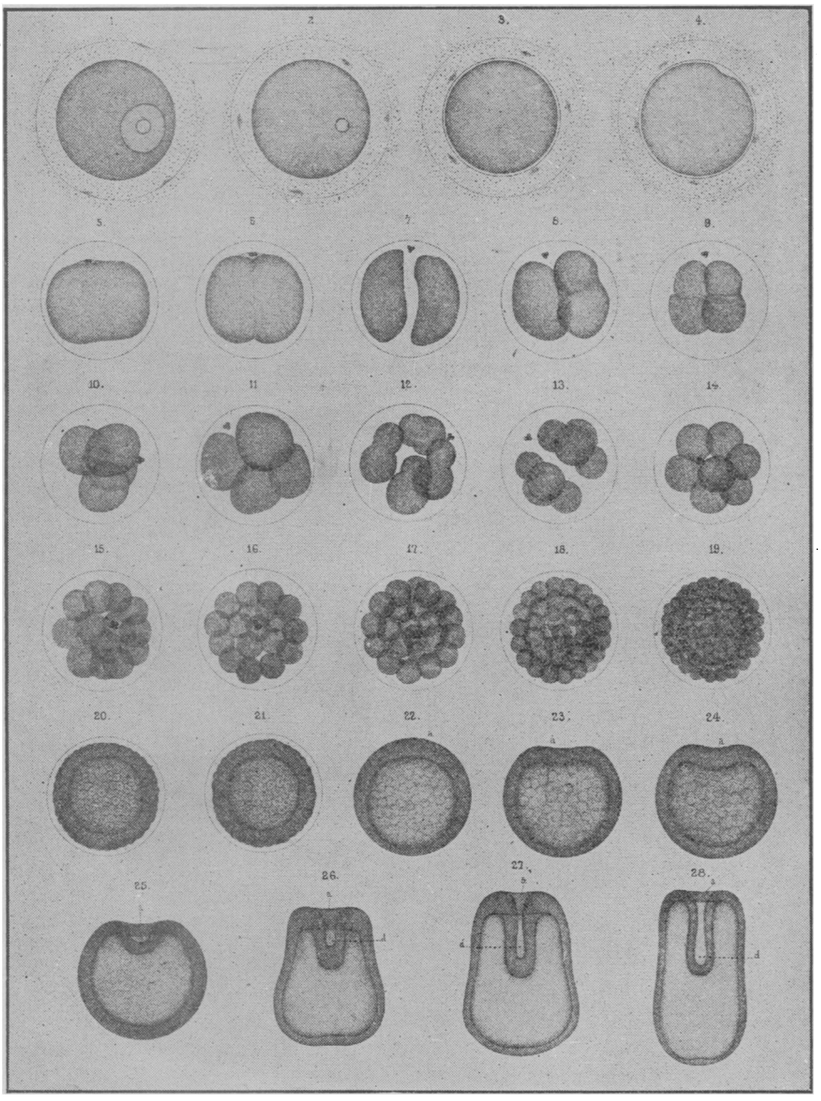
Classics of Science: Development of the Starfish



The Starfish Embryo up to and just after hatching

In the following quotation from the first chapter of Agassiz' monograph, the method of studying the development of the starfish egg up to the time of hatching is described so clearly that it is easy to repeat the procedure.

EMBRYOLOGY OF THE STARFISH, by Alexander Agassiz, Cambridge, Mass. 1864.

Difference of the Sexes

The males and females of our common species of Starfishes, Asteracanthion pallidus *Ag.* (A. vulgaris *Stimp.*?), and Asteracanthion berylinus *Agass.*, can readily be distinguished by their difference in coloring; all those having a bluish tint being invariably females; a reddish or reddish-brown color indicating a male. Among the many specimens I have had occasion to open, I have thus far never found a single exception. When cut open, so as to expose the genital organs, the difference between the males and females is still more striking. The long grape-like clusters of reproductive organs extending from the angle of the arms, on both sides of the ambulacral system, to the extremity of the rays, present very marked differences in the two sexes. The ovaries are bright orange, while the spermaries are of a dull cream-color. At the time of spawning, which is very different in the two species mentioned above, the genital organs are distended to the utmost, filling completely the whole of the cavity of the ray; the abactinal system itself being greatly expanded by the extraordinary development of these organs.

