THE EMBRYOLOGY AND LARVAL DEVELOPMENT OF BAIRDIELLA CHRYSURA AND ANCHOVIA MITCHILLI

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INTRODUCTION.

The present paper embodies the results of observations made on the eggs and larvæ of two species of teleosts, *Bairdiella chrysura* and *Anchovia mitchilli*. The work was carried on at the United States Fisheries Laboratory at Beaufort, N. C., during the summer of 1913.

It is not the purpose of this paper to discuss at length any of the merely technically interesting points in the development of pelagic fish eggs. Nor does it contribute anything essentially new to our knowledge of the embryology of teleosts. The work was undertaken for the purpose of securing a record as complete as possible of the time of spawning and of the embryological and larval development of fishes with pelagic eggs breeding in these waters during the summer, one of the primary objects being to afford a ready means of identifying either eggs or larval fishes at any time during embryological and larval life.

Observations were made as far as possible on living material. The eggs were collected in the tow net. The larval fishes were taken primarily in the stow net, the bunt of which was provided with a hood of cheesecloth terminating at its apex in a large collecting bottle. A small per cent of the larval fishes taken in this manner were brought into the laboratory alive. The large majority of them, however, were dead before being taken from the net.

Eggs collected at the same hour on successive days were found to be in approximately the same phase of development. Obviously, spawning occurs regularly each day at approximately the same hour. Observations show that both species under consideration spawn regularly in the early evening, probably before 8 o'clock.

The eggs of these species are relatively small and contain but little yolk material. Embryological development, therefore, proceeds very regularly and requires a relatively short time. The eggs of *Anchovia mitchilli* require approximately 24 hours for hatching. Those of *Bairdiella chrysura* hatch in approximately 18 hours. The time required for hatching, doubtless, varies somewhat with the temperature of the water. The height of the spawning season of *Bairdiella chrysura* occurs during the last week of June and the first week of July. *Anchovia mitchilli* spawns freely during June, July, and August. The height of the spawning season of this species, doubtless, occurs in July. The average temperature of the water in the vicinity of the laboratory for the latter half of June was 27.15° C. The average temperature for the entire month of July was 27.77° C. These averages are based on daily readings taken at 5 o'clock p. m.

The young of *Bairdiella chrysura* were taken in small numbers at intervals throughout the latter half of June and the greater part of July. After the spawning season began to wane very few young of this species were taken. The young of *Anchovia mitchilli* were taken in considerable numbers throughout June, July, and August.

BAIRDIELLA CHRYSURA.

Spawning.—The eggs of *Bairdiella chrysura* were present in the plankton when work was begun on June 9, and were taken in the tow net nearly every day after that date until July 18, when they became relatively rare. Individual eggs were taken occasionally as late as August 15. Eggs of this species were at no time abundant. They were sufficiently numerous, however, to be readily obtained for study. They occurred in greatest abundance during the last week in June and the first week in July. These two weeks, doubtless, witnessed the height of the spawning season.

Adult specimens of *Bairdiella chrysura* were frequently taken in small numbers in the pound net and in the seine. Nearly all the adult fishes taken during June and July had already spawned. On June 20 and again on June 27 a single female ripe for stripping was brought into the laboratory. On the former occasion a few eggs were successfully fertilized. All of these eggs, however, died during early cleavage.

Eggs.—The eggs of this species are spherical in form and 0.7 to 0.8 mm. in diameter. The mature unfertilized egg is slightly yellowish in color. The yolk contains a relatively large oil globule. After fertilization has taken place and the blastodisc has become differentiated, the egg is almost perfectly transparent. The egg membrane is thin and horny. Between the egg membrane and the delicate vitelline membrane inclosing the yolk sphere there is a perceptible perivitelline space. The oil globule normally rests near the upper pole while the blastodisc hangs at the lower pole of the yolk sphere. The spherical form of the egg is maintained until the time of hatching.

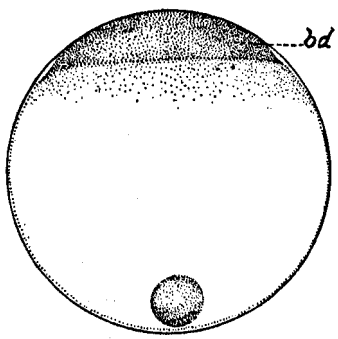
Segmentation.—In the mature unfertilized egg the yolk sphere is covered by a thin layer of protoplasm. After fertilization has taken place the protoplasm of this layer becomes concentrated at the pole opposite the oil globule, where it forms a lenticular cap on the surface of the yolk. This lenticular mass of protoplasm is the blastodisc. The "streaming" movements which occur in the protoplasm as it becomes concentrated to form the blastodisc have been well described and figured by Ryder (1882) for the cod [a] and more recently by other investigators for other species of teleosts.

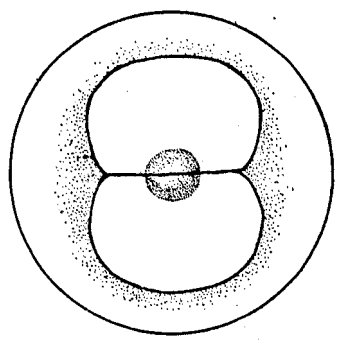
The fully developed blastodisc (fig. 1, *bd*) is circular in outline. Its periphery fades away almost imperceptibly into the very thin layer of protoplasm which remains at the surface of the yolk sphere. No protoplasm is noticeable within the yolk except in the vicinity of the oil globule. Here there is a small amount of protoplasm which can hardly be detected in the newly fertilized egg, but which, as development advances, becomes concentrated to form a protoplasmic cap covering about one-third of the surface of the oil globule.

Just before the first act of cleavage occurs one axis of the blastodisc becomes slightly longer than the other. The first plane of cleavage cuts the blastodisc at right angles to the longer axis (fig. 2). The second cleavage plane cuts the first at right angles (fig. 3). The first two cleavage furrows are meridional and cut deeply into the

[a] Ryder, John A.: Embryography of osseous fishes. Report United States Fish Commission 1882, p. 455–605.

blastodisc. In surface view the early blastomeres appear distinctly outlined peripherally (fig. 3). Viewing the early blastoderm in optical section from the side, however, it is apparent that the blastomeres are not entirely cut off peripherally, but are continuous with the thin layer of protoplasm at the surface of the yolk. This condition is illustrated in figures 25 and 27, in eggs of *Anchovia mitchilli*. The first four blastomeres are usually quite symmetrical and approximately equal in size. They





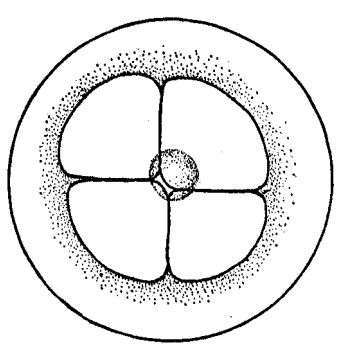
BAIRDIELLA CHRYSURA.

