and it is possible that some may be so minute that they can never be seen. It has been observed that certain fluids derived from the culture of micro-organisms may be filtered through thick asbestos filters, so that no particles are seen with the highest powers, and yet those fluids have properties that cannot be explained by supposing that they contain toxic substances in solution, but rather by the assumption that they contain a greater or less number of organic particles so small as to be microscopically invisible. I am of opinion, therefore, that it is quite justifiable to assume that vitality may be associated with such small particles, and that we have by no means reached what may be called the vital unit when we examine either the most minute cell or even the smallest particle of protoplasm that can be seen. This supposition may ultimately be of service in the framing of a theory of vital action.

Weismann in his ingenious speculations has imagined such a vital unit to which he gives the name of a biophor, and he has even attempted numerical estimates. Before giving his figures let us look at the matter in another way. Take the average diameter of a molecule as the millionth of a millimetre, and the smallest particle visible as the $\frac{1}{20000}$th of a millimetre. Imagine this small particle to be in the form of a cube. Then there would be in the side of the cube, in a row, fifty such molecules, or in the cube $50 \times 50 \times 50 = 125,000$ molecules. But a molecule of organised matter contains about fifty elementary atoms. So that the 125,000 molecules in groups of about fifty would number $\frac{125000}{50} = 2500$ organic particles. Suppose, as was done by Clerk Maxwell, one half to be water; there would remain 1250 organic particles. The smallest particle that can be seen by the microscope may thus contain as many as 1250 molecules of such a substance as a proteid.

Weismann's estimates as to the dimensions of the vital unit to which he gives the name of biophor may be shortly stated. He takes the diameter of a molecule at $\frac{1}{2000000}$th of a millimetre (instead of the one millionth) and he assumes that the biophor contains 1000 molecules. Suppose the biophor to be cubical, it would contain ten in a row, or $10 \times 10 \times 10 = 1000$. Then the diameter of the biophor would be the sum of ten molecules, or $\frac{1}{2000000} \times 10 = \frac{10}{2000000}$ or $\frac{1}{200000}$th of a millimetre. Two hundred biophors would therefore measure $\frac{200}{200000}$ or $\frac{1}{1000}$ mm. or 1 μ (micron $= \frac{1}{1000}$th mm.). Thus a cube one side of which was 1 μ would contain $200 \times 200 \times 200 =$ 8,000,000 biophors. A human red blood corpuscle measures about 7·7 μ; suppose it to be cubed, it would contain as many as 3,652,264,000 biophors.

Now if the smallest particle that can be seen ($\frac{1}{20000}$th mm.) may contain 1250 molecules, let us consider how many exist in a biophor, which we may imagine as a little cube, each side of which is $\frac{1}{200000}$th mm. There would then be five in a row of such molecules, or in the cube $5 \times 5 \times 5 = 125$ molecules; and if the half consisted of water about sixty molecules.

Let us apply these figures to the minute particles of matter connected with the hereditary transmission of qualities. The diameter of the germinal vesicle of the ovum is $\frac{1}{20}$th of a millimetre. Imagine this a little cube. Taking the diameter of an atom at $\frac{1}{10000000}$th of a millimetre, and assuming that about fifty exist in each organic molecule (proteid, &c.), the cube would contain at least 25,000,000,000,000 organic molecules. Again, the head of the spermatozoid, which is all that is needed for the fecundation of an ovum, has a diameter of about $\frac{1}{200}$ mm. Imagine it to be cubed; it would then contain 25,000,000,000 organic molecules. When the two are fused together, as in fecundation, the ovum starts on its life with over 25,000,000,000,000 organic molecules. If we assume that one half consists of water, then we may say that the fecundated ovum may contain as many as about 12,000,000,000,000 organic molecules. Clerk Maxwell's argument that there were too few organic molecules in an ovum to account for the transmission of hereditary peculiarities does not apparently hold good. Instead of the number of organic molecules in the germinal vesicle of an ovum numbering something like a million, the fecundated ovum probably contains millions of millions. Thus the imagination can conceive of complicated arrangements of these molecules suitable for the development of all the parts of a highly complicated organism, and a sufficient number, in my opinion, to satisfy all the demands of a theory of heredity. Such a thing as a structureless germ cannot exist. Each germ must contain peculiarities of structure sufficient to account for the evolution of the new being, and the germ must therefore be considered as a material system.

Further, the conception of the physicist is that molecules are more or less in a state of movement, and the most advanced thinkers are striving towards a kinetic theory of molecules and of atoms of solid matter which will be as fruitful as the kinetic theory of gases. The ultimate elements of bodies are not freely movable each by itself; the elements are bound together by mutual forces, so that atoms are combined to form molecules. Thus there may be two kinds of motion, atomic and molecular. By molecular motion is meant "the translatory motion of the centroid of the atoms that form the molecule, while as atomic motion we count all the motions which the atoms can individually execute without breaking up the molecule. Atomic motion includes, therefore, not only the oscillations that take place within the molecule, but also the rotation of the atoms about the centroid of the molecule."[1]

Thus it is conceivable that vital activities may also be determined by the *kind* of motion that takes place in the molecules of what we speak of as living matter. It may be different in kind from some of the motions known to physicists, and it is conceivable that life may be the transmission to dead matter, the molecules of which have already a special kind of motion, of a form of motion *sui generis*.

I offer these remarks with much diffidence, and I am well aware that much that I have said may be regarded as purely speculative. They may, however, stimulate thought, and if they do so they will have served a good purpose, although they may afterwards be assigned to the dust-heap of effete speculations. Meyer writes as follows in the introduction to his great work on "The Kinetic Theory of Gases," p. 4:—"It would, however, be a considerable restriction of investigation to follow out only those laws of nature which have a general application and are free from hypothesis; for mathematical physics has won most of its successes in the opposite way, namely, by starting from an unproved and unprovable, but probable, hypothesis, analytically following out its consequences in every direction, and determining its value by comparison of these conclusions with the result of experiment."

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

SIR PHILIP MAGNUS will distribute the prizes to students of the Morley Memorial College, Waterloo Road, on October 1.

THE Report of the Board of Education, reviewing the proceedings of the Board for the year which ended with last year, has been published as a Blue-book. Reference is made to the Committee appointed to consider the best means of coordinating the technological work of the Board with that at present carried on by other educational organisations. The report of the Committee was received some time ago, and is now "under consideration." It is to be hoped that the report will soon be issued and action taken upon it.

SCIENTIFIC SERIALS.

The American Journal of Science, September.—The discharge current from a surface of large curvature, by John E. Almy. It was found that the current discharging from a fine wire to a concentric cylinder is given by the equation

$$I = LaV(V - b)/r^3,$$

where I is the discharge current, V is the potential difference between the wire and cylinder, L is the length of the discharge wire, r the radius of the cylinder, b the minimum potential necessary to produce a measurable discharge, and a a constant depending upon the size of the wire, the nature of the discharging gas and the sign of the discharge.—On octahedrite and brookite from Brindletown, North Carolina, by H. H. Robinson.—On the behaviour of small closed cylinders in organ pipes, by B. Davis. When small gelatine capsules or light paper cylinders were placed in a stopped organ pipe, on sounding the pipe the cylinders immediately moved to the middle of the stationary loop and arranged themselves in rows across the pipe. The effects produced were of the same nature as the Kundt dust figures.—On a cæsium-tellurium fluoride, by H. L. Wells and

[1] Meyer, "Kinetic Theory of Gases." Translated by Baynes, London, 1899, p. 6.