Art. X.—*The Cause of Gravitation.* By T. Wakelin, B.A.N.Z.Univ.

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The title to this paper is merely descriptive. Some philosophers object to the word cause. The reader can supply any other word, as antecedent, which he may think more correct.*

It is generally advisable to survey the ground from which we start in making any enquiry. Some of the most eminent astronomers and physicists, the reader will perhaps rightly consider, should be referred to for this information.

"The illustration of supposing the sun connected with the earth by a steel bar, will serve to give us some notion of the wonderful connection which that mystery of mysteries, gravitation, establishes between them. The sun *draws* or pulls the earth towards it. We know of no means of communicating a pull to a distant object more immediate, more intimate, than grappling it with bonds of steel. The velocity of sound, or of any other impulse, conveyed along a steel bar, is about sixteen times greater than in the air. Now suppose the sun and the earth connected by a steel bar. A blow struck at one end of the bar, or a pull applied to it, would not be delivered—would not begin to be felt—at the sun till after a lapse of three hundred and thirteen days. Even light, the speed of which is such that it would travel round the globe in less time than any bird takes to make a single stroke of his wing, requires eight and one-third minutes to reach us from the sun. But the *pull* on the earth which the sun makes is *instantaneous*, or at all events incomparably more rapid in its transmission across the interval than any solid connection would produce, and even *demonstrably far more rapid* than the propagation of light itself."†

"The opinion of most leading astronomers is that the velocity of the gravitational pull, so to speak, is infinite—that is, it is instantaneous. If it were not so, the members of the solar system would get beyond control, and the whole system would run into disorder."‡

The law of gravitation is that every mass of matter attracts every other mass with a force directly proportional to the mass, but inversely as the square of the distance. The mass of a body can be determined by its inertia. This would be the more rigorously exact and mathematical method of determining the mass of a body. The determination of mass at

* Even thus qualified this title is perhaps not strictly appropriate.

† Sir John Herschel:—"Lecture on the Sun."

‡ R. A. Proctor.—A note in one of his works. (The words are imperfectly given from memory).

the surface of the earth is made, however, by simply weighing small bodies. For comparatively small masses "it has been established by experiment, that the two modes of comparing masses perfectly coincide."* The mass of matter in a planet can of course only be inferred from the degree of gravitational force exerted by that planet.

The *pull* which the earth exerts upon, say a ton mass of iron at the surface of the earth, is what we mean by the *weight* of that mass. The force of gravity at the surface of the sun—that is the gravitational *pull*—is nearly twenty-eight times that at the surface of the earth.† The same mass of iron at the surface of the sun would therefore weigh nearly twenty-eight tons. If this ton mass of iron were placed at the distance of Mercury from the sun the pull of the gravitational power of the sun would give this mass a weight of only $9\frac{1}{2}$ pounds. At the distance of the earth from the sun, the pull exerted by the sun would give to this ton mass only a weight of $1\frac{1}{3}$ pounds. Under a vertical sun at mid-day, a ton mass at the surface of the earth, owing to the pull exerted by the sun, would weigh in a spring balance $2\frac{2}{3}$ pounds less than it did at midnight at the same place. It is this very small difference in the force of gravity on opposite sides of the earth (where mid-day and midnight), that causes the earth to gravitate to, and on account of its motion to revolve around, the sun.

The bearing on this enquiry of the next two or three extracts is not perhaps very direct, but the extracts will aid us considerably in forming an opinion of what the "gravific" force may be.

"From this phenomenon (Faraday's lines of magnetic force) Thompson afterwards proved by strict dynamical reasoning that the transmission of magnetic force is associated with a *rotatory* motion of the small part of the medium. He showed at the same time how the *centrifugal force due to this motion would account for magnetic attraction.* The explanation of electrostatic stress is less satisfactory, but there can be no doubt that a path is now open by which we may trace to the action of a medium all forces like electric and magnetic forces." "Such a state of stress as is necessary to produce gravitation we have not however been able hitherto to imagine." ‡

The æther fills space, and is necessary in the undulatory theory of light—long accepted—to account for the transmission of light. "It interpenetrates all the transparent bodies, and probably all opaque bodies too. We must consider the æther in dense bodies as somewhat loosely connected with the dense bodies, and we have next to enquire whether when these dense bodies

* Deschanel's Natural Philosophy, "Mass," p. 55.