Artificial Fecundation

If we take a male and female Starfish in this state, and cut a portion of the genital organs into small pieces, we shall find that the eggs and spermaries escape in such quantities as to render turbid the water in which they are placed. Throwing these small pieces of the genital organs into shallow dishes containing fresh sea-water, and stirring the mixture thoroughly to insure the contact between the spermaries and the eggs, will be sufficient to fecundate the latter. In order to make the operation perfectly successful, some precautions are necessary: all the pieces of the genital organs, which are left after repeated stirring, must be carefully removed; there must not be too many eggs in one dish, so that the water can have free access to them in every direction. The removal of the remnants of the ovaries and spermaries is very necessary, as the pieces which remain clodded together decompose very rapidly, and endanger the safety of the egg, even when the water can be changed with the greatest facility. As soon as the fecundation is fulfilled, the water in the dishes must be repeatedly changed until it becomes perfectly clear, for the presence of too many spermaries, rendering the water milky, prevents a favorable result. It is best only to use one male and one female for the mixture in each vessel, as eggs taken from many individuals lessen the chances of success. The eggs sink to the bottom, so that the water can be poured off and changed without much danger of throwing them away. Immediately after the mixture is made, the water should be changed three or four times in succession; after that, every half hour, until the fourth hour, when an interval of two to four hours may elapse before renewing the water. As it is extremely difficult to change the water after the embryos have hatched and are swimming freely about in the jar, without losing many of them, it is advisable, before they hatch, which is about ten hours after the fecundation, to reduce the water to a minimum volume, and then simply to add a little fresh sea-water and remove the contents of the vessel to larger and larger jars. In this way the water can be maintained sufficiently pure, until the

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young embryos have taken the habit of swimming near the surface, when it may all be drawn off by means of a siphon. A great deal of time and trouble will be saved by this mode of procedure, and fewer specimens lost. The jars containing the eggs should be kept in a cool place; the most convenient method of securing a low and even temperature is to place the small jars in large tubs filled with cold water.

Changes in the Egg

At the time of spawning, the eggs in the ovaries are so closely packed that they are pressed into all sorts of shapes, triangular, polygonal, elliptical; but when placed in water, and allowed to remain a short time, they soon become perfectly spherical (Pl. I. *Fig.* 1). The following numbers are the ratios of the diameters of the yolk, the germinative vesicle, and the germinative dot, the outer envelope being 1: the yolk is 0.75, the germinative vesicle 0.22, and the germinative dot 0.08. . . . .

The spermatic particles, which swim about with great rapidity on escaping from the spermaries, soon find their way to the outer envelope of the egg to which they attach themselves, beating about very violently the whole time. The particles remain embedded in the thickness of the outer envelope, and are sometimes so crowded as to form a halo round the egg (Pl. I. *Figs.* 1-4). I have not, in a single case, seen any of the particles penetrate through the outer envelope and reach the yolk itself. . . .

The first phenomenon which precedes any change in the egg is a rotary motion given to the whole egg by the constant beating of the spermatic particles; the germinative vesicle disappears (Pl. I. *Fig.* 3). The yolk has then all the appearance of an egg which has undergone segmentation, and the yolk of which should consist of innumerable small spheres. The yolk has the same granular structure previous to segmentation which has usually been considered to belong to it only after the segmentation is complete. . . . . The disappearance of the germinative dot is accompanied by a separation of the yolk from the inner wall of the outer envelope of the egg (Pl. I. *Fig.* 3); this is the first step towards segmentation, and the presence of such a marked interval would greatly facilitate the detection of spermatic particles upon the surface of the yolk, if any of them had penetrated through the outer membrane. The first trace of segmentation consists in a depression of the yolk, visible on one side of the sphere (Pl. I. *Fig.* 4), and is soon followed by a similar change on the opposite pole.

