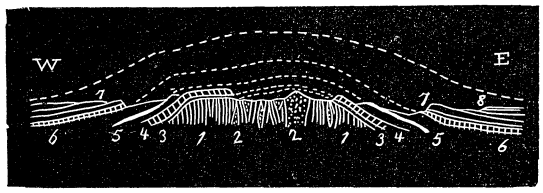
the carboniferous strata which surmounts it; indeed, according to the results of the survey, has been removed from the entire uncovered archæan nucleus. Here a remarkable gap occurs; the next succeeding formation is the carboniferous, and we pass from the primordial at one step to the end of the palæozoic strata, with the striking omission of the Silurian and Devonian systems. We are then told that the carboniferous limestone overlies *conformably* this lower rock—a statement hardly credible—that its hard and resistant strata rise in conspicuous relief like an amphitheatric wall around the included and debased archæan area, with a talus of *debris* composed of its own and Potsdam fragments, piled upon its sides. Beyond the mural escarpments of the carboniferous, a trough-like valley encircles the latter formation like a moat, the bottom of which is formed of the Red Beds, probably Trias or Jura. These consist of marls and clays, sandstone or limestone bands, whose soft material has been easily and largely removed. Beyond this again, and rising from it in steep cliffs, the mechanical basis of the cretaceous is met—the Dakota Sandstone—forming the foot hills which encircle as a final group this geological unit. Beyond again stretches the plains of tertiary strata.

The history of the Black Hills, as written by this survey, is this: A low archæan area primarily, whose erasion and degradation has furnished the sands, and fragments of which the Potsdam sandstones, conglomerate, and quartzites have been formed, has been finally overlaid upon submergence with a regular but unconformable sheet of Potsdam rock. The dome thus made has been lifted from the water and for the long time from the Potsdam to the Lower Carboniferous remained dry land, not even subjected—an extraordinary statement—to considerable denudation. Then the carboniferous sea flowed over all and deposited its even floor of limestone over the Potsdam, which two, most regularly superimposed, now form the walls of the archæan inclosure, from which they have been removed by erasion.

The Triassic and Jurassic followed, surmounting the carboniferous with beds of marl and clays, and adding their accumulations to the rising mound of strata.

Lastly, the cretaceous sealed in the column of deposits so that the ideal dome assumed the form of the adjoined section after upheaval.



IDEAL CROSS-SECTION OF THE BLACK HILLS.

1. Archæan Schists.
2. Granite.
3. Potsdam.
4. Carboniferous.
5. Red Beds.
6. Jura.
7. Cretaceous.
8. Tertiary.

Then the uplift occurred which brought these heavy beddings upward in a flat-topped oval displacement, a highland from which, by a process of enormous denudation, the cretaceous and the Jura and Red Beds have been pared away, their slanting beds and monoclinals now surrounding the hills. The carboniferous and Potsdam have also disappeared from the large area on the east side of the dome, where the archæan schists are exposed, and in time will retreat further and further, uncovering new portions of the azoic terrain. The carboniferous now forms the surface rock of the wide western plateau, and is deeply cut by a net-work of anastomosing cañons. A bird's-eye view of the whole presents the aspect of an overturned colossal pastry, with its bottom crust on one side badly gnawed away. In this place it would be impossible to discuss the serious questions which arise in reference to this exposition. Its guarantee is in the field work and observations of its authors, and it certainly presents a geological chapter of extreme interest.

Prof. Whitfield's important contributions in the palæontology form a striking feature in the report. Mr. Jenney reports, after a detailed examination of the mineral resources of the country, that "the Black Hills are pre-eminently a gold-producing region." Mr. Caswell contributes a chapter on the lithology of the Black Hills.

Very much of general scientific interest is found throughout this handsome volume, and the United States Government have, in its publication, added one more honor to its deserved eminence amongst nations re-organizing science, and added one more debt to the increasing sum due to it from all scientific students.

L. P. GRATACAP.

WASHINGTON, 1880.

THE GREAT PRIMORDIAL FORCE.*

By HENRY RAYMOND ROGERS, M. D., Dunkirk, N. Y.

The law of "*Conservation of Force*" having received the full and unqualified endorsement of all true scientists, is to-day the basis of all physical philosophy and the key to the explanation of all physical phenomena. No view of force can henceforth be accepted which is incompatible with it.