† Newcombe, 27·71 times.

‡ J. C. Maxwell's article, "Attraction," in Encyclopædia Britannica, ninth edition (now being published).

are in motion through the great ocean of æther, they carry along with them the æther they contain, or whether the æther passes through the solid as the water of the sea passes through the meshes of a net when it is towed along by a boat.

"The experiment (to determine this question) was tried at different times of the year, but only negative results were obtained. We cannot, however, conclude absolutely from this experiment that the æther near the surface of the earth is carried along with the earth in its orbit. If the æther is molecular, the grouping of the molecules must remain of the same type, the configuration of the groups being only slightly altered during the motion."* The density of the æther is extremely small compared with that of air, even in the vacuum of a Sprengel air-pump.

One who has made a special study of the subject of this paper in effect remarks† :—The forces we have to deal with are vast, and, to our ordinary perceptions, occult. We need not, however, on this account doubt their existence any more than we need doubt the existence of light in space surrounding a luminous body, but which light we cannot see. Force is measured by momentum. *When the mass is extremely small and the force great the velocity must be proportionately great.* In accounting for gravitation we must look for an extreme velocity with extreme tenuity of matter.

The pull exerted by the sun upon any of the planets is transmitted with an "infinite velocity"—that is, the pull is made "instantaneously" both at the sun and planet. If we try to gather in the logical meaning of this we shall see that the force that causes the planet to gravitate to the sun exists both at the sun and at the planet's place in space. If there is a medium, then why should not the force be in the medium and not in the sun? That the force that causes gravitation should exist in space has been the hope and the aim of perhaps most philosophers since the time of Newton. This notion seems somewhat in conflict with what is strikingly manifest—that all planetary bodies are held in their orbits by a central body; but, if we conceive the idea that the action of the central body is *directive* and not *productive*, then the apparent antagonism is cleared away. In this case the central body may so influence the æther of space as to cause it to surround the body as the atmosphere surrounds the earth, the density, say, and in any case the force, decreasing with the distance from the centre of the body.

If gravitation is owing to any action of the æther, it would seem to be most likely that of a current. If we hold a plank end-ways against a current of water, the force necessary to hold it may not be much. If we hold

* J. C. Maxwell's article, "Æther." Encyc. Brit., 9th ed.

† S. Folver, Preston, July or October number, Journal of Science, 1878.

the plank transversely against the current, especially with its face fair against the stream, the force required would be very much greater. The water acts only on the outsides of the plank. If we hold the plank above the ground in any other way the "gravific" current of æther will carry it to the earth with exactly the same force or weight in whatever position it may be held. This supposed current does not act then only on the outsides of the plank; it must act on every particle of it. The æthereal current must flow through the plank as a current of air would flow through a sail made of netting. Every central body would in this case be a reservoir, into which the æther rushes with very great rapidity.

Let us apply this notion of a current to the case of a planet and its satellite. The attraction is mutual between them; there must therefore be a current flowing, in space, from the planet to its satellite, and another æthereal current at the same time flowing from the satellite to its planet. The currents would therefore oppose each other, and one would be destroyed. The attractive power would be reduced, and the larger body would not move at all towards the smaller; we cannot therefore consider gravitation to be caused by currents.

