through the animal in Fig X.

Fig. XVIII shows very clearly the double structure of the median eye and each of these adjacent eyes seems to be almost complete, lens and retina both being present. A section (not illustrated) through the posterior part of this eye shows that two sets of cerebral lobes lie very close together. A more posterior view (Fig. XVII) pictures the actual elimination of duplicity in the brain. In fact, it is seen to be single in its dorsal structures but double in its ventral ones, since there is but one set of optic lobes, but a third ventricle on each of the two ventro-lateral positions. A section still more posterior shows that the brains become completely joined. However, the important point in a double monster of this kind seems to be that the union of the dorsal structures occurs in front of the union of the ventral structures.

A section through the pectoral region of the same embryo may be seen in Fig. XVI. The double notochord is the outstanding feature, and it indicates that duplicity may occur again, even after a complete union in this case and after a partial union as in the specimen shown in Fig. IX. The spinal cord is single but its triangular outline, as opposed to the normal circular outline, indicates that there is a tendency


liver
fused median eyes
17
18
notochord
gut
mouth
rudimentery
eye
16
heart


19
normal
eye


fused median eyes
mouth
heart

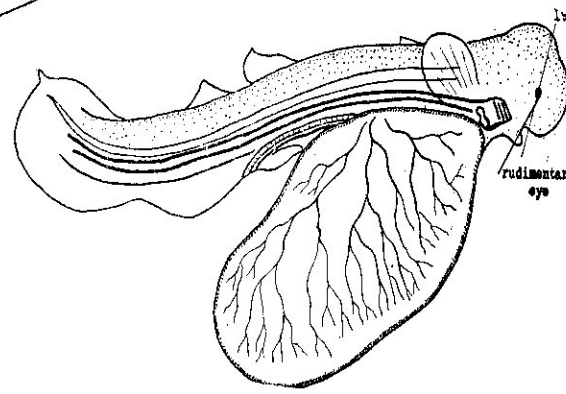

19
rudimentary
eye

FIG. X.

FIG. XI.

towards duplication. Gemmill[8] has found monsters of this class in which the spinal cord is single at its anterior end but doubled a few segments back. The same tendency is evidently operating here, but it has not resulted in complete separation, but in a distorted spinal cord.

CYCLOPEAN MONSTERS.

The second group of monsters which will be discussed exhibited the phenomenon of cyclopia, a tendency towards the possession of one eye rather than two. It is not so fundamental a peculiarity as twinning. Stockard[9-10] has shown that an artificial cyclopean embryo may be produced by altering the conditions of development at a much later stage than the latest stage necessary for producing an artificial twin. The concensus of opinion seems to be that cyclopia is not so much a germinal as a somatic variation.

Cyclopia is exhibited by the embryos illustrated in Figs. III, X and XI. In Fig. XI is seen the only single specimen to possess the defect and a section through the rudimentary eye is shown in Fig. XIX. This embryo appeared rather unhealthy, and in fact it was very close to death when sketched. Fig. XIX shows the right eye as a group of pigmented cells with no trace of any nervous associations with the brain.

A section through the double monster in Fig. III cut as to show the rudimentary eye, is illustrated in Fig. XX. Its structure is almost identical with that of the eye seen in Fig. XIX. It is interesting that the defects of the eye in this embryo are associated with other defects in the brain, the two cerebral lobes having fused to form a single lobe. This condition was noted by Gemmill[11] in his series of cyclopean trout embryos.

In Fig. XVII, a third example of cyclopia may be viewed in a section from the embryo shown in Fig. X. In this case

[8] Gemmill, J. F. *The Teratology of Fishes*, p. 14.
[9] Stockard, C. R. *Jour. Exptl. Zool.* Vol. VI, No. 2, p. 291, **1909**.
[10] Stockard, C. R. *Amer. Journ. Anat.*, **28**, No. 2, 132 and 152, **1921**.
[11] Gemmill, J. F. *The Teratology of Fishes*, 40.