It may be said to be the product of the last half century, its origin being obscure and uncertain. Its earlier conceptions evinced but little promise of the grand future that awaited it, and its advancement, like that of all fundamental truths, has been exceedingly slow. It must be confessed that to-day, even, our knowledge of its provisions is but *rudimentary*. In the way of applying it to the explanation of the mysteries of nature's varied phenomena but little has yet been done. We are confident that whenever this immutable law shall be properly applied, a new era will have dawned upon physical science.

Another fundamental principle of recent discovery has been developed *pari passu* with that mentioned, and in importance is only secondary to it, viz:—the "Unity of Force,"—the correlation of all the forces. It has been demonstrated that all forms of force are resolvable into one another, it is therefore manifest that whatever name, or designation, we may give to these varied forms, but one essence pervades and animates them all. Instead of many independent forces, set forth in an irrational, contradictory, and mostly complicated philosophy, actually there exists *One Great Primordial Force*; simple in its character, competent to explain all physical phenomena, and in harmony with the nature of things. It is the force that rules the universe of matter,—innumerable star-suns and minutest atoms alike; and, for its realm, it has the vast bewildering space and all the cosmical bodies which occupy its depths.

This force is real and *substantial*. "Conservation of force proves as certainly as it proves anything, that all force is substantial. Nothing can be conserved, or preserved, unless it is something that exists, and it seems to be an axiomatic truth that nothing can exist unless it be a substance of some kind. If force in one form is convertible into force of another form, then all force in whatever form it may be exerted is substance, since it is impossible to conceive of the conversion of one thing into another thing, and neither thing be anything substantial. Our inability to take cognizance of the constituents, or corpuscles of a force, is no valid reason to a thoughtful

* Read before the A. A. A. S., Cincinnati, 1881.

mind why such force should not be regarded as a real substance—as literally and truly an entity, as is the air we breathe."

The two fundamental principles having been ascertained, our acquaintance with the essential nature of the primordial force depends upon the use we make of our positive knowledge of the specific operations of the several forms of force, as now, for the first time, we are enabled to understand and interpret them. Since we are just beginning to appreciate the great law of conservation of force and the great fact of the unity of all the forces, a better reading of physical phenomena is rendered possible. By these data we plainly read that this force is *electric* in its constitution. We claim that the electric theory is a factor in the explanation of all the phenomena.

We are able to perceive that a great celestial battery is in operation, to which the primordial force owes its perpetual development; a battery differing from our own magneto, and dynamo-electric batteries only in scale of operation. It has the same essential constitution, and *modus operandi*. Quite like the battery of man's construction, the celestial battery requires the co-operation of two elements, either of which, acting independently, is incapable of producing force, but acting in concert, the two develop all known forces of the universe. These two elements which have never yet been adequately associated in the interpretation of the phenomena of gravity, heat, light, etc, are *motion* and *magnetism;* the motions of the celestial spheres, and the magnetic constituent of each celestial sphere. True, the scientific world has vaguely conceived of the development of power through the agency of celestial motions, but it has failed to formulate any *exact philosophy* of the manner in which those motions should develop actual force. Such a philosophy is accessible.

It is known that the earth is a vast magnet, having a magnetic axis nearly corresponding to its geographical axis, and terminating in a *positive*, or northern pole, and in a *negative*, or southern pole. But the earth's inherent magnetic force must remain purely *potential*, or *static*, and without the ability to act, or to move, except through the co-operation of a separate and independent force, whereby this static magnetism may be converted into active, vital currents. From our experience with the electric battery, we know that motion, and change of polarity, are capable of producing vital, active force, from force inert and dormant. In the celestial, as in the terrestial battery, motion and change of polarity are prerequisite to the awakening of inert, dormant force, into vital, active force.

That electricity may be obtained from magnetism by motion, or that magnetism, conjoined with motion, may be made the source of electricity, is well understood. So, by their unceasing rotation the magnetic sun and earth furnish both the needed motions, and the incessant change of polarity, which are requisite to the completion of the celestial battery. Thus, through the medium of revolving celestial armatures, acting upon celestial magnets, *statics* are converted into *dynamics*, on a scale commensurate with the demands of the universe; and that dream of the ages, *perpetual motion*, is found a realized fact in nature.

