

THE RADIOMETER AND ITS LESSONS.

SOMEWHAT less than two years ago, the large assemblage of scientific men gathered at the *soirée* of the Royal Society was startled at the sight of a phenomenon which was altogether new and strange to the great majority of them. In the interior of a thin glass globe, about the size of a small orange, prolonged below into a cylindrical stem by which it was supported on a stand, Mr. Crookes presented to our view a horizontal cross of four slender arms radiating at right angles from a common centre; the extremity of each arm carried a thin disc about the size of a threepenny piece, black on one side and white on the other, the black sides all facing alike; while beneath the centre was a pointed steel pivot, resting on a cup that formed the summit of a rod fixed into the cylindrical stem,¹ on which the cross with its terminal discs was free to revolve horizontally—exactly after the fashion (in miniature) of Dr. Robinson's cup-anemometer for recording the velocity of wind. The globe, Mr. Crookes informed us, had been exhausted of air to the utmost degree attainable by the 'Sprengel pump' as improved by himself, and had been then hermetically sealed. Without any other perceptible agency than the general light of the apartment, the cross slowly rotated horizontally in the direction of the white sides of the discs. When a candle was brought within a foot or so of the globe, the rotation became much quicker. When the candle was approximated to within two or three inches of the globe, the cross spun rapidly round. And when a piece of magnesium wire was burned close to it, the rapidity of the rotation became so great that the discs could no longer be separately distinguished!

The effect was not perceptibly diminished by the interposition, between the globe and the candle or other source of light, of a glass trough containing a solution of alum, which, while transparent to light, stops a large part of the radiant heat which accompanies it. And—what was yet more remarkable—if, while the cross was rotating rapidly under the influence of a candle within a short distance, the

¹ In the Radiometer as now constructed, the arms radiate from an inverted cup, which rests upon the pointed pivot—an arrangement that is in many respects more convenient.

flame of a spirit-lamp was made to play over the surface of the globe, the rotation was checked in a very peculiar manner; the cross being, as it were, pulled up with a jerking action, much as when the swinging of a compass-needle is stopped by the attraction of a magnet brought near it. When, on the other hand, the spirit-lamp was withdrawn, the candle remaining where it was, the rotation commenced anew as the globe cooled.

It is scarcely surprising, then, that a general impression should have at once prevailed that a capital discovery had been made—that of the *direct mechanical action of light*; which, though not indicating the existence of a new force in nature, showed that the most universally diffused of all forces, next to gravitation, has a *mode of action* which was previously not merely unknown, but altogether unsuspected. And this impression was not confined to those who had only a general acquaintance with Physical Optics; for it was shared by the greatest masters of that department of science, who had followed the course of the experimental researches on which Mr. Crookes had been for some time engaged, and of which this discovery was the culmination.

The origin of these researches was rather singular. In the course of the weighings made by Mr. Crookes to determine the atomic weight of the new metal *thallium*, his discovery of which by spectrum analysis had acquired for him deserved distinction as a chemist, he noticed that when the balance was enclosed in a case, and the substance weighed was of a temperature higher than that of the surrounding air and apparatus, there was an interference with the due action of the balance, which seemed attributable to the currents set up in the air within the case by the inequality of its temperature. Experiments were then made to render the action more sensible, so as to discover and eliminate sources of error; and in the course of these it was discovered that when a small light body is delicately suspended in the most perfect vacuum that can be produced, it is *repelled* by radiant heat or light, although the same body suspended in the same vessel, from which the air has not been exhausted, seems *attracted* by the same radiant force. This can be demonstrated by suspending a bar of pith by a fibre of cocoon-silk within a glass globe, so as to constitute what is known as a 'balance of torsion,' and subjecting one end of this bar to the influence of heat. When the globe is full of air, the warmed end of the bar swings towards the source of heat; but when the globe has been thoroughly exhausted and hermetically sealed, the bar is made to swing away to the extent of 90°, by merely touching with the finger the part of the globe near one of its extremities; whilst, on the other hand, it follows a piece of ice as a suspended needle follows a magnet. These contrary effects are very strikingly shown when two similar globes, each having a pith-bar suspended in it, but the one full of air and the other exhausted, are placed side by

side; and a hot glass rod on the one hand, and a piece of ice on the other, are moved round each in succession. For the bar in the unexhausted globe behaves exactly with the heated rod as the bar in the exhausted globe does with the ice; and the bar in the unexhausted globe behaves with the ice exactly as the bar in the exhausted globe behaves with the heated rod. Again, when a candle is brought within about two inches of a well-exhausted globe, the pith-bar begins to oscillate backwards and forwards, its swing gradually increasing until its position is reversed; and when the 'dead centre' has been passed, it revolves continuously, until the torsion of the suspended fibre offers a sufficient resistance to prevent any further movement in the same direction. A contrary revolution then begins, which proceeds as far in the opposite direction; the alternating series of revolutions being kept up as long as the candle burns.

