the absence of the humanistic sciences from the freshman and sophomore years, along with the requirement of continuing courses, has operated to keep students out of these subjects. This defect has now been remedied by introducing philosophy into the sophomore year, and a course on "social and economic institutions" into the freshman year.

The curriculum now adopted is to be regarded as but a station on the road to a course almost wholly prescribed, and organized about one great central purpose, that, namely, of initiating the student into an understanding of human experience and the moral and intellectual problems of the times. President Meiklejohn offers a sketch of the ideal college course, as he sees it coming—merely a sketch, confessedly, which will need correction as the result of abundant discussion. The plan certainly is radical. Of the four-year course, 66 per cent. is prescribed, and half of the remainder must be devoted to the senior "major," which is itself to be a continuation of some junior study. The prescribed work is divided as follows: 15 per cent. (of the whole curriculum) to mathematics and natural science, 15 per cent. to literature and 36 per cent. to the humanistic sciences. In favor of this plan, there is this at least to be said, that it follows the trend of the times. While discussion has been raging over the relative values of natural science and the classics, the student body, where free, has attached itself to modern literature and especially to the humanistic sciences. At Harvard, according to Dean Ferry's figures, 3 per cent. of student registration goes to the ancient languages, 25 per cent. to mathematics and science, 28 per cent. to modern literatures and 44 per cent. to "other subjects"; and Professor Hervey has found almost exactly the same proportions among elective subjects in Columbia College. The emphasis on the "other subjects," in President Meiklejohn's plan, may thus be taken as meeting a demand voiced by the students. The question may indeed be raised whether it is worth while, by faculty legislation, to require all students to do what the majority do of their own choice. Another query is suggested by President Meiklejohn's objections to the elective system.

> Under the elective scheme, no subject is essential. Why study physics hard when other students are getting an education without it? . . . The argument is bad but none the less convincing.

Under a required curriculum, the difficulty may be to keep the student in ignorance of the fact that the requirements are different at other colleges. It may also be difficult to explain to him why he should specialize on some one subject to the extent of devoting most of his senior year to it, when his classmate is acquiring a liberal education, presumably just as good, without specialization in this particular direction. If the student is genuinely in love with his subject, well and good—or if he sees a vocational value in it; but vocational values, we are assured, are to be left entirely aside from the curriculum of a liberal college.

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SPECIAL ARTICLES

On Some Non-Specific Factors for the Entrance of the Spermatozoon into the Egg

1. While formerly fertilization was considered a single process which could be adequately described by the entrance of the spermatozoon into the egg or the fusion of the egg nucleus with the sperm nucleus, we know now, through the methods of experimental biology, that fertilization consists of at least three different groups of phenomena. These are, first, the transmission of paternal characters through the spermatozoon. This process is obviously a function of the chromosomes. Second, the causation of development of the egg, which is apparently independent of the chromosomes since the experiments on artificial parthenogenesis have shown that it can be induced by certain non specific agencies. The causation of development is a complicated process since it requires at least two agencies, one inducing an alteration of the surface of the egg (which sets the chemical processes underlying development in action), and the

other a corrective agency which guarantees a normal development.

The third group of factors involved in the process of fertilization is that determining the entrance of the spermatozoon into the egg. This note will deal with the latter problem.

2. We can undertake the analysis of the conditions necessary for the entrance of the spermatozoon into the egg from two different starting points, namely, by finding means for fertilizing the eggs with the sperm of distant species against which the egg is naturally immune; or by rendering the eggs immune against sperm of their own species. The former problem was solved for certain cases when the writer found that the eggs of the sea urchin (*Strongylocentrotus purpuratus*) which under normal conditions can not be fertilized by the sperm of the starfish or holothurians can be fertilized with such sperm if the sea-water is rendered more alkaline.

Last winter the writer found that an addition of calcium chloride to sea-water acts in the same way. In this case the above-mentioned hybridization can be brought about if little or no alkali is added to the sea-water. This suggested the idea that the forces determining the entrance of the spermatozoon into the egg depended upon the concentration of calcium and hydroxylions in the sea-water.

3. If this idea was correct it was to be expected that the elimination of these two substances might render the eggs which are naturally fertilized in normal sea-water immune against sperm of their own species. This was found to be the case. If eggs and sperm of *Arbacia* or *purpuratus* are freed from sea-water and put into a neutral mixture of $NaCl + KCl$ or $NaCl + MgCl_2$, or of $NaCl + KCl + MgCl_2$ (in the concentration and proportion in which these salts exist in the sea-water) no egg is fertilized. Yet it can be seen that sperm remains motile in these solutions for a long time (twenty-four hours or longer) and it can also be shown that newly fertilized eggs are able to segment in these solutions. If calcium chloride is added to these solutions fertilization will take place at once. The same is true when a trace of a base is added to the mixture of $NaCl + MgCl_2$ or of $NaCl + KCl + MgCl_2$.