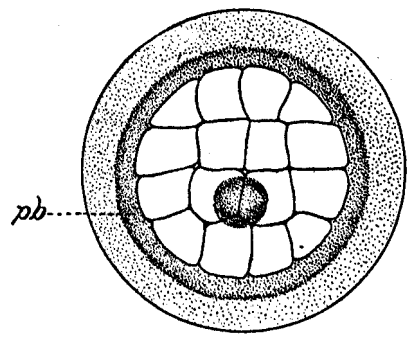
FIG. 1.—Egg with fully developed blastodisc (*bd*). × 55.

FIG. 2.—Egg with blastoderm of 2 cells. × 55.

also show a decided tendency to assume a spherical form, as is indicated by the deep indentations between the cells at the periphery of the blastoderm and the open area at the center (fig. 3). In the 4-cell stage the two axes of the blastoderm are approximately equal.

The third cleavage furrows cut the blastoderm approximately parallel with the first. When the third act of cleavage is completed and the blastoderm is composed of 8 cells,





BAIRDIELLA CHRYSURA.

FIG. 3.—Egg with blastoderm of 4 cells. × 55.

FIG. 4.—Egg with blastoderm of 16 cells; *pb*, periblast. × 55.

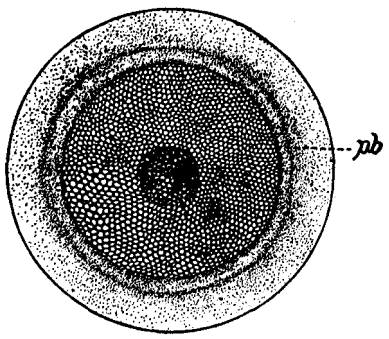
one axis is again distinctly longer than the other. In the 16-cell stage (fig. 4) the blastoderm is usually more or less nearly circular in outline.

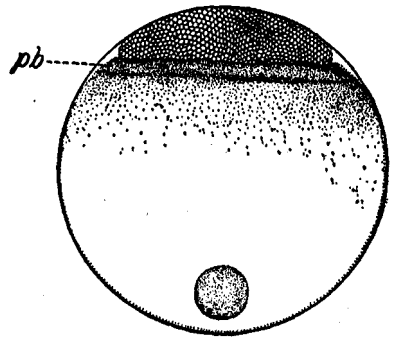
While blastoderms in the early cleavage stages show considerable variation, cleavage in these eggs may in general be said to proceed very regularly. The majority of the blastoderms observed in the 4-cell stage were almost ideally symmetrical. The same may be said of many of the blastoderms of 8 cells. At this stage irregularities are not uncommon, however. A marked tendency toward regularity is apparent also in blasto-

derms of 16 and 32 cells. This tendency may still be recognized in blastodorms of 64 cells.

The successive acts of cleavage follow each other in rapid succession. Eggs showing blastoderms in advanced stages of cleavage may be observed within three or four hours after the time of spawning. Such eggs were usually observed between 9 and 11 o'clock p. m.

Formation of the periblast.—During the early cleavage stages the marginal cells of the blastoderm are not definitely limited peripherally, but are continuous with the thin layer of protoplasm which remains at the surface of the yolk sphere. At the periphery of the blastoderm this protoplasmic layer is concentrated to form a low ridge. This ridge of protoplasm gives rise to the periblast (fig. 4, *pb*). As segmentation advances nuclei become apparent in the periblast. These nuclei, as observed by Agassiz and Whitman[a] (1884), are, doubtless, derived from the marginal cells of the blastoderm. The cells at the margin of the blastoderm gradually become more definitely limited peripherally until in the advanced stages of cleavage they are completely cut off from





BAIRDIELLA CHRYSURA.

FIG. 5.—Egg with blastoderm of many cells, late cleavage stage, surface view; *pb*, periblast. × 55.

FIG. 6.—Egg with blastoderm of many cells, late cleavage stage, lateral view; *pb*, periblast. × 55.

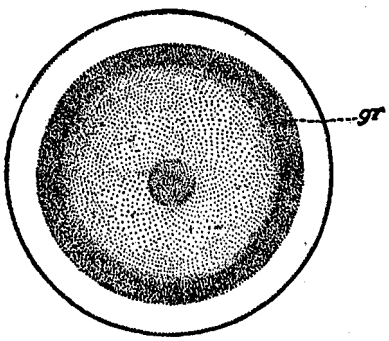
the periblast (fig. 6). The blastoderm is now more or less dome-shaped and beneath its central area may be observed a perceptible cleavage cavity. During the later cleavage stages the periblast becomes somewhat more definitely outlined, increases somewhat in width, and also sends a thin sheet of protoplasm centripetally beneath the cleavage cavity.

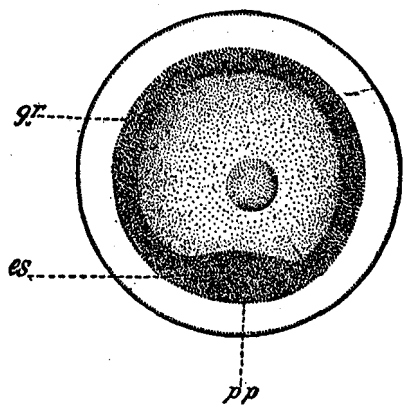
Formation of the germ ring and differentiation of the embryo.—While the marginal cells of the blastoderm are becoming cut off from the periblast there appears a slight thickening at the periphery of the blastoderm. This thickening represents an early stage in the differentiation of the germ ring. It is caused primarily by the thinning of the central area of the blastoderm and secondarily by the ingrowth (invagination) of the marginal cells. The part played by invagination in the formation of the germ ring and the embryonic shield is discussed at some length by Wilson (1889) in his paper on the embryology of the sea bass.[b] Evidence of invagination first appears at the

[a] Agassiz and Whitman: On the development of some pelagic fish eggs. Proceedings of the American Academy of Arts and Sciences, vol. 20, 1884.

[b] Wilson, H. V.: The embryology of the sea bass (*Serranus atrarius*). Bulletin of the United States Fish Commission, vol. IX, 1889, p. 209–277, pl. LXXXVIII–CVII.

posterior, i. e., the embryonic pole of the blastoderm. At this pole a broad tongue of cells, several layers in depth, may be observed before any evidence of invagination is apparent around the rest of the periphery of the blastoderm. Figure 7, plate II, illustrates an early stage in the differentiation of the germ ring. In this blastoderm invagination was not yet apparent. The following figure (fig. 8) illustrates a blastoderm in which the broad tongue of cells is already growing forward from the embryonic pole, and the entire germ ring is well differentiated. At this stage the central area of the blastoderm has become materially thinner than the peripheral area. Viewed from the under side the blastoderm is now distinctly concave. Between its concave surface and the periblast there is a perceptible subgerminal cavity closed in on all sides by the germ ring. The blastoderm gradually increases in size by centrifugal growth. The germ ring, therefore, which in its earlier stages is comparatively narrow, increases in width both by the invagination of the marginal cells and by the centrifugal growth of the blastoderm.





BAIRDIELLA CHRYSURA.

FIG. 7.—Egg with blastoderm showing early germ ring (*gr*). × 55.

