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How could increase in permeability to electrolytes allow the development of the egg?

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I found that the electric conductivity of the sea urchin's egg increased about one fourth on fertilization or when made to develop parthenogenetically with sea water containing acetic acid.

Galeotti¹ observed changes in electric conductivity of animal tissues and explained them by the formation and dissociation of ion-proteid compounds. However he observed that the freezing point sometimes did not change appreciably and never changed in proportion to changes in conductivity. Therefore it seems more probable that the changes in conductivity were due to changes in permeability of membranes.

It seems probable, from observations on the volume of the egg, that its osmotic pressure does not appreciably change, even momentarily, on fertilization. For this and other reasons² I conclude that the increased electric conductivity is due to increased permeability of the plasma membrane.

¹Zeit. f. Biol., neue folge, xxv, 289, xxvii, 65.

²Dynamics of Cell Division, ii, *Am. Jour. Physiol.*, in press.

Since the egg changes in volume on change in concentration of the electrolytes, as well as some non-electrolytes, in the surrounding medium, it must be less permeable to electrolytes than to water, so by electrolysis one should be able to determine whether it is equally permeable to anions and kations. If an electric current be passed through the egg it begins to disintegrate first at the anode. Loeb and Budgett¹ found that the anodal disintegration of infusoria resembled the dissolution that occurs in alkali more than the coagulation in acid, and concluded that it was caused by the accumulation of kations, forming alkalis, on the outside of the animal. I found that coagulation is not the first effect of all acids. When acetic acid is passed under the cover glass of an infusorian preparation, those individuals first affected die so quickly that the process cannot be analyzed, but those specimens receiving the acid very gradually first undergo dissolution of their membranes and the protoplasm flows out, coagulating only after it reaches acid of greater concentration.

The sea urchin egg undergoes cytolysis in sea water containing acetic acid (as well as in alkalis). On passing a current through sea water in which eggs are placed the cytoplasm disintegrating at the anode is not alkaline to neutral red or to the egg pigment as it should be if the disintegration were due to alkalis massed on the outside of the egg. Furthermore, much less current is required for anodal disintegration of eggs in isotonic sugar solution than in sea water, although in the latter case more kations would be thrown against the anode end of the egg. Therefore it is concluded that the anodal disintegration of the egg is due to confined anions, and indicates relative impermeability to these anions. Probably the anions affect the protoplasm without dissociating water, and some of them may be hydroxyl ions. The anions may change the permeability of the plasma membrane and the swelling of the protoplasm occurs as an effect of the resulting diffusion of undetermined substances.

That the anodal disintegration is due to confined anions is an *a priori* conclusion if the plasma membrane be less permeable than the cytoplasm in general, to ions, since the anions migrating in the interior would be stopped by the membrane but the kations

¹*Arch. f. d. ges. Physiol.*, lxxv, 518 : but see *ibid.*, cxvi, 193.

in the sea water would be free to move around the egg. Höber¹ has shown that the plasma membrane of the erythrocyte is less permeable than the interior, to ions, and this is also probably true of the egg.

In sugar solution unfertilized eggs showed anodal disintegration with less current than did fertilized eggs, indicating that the latter were more permeable to anions, or that the electrolytes had already diffused out, in either case showing an increased permeability to electrolytes.

In a molecular solution of dextrose (approximately isosmotic with sea water) fertilized eggs were plasmolysed more rapidly than unfertilized eggs, indicating that the latter were less permeable to the salts exerting the internal osmotic pressure.

To sum up, the increased electric conductivity and liability to plasmolysis with molecular sugar solution and the decreased liability to anodal disintegration, of the fertilized egg, indicate that it is more permeable than the unfertilized egg, to electrolytes. How could this increase in permeability to electrolytes be related to the development of the egg?

Loeb has shown that oxygen and hydroxyl ions in the medium are necessary for development. But eggs will not develop in sea water (which contains oxygen and OH ions) unless some change is induced. Probably this change allows oxygen and hydroxyl ions to reach such a concentration *within* the egg that rapid oxidation may take place. The accumulation of carbon dioxide within the unfertilized egg lowers the concentration of hydroxyl ions. Increased permeability to electrolytes, including carbonic acid, would allow the escape of the latter and the rise in concentration of hydroxyl ions.

The increase in permeability probably causes the increased elimination of carbon dioxide and catalase, and the increased absorption of oxygen, which have been observed by Lyon, Warburg, Loeb and others.

¹*Arch. f. d. ges. Physiol.*, cxxx, 237.