All space being pure vacuum, distance is virtually annihilated, and all the spheres are brought relatively into close proximity, Mercury, 37,000,000 of miles from the sun, and Neptune 2,800,000,000 of miles, stand alike in their relation with the great central orb. This condition is thus favorable to such "*action at a distance*," as is found *indispensable* to the inter-communications going on between the bodies which constitute the universe of matter. The fact of instantaneous action at a distance, and without a medium of transmission, though questioned, is demonstrated in the action of gravity.

Through the operation of the celestial battery a great current of force is incessantly in motion from the sun to the earth. Both the law of conservation, and the law of magnetic action, demand that a current of equal proportion shall as incessantly return from the earth, to the sun;—the one current cannot for a moment exist without the other. Were this return current interrupted, the light of the sun would instantaneously cease, all life would become extinct, and, the power of cohesion being suspended, the earth and everything thereon would return to their original elements, and vanish into space. In this action, and retro-action, we find a grand magnetic circuit between the earth and sun, through the operation of which the earth's portion of the primordial force is utilized. The same conditions which exist between the sun and earth, as described, exist also between every satellite and its primary, and between the star-suns of the universe.

SOLOMON was wiser in some respects than the scientists of the present day. He says that "The wind returneth again according to his *circuits*. All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come, thither they return again." Science recognizes the immense movement of force from the sun to the earth,—but has she made sufficient account of the fact that the earth is not full? Has she recognized the fact that back to the sun again, in some form or other, the rivers of energy must return in ceaseless circuit? And yet, the law of conservation demands it, and the electrical theory satisfies the demand.

The various manifestations, or affections, of the primordial force which receive the appellation of the great physical forces have their fullest and clearest explanation through the interpretation given by the electrical theory.

GRAVITY CONSIDERED AS AN AFFECTION OF THE PRIMORDIAL FORCE.

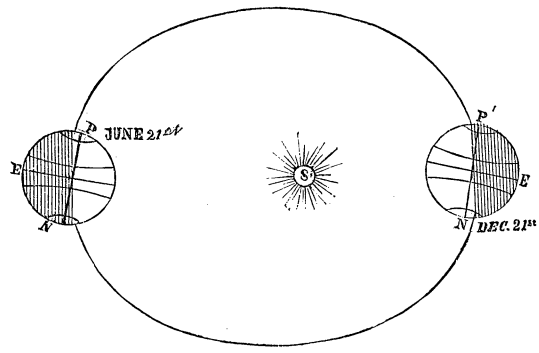
Science has strangely neglected to examine the field which gives best promise of an ultimately satisfactory explanation of this phenomena.

According to the present popular philosophy, "gravity acts directly as the mass, and inversely as the square of the distance." FARADAY says, "The received idea of gravity appears to me to ignore entirely the principle of the conservation of force, and, by the terms of its definition, if taken in an absolute sense, 'varying inversely as the square of the distance' to be in direct opposition to it."

If gravity acts directly as the mass, then surely, as the sun's mass is *constant*, and the earth's mass is also *constant*, the force of attraction should at all times remain invariable, and the earth's orbit should consequently be a true circle, instead of an ellipse. If gravity acts inversely as the square of the distance, then the earth at aphelion could not without the aid of some other force or interfering cause, be returned to perihelion, but the lessening attraction would permit it to move on indefinitely into space.

The electrical theory, however, suggests a more rational, clear, and satisfactory philosophy, and makes provision for the elliptical orbit of the members of the solar system. In order that the earth's orbit, for example, should be elliptical, the mutual attraction existing between the sun and the earth must necessarily increase and diminish with mathematical exactness and regularity. To such *regularly varying attraction*, and to no other cause, can the ellipticity be due. Attraction is greatest about the 21st of December when the two bodies are nearest each other, and least about the 21st of June, when they are relatively the most distant. Whether the attraction between the sun and earth shall be greater, or shall be less, depends altogether upon their relative position. Thus when the earth's south-pole presents nearest the sun, the attraction between the two bodies is the greatest, and when the earth's north-pole so presents,

attraction is least. Why should this variation in position produce such a variation in attraction? In the light of the electrical theory the following explanation is confidently advanced:



On the 21st of December the *positive* sun, (S.) and the *negative* south-pole of the earth's magnetic axis (N.) are in closest relation to each other, and the north-pole, (P.) is out of the field, therefore the opposing conditions, viz: the *positive* sun, and the *negative* portion of the earth, represented by the south-pole, acting in concert, produce attraction between the two bodies, according to the electrical law that *unlikes* attract each other. At that date the centre of the great electric sun-current strikes the earth at a point 23½ degrees south of the equatorial line, and from thence moves in the direction of its mass towards, and along the earth's natural magnetic axis; in this instance, towards the north. This northerly movement of the electric mass is *concurrent* with the earth's magnetic axis, and the force of attraction between the two bodies is thereby increased to its maximum.