A still more sensitive apparatus of the like kind was afterwards devised by Mr. Crookes, in which two discs of pith were attached to the extremities of a very slender glass rod, and this was suspended horizontally by a fine fibre of spun glass; the whole being hermetically sealed within a glass vessel of suitable form, from which the air was removed as completely as possible. The advantage of suspending the beam by a *glass* fibre lies in its elasticity; which is so perfect, that, however much the fibre may have been twisted, the beam always returns accurately to zero when free to do so. And by drawing out the fibre to the requisite degree of fineness, this 'torsion-balance' may be made of any degree of sensitiveness that may be required; one which was used in Mr. Crookes's subsequent experiments being so delicate as to turn to the *millionth of a grain*.

From this form of apparatus, the transition was obvious to one in which the arms, instead of being suspended by a fibre, should rest on a point, so as to be free to rotate continuously in either direction; and thus originated the *Radiometer*,—the name given to it by Mr. Crookes being intended to express its action as a measurer of the *mechanical* power directly exerted by that Radiant Energy which had been previously known to manifest itself only under the forms of Light, Heat, and Actinism (or chemical agency). This was the sense in which its phenomena were brought under discussion at the ordinary meeting of the Royal Society next following the first exhibition of the radiometer; and so demonstrative did these seem to be of 'A Repulsion resulting from Radiation' (the title of Mr. Crookes's memoir), that no one of the eminent Physicists present on the occasion called his interpretation of them in question; Professor Stokes, in particular, confining himself to the statement that such mechanical action must lie *outside* the Undulatory Theory, which deals only with light *as* light—*i.e.* as producing visual phenomena. But it was noticed by several as anomalous, that the *black* should be the 'driving' side of the discs, since it might have been anticipated that the

mechanical action of light would manifest itself in pushing away the surface from which its rays are reflected, and that the surface into which they are absorbed would move towards the source from which the rays emanate.

In subsequent communications to the Royal Society, Mr. Crookes committed himself explicitly to the doctrine that the Radiometer (to which he also gave the name of 'light-mill') is driven by *light*, the mechanical effect of which he assumed to be proportional to its illuminating power; so that an exact measurement of the former would furnish an equally exact measurement of the latter. And thus, as a Thermometer, which measures *heat* by its physical action in producing expansion, is a far more trustworthy instrument than the human hand, the action of heat upon which gives rise to a sensation that is not capable of precise measurement and may be altogether deceptive,—so, he contended, the Radiometer, which measures *light* by its physical power of repulsion, is a far more exact photometer than any which depends upon the physiological action of light upon the retina.

For the *absolute* measurement of the repulsive force exerted by radiation, Mr. Crookes employed the delicate torsion-balance already described; and found the mechanical effect of the light of a candle at twelve inches' distance, acting on two square inches of surface, to be 444 *millionths* of a grain. This he called 'weighing a beam of light.' In his subsequent lecture at the Royal Institution, he stated it as the result of his experiments, that the radiant energy of the Sun equals that of 1,000 candles at twelve inches' distance, its mechanical power upon two square inches of surface being thus equal to 444 *thousandths* of a grain. This is equivalent to about 32 grains per square foot, to 2 cwt. per acre, to 57 tons per square mile, or to nearly 3,000,000,000 tons on the exposed surface of the globe—sufficient to 'knock the earth out of its orbit if it came upon it suddenly,' and to 'drive the globe into space if it were not counteracted by the force of gravitation.' But, as Mr. Crookes considerably added, 'it must be remembered that our earth is not a lamp-black body enclosed in a glass case; nor is its shape such as to give the maximum of surface with the minimum of weight.'