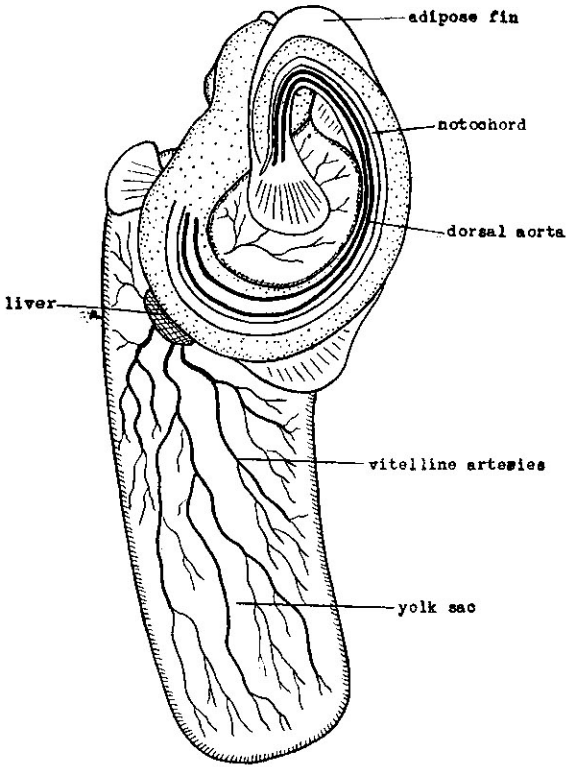


FIG. XII.

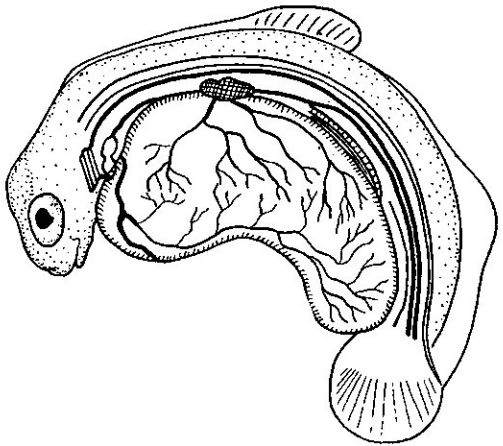


FIG. XIV.

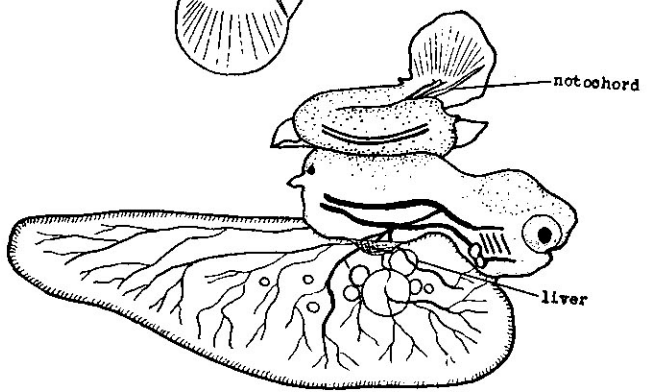
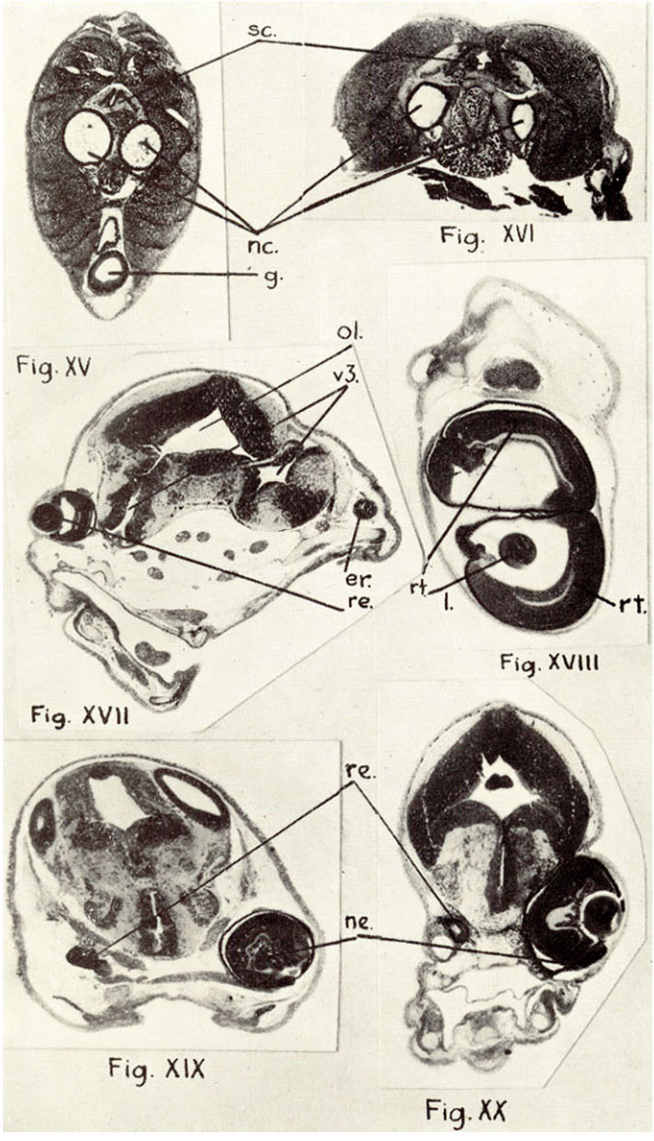


