the field of action, carrying away the heat as rapidly as it is supplied to the furnace as latent heat of volatilization or as energy stored up as potential chemical energy. It is true that the temperature of volatilization might be increased by subjection to high pressure, but this involves construction of a container which can be made only of solid materials, having limitations imposed by the fusing temperatures. The electric arc maintained through a carbon vapor furnishes perhaps the highest degree of temperature attainable, the temperature of which is usually considered as being definitely fixed by the volatilization of carbon. Through limitations upon our methods of measuring these high temperatures the exact value to be assigned to the temperature of the electric arc cannot be stated, though the most satisfactory measurements give values ranging between 3,600 deg. and 4,000 deg. C. Whether this is the ultimate limit to be attained by electrical means is difficult to say. There is, of course, the possibility of exceeding it by maintaining the arc under a high atmospheric pressure, or by feeding electrical energy to the arc more rapidly than it can be dissipated by the volatilization of carbon, or in other words, superheating the carbon vapor. Such speculation, however, is not necessary to show that the electric furnace has unbounded possibilities, since the range of temperatures below that of the ordinary arc offers an unlimited field for usefulness.

The maximum temperature which may be obtained theoretically by the combustion of carbon in oxygen is higher than that which has been attained in the electric furnace, but practical conditions place a greater restriction upon it. At high temperatures carbon cannot be consumed to CO_2 , but rather to CO , and this gaseous product escapes rapidly and carries the heat away from the furnace. Further, it is impossible under practical conditions to supply pure oxygen, and in utilizing the atmospheric supply not only must the large quantity of accompanying nitrogen be heated, but the excess of air which must always be supplied also carries away a large amount of heat. The maximum temperature which has been attainable in the combustion of fuel in the gaseous, solid or liquid form, from which volatile products of combustion are formed, probably does not exceed 2,000 deg. C., and even this value can be obtained only at a low efficiency, and under most favorable conditions for the conservation of heat.

Since the introduction of the electric furnace, other new methods have been worked out for obtaining the higher temperatures. One of these is known as the thermit method, in which aluminium is the fuel consumed, the product of combustion being aluminium oxide, which is not volatile at the high temperatures, and therefore does not carry away the heat. By this means temperatures considerably exceeding 3,000 deg. can be readily attained. Calcium, magnesium, and certain other electropositive elements may be similarly utilized for attaining high temperatures, but the electric furnace stands alone as a means of producing these temperatures economically. The great advantage of electric heating is that it is not necessarily associated with products of combustion and does not need for its production a consumption of materials. In other words it gives "pure, unadulterated heat." Therefore, for temperatures exceeding 2,000 deg. the electric furnace, if not the only means, is the most economical one to be employed.

Another advantage which the electric furnace has over combustion furnaces is that a great amount of heat can be developed in a compact and limited space and that the same degree of temperature can be attained whether the furnace is operated on a laboratory or on an industrial scale.

From the standpoint of refractory materials the electric furnace represents a distinct gain. The temperature at which ordinary crucible or muffle furnaces can be operated is limited by the resistance which available refractory materials offer to melting, and to the corrosive and fluxing action of materials to which it must be exposed. The same refractory materials may be used for higher electric furnace temperatures since the materials to be heated, as well as the source of heat, are within the refractory walls. Where the heat has to be transmitted through such walls in other forms of furnaces the material to receive the heat cannot receive so high a temperature. Further than this, the refractory walls of the electric furnace can be kept cool by artificial means such as an air blast or water circulation, and a still more advantageous property is that the material undergoing treatment may itself constitute the walls of the furnace. This advantage of interior heating is utilized in the production of phosphorus and carbon bisulphide, most of which is now produced in the electric furnace, the greater cost of electrical heating being more than compensated by the saving in crucibles and retorts, the destruction of which constituted large items under the older methods.

In the matter of control of heat, the electric furnace stands by itself, for the rapidity of heating, duration of heating, and adjustment of the temperature are under the full and exact control of the operator.

Fusions can be carried out under oxidation or reducing conditions, for the construction of the furnaces makes it very easy to operate in an atmosphere of any gas desired. Higher purity can thus be attained.

The final advantage, which is really a summary of all the others, is economy of operation. The economy of the electric furnace as compared with that of other furnaces requires the balancing of electrical energy against energy obtained from the combustion of fuel; cost of installation and maintenance of the equipment, amount of labor, value of product, danger to operatives. A

careful weighing of these factors in a considerable number of metallurgical and chemical operations on an industrial scale has shown the resultant advantage to lie with the electric furnace.