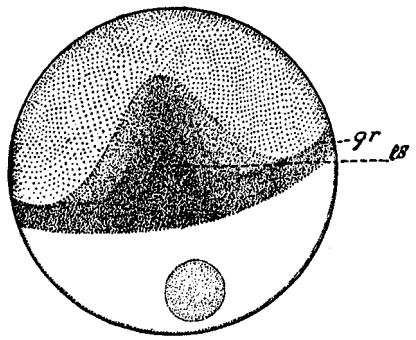
FIG. 8.—Egg with blastoderm showing fully developed germ ring (*gr*) and beginning of embryonic shield (*es*); *pp*, posterior pole of blastoderm. × 55.

While the germ ring is becoming differentiated the cells forming the surface layer of the blastoderm become thin and flattened. This flattening of the surface cells is less apparent in the region of the germ ring, especially in the neighborhood of the embryonic pole, than in the central area of the blastoderm. In the neighborhood of the embryonic pole the surface cells remain relatively thick and more or less polygonal in form.

After the germ ring is completely differentiated the blastoderm increases in size more rapidly than in the earlier stages and advances around the surface of the yolk sphere. The broad tongue of cells which grows into the subgerminal cavity from the embryonic pole of the germ ring also increases in size, and the area of the blastoderm immediately over this ingrowing tongue of cells becomes differentiated. This differentiated area represents an early stage in the formation of the embryonic shield (fig. 9).

Soon after the embryonic shield has become distinctly outlined there occurs a thickening along its antero-posterior axis. This relatively opaque linear area repre-

sents the axis of the future embryo. We may now distinguish an embryonic and an extra-embryonic area within the embryonic shield. The differentiation of the embryonic axis begins in the head region and gradually advances posteriorly until it reaches the posterior pole of the blastoderm. When the embryonic area becomes distinctly



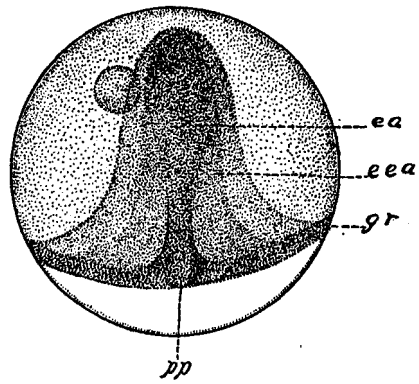


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FIG. 9.—Egg showing later stage in differentiation of embryonic shield; *gr*, germ ring; *es*, embryonic shield.

FIG. 10.—Egg showing embryonic shield (*es*) with embryonic area (*ea*) outlined; *eea*, extra-embryonic area; *gr*, germ ring; *pp*, posterior pole of blastoderm.

outlined it is somewhat broader in the anterior or head region than in the posterior region. Observed in surface view (fig. 10) the embryonic area now has a more or less regular spatulate form. While the embryonic shield is growing forward into the subgerminal cavity and the embryonic axis is becoming differentiated, the germ ring is continually advancing around the yolk sphere. By the time the embryonic axis becomes well differentiated the blastoderm covers more than three-fourths of the surface of the yolk (fig. 11).

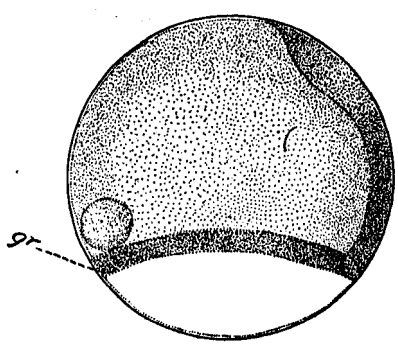
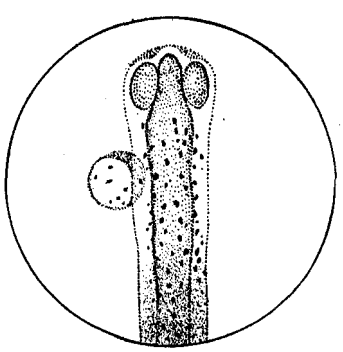


FIG. 11.—Same as figure 10, lateral view. × 55.

The further differentiation of the embryo advances very rapidly and the germ ring continues to advance round the yolk until the blastoderm covers the entire surface of the yolk sphere and the blastopore is completely closed. In the eggs observed while the germ ring was advancing round the yolk sphere the posterior pole of the blastoderm maintained approximately the same position with respect to the oil globule. Inasmuch as the oil globule maintains a more or less constant position with respect to the early blastoderm, it is obvious that the posterior pole of the blastoderm remains at a relatively fixed point. This Wilson (1889) observed to be the case also in the eggs of *Serranus atrarius*. In the eggs under observation the closure of the blastopore occurred before 1 o'clock a. m. This is probably not more than six hours after fertilization.

At the time of the closure of the blastopore the embryo extends about halfway round the circumference of the yolk sphere. There is as yet no evidence of pigmentation in either the egg or the growing embryo. Within one and one-half or two hours after the closure of the blastopore, yellow chromatophores become sparsely distributed over the

dorsal and dorso-lateral aspects of the embryo. A few yellow chromatophores are apparent also on the surface of the oil globule. The distribution of chromatophores at this stage is illustrated in figures 12 and 13. Kupffer's vesicle (fig. 13, *Kv*) now appears as a small bubblelike body on the ventral surface near the posterior end of the embryo.



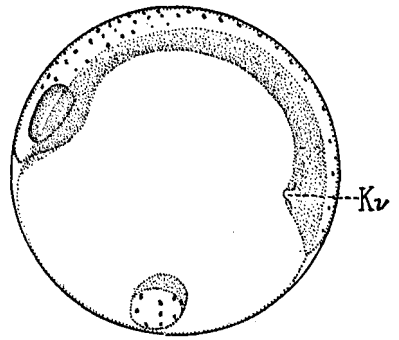


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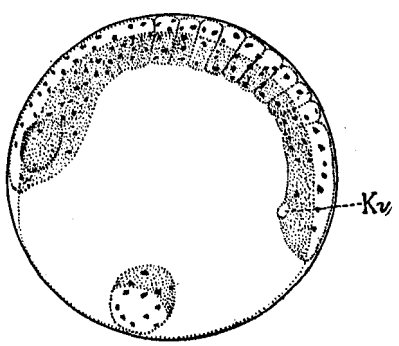
FIG. 12.—Early embryo showing distribution of chromatophores, dorsal view. × 55.

FIG. 13.—Early embryo showing distribution of chromatophores; *Kv*, Kupffer's vesicle. × 55. Lateral view.

An hour later (fig. 14) the chromatophores have become more numerous and are distributed more or less uniformly over the entire dorsal and lateral surfaces of the embryo. Kupffer's vesicle has now reached its maximum development. After this it gradually decreases in size until it disappears. The length of the embryo now exceeds half the circumference of the yolk sphere and shows 10 to 12 somites.

As development advances and the time of hatching approaches, the distribution of the chromatophores undergoes a material change. A few hours before hatching the



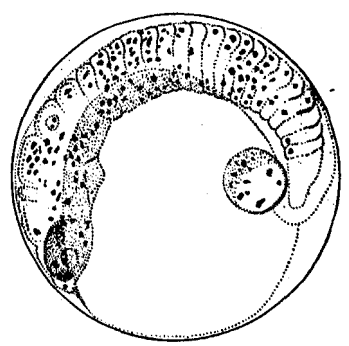


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FIG. 14.—Egg with embryo showing 10 somites; *Kv*, Kupffer's vesicle. × 55.