On the 21st of June precisely opposite conditions exist: the *positive* sun, and the *positive* north-pole, are in closest relation to each other, and the south-pole is out of the field; attraction between the two bodies is consequently at that date lessened, and this in accordance with the electrical law that *likes* repel each other. And, too, the centre of the great sun-current strikes the earth at a point 23½ degrees north of the equator, and its mass moves in a southerly direction. The direction of this electrical movement is *contrary* to the earth's natural magnetic axis, and the force of attraction between the two bodies is further lessened; consequently at that date they are found at their greatest distance apart,—viz: several millions of miles more distant than on the 21st of December.

On the 20th of September, and the 20th of March, the sun is equidistant from the earth's two polar extremities, and the centre of the great sun-current strikes the earth at the equator in a direction at right-angles with the earth's magnetic axis. The electrical conditions are thus balanced, and the earth at those periods is equally distant from the sun.

The degree of ellipticity of each planetary orbit is due to the inclination of its axis: if the axis is at right angles with the plane of the ecliptic, the poles must be equidistant from the sun, and attraction and repulsion thus become equalized, and the orbit must necessarily be circular. Had the axis of the earth been perpendicular to the plane of the ecliptic, the sun would always have appeared to move in the equator, the days and nights would have been equal, and there could have been no change in the seasons.

The extent of ellipticity in any orbit is governed by the amount of axial divergence from such right-angle.

As a further demonstration of the ability of the electrical theory to account for the grand phenomena of the universe, we will apply it to the philosophy of the earth's axial motions. Electricity and Magnetism are regarded by scientists at the present day as virtually identical. The correlation of heat and magnetism is apparently as pronounced, as witness certain natural phenomena which bear directly upon this point. The tropical plant, the *phytolacca electrica*, is known to produce marked electrical effects; a touch of a twig gives to the hand as vivid a shock as that of a Rumkorff battery. At the distance of seven or eight paces, the influence of the plant is manifested through a compass needle, the closer the proximity, the more marked are the demonstrations; and if the compass is placed in the centre of the bush, the movement of attraction previously shown by the needle is changed into that of rapid rotation. The intensity of the phenomena varies with the time of day. At two o'clock P.M. it attains its maximum, and at night its magnetic powers are scarcely perceptible. It is thus demonstrated that at precisely the same hour, viz: two o'clock P.M. *heat* intensity, and *magnetic* intensity are *co-incident*. From this hour each diminishes, and from the morning until two o'clock P.M. each increases in the same proportion. The hour of the least magnetic effect, or the most *negative* condition, is shown by the following phenomenon to occur at a period of time opposite to that of its maximum, or *positive* condition, viz: two o'clock A.M. It is the experience of miners whose lives are passed in the depths of the earth, that between twelve and two o'clock in the night, if there is a loose stone or bit of earth in the mine it is sure to fall. Says a miner of many years experience: "About this time it seems that everything begins to stir, and soon after twelve o'clock, although the mine has been as still as the tomb before, you will hear particles of rock and dirt come tumbling down, and if there is a caving piece of ground in the mine it is sure to give way."

From these and such like familiar suggestions on the part of nature we may infer that the portion of the earth which is at any given time specially under the action of the great sun-current, becomes *electro-positive*, the maximum intensity occurring at two o'clock P.M. During the night the magnetic condition changes, and is at two o'clock A.M. most *electro-negative*. Thus at two o'clock P.M. the sun on the one hand, and that portion of the earth on the other hand, being in like electrical conditions, viz: *electro-positive*, mutually repel each other, and the consequent *push* moves the earth in revolution. The revolving earth turning eastward, is continually carrying its *negative* condition of the night into the field of the *positive* sun, a mutual attraction therefore takes place with its consequent *pull* upon that side; and thus is generated the process of an incessant attraction on the east side, and of repulsion on the west side, giving to the earth its axial motion.

Gravity may therefore legitimately be claimed as purely an electrical phenomenon.

