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MOLECULAR MOTION IN HYDRODYNAMICS.

PROFESSOR JOSIAH P. COOKE'S "New Chemistry" has done much to dissipate the mystery which hung around the subject of molecules in my mind before this light was turned on. The physicist, says Professor Cooke, "may prefer to define molecules as those small particles of bodies which are not subdivided when the state of aggregation is changed by heat, and which move as units under the influence of this agent. To the chemist, on the other hand, the molecules determine those differences which distinguish substances. . . . Hence the chemist's definition of a molecure: 'The smallest particles of a substance in which the qualities inhere, or the smallest particles of a substance which can exist by themselves,' for both definitions are essentially the same" ("New Chemistry," pp. 99, 100). When we try to contemplate the magnitude of these small particles, the mind becomes bewildered by the immensity of the minuteness, in the same way that it is bewildered by the immensity of the expansion when it tries to penetrate the uttermost depths of the celestial spaces. But every child who sees the stars at night peers into these depths, and every one who hears the whistle or the rumble of a steam-engine is listening to the sound of work done by the movement of these minute particles

In the long series of experiments which enabled Mr. William Crookes to develop the radiometer and Crookes's tubes, he became very familiar with these small bodies: not quite enough so to handle them as a boy does his marbles, or a sportsman his shot; but he furnished abundant proof, if any further proof was required, that the molecules are separate bodies of matter, each with the capacity for its own proper motion and of doing its own proper work. It is true that he did not prove that one molecule by itself could be made to do work like a rifle ball, because he failed to separate one from all others; but he leaves no doubt that when moving together, like shot from a smooth-bore gun, each molecule has its own proper motion and does its own proper work.

Applying this determination to the phenomena of hydromechanics, the explanation it affords is astonishing for its simplicity. This application is entirely legitimate; for while Mr. Crookes's operations were on matter in gaseous form, it is now well known that all matter can be changed from one form to another, and the change of the substance which is the subject of hydromechanics from the solid form of ice to the liquid form of water and the gaseous form of vapor, are amongst the most obvious of all phenomena. Moreover, the very fact that water flows, demonstrates its separation into particles each capable of independent motion of its own. When grain passes along a conduit in an elevator, or when seed or shot are poured from one bag or vessel into another, there is a flow, each particle having a certain motion of its own; one moves faster and another slower, as it happens to be more or less subjected to the impelling force. If the particles did not change position in respect to each other, the phenomena would be sliding, not flowing. The essential difference between sliding and flowing is that in the one case, the particles, large or small, constituting the moving body, do not necessarily change position in respect to each other, while in the other this change of relative position of the particles really constitutes the movement of the mass. This is beautifully illustrated by pouring corn into a hopper or bin. When the bag or vessel containing the corn is tilted the grains on top begin to move toward the lower side, and presently begin to pour over, and are followed by the others, each one moving in obedience to its own gravitation and the pressure, if any, from grains above it, and its movement is determined by the resistance it encounters from other grains and the sides of the containing vessel. When the operation is completed no two grains probably occupy the same position in respect to each other, in the hopper or bin, that they did in the vessel from which they were poured. It is said that no two grains are precisely alike in every particular, and it is certainly probable that when a mass of grain flows from one vessel into another, no two of them have identically the same motion both in direction and velocity. The gravitational pull on each is the same, but the variation in pressure and resistance to which they are respectively subjected is practically infinite.

This phenomenon of flow is impossible except in a mass composed of particles free to move in respect to each other, and, therefore, the flowing of water is itself sufficient evidence that the water is composed of particles free to move in respect to each other, and that this motion of particles actually occurs whenever water or any other liquid flows. The decomposition of water has demonstrated that the particles composing it are molecules, as defined by Professor Cooke; that is to say, the particles constituting the water itself are the smallest in which the qualities of the substance inhere, and not aggregations of these smallest particles. When a molecule of water is subdivided, as it may be, there is no water left; the water is destroyed, and the matter assumes the form of oxygen and hydrogen, which in certain combination form the molecule of water. (Decomposition, *ex vi termini*, imports a separation of particles; thus when ice is decomposed into water, the particles separate, and there is a further separation of particles when water is decomposed into vapor; therefore when further decomposition destroys the substance itself, it is obvious that the substance must have been subdivided by precedent decomposition into the smallest particles in which its qualities inhere.) It is obvious, therefore, that a vessel full of water is filled with an aggregation of molecules, in the same sense precisely that a bushel measure full of corn is filled with an aggregation of grains.

It is not necessary for us to determine whether the molecules of water are held apart and kept separate by intermo-