VARIOUS FORMS OF FURNACES.

A considerable variety of expression is found in the classifications of electric furnaces by different authorities. It is common to classify them as follows:

Arc furnaces, in which the material is heated by an arc, usually established between carbon electrodes.

Resistance furnaces, in which the heat is developed by the passage of current through a solid conducting medium.

Electrolytic furnaces, in which heat is generated by the passage of current through a fused mass, and in which at the same time the material is decomposed by the electrolytic effect of the current.

Since in all of these classes the current flows through a conducting medium and therefore encounters a "resistance" it is not logical to employ the term resistance furnace to designate any one of them. A more satisfactory classification would be in accordance with the character of the medium which constitutes the conductor. This gives three classes:

1. Furnace in which the heat is developed by the passage of current through a solid conducting medium or "resistor."
 - a. The conducting medium, or core, may consist of the material which is to undergo useful transformation.
 - b. The heat is developed in a core of conducting material, and this heat is in turn communicated to surrounding material constituting the charge, either with or without the interposition of a wall separating the two materials.
2. Furnace in which the heat is developed by the passage of current through a liquid conducting medium.
 - a. Electrolytic.
 - b. Non-electrolytic.
3. Furnace in which the heat is developed by passage of current through a gaseous conducting medium.
 - a. Arc furnaces.

Where arc plays between two or more carbon electrodes in the neighborhood of material to be heated.

Where arc is maintained between one carbon electrode and another electrode of the material to be heated.

- b. High tension furnaces.

Where arc or high tension discharge plays between two electrodes in a gaseous medium for the production of chemical change in such medium.

(To be concluded.)

THE CHEMICAL FERTILIZATION OF SEA-URCHINS' EGGS.*

By JACQUES LOEB.

In a series of papers I have described a method by which it is possible to produce swimming larvae from the unfertilized egg of the sea-urchin. This method consists in putting the sea-urchins' eggs for about two hours into sea-water whose concentration is raised by the addition of about 15 cubic centimeters $2\frac{1}{2}\text{N}$ NaCl to 100 cubic centimeters of sea-water. The development of these eggs, however, differs in four essential points from that of the eggs fertilized with sperm. In the first place, the eggs fertilized with sperm form a characteristic membrane as soon as the spermatozoon has entered, while the unfertilized eggs treated with hypertonic sea-water develop without the formation of a membrane. Second, the rate of development is considerably faster in the fertilized egg than in the egg caused to develop parthenogenetically. Third, the larvae originating from fertilized eggs rise to the surface of the water as soon as they begin to swim, while those originating by the above mentioned osmotic process swim at the bottom of the dish. Fourth, the number of larvae developing from fertilized eggs is, as a rule, practically a hundred per cent, while in the case of artificial parthenogenesis a much smaller percentage of the eggs develop into swimming larvae. In the case of Arbacia I often succeeded in causing more than twenty per cent of the unfertilized eggs to develop, but in the case of Strongylocentrotus—the form of the sea-urchin common at Pacific Grove—I was rarely able to obtain even as high a percentage of developing eggs. Often enough only a fraction of one per cent of the eggs yielded swimming larvae by the osmotic method of artificial parthenogenesis.

In thinking over the possible cause of this difference between the development of the egg fertilized by sperm and of the egg caused to develop by osmotic influences, it occurred to me that the spermatozoon might carry into the egg not one, but several, substances or conditions, each of which was responsible for only a part of the specific features of sexual fertilization; and that in order to completely imitate the action of the spermatozoon it might be necessary to combine two methods of artificial parthenogenesis, each of which alone imitated the process of sexual fertilization only partially. This latter idea proved correct far beyond my expectations.

In looking for substances which might be utilized for bringing about artificial parthenogenesis I tested the effects of ethylacetate, an ester, which had shown itself so effective in experiments on the control of the

heliotropic reactions of fresh-water Crustaceans, recently published in this Bulletin. I found that if the unfertilized eggs of Strongylocentrotus are brought into 50 cubic centimeters of sea-water, to which about 0.6 cubic centimeter of a grammolecular solution of ethylacetate is added, and left in this water for from two to four minutes, they not only form a membrane* when put back into normal sea-water, but begin also to segment. At a temperature of about 19 deg. or 20 deg. C. they begin to divide into two cells, about five or six hours after the treatment with ethylacetate, and later they may divide into more cells. In about twenty-four hours, however, all the eggs disintegrate, and I have never seen an egg which had been thus treated reach the blastula stage.