The segmentation takes place very rapidly, passing in about eight hours from the stage represented by Pl. I. *Fig.* 3 to that of Pl. I. *Fig.* 21, immediately before the escape of the embryo from the egg. The spheres in the earlier stages of segmentation are well separated (Pl. I. *Figs.* 7, 9, 11, 13). They have a centrifugal tendency, and, as they increase in numbers, arrange themselves in a shell-like envelope, which eventually becomes the wall of the embryo. This tendency is already apparent when there are not more than eight spheres (Pl. I. *Figs.* 13, 14); and as early as the stage represented on Pl. I. *Fig.* 16, where there are only thirty-two spheres, the envelope is quite prominent. The rotation of the spheres of segmentation commences before this (Pl. I. *Fig.* 6), and is entirely independent of the motion given to the whole egg by the spermatic particles; this stops soon after the rotation of the spheres of segmentation has commenced. . . .

The Embryo after Hatching

At about the end of the tenth hour after fecundation, the segmentation has been carried so far that the walls of the future embryo have become quite conspicuous, and it is now ready to hatch (Pl. I. *Fig.* 21). When the outer envelope is torn, the young rotate slowly about round a shifting axis, by means of very minute cilia placed over the whole surface; the walls are everywhere of the same thickness, and the embryo is perfectly spherical. A difference soon becomes evident; the walls thicken at one pole of the sphere (Pl. I. *Fig.* 22, *a*), and the thickening is accompanied by a flattening of the same side (Pl. I. *Fig.* 23, *a*). The next change consists in a slight depression at this flattened pole (Pl. I. *Fig.* 24 *a*); the wall bends inward forming a very shallow depression, growing deeper and deeper, until it forms a pouch extending half the length of the embryo (Pl. I. *Figs.* 25, 26, *d*, 27, *d*). While a cavity (*d*) is thus formed by the simple folding in of the outer wall, the embryo is constantly lengthening and becomes more cylindrical; the walls of the extremity opposite the pouch becoming attenuated, while, immediately round the opening of the cavity, the walls have not lost their original thickness (Pl. I. *Figs.* 26, 27, *a*). Water flows freely into and out of this cavity; currents are established, running in different directions along opposite walls of the pouch, showing this opening to be for the present a mouth; the pouch, or digestive cavity, sustains the same relation to the whole body as in the most regular and circular radiated animals, such as young Actiniae, or young Porites. The motion of the embryo, which immediately after escaping from the egg is an extremely slow rotation, increases in rapidity as it lengthens, and by the time the cavity equals half the length of the embryo (Pl. I. *Fig.* 27, *d*), the motion is much accelerated. Instead of a simple slow rotation, with scarcely any motion of translation, the latter is now quite rapid, and is accompanied by a slow rotation round a vertical axis, through the center of the longer diameter of the animal; the opening leading into the coecum is foremost during their motion.

At the end of about twenty hours after fecundation, the embryo has reached the condition just described; it is now somewhat pear-shaped, with rounded extremities (Pl. I. *Fig.* 27), having at one end an opening (*a*), leading into a pouch (*d*), which extends half the length of the cylinder. We have now the embryo in a condition which can best be compared to the embryos of other Radiates; for there is as yet, nothing of the complication hereafter introduced in the subject by the development of bilateral parts, obscuring the plan upon which the embryo is built. It is an embryo closely resembling those of the other Radiates, in which, however, the class-characters, distinguishing it from the embryos of the other classes of the type, are already developed beyond question.

Alexander Agassiz was born December 17, 1835, in Neuchatel, Switzerland, died at sea between England and America, March 27, 1910. He was the son of Louis Agassiz, who came to America in 1846. At the age of 20 he graduated from Harvard University, and published his first scientific paper four years later. In 1867 he became superintendent of the Calumet Copper mine in Michigan, which at that time was unsuccessful. He united the Hecla mine to it and started them toward the enormous prosperity they have since enjoyed. From them Agassiz received a fortune which he devoted to scientific work. He was interested in many branches of natural history, but did most of his work on forms of marine life, especially Acalephs and Echini. Beginning in 1875, he led many expeditions in the Atlantic, Pacific and Indian Oceans for the study of oceanography.