FIG. 15.—Egg with advanced embryo. × 55.

embryo becomes quite active within the egg membrane. The posterior portion of the body is now free from the yolk sphere and narrow fin folds are apparent both dorsally and ventrally (fig. 15).

Larval development.—At the time of hatching the larval fishes are 1.5 to 1.8 mm. in length. The head is slightly deflected at the anterior end of the large oval yolk sac.

The oil globule appears as a yellowish opaque body on the surface of which are scattered a few yellow chromatophores. It is located in the posterior region of the yolk sac. The fin folds are continuous. The dorsal fold arises just posterior to the head; the ventral fold is continuous with the yolk sac. The depth of each fin fold is less than the depth of the body. The body is brownish yellow, marked by five vertical yellow bands. These vertical bands are composed of more or less closely aggregated chromatophores. A few scattered chromatophores occur also between the vertical bands. The fin folds and the posterior tip of the body are transparent. Figure 16 illustrates a larval fish about two hours after hatching.

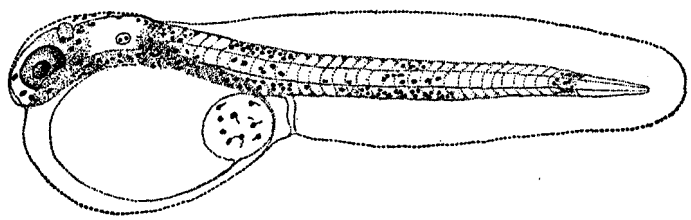

FIG. 16.—*Bairdiella chrysura.* Newly hatched fish, actual length 1.8 mm.

For some time after hatching the general color of the body remains unchanged. The distribution of the yellow chromatophores, however, undergoes marked changes. Five hours after hatching (fig. 17) the vertical bands have become broken up. A distinct vertical yellow band remains located approximately two-thirds the distance from the vent to the posterior end of the body. Another less distinct vertical band occurs just posterior to the head. Groups of scattered chromatophores occur in the head region and above the vent. A few more or less isolated chromatophores occur also on the posterior half of the body.

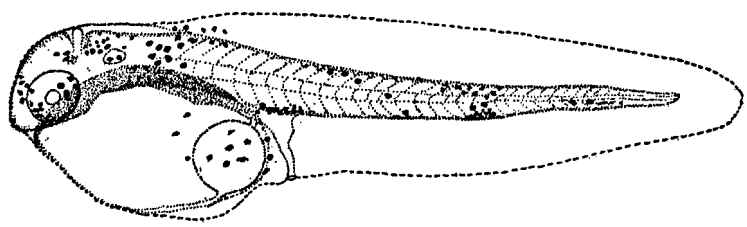

FIG. 17.—*Bairdiella chrysura.* Larval fish 4 to 5 hours after hatching, actual length 2 mm.

At one day after hatching (fig. 18) the young fish has grown to a length of 2.4 to 2.6 mm. A small mass of yolk remains unabsorbed. The head is no longer deflected, but slightly elevated. The body is distinctly flattened. The greatest depth of the body occurs posterior to the head. From this point the body tapers gradually toward the posterior end. The depth of each fin fold is greater than the depth of the posterior half of the body. The general color of the body remains brownish yellow. The fin folds and the posterior one-fifth of the body remain transparent. The yellow chromatophores have become fewer. The posterior vertical band now consists of a dorsal and a ventral group of chromatophores. There is no distinct vertical band in the anterior region at this stage, but a few yellow chromatophores remain scattered over the head and the anterior region of the trunk.

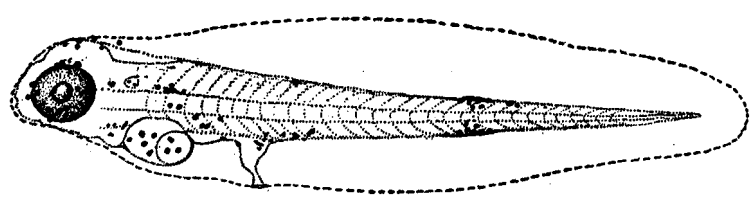

FIG. 18.—*Bairdiella chrysura.* Larval fish 1 day after hatching, actual length 2.5 mm.

During the following day the larval fishes do not increase in size materially. They undergo material changes in form and color, however. At two days after hatching (fig. 19) they remain 2.5 to 2.8 mm. in length. The yolk is completely absorbed. The depth of the head is now greater than the depth of the body. The fin folds remain continuous and the depth of each fold remains greater than the depth of the body posterior to the vent. The general color of the body is light brownish yellow, marked by two distinct vertical bands. The anterior vertical band is located just posterior to the head. It is composed of yellow chromatophores on a blackish background. The general macroscopic effect of this band is blackish. The posterior vertical band is located approximately two-thirds the distance from the vent to the posterior end of the body. It is composed of a dorsal and a ventral group of yellow chromatophores on a diffuse blackish background. The macroscopic effect of this band is yellowish. Yellow chromatophores no longer appear on other parts of the body. The fin folds and the posterior end of the body remain transparent.

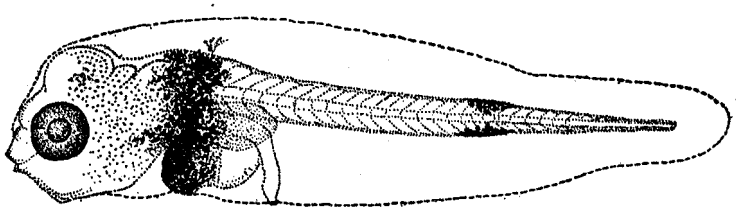

FIG. 19.—*Bairdiella chrysura.* Larval fish 2 days after hatching, actual length 2.6 mm.

The critical period for these larvæ begins during the third day after hatching. When kept in dishes of sea water they began at this time to die rapidly. Few survived until the fourth day. Means of keeping the larvæ alive for a longer period was not available. Observations on the later larval development, therefore, were made on larval fishes taken alive in the stow net.