For *comparative* estimates, however, Mr. Crookes devised another form of 'torsion-balance,' in which one half of the pith-bar was blacked and the other left white, so that, when the whole was subjected to a broad beam of light, the bar would be made to swing by its different action on the white and on the black surfaces. This bar being made to carry a mirror and a small magnet, its slightest deflection from the N. and S. zero could be detected, by the movement of a spot of light reflected from the mirror along a graduated scale; whilst the mechanical force required to produce any degree of deflection could be very exactly estimated, the apparatus being made more

or less sensitive, as desired, by the use of a controlling magnet on the outside. The results of a long series of experiments served to show the photometric value of this apparatus, when lights of the *same* kind were compared; the amount of deflection produced by the light of the same standard candle at different distances being obviously conformable to the law of inverse squares, whilst the effect of two such candles placed side by side was found to be practically double that of a single candle, and that of three candles practically triple. Again, when a candle was placed on either side of the apparatus and equidistant from it, so that each would neutralise the effect of the other, the index-spot of light remained at zero; but by shading one or other of the candles, the index-spot was made to fly off to the extremity of the scale.

This arrangement afforded a ready means of comparing the Radiant Energy of *different* sources of light. Thus, if a 'standard candle' was placed on one side at a distance of 48 inches, and a gas-burner on the other was found to bring the index-spot to zero when removed to a distance of 113 inches, their relative motor powers would be as 48^2 to 113^2 —that is, the radiant energy of the gas-burner was equal to that of $5\frac{1}{2}$ candles. But it was as pure an assumption on Mr. Crookes's part to affirm that the *mechanical* action exerted by two flames of different kinds would measure their relative *illuminating* powers, as it would have been to say that their heating action would be proportional to their illuminating action, which we know perfectly well *not* to be the case,—the gas flame, as everyone knows, having a much greater heating power than the candle flame, in proportion to the light it gives.

The same form of 'torsion-balance' was employed by Mr. Crookes to determine the relative effects of the interposition of screens of different kinds. Thus, a deflection to 180° being produced by a candle at three feet distance, its amount was reduced to 161° by the interposition of a screen of yellow glass, to 128° by a screen of red glass, and to 102° and 101° respectively by screens of blue and green glass. A far more potent effect, however, was produced by the interposition of a glass trough containing water, which brought down the deflection to 47° , whilst a screen formed of a plate of alum reduced it to 27° . As the absorption of the luminous rays in passing through such transparent media must have been very slight, whilst they practically cut off the rays of 'dark heat,' this marked reduction would seem mainly attributable to the abstraction of the latter; but, strong in his conviction of the immediate mechanical effect produced by radiation, Mr. Crookes thus expressed himself in regard to it: 'There is no real difference between heat and light; all we can take account of is difference of wave-length, and a ray of a definite refrangibility cannot be split up into two rays, one being heat and one light. Take, for instance, a ray of definite refrangibility in the red. Falling on a

thermometer it shows the action of heat ; on a thermopile it produces an electric current ; to the eye it appears as light and colour ; on a photographic plate it causes chemical action ; and on the suspended pith it causes motion.' Now, so far as Light, Heat, and Chemical action are concerned, this mode of expressing their relations is undoubtedly that which all physicists now accept ; these agencies being regarded, not as separate and distinct, but as different manifestations of that one physical action which constitutes Radiation. This action, according to the undulatory theory, consists in the propagation, through an ethereal medium, of systems of waves of different lengths ; and it is in virtue of this difference that their direction is more or less altered by refraction, the longest waves being *least*, and the shortest *most* deflected by passing through the prism. The solar beam is the composite resultant of the whole aggregate of these undulations. When falling on the eye it excites the sensation of colourless light ; when falling on the hand it affects us with the sensation of warmth ; when falling on the bulb of the thermometer it causes the expansion of the mercury ; and when falling on a photographic surface it produces chemical change. But when made to pass through a prism, it is decomposed not only into that succession of colour-bands, formed by rays of different degrees of refrangibility, which constitutes the luminous spectrum ; but into two other successions of rays, one of much *lower* and the other of much *higher* refrangibility, which lie beyond the two ends of the luminous spectrum.

These dark rays are not recognisable by the eye, because the retina is no more sensible to them than the ordinary cutaneous surface is to luminous impressions ; but their heating power can be measured by a thermometer or a thermopile, and their chemical power by the action they excite on a photographically prepared surface. The Heating power is thus found to attain its maximum a little outside the red end of the colour-spectrum ; and from that point it progressively diminishes towards the violet end of the luminous spectrum, beyond which it is scarcely traceable ; whilst it diminishes in the contrary direction also, until it dies out at about the same distance from the maximum on one side, as that at which the violet lies on the other. The Illuminating power has its maximum in the yellow band of the spectrum, and shows a gradual reduction towards the violet end, a more rapid towards the red. The Chemical power, on the other hand, has its maximum in the violet band ; and whilst it gradually diminishes towards the red end of the luminous spectrum, beyond which it is scarcely traceable, it diminishes at about the same rate in the opposite direction ; dying out at nearly the same distance from the maximum on one side, as that at which the red lies on the other. Thus, while the rays of *low* refrangibility, whose wave-length exceeds 812 millionths of a millimetre, are characterised almost exclusively by their *heating* power, and those of *high* refrangibility, whose wave-length is less than