On the other hand, these eggs can be fertilized by sperm of their own species in neutral solutions containing calcium, namely $NaCl + CaCl_2$ or $NaCl + KCl + CaCl_2$, or $NaCl + CaCl_2 + MgCl_2$, or $NaCl + KCl + MgCl_2 + CaCl_2$. Similar results were obtained in regard to the fertilization of the eggs of an annelid (*Chætopterus*) and a mollusk (*Cumingia*). It can, therefore, be stated that the entrance of a spermatozoon into an egg of its own or foreign species is determined by forces which are influenced by the concentration of calcium and hydroxylions in the solution, the difference in both cases being only in the concentration of these substances required.

4. The question arises which forces in the egg or spermatozoon are influenced by these two agencies. Since it seems tolerably certain that neither the strong base nor the calcium salts enter into the egg or the spermatozoon, the forces acted upon by these substances must be located at the surface of the egg or spermatozoon. There are only three kinds of forces that need be taken into consideration; namely, (1) surface tension, (2) adhesion between spermatozoon and egg surface, (3) cohesion or degree of fluidity of the surface of the egg. Experiments which the writer carried out last winter in Pacific Grove seem to indicate that the adhesion of the spermatozoon to other bodies is strongly influenced by both calcium and bases. The egg of the sea urchin is surrounded by a jelly which the spermatozoon must penetrate before it reaches the egg. If it should stick to the inner surface of the jelly it might still come in contact with the egg and might be able to impart to the surface of the egg, the membrane-forming substance; but through its adhesion to the jelly it might be prevented from entering the egg. The egg should, in consequence, be in the same condition as one in which the membrane formation has been induced by butyric acid but which has not been treated with the second corrective factor. It should show a membrane formation and a beginning of development, but should then perish.

The writer had observed in his earlier experiments on heterogeneous hybridization that when 80 or 100 per cent. of the eggs of *purpuratus* formed membranes upon fertilization with the sperm of starfish in hyperalkaline sea-water, often less than one per cent. of the eggs developed into larvæ, while the rest behaved as if only artificial membrane formation had been induced. Last winter the writer and Dr. Gelarie made sure that (as was already indicated by observations of Dr. Elder) only those eggs developed into larvæ in which a sperm nucleus was found, while the eggs which formed membranes without developing did not contain a sperm nucleus. The writer found, also, that when the concentration of NaHO and $CaCl_2$ used was comparatively high a smaller proportion of the eggs with membranes developed than when the concentration was low. This was easily understood on the assumption that the addition of NaHO as well as of $CaCl_2$ to the sea-water increased the adhesion of the starfish sperm to the jelly of the sea urchin egg, thus allowing the sperm to induce membrane formation, but preventing or rendering difficult its entrance into the egg.

It occurred to the writer that if this assumption was correct sea urchin eggs which had been deprived of the surrounding jelly by a treatment with hydrochloric acid should all develop when fertilized with starfish sperm and that they should no longer show a mere membrane formation without development. This was found to be true. Sea urchin eggs (*purpuratus*) were deprived of their jelly and several hours or a day later fertilized with starfish sperm in sea-water to which some $CaCl_2$ and NaHO had been added. Often as many as 50 per cent. of the eggs formed membranes and practically all developed into larvæ; while the eggs of the same female not deprived of jelly when fertilized under the same conditions would all form membranes, but with a very small percentage of eggs developing into larvæ. This indicates that Ca and NaHO may increase the adhesion of the spermatozoa of the starfish to the egg jelly of the sea urchin. It does not prove, however, that this increase of adhesive power is the factor by which the $CaCl_2$ and NaHO influence the entrance of the spermatozoon into the egg. It is possible that in addition these two substances also influence the surface condition of the egg by increasing the fluidity of the surface of the egg, thus favoring the spreading of the fertilization cone of the egg around the spermatozoa.

5. The question arises whether or not the addition of $CaCl_2$ and of bases favors the phenomenon of sperm agglutination[1] caused by the supernatant sea-water of the eggs of the same species, which F. Lillie has discovered. This is not very probable, since the addition of NaHO to sea-water shortens the duration of the agglutination[2] and therefore acts like an "antiagglutinin." It is true that the addition of $CaCl_2$ favors the agglutination, but so does the addition of $MgCl_2$; yet the latter substance without the presence of $CaCl_2$ or the addition of a base does not enable the spermatozoon to enter the egg.

It is, however, possible, if not probable, that some specific substance in the surface of the egg or spermatozoon or of both may also aid in the entrance of the spermatozoon into an egg of its own species. If this be true, in certain cases an excess of alkali or of $CaCl_2$ may compensate to some degree the lack of specific substances for the entrance of the spermatozoon into the egg, *e. g.*, in the fertilization of the egg of the sea urchin by the sperm of starfish, brittle stars, holothurians and others.

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[1] On the basis of observations on the sperm of *purpuratus* the writer was doubtful whether the specific cluster formation of the sperm caused by the supernatant sea-water of the eggs of the same species was a phenomenon of agglutination or a tropistic reaction. In *Arbacia* the agglutination is much more pronounced than in the case of *purpuratus*. The surface tension phenomena which the writer described may therefore find their explanation on the assumption of an agglutination, at least in the case of *Arbacia*.

[2] *The Journal of Experimental Zoology*, Vol. 17, page 123, 1914.