After the critical period is passed the little fishes feed actively and probably grow comparatively rapidly. Figure 20 illustrates a young fish 3.5 mm. in length. The relative depth of the body in fishes of this size is materially greater and the trunk tapers more rapidly toward the posterior end than in larvæ which have not yet passed the critical period. The posterior end of the notochord is slightly elevated. The posterior end of the body is asymmetrical and betrays an ancestral heterocercal condition of the tail. The fin folds remain continuous. The depth of each fold is now less than the depth of the body posterior to the vent. The general color of the body is somewhat lighter than in the earlier larvæ. Both vertical bands are distinctly blackish. Yellow pigment is still present in the vertical bands, but is obscured by the denser blackish ground color. From the anterior vertical band two blackish bands extend antero-ventrally. One of these blackish bands terminates in proximity with the eye, the other extends diagonally over the preopercle and cheek. The posterior vertical

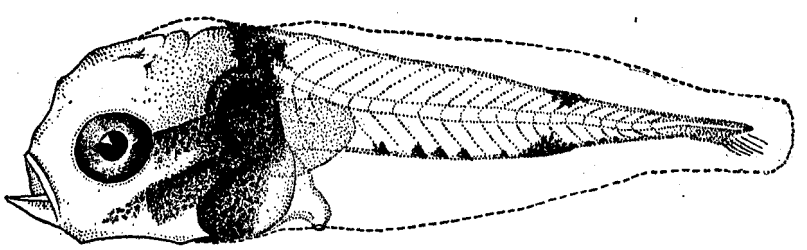

FIG. 20.—*Bairdiella chrysura.* Larval fish 3.5 mm. in length.

band is composed of a dorsal and a ventral pigmented area. These two areas are now so widely separated that in lateral view the band no longer appears continuous. Several blackish pigment spots occur also along the ventral margin of the body between the vent and the posterior vertical band.

Larval fishes 5 mm. in length (fig. 21) retain the same general form as the one 3.5 mm. in length above described. The posterior end of the notochord is curved upward more strongly and the heterocercal character of the tail is more apparent. The general color of the body has changed to silvery gray. The anterior vertical band and

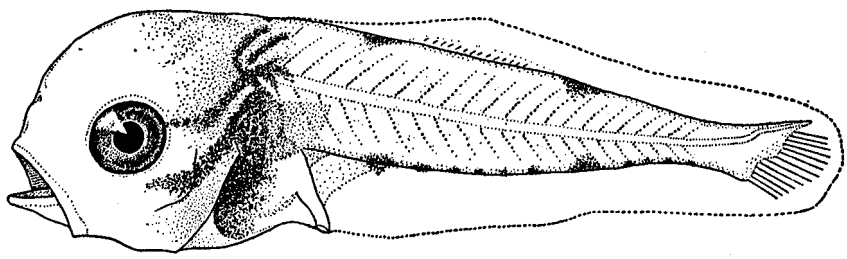

FIG. 21.—*Bairdiella chrysura.* Larval fish 5 mm. in length.

the dorsal and ventral pigmented areas in the region in which in the earlier larvæ the posterior vertical band is located are distinctly blackish. A small dark area occurs dorsally opposite the vent. Several small darkly pigmented areas occur also along the ventral margin of the body posterior to the vent.

As the little fishes grow larger the trunk posterior to the vent becomes relatively deeper until there is no longer an abrupt break in the ventral contour of the body. The caudal end of the body gradually becomes symmetrical dorso-ventrally and the tail assumes its true homocercal character. The general color of the body remains silvery

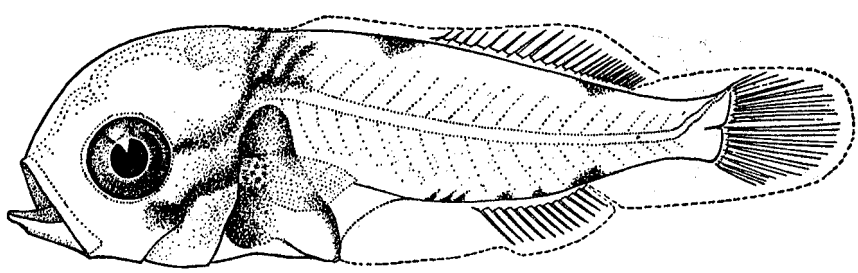

FIG. 22.—*Bairdiella chrysura.* Larval fish 7.5 mm. in length.

gray, distinctly darker dorsally than ventrally. The anterior vertical band and the other darkly pigmented areas are retained until the little fishes have grown to a length of 8 to 9 mm. After this they gradually disappear. In fishes 11 to 12 mm. in length (fig. 23) there remain only traces of these pigmented areas.

After the little fishes have attained a length of 7 to 8 mm. (fig. 22) they rapidly assume the general form and appearance of the adult individuals of the species. In fishes 10 to 12 mm. in length (fig. 23) the fins are well differentiated and the full numbers of fin rays are already present. Fishes of this size have the general

appearance of adult individuals. However, the depth of the body in the thoraxic region is relatively great and the head is relatively large and blunt. They are also somewhat lighter in color.

Figure 24 illustrates a young fish 30 mm. in length. The fins are now fully differentiated and the entire surface of the body is covered with scales. However, the scales are still small and deeply embedded in the skin. They are, therefore, not

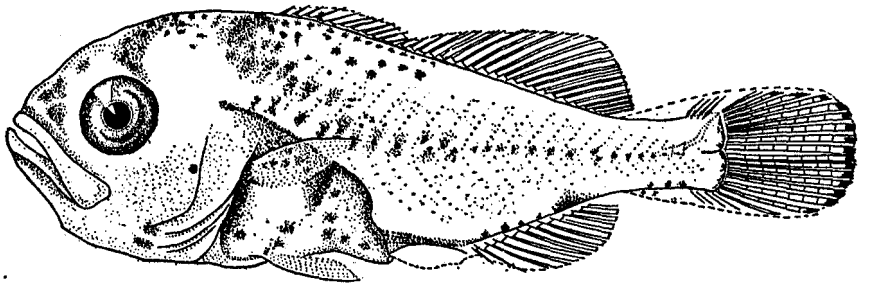

FIG. 23.—*Bairdiella chrysura.* Larval fish 11 mm. in length.

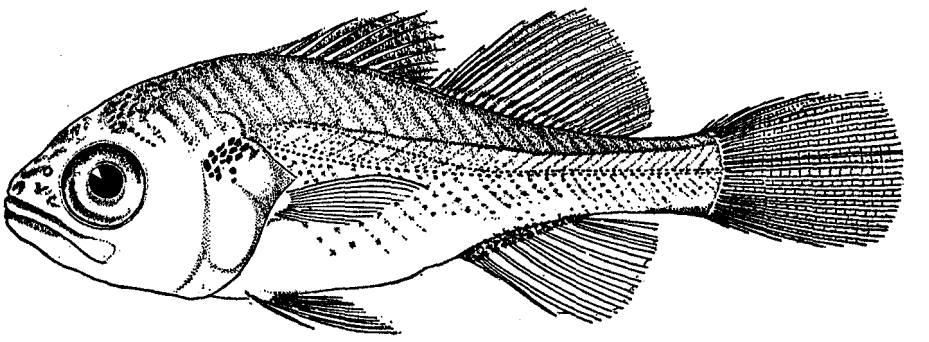

FIG. 24.—*Bairdiella chrysura.* Fish 30 mm. in length.

shown in the drawing. In form and color fishes of this size are practically identical with adult individuals. In short, they show all the diagnostic characters of the species.

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Spawning.—The eggs of *Anchovia mitchilli* were present in the plankton when work was begun on June 9, and were collected in the tow net nearly every day after that date until August 23, when the work was discontinued. During the second and third weeks in June the eggs of this species were not abundant, though they were sufficiently numerous to be readily obtained for study. Toward the close of June they became numerous, and they were much more abundant in the plankton during July and August than the eggs of any other fishes spawning during these months. The height of the spawning season is probably reached during July.