400 millionths of a millimetre, are characterised almost exclusively by their *chemical* power, the rays of *medium* refrangibility, whose wave-lengths are between 400 and 800 millionths of a millimetre, combine these with *illuminating* power, in proportions varying with their respective wave-lengths. But there is no more reason, as Mr. Crookes has justly remarked, for attributing these several effects to different rays, than there is for hypothetically splitting up the element iron (for example) into a number of components, of which one gives its specific gravity, a second its chemical reactions, a third its magnetic properties, and so on.

But to the *three* attributes of Radiation universally recognised by Physicists, Mr. Crookes proposes (in the passage already cited) to add a *fourth*, the power of producing an electric current in a thermopile; and a *fifth*, the power of producing mechanical motion when acting on light bodies freely suspended in a vacuum. Now the notion that radiation *directly* excites the electric current of a thermopile, is one (I apprehend) which no well-informed Physicist would endorse; for (as the name of the instrument implies) it is by the disturbance of the *thermal* equilibrium between the two metals of which it is composed, that the electric current is produced. And since this disturbance may be produced in a variety of ways (as by friction or conduction), and the potency of the electric current is strictly proportional to the amount of that disturbance, there is no reason whatever for attributing to radiation any other power of exciting an electric current, than that which it exerts *mediately* through its power of heating the thermopile. And the question which, after the first shock of novelty passed off, has greatly exercised the minds of Physicists, is whether the mechanical motion, also, is not an *intermediate* effect of some one of the previously known forms of radiant energy;—that which first suggests itself being the action of Heat upon that residual vapour of which it is impossible to get rid entirely by any means at present known.

This idea very early occurred to some of the distinguished Physicists who took most interest in the experiments first communicated by Mr. Crookes to the Royal Society. I more than once conversed with Wheatstone on the subject; and he expressed a very strong belief that the swinging round of the pith-bar was due to the disturbance of the thermal equilibrium in the residual vapour, dwelling very strongly upon the impossibility of obtaining a *perfect* vacuum, since ‘even glass,’ he said very emphatically, ‘would give off a vapour, if all other vapour were withdrawn.’ On the other hand, two of the most distinguished among British mathematical Physicists, whose opinions I had the opportunity of learning from themselves, were disposed to concur with Mr. Crookes in regarding the repulsion of the heated end of the pith-bar as an *immediate* effect of Radiant Energy; dwelling especially on the fact, that the

repulsion was stronger in proportion to the completeness of the vacuum, from which it seemed fair to infer that it would be *most* strongly manifested in a *perfect* vacuum (if such could by possibility be obtained), in consequence of the entire removal of mechanical resistance (save the friction of the pivot) to the rotation of the mill.

Now, since our belief in Newton's *First Law of Motion* has no other experiential basis than the fact, that, the more completely we can eliminate friction and the resistance of the air, the longer is the persistence of motion in a body once put in movement, provided that no opposing force be brought to bear upon it, this argument for the directness of Radiant Repulsion seemed alike valid and cogent. We shall presently see, however, that it proves fallacious when brought to an experimental test of greater delicacy.

The doctrine propounded by Mr. Crookes was first explicitly called in question in a communication made to the Royal Society on the 18th of June, 1874, by Professor Osborne Reynolds; who maintained that, on the *kinetic* theory of gases (which represents any gaseous substance as consisting of molecules constantly in motion at great velocities), the effect on the torsion-balance is really due to alternate evaporation of vapour from, and its condensation at, the surface of the pith; evaporation producing a reactionary force equivalent to an increase of pressure on the heated surface, whilst condensation must be attended with a force equivalent to a diminution of pressure over the cooling surface. Thus, when the heat radiated from the lamp falls on the pith, its temperature will rise, and any moisture on it will begin to evaporate, thus generating a mechanical force which will drive the pith *from* the lamp. Conversely, when a piece of ice is brought near, the temperature of the pith will be reduced, causing a condensation of vapour which will cause the pith to move *towards* the ice. When the two arms of the pith-bar are unequally exposed to heat, the evaporation will be greatest in that which is nearest the lamp; and this is driven away, therefore, until the force on the other arm becomes equal, after which the bar will come to rest, unless the momentum it has acquired in swinging carries it further.