The notion, however, of a current of extremely attenuated gas flowing through a solid, helps us very considerably in our conception of what is required. If the æther could be stationary, and act like a current, this kind-of-current theory would account for gravitation. Clothes are run through two elastic-rollers of a mangle. If the rollers are made to revolve, and the clothes are brought within their grip, the clothes acquire the velocity of the rollers. If, between the same two rollers, we place a long bar of smooth steel, and the rollers be adjusted so as to press lightly on the bar, they will make many revolutions before the bar acquires a perceptible motion. It seems as if a medium that would act on every particle of matter, as these rollers act on the bar of steel, would produce the gravitational motion of bodies. We might at once suppose that revolving spheres of matter, as of the common india-rubber balls, would be sufficient. If the spheres revolve and come in contact with matter under a very small pressure, the matter they are in contact with would begin to acquire the motion of this revolving shell. As one side moves one way, and the other side the opposite way, the body would not move from its place, whatever other motion it might acquire. These revolving spherical shells are then insufficient.

Let us take a piece of gutta-percha, or india-rubber tubing, of a suitable length, say eight to twenty times the diameter of the tube. Let this tube revolve exactly as the rollers of a mangle revolve, and let the velocity of rotation be increased to any necessary degree. As the rate of rotation increases the tube expands. At the most suitable time, while the rate of rotation is increasing, let the revolving tube be bent round till the ends touch; join the two ends fast. We have now a rapidly revolving tubular ring,* the length suitably chosen and the velocity of rotation having also been suitably determined, the insides of the tube may be considered to touch, or rather nearly to touch. The outsides of this tubular ring are going one way, while the insides of the tubular ring, almost touching, are moving in the opposite direction. If two masses of matter touch this *tubular ring* on opposite sides they will both be impelled in the *same direction.* If two masses of matter touch a *revolving sphere* on opposite sides they will be impelled in *opposite directions.*

The æther may be conceived to be made up of these tubular rings, which may be called "æthereal corpuscles."† *The axis of revolution is a circular axis.* One of the fundamental laws of mechanics is that no revolving body, or system of bodies, can, by the mutual interaction of its parts, either accelerate or diminish its rate of rotation. The æthereal corpuscle would therefore continue to revolve with an undiminished velocity so long as it came in contact with nothing. These corpuscles must be conceived as so small that they will freely enter the pores of any solid.

Mass for mass they may be considered as much stronger than steel, that is as we know the strength of steel by subjecting it to a strain. In particular it would be found advisable though not necessary to ascribe an almost perfect elasticity to the matter of the shell of this tubal ring. If this is not done, the corpuscles must be considered as of every size. It would be best to proceed with the enquiry on the supposition that these corpuscles are all of the same mass. If we alter the direction of our enquiry this would not be necessary, though less satisfactory.

These corpuscles constituting the æther, of course do touch each other, but, their direction of rotation being the same, there would be no conflict unless any of the corpuscles move slower than the contiguous ones. In case of conflict, all contiguous corpuscles would adjust their directions of rotation to the larger and therefore predominant mass close to them. We must follow out this notion of adjustment:—If a mass of matter were suddenly placed in the æther—say, far from any other mass of matter,—and kept immoveable in its place, the corpuscles would proceed to adjust themselves to it. For convenience of conception, a mass of matter may be con-

* In Chambers' Encyclopædia, article "Vortex," and in Tait's "Advances in Physical Science," (last lecture), will be found wood-cuts of smoke-rings. They will illustrate the action, and to some extent the form, of this tubular ring.

† See note to Sir John Herschel's lecture on "Weather," where he speaks of "æthereal molecules."

sidered as spherical and nearly smooth, and as impermeable to the corpuscles. Some, one way, would be more stable than another. Whatever this way might be, all the corpuscles around the body would revolve in the same direction. It becomes, then, a question whether the corpuscles will so adjust themselves to the body that the direction of rotation of their outsides shall be towards the body or from it. There is a slight pressure supposed to be exerted by the corpuscles on one another. For convenience, one æthereal corpuscle vastly enlarged may be considered as acting on a smooth table—*firstly*, with the *insides revolving downward*, and, of course, the outsides revolving upward. Let it be tilted considerably on one side. It will at once turn right over, owing to the reaction from striking the table downwards. While thus revolving with its *outside downwards* let the corpuscle be again tilted considerably. The motion of the outside being down the reaction will be such as to cause the corpuscle to resist being tilted over. *That position, then, of the corpuscle when it revolves with its outsides downwards is the position of greater stability.* All masses acted on by these corpuscles will thus be impelled towards the central body.