The words of the grand old FARADAY now stand forth in lines of light, viz: Gravity, surely this force must be capable of an experimental relation to electricity, magnetism, and the other forces, so as to bind it up with them in reciprocal action, and equivalent effect.

SUN HEAT, *as an Affection of the Great ONE-FORCE.*

The demonstrations of our senses, as well as the teachings of all the ages, lead us to attribute to the sun the possession of a most dazzling brilliancy, an unlimited amount of heat. So it certainly appears. Yet the simple fact that the earth receives its heat through the agency of the sun, is not conclusive evidence that the sun is itself hot. On the contrary, it is well known that heat rapidly diminishes in the direction of the sun, and that at the altitude of considerably less than three miles lies the line of perpetual frost, the temperature of space progressively lowering beyond that point. The space therefore which separates the earth from the sun, 93,000,000 of miles in extent, is inconceivably cold; its intensity is variously estimated at from *minus* a few hundred degrees, (Fahr.) to

minus 18,000,000 of degrees. It seems incredible that scientists who possess the knowledge of these facts can entertain the thought, or attempt to maintain the theory, that heat comes from the sun, *as heat*, through such a distance, and such a medium. And, if not coming as heat, then the previously existing philosophies of the functions of the sun are *fundamentally erroneous*.

Science at the present time admits of four different explanations of the production of sun heat, viz: (1.)combustion of cosmical substances falling into the sun; (2.) arrest of motion of substances thus supposed to fall into the sun; (3.)contraction of the solar mass; and (4.) dissociation of compound bodies in the sun's substance. Each of the foregoing hypotheses stands in direct opposition to the inexorable law of conservation of force. Each recognizes the presence of a vast flood of heat, light, and force incessantly issuing from the great solar mass, and proceeding therefrom with inconceivable velocity to the earth. Yet neither of them makes provision for the retro-acting, or returning current, which under the law of conservation, becomes indispensable. Each assumes the actual and indispensable presence of heat at the sun, as an element in the solar economy. But inasmuch as heat cannot come from the sun *as heat*, there really exists at the sun no necessity for the enormous production there, such as these hypotheses demand. The prodigious destruction of material claimed to be involved in the production of heat at the sun, and the expenditure of an inconceivable amount of force in projecting the same in all directions, and to inconceivable distances into space, are uncalled for, and therefore irrational. Upon the electrical theory, no such extravagant and irrational processes are needful.

A true understanding of the great physical phenomena of our earth depends upon a correct knowledge of the constitution of its atmosphere. There is a more vital element than clouds, vapors, gases. This constituent is magnetic in its character, and may be designated as *static*, from its habit in equilibrium, and also in contradistinction from the vast *active* current which fills the space between the sun and the earth. In all scientific formulæ of its constitution, this principle as a real entity has been ignored. The fact that the atmosphere is a vast magnetic reservoir, that it is the most magnetic of all earthly bodies except iron, nickel, and cobalt, is well understood; yet there appears to have been no suspicion of the grandeur and importance of its functions in the earth's physical economy. As constituted, the atmosphere is peculiarly adapted to co-operate with the sun in this economy.

In fact it is the medium and instrument of all the sun's terrestrial operations. Prepared by such knowledge of the constitution of the atmosphere, we can better comprehend the philosophy of the action of the great sun-current so incessantly moving earthward.

By means of the dynamo-electric machine, it is demonstrated that motion or magnetism, (or both,) is converted into heat and light; so does not analogy suggest that the grand motions of the heavenly spheres are by the same principle converted into sunlight, and sun-heat; thus making unnecessary the measureless and ceaseless destruction of material that is demanded by the present theory? Our atmosphere supplies the conditions represented by the "carbon point," and the "platinum coil," in practical electricity. A current invisible, without manifestation, passes through space, as electricity through wires, until, meeting the resistance and favorable conditions of our atmosphere, there occur those wonderful and important phenomena, heat, and light. No particle of either heat or light need therefore come as such from the sun to the earth, the current being wholly invisible and cold in its passage. For a practical demonstration of such transmission of a current, we are much indebted to experiments made by Prof. MAHLON LOOMIS, of WASHINGTON, D. C. Without any visible means of transmission, he succeeded in sending the magnetic current from one mountain top to another twenty miles distant.