In a subsequent communication (March 23, 1876) Professor O. Reynolds applied a similar doctrine to the continuous rotation of the 'light-mill;' maintaining, from theoretical considerations, the existence of reactionary forces, or 'heat reactions,' whenever heat is communicated from a surface to a gas, and *vice versâ*; and showing that there is enough residual air in the best exhausted globe to enable an amount of force to be thus developed, which is sufficient to keep up the rotation of its contained mill. This explanation obviously implies the existence of a reactionary force, communicated by the intervening gas, between the discs of the mill and the enclosing glass; and the existence of such a reaction was experimentally proved by an ingenious arrangement first devised by Dr. Schuster and subse-

quently improved on by Mr. Crookes. A Radiometer, on whose arms a magnet is fixed, is floated in a vessel of water, round which four candles are fixed, so as to keep the mill in rotation. When a powerful magnet is brought near the outside of the globe, the arms immediately stop; but at the same time the globe begins to revolve slowly in the opposite direction, and continues to do so as long as the candles burn, and the arms remain fixed by the magnet. When the magnet is removed, the 'mill' begins to rotate in its original direction, and the glass envelope quickly comes to rest.

Now, as the existence of a *reactionary* force, which seems unmistakably indicated by this experiment, cannot be accounted for on the supposition that the 'mill' is driven round by the immediate mechanical impulse of radiation, whilst it is exactly what would be anticipated if the radiant energy acts calorifically on the residual gas, a very strong support is obviously afforded to the latter interpretation. And hence, although Physicists may differ as to the precise manner in which the unequal heating of the discs produces the movement,² there is now, I believe, a very general accordance in the conclusion that this is the real *modus operandi* of the Radiant Energy; so that, instead of either a 'new force,' or a 'new mode of force,' we have simply a well-known mode of force acting under peculiar conditions.

This conclusion derives very striking confirmation from two of Mr. Crookes's more recent experiments, which seem to possess a *crucial* value. Having still further improved his 'Sprengel pump,' he has been able to carry the exhaustion of his globe to a yet greater degree than before, so that its internal condition more nearly approaches a perfect vacuum. Now, while the rate of rotation of the 'mill' at first increases with the degree of attenuation of the gaseous atmosphere in which it moves, and ought, on Mr. Crookes's original principle, to go on increasing, it is found to attain its maximum at a certain degree of exhaustion, and, when the exhaustion is carried beyond that degree, to undergo a retardation; and this can scarcely be accounted for in any other way, than on the supposition that the mechanical power exerted by the disturbance of thermal equilibrium in the residual gas, then diminishes at a more rapid rate than its mechanical resistance to the rotation of the discs. Again, it has been found that when the place of air in several radiometers is taken by different gases (as oxygen, hydrogen, carbonic acid, &c.), and their globes are all exhausted to the same degree, as tested by a delicate pressure-gauge, their 'mills' rotate at different rates. Now this is exactly what would be expected on the *kinetic* theory of gases; since these different gases have such diverse rates of molecular movement, that the reactionary forces generated by the disturbance of thermal equilibrium will likewise vary; whilst, on the other hand,

² See Mr. Johnstone Stoney, in *Philosophical Magazine*, April 1876.

there seems no reason whatever why the rate of rotation should be affected by the nature of the residual gas (its elastic force, and therefore the mechanical resistance it exerts, remaining the same), if the repulsion of the discs is *directly* produced by Radiant Energy.

Before advertng to the lessons which this remarkable history seems to me to convey, I would point out that this change of interpretation of the facts discovered by Mr. Crookes, does not in the least diminish either the interest of the facts themselves, or the merit of his discovery. Nor is the value of his Radiometer in any degree lowered by the demonstration, that it does not (as Mr. Crookes at first supposed) afford a mechanical measure of Radiant Energy under any of its aspects. What (according to present views) it really does measure, is the amount of 'heat reaction' producible in gaseous atmospheres of different kinds and of different degrees of attenuation. And such a precise method of measurement appears more likely than any other mode of investigation, to furnish a test of that *kinetic* theory of gases, the recent development of which by Professor Clerk-Maxwell is regarded by competent judges as constituting (if it should receive such verification) the most important advance ever made in Molecular Physics. Most deservedly, therefore, did Mr. Crookes receive from the Royal Society the award of one of its chief distinctions; and I would not be thought for one moment to disparage his merits as the inventor of the Radiometer, by now bringing into contrast with the admirable series of scientific investigations which led up to that invention, what I cannot but regard as his thoroughly unscientific course in relation to another doctrine of which he has put himself prominently forward as the champion.