The sun being vastly the predominant body in the solar system, the æther will, to a proportionate extent, adjust itself to it. The motion of rotation of the æthereal corpuscles will be directed to the sun, unless more strongly affected by other bodies. *The sun thus has a directive action on the medium, causing all bodies to gravitate towards itself.* We have now to enquire in what way minor bodies, as the planets, affect the æther. They do, of course, affect it in the same way as the sun (considered only as a solid body) affects it. To what distance from the surface of any planet does the planet affect the æther more powerfully than the sun does? When we know this we shall know when bodies will gravitate towards the planet instead of towards the sun.

The corpuscles in contact with any mass of matter will have their velocity of rotation constantly diminished by such contact. The tension and elasticity of the corpuscles being great, and the velocity being diminished, the corpuscle will contract. The corpuscles outside the first series being in contact with slower-revolving inner corpuscles will have their velocity of rotation diminished, and will likewise contract in size. And so on with the æther immediately surrounding the planet or any other body. At the surface of any body, as the sun, a planet, or satellite, the size of the corpuscles will be enormously reduced—that is, the æther (every corpuscle being of equal mass) will increase in density as we near the surface of those bodies. And the size of the æthereal corpuscles will increase the farther we go from such bodies.

Let us take any body, as a planet, and from its central point draw two lines indefinitely into space, with an angle so extremely small that at the surface of the planet they just touch the opposite sides of a single corpuscle. If we now bring to mind that the corpuscles not far distant from the surface of the planet *have all been reduced to their different sizes by actual contact,* we shall see that a column of corpuscles singly, one above another, will just touch both these narrow angular lines. Whatever the distance of the surface from the centre of a planet, at twice that distance from the centre the diameter of the corpuscle will be exactly double of the diameter of the corpuscle at the surface of the planet. The diameter of the corpuscle at three times the distance, will be three times the diameter of the corpuscle at the surface, and so on. At some distance therefore from the planet the density of the æther surrounding the planet will be equal in density to the æther surrounding the sun. At this point bodies will gravitate indifferently either to the planet or the sun. Owing, however, to the motion of the planet through the æther, there may be a deep zone or stratum of neutral action. Inside this neutral space, however, the æther surrounding the planet would travel with the planet through space.

The form of this æthereal corpuscle is a matter of great importance. Revolving with an enormous velocity the tension of the shells of the tube must be extremely great. The centrifugal force being so very great, will therefore determine the form of the corpuscle, the matter of it being considered extremely elastic. It will expand more internally, both above and below the plane of the circular axis, than it will externally. The inside of the corpuscle will consequently be but slightly curved, while the outside will be very considerably curved, almost spherically so. What velocity of rotation will determine the different sizes of the corpuscles cannot be settled. The greater tension of the more swiftly revolving corpuscles, those farther from the central body, increasing with the distance, would perhaps be taken as an indication that the more swiftly revolving corpuscles are smoother. They would therefore have a less frictional effect on any mass of matter. At higher velocities, too, the friction of one on another becomes considerably less than at lower velocities. It is not yet known what this ratio of decrease is.* As these two points are of very great importance, and as the velocity of rotation is also unknown on solely dynamical grounds, no calculations, at present, can be made on the effect of the æther on the same mass of matter removed to different distances from a central body. We should want to know, besides, the form, though not the size, of the pores or spaces in the supposed mass.