FIG. XIII.


sc.
nc.
g.
Fig. XVI
Fig. XV
ol.
v3.
er.
re.
Fig. XVII
rt.
l.
rt.
Fig. XVIII
re.
ne.
Fig. XIX
Fig. XX

the smaller eye is almost structurally complete although an optic stalk could not be detected in section. The same figure shows a group of cells on the other side of the head which possesses the essential features of an eye rudiment. A thorough study of a series of such eye rudiments should be of the greatest value in a study of the development of the eye and it would be interesting to compare the results of such an investigation with the accepted theories.

Abnormalities of Attachment to the Yolk Sac.

There remains one more group of abnormalities to be discussed, that of unnatural relations of the embryo with the yolk sac. On the whole, it is a minor type of monstrosity due in part to unusual physical conditions affecting the embryo while still contained within its egg envelope.

In Figs. XII and XIII embryos are shown which have become coiled. Some factors have caused them to grow thus within the egg and evidently they never recover. Since they cannot swim, this abnormality would operate against their survival in nature. Fig. XIV shows an embryo which is attached along its whole length to the yolk sac, a condition which should be compared with the normal attachment shown in Figs. I and II. Inasmuch as such conditions do not affect the fundamental organization of the embryo, they are of only passing importance and of little value for the derivation of principles.

Discussion and Conclusions.

The scope of the conclusions from a piece of work of this kind is limited very much by the small number of specimens studied. However, the group of eight double monsters were fairly generally distributed amongst the various classes and representatives of the most important types were present.

From the evidence presented, a few provisional generalizations with respect to double monstrosities may be drawn

up and the following tendencies, may be said to have been observed:

(1) There is a tendency to ventral convergence in double embryos in which the union takes place posterior to the pectoral region.

(2) There is a tendency to dorsal convergence in double embryos in which the union takes place anterior to the pectoral region.

(3) There is a tendency in partial twins towards the persistence of duplicity in the fins far posterior to the point of union of the trunks.

(4) There is a tendency in partial twins causing the internal organs in one member to be the mirror images of the corresponding organs in the other member.

These generalizations follow from the specimens observed and they are in agreement with many observations made by various investigators not only upon fishes, but in other groups as well. However, further investigation may restrict their application to particular classes of double monsters only.

The writer wishes to acknowledge his indebtedness to Dr. F. R. Hayes who suggested and directed the work, and to Dr. Dixie Pelluet, whose criticisms and suggestions have been invaluable.

Lettering in Figs. XV-XX.

er. Eye Rudiment.
int. Intestine.
l. Lens.
nc. Notochord.
ne. Normal Eye.
ol. Optic Lobes.
re. Rudimentary Eye.
rt. Retina.
sc. Spinal Cord.
v3. 3rd ventricle.