areas throughout all the known portion of the earth, forming the substance of many mesas, plateaus, and mountain systems, in which valleys and valley systems are carved. The pouring-out of this volcanic matter is not confined to the present time, or to late geologic time. Nor can the geologist assert that the rate of extravasation has increased or diminished from the earliest known geologic time to the present. It seems to have been paroxysmal by districts, but uniform, considering the whole extent of the surface of the earth. The magnitude of the volcanic formations exposed at the surface is such that the origin of the material cannot be attributed to local and trivial causes: it must be explained by laws of universal application. Extravasation is always associated, so far as the phenomena have been studied, with displacement; and this association is of such a nature that they must have a common explanation. This common explanation, as postulated by geologists, is a fluid interior.

III. The argument from internal temperature.

The hypothesis of a fluid interior is reached by another inductive method, — through the facts relating to increase of temperature from the surface downward. The rate of increase is not well known; it seems to be greatly variable. In general, it may be roughly stated, as it is by Thomson and Tait, as about one degree for each fifty feet; but in many cases the rate is much higher. Such an increase, known to extend so far down as observation and experiment have reached, if continued at the same rate, would soon give a temperature at which all known rocks would be melted; and the hypothesis of a fluid condition is thereby strengthened.

IV. The argument from the 'flow of solids.'

It is an hypothesis worthy of consideration, that pressure itself would reduce the interior of the earth to a fluid condition. That rigidity, which is the characteristic of the solid state, is due to molecular cohesion; but geologists everywhere in their researches discover that this molecular cohesion, or rigidity, may be overcome by pressure: for everywhere they find that rocks may be squeezed into new forms, bent, contorted, and implicated; that is, the force of compression existing in many thousands of feet of superincumbent rock overcomes molecular cohesion to such an extent as to cause rocks to yield (the molecular cohesion is broken down). Doubtless the element of time is involved, to some extent, as a rock may be bent with a small force, if sufficient time be allowed. But with increase of force there may be decrease of time; and the force engaged in compression, being the weight of miles of superincumbent rock, must be sufficient to greatly reduce the element of time, and perhaps to cause it to disappear. The last few years of experiment have added to the argument derived from geologic observation. Many solids have already been found to flow under pressure. The molecular constitution of solids is found to undergo a change by reason of pressure, so that new compounds may be formed thereby; and in pressure we have conditions for chemical change analogous to the conditions produced by melting. It is therefore an inductive hypothesis of the highest value, that all rocks may be reduced to a fluid condition — i.e., be caused to behave as bodies of minute parts, without rigidity of structure — by pressure alone.

The facts of observation and experiment characterized above are vastly multifarious and cumulative, and the conclusions in each case are strictly inductive. The theory reached by the consilience of these four inductive processes is so strong, that structural geologists are compelled to accept it, and contradictory conclusions are rejected. It therefore behooves the physicist to re-examine his data and his methods of logical procedure; for, perchance, he may discover that an error lurks therein. J. W. POWELL.

INERTIA.

RECENT conversations with teachers of physics have shown me that there exists, in this country at least, great diversity of opinion as to the proper definition and use of the term 'inertia.'

Elementary text-books usually speak of inertia as a mere *inability*, — the inability of a body to set itself in motion, or to stop itself when once in motion. This is an old use of the term, but certainly not the best use. Maxwell states,[1] that at the revival of science, "while the men of science understood by this term [the inertia of matter] the tendency of the body to persevere in its state of motion (or rest), and considered it a *measurable quantity* [the Italics are mine], those philosophers who were unacquainted with science understood inertia in its literal sense as a quality — mere want of activity, or laziness."

Maxwell suggests certain simple experiments

[1] Theory of heat, p. 86.

which the student may perform in order to become thoroughly acquainted with that property of matter which he calls inertia. I shall describe an additional experiment, for I find that the difficulty is not merely one of words. There are many people who do not recognize the physical facts to be dealt with.

Take a heavy weight, fifty pounds let us say, and suspend it by a long cord. To the weight thus hanging attach another cord, strong enough to sustain the fifty pounds. By means of this latter cord give a sharp horizontal pull to the weight. The cord is broken, while the weight hardly moves, — is left slightly swinging. Is it possible for any one to try this experiment, and not recognize that we have to do here with something more than the inability of matter to set itself in motion? Evidently we encountered a *resistance* in setting the body in motion. Whence came that resistance? Not from gravity: the pull was horizontal; and, moreover, the cord we have broken would have served to lift the weight. Assuredly not from friction, or resistance of the air. We are driven to the conclusion that matter possesses a property in virtue of which it *offers resistance* to an agency which is setting it in motion. We should find, too, by experiment, that matter offers a similar resistance when its motion is being changed in any way, either in magnitude or in direction. This property of matter, which is much more than the mere inability to set itself in motion, is what Maxwell, Thomson, and Tait call inertia.

Now, we must distinguish very carefully between inertia itself, a property of matter, and the resistance which matter can exert in virtue of that property, somewhat as we must distinguish between a man's strength (that is, the property in virtue of which he can exert force) and the force which he may be actually exerting at any time.

Returning to experiment, let us attach to our fifty-pound weight a weak thread, capable of sustaining a few ounces. Pull gently and steadily in a horizontal direction upon this thread. A resistance is felt, to be sure; but the weight is moved perceptibly in the direction of the pull, and acquires, perhaps, a greater velocity than we succeeded in giving to it by a pull which broke the cord previously used.

This experiment proves that the resistance which a given body can, in virtue of its inertia, offer to an agency which is setting it in motion (and it would be the same for any change in its motion), is a variable quantity — let us leave the statement unfinished for a moment, while we look for the conditions and the law of this variation. When the stout cord was broken in pulling at the hanging weight, the latter acquired a small velocity, it is true; but it acquired that velocity in a very short time, a fraction of a second. When pulled by the thread, the weight acquired a somewhat greater velocity, it may be; but a much longer time was occupied in the change. The exact quantitative law, which can be determined by experiment with such apparatus as, for instance, Atwood's machine, is expressed by completing the interrupted statement in the following words: — being proportional to the rate at which the agency is changing the body's motion.

This definite law being recognized, there should be an end of the current vague attempts at explaining such phenomena as, for example, that of a half-open door pierced by a cannon-ball without being shut. Text-books too frequently say, in such a connection, that "masses of matter receive motion gradually and surrender it gradually," or that "it requires time to impart motion to a body as a whole," — statements from which the student is in danger of getting the idea, if indeed he gets any idea, that the *time* is required in order to draw things taut within the body, and get its particles to acting upon each other, somewhat as it takes time and a succession of jerks to take up the slack of a freight-train while it is being started.

Let us note again that the resistance which has just been considered is not the body's inertia, but is merely the manifestation of that property. But if the manifestations of inertia, in the case of a given body, are so variable, how can we speak of inertia as a measurable quantity, as Maxwell does in the quotation already made from him?

Suppose we take a certain body, and ascertain what force, reckoned in any units we please, is required to impart to this body a certain velocity in a certain time. Then we take a second body, and ascertain what force is required to give it the same velocity in the same time. The second force may be equal to, less than, or greater than, the first. If the forces are equal, we may say that the two bodies have equal inertias. If the second force is n times the first, we may say that the second body has n times as much inertia as the first. This is comparison of inertias. If we wish for what is called *measurement*, we have merely to select some body, and agree to call its inertia the unit inertia.

E. H. HALL.