In the *Quarterly Journal of Science* for July 1871, there appeared a paper by Mr. Crookes, entitled 'An Experimental Investigation of a New Force;' in which he not only gave an account of his own experiences with Mr. Home and other Spiritualistic 'mediums,' but indulged in very unseemly reflections on the conduct of 'scientific men,' whom he charges with having 'refused to institute a scientific investigation into the existence and nature of facts asserted by many competent and credible witnesses, which they are freely invited to examine when and where they please.' The principal evidence adduced by Mr. Crookes for the existence of this 'new force' was the power he attributed to Mr. Home of being able to 'alter the weight of bodies;' the chief proof of which was Mr. Home's depression of a lever-board, whose farther end was attached to a spring balance, by laying upon it near its fulcrum the tips of the fingers of both his hands; placing a small hand-bell under one hand, and a little card match-box under the other, to satisfy the bystanders that he was not himself exerting any downward pressure. Now 'common sense' would teach that if the end of a board kept up by a spring goes down

when a man's hands are laid upon it, however near to its fulcrum, its going down is due to the pressure of those hands; and the *onus probandi* obviously lies with those who affirm that it is *not* so. Nothing would have been easier than for Mr. Crookes, on the one hand, to have carefully watched Mr. Home, to have precisely imitated his whole procedure, and to have done his best to depress the board to the same degree by his own muscular effort; and, on the other hand, to have devised an 'indicator' for *downward* pressure (on the principle of Faraday's for *lateral* pressure), by which it could be at once determined whether Mr. Home could depress the lever-board without such muscular effort. But although Mr. Crookes, so far as I am aware, has never published any proof obtained from either of these test-experiments, although explicitly challenged to do so,³ he leaves on record the claim to the possession of a power to alter the weight of bodies which he originally advanced for Mr. Home, together with his own assertion of the existence of a 'new force,' and his charge against 'scientific men' for not experimentally investigating it. Their justification for abstaining from such an investigation was the utter unreliability of the evidence adduced, which consisted simply in Mr. Home's assertion that he *was not* exerting downward pressure, and in Mr. Crookes's belief that he *could not* thus have produced the effect; but having previously allowed himself to become 'possessed' by the spiritualistic idea, Mr. Crookes could not see this fallacy, accepted Mr. Home's assertion as a scientific fact, and scolded 'scientific men' for their incredulity! And yet, while asserting that they were 'freely invited to examine [these asserted facts] when and where they please,' Mr. Crookes admitted that Mr. Home's preternatural power could not be commanded, that he was 'subject to unaccountable ebbs and flows of this force,' and that 'it has but seldom happened that a result obtained on one occasion could be subsequently confirmed and tested with apparatus specially contrived for the purpose.'

Now this is precisely what has happened over and over again within my own and others' experience of these pseudo-scientific phenomena, which depend upon the instrumentality of a Human *personnel*. Thus it was claimed by Mr. Lewis, a noted Mesmerist of twenty-five years ago, that he could not only draw his somnambules after him by mesmeric traction, but could raise them off the ground against the force of gravity.

When Mr. L. stood on a chair (says Dr. Gregory⁴), and tried to draw Mr. H. without contact, from the ground, he gradually rose on tiptoe, making the most violent efforts to rise, till he was fixed by cataleptic rigidity. Mr. Lewis said that had he been still more elevated above Mr. H., he could have raised him from the floor without contact, and held him thus suspended for a short time, while some spectator should pass his hand under the feet. Although this was not done in my presence (continues Professor Gregory), yet *the attraction upwards was so strong*

³ *Quarterly Review*, October 1871, p. 345.

⁴ *Letters on Animal Magnetism*, p. 351.

that I see no reason to doubt the statement made to me by Mr. Lewis and by others who saw it, that this experiment has been successfully performed.