In the light tenuous atmosphere of the summits of lofty mountains, the human body often experiences the fiercest effects of sun-heat, and the pyrheliometer of POUILLET also records such effects for the reason that the body and the instrument become *objects of resistance* to the current, and a local heat is thus developed, which is far greater than that of the light atmosphere surrounding, which offers no such resistance. It is hardly necessary to add that the greater heat always manifested on the surface of the earth beneath is owing to the fact of a denser medium, and a consequent greater resistance.

The battery of mundane construction—our best aid and interpreter in the reading of universal phenomena—while it is the developer of heat, light, and power, is itself neither luminous, hot, nor magnetic. To explain the effects of the sun, therefore, there is not the least reason to infer that it is itself luminous, or even warm. Potential action generated in a dark, cold body may produce great heat, light, and attraction, at a distance from the seat of activity, and what is thus wrought artificially, in a small way, may surely be done naturally, and in a tremendous fashion, by the grand forces of the sun.

SUNLIGHT.

The same process develops sunlight. If lines be drawn from the sun to the earth, tangent to both, these lines will enclose a tapering space, the sun at the big end, the earth at the small end, and the space between a truncated cone; this space may be designated the solar cone or cone-space. Within this space incessant circulation is going on, and all the phenomena of gravity, heat, light, are produced through their reciprocal activity. The field of encounter between the forces of the sun and earth is our atmosphere, and in the collision light is generated. Being thus conditioned upon the atmosphere, light and heat cannot be found in space beyond the lines of the solar cone.

It is to be observed that light rapidly diminishes in the direction of the sun, even as we have seen to be the case with heat. Beyond the lower portion of the atmospheric mass, there is no dazzle; and the human eye in looking upon the great orb is not dazed. Thus the exceeding brilliancy which characterizes the sun's rays, so far from being a phenomenon located in the sun itself, as is the popular, and even the scientific conception, is actually confined to the lower strata of our atmosphere.

If light were transmitted to us from the sun in perfect intensity, the entire vault of heaven must appear as luminous as our sun.

The sun is therefore not the manufacturing place and distributing reservoir of *actual* light and heat; it is rather the source from whence the whole solar system is supplied with the *invisible, potential* light and heat, which become developed where it is required. The great central orb may therefore be regarded as like unto the earth, on its surface, and in its surroundings, viz: a dark, cool, habitable body.

OTHER RECOGNIZED FORMS OF FORCE.

All other recognized forms of force have their best explanation in the same theory.

It may be necessary to caution against a natural misconception which is fruitful in seeming objections against the theory advanced. Let it be understood then, that man's machinery must always work to disadvantage when made to illustrate the operations of nature. The machine itself is an inert thing, a dead weight interposed, the working of which requires the expenditure of force. In nature's operations, on the contrary, without labor or friction, one form of force under proper conditions transmutes itself into another form, there being no loss of force in the change. We must recognize the fact of an unimpaired energy in the universe, the fact that force is never lost nor wasted.

The Great Primordial force owes its genesis to the initial impulse which set all spheres in motion in vacuous space. To this universal principle, not only all physical force, but new life itself is due.

HUMBOLDT says: "It is indeed a brilliant effort, worthy of the human mind, to comprise in one organic whole the entire science of nature, from the law of gravity to the formative impulse in animated bodies."

That the earth, and the sun, and all the heavenly bodies, are possessed of the mysterious magnetic energy, and consequently exert a powerful magnetic influence over each other, has long ago been conceived by such men as HERSCHEL, HUMBOLDT, FARADAY; and is the faith of scientists to-day. But when we have arrived at such a conclusion, it is impossible for us to stop short, and not make the necessary deductions therefrom. Mighty magnets, when involved in mighty motions, must produce mighty currents and mighty effects. It is not for nothing that these powers and conditions exist. If we admit the premises, we must not ignore the conclusions that are necessitated. Provision must be made for the outcome of every admitted fact in science.

Therefore, it is with assurance that we urge the electric theory, and maintain that the burden of proof rests with those, who, admitting the elements of motion and magnetism, have yet made no provision whatever for their keeping.

Besides, there are two other principles already alluded to—the conservation of force, and the unity of all the forces—with respect to which it may be demanded, to what other result do they lead, and can they lead, in all reason and logic, than to the admission of the grand fact of a Great Primordial Force.

THE TIDAL EVOLUTION OF THE MOON.