Though we cannot make calculations in detail, we can determine the total amount of the effect produced by the corpuscles on a mass of matter

* Encyclopædia Britannica, ninth edition, article "Friction" (Galton's experiments).

at various distances from a centre, if we make one or two reasonable assumptions. The law of gravitation would declare that the force of gravity on the same mass of matter, at increasing distances from a central body, would vary inversely as the square of the distance, and the assumptions are that the pores or spaces of the mass of matter shall be as large as the largest corpuscle in the region of the æther in which the mass is placed, and that the pores or spaces shall be of the same volume as the corpuscle, or a volume which is an exact multiple of that volume. The æther will thus pass through the mass of matter. As the mass of matter comes from, say, a great distance to the surface of the central body, the number of corpuscles passing through it will be inversely as the cube of the distance. The corpuscles, however, being only able to touch the surfaces of the pores or spaces of the body, the *number of points of contact can only increase inversely as the square of the distance.* As this is the law of gravity, it would show that the frictional effect of each single corpuscle, at any distance, is always the same, no matter what its size and velocity of rotation may be.

As every planet is surrounded by its own æther, the æther surrounding the sun cannot act directly on the mass of the planet. Let us take the case of the moon producing a tidal wave. We may consider the action of the moon to diminish the force of gravity of the earth at that place which is under the moon. The waters of the ocean in this zone, relieved to some extent of the force of gravity, will rise into a wave, as the water in a pump rises when relieved from the pressure of the atmosphere. If we *increase the pressure between the corpuscles of the æther, we increase the frictional effect;* and if we reduce the pressure, the force of gravity will be diminished. The action of the moon may be taken therefore as reducing the pressure among the corpuscles in the æther between the moon and the earth. In the same way the centrifugal action of the *planet* is such that it diminishes the pressure among the corpuscles in the æther *between it and the sun,* and the planet must, for the same reason, increase the pressure in the æther on the side opposite to the sun. On account of this difference of pressure the planet will be constantly deflected from the straight course it would otherwise take. Owing to the rapid motion of the planet through space, the force of gravity would probably be greatest on the outer forward quarter of its surface—that is, the force of gravity would be greatest between midnight and sunrise. We might think, and perhaps it may be the case, that the additional pressure upon this quarter of the planet causes it to revolve.

NOTE.—One of the reasons why it would be most important to consider the corpuscle extremely elastic, or, at any rate, capable of extreme tension, is that the force of explosives, as of gunpowder, may be due to this tension. Imagine a particle of matter to be of the form of a cone, and let a corpuscle become impaled on it, it will rush down the cone and grip it with enormous force. These cones may be taken as of all degrees of fineness or thickness. When very short and thick, the corpuscle gripping it might easily, as by a sudden blow, be thrown off. Owing to its extreme tension it would revolve with extreme rapidity in the direction opposite to what it had when it rushed down the cone. It would therefore expand with great and sudden force, which is the action of an explosive.

ART. XI.—*On the neglected Forest Products of New Zealand.*

By T. KIRK, F.L.S.

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Tar.	*Burgundy Pitch.*
Creosote.	*Kauri Resin.*
Oil of Tar.	*Turpentine.*
Pitch.	*Oil of Turpentine.*
Lampblack.	*Potash.*
Resin.	*Charcoal.*

Woodware.

THE value of the tar, pitch, resin, turpentine and varnish, etc. imported into New Zealand during the year 1875, was declared to be £13,587, and it has increased at the rate of £850 per annum, the value of the imports for 1879 being close upon £17,000. It is not too much to say that nearly the whole of this large sum might be retained in the colony and expended in producing the articles from native products, which are either entirely neglected or are exported in the raw condition to be manufactured in other countries and returned, after incurring heavy charges for commission, outward and inward freight, and (so far as varnish is concerned) an *ad valorem* duty of 15 per cent. The object of the following paper is to draw attention to the profitable outlet for labour presented by our abundant supply of raw material suitable for this class of manufactures.

Tar and pitch can be produced from material which at present is not only wasted but is a constant source of danger—the tops, branches, and other small timber which is usually left on the ground after falling and which often leads to the destruction of the forest by fire.

To what extent a substitute for turpentine may be furnished by our native pines can only be determined by actual experiment; there can, however, be no doubt but that the *kauri*, *rimu*, and *kahihatea* may be made to yield considerable quantities.