

forces except in the mode of their manifestation, and that *this* is due to the difference in the material substratum through which they in each case manifest themselves. That in short, the vital and physical forces are correlated the one to the other.

And before proceeding further it may be well to state clearly what is meant to be implied in the following pages by the term "correlation." It may be thus defined,—one force, A, operates upon a certain form of matter and disappears, but in its place a second force, B, is developed; again, B is made to act upon some other form of matter, and in its turn disappears, and now A is reproduced, or perhaps not A, but some other form of force, C, D, or E.

Now this conversion of one force into another, if such we like to consider it, necessarily implies a definite quantitative relation existing between the forces thus capable of being changed the one into the other; that is, a certain amount of force A is equal to, and will produce a certain amount of force B, which in its turn shall be capable of reproducing the same amount of force A as originally existed. Thus a certain quantity of zinc is oxidated in the cells of a galvanic battery and a certain quantity of electricity, the result of the oxidation passes along the wires connected with the battery; but as a second consequence of the chemical action heat is evolved, so that we cannot have all the chemical force continued as electricity; nevertheless a remarkable relation has been shown to exist between these two, for if the electricity be employed in the decomposition of water, it will be found that for every equivalent of zinc that has undergone oxidation in each cell of the battery, an equivalent of water is decomposed;* so that the oxygen that disappears in one place reappears in the other, and the force that is set free in the union of the oxygen with the zinc is again taken up in the act of decomposing the water.

It is rarely, if ever, that we can reproduce so as to measure in another form all the force which has in any case thus merged itself; still in the case of some of the physical forces it has been determined, at least approximately, how much of one is required to produce, or be equal to, a certain quantity of another. Thus the experiments of Mr. Joule,† which Prof. Grove considers the most reliable that have been made upon the subject, show that the heat necessary to raise one pound of water through one degree Fahr., is equivalent to the motor force required to raise 772 pounds one foot.

This theory of the correlation of forces, followed to its consequences, naturally leads to the idea of the conservation of force, which supposes that as with matter so with force, there is a certain quantity in the universe, of which none is ever annihilated, and to which none is ever added, that in every case where one form of force disappears, another takes its place; and in like manner every force, which is in any case evolved, is so from an antecedent force which has been converted into it; and as this is true of every form of force so no one of these stands first more than another, and so no one can be said abstractly to be the cause of

* Faraday "On definite electrolysis." Phil. Tran. 1834, p. 77.

† Joule "On the mechanical equivalent of heat," Phil. Tran. 1850, p. 61, and quoted by Grove. "Correlation of physical forces," p. 130.