If the eggs are left in the mixture of ethylacetate and sea-water they neither form a membrane nor do they segment.

On the other hand, the application of my old method of artificial parthenogenesis gave me this year poor results, owing possibly to the fact that the breeding season of Strongylocentrotus is just beginning. I succeeded in causing only a fraction of one per cent of the unfertilized eggs treated with hypertonic sea-water (100 cubic centimeters sea-water plus 15 cubic centimeters $2\frac{1}{2}\text{N}$ NaCl) to develop into swimming larvae; and even these larvae, as a rule, died in an early larval period.

When I applied both methods in succession, however, namely, the original osmotic method and the treatment with ethylacetate, I obtained surprising results. Instead of a fraction of one per cent of the eggs developing, I had it in my power to cause ninety to one hundred per cent of the eggs to develop. All the eggs formed the membrane which is characteristic of the egg fertilized with sperm. The rate of segmentation was practically the same as that of the eggs of the same female, fertilized with sperm. A large percentage of the blastulae originating from this combination of methods looked perfectly normal, and rose to the surface of the sea-water. Their further development into gastrulae and plutei occurred with the same velocity as that of the control eggs, which had been fertilized by sperm; and the larvae showed an equal degree of vitality.

The order in which these two methods, namely, that of treating the eggs with ethylacetate and with hypertonic sea-water, were applied was not immaterial. The results were much better when the eggs were first submitted to the hypertonic sea-water, and afterward to the ethylacetate, than if the order was reversed. The usual procedure was to put the unfertilized eggs for about two hours and twenty minutes into a mixture of 100 cubic centimeters sea-water and 15 cubic centimeters N NaCl at a temperature of about 19 or 20 deg. C. The eggs were then put into normal sea-water, where they were left for about five or ten minutes, and then put into another dish with 50 cubic centimeters sea-water. Then 0.6 cubic centimeter of a grammolecular solution of ethylacetate was added in drops and the whole stirred with a pipette, so as to bring about a rapid and thorough mixture of the ethylacetate and the sea-water, and to expose the eggs to the diluted ethylacetate.

From time to time a few drops containing eggs were put into a watch glass containing about 10 cubic centimeters of pure sea-water, in order to ascertain whether the eggs were ready to throw out the membrane. As soon as the eggs formed the membrane when put into normal sea-water, they were transferred from the ethylacetate solution into normal sea-water. This was usually the case in from two to four minutes after the eggs had been put into the ethylacetate solution.

When the eggs were taken out a little too early—namely, at a time when only a number, but not all, of the eggs formed a membrane—it was found as a rule that only such eggs showed a normal and rapid segmentation as had formed a membrane. The other eggs, as a rule, did not segment at all, or if they segmented, which occurred only exceptionally, they segmented at the slow rate of the eggs treated only with hypertonic sea-water. The fact that in such cases only those eggs developed which had formed a membrane is another coincidence between this new method of artificial parthenogenesis and sexual fertilization.

It is thus obvious that we are now able to imitate the process of sexual fertilization in the egg of the sea-urchin completely and in all its essential features by purely physical and chemical means. The fact that a number of the parthenogenetic larvae raised by the new method seem to have the same vitality as the larvae produced by normal fertilization arouses the hope that it will now be possible to undertake the solution of the various problems for which the raising of parthenogenetic larvae in large numbers is a prerequisite.

AFRICAN PYGMIES.

THE well-known explorer, Col. Harrison, is returning to England after his latest expedition to Central Africa. He is accompanied by six pygmies from the Ituri or Stanley Forest of the Congo Free State. Four of the pygmies are men and two are women, and all are between eighteen and thirty-four years of age. Their heights vary from 3 feet 8 inches to 4 feet 6 inches. They are visiting London of their own free will, Col.

*The formation of a membrane in unfertilized eggs has already been observed by former experimenters. In 1887 O. and R. Hertwig noticed that the unfertilized eggs of a sea-urchin formed a membrane when put into sea-water to which chloroform had been added. Hertwig noticed in 1892 that a number of substances, such as xylol, toluol, benzol, act in the same way. More recently he has obtained similar results with silver salts. (Hertwig, Mittheilungen aus der zoologischen Station zu Neapel. Vol. 16, p. 445, 1904.)

* From the Rudolph Spreckels Physiological Laboratory of the University of California.