As already indicated, this species, like *Bairdiella chrysura*, spawns regularly in the early evening, probably before 8 o'clock p. m. On a few occasions newly spawned eggs were collected before 6 o'clock p. m. Usually, however, no newly spawned eggs were

taken before 8 o'clock p. m. Eggs were found occasionally in the early cleavage stages as late as 9.30 o'clock p. m. Newly spawned eggs were taken in the tow net alike on the flood and the ebb tides.

Eggs.—The eggs of this species are not spherical, but slightly elongated. The major axis, which is 0.65 to 0.75 mm. in length, is 0.1 to 0.3 mm. longer than the minor axis. These eggs are almost perfectly transparent and contain no oil globule. Furthermore, the yolk is composed of separate masses. It has the appearance under the microscope of being broken up into large cells. As observed by Wenckebach [a] in 1886 and later by other European naturalists, the elongated form of the egg and the segmented character of the yolk is characteristic also of the European anchovy (*Engraulis encrasicholus*). The eggs of this species, however, are somewhat larger than the eggs of *Anchovia mitchilli*. The difference in length of the major and the minor axes in the eggs of the former species also is considerably greater. According to Heincke and Ehrenbaum [b] (1900), the greater diameter of the eggs of the European species is 1.1 to 1.5 mm., and the lesser 0.7 to 0.9 mm. These measurements approximate very closely the dimensions of the eggs of the American species, *Anchovia brownii*.

Eggs in advanced stages of development and newly hatched larvæ were rarely taken in the tow net at the surface of the water. This fact suggests that before the time of hatching the specific gravity of the eggs is increased sufficiently to cause them to sink. This conclusion is verified by the results of experimental observations. Eggs placed in a dish of sea water 12 to 16 hours after fertilization float at the surface for several hours and then sink to the bottom of the dish. After hatching the larval fishes may be found at any level in the dish. The eggs of this species are very delicate. When placed in a dish of sea water many die before hatching. All the eggs alike, however, sink to the bottom before any are hatched.

Embryology.—The eggs of *Anchovia mitchilli*, like those of *Bairdiella chrysura*, develop in a manner typical for pelagic teleostean eggs, and the development differs from that of Bairdiella only in a few unimportant details. The embryological development of *Anchovia mitchilli* will therefore be discussed but briefly and with reference to the above discussion of the embryology of *Bairdiella chrysura*.

As indicated above, the eggs of *Anchovia mitchilli* are not spherical, but slightly elongated. As the thin protoplasmic layer investing the yolk becomes concentrated to form the blastodisc, the protoplasm "streams" toward one pole of the major axis. When fully differentiated the blastodisc appears as a lenticular cap of protoplasm lying on the somewhat flattened lower end of the yolk mass. The periphery of the blastodisc fades away almost imperceptibly into the very thin layer of protoplasm which remains at the surface of the yolk. Between the thin egg membrane and the delicate vitelline membrane there is now a perceptible perivitelline space.

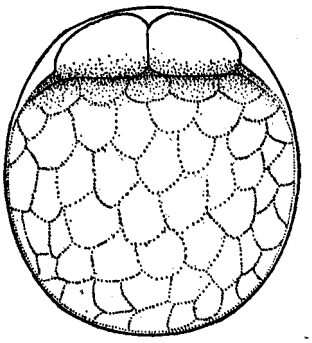
Cleavage in these eggs advances with great regularity. It conforms in all essential details to the process of cleavage, as above recorded, in the eggs of *Bairdiella chrysura*. In many instances the early blastoderms in these eggs are even more symmetrical than in the eggs of the latter species. Early blastoderms which are quite typical of the eggs

[a] Wenckebach, K. F.: De embryonale outwikkeling van de ansjovis (*Engraulis encrasicholus*). Verhandeling der Kaiserlichen Akademie van Wetenschappen. 1887.

[b] Heincke, Fr., und Ehrenbaum, E.: Eier und Larven von Fischen der Deutschen Bucht. II. Die Bestimmung der schwimmenden Fisheier und die Methodik der Eimessungen. Wissenschaftliche Meeresuntersuchungen, n. f., bd. III, Abteilung Helgoland, 1900, p. 127–332, taf. IX–X.

of *Anchovia mitchilli* are illustrated in figures 25, 26, and 27. Figure 28 illustrates an egg in an advanced stage of cleavage in which the marginal cells of the blastoderm are already cut off from the periblast. Eggs in this stage of development were usually observed between 11 and 12 o'clock p. m.

The germ ring (fig. 29, *gr.*) and the embryonic shield (fig. 30, *es*) are differentiated in the manner described above in the eggs of *Bairdiella chrysura*. Soon after the germ



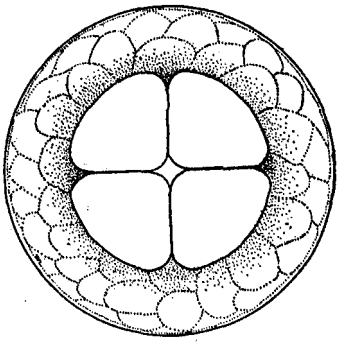


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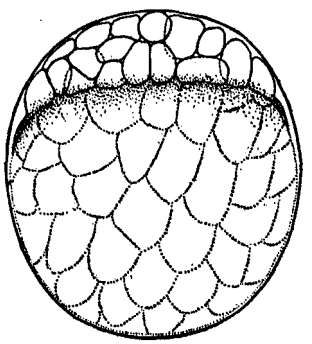
FIG. 25.—Egg with blastoderm of 2 cells, lateral view. × 60.

FIG. 26.—Egg with blastoderm of 4 cells, surface view. × 60.

ring is fully differentiated the blastoderm begins to grow around the yolk more rapidly than in the earlier stages. The posterior pole of the blastoderm, however, does not remain at a relatively fixed point, as is the case in many teleostean eggs, but recedes as the anterior pole advances. As the blastoderm grows around the yolk, therefore, its center remains at one pole of the major axis of the egg. The blastopore finally closes at the opposite pole (fig. 34, *bl*). When the embryo is fully differentiated, therefore, it lies approximately parallel with the major axis of the egg (fig. 35).



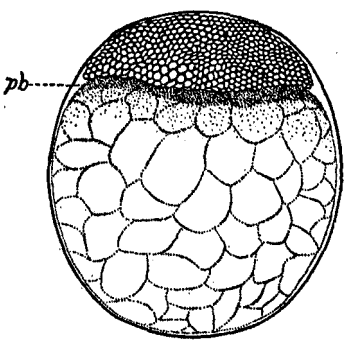


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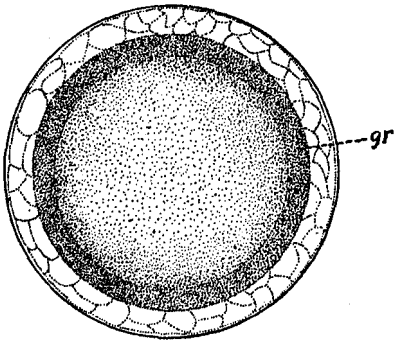
FIG. 27.—Egg with blastoderm of 32 cells, lateral view. × 60.