Yet when a committee of Aberdeen Professors subsequently tested Mr. Lewis's powers, under conditions admitted by himself to be perfectly fair,⁵ not only did he entirely fail in his endeavour to control the actions of his 'subjects' from a distance, but, finding himself unable to keep either of them, when standing sideways against a wall on the foot nearest to it, in the erect position, he explained that he had never claimed any other power of overcoming the force of gravity, than that which he exerted in causing a subject lying on the ground, by the traction of his hand above him, to rise and stand upright. This is the Mr. Lewis whose pretensions have been recently endorsed by Mr. Alfred R. Wallace; a gentleman for whose achievements in the domain of natural science I have the same respect as I have for those of Mr. Crookes in the line of physical research, but all whose statements on this subject are vitiated (like those of Mr. Crookes) by his deficient knowledge of the abnormalities of *human* nature, by his want of due discrimination between *facts* and *inferences*, and by his disability to perceive how much greater should be the cogency of the evidence adduced to command our belief in statements of a most *extraordinary* kind, than that on which we rest our acceptance of the *ordinary* facts of daily life.

Thus, to revert to the cases just cited, the *fact* in the first of them was simply that the lever-board went down when Mr. Home's hands were laid upon it; and the testimony of Mr. Crookes and his friends was quite sufficient to justify others in accepting it as such. On the other hand, Mr. Crookes's assertion that the lever-board went down in obedience to some other force than that of Mr. Home's muscular pressure was *not* a fact, but an inference drawn by Mr. Crookes; and this inference he had no scientific right to draw, until he had assured himself by every conceivable test that Mr. Home *did* not and *could* not so depress it. So, again, the rising-up of Mr. Lewis's subject from the prostrate to the erect position, under Mr. Lewis's outstretched hand, was a *fact* as to which Professor Gregory's testimony may be unquestioningly accepted, since it involves no improbability whatever; but of Mr. Lewis's power to lift him *off* the ground and to keep him suspended in the air, we obviously require a much stronger assurance than the assertion made to Professor Gregory by Mr. Lewis and by others who saw it. And those who refused to accept that assertion at the time, were fully justified by Mr. Lewis's explicit disavowal of it to the Aberdeen professors a few months afterwards.

So, again, Mr. Wallace's recently reiterated affirmation of the possession of the *clairvoyant* power by Alexis, Adolphe, and other

⁵ *Edinburgh Monthly Journal of Medicine*, 1852.

somnambules, is merely the believer's *inference* from facts which no extraordinary testimony is needed to establish, viz. that they read books or played cards with their eyes bandaged, or deciphered words in closed boxes put into their hands. But the sceptic's 'common sense' inference from the very same facts would be that, in the first case, the eyes of the supposed *clairvoyants* had not been effectually blinded; and, in the second, that they had either taken a sly peep into the boxes (as George Goble was detected in doing), or had guessed the word by 'fishing' with the help unconsciously given by the questioner, as I saw Alexis and Adolphe do many times. And that this latter inference is the true one, is indicated, on the one hand, by the failure of one performer after another under adequate test-conditions (as in the cases investigated by the French Academy of Medicine and Sir John Forbes, and in many besides), and, on the other, by the detection of the mode in which the cheat was practised. I am confident that Mr. Wallace cannot point to a single case of *clairvoyance* thoroughly investigated by a sceptical expert, which has survived such investigation. But of cases which satisfied intelligent and truthful witnesses, upon whose testimony we should rely in the ordinary affairs of life, and who were yet afterwards proved to have been completely taken in, there are enough to show how little such testimony is worth as to matters requiring special qualifications for their thorough investigation.

Of the two distinct claims set up by Mr. Crookes, therefore, to the discovery of a new agency in nature, I hold the one to have been as scientific as the other was unscientific. The *facts* of radiant repulsion did not rest upon the unsupported testimony of Mr. Crookes and his friends; they could be exhibited to as many as wished to see them, and could be verified for himself by every one who could construct the apparatus. And while his *inference* from the first series of those facts (ascertained by the torsion-balance) was regarded by some of our most eminent Physicists as by no means improbable, there were few, if any, among those who saw the Radiometer spin round when a candle was brought near it, who did not for a time accept his view. In assuming, however, that there was such a quantitative relation between Radiant Repulsion and Light as justified the use of his Radiometer as a Photometer, Mr. Crookes undoubtedly went beyond what his facts warranted; and his claim to have 'weighed a beam of light' I feel sure that he would now abandon. But no sooner was adequate ground shown for calling in question his interpretation of the phenomena, and a *vera causa* found in an agency already known, than Mr. Crookes evinced the spirit of the true philosopher in varying his experiments in every conceivable mode, so as to test the validity of his original interpretation. And if he still shows some lingering unwillingness to surrender his position, it is no more than the best of us would probably feel under the like circumstances in regard to a pet hypothesis.