On Saturday, June 4th, in the Museum Buildings, Trinity College, Dr. Ball, Astronomer Royal for Ireland, delivered an interesting and instructive lecture on recent discoveries in astronomical science. Dr. Ball said that from the variety of topics which might fairly be dealt with in his lecture he would select three, and in making this selection he had been mainly guided by the relative importance of different astronomical problems. He had also endeavored to exercise his choice so that his lecture should, as far as possible, refer to the various branches of astronomy. Having dealt with two branches of his subject, Dr. Ball described "Darwin's Theory of the Tidal Evolution of the Moon." It had, he said, been the triumph of modern gravitational astronomers to indicate the changes which must be going forward in a system devoid of rigidity. It was at all events easy to show that the tendency of these changes lay in one direction, and this was the most important point for consideration. Everyone was aware of the daily movements of the sea, which were called the tides. Most people were aware that the movements of the waters were caused by the attraction of the sun and the moon. Let them ponder therefore on the tides, as they seemed to give a clue to some of the profoundest of nature's secrets. He had heard that the port of Dublin was gradually being improved by the deepening of the bar. He had heard that the deepening of the bar had been attributed to the judicious action of the Port and Docks Board. But what the board had chiefly done was to call into requisition the scouring power of the tide, which, as he was informed, was gradually reducing or bearing away the bar. The tide was therfore accomplishing, at the bar of Dublin, the same kind of work as could be accomplished by men or by steam-engines. In other words, the tide was here doing a useful work that could otherwise only be done by the expenditure of energy. It was the same elsewhere. The tides were doing work useful or the reverse, and expending energy in so doing. Where did the energy come from? It could not be created. It could only come from the store of energy available for such purposes in the solar system. The reserve energy whence the tides drew the supplies they were daily consuming consisted partly in the daily rotation of the earth on its axis. The earth was like a mighty flywheel which would absorb a prodigious amount of energy in setting it in motion, and which would give out that energy before it would be brought to rest. The rotation of the earth on its axis was a vast but not inexhaustible storehouse of energy, on which the tides could draw for thousands of years. Energy also existed in the solar system in many other forms, some of which could also be rendered available for the tides. So far as was known, the total amount of energy could not be increased. The important question was—Can that total ever be diminished? The tides were diminishing it every day. The small oceanic tides were not the sole source of the expenditure. The solid body of the earth itself must be subject to tides; still more must the fluid or gaseous members of our system be subjected to tides. All tides involved friction, and all friction involved loss of energy. Here, then, was the great discrepancy between the theory of Lagrange and the actual condition of our system. Lagrange's calculations assumed that the total energy of the solar system was constant, but the actual fact was that the energy was slowly diminishing. The tracing of tidal evolution was chiefly due to the labors of Mr. G. H. Darwin, son of the celebrated naturalist. The influence of the tides had already been recognized as the cause of the same face of the moon being always bent on the earth. Whether the tides were merely oceanic, or whether they were actual bodily tides, the results remained much the same. At the present time the moon revolved around the earth in a month: the earth revolved on its axis in a day. The tides produced in the earth by the moon must act to reduce the rate of the earth's rotation. The effect of the tides on the earth was to lengthen the day. The day was gradually lengthening, but this change could not take place without a reactionary change on the moon. The change undergone by the moon was perhaps a little difficult to understand, as it depended on some by no means simple dynamical principles. The friction of the tides consumed the energy of the system. It turned a large portion of that energy into heat, which was then radiated off into space to be forever lost. But the friction of the tides could not alter the moment of momentum of the system. As the earth became gradually slower and slower in its rotation its moment of momentum decreased, yet for this to happen the moment of momentum of the moon should increase. It followed mathematically that as the tides gradually made the earth rotate more and more slowly, the moon must be getting farther and farther away from us. At the end of a million years from the present time the day will be more than one day of twenty-four is now; and in one million years hence the moon will move round the earth at a greater distance than she does now, and the length of the month will be correspondingly increased. In the far distant future therefore, we are to look for an increased length of month. The length of day will, however, increase much faster than the length of the month, until at length the duration of the day equals that of the month. When this time arrives the moon will have moved out to a distance half as great again as it is at present, and the length of the month will have increased to two months. Our day will then have increased from twenty-four hours up to nearly two months. and as the moon continues to to show the same face to us, we are destined to turn the same face on the moon. Were the earth and the moon the only bodies in the universe, such a state of things might go on forever. The sun, however, will produce tides in the earth which will again modify their movements. He had said that the moon was gradually receding farther and farther from the earth, and that the