FIG. 28.—Egg with blastoderm in advanced stage of cleavage; *pb*, periblast. × 60.

In the majority of the eggs observed the blastopore closed between 4 and 5 o'clock a. m.—i. e., approximately 10 hours after spawning. At this time the length of the embryo is somewhat greater than half the greater circumference of the egg. Soon after the closure of the blastopore, Kupffer's vesicle arises as a bubble-like body on the ventral aspect of the embryo near its posterior extremity (fig. 35, *Kv*). The vesicle soon reaches its maximum development and then gradually decreases in size until it disappears.

After the closure of the blastopore the embryo increases in length until it extends more than two-thirds around the greater circumference of the yolk (fig. 36). In some instances, before the time of hatching, the embryo extends entirely around the circumference of the yolk.

Larval development.—The time required for hatching, as already indicated, is approximately 24 hours. Hatching usually occurs between 6 and 9 o'clock p. m. The



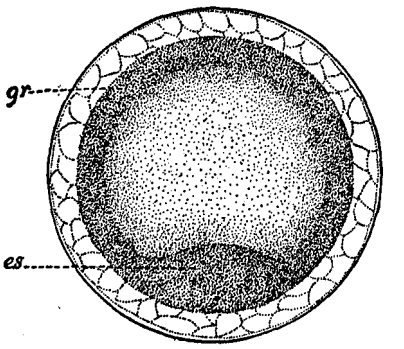


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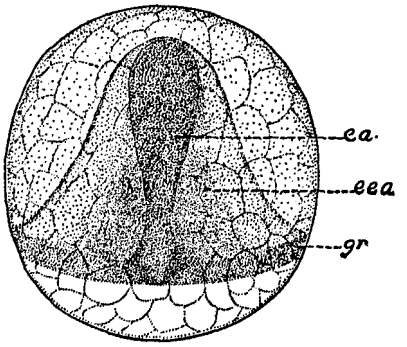
FIG. 29.—Egg with blastoderm, showing early germ ring (*gr*). × 60.

FIG. 30.—Egg with blastoderm showing fully developed germ ring (*gr*) and beginning of embryonic shield (*es*). × 60.

newly hatched larvæ (fig. 37) are 1.8 to 2 mm. in length. The yolk sac, which remains comparatively large, is greatly elongated and tapers to a point posteriorly. The segmented character of the yolk, already noted in the egg, is still apparent. The head of the young fish is deflected at the anterior end of the yolk sac. The body is appreciably flattened and comparatively slender. The fin folds are continuous. The depth of



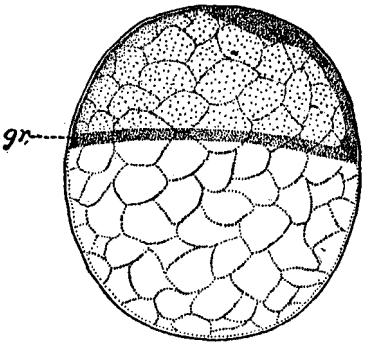


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FIG. 31.—Egg showing advanced stage in development of embryonic shield (*es*), embryonic area (*ea*) outlined. × 60.

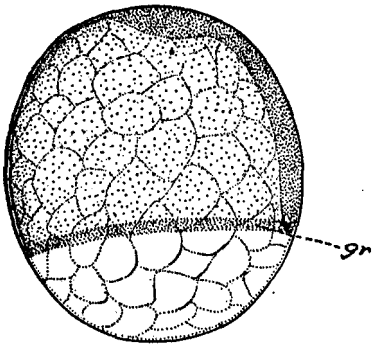
FIG. 32.—Same as figure 7, lateral view; *gr*, germ ring. × 60.

each fin fold is less than the depth of the body. The larval fish is almost perfectly transparent and shows no evidence of pigmentation.

At 12 hours after hatching (fig. 38) the larval fish has grown to a length of 2.6 to 2.8 mm. The remaining yolk mass retains its elongated form and its segmented character. The head of the young fish is no longer deflected.

The yolk sac decreases in size until at 15 to 18 hours after hatching it is completely absorbed. For some time after the yolk is absorbed the larval fishes increase in size

very slowly. Nor do they undergo any material changes in form or appearance. They are relatively long and slender and highly transparent. At 36 hours after hatching (fig. 39) the mouth is apparently functional and soon begins to show the form character-



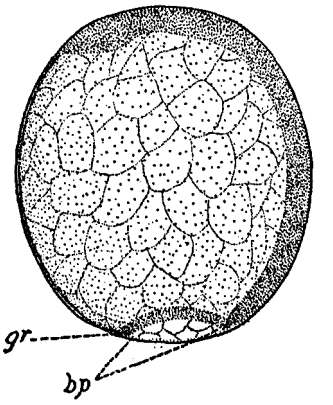


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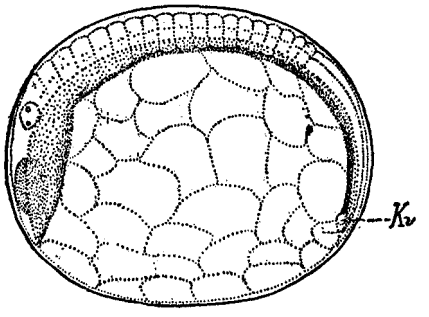
FIG. 33.—Egg showing blastoderm spreading over yolk; *gr*, germ ring. × 60.

FIG. 34.—Egg showing blastopore nearly closed; *bp*, blastopore; *gr*, germ ring. × 60.

istic of anchovies. The maxillaries are comparatively long. The lower jaw is long and narrow. The tip of the head, however, does not as yet extend forward beyond the mouth.



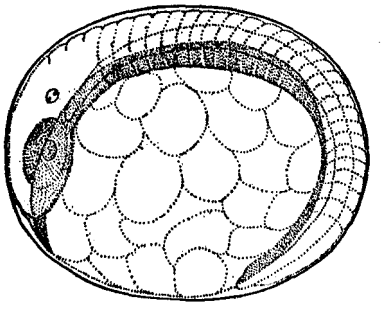


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FIG. 35.—Egg with embryo showing 18 to 20 somites; *Kv*, Kupffer's vesicle. × 60.

FIG. 36.—Egg with advanced embryo. × 60.

The critical period for the larvæ of this species begins before the close of the second day after hatching. When kept in dishes of sea water many of them died before reaching the third day. Observations on the later larval development were made on larval fishes collected in the stow net.

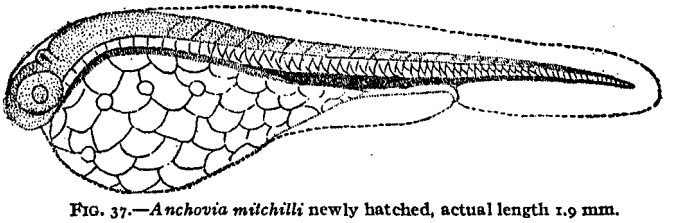

FIG. 37.—*Anchovia mitchilli* newly hatched, actual length 1.9 mm.