Yet at the very time that Mr. Crookes was carrying out this beautiful inquiry in a manner and spirit worthy of all admiration, he gave to the public, in his 'Notes of an Inquiry into the Phenomena called Spiritual,'⁶ the most conclusive evidence that his mind has its unscientific as well as its scientific side; so that, while pursuing with rare ability and acuteness a delicate Physical investigation in which nothing is taken for granted without proof satisfactory to others as well as to himself, he has yet allowed himself to become so completely possessed by a 'dominant idea' in regard to the 'phenomena called Spiritual,' as to accept either the products of his own imagination, or the deceptions practised upon him by others, as facts that should command the same credence as the demonstrations of his Radiometer. Of 'The Alteration of Weight of Bodies,' a class of phenomena capable of precise physical determination, Mr. Crookes simply says:—'I have repeated the experiments already described in this journal, in different forms, and with several mediums.' But why does he not tell us precisely what were the weights so altered, and what force was exerted by the medium, as determined in each case by the precise measurement he so well knows how to apply? Of his yet more extraordinary assertions, the following are samples:—

On one occasion I witnessed a chair, with a lady sitting on it, rise several inches from the ground. On another occasion, to avoid the suspicion of this being in some way performed by herself, the lady knelt on a chair in such a manner that its four feet were visible to us. It then rose about three inches, remained suspended for about ten seconds, and then slowly descended. At another time two children, on separate occasions, rose from the floor with their chairs, in full daylight, under (to me) most satisfactory conditions; for I was kneeling and keeping close watch upon the feet of the chair, and observing that no one might touch them.—On three separate occasions I have seen Mr. Home raised completely off the floor of the room, once sitting in an easy chair, once kneeling on his chair, and once standing up.—There are at least a hundred recorded instances of Mr. Home's rising from the ground, in the presence of as many separate persons.

A beautifully formed small hand rose up from an opening in a dining-table, and gave me a flower; it appeared and then disappeared three times at intervals, affording me ample opportunity of satisfying myself that it was as real in appearance as my own. This occurred in the light in my own room, whilst I was holding the medium's hands and feet.—I have more than once seen, first an object move, then a luminous cloud appear to form about it, and, lastly, the cloud condense into shape and become a perfectly formed hand.—In the light I have seen a luminous cloud hover over a heliotrope on a side table, break a sprig off, and carry the sprig to a lady; and on some occasions I have seen a similar luminous cloud visibly condense to the form of a hand, and carry small objects about.—A luminous hand came down from the upper part of the room, and, after hovering near me for a few seconds, took the pencil from my hand, rapidly wrote on a sheet of paper, threw the pencil down, and then rose up over our heads, gradually fading into darkness.

Whether, since the exposure of Katie King in Boston, U.S., the exhibition in the same city of the methods by which numerous 'spiritu-

⁶ *Quarterly Journal of Science*, January 1874.

alistic' tricks have been played, the publication in this country of the affidavit of Mrs. N. Culver, the near relative of the sisters Fox, as to the mode in which these originators of 'Spiritualism' played on the credulity of the public, and the imitation of many of the performances of its professors by Messrs. Maskelyne and Cooke, Mr. Crookes has begun to question whether he may not have been rather hasty in committing himself, I have no means of knowing; but I do not think that any save those who have themselves yielded to the same 'possession' will entertain any doubt about the matter. Any one who reads the account of the New England witch epidemic nearly two hundred years ago, will find that able, intelligent, and honest judges and juries, under the influence of a theological prepossession, allowed themselves to be 'sadly deluded and deceived' (as they themselves afterwards found out) to the extent of hanging some scores of innocent people; so that the curious 'duality' of Mr. Crookes's mental constitution has plenty of parallels in past time, to say nothing of the present.

The lesson which this curious contrast seems to me most strongly to enforce is, that of the importance of training and disciplining the *whole* mind during the period of its development, of cultivating scientific habits of thought (by which I mean nothing more than strict reasoning based on exact observation) in regard to *every* subject, and of not allowing ourselves to become 'possessed' by any ideas or class of ideas that the common sense of educated mankind pronounces to be irrational. I would not for a moment uphold that test as an infallible one. But it ought to be sufficiently regarded, to make us question the conclusions which depend solely upon our own or others' subjectivity; and to withhold us from affirming the existence of new Agencies in Nature, until she has been questioned in every conceivable way, and every other possibility has been exhausted.

W. B. CARPENTER.