Larval fishes 3 to 4 mm. in length (fig. 41) do not differ markedly in appearance from larvæ in which the yolk sac is just absorbed. They retain the same general form and remain almost perfectly transparent. The fin folds remain continuous. Their relative depth, however, has materially decreased.

Fishes 5 mm. in length (fig. 42) illustrate an early stage in the differentiation of the dorsal and the anal fins. In larvæ of this size the posterior region of the intestine is already convoluted. In lateral view these convolutions have the appearance of vertical folds. This character is apparent externally until the little fishes have attained a length of 15 to 20 mm.

In fishes 7 to 8 mm. in length (fig. 43) the dorsal and anal fins are becoming definitely outlined. In some instances the full number of fin rays is already present.

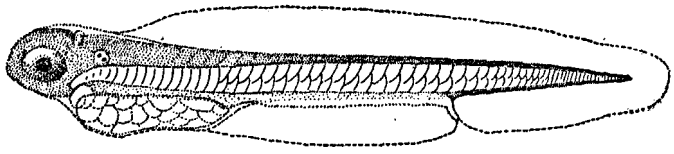

FIG. 38.—Larval fish 12 hours after hatching, actual length 2.7 mm.

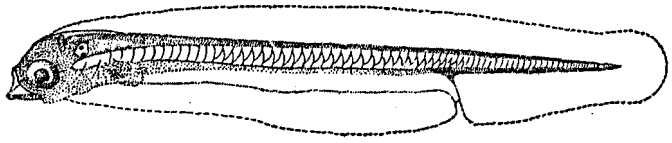

FIG. 39.—Larval fish 36 hours after hatching, actual length 2.9 mm.

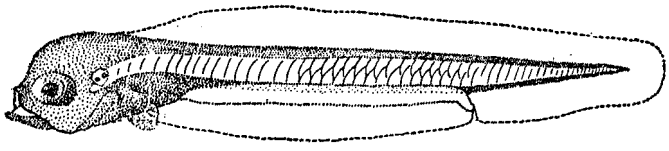

FIG. 40.—Larval fish 3 days after hatching, actual length 2.7 mm.

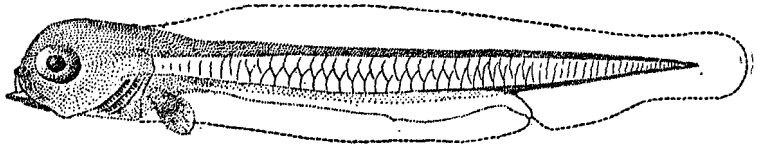

FIG. 41.—Larval fish 3.4 mm. in length.

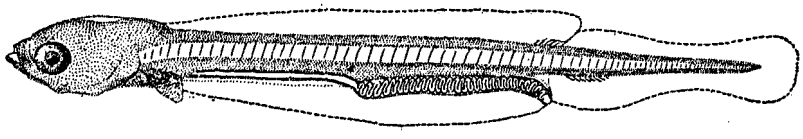

FIG. 42.—Larval fish 5 mm. in length.

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A few small darkly pigmented areas are now apparent along the ventral margin of the body in the thoracic region and at the base of the anal fin.

As the young fishes grow larger they become less transparent, but show very little pigment. They undergo no marked changes in form, but gradually assume the appearance of adult fishes, showing all the diagnostic characters of the species. The silvery, longitudinal band characteristic of adult anchovies, however, does not appear until the young fishes have attained a considerable size.

During the early summer larvæ of *Anchovia mitchilli* and *Anchovia brownii* were frequently taken together. In this stage the two species are very similar and might readily be confused, the larvæ of the latter, however, being somewhat the longer and comparatively more slender. The vent is also located correspondingly farther posteriorly in the latter than in the former. As soon as the dorsal and anal fins have become fully differentiated, the young of either species may be recognized by the character of the anal fin. The number of anal fin rays in *Anchovia brownii* usually does not exceed 20. In *Anchovia mitchilli* the anal fin rays number 25 to 28. In the latter species the anal fin also is longer and terminates less abruptly and nearer the base of the caudal fin than in the former.

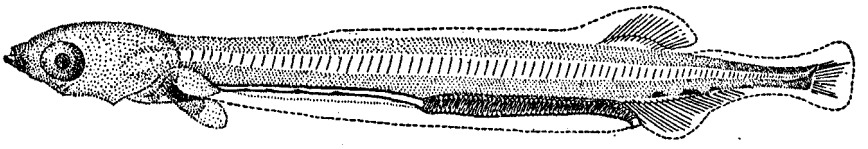

FIG. 43.—Larval fish 7.5 mm. in length.

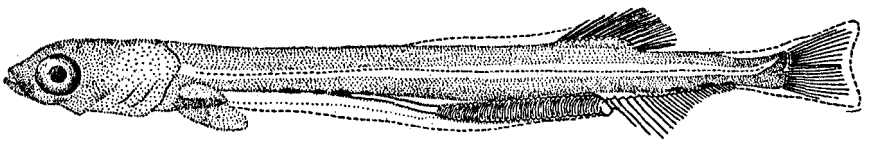

FIG. 44.—Larval fish 10 mm. in length.

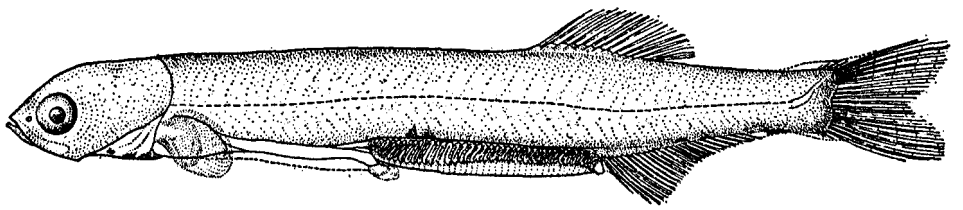

FIG. 45.—Larval fish 15 mm. in length.

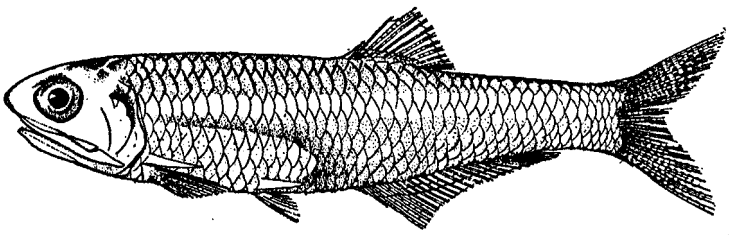

FIG. 46.—Adult fish 7 cm. in length.

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Figure 46 illustrates an adult fish. The adult of this species does not differ markedly in form and appearance from the adult of *Anchovia brownii*. The average length of the body is somewhat greater and its relative depth is somewhat less in the latter, while the silvery lateral band of *A. mitchilli* is narrower and less distinct than in *brownii*. More distinctive characters are the anal fin, as indicated above, and the position of the vent. In the larvæ of both species the vent is located opposite the middle of the dorsal fin or farther posteriorly. In the adult of *Anchovia mitchilli* the vent is located opposite the origin of the dorsal fin, while in the adult of *Anchovia brownii* the vent is located approximately opposite the middle